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HAZARD AND ACCIDENT ANALYSIS

This chapter: (1) systematically identifies the potential hazards resulting from Waste Isolation Pilot Plant (WIPP) disposal-phase handling and emplacement normal operations, and (2) assesses those hazards to evaluate abnormal, internal operational, external, and natural phenomena events that could develop into accidents. The hazard analysis: (1) considers the complete spectrum of accidents that may occur and qualitatively analyzes the accident annual occurrence frequency, and the resultant potential consequences to the public, workers, facility operations, and the environment; (2) identifies and assesses associated preventative and mitigative features for defense-in-depth; and (3) identifies a subset of accidents to be quantitatively evaluated in the accident analysis. The accident analysis evaluates these accidents against risk evaluation guidelines to verify the adequacy of the preventative and mitigative systems.

The methodology and requirements of DOE Order 5480.23,[1] and its implementing standards DOE-STD-1027-92[2] and DOE-STD-3009-94[3] were utilized in the development of this chapter. The potential hazards associated with the long-term waste isolation phase are addressed in the WIPP performance assessment submitted to EPA in October, 1996. The performance assessment is summarized in Section 5.5.

This chapter only addresses contact handled (CH) transuranic (TRU) waste handling and emplacement operations described in Chapter 4. Future updates of this chapter (currently scheduled for FY-1999) will include a hazard and accident analysis of remote handled (RH) TRU waste handling and emplacement operations.

5.1 Contact Handled (CH) Transuranic (TRU) Hazard Analysis

The CH TRU hazard analysis involved a multi-step process which included (1) identification of the potential hazards associated with WIPP operations, (2) characterization of the waste expected at the WIPP, (3) a hazard evaluation in the form of a Hazard and Operability Study[4] (HAZOP) for the CH TRU waste handling and emplacement process, (4) the identification of potential accidents requiring quantitative accident analysis, (5) development of the WIPP defense-in-depth philosophy, and (6) an evaluation of worker protection from those accidents identified in the qualitative hazards analysis.

The hazard analysis in this section includes a thorough review of existing documentation [Final Environmental Impact Statement (FEIS),[5] Final Supplement Environmental Impact Statement (SEIS),[6] WIPP Fire Hazards and Risk Analysis,[7] and Failure Modes and Effects Analyses (FMEA)] to ensure hazards were thoroughly evaluated.

5.1.1 Hazard Identification

A hazard is defined as a material, energy source, or operation that has a potential for causing injury or illness in humans, or damage to a facility or the environment, without regard for the frequency or credibility of accident scenarios or consequence mitigation.[3] Hazards associated with normal WIPP operations include mining dangers, high voltage, compressed gases, confined spaces, radiological and nonradiological hazardous materials, non-ionizing radiation, high noise levels, mechanical and moving equipment dangers, working at heights, construction, and material handling dangers. Operations at the WIPP do not involve high temperature and pressure systems, rotating machinery, electromagnetic fields, or use of toxic materials in large quantities.

Routine occupational hazards are clearly regulated by DOE-Prescribed Occupational Safety and Health Act (OSHA) and by Mine Safety and Health Act (MSHA) standards. Programs for protecting WIPP workers from routine occupational hazards are discussed in Chapter 8.

As part of normal operations activities at the WIPP, the waste containers (having met the WIPP Waste Acceptance Criteria[8] (WAC)) are closely inspected and surveyed for radiation, contamination, and damage before transfer to the underground repository. Most significantly, the cleanliness of containers is required to not be in excess of the DOE's free release limits (20 disintegrations per minute [dpm](0.3 Bq)) alpha per 15.5 in^2 (100 cm^2), or 200 dpm (3 Bq) beta/gamma per 15.5 in^2 (100 cm^2) prior to shipment from the generator sites. (See Section 7 for the basis for radiological and hazardous material protection limits.) WIPP normal operations do not entail any planned or expected releases of airborne radioactive materials which may present an internal occupational radiological hazard to workers, or present a hazard from the airborne pathway to the offsite public. Therefore, the radiological hazards for normal operations are limited to worker occupational external radiation exposure from the waste containers. Nonradiological hazards to the public and worker during normal operations may result from small releases of Volatile Organic Compounds (VOCs) from waste containers. Protection of the public and the worker from hazards involved with radiological and nonradiological materials during normal WIPP operations are further discussed in detail in Chapter 7. Therefore, for the purposes of establishing an inventory of radiological and nonradiological material, only that material contained in the waste drums is considered.

Operational, natural phenomena (such as earthquakes and tornadoes), and external hazards (such as aircraft crashes) are considered further in this chapter when they are identified as an initiating event leading to an uncontrolled abnormal or accidental release of waste container radiological or nonradiological materials.

For all conceivable operations and activities during the operational disposal-phase, few credible mechanisms can be identified that could lead to accidental releases of waste container radiological and nonradiological materials. The CH waste containers are designed and fabricated in accordance with stringent regulatory requirements. The integrity of the waste containers is ensured during the design life in relation to the time interval of the disposal-phase. While accidents or incidents could occur to individual waste containers, the structural capabilities of the containers as designed can sustain anticipated waste container drops from waste handling equipment. In addition, as discussed above, WIPP operations do not entail any dispersal energies from high pressure, high temperature, or high energy systems that could result in breach of waste container integrity.

Additionally, it should be noted that the hazards identified as a result of WIPP operations, in relation to most high or moderate hazard nuclear facilities, do not require safe shutdown of the facility in a specific manner in terms of time and technical conditions. The WIPP facility and operations either individually, or collectively, can be shutdown or stopped at any time.

Inventory of Hazardous Materials

The hazard identification process resulted in identifying process operation locations within the Waste Handling Building (WHB) and the underground disposal horizon for which an inventory of radiological material could be identified. The anticipated inventory was determined based on material form, location, and quantity associated with the process of receipt, handling, and disposal of CH TRU waste.

These process operation locations include:

1. Waste Handling Building (CH Bay)

   - CH Bay
   - Shielded Holding Area
   - Conveyance Loading Room

2. Underground Horizon

   - Waste Shaft Station
   - Disposal Panel

Table 5.1-1 summarizes the maximum CH TRU waste container inventory by facility process location. The radiological and nonradiological waste container contents are characterized in Section 5.1.2. The bounding radiological and nonradiological hazardous material inventory for each process location may be obtained by multiplying the number of waste containers by the maximum waste container contents derived in Section 5.1.2.

5.1.2 CH Waste Characterization

This section describes the methodology used in the development of waste container contents (radioactive/chemical content) to be disposed of at the WIPP. A description of waste containers, types, volumes, radioactive and nonradioactive constituents, and discussions on content development are included for use in the hazards and accident analysis.

Waste container types considered for this analysis are standard DOT Type A 55-gallon (208 L) drums (or equivalent) or standard waste boxes (SWBs), ten drum overpacks (TDOP), 85-gallon (321 L) overpacks, and pipe containers in 55-gallon (208 L) drums (pipe overpack payload containers). The design of these containers is discussed in detail in Section 4.2.

5.1.2.1 CH TRU Wastes

As defined in Public Law 102-579, WIPP Land Withdrawal Act,[9] the term "transuranic waste" means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half lives greater than 20 years, except for: a) high-level radioactive waste; b) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations; or c) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations.

TRU waste is classified as either CH or RH, depending on the external dose rate at the waste container surface. CH TRU wastes are packaged with an external surface dose rate of up to 200 millirem per hour. CH TRU waste decays principally by alpha emission, with some beta, gamma, and neutron emissions. Alpha emitting radionuclides result in no external radiation exposure to humans, but are hazardous if inhaled or ingested. Since beta emissions, like alpha, have limited penetrating energy, adequate personnel protection is provided by the waste container. Gamma and neutron radiation are more penetrating, and require shielding for safe management and storage. CH TRU waste contains predominantly alpha-emitting radioisotopes, and closed containers provide protection from inhalation or ingestion.

5.1.2.1.1 CH TRU Radionuclide Inventory

The WIPP TRU Waste Baseline Inventory Report[10] (BIR), Revision 3, provides estimated volumes of CH TRU waste to be supplied by the 19 DOE waste generator and/or storage sites, including small quantity sites. Historically, ten generator/storage sites had been listed as sources of TRU waste for disposal at WIPP. Activities associated with the Federal Facilities Compliance Act[11] (FFCA) resulted in the identification of nine additional sites that routinely engage in TRU waste activities. The wastes from these additional sites are included in the totals in the BIR. The radionuclide inventory by final waste form, stored waste volume, and waste site, as derived from a June 1996 query of Revision 3 of the BIR database, is shown in Table A-1 of Appendix A. Table A-1 is a summary of data reported by the generator sites for 569 individual waste streams shown in Table A-2, which organizes the waste streams by final waste form and radionuclide concentration, expressed in terms of PE-Ci/equivalent 55- gallon drums (0.208 m^3) (See Appendix B for a discussion on the PE-Ci concept). Waste form definitions are discussed in more detail in Section 5.1.2.2.

The right side of Table A-1 shows the volume percent (and range of average radionuclide concentration in PE-Ci/drum) of each final waste form that fall into a combination of two categories: (1) not to be processed/repackaged before WIPP disposal, and (2) to be processed/repackaged before WIPP disposal. Three bins are used to represent the distribution of radionuclide concentrations among the waste streams.

- The highest bin gives the volume percent consisting of waste streams whose average PE-Ci content is greater than 20 PE-Ci/drum equivalent. This value was selected because it is a factor of four below the 80 PE-Ci value (derived below) selected for bounding consequence calculations, but also above drums that will be loaded primarily with Pu-239.

- The lowest bin upper cutoff was selected at 8 PE-Ci to provide an indication of the volume percentage of waste that would produce a consequence at least a factor of ten below the bounding consequences calculated for this SAR.

- The middle bin may be considered to generally correspond to the volume percentage of drums that may approach the WAC nuclear criticality loading limits (200 fissile gram equivalents (FGE)) imposed for waste consisting of primarily Pu-239 operations material.

It should be noted that waste planned for processing/repackaging before shipment to the WIPP is reported for its current storage configuration, so the radionuclide concentrations associated with them may change prior to receipt at the WIPP, especially if the higher concentration waste streams consist of Pu-239, which is limited to 200 fissile-grams (16.8 PE-Ci) per 55-gallon (208 L) drum.

Table A-3 in Appendix A shows the individual waste streams listed by declining average waste stream radionuclide concentration. This table also shows the Ci/drum concentration of the major isotopes that contribute to the PE-Ci content in each waste stream. As can be seen from Table A-3, the radionuclide composition of CH TRU waste varies widely among the DOE waste generator facilities in terms of waste form or waste stream, TRU radionuclide composition, and waste volume.

Additionally, the radioisotopes found in waste containers are the result of various plutonium "processes" with very specific "mixes" or radionuclide distributions, which also varies widely among the waste generator facilities as shown in Table A-3. The Pu-mixes and the associated isotopic weight distributions used for this analysis are identified in DOE/WIPP 91-058, Radionuclide Inventory for the Waste Isolation Pilot Plant.[12] Although the inventory data in DOE/WIPP 91-058 is outdated, the document is used solely to provide the approximate isotopic weight distributions for all of the Pu-mixes. Appendix H of the BIR also provides isotopic mixes and distributions for Idaho National Engineering and Environmental Laboratory (INEEL) and Los Alamos National Laboratory (LANL) waste. Waste received at WIPP will include waste contaminated with the Pu-51 through Pu-83 mixes which include Pu-239 (weapons grade, fuel grade, reactor grade), and Pu-238 (heat source) operations mixes. Based on the BIR and DOE/WIPP 91-058, the isotopic composition (in weight %) of CH TRU waste from weapons grade Pu-239 operations waste is approximately 93% Pu-239, 6% Pu-240, and less than 0.01% total Pu-238, Pu-241, and Pu-242. For heat source Pu-238 operations, the approximate numbers are: 80% Pu-238, up to 20% Pu-239, and less than 3% total Pu-240, Pu-241, and Pu-242.

5.1.2.1.2 Waste Container Radionuclide Inventory for Safety Analysis Calculations

Background

Past WIPP safety analyses have established a waste container radionuclide inventory (CI) for use in accident analysis calculations based: (1) strictly on the weapons grade mix (Pu-52 distribution), or (2) based on an average or representative waste container content. Additionally, an arbitrarily chosen radionuclide inventory of 1000 PE-Ci was previously used for bounding accident analysis consequence calculations, and established as the WIPP WAC[8] Pu-239 Equivalent Activity Operations and Safety limit.

Past safety analysis consequence calculations were performed predicated on the WIPP WAC Operations and Safety requirement that waste materials be immobilized if >1% by weight is particulate material < 10 microns in diameter, or if > 15 % by weight is particulate material< 200 microns in diameter. However, deletion of this constraint is desirable due to the risk and cost in characterizing the size distribution of deposited radionuclide surface contamination on combustible and noncombustible solids. This SAR has evaluated a reasonable range of CIs for "untreated" (not solidified, vitrified, or overpacked) CH TRU waste. Based on a maximum reasonable CI, used in conservative safety analysis with updated airborne release and respirable fractions and the radionuclide limitations for untreated waste derived below, the potential dose consequences due to inhalation by immediate workers, the noninvolved worker, and the maximally exposed individual (MEI) from operational accidents whose frequencies greater than 1E-06/yr are within the risk evaluation guidelines established in Section 5.2.4. As a result, immobilization is no longer required.

In conjunction with this goal, the establishment of the radionuclide CI for use in accident analysis calculations must also involve: (1) an evaluation of existing safety analysis orders and guidance documents to establish the appropriate level of conservatism for the CI for safety analysis calculations; (2) consideration of the projected waste inventory in Appendix A, and the desire to encompass as much of the Pu-239 and Pu-238 operations waste as possible with the least design or operational impacts to both the waste generator and the WIPP; and (3) evaluation of the existing WAC transportation constraints (nuclear criticality (Pu-239 FGE) and Thermal Power (< 40 watts per TRUPACT-II) criteria). The adequacy of the WIPP facility design, and operational administrative controls (the maximum CI derived below, and elimination of the immobilization requirement as a WAC criterion) is evaluated, based on the accident results in Section 5.2, in detail in Section 5.2.4.

As shown in Table A-4 of Appendix A, each Pu-mix is scaled to the WAC[8] nuclear criticality limit of 200 fissile-gram equivalents (FGE) for 55-gallon (208 L) drums, and 325 FGE for SWBs, using the isotopic weight distributions in DOE/WIPP 91-058,[12] and converted to Plutonium-239 Equivalent Curies (PE-Ci) (see Appendix B for a discussion of the PE-Ci concept). The scaled drum PE-Ci values range from 16.8 PE-Ci for the Pu-52 mix, to 47.2 PE-Ci for the Pu-57 mix, and 9,070.0 PE-Ci for the Pu-83 mix; the values for the scaled SWB range from 27.4 PE-Ci for the Pu-52 mix, to 76.7 PE-Ci for the Pu-57 mix, and 14,739.0 PE-Ci for the Pu-83 mix.

The WIPP WAC Thermal Power transportation requirements, limit the decay heat from all CH-TRU waste to 40 watts per TRUPACT-II. Using the Pu-239 "weapons-grade" distribution in Table A-4 of Appendix A, calculations indicate that the 40 watt limit equates to a maximum total possible PE-Ci for a TRUPACT-II shipment of Pu-239 waste of approximately 1,430 PE-Ci. However, based on the above discussions, for the predominant Pu-239 weapons grade operations waste, the most restrictive of the applicable WIPP WAC criteria is the nuclear criticality criterion, which restricts a single drum to 200 FGE (16.8 PE-Ci), and 325 FGE for SWBs (27.4 PE-Ci), and 325 FGE/TRUPACT-II (27.4 PE-Ci).

Using the Pu-238 "heat source" distribution in Table A-4 of Appendix A, calculations indicate that the 40 watt limit equates to a maximum total possible PE-Ci for a TRUPACT-II shipment of Pu-238 waste of approximately 1,117 PE-Ci. For the less predominant Pu-238 heat source operations waste, the most restrictive of the applicable WIPP WAC criteria is the thermal power criterion, which restricts the total PE-Ci for a TRUPACT-II shipment of Pu-238 waste to approximately 1,117 PE-Ci, much less than the theoretically possible 9,070 PE-Ci (200 FGE) in a single drum. These values are considered below in conjunction with the data in Appendix A for determining a maximum CI.

Approach for Developing the Waste Container Radionuclide Inventory for Safety Analysis Calculations

DOE-STD-3009-94[3] and its draft appendix state that the accident analysis source term material at risk (MAR) should "represent a reasonable maximum for a given process or activity, as opposed to artificial maximums unrepresentative of actual conditions." Additionally, Section A.3.1 of the draft appendix to DOE-STD-3009-94, states that documentation may be used to "back off" of bounding estimates of the MAR.

TRUPACT-II shipments to the WIPP are assumed to be comprised of 14 Type A 55-gallon (208L) drums (or equivalent), two TRUPACT-II SWBs, or one-ten drum overpack (TDOP), as these are currently the only payload containers authorized for unloading at the WIPP by the WAC. The use of a pipe overpack in a 55-gallon (208 L) drum for high concentration TRU waste will provide double containment of that waste. Furthermore, the 1/4" thick stainless steel pipe container that will be placed in the 55-gallon (208 L) drum is judged to be strong enough to permit the overpacked configuration to survive all postulated accidents without a release.

Accident scenarios may involve damage to one, some, or all of the waste containers within the TRUPACT-II. Since the MAR for an accident scenario is a function of the number of waste containers assumed damaged in the scenario and their individual radionuclide CI (MAR = CI * (number of containers damaged)), deriving a reasonable maximum for MAR must also involve deriving a reasonable maximum for CI, as well as for the distribution of PE-Ci contents in the individual waste containers assumed to be involved or damaged.

Based on the data in Appendix A, it is considered "realistic" that the MAR (total of the distribution of PE-Ci contents in the waste containers assumed to be involved or damaged in an accident scenario) is such that each waste container is at or below the average CI derived below. As shown in Table A-3, approximately 86 percent of the volume for all waste forms, including the predominant heterogeneous, uncategorized metal, and combustible waste forms average less than 8 PE-Ci, and 70 percent average less than 3.0 PE-Ci.

Consistent with DOE-STD-3009-94, based on the data in Appendix A, for accident scenarios analyzed in Section 5.2 which involve multiple waste containers, it is conservatively assumed that a "reasonable maximum" MAR (total of the distribution of PE-Ci contents in the waste containers assumed to be involved or damaged in an accident scenario) is such that (1) one waste container contains the maximum radionuclide inventory, and (2) the remaining waste containers contain an average radionuclide inventory, both of which are derived below. For accident scenarios which involve single waste containers, it is conservatively assumed that the waste container contains the maximum radionuclide inventory. Table A-5 of Appendix A, which accomplishes a binomial sampling analysis of the waste drum population, demonstrates that the probability that mixtures of drums exceeding the MAR used above being involved in accidents is very low. Therefore, it may be conservatively concluded that the above assumptions produce reasonable maximum MAR.

It is considered "bounding" that the total of the distribution of PE-Ci contents in the waste containers assumed to be involved or damaged in an accident scenario is at the maximum allowable PE-Ci of 27.4 PE-Ci (325 FGE TRUPACT-II limit) for weapons grade waste, or 1,117 PE-Ci (TRUPACT-II Thermal Power 40-watt limit) for heat source waste.

Average Waste Container Radionuclide Inventory for Safety Analysis Calculations

Section 5.1.2.1.1 has established the variability in the average waste container inventory among the DOE waste generator facilities in terms of waste form or waste stream, and TRU radionuclide composition or Pu process mix. As shown in Table A-3, the waste stream dependent average waste container inventory varies from approximately 1,600 PE-Ci/drum to less than 1 PE-Ci/drum. A "reasonable maximum" average radionuclide inventory of 8 PE-Ci (Table A-1 lowest bin upper cutoff) is established. As shown in Table A-3, 86 percent of the volume for all waste forms have radionuclide concentrations below 8 PE-Ci/drum, including the predominant heterogeneous, uncategorized metal, and combustible waste forms. Additionally, as shown in Table A-2, 96 percent of the volume of uncategorized metals (chosen in Section 5.2.1.1 as the waste form for waste container breach/impact analyses) have radionuclide concentrations below 8 PE-Ci/drum.

It is judged that the waste stream averaged radionuclide concentrations are a good indication of the radionuclide content in individual drums. First, there are 569 individual waste streams, and many sites have multiple waste streams assigned to the same final waste form. A waste stream is defined by the WAC as "material generated from a single process or activity that is similar in material, physical form, isotopic makeup, and hazardous constituents." While it is possible to have variability in the content of individual drums, it should be noted that the heavily loaded drums must be only a small fraction of the total number of drums in a waste stream. For example, a drum that has 5 times the average PE-Ci/drum would require 5 drums having 20% of the average to offset that one heavily loaded drum. As a result, consequence calculations, for multiple drum accidents, assuming that one waste container contains the maximum radionuclide inventory, and the remaining waste containers contain a "reasonable maximum" average radionuclide inventory is reasonable.

Maximum Waste Container Radionuclide Inventory for Safety Analysis Calculations

The maximum CI that complies with DOE-STD-3009-94 guidance on the level of conservatism for the accident analysis source term MAR is established by: (1) enveloping and allowing for disposal at WIPP as much of the stored Table A-3 waste streams contaminated from Pu-239 operations, and high curie content Pu-238 operations waste; and (2) considering the above discussion relating to the WIPP WAC nuclear criticality criterion.

The “reasonable maximum” drum CI for use in accident consequence analysis was established in a previous revision of the SAR by: (1) multiplying the Pu-52 mix scaled 16.8 PE-Ci by a factor of five, and rounded down to 80 PE-Ci for conservatism to encompass the 200 FGE scaled radionuclide content of waste streams contaminated by Pu-239 operations mixes; and (2) evaluating the appropriateness of 80 PE-Ci based on the data provided in Appendix A. The SWB radionuclide inventory is established by multiplying the Pu-52 mix scaled value of 27.4 by a factor of five, and rounding down to 130 PE-Ci. The discussion below confirms that these TRU loadings are a reasonable maximum for use in accident consequence analysis.

As shown in Table A-3 of Appendix A, the maximum radionuclide drum CI of 80 PE-Ci will encompass and allow for disposal a majority (over 99 percent) of the waste volume contaminated from Pu-239 and Pu-238 operations. It is acknowledged that some percentage of the system waste volume will exceed the 80 and 130 PE-Ci values. However, as shown in Table A-3, approximately 27 of the 569 waste streams (less than 5 percent) fall into this category. Within those 27 waste streams, there are 541 equivalent 55-gallon (208 L) drums, or 0.2 percent of the 281,410 total system stored equivalent drums. Of the 27 waste streams, 20 of those waste streams (474 drums) will be processed/repackaged prior to shipment to WIPP.

The maximum container loads of 80 PE-Ci (drums) or 130 PE-Ci (SWBs) used to formulate the MAR are the maximum "untreated" TRU waste container content that may be shipped to the WIPP. As a defense-in-depth approach to prevent potential unacceptable dose consequences to the MEI, noninvolved worker, and immediate worker (the primary receptor of concern for evaluation of the adequacy of the immobilization criterion) from high PE-Ci untreated waste, the WAC requires that waste containers exceeding the 80 PE-Ci (drums) or 130 PE-Ci (SWBs) values must be overpacked (drum within a SWB or TDOP), or solidified, or vitrified (thus immobilized) prior to acceptance at WIPP. Solidification and vitrification both greatly inhibit the release of the waste form should a container be breached during an accident. Overpacking provides an additional barrier that will greatly reduce the frequency of breach during accidents. These two factors, combined with the low percentage of high TRU waste volume that currently exists in the inventory, are judged to make the risks associated with high PE-Ci waste forms small compared to those estimated for the "reasonable maximum" MAR.

As discussed above, the WIPP WAC Thermal Power TRUPACT-II requirement limits the maximum <u>total</u> PE-Ci for a TRUPACT-II shipment of Pu-238 waste to approximately 1,117 PE-Ci. Therefore, the WAC Pu-239 Equivalent Activity Operations and Safety maximum <u>allowable</u> waste container radionuclide inventory of 1,100 PE-Ci for <u>overpacked</u> and 1,800 PE-Ci for solidified/vitrified waste is established.

The adequacy of these assumptions and the WIPP CH TRU facility design basis are evaluated in detail based on the accident results in Section 5.2.4. Receipt of waste for disposal at WIPP that does not meet the applicable Operations and Safety Requirements of the WIPP WAC will first require the performance of an Unreviewed Safety Question Determination (USQD) in accordance with the requirements of DOE Order 5480.21, Unreviewed Safety Questions.[13]

5.1.2.2 TRU Mixed Waste

Hazardous waste, as defined in 40 CFR 261, Subparts C and D,[14] often occurs as co-contaminants with TRU waste from defense-related operations, resulting in "TRU mixed waste." The BIR[10] estimates the quantities of Resource Conservation and Recovery Act (RCRA) regulated TRU waste to be shipped from each generator site. The most common hazardous constituents in the TRU mixed waste consist of the following:

Metals

Some of the TRU mixed waste to be emplaced in the WIPP facility contains metals for which toxicity characteristics were established (EPA hazardous waste codes D004 through D011). These materials are known to be present based on acceptable knowledge of waste-generating processes and various analytical results used to verify acceptable knowledge. Cadmium, chromium, lead, mercury, selenium, and silver are present in discarded tools and equipment, solidified sludges, cemented laboratory liquids, and waste from decontamination and decommissioning activities. A large percentage of the waste consists of lead-lined glove boxes, leaded rubber gloves and aprons, lead bricks and piping, lead tape, and other lead items. Lead, because of its radiation-shielding applications, is the most prevalent toxicity-characteristic metal present.

Halogenated Volatile Organic Compounds

Some of the mixed waste to be emplaced in the WIPP facility contains spent halogenated organic solvents (EPA hazardous waste numbers F001 through F005). The presence of these compounds is confirmed by analytical results from headspace gas sampling of TRU mixed waste. Tetrachloroethylene; trichloroethylene; methylene chloride; carbon tetrachloride; 1,1,1-trichloroethane; and 1,1,2-trichloro-1,2,2-trifluoroethane (EPA hazardous waste codes F001 and F002) are the most prevalent halogenated organic compounds identified in TRU mixed waste that may be managed at the WIPP facility during the Disposal Phase. These compounds are commonly used to clean metal surfaces prior to plating, polishing, or fabrication; to dissolve other compounds; or as coolants. Because they are highly volatile, only very small amounts typically remain on equipment after cleaning, or in the case of treated wastewaters, in the sludges after clarification and flocculation.

Nonhalogenated Volatile Organic Compounds

Xylene, methanol, and n-butanol are the most prevalent nonhalogenated VOCs in TRU mixed waste that may be managed at the WIPP facility during the Disposal Phase. These compounds occur in TRU mixed waste materials in much smaller quantities than halogenated VOCs. Like the halogenated VOCs, they are used as degreasers and solvents, and are similarly volatile. The same analytical methods that are used for halogenated VOCs are used to detect the presence of nonhalogenated VOCs.

TRU mixed waste generated at DOE sites results from specific processes and activities that are well-defined and well-controlled, enabling the DOE to characterize waste streams on the basis of knowledge of the process and the raw materials used. Examples of the major types of operations that generate TRU mixed waste include:

- Production of Nuclear Products—Production of nuclear products includes reactor operation, radionuclide separation/finishing, and weapons fabrication and manufacturing. The majority of the TRU mixed waste was generated by weapons fabrication and radionuclide separation/finishing processes. More specifically, wastes consist of residues from chemical processes, air and liquid filtration, casting, machining, cleaning, product quality sampling, analytical activities, and maintenance and refurbishment of equipment and facilities.

- Plutonium Recovery—Plutonium recovery wastes are residues from the recovery of valuable plutonium-contaminated molds, metals, glass, plastics, rags, salts used in electrorefining, precipitates, firebrick, soot, and filters.

- Research and Development (R&D)—R&D projects include a variety of hot cell or glove box activities that often simulate full-scale operations described above, producing similar TRU mixed wastes. Other types of R&D projects include metallurgical research, actinide separations, process demonstrations, and chemical and physical properties determinations.

- Decontamination and Decommissioning—Facilities and equipment that are no longer needed or usable are decontaminated and decommissioned, resulting in TRU mixed wastes consisting of scrap materials, cleaning agents, tools, piping, filters, Plexiglas™, glove boxes, concrete rubble, asphalt, cinder blocks, and other building materials. This is expected to be the largest category by volume of TRU mixed waste to be generated in the future.

Hazardous Constituents

Hazardous constituents in TRU mixed wastes to be shipped to the WIPP may exist in both the gaseous and solid states within the waste containers. For potential accident scenarios involving the breach of waste containers, knowledge of the hazardous materials in the gaseous state is necessary. Information on headspace gas concentrations is taken from the DOE/WIPP-91-005, Waste Isolation Pilot Plant RCRA Part B Permit Application,[16] for use in analyzing potential waste container breach/puncture scenarios. (Headspace is the void surrounding the waste). Analytical data on the concentrations of 29 VOCs in the headspace gases has been calculated and is summarized in the RCRA Part B Permit Application, Table D9-7.[16] The most prevalent VOCs observed in the headspace gases are methylene chloride and carbon tetrachloride. Additionally, methylene chloride and carbon tetrachloride, as well as chloroform are considered potential carcinogens. A comparison of the headspace weighted averages (ppmv) with the chemical OSHA permissible exposure limit time weighted average (PEL-TWA)(see section 3.3.5) indicates that the headspace weighted averages of carbon tetrachloride, chloroform, and 1,1,2,2-tetrachloroethane initially exceed the PEL-TWA, and require further analyses of the potential exposures during accident conditions. Therefore, methylene chloride, carbon tetrachloride, and chloroform (due to prevalence and as carcinogens), and 1,1,2,2-tetrachloroethane (due to prevalence) are selected for consideration for accidental releases involving the release of headspace gases (Table 5.1-2).

Fire scenarios require knowledge of the hazardous materials in the solid/liquid state. The BIR,[10] indicates that the largest volume of existing TRU mixed waste is from the Idaho National Engineering and Environmental Laboratory (INEEL). As such, the INEEL Hazardous Stored TRU Waste Source Term for the Radioactive Waste Management Complex Transuranic Storage Area[15] is used to develop the total waste container nonradioactive hazardous material inventory (Table 5.1-3).

The waste that will come to WIPP will be addressed by programs at the TRU waste generator sites that implement WIPP requirements. These programs will include the requirements of the Waste Analysis Plan (WAP) found in the WIPP RCRA Part B Application, Chapter C.[16] The WAP defines the required waste characterization activities to be performed by the TRU waste generator sites. Every container of waste that will be shipped to WIPP will also meet the certification requirements contained in the WIPP WAC.[8] These criteria ensure that the waste is compatible with the transportation, management, and long-term disposal requirements for the WIPP and that have been characterized to meet regulatory requirements.

The WAC requires the generator to prepare a waste certification program that lists the methods and techniques used for determining compliance with the WAC and associated quality assurance/quality control (QA/QC) criteria. The WAC contains all of the health and safety based limits that the waste must meet for acceptance by WIPP. Also, the WAC contains transportation related limits based on the Certificate of Compliance for the TRUPACT-II (Nuclear Regulatory Commission) and for hazardous waste (EPA).

Waste Acceptance

Waste acceptance refers to the process whereby a final determination is made, on a container-by-container basis, that waste can be managed at the WIPP in a manner that is protective of human health and the environment, and is in compliance with the regulations. Waste that is finally accepted for disposal at the WIPP will have undergone the screening scrutiny that is required by the WIPP programmatic documents. This means that waste must meet the requirements of the WIPP WAC,[8] WIPP RCRA Part B, Chapter C (WAP),[16] and the data quality objectives of the QAPP.[17] These programmatic documents require that data collected regarding the waste be verified at the point of generation, by the generating site project office, and then again by WIPP. The WAC establishes minimum criteria that the waste must meet, and limits that cannot be exceeded in order to maintain health and safety parameters.

The following waste is unacceptable for management at the WIPP facility:

- Ignitable, reactive, and corrosive waste
- Liquid wastes, (all waste must meet the WAC criteria regarding residual liquid content)
- Compressed gases
- Incompatible waste, (waste must be compatible with backfill, seal and panel closure materials, container, cask, and TRUPACT-II materials as well as with other waste)
- Headspace-gas VOC concentrations resulting in average annual emissions not protective of human health and the environment
- Wastes with EPA codes not listed on RCRA Part A permit application, which is Chapter A of the RCRA Part B permit application[16]
- Waste with equal to or more than 50 parts per million (ppm) (50 milligrams per liter [L]) polychlorinated biphenyls (PCB)

The WIPP facility will not accept waste that exhibits the characteristics of ignitability, reactivity, or corrosivity. The DOE ensures through administrative and operational procedures at the generator sites that TRU mixed waste received at the WIPP facility does not exhibit these characteristics. These characteristics are generally associated with liquid wastes or specific waste forms that may react violently. The WAP and the WAC, therefore, prohibit liquid waste, explosives, compressed gases, oxidizers, and pyrophorics. The absence of these wastes is confirmed by RTR, visual examination, and headspace analysis, as discussed previously. The prohibition of these materials is key to limiting the hazards associated with WIPP CH TRU waste handling activities.

The TRU mixed waste received at the WIPP facility will not be aqueous or liquid, will not contain WAC-prohibited materials, and will be capable of being handled at standard temperatures and pressures without reaction to oxygen or water. The WAC specifies that liquid waste is not acceptable at the WIPP. The WIPP facility will not accept containers holding waste that would be considered a liquid waste. Every container holding waste shall contain less than 0.53 gallons (2 L) of liquid for a 55-gal drum (208L), or 2.1 gallons (8 L) for a SWB. Each container must contain as little residual liquid as is reasonably achievable, and all internal containers (e.g., bottles and cans) must contain less than one inch (2.54 cm) of liquid at the bottom of the container.

Additionally, TRU mixed waste cannot contain explosives, compressed gases, oxidizers, or nonradionuclide pyrophoric materials. (Waste generators have submitted information on waste streams based on known waste generation processes that indicate certain waste streams may have the potential for reactivity, ignitability, or corrosivity.) These characteristics must be eliminated prior to waste acceptance for disposal at the WIPP.

The WIPP will manage TRU mixed waste in a manner that mitigates the buildup of explosive or flammable gases within the waste. Containers are vented through individual particulate filters, allowing any gases that are generated by radiolytic and microbial processes within a waste container to escape; to prevent over pressurization.

The WIPP facility is designed to manage only compatible waste. Therefore, a compatibility analysis was performed to identify potential incompatibilities for all defense generated TRU mixed waste reported in the BIR.[10] Wastes were screened for incompatibilities based on their chemical content and physical waste form. The compatibility analysis also took into account waste compatibility with various aspects of the repository such as shaft, seal, and panel closure materials, backfill, and fire suppressant materials.

To ensure the integrity of the WIPP facility, waste streams identified to contain incompatible materials or materials incompatible with waste containers cannot be shipped to WIPP unless they are treated to remove the incompatibility. Only those waste streams that are compatible, or have been treated to remove incompatibilities, will be shipped to WIPP.

The DOE will only allow generators to ship those waste streams with EPA Hazardous Waste Codes listed on Part A of the RCRA Permit, which is Chapter A of the RCRA Part B Permit.[16] Characterization of all waste streams will be performed as required by the WAP. If during the characterization process, new hazardous waste codes are identified, those wastes cannot be accepted for disposal at the WIPP facility until a permit modification has been submitted and approved. Similar waste streams at other generator sites will be examined more closely to ensure that the newly identified code does not apply. If other waste streams also require a new hazardous waste code, shipment of these waste streams will also cease until a permit modification has been submitted and approved. Approval will be based on the physical and chemical properties of the waste.

Transformer oils containing PCBs have been identified in a limited number of waste streams included in the Waste Matrix Code corresponding to organic sludges. Because the WIPP facility is not seeking permission to manage PCB waste, these waste streams are required to be screened to assure PCB levels are below 50 ppm.

The WAC requires the following information about the waste to be shipped to WIPP: radionuclide identification and quantities; RTR confirmation of the waste form, identification, and indication that no excluded items have been detected; identification of the RCRA constituents identified from headspace gas analysis; totals analysis of homogeneous waste. The WAC also requests other information that is required for transportation, safe handling, and disposal of the waste.

5.1.3 CH Hazard Categorization

The hazard categorization for the CH TRU Waste Handling Process was developed based on the methodology and requirements in DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.[2] The Standard requires that a nonreactor nuclear facility be placed in a hazard category based on the unmitigated release of material from the facility. The material then is compared against Threshold Quantities (TQs) identified in Attachment 1 of the Standard.

The maximum drum radionuclide inventory developed in Section 5.1.2, susceptible to an unmitigated accidental release is 80 PE-Ci. Since this quantity exceeds the Hazard Category 3 threshold of 56 Ci for Pu-239 (Attachment 1 of Standard), the WIPP is classified overall as a Hazard Category 2 facility.

5.1.4 Hazard Evaluation

The WIPP CH TRU handling process was qualitatively evaluated using a HAZOP (Summarized in Appendix C).[4] This systematic approach to hazard analysis was conducted by a leader knowledgeable in the HAZOP methodology, and consisted of personnel from various disciplines familiar with the design and operation of the WIPP (HAZOP Team). The HAZOP Team identified deviations from the intended design and operation of the waste handling system that could: (1) result in process slowdown or shutdown, (2) result in worker injury or fatality, and (3) result in the release of waste container radiological and nonradiological materials.

The HAZOP Team assigned a qualitative consequence and frequency ranking for each deviation as discussed below. A hazard evaluation ranking mechanism utilized the frequency and the most significant consequences to separate the low risk hazards from high risk hazards that may warrant additional quantitative analysis. Based on this ranking approach a basic set of accidents was chosen for further quantitative assessment in Section 5.2 to: (1) verify and document the basis for the qualitative frequency and consequence assignments in the HAZOP, and (2) identify the need for Design Class I (safety-class) structures, systems, or components (SSCs) and Technical Safety Requirements (TSRs).

The HAZOP replaces previous hazards analyses in existing documentation including the Final Environmental Impact Statement (FEIS),[5] Final Supplement Environmental Impact Statement (SEIS),[6] WIPP Fire Hazards and Risk Analysis,[7] and Failure Modes and Effects Analyses (FMEAs), for the purposes of identifying initiating events for quantitative accident analysis in Section 5.2. However, these documents were reviewed in preparation of this section, to ensure that all hazards associated with CH TRU waste handling were identified in the HAZOP.

Since the performance of the HAZOP, an update of the WIPP Fire Hazards Analysis[32] has been performed to meet the requirements of DOE Order 5480.7A.[18] The updated Fire Hazards Analysis presents considerable evidence that supports the previous evaluation that the frequency of room or structural fire, as an accident in the Waste Handling Building (WHB) resulting in a direct release of radioactive material from the waste containers engulfed in the fire, is beyond extremely unlikely. The low frequency of this scenario is due primarily to the very low amounts of combustibles in waste handling areas, and lack of favorable propagation factors in the WHB. The most likely ignition source for fires in this area, are electrical fires involving transmission equipment, electric motors, appliances, and process equipment (including waste hoist motor and controls, 6-ton bridge crane motor, and electrical waste handling equipment motors). Fire detection and suppression systems are not required to prevent or mitigate room or structural fires leading to the accidental release of radioactive material. However, the updated fire hazards analysis indicates that the existing WHB fire detection and suppression systems are adequate to meet the requirements of DOE Order 5480.7A.

Because of proximity of the WIPP Support Building and the TRUPACT Maintenance Facility (TMF) to the WHB, the 1997 update of the FHA investigated the likelihood of fire propagating from either of these two buildings to the WHB with the potential to fully engulf the WHB, resulting in the collapse of the roof of the Contact Handling Bay (CH Bay) over the stored waste drums, resulting in an uncontrolled release of hazardous materials to the environment. The analysis determined that the frequency that a significant fire in either the Support Building or TRUPACT Maintenance Facility will propagate to the CH Bay of the Waste Handling Building and cause structural failure over the waste storage area is beyond extremely unlikely (less than 1E-6 per year). When the entire sequence of events required to produce structural failure is quantified, the likelihood of a structural collapse is about 2E-12/year for fires originating in the Support Building, and about 2E-10/year for fires originating in the TRUPACT Maintenance Facility. When no credit is taken for the fire suppression system, a fire that could result in an uncontrolled release of hazardous materials from a structural failure over the waste storage area, or from direct radiation is beyond extremely unlikely (less than 1E-6 per year).

The HAZOP evaluates the WHB waste handling equipment fires, and fires associated with diesel waste handling equipment in the underground as low frequency, low consequence events. Such fires may lead directly to waste handling equipment failure, or small fires impacting waste containers, both of which may lead to a release of radionuclides. The update FHA investigated the increased potential for fires resulting from the introduction of the additional fuel and ignition source of the diesel powered vehicle into the waste panels. The analysis found that the frequency of waste container breach due to a forklift-induced fire is less than 1E-6 per year, or beyond extremely unlikely. As a result of the FHA evaluation, it was determined that the use of diesel driven forklifts to place waste containers and MgO sacks in the underground will have negligible impact of safety. The updated FHA, and the HAZOP, both conclude that adequate equipment and manual fire suppression is available to prevent or mitigate these potential low risk fires.

The bounding amount of combustible material, as well as the presence of an ignition source, for the quantitative evaluation of a sustained fire scenario in both the WHB and the underground, is within the waste container. Such sustained internal waste container fires are assumed unmitigated by manual or automatic fire suppression systems. Additionally, spontaneous ignition within a waste container is considered of special interest due to the Waste Acceptance Criteria administrative controls that act to prevent such accidents. As such, spontaneous ignition within a waste container, evaluated qualitatively as extremely unlikely by the HAZOP Team, is evaluated quantitatively in Section 5.2.

PLG-1167,[33] Analysis of Roof Falls and Methane Gas Explosions in Closed Rooms and Panels investigated the possibility of a combustible gas explosion in a closed panel. Combustible gases, consisting primarily of methane, can be generated within waste drums containing organic materials. These gases can be released to the underground horizon through activated carbon venting plugs provided in each waste container. In unventilated areas, these gases may build up over a period of time, leading to a concern about the potential for an explosive mixture to form. The Panel Closure System has been designed to remain intact during such an event. PLG-1167,[33] examined the uncertainties in the generation of methane gas using recent information that indicate that concentrations will not reach potentially explosive concentrations during the time frame that an individual panel will remain open to ventilation. In addition, it concludes that the Panel Closure System design is adequate to address the range of conditions that might be expected within the sealed panel over the operational lifetime of the WIPP facility. The results show that for the worst case assumptions regarding the parameters of interest, the explosion pressure never exceeds the interface stress, and the gases from the explosion pressures would be contained. Therefore, it may be concluded that the likelihood of a breach of the Panel Closure System due to a methane explosion is beyond extremely unlikely.

5.1.4.1 HAZOP Methodology

The HAZOP technique, based on a creative systematic interaction of a multi-disciplinary team, evaluated the significance of deviations from the normal waste handling process. The HAZOP Team consisted of experienced personnel from Facility Operations, Maintenance Operations, (including previously qualified waste handlers experienced in TRUPACT and drum handling activities), industrial and nuclear safety, engineering, and regulatory compliance.

The HAZOP process started with the receipt of a CH TRU waste transporter at the front gate and ended with CH TRU waste being disposed of in the underground. HAZOP nodes (process steps) were selected to define the movement of CH TRU waste through the facility. Deviations were postulated for each node, and once the deviation was confirmed to be plausible, the HAZOP Team determined the possible causes for the deviation. The resulting potential consequences were explored without taking into consideration any mitigating features.

An evaluation was made to determine if mitigating safeguards were in place to alleviate the consequences. Some of the potential deviation consequences or concerns identified by the HAZOP Team are:

- Worker injury or fatality,
- Process slowdown or shutdown,
- Internal and external conditions may result in breach/rupture of waste containers resulting in the airborne release of radiological and/or nonradiological hazardous materials (loss of primary confinement),
- External waste container surface contamination and need for decontamination,
- Worker and public exposure to radiation and airborne radiological and nonradiological hazardous materials,
- Potential for receipt of damaged waste containers and need for overpack operations.

The HAZOP deviation ranking process used a two-number system, consisting of a qualitative consequence classification (Table 5.1-4) and a qualitative frequency (Table 5.1-5) classification. The qualitative consequence classification was ranked without consideration for mitigation. The qualitative frequency was ranked taking into consideration the probability of failure of identified safeguards and mitigation for that deviation. The HAZOP Team concluded that:

- Safeguards currently exist at the WIPP to prevent or reduce the frequency of such deviations from occurring. Identified safeguards include facility and equipment design, procedures, training, preventative maintenance and inspection, and administrative controls including the WIPP WAC[8] (see Table 5.1-7 and Appendix C).

- Mitigation exists to reduce the consequences of any postulated deviation to acceptable levels. Identified mitigation includes confinement/ventilation systems and associated HEPA filtration systems (see Table 5.1-7, and Appendix C).

As qualitatively concluded from this HAZOP, the design of the WIPP CH TRU Waste Handling System is sufficient to ensure the safety of the public, workers, and the environment. The HAZOP Team identified no substantial recommendations for the WIPP management to consider to reduce the severity or frequency of any of the postulated deviations.

5.1.4.2 Selection of CH Potential Accidents

The HAZOP[4] provided a list of deviations that were qualitatively ranked by relative consequence and frequency using the ‘total rank’ consequence criteria of Table 5.1-4, and the frequency criteria of Table 5.1-5. This resulted in the ‘total rank’ recorded in Appendix C. As stated in the HAZOP[4], the consequence ranking (total ranking) of each deviation included both the resultant consequence to the worker and the radiological and nonradiological consequence to the offsite public. In most deviations, the possibility of worker fatality resulted in the assignment of the highest possible consequence ranking of four. The total rank results in Appendix C are used for the evaluation of worker protection from accidents in Section 5.1.7.

In order to select potential CH accidents for quantitative accident analysis, the total list of hazards was narrowed to focus on risk posed by the accidental release of radiological and nonradiological hazardous material, by using the ‘hazard rank’ consequence criteria Table 5.1-6. This eliminated occupational deviations exclusive of the hazardous materials involved, providing a subset ‘hazard rank’ (also recorded in Appendix C).

In order to determine the risk associated with each deviation, the relative frequency and hazard consequence ranking (hazard rank) were combined. The deviations were then categorized as acceptable, moderate, or high risk based on the Relative Frequency and Consequence Ranking Matrix (Figure 5.1-1). Those deviations with a frequency and consequence combination that is in the matrix area of acceptable risk were excluded from further consideration for quantitative evaluation, with the exceptions of the waste hoist drop (CH5), earthquake (CH6), and aircraft crash (CH8). The waste hoist drop (CH5) was also selected for its significant interest to external organizations, as well as the earthquake (CH6) as a natural event, and the aircraft crash (CH8) as an external event as required by DOE-STD-3009-94.[3]

Table 5.1-7 lists the deviations whose combined “hazard rank” were identified to be of moderate or high risk. The list of deviations in Table 5.1-7 is used for the selection of accidents for quantitative analysis in Section 5.2.

5.1.5 Prevention of Inadvertent Nuclear Criticality

The intent of a criticality safety program is to prevent the accumulation of fissile and fissionable material and neutron moderating or reflecting materials in quantities and configurations that could result in an accidental nuclear criticality.

To ensure adequate margins of criticality safety for adherence to DOE Order 5480.5,[19] the WIPP facility was designed so that during each operation involving fissile material K_{eff} does not exceed a value of 0.95 (at the 95 percent confidence level) for the most reactive set of conditions considered credibly possible. The calculation of K_{eff} includes the effect of neutron interaction and reflection between fissile elements and dimensional variations resulting from fabrication tolerances and changes due to corrosion and mechanical distortion. As discussed below, these calculations indicate the combination of conditions enabling the K_{eff} limit of 0.95 to be exceeded for the CH waste forms handled at the WIPP facility is incredible.

5.1.5.1 WIPP Nuclear Criticality Safety Program Elements

The WIPP nuclear criticality program elements consist of mass limits control, TRU waste disposal configuration control, and analytical verification of subcriticality.

Mass Limits Control

The WIPP WAC[8] limits the fissile or fissionable radionuclide content of CH TRU waste, including allowance for measurement errors, to 200 Fissile-Gram Equivalent (FGE) for a 55-gallon (208 L) drum and 325 FGE for a SWB. Further, the WAC limits the TRUPACT II payload, including error allowance, to 325 grams of FGE total. Overpack containers are limited by the FGE limit on the containers they overpack.

TRU Waste Disposal Configuration Control

In addition to the mass limits control, geometry controls are required for the emplacement and/or in-transit handling disposal configurations. Drum arrays shall not exceed three drums high, and may be infinite in both horizontal directions. With the current plutonium loading limits, the axial height of the WIPP disposal array is limited by the maximum height of 55 gallon drums, not SWBs or overpack containers.

CH TRU Nuclear Criticality Safety Analysis

In compliance with DOE Order 5480.5,[19] a criticality analysis[20] was performed to ensure that no credible criticality accident could occur at the WIPP. The analysis was based on the mass limit control and geometry control discussed above, with additional conservative assumptions in terms of; isotopic content, density and configuration modeling, moderation, and reflection. Further, for the CH waste analysis, it was assumed that the waste package storage array is infinite in both horizontal directions.

The results of the WIPP CH TRU criticality analysis[20] indicate that, for each of the conditions analyzed, the calculated effective multiplication factor, K_{eff}, is less than 0.95 including uncertainties at 95 percent probability at 95 percent confidence level. Accordingly, no credible criticality hazard exists at the WIPP for CH TRU operations.

DOE Order 5480.24[21] requires additional analysis of nuclear criticality safety. The WIPP CH TRU criticality analysis[20] was examined for compliance with the order and all the applicable requirements for the order performance of criticality analysis were complied with within the analysis.

5.1.5.2 Compliance with Mandatory ANSI/ANS Standards

The existing WIPP nuclear criticality safety program elements were reviewed to ensure compliance with the six mandatory American Nuclear Society ANSI/ANS nuclear criticality safety standards as the Order requires. The six mandatory standards are: ANSI/ANS-8.1,[22] 8.3,[23] 8.5,[24] 8.7,[25] 8.15,[26] and 8.19.[27]

The WIPP nuclear criticality safety program elements are found to be in compliance with the requirements of ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors,[22] and ANSI/ANS-8.15, Nuclear Criticality Control of Special Actinide Elements,[26] in regard to: mass control, geometry control, and performance of criticality analyses.

The criticality-related administrative control provisions were determined to be in compliance with ANSI/ANS-8.19, Administrative Practices for Nuclear Criticality Safety.[27]

Since it has been established by analyses[20] that a criticality accident is beyond extremely unlikely (frequency $\leq$ 1 E-06/yr) at the WIPP, ANSI/ANS-8.3,[23] a Criticality Accident Alarm System, is not applicable as called for in the Order.

The two facility-specific standards, ANSI/ANS-8.5, Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material,[24] and ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials,[25] are not applicable to the WIPP.

The existing WIPP nuclear criticality safety program elements are therefore in compliance with the Order-required mandatory criticality safety standards.

5.1.6 Defense-in-Depth

A defense-in-depth philosophy is employed in WIPP's approach to enhancing the safety of the facility in conjunction with its design and operations. The WIPP defense-in-depth safety approach provides layers of defense: (1) against release of radiological and nonradiological hazardous waste container materials and the resultant consequences to the public and the environment, and (2) for protection of the worker against accidents. The WIPP approach provides three layers of defense against releases. Each successive layer provides an additional measure of the combined defense strategy.

The ultimate safety objective of the first, or primary layer of WIPP defense-in-depth is **accident prevention**. The reduction of risk (as the product of frequency and consequence) to both workers and the public from WIPP CH TRU waste handling and emplacement operations is primarily achieved by reducing the frequency of occurrence of postulated abnormal events or accidents. The conservative design of the facility's structures, systems, and components (SSCs), with operations conducted by trained/qualified personnel, to the standards set forth in approved procedures, provides the first layer. Specific preventative measures are identified in Appendix C for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis.

The occurrence frequency for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis, is primarily derived from process inherent events, equipment failure, and human error. To reduce the frequency of equipment failure, the facility design, fabrication, and construction were undertaken in accordance with applicable codes and standards, based on the design classification of SSCs established in Chapter 4. Extensive pre-operational tests were conducted to verify that SSCs perform their design function. This is followed up presently by in-service and pre-operational checks and inspections, and preventive maintenance and quality assurance programs. The WIPP employs configuration management change control and modification retest to ensure quality throughout facility life. For hazards associated with underground operations, a substantial array of ground control planning and practices, support systems, instrumentation, monitoring, and evaluation exist to reduce the frequency of potential underground accidents. Technical Safety Requirement (TSR) Administrative Controls (ACs) are derived in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR) to ensure that the high level of design is maintained throughout the facility lifetime.

Additionally, as identified in the HAZOP, accident prevention for process inherent events such as spontaneous ignition, is achieved administratively through the WAC[8] (as discussed in detail in Section 5.1.2.2) which restricts waste elements (such as the presence of pyrophorics) which may be initiating events for accidents. In addition, the following provide administrative controls to prevent the risk from postulated accidents from being unacceptable: (1) WAC limits on the radionuclide and fissile content of each waste container, (2) waste container integrity provisions ensure the robustness reflected in the waste container accident release analyses, and (3) criticality safety is a designed in-storage and handling configuration that ensures (in conjunction with waste characteristics) that active criticality control is not required.

Prevention of human error as an initiating event is achieved by the extensive training and qualification programs, operational procedures, and conduct of operations programs. TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR) to ensure that these programs are maintained, and operations continue to be conducted with highly qualified and trained personnel using current approved procedures.

The second layer of defense-in-depth provides protection against anticipated and unlikely operational events that might occur in spite of the protection afforded by the first layer of defense. The second defense layer is characterized by detection and protection systems, and controls that: (1) indicate component, system, or process performance degradation created by compromises of the first layer, and (2) provide adequate mitigation and accommodation of the consequences of those operational accidents which may occur.

Specific mitigative features are identified in Appendix C for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis. In general, the WHB and underground radiation and effluent monitoring systems and HEPA filtration systems, and the WIPP emergency management program[30] provide this layer of defense-in-depth. In addition, the WIPP Human Factors Evaluation,[31] determined that well established policies and procedures are in place ensuring normal and emergency procedures are implemented, adequate directions have been provided to shift personnel concerning actions to be taken in a potential accident environment, and adequate procedures are available for follow up response. TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document (Attachment 1 to the SAR) supporting the second level of defense-in-depth. Programs supporting defense-in-depth as required by the TSRs, are discussed in detail in Chapters 7, 8, and 9.

The third layer of defense-in-depth supplements the first two layers by providing protection against extremely unlikely operational, natural phenomenon, and external events. These events represent extreme cases of failures and are analyzed in Section 5.2.3 using conservative assumptions and calculations to assess the radiological and nonradiological effects of such accidents on the MEI, noninvolved worker, and immediate worker to verify that a conservative design bases has been established. These accidents include sustained waste container internal fire, waste hoist failure, and roof fall in the underground.

5.1.7 Protection of Immediate Workers from Accidents

The HAZOP[4] for the CH TRU Waste Handling System identified a number of waste handling process hazards that could potentially lead to events resulting in immediate worker injury or fatality, or exposure to radiological and nonradiological hazardous materials. The Total Rank (or risk) for each postulated deviation as identified in Appendix C, is the qualitative product of the frequency of the event and the potential consequences. As shown in Appendix C, the consequences of the postulated deviations were dominated by the assumption that a worker fatality may result without safeguards in place, regardless of dose or dosage received.

Consistent with: (1) Paragraph 6 of Attachment 1 of DOE Order 5480.22, Technical Safety Requirements;[28] (2) the defense-in-depth philosophy discussed in Section 5.1.6; and (3) the philosophy of Process Safety Management (PSM), as published in 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals,[29] reduction of the risk to workers from accidents is accomplished at the WIPP primarily by identifying controls to **prevent the event from happening**. (note: Compliance with 29 CFR 1910.119 is not required by WIPP. However, the WIPP philosophy of reduction of accident risk discussed in this section, is consistent with this standard.) As stated in paragraph 6 of Attachment 1 of DOE Order 5480.22, "The TSRs are not based upon maintaining worker exposures below some acceptable level following an uncontrolled release of hazardous material or inadvertent criticality; rather the risk to workers is reduced through the reduction of the frequency and potential impact of such events."

Consistent with this statement, in conjunction with the defense-in-depth philosophy described in the previous section, total risk is evaluated by: (1) performing engineering analyses in the form of event tree/fault tree analysis to identify systems, structures, components, processes, or controls that contribute most to the accident phenomena frequency for the purposes of verifying their adequacy or identifying improvements to reduce the accident frequency and therefore risk, and (2) evaluating human error as an initiating event.

As discussed in Section 5.1.4.1, the HAZOP Team identified a significant number of existing preventative safeguards that lower the frequency of occurrence of each deviation, substantially reducing the risk of injury or fatality to workers. The HAZOP Team concluded, consistent with the first layer of defense-in-depth, safeguards currently exist at the WIPP to prevent or reduce the frequency of such deviations from occurring. Identified preventative safeguards as shown in Appendix C, and Table 5.1-7 generally include the following:

- Facility and equipment design, application of appropriate design classification and applicable design codes and standards,
- Programs relating to configuration and document control, quality assurance, and preventative maintenance and inspection,

- Administrative controls including the WIPP WAC,[8] waste handling procedures and training, and the WIPP Emergency Management Program[30] and associated procedures.

Due to the importance of these preventative features in WIPP defense-in-depth and worker protection from accidents, TSR ACs are derived in Chapter 6, and required in the WIPP TSR Document (Attachment 1 to the SAR).

Section 5.2.3 evaluates the accident dose consequences to immediate workers from operational waste container handling accidents whose frequency is greater than 1E-06/yr, and may be initiated by waste handling equipment failure or directly through human error by a worker performing a waste handling operation. These accidents include crane failure, and waste container drops or puncture in the Waste Handling Building and the underground. The immediate worker is that individual directly involved with the waste handling operation for which the accident is postulated. This evaluation will ensure that the maximum allowable radionuclide inventory, in conjunction with the other layers of defense-in-depth, will preclude worker exposure from being unacceptable. A detailed summary of the evaluation of the WAC maximum allowable radionuclide inventory is provided in Section 1.3.2.4. Releases from such accidents are conservatively assumed to be instantaneous, and, although procedures dictate that workers exit the area immediately, such accidents present an immediate risk due to the inhalation of airborne radionuclides to the worker performing the waste handling operation.

To evaluate the risk to immediate workers from extremely unlikely operational accidents such as roof fall in the underground and waste hoist failure, the direction of resources in this SAR is more focused on the evaluation of system/facility reliability (accident prevention) than on an in-depth evaluation of radiological consequences to an immediate worker and post accident mitigative systems and controls. This evaluation is conducted in the event tree/fault tree analysis in Appendix D, and the accident scenario and evaluation of design adequacy descriptions for each applicable accident in Section 5.2.3. The risk to workers from extremely unlikely process inherent events such as spontaneous ignition, is a result of the failure of the WIPP WAC to restrict waste elements (such as the presence of pyrophorics) that may cause the initiating event. Again, the direction of resources is focused on the evaluation of the adequacy of the WAC certification process to prevent this type of accident, than on the evaluation of a survivable, specified radiological consequence for which mitigative SSCs or administrative controls may be derived. This evaluation is conducted in the event tree/fault tree analysis in Appendix D, and discussed in Section 5.1.2, and the accident scenario descriptions for CH1 and CH7 in Section 5.2.3.

In addition to these fault tree analyses, human error as an initiating event has been evaluated in the WIPP Human Factors Evaluation.[31]

As derived from the WIPP HAZOP, the risk to immediate workers from severe natural phenomenon (design basis earthquake and/or tornado), is dominated by worker fatality due to the energetic phenomenon during the event, as opposed to a specified radiological dose for which additional mitigative SSCs or administrative controls may be derived. This SAR is focused more on the evaluation of the existing facility design when subjected to the severe natural phenomenon (to reduce the likelihood of worker fatality, as well as breach of waste containers), rather than on the evaluation of radiological consequences to an immediate worker. This evaluation is conducted in the accident scenario and evaluation of design adequacy descriptions for each applicable accident in Section 5.2.3.

5.1.8 Defense-in-Depth Structures, Systems, and Components (SSCs)

As discussed in Sections 5.1.6 and 5.1.7, specific preventative and mitigative SSCs are listed in Appendix C for each postulated deviation as identified in the HAZOP,[4] and in Table 5.1-7 for each deviation considered for quantitative accident analysis. Specific SSCs that fulfill a defense-in-depth function, or considered essential for waste handling, storage and/or disposal operations are as follows: (1) Waste Handling Building (WHB) Heating, Ventilation and Air Conditioning (HVAC) (excluding RH area ventilation unless the RH area is used for CH storage or handling), and Underground Ventilation and Filtration System (UVFS) (including underground shift to filtration); (2) Waste Hoist Equipment (including Brake System); (3) Waste Handling Equipment (including the TRUDOCK Bridge Crane, forklifts, transporters, etc., as required), (4) WHB structure including tornado doors, (5) Central Monitoring System (to support underground shift to filtration only); and (6) Radiation Monitoring System, active waste disposal room exit alpha CAM (for underground shift to filtration).

Section 5.2.4.1, Evaluation of the Design Basis, discusses in detail: (1) the evaluation of safety significant SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

References for Section 5.1

1. DOE Order 5480.23, Nuclear Safety Analysis Reports, April 1992.

2. DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports, 1992.

3. DOE-STD-3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports, July 1994.

4. WCAP 14312, Hazard and Operability Study for CH TRU Waste Handling System, Waste Isolation Pilot Plant, Westinghouse Waste Isolation Division, April, 1995.

5. DOE/EIS-0026, Final Environmental Impact Statement, Waste Isolation Pilot Plant, 2 Vols, U.S. Department of Energy, Carlsbad, N.M., 1980.

6. DOE/EIS-0026-FS, Final Supplement Environmental Impact Statement, Waste Isolation Pilot Plant, U.S. Department of Energy, Carlsbad, N.M., 1990.

7. DOE/WIPP 91-031, WIPP Fire Hazards and Risk Analysis, May 1991.

8. WIPP-DOE-069, Rev. 5, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, April 1996.

9. Public Law 102-579, WIPP Land Withdrawal Act, October 30, 1992.

10. DOE/CAO-95-1121, U.S. Department of Energy Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report (BIR), Revision 3, December 1995.

11. Public Law 102-386, Federal Facility Compliance Act, U.S. Congress, 1992.

12. DOE/WIPP 91-058, Radionuclide Inventory for the Waste Isolation Pilot Plant, Rev. 0.

13. DOE Order 5480.21, Unreviewed Safety Questions, December 1991.

14. CFR (Code of Federal Regulations) 40, Part 261, Identification and Listing of Hazardous Waste.

15. ENV-003, Hazardous Stored TRU Waste Source Terms for the RWMC's TSA, 1990.

16. DOE/WIPP-91-005, Waste Isolation Pilot Plant RCRA Part B Permit Application, Revision 6, U.S. Department of Energy, Carlsbad, N.M. .

17. CAO-94-1010, Revision 0, Transuranic Waste Characterization Quality Assurance Program Plan, U.S. Department of Energy, Carlsbad, N.M., 1995.

18. DOE Order 5480.7A, Fire Protection, 02/17/93, U.S. Department of Energy, Washington, DC 20585.

19. DOE Order 5480.5, Safety of Nuclear Facilities, September 23, 1986.

20. WIPP Nuclear Criticality Safety Evaluation, July 1998.

21. DOE Order 5480.24, Nuclear Criticality Safety, August 12, 1992.

22. ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors.

23. ANSI/ANS-8.3, Criticality Accident Alarm System.

24. ANSI/ANS-8.5, Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material.

25. ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials.

26. ANSI/ANS-8.15, Nuclear Criticality Control of Special Actinide Elements.

27. ANSI/ANS-8.19, Administrative Practices for Nuclear Criticality Safety.

28. DOE Order 5480.22, Technical Safety Requirements, Change 1, September 15, 1992.

29. 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals.

30. WP 12-9, WIPP Emergency Management Program

31. PLG-1004, Waste Isolation Pilot Plant Human Factors Evaluation, July, 1994.

32. DOE-WID-96-2176, Revision 2, WIPP Fire Hazards Analysis Report, August, 1998.

33. PLG-1167, Analysis of Roof Falls and Methane Gas Explosions in Closed Rooms and Panels

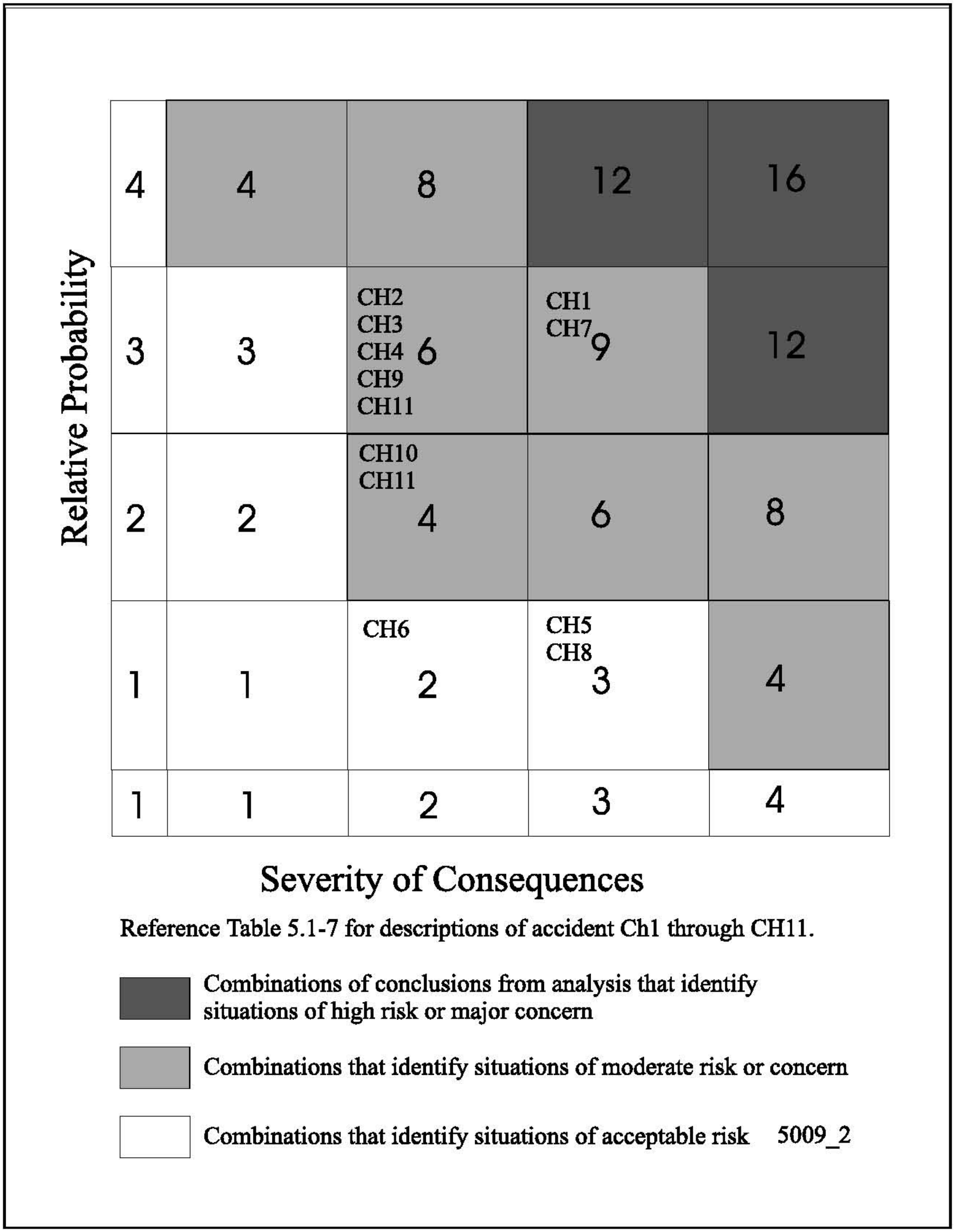

Figure 5.1-1, Relative Frequency and Consequence Ranking Matrix for Hazard Evaluation

Table 5.1-1, Maximum Hazardous Material Inventory by Facility Location

Hazard Type	Material Form	Location (Facility Process)	Inventory Number of Drums	Inventory Number of SWBs	Basis for Number of Drums/SWBs
WASTE HANDLING BUILDING					
Radioactive/ Nonradioactive Material	CH TRU Waste	CH Bay	196	28	7 Facility Pallets
				1	Derived Waste Storage - 1 SWB
		Shielded Holding	28	4	1 facility pallet
		Conveyance Loading Room	28	4	1 facility pallet
UNDERGROUND HORIZON					
Radioactive/ Non radioactive Material	CH TRU Waste	Waste Shaft Station	28	4	1 facility pallet
		Disposal panel	81,000	11,580	Total waste capacity/panel divided by waste container volume

Table 5.1-2, VOC Concentrations

Chemical	Weighted[1] Average (ppmv/mole gas)	Mole Fraction (1.0E-06 mole VOC/ppmv)	Moles gas/drum (moles gas)[4]	Molecular Weight (g/mole)	Unit Conversion 0.0022 lb/g (1.0E+03mg/g)	Drum Inventory[2] lb (mg)	SWB Inventory[3] lb (mg)
Methylene Chloride	368.5	1.0E-06	6.56	84.9	2.2E-03 (1.0E+03)	4.5E-04 (205.2)	1.81E-03 (820.9)
Chloroform	25.3	1.0E-06	6.56	119.4	2.2E-03 (1.0E+03)	4.36E-05 (19.8)	1.74E-04 (79.3)
1,1,2,2-Tetrachloroethane	9.4	1.0E-06	6.56	167.9	2.2E-03 (1.0E+03)	2.29E-05 (10.4)	9.11E-05 (41.4)
Carbon Tetrachloride	375.5	1.0E-06	6.56	153.8	2.2E-03 (1.0E+03)	8.36E-04 (378.9)	3.33E-03 (1,515.4)

Notes:

1. Data from DOE/CAO-96-2160, WIPP No Migration Variance Petition, June 1996 .

2. Drum Inventory = weighted average (ppmv VOC/mole gas) x mole fraction (1E-06 mole VOC/ppmv VOC) x moles gas/drum (6.56 moles gas at STP/drum) x molecular weight (g/mole VOC) x (2.2E-03 lb/g)

3. SWB Inventory =(4 drum equivalents) x (Drum Inventory)

4. Assumption: 70% void space in TRU waste drums
   55 gallons/drum at STP: air =0.01076 lbs/gallon; molecular weight air = 0.06372 lbs/mole
   Air moles/l = (0.01076 lbs/gallon)/(0.06372 lbs/mole) = 0.1703 mole/gallon
   Moles gas /drum = (0.70)(55 gallons/drum)(0.1703 mole/gallon) = 6.56 moles/drum

Table 5.1-3, Hazardous Material Concentrations Used in Fire Scenarios (CH1 and CH7)

Chemical	Average[1] Weight Fraction	Inventory - lbs (mg)[2] (Based on 243 lbs/drum)
Asbestos	2.7E-03	0.66 (3.0E+05)
Beryllium	2.1E-04	0.051 (2.3E+04)
Cadmium	3.0E-06	7.3E-04 (3.3E+02)
Lead	8.3E-03	2.00 (9.1E+05)
Butyl Alcohol	3.0E-03	0.73 (3.3E+05)
Carbon Tetrachloride	6.3E-03	1.52 (6.9E+05)
Mercury	3.5E-03	0.86 (3.9E+05)
Methyl Alcohol	8.0E-06	1.9E-03 (8.8E+02)
Methylene Chloride	4.0E-04	0.10 (4.4E+04)
Polychlorinated Biphenyl (PCB)	8.5E-03	1.98 (9.0E+05)
Trichlorethylene	3.9E-03	0.95 (4.3E+05)

Notes:

1. Data from Reference 15, Table 1. Data listed is average weight fraction of each hazardous material of the total drum weight. Sum will not add to unity, as other nonhazardous materials are within each drum.

2. Drum Inventory = (Weight Fraction) x (243 lbs/drum) [x (453.592 g/lb) x (1E+03 mg/g)]

Table 5.1-4, Total Rank Qualitative Consequence Classification Table

Consequence Category	Description
1	May cause facility worker injury as a result of an industrial accident or acute exposure from radiological or toxicological material with no lost time. Negligible offsite impact to people or environs. May result in facility contamination with no significant disruption of facility operation.
2	May cause facility worker injury as a result of an industrial accident or acute exposure from radiological or toxicological material with lost time and with no disability. Negligible offsite impact to people or environs. May result in facility contamination, or facility damage with minor disruption of facility operation.
3	May cause severe facility worker injury with disability. Minor offsite impact to people or environs. May result in facility contamination, or facility damage with major disruption of facility operation.
4	May cause deaths to facility workers. Considerable offsite impact to people and environs. Offsite contamination requiring cleanup, or facility destruction.

Table 5.1-5, Qualitative Relative Frequency Classification Table

Relative Frequency Category	Estimated Annual Frequency of Occurrence	Description
1 Beyond Extremely Unlikely	$10^{-6} \geq f$	All accidents not included in other categories. Frequency of less than once in a million years.
2 (Extremely Unlikely)	$10^{-4} \geq f > 10^{-6}$	Accidents that will probably not occur during the life cycle of the facility. This class includes the design basis accidents. Frequency between one in 10,000 years and once in 1,000,000 years.
3 (Unlikely)	$10^{-2} \geq f > 10^{-4}$	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this class include: Uniform Building code-level earthquake, 100-year flood, maximum wind gust, etc. Frequency between one in 100 years and once in 10,000 operating years.
4 (Anticipated)	$10^{-1} \geq f > 10^{-2}$	Incidents that may occur several times during the lifetime of the facility (incidents that commonly occur). Frequency is between one in 10 years and one in 100 operating years.

Table 5.1-6, Hazard Rank Qualitative Consequence Classification Table

Consequence Category	Description
1	May cause facility worker injury as an acute exposure from radiological or toxicological material with no lost time. Negligible offsite impact to people or environs. May result in facility contamination with no significant disruption of facility operation.
2	May cause facility worker injury as an acute exposure from radiological or toxicological material with lost time and with no disability. Negligible offsite impact to people or environs. May result in facility contamination, or facility damage with minor disruption of facility operation.
3	Minor offsite impact to people or environs. May result in facility contamination, or facility damage with major disruption of facility operation.
4	Considerable offsite impact to people and environs. Offsite contamination requiring cleanup, or facility destruction.

Table 5.1-7, HAZOP Accident Scenario Ranking **Page 1 of 3**

Accident	Scenario	# Node	Deviation	Consequence	Qualitative Consequence Ranking (Table 5.1-6)	Qualitative Frequency Ranking (Table 5.1-5)	Risk	Prevention/Mitigation
CH1	Fire/spontaneous ignition	07 TRUPACT II internal condition	Fire in TRUPACT II	Minor radioactive materials released	3	3	9	Prevention: Type A container, Waste container integrity, QA, Reinstall ICV lid, Building Construction, Stable drum history, TRUPACT II integrity, Vented drums, WAC criteria. Mitigation: Reinstall ICV lid, WHB HEPA filtration and fire suppression systems, Emergency response plan and teams.
CH2	Crane failure/breach	08 Transfer of payload from TRUDOCK to facility pallet	Failure of lifting equipment	Negligible radioactive materials released	2	3	6	Prevention: Type A container, Crane fail safe design, QA, Operator training & qualification, PM program, Procedures, Stretch wrapping, WAC criteria, Hoisting & rigging practices, two operators, pre-op checks, waste container integrity. Mitigation: Building Exhaust HEPA filtered, Emergency response plan and teams.
CH2	Crane failure/breach	08 Transfer of payload from TRUDOCK to facility pallet	Failure to secure load	Negligible radioactive materials released	2	3	6	Prevention: Type A container, Fail safe design, QA, Operator training & qualification, Preoperational checks on equipment, PM program, Procedures, Stretch wrapping, WAC criteria, Hoisting & rigging practices, Two operators, Waste container integrity. Mitigation: Building Exhaust HEPA filtered, Emergency Response Plan and teams .
CH3	Fork lift mishap/puncture	09 Transfer facility pallet to conveyance car	Fork lift improper engagement of load	Negligible radioactive materials released	2	3	6	Prevention: Forklift design, QA, Adequate lighting, Operator training & qualification, Pre-op checks, PM program, Procedures, Spotters, WAC criteria, Type A container, Drum integrity, Waste container integrity. Mitigation: Building Exhaust HEPA filtered, Emergency response plan and teams.
CH4	Fork lift mishap/breach	09 Transfer facility pallet to conveyance car	Moving accident	Negligible radioactive materials released	2	3	6	Prevention: Type A container, Operator training & qualification, PM program, Stretch wrapping, Spotters, Tie-down strapping, WAC criteria, Procedures, Pre-op checks, QA, Drum integrity, Waste container integrity. Mitigation: Building Exhaust HEPA Filtered, Emergency Response Plan and Teams.

Table 5.1-7, HAZOP Accident Scenario Ranking **Page 2 of 3**

Accident	Scenario	# Node	Deviation	Consequence	Qualitative Consequence Ranking (Table 5.1-6)	Qualitative Frequency Ranking (Table 5.1-5)	Risk	Prevention/Mitigation
CH4	Fork lift mishap/breach	09 Transfer facility pallet to conveyance car	Mislocation on the conveyance car	Negligible radioactive materials released	**2**	**3**	**6**	Prevention: Type A container, QA, Air lock doors interlocked, Local alarms, Operator training & qualification, Restricted access, Robust doors & walls, Stretch wrapping, Spotters, WAC criteria, Procedures, Tie-down strapping, Waste container integrity, PM program, Pre-op checks. Mitigation: HEPA filtration, Emergency response plan and teams.
CH4	Car/breach	10 Transfer conveyance car load onto the waste cage	Moving accident	Negligible radioactive materials released	**2**	**3**	**6**	Prevention: Type A container, QA, Operator training & qualification, Procedures, Stretch wrapping, Spotters, Strapped containers, WAC criteria, Waste container integrity, PM program, Pre-op checks. Mitigation: HEPA filtration, Emergency response plan and teams.
CH5	Hoist failure/breach	11 Waste hoist	Waste hoist drop	Minor radioactive materials released	**3**	**1**	**3**	Prevention: Brake testing, Cable NDT exams, Acoustics exam for failed parts, Control system has elevation check mechanisms, Four independent valve failures required to fail brakes, Brakes checked with full power, Catch gear, Cage fails up, Maintenance procedures & program, Mine rescue equipment, MSHA inspections, Preoperational checks, Qualified personnel, Redundant brakes & controls, Sump under shaft, Six hoist ropes each capable of holding load, inspections, Training and qualification, Weekly inspections, annual vendor inspection, visual inspection of structural steel assemblies, QA. Mitigation: HEPA filtration, Emergency response plan and teams.
CH6	Seismic	15 Natural events	Seismic event	No radioactive materials released	**2**	**1**	**2**	Prevention: Drum integrity, DBE qualified Class II and IIIA SSCs, TRUPACT II integrity, WAC criteria, Type A containers, QA. Mitigation: Shutdown procedure, Emergency response plan and teams.

Table 5.1-7, HAZOP Accident Scenario Ranking **Page 3 of 3**

Accident	Scenario	# Node	Deviation	Consequence	Qualitative Consequence Ranking (Table 5.1-6)	Qualitative Frequency Ranking (Table 5.1-5)	Risk	Prevention/Mitigation
CH7	Spontaneous ignition	27 Drum fire	Drum fire	Minor radioactive materials released	3	3	9	Prevention: Type A container, Waste container integrity, Reinstall ICV lid, Building Construction, Stable drum history, TRUPACT II integrity, Vented drums, WAC criteria. Mitigation: HEPA filtration, Emergency response plan and teams.
CH8	Crash/fire/breach	16 External events	Aircraft crashes into WHB	Minor radioactive materials released	3	1	3	Prevention: Flight patterns, Remote location. Mitigation: Emergency response plan and teams.
CH9	Fork lift mishap/breach	23 Life of facility	Floor distortion	Negligible radioactive materials released	2	3	6	Prevention: Drift inspections, Floor surveys, MSHA inspections, Forklift design, Type A containers, Procedures, Training. Mitigation: Ventilation flow, Emergency response plan and teams, HEPA filtration, .
CH10	Tornado	15 Natural events	Tornado	Negligible radioactive materials released	2	2	4	Prevention: CMR monitors weather conditions, DBT qualified Design Class II and IIIA SSCs, Drum integrity, Procedural guidance for personnel protection, TRUPACT II integrity, WAC criteria, Type A containers. Mitigation: Emergency response plan and teams.
CH11	Roof fall/breach	22 Storage room	Roof collapse during emplacement	Negligible radioactive materials released	2	3	6	Prevention: Inspections & assessments, Ground control, Mine instrumented and monitored, MSHA inspections, Predictive monitoring, Pre-emplacement checks, Type A containers, WAC, procedures, training. Mitigation: Emergency response plan and teams, HEPA filtration.
CH11	Roof fall	23 Life of facility	Roof collapse in life of facility area	Negligible radioactive materials released	2	2	4	Prevention: Floor surveys, MSHA inspections, Shift inspections, WAC criteria, Instrumentation and monitoring, Ground control, Bi-monthly visual and instrument inspections, Procedures, Training. Mitigation: Ventilation during emplacement, HEPA filtration, Emergency response plan and teams.

NOTE: **Accidents CH5, CH6, CH8, and CH11 were retained in the safety analysis due to being an external event, a natural event, or an event of significant interest.**

5.2 CH TRU Accident Analysis

This section quantitatively analyzes the postulated accident scenarios selected as discussed in Section 5.1.4. The selected accidents are considered "Derivative Design Basis Accidents," (DBAs) as defined in DOE Standard 3009-94.[1] These derivative DBAs are used to estimate the response of WIPP systems, structures, and components (SSCs) to "the range of accident scenarios" that bound "the envelope of accident conditions to which the facility could be subjected" in order to evaluate accident consequences. The principal purpose of the accident analysis is to evaluate the derivative DBAs for the purposes of identifying safety (safety-class or safety-significant) SSCs and TSRs necessary to maintain accident consequences resulting from these derivative DBAs to within the accident risk evaluation guidelines. For the purposes of establishing safety SSCs, the consequences of these accidents are analyzed to a noninvolved worker conservatively assumed to be 100 meters from each release point, and to the MEI located at the WIPP Exclusive Use Area. An evaluation of operational accidents "beyond" the derivative design basis is conducted by evaluating the accident scenarios in response to the bounding conditions as derived from the WIPP Waste Acceptance Criteria (WAC). For simplicity, the term "derivative" is dropped for the remainder of this chapter; DBA refers to derivative DBAs.

DOE Standard 3009-94 states that use of a lower binning threshold such as 1E-06/yr is generally appropriate, but should not be used as an absolute cutoff for dismissing physically credible low frequency operational accidents without an evaluation of preventative or mitigative features. As such, DBAs identified in this section whose frequency are less than 1E-06/yr (beyond extremely unlikely), are also analyzed quantitatively for the sole purpose of providing a perspective of the risk associated with the operation of the facility. The results of these analysis are found in the respective accident evaluation in Section 5.2.3.

An assessment of immediate worker accident consequences is also conducted for the operational waste handling scenarios whose frequency is greater than 1E-06/yr (waste container breaches due to drop or impact), that may be initiated by waste handling equipment failure or directly through human error by a worker performing a waste handling operation. Again, accidents whose frequency is less than 1E-06/yr (beyond extremely unlikely) are also analyzed quantitatively in the respective accident evaluation in Section 5.2.3 for the sole purpose of providing a perspective of the risk to the immediate worker associated with the operation of the facility. The immediate worker is that individual directly involved with the waste handling operation for which the accident is postulated. As discussed in Sections 5.1.2.1.2 and 5.1.7, the assessment of immediate worker consequences will ensure that the maximum allowable radionuclide inventory, in conjunction with the other layers of defense-in-depth, will preclude worker exposure from being unacceptable.

The models and assumptions used in the analysis for determining the amount of radioactivity released to the environment and the extent of exposure to the MEI, noninvolved worker, and immediate worker are provided in the following sections. Activity releases to the environment are given for each postulated accident. Committed Effective Dose Equivalents (50 yr CEDE) were calculated for what are considered to be hypothetical individuals located: (1) MEI at the WIPP Exclusive Use Area boundary and off-site public at the site boundary (16 Section Boundary)), (2) noninvolved worker at 328 feet (100) m from each release point, and (3) immediate worker within the immediate area of the accident. The meteorological conditions under which these doses are evaluated are discussed in Section 5.2.1.

All radioactive material at the WIPP facility that has the potential to be released to the off-site environment (except contamination on the container surface) is contained within the waste container. Physical properties and assumptions for waste container inventories used in this analysis are presented in Section 5.1.2.

In evaluating hypothetical accidents, the level of conservatism in the safety analysis assumptions provide consequences which result in postulated releases that are overestimated rather than underestimated. The level of conservatism in each of the safety analysis variables is consistent with DOE-STD-3009-94 and its draft appendix. Although draft documents are not necessarily appropriate for reference in this SAR, the draft appendix provides reasonable guidance for consideration and use. The level of conservatism chosen provides reasonable assurance that when considering the variability in waste form, TRU activity content, and radionuclide distributions that: (1) the safety envelope of the facility is defined, (2) the design of the facility is adequate in response to the accident scenarios analyzed, and (3) the Technical Safety Requirements (TSRs) derived will provide for the protection of the public, the worker, and the environment.

Based on the results of the HAZOP, operational events are binned into two major accident categories, fire and breach of waste container. Since breach of waste containers may occur due to drop or vehicle impact, accidents involving both of these breach mechanisms are evaluated. Accidents involving waste container drops are further evaluated based on the energy involved due to drop height. Due to the differences in release and dispersion mechanisms possible, accidents of each category are evaluated in the above ground and underground areas of the facility. Operational, Natural and External initiating events that require further evaluation as determined by the hazard analysis are listed below.

1. Operational Events

Fires

- CH1 Spontaneous Ignition (Drum) in the WHB
- CH7 Spontaneous Ignition (Drum) in the Underground

Waste Container Breaches

- CH2 Crane Failure in the WHB
- CH3 Puncture of Waste Containers by Forklift in the WHB
- CH4 Drop of Waste Containers by Forklift in the WHB
- CH5 Waste Hoist Failure
- CH9 Drop of Waste Containers by Forklift in the Underground
- CH11 Underground Roof Fall

2. Natural Events

- CH6 Seismic Event
- CH10 Tornado Event

3. External Events

- CH8 Aircraft Crash

5.2.1 Accident Assessment Methodology

5.2.1.1 Noninvolved Worker and MEI Accident Assessment Methodology

Receptors

A hypothetical maximally exposed individual (MEI) located at the Exclusive Use area (Figure 5.2-1) was selected for the accident-related consequence assessment. Review of the WIPP Land Management Plan[2] indicates that public access to the WIPP 16-section area up to the exclusive use area shown in Figure 5.2-1 is allowed for grazing purposes, and up to the DOE off limits area "for recreational purposes." Although analysis are traditionally conducted for an MEI at the facility site boundary, in accordance with DOE Order 6430.1A, Section 1300-3.2,[3] the location of the MEI is located at the "closest point of public access," or the DOE "exclusive use area." The location of the MEI is also consistent with Appendix D9 of DOE/WIPP-91-005, Waste Isolation Pilot Plant RCRA Part B Permit Application, Revision 6, U.S. Department of Energy, Carlsbad, N.M.[55] Calculations are also performed at the site boundary for reference purposes.

Although prevailing winds are towards the northwest at the WIPP Site, the closest distance to the exclusive use area (without regard to direction) from the exhaust shaft vent and the WHB vent was used in the dose assessment calculations. The closest distance to the exclusive use area boundary from the exhaust shaft vent lies south at approximately 935 feet (285 meters) and the closest distance to the exclusive use area boundary from the WHB lies southeast at approximately 1150 feet (350 meters) (Figure 5.2-2).

The noninvolved worker is assumed to be a worker not directly involved with the waste handling operation for which the accident is postulated. The maximally exposed noninvolved worker is assumed to be located at a distance of 328 feet (100 meters) from each release point due to the restrictions on dispersion modeling at close-in distances.

Source Term Methodology

The following equation from *DOE Handbook 3010-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities,*[5] reflects the calculation for source term:

Q = MAR * DR * ARF * RF * LPF

where:

Q	=	The Source Term (Ci or mg)
MAR	=	Material At Risk - The maximum amount and type of material present that may be acted upon with the potentially dispersive energy source (Ci or mg).
DR	=	Damage Ratio - The DR is that fraction of the MAR actually impacted by the accident condition.
ARF	=	Airborne Release Fraction - The fraction of that radioactive material actually impacted by the accident condition that is suspended in air.
RF	=	Respirable Fraction - Fraction of the airborne radioactive particles that are in the respirable size range, i.e. less than 10 μm in aerodynamic equivalent diameter.
LPF	=	Leakpath Factor - The LPF is the cumulative fraction of airborne material that escapes to the atmosphere from the postulated accident.

The quantity MAR is calculated as the quantity (CI * CD), where CI is the waste container radiological or nonradiological inventory, CD is the number of containers damaged by the accident phenomenon (e.g., number of drums breached).

The resulting equation is:

$$Q = CI * CD * DR * ARF * RF * LPF \quad (5\text{-}1)$$

Each of the source term variables are a function of the accident phenomenon under consideration and are derived in the following discussions. The level of conservatism in each of the safety analysis variables is consistent with DOE-STD-3009-94[1] and its draft appendix.

Waste Container Radiological and Nonradiological Inventories (CI) and Containers Damaged (CD)

The source term equation radiological CI used in the accident analyses, is based on the waste characterization analyses in Section 5.1.2. DOE-STD-3009-94[1] and its draft appendix state that the source term material at risk (MAR = CI * CD) should "represent a reasonable maximum for a given process or activity, as opposed to artificial maximums unrepresentative of actual conditions." Additionally, Section A.3.1 of the draft appendix to DOE-STD-3009-94, states that documentation may be used to "back off" of bounding estimates of the MAR. Consistent with this statement, based on the data found in Appendix A (as discussed in Section 5.1.2.1), since CH TRU waste operations accidents may result in more than one container damaged in a postulated accident (CD > 1), for safety analysis calculation purposes it is conservatively assumed that one waste container contains the maximum radionuclide inventory and the remaining waste containers each contain an average radionuclide inventory. As described in Section 5.1.2.1, the maximum drum radionuclide inventory that is not solidified, vitrified, or overpacked is 80.0 PE-Ci, and the maximum SWB radionuclide inventory that is not solidified, vitrified, or overpacked is 130 PE-Ci. For accident scenarios which involve single waste containers (CD = 1), it is conservatively assumed that the waste container contains the maximum radionuclide inventory. The value CD is determined in each specific accident scenario.

As discussed previously, two major types of accident scenarios are identified for quantitative analysis: (1) internal waste container fire as a result of spontaneous ignition, and (2) waste container breaches from drops or waste handling equipment impacts. The waste forms defined in the BIR were examined to determine the types most susceptible to these types of scenarios. For internal waste container fire scenarios, combustible waste is defined as consisting of paper, kimwipes, and cloth (dry and damp); various plastics such as polyethylene and polyvinyl chloride; wood; and filters contaminated with trace quantities of halogenated organic solvents; and noncombustibles as sludges, filters, asphalt, soil, glass, metal, and others. Therefore, it is conservatively assumed that a spontaneous ignition occurs in a waste container classified as containing combustible waste, with a 95 percent combustible and 5 percent noncombustible content. Since the sustained waste container fire is assumed to occur in a single waste container (CD=1), the CI for the spontaneous ignition scenarios is 80 PE-Ci for drums.

For waste container breach scenarios resulting from drops or impacts, the accident is characterized by a sharp impact to the waste container and damage to the waste container, followed by an airborne release of radioactivity due to shock/vibration effects. The waste forms defined in the BIR were examined to determine the types most susceptible to waste container breach scenarios. Based on DOE-HNDBK-3010-94*, DOE Handbook, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities,*[5] noncombustible waste forms that have a hard, unyielding surface and do not undergo brittle fracture are the most susceptible to the airborne release of radioactivity in highly respirable form due to shock/vibration effects. Although DOE-HNDBK-3010-94 bounding airborne release fraction for combustible and noncombustible waste is the same (1E-03), the respirable fraction is higher for noncombustibles (1.0) than for combustibles (0.1). Therefore, it is conservatively assumed that the breach accident scenarios occur with waste containers classified as containing noncombustible uncategorized metal waste, with a 95 percent noncombustible and 5 percent combustible content.

Uncategorized metal waste is chosen for drop and impact scenarios due to: (1) the relatively high waste volume (approximately 18.5 percent) of the total waste volume, and (2) the combustible/noncombustible fractions from the definition of the waste form in the BIR. Although heterogeneous waste has the highest projected volume (approximately 40 percent), based on the definitions in the BIR, uncategorized metal waste has the highest potential fraction of noncombustible waste (95 percent), and is therefore more conservative for use in accident analysis calculations.

As discussed in Section 5.1.2.1.2, since the breach scenarios may damage multiple waste containers, one CI is assumed to be at the maximum (80 PE-Ci drums, 130 PE-Ci SWBs), and the remaining waste containers contain an average of 8 PE-Ci each for drums, and 32 PE-Ci for SWBs (4 drum equivalents). The average values are obtained from Table A-1 for all waste streams reported as uncategorized metals (over 96 percent of the volume of this waste form has an average less than 8 PE-Ci each). Over 86 percent of the volume of all waste forms have average TRU concentrations of less than 8 PE-Ci/drum, including the predominant heterogeneous, uncategorized metal, and combustible waste forms.

Based on the data in Table A-1, use of the above values for CI and combustible/noncombustible fractions provides reasonable assurance of obtaining bounding consequences in the spontaneous ignition and waste container breach accident consequence analysis.

The nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100 percent of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Solid and liquid chemical concentrations that would be expected to be within a waste container during a spontaneous ignition of a waste container are listed in Table 5.1-3. Radiological and chemical source terms (chemical solids/liquids used in the CH1 and CH7 scenarios) developed for specific accidents are estimated using Equation 5-1.

Damage Ratio (DR)

Based on the discussion in Section A.3.3 of the draft appendix of DOE-STD-3009-94,[1] realistic values are acceptable for estimation of the DR. For internal waste container fire (as a result of spontaneous ignition), it is assumed that sufficient internal pressure is generated as a result of the accident phenomenon to cause a breach of the waste container. As a result of the airborne release generated by the fire phenomenon, it is assumed that the DR for this scenario is 1.0 (DR=1.0).

For waste container breaches from drops or waste vehicle impacts (punctures), three specific accident conditions are "realistically" examined: (1) drops of waste containers from heights greater than 4 ft, but equal to or less than 5 ft (4 ft $< h \leq$ 5 ft) (associated with drops from forklifts); (2) drops of waste containers from heights equal to or less than 10 ft (5 ft $< h \leq$ 10 ft)(associated with drops as a result of crane failure, or drops from the second and third layers of the underground waste disposal stack); and (3) impacts (punctures) from slow speed waste handling vehicles or equipment (forklifts).

The upper limit for which waste drums are certified (DOT Type A or equivalent) to not release any of their solid waste form contents is four feet. The DR from drops of waste containers from less than or equal to four feet is zero (DR=0). Tests performed on Type A packaging[6,7,8,9] and their simulated contents provides the data used to estimate damage to the waste containers from heights greater than four feet (from the conditions discussed above), and assign an estimated DR. Since the conditions associated with the accident scenarios analyzed for the WIPP (such as drums dropped in a stretch wrapped seven-pack configuration and tied down to a facility pallet or overpacked waste containers), differ from those in the relatively small amount of well-documented tests, some amount of engineering judgement is used in applying the test data in assigning the DR for WIPP breach scenarios. However, the approach is to apply the data conservatively for the analyzed accident conditions.

For drops greater than four feet, estimates of waste container damage and DR (as a function of drop height), are based on the analysis (provided in PLG-1121, *Damage Assessment of Waste Containers Involved in Accidents at the Waste Isolation Pilot Plant*)[10] of waste container weight and drop kinetic energy, impact kinetic energy (for waste handling equipment impacts and underground roof falls), and the comparison of the analyses results to the available test data.[6,7,8,9] Based on the overall test data, "light" drums (empty $<$ weight $\leq$ 400 lbs), are shown to deform less readily than heavy drums (600 lbs $<$ weight $\leq$ 800 lbs). Based on the average waste form densities found in the BIR, drums containing uncategorized metals, heterogeneous, and combustible waste are assumed to be "light" drums. Solidified waste forms contained within other waste containers such as drums, are assumed to be "heavy" waste containers. The DRs provided in Section 4 of PLG-1121 are based on tests of Type 17H waste containers conducted by Westinghouse Hanford Company (WHC).[9] These tests were performed with drums having a gross weight of 1,000 lbs (heavy drums). Consistent with the deformation test results discussed above, based on engineering judgement, the DR for light waste containers is assumed to be less that the DR for heavy waste containers. As such, the application of DRs derived from tests using heavy drums, in this safety analysis, for the light drums containing uncategorized metal waste is considered sufficiently conservative to encompass the uncertainty in the application of the test data to WIPP scenarios.

Other analyzed waste containers (standard waste boxes, and overpack containers (TDOPs, 85-gallon drum overpacks)) are also assumed to be "heavy" waste containers. However, as discussed in Section 2.2 of PLG-1121, primarily due to the robustness of the design of the SWB, no loss of contents were reported in 15-ft and 25-ft drop tests.[6] As such, based on engineering judgement, the DR for SWBs and overpack containers is assumed to be slightly less than the DR for heavy waste containers (as a function of drop height) in each evaluation in the following paragraphs.

For drops of multiple Type A waste containers associated with typical forklift waste handling operations, drops are considered to occur from a height of greater than 4 ft, and less than or equal to 5 ft. This height range is associated with the height the forklift tines are above the ground, plus the height from a fall of the top waste containers that are stacked two high (as on a facility pallet). Based on analysis,[10] it is considered by engineering judgement that the DR for releases from drops of waste containers from heights less than or equal to 5 ft is less than 0.01 ($DR < 0.01$). However, it is conservatively assumed, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.01 ($DR=0.01$), and the DR for SWBs and overpack containers is 0.001 ($DR=0.001$).

For drops of waste containers from the heights associated with crane failure, or drops from the third layer of the waste stack (from heights greater than 5 ft, and equal to or less than 10 ft ($5 \text{ ft} < h \leq 10 \text{ ft}$)), based on analysis,[10] it is conservatively assumed, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.025 ($DR=0.025$), and the DR for SWBs and overpack containers is 0.01 ($DR=0.01$).

For the waste hoist accident scenario which involves a waste container drop of over 2,000 ft, it is conservatively assumed that complete lid/body separation occurs resulting in a bounding DR of 0.25 for drums, SWBs, overpack containers, and pipe overpack payload containers.

For all drops involving pipe containers in 55-gallon (208 L) drums (pipe overpack payload containers) from heights less than 11 ft, due to the robust design and drop test results,[12] the DR for this waste container is assumed to be zero ($DR=0.0$). The pipe overpack payload container test program demonstrated the capability of the pipe container to maintain structural integrity after hypothetical accident 30-foot drop tests.[12] No loss of containment in any impact drop test occurred.

For scenarios involving the breach of waste containers due to impact with waste handling equipment, the kinetic energy associated with slow moving waste handling equipment (primarily forklifts) was evaluated[10] to determine the level of waste container damage when compared to test data. Additionally, breaches due to forklift tine impact are evaluated based on the current WIPP forklift tine design. Based on the analyses[10] of the speeds expected during waste handling and resulting possible breach mechanisms, it is considered by engineering judgement that, to encompass the uncertainty in the application of test data and the variation in waste forms, the DR for Type A drums (or equivalent) in this class of accident is 0.05 ($DR=0.05$), and the DR for SWBs and overpack containers is 0.01 ($DR=0.01$).

For drums containing noncombustible solids "overpacked" in a SWB or overpack container, the DR for drops is determined by the algorithm provided in Table D.3.17 of the Final Supplement Environmental Impact Statement.[13] The assumption is that material is released in two stages: (1) release from the internal container (drum) due to breach from the impact, into the outer container (SWB or overpack containers), and (2) release from the interior of the SWB or overpack container to the environment from damage to the SWB or overpack container during the impact event. The algorithm models this type of a release as a product of the DR for each respective waste container. For drops that are considered to occur from a height of greater than 4 ft, and less than or equal to 5 ft, it is conservatively assumed that the DR is the product of the DR for drums and SWBs/overpack containers for this class of accident scenario, or (0.01)(0.001) or (DR=1E-05). For drops of overpacked waste containers from the heights associated with crane failure, or drops from the waste stack, the DR is conservatively assumed to be the product of the DR for drums and SWBs/overpack containers for this class of accident scenario, or (0.025)(0.01) or DR=2.5E-04.

For drums containing noncombustible solids "overpacked" in a SWB or overpack container, the DR for punctures is conservatively estimated based on the damage assessment[10] for single waste containers due to impact or puncture events. It is assumed that the combined drum and SWB/overpack container wall thickness reduces the penetration velocity, resultant damage, and thus DR for puncture events. As discussed above, the puncture DR for individual Type A drums (or equivalent) is 0.05 (DR=0.05), and the DR for SWBs and overpack containers is 0.01 (DR=0.01). It is therefore considered conservative that the puncture DR for waste drums "overpacked" in a SWB or overpack container is 0.01 (DR=0.01).

Airborne Release (ARF) and Respirable (RF) Fractions

Based on the discussion in Section A.3.2 of the draft appendix of DOE-STD-3009-94,[1] bounding values for the Airborne Release Fractions and the Respirable Fractions are utilized based on *DOE Handbook, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.[5] The ARF for the burning of contaminated combustible materials in a waste container is 5.0E-04 and the airborne release fraction for noncombustible materials in a drum is 6.0E-03. These values represent bounding airborne release fractions for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[5] The bounding RFs for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces are 1 and 1.0E-02, respectively (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[5]

The ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF applied to airborne combustible material released due to impact is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] Therefore, the ARF and RF for combustible waste forms are conservatively applied to the combustible fraction of material for accident consequence analyses for the waste container impact or drop scenarios.

The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solids that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF for contaminated noncombustible materials which are subjected to impact and breach of the waste container is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] Therefore, the ARF and RF for noncombustible waste forms are conservatively applied to the noncombustible fraction of material for accident consequence analyses for the waste container impact or drop scenarios.

The ARF x RF for solids that undergo brittle fracture (e.g. aggregate, glass) due to crush-impact forces is given by Equation 5-1 of DOE-HDBK-3010-94. Applying this equation for solidified waste forms to the drop of waste container from heights equal to or less than 10 ft ($5 \text{ ft} < h \leq 10 \text{ ft}$), the calculated ARF x RF = 1.64E-05. Comparing this factor with that obtained for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solid that do not undergo brittle fracture, solidification offers a two order magnitude reduction in respirable airborne radioactive material for the scenarios analyzed in this SAR. A summary of the values for DR, ARF, and RF, and their overall products for waste container breach scenarios is as follows:

Waste Form	DR	ARF	RF	Overall Product
Combustible Solids (95%), drops less than 5 ft (drums)	1E-02	1E-03	1E-01	1E-06
Combustible Solids (95%), drops less than 5 ft (SWBs/overpack containers)	1E-03	1E-03	1E-01	1E-07
Combustible Solids (95%), drops less than 10 ft (drums)	2.5E-02	1E-03	1E-01	2.5E-06
Combustible Solids (95%), drops less than 10 ft (SWBs/overpack containers)	1E-02	1E-03	1E-01	1E-06
Noncombustible Solids (95%), drops less than 5 ft (drums)	1E-02	1E-03	1.0	1E-05
Noncombustible Solids (95%), drops less than 5 ft (SWBs/overpack containers)	1E-03	1E-03	1.0	1E-06
Noncombustible Solids (95%), drops less than 10 ft (drums)	2.5E-02	1E-03	1.0	2.5E-05
Noncombustible Solids (95%), drops less than 10 ft (SWBs/overpack containers)	1.0E-02	1E-03	1.0	1.0E-05
Noncombustible Solids (95%), vehicle impact and puncture (drums)	5E-02	1E-03	1.0	5E-05
Noncombustible Solids (95%), vehicle impact and puncture (SWBs/overpack containers)	1E-02	1E-03	1.0	1E-05
Solidified Solids, drops less than 10 ft (SWBs/overpack containers)	1E-02	1.6E-05	----	2E-07

Solidified Solids, vehicle impact and puncture	1E-02	1.6E-05	---	2E-07
Overpacked Noncombustible Solids, (95%) drops less than 5 ft (drum within SWB or overpack container)	1E-05	1E-03	1.0	1E-08
Overpacked Noncombustible Solids, (95%) drops less than 10 ft (drum within SWB or overpack container)	2.5E-04	1E-03	1.0	2.5E-07
Overpacked Noncombustible Solids (95%), vehicle impact and puncture	1E-02	1E-03	1.0	1E-05
Noncombustible Solids (95%), drops of 2000 ft (waste hoist)	2.5E-01	1E-03	1.0	2.5E-04

Leakpath Factor (LPF)

Specific source terms for the postulated accident scenarios described in the accident analysis represent the total amount of respirable radioactive material released to the environment from a postulated accident. The Leak Path Factor (LPF) for WIPP accident scenarios is that fraction of the airborne material released in the WHB that is not filtered out by the permanently installed continuously on-line two-stage HEPA filtration systems, or for underground releases, by the underground exhaust HEPA filtration systems when shift to filtration is actuated manually or automatically. Based on the discussion in Section A.3.3 of the draft appendix of DOE-STD-3009-94,[1] realistic values are acceptable for estimation of the LPF. The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors (DF) have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook.[37] Based on the handbook, a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case, and 1.0 for the no-mitigation case.

Dispersion Modeling Methodology

Nuclear Regulatory Guide (NRG) 1.145,[14] "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1, November 1982, was used to model the accidental releases from the WIPP underground exhaust shaft and the Waste Handling Building. NRG 1.145[14] provides an NRC acceptable methodology to determine site-specific relative concentrations, χ/Qs, as a result of accidents. The model reflects experimental data on diffusion from releases at ground level at open sites and from releases at various locations on reactor facility buildings during stable atmospheric conditions with low wind speeds.

Two type of release models are provided in NRG 1.145:[14] (1) releases through vents or other building penetrations; and (2) stack releases. All release points or areas that are effectively lower than 2.5 times the height of adjacent solid structures are considered nonstack releases. Release points that are at levels 2.5 times the height of adjacent solid structures or higher are considered stack, or elevated releases. Therefore, applying this criteria to the WIPP exhaust shaft and the Waste Handling Building the releases are considered as nonstack releases.

Although the criteria provided in the NRG 1.145[14] suggest a nonstack release, both stack and vent (nonstack) models were evaluated to determine the differences in the dispersion coefficients. The Atmospheric Dispersion Code, GXQ 3.1, described in "Westinghouse Hanford Corporation Support Document," WHC-SD-GN-SWD-30002, Revision 0, June 8, 1993,[15] incorporates the equations used in NRG 1.145[14] and was utilized to evaluate the different models and how they affected the dispersion coefficients. Multiple variations of the models for stack and ground level releases were analyzed with GXQ using various wind speeds and stabilities. However, a ground level release considering a constant wind speed of 4.9 ft/s (1.5 m/s) and stability F resulted in larger dispersion coefficients to the receptors of concern which would represent a vent release. These conditions were assumed to prevail for the duration of the accidental release. Therefore, for determining the consequences from the result of postulated accidental releases from the underground or the Waste Handling Building, the following were utilized:

1. NRG 1.145, Releases through Vents or Other Building Penetrations (NRG 1.145, Section 1.3.1)[14] vent release models

2. Pasquill-Gifford-Turner horizontal and vertical diffusion coefficients (GXQ Manual Section 3.1)[15]

3. Atmospheric Conditions:

   - Stability F, 4.9 ft/s (1.5 m/s) (wind speed and stability are assumed to remain constant in the direction of the receptor)

4. Dimensions (smallest cross section) of the filter building and the Waste Handling Building:

   - Filter Building - 23 feet (7 m high), 88.6 feet (27 m) wide

   - Waste Handling Building - 63 feet (19.2 m) high, 157 feet (47.8 m) wide

As recommended by the NRG 1.145 Guide,[14] χ/Q values were calculated using equations 5-2, 5-3, and 5-4 below. The values from equations 5-2 and 5-3 were compared and the higher value selected. This value was compared with the value from equation 5-4, and the lower value of these two was selected as the appropriate χ/Q value. Examples and a detailed explanation of the rational for determining the controlling conditions are given in Appendix A of the NRG 1.145 Guide.[14]

Consistent with DOE-STD-3009-94[1] and its draft appendix, the values for atmospheric conditions: Stability F, 4.9 ft/s (1.5 m/s) (wind speed and stability are assumed to remain constant in the direction of the receptor), were chosen due to the lack of reliable recorded WIPP specific meteorology data. Future SAR annual updates will include this analysis when data becomes available.

Equation $$\chi/Q = \frac{1}{U_{10}(\pi\sigma_y\sigma_z + \frac{A}{2})} \qquad \textbf{(5-2)}$$

Equation $$\chi/Q = \frac{1}{U_{10}(3\pi\sigma_y\sigma_z)} \qquad \textbf{(5-3)}$$

Equation $$\chi/Q = \frac{1}{U_{10}\pi\Sigma_y\sigma_z} \qquad \textbf{(5-4)}$$

where:

- χ/Q is relative concentration, in sec/m^3. χ/Q (328 ft [100 m])=5.11E-03; χ/Q (935 ft [285 m])=8.43E-04; χ/Q (1150 ft [350 m])=5.96E-04.
- π is 3.14159
- U_{10} is wind speed at 33 feet (10 meters) above plant grade, in m/sec. (assumed 4.9 ft/s [1.5 m/sec.])
- σ_y is lateral plume spread, in meters, a function of atmospheric stability and distance (class F stability). σ_y (328 ft [100 m])=4.6; σ_y (935 ft [285 m])=11.9; σ_y (1150 ft [350 m])=14.3; σ_y (2625 ft [800 m])=30.2
- σ_z is vertical plume spread, in meters, a function of atmospheric stability and distance (class F stability). σ_z (328 ft [100 m])= 2.3; σ_z (935 ft [285 m])=5.3; σ_z (1150 ft [350 m])=6.2
- Σ_y is the lateral plume spread with meander and building wake affects, in meters, as a function of atmospheric stability, wind speed U_{10}, and distance (for distances of 2625 ft [800 meters] or less), $\Sigma_y = M\sigma_y$, for distances greater than 2625 feet [800 meters], $\Sigma_y=(M-1)\sigma_{y\ 800m}+\sigma_y$, where M=4 determined from Figure 3 of NRG 1.145.[14]
- A is the smallest vertical-plane cross sectional area of building, in m^2.

Appendix A of NRG 1.145[14] contains a rationale section which indicates that the equations used in NRG 1.145[14] provide an assessment of atmospheric diffusion, including the effects of building wake mixing that occur during moderate wind speed conditions (>10 ft/sec [3 m/sec]). The equations have been found to provide estimates of ground-level concentrations that are consistently too high during light wind and stable or neutral atmospheric conditions for 1-hour release durations. Consequently the use of these equations in the modeling of the effluent under light wind (4.9 ft/sec [1.5 m/sec]) and stable atmospheric conditions (F-Class) provides built-in conservatism.

Consequence Methodology

Consequence assessment calculations are determined for the: (1) MEI located at the Exclusive Use Area boundary and (2) noninvolved worker (328 ft [100 m]) for releases from the WHB vent and the exhaust shaft vent. Atmospheric transport is the only significant release and exposure pathway during normal operations and accident conditions during the disposal phase. Based on the site characteristics information in Chapter 2, surface water and groundwater transport from normal or accidental releases of radioactive material is not considered likely. Human exposure pathways from the airborne radioactive material include inhalation, air immersion, ingestion, and ground-shine. Radiological dose consequences are calculated assuming the inhalation pathway in CEDE and are calculated using Equation 5-5. External (ground-shine and air immersion) and ingestion dose calculations are not performed due to their minimal contribution to the Total Effective Dose Equivalent (TEDE), therefore CEDE will be reported as the dose consequences for each of the accidents evaluated. The calculated dose in CEDE is then compared to the noninvolved worker and MEI radiological risk evaluation guidelines discussed in Section 5.2.2 (Tables 5.2-1a and 5.2-1b). For nonradiological consequence calculations, the chemical concentration at the MEI (935 ft [285 m]) and noninvolved worker (328 ft [100 m]) in mg/m^3 is calculated using Equation 5-6 for comparison with the nonradiological risk evaluation guidelines discussed in Section 5.2.2 (Table 5.2-2).

Detailed spreadsheets for the source term and consequence calculations for each postulated accident are found in Appendix E and summarized in Tables 5.2-3 and 5.2-4. To assess the potential releases of radiological and nonradiological material the following equations were utilized:

Radiological Releases

$$D = Q * \chi/Q * BR * DCF \qquad (5\text{-}5)$$

where:

D = Radiological dose (Committed Effective Dose Equivalent (CEDE)) (rem)
Q = Radiological Source Term (Ci) (Appendix E)χ/Q
χ/Q = Atmospheric dispersion coefficients calculated for specific distances (s/m^3). χ/Q (328 ft [100 m])=5.1E-03s/m^3; χ/Q (935 ft [285 m])=8.43E-4s/m^3; χ/Q (1150 ft [350 m])=5.96E-04 s/m^3
BR = Breathing rate (standard man) (m^3/s) International Commission on Radiological Protection (ICRP) No.23[16] (Light activity 5.3 gallons/min [20.0 liters/min or 3.33 E-04 m^3/s]
DCF = Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public[17] (Pu-239 Class W CEDE Inhalation 5.1E+02 rem/uCi or 5.10E+08 rem/Ci)

Chemical Releases

$$C = (Q * \chi/Q)/RR \qquad (5\text{-}6)$$

where:

C = Concentration (mg/m^3)
Q = Chemical Source Term (mg) (Section 5.1.2 and Tables 5.1-2 and 5.1-3)
RR = Release Rate [VOC releases assumed an instantaneous (1 sec) fire within a drum assumed release duration (900 sec)]
χ/Q = Atmospheric dispersion coefficients calculated for specific distances (s/m^3). χ/Q (328 ft [100 m])=5.1E-03s/m^3; χ/Q (985 ft [285 m])=8.43E-4s/m^3; χ/Q (1150 ft [350 m])=5.96E-04 s/m^3

Frequency Determination Methodology

The methodology for verifying the annual occurrence frequencies, qualitatively estimated in the HAZOP, of operational initiating events is based on the evaluation of process inherent events (spontaneous ignition), equipment failures, and human error. Section 5.2.3 and Appendix D contain the detailed assessment of occurrence frequencies of the accidents evaluated. Table D-1 presents the estimated occurrence frequencies for process events, equipment failures, and human errors, based on existing references and engineering judgement. The table provides cross references to documents from other DOE sites with similar operations, and from generic industry data bases that have been judged to be applicable and appropriate for use in WIPP accident scenarios.

Equipment failure rates and human error probabilities were combined with WIPP specific operational data to obtain WIPP specific initiating event occurrence frequencies. The individual scenario is discussed in Section 5.2.3, and the supporting detailed event tree/fault tree analysis for each postulated accident is included in Appendix D. The table and figures in Appendix D document the analysis of failure of associated preventative and mitigative systems and develops the annual occurrence frequency for both mitigated and no-mitigation accident sequences.

The annual occurrence frequencies derived from the event tree/fault tree analysis are not intended to represent detailed probabilistic calculations requiring sensitivity or uncertainty analysis. Rather, they are used to provide reasonable assurance that each scenario's accident frequency is in a specific qualitative frequency range (i.e. extremely unlikely) or "bin"for the purposes of selecting an appropriate risk evaluation consequence guideline.

To estimate the occurrence frequencies, logic models were used to describe combinations of failures that can produce a specific failure of interest (TOP event). The logic is developed and explained in Section 5.2.3 and Tables D-2 through D-20 of Appendix D. The basic events documented in Table D-1 provide specific component failure or human error rates which provide input to the logic model to calculate the frequency of the TOP event. Logical AND (*) or OR (+) functions (gates) are used to show how events can combine to cause the TOP event. The TOP event is quantified in the top row of the appropriate table, with the equation delineating the logic by which it was developed and any necessary comments. Each contributor to that equation is then developed in subsequent rows, using` references as necessary to the basic events documented in Table D-1 to complete the line of reasoning.

For the purposes of establishing safety (safety-class or safety-significant) preventative and mitigative SSCs, an iterative process is performed. The safety (safety-class or safety-significant) iterative process (see Section 3.1.3) initially involves comparing the "no-mitigation" accident consequences to the MEI and noninvolved worker (with associated "no-mitigation" accident frequency from the event tree analyses in Appendix D) to the off-site and on-site risk evaluation guidelines respectively. The process is continued taking credit for additional preventative/mitigative SSCs until the risk evaluation guidelines are met. Systems required to keep estimated consequences below the risk evaluation guidelines are designated as safety (safety-class or safety-significant) SSCs.

5.2.1.2 Immediate Worker Accident Assessment Methodology

The assessment of the immediate worker accident consequences is based on the evaluation of operational waste handling scenarios (waste container breaches), whose frequency is greater than 1E-06/yr, that may be initiated by waste handling equipment failure or directly through human error by a worker performing a waste handling operation. The immediate worker is that individual directly involved with the waste handling operation for which the accident is postulated. Although procedures dictate that workers exit the area immediately, such accidents present an immediate risk due to the inhalation of airborne radionuclides to the worker performing the waste handling operation.

Receptors

The methodology for assessment of the immediate worker consequence is based on information provided by the Environmental Evaluation Group (EEG).[18] For the assessment of consequences to workers in the waste handling building (WHB) accident scenarios, the receptor of concern is the waste handler in the immediate vicinity of the accident. Waste handling procedures, require that the worker exit the area immediately following an accident. However, it is assumed in this scenario that a worker remains within the CH Bay area for a period of 60 secs, derived from the time to: (1) stop waste handling operations (10 secs), (2) examine the dropped waste containers, recognize that a waste container has been breached, and evaluate the situation (20 secs), and (3) exit the CH Bay normally through the nearest exit (airlock) (30 secs).

Evaluations of other situations (such as disabled worker scenarios), are not performed for the type of accident breach scenarios being analyzed (forklift drops and punctures). Based on the HAZOP results and the accident scenario descriptions in Section 5.3, the conditional likelihood of scenarios involving a worker failing to follow procedure to leave the area immediately, or a coincident worker (immediate waste handler) injury during the drop and puncture scenarios, are extremely unlikely compared to receiving a survivable, specified radiological consequence. Therefore, the overall frequency of the scenario analyzed plus conditional likelihood of failing to follow procedure or immediate worker injury would be beyond extremely unlikely.

For the assessment of consequences to workers in the underground accident scenarios, due to: (1) the ventilation flow path in the underground disposal rooms and exhaust drifts, and (2) the waste emplacement process described in Section 4.3, the receptor of concern is a hypothetical worker who may be in the exhaust drift at the time a CH waste handling accident occurs "upstream." For the underground waste container breach scenarios, due to the high ventilation flow rate the workers are conservatively assumed to be exposed to the entire contaminated volume of air before exiting the area. With an assumed exhaust drift velocity of 2 ft/s (0.6 m/s) (assuming a flow rate of 883 ft^3/sec [25 m^3/sec] and exhaust drift dimensions of 33 ft x 13 ft (10 m x 4 m), it is conservatively assumed that workers are exposed to the undiluted radioactive cloud at a normal working breathing rate for one second.

For fire release scenarios, due to the extended release time (900 secs assumed), and the assumption that worker exposure in both the WHB and underground is for a period of 10 secs, the accident scenario source terms for the fire scenarios are adjusted by the factor: (exposure time / release time) or (10 secs/900 secs).

Source Term Methodology

The accident scenario specific source term for immediate worker accident assessments is the "no-mitigation" source term developed for the noninvolved worker and MEI accident assessments.

Frequency Determination Methodology

The frequency of each accident analyzed for immediate worker consequences is the "no mitigation" frequency in each detailed event tree/fault tree analysis for each postulated accident is included in Appendix D.

Immediate Worker Consequence Modeling Methodology

The onsite and offsite dose model (Equation 5-5) is modified for immediate worker consequence assessment as follows:

Radiological Releases

$$D = (Q * T * BR * DCF)/V \qquad (5\text{-}7)$$

where:

D = Radiological dose (Committed Effective Dose Equivalent (CEDE)) (rem)
Q = Radiological Source Term (Ci) (Appendix E)
T = Exposure Time (sec) (scenario dependent)
BR = Breathing rate (standard man) (m^3/s) International Commission on Radiological Protection (ICRP) No.23[16] (Light activity 5.3 gallons/min [20.0 liters/min or 3.33 E-04 m^3/s])
DCF = Dose Conversion Factor (rem/Ci) Internal Dose Conversion Factors for Calculation of Dose to the Public[17] (Pu-239 Class W CEDE Inhalation 5.1E+02 rem/uCi or 5.10E+08 rem/Ci)
V = Volume in which radionuclides are released (m^3)

This model was further modified by the EEG[18] to account for the expanding nature of the contamination "cloud" within the WHB. The expanding cloud model modifies Equation 5-7 as follows:

$$V = 2/3\pi\, r^3$$

where:

V = volume of hemisphere of air (m^3)
r = radius of hemisphere = (a) x (t)

where:

a = cloud expansion rate 0.82 ft/s (0.25 m/s)
t = time after accident (s)

therefore:

$V = 2/3\ \pi\ (a * t)^3 = 2/3\ \pi\ a^3\ t^3$

Substituting for V in Equation 5-7 and integrating with respect to time results in the following relationship:

$$\mathbf{D = Q * BR * DCF * [3/(4\pi a^3) * (T_1^{-2} - T_2^{-2})]} \qquad \textbf{(5-8)}$$

where:

T_1 = Time cloud encountered by the worker (secs)
T_2 = Time exposure ends (secs)

For breach of waste container due to drop, the release in the WHB is modeled as an instantaneous release into an initial cloud with the same volume as a seven drum array (6.6 ft [radius 2 m]). For breach of waste container due to puncture, the release in the WHB is modeled as an instantaneous release into an initial cloud with the same volume as a two drum array (3.3 ft [radius 1 m]). For the assessment of consequences to workers in the waste handling building accident scenarios, the source term release cloud is then modeled as a hemisphere expanding at the ventilation flow rate in the CH Bay (assumed to be 0.82 ft/sec [0.25 m/sec]). For breach of waste container due to drop, the expanding cloud will take approximately 8 secs for the cloud model to provide the proper initial condition, and an additional 12 secs to reach the worker, based on an assumed distance from the crane or forklift operator to dropped/punctured waste containers of 10 ft (3 m). Thus, for breach of waste container due to drop, T_1 in Equation 5-8 is 20 secs. For breach of waste container due to puncture, the expanding cloud will take approximately 4 secs for the cloud model to provide the proper initial condition, and additional 12 secs to reach the worker. Thus, for breach of waste container due to impact, T_1 in Equation 5-8 is 16 secs.

As discussed above, it is assumed that it takes 30 secs for the worker to recognize that a release has occurred, evaluate the situation, and begin to exit the area. During this time frame the cloud is assumed to engulf the worker, and for which a dose consequence is calculated. Thus T_2 in Equation 5-8 is 30 secs.

Solution of Equation 5-8 for a seven drum array, with T_1 = 20 secs, and T_2 = 30 secs, yields:

$$\mathbf{D = Q * 3.6E{+}03\ rem/Ci} \qquad \textbf{(5-9)}$$

Solution of Equation 5-8 for a two drum array, with T_1 = 16 secs, and T_2 = 30 secs, yields:

$$\mathbf{D = Q * 7.3E{+}03\ rem/Ci} \qquad \textbf{(5-10)}$$

Equation 5-9 is carried forward into Appendix E for the assessment of immediate worker consequences in the WHB.

For the assessment of consequences to workers in the underground, the source term is assumed to be released instantaneously into a slug of air with a volume of 850 ft^3 (24 m^3). This volume is based on an instantaneous release and the assumed ventilation flow rate 0f (2 ft/s [0.6 m/sec]), and the dimensions of the underground exhaust drift, or V = (2 ft/s [0.6 m/s]) * (1 sec) * (33 ft [10 m]) * (13 ft [4 m]) = 24 m^3.

Chemical Releases

$$C = Q / V \qquad \textbf{(5-11)}$$

where:

C = Concentration (mg/m^3)
Q = Chemical Source Term (mg) (Section 5.1.2 and Tables 5.1-2 and 5.1-3)
V = Volume (m^3) of expanding cloud, derived above for Equation 5-8, at time T_1, at which receptor first encounters chemical

5.2.2 Off-site and On-site Radiological/Nonradiological Risk Evaluation Guidelines

The on-site and off-site radiological and nonradiological risk evaluation guidelines are developed in Sections 3.3.5 and 3.3.6, and for convenience the discussion is repeated here. Guidelines do not exist for the frequency range of beyond extremely unlikely (frequency ≤ 1E-06/yr). The consequences of accidents in that range are conservatively evaluated against the guidelines for the extremely unlikely range for the sole purpose of evaluating the risk associated with facility operations.

Radiological

Off-site radiological dose criteria for accident analyses have been well established by national standards through the licensing process of nuclear facilities regulated by the Nuclear Regulatory Commission (NRC). These criteria are based on the probabilities of occurrence of the accidents or events hypothesized for the accident analysis. For nuclear power plants, the operational accidents or events are classified as Plant Conditions (PC) in accordance with the estimated frequency of occurrence.[19,20] This established scheme (ANSI/ANS-51.1)[19] has also been adopted by the WIPP to compare accidental releases from postulated events to dose limits based on estimated frequency of occurrence.
Table 5.2-1a summarizes the risk evaluation guidelines for the assessment of off-site radiological exposures.

The same conceptual approach is used for the on-site risk evaluation guidelines as for the off-site (public) dose. However, on-site risk evaluation guidelines are greater than those for the public by assuming that entry onto the site implies acceptance of a higher degree of risk than that associated with the off-site public. This assumption is not considered remiss with regards to safety assurance because the on-site risk evaluation guidelines do not result in any health effects noticeable to exposed individuals at frequencies greater than 1 E-4 event per year and would not result in any acute life-threatening effects.

A three-tiered step function is again used. For accidents with an estimated frequency between 0.1 event per year and 0.01 event per year, the limit is 5 rem (50 mSv) based on the allowable yearly worker exposure limits cited in 10 CFR 835.[21] For the estimated frequency range of 1 E-2 to 1 E-4 event per year, the threshold is 25 rem (250 mSv) for the same reason the USNRC provided in 10 CFR 100[22] for using it for design basis reactor accident calculations (i.e., value at which no significant health effects result).

Potential guideline values for the final frequency range of 1 E-4 to 1 E-6 event per year were examined in detail. A value for this range is specified consistent with the use of the Emergency Response Planning Guidelines-3 (ERPG-3) value for toxicological onsite hazards. This value accepts the possibility of some noticeable health effects but precludes the possibility of lethal effects for “nearly all individuals."

The DOE *Emergency Management Guide for Hazards Assessment*[23] uses 100 rem (1 Sv) whole body exposure as a threshold for early severe effects. It also acknowledges that early severe effects would not actually be experienced for a 50-year *dose* of 100 rem (1 Sv) due to alpha emitters. The guide also selects the ERPG-3 *dosage* as a threshold for early severe effects for non-radiological releases. The two values are roughly consistent in intent. Accordingly, a value of 100 rem (1 Sv) was assigned for the 1 E-4 to 1 E-6 event per year range. This information is summarized in Table 5.2-1b.

Nonradiological

Nonradiological risk evaluation guidelines definitions are consistent with the discussion below and Table 5.2-2.

A unique set of approved nonradiological risk evaluation guidelines is not found in existing DOE orders. Proposed guidelines for application to WIPP is based on Emergency Response Planning Guidelines (ERPG) published by the American Industrial Hygiene Association (AIHA).

Other commonly used guidelines that have been considered in the development of risk evaluation guidelines for the accident analysis include the following:

- Threshold limit value-Time-weighted average (TLV-TWA)
- Threshold limit value-Short-term exposure limit (TLV-STEL)
- Threshold limit value-Ceiling (TLV-C)
- Permissible exposure limits (PEL)
- Immediately dangerous to life or health (IDLH)
- Emergency response planning guidelines (ERPGs)
- Emergency exposure guidance level (EEGL)
- Short-term public exposure guidance level (SPEGL)

Currently, ERPGs do not exist for most of the nonradiological materials found in TRU mixed waste. Chemicals without established ERPG values will use the following alternate risk evaluation guidelines to derive a substitute ERPG assignment:[24]

ERPG-1 (designated TOX-1): Alternate risk evaluation guidelines:

- PEL-STEL
- TLV-STEL
- TLV-TWA x 3

ERPG-2 (designated TOX-2): Alternate risk evaluation guidelines:

- EEGL (60 minute) or
- PEL-C
- TLV-C
- TLV-TWA x 5

ERPG-3 (designated TOX-3): Alternate risk evaluation guidelines:

- EEGL (30 minute)
- IDLH

The derived toxicological limits from the ERPG and alternate risk evaluation guidelines are labeled as TOX-1, TOX-2, and TOX-3. The TOXs correspond to ERPG-1, ERPG-2, and ERPG-3, respectively. The compilation of the basis limits for derivation of alternate ERPG limits is provided in Table 5.2-2.[25,26,27]

5.2.3 Accident Analysis

5.2.3.1 CH1 Spontaneous Ignition (Drum) in the WHB

Scenario Description - The spontaneous ignition within a drum in the WHB is an internally initiated accident resulting from failure to conform to the WIPP WAC,[29] which prohibits pyrophorics in a waste container. The HAZOP[28] for CH TRU Waste Handling System postulated a spontaneous ignition within a drum while opening the TRUPACT-II. However, it is conceivable that spontaneous ignition could occur at any time within any one of the drums being handled or temporarily held in the WHB.

The frequency and magnitude of potential releases depend on the number of drums having a given quantity of TRU waste that also contain an ignition source, as well as sufficient combustible material and oxidant to generate the energy needed to produce a breach. Due to its robust design and bolted lid, a breach of a standard waste box due to spontaneous ignition is considered incredible, so for the purposes of this analysis, all waste is assumed to be stored in 55-gallon (208 L) drums. The quantitative accident evaluation presented here makes use of the information now available in the BIR[30] to estimate the frequency of releases of varying magnitudes resulting from a sustained drum fire based on radionuclide concentration, final waste form, and method of verification of conformance to the WIPP WAC.

As analyzed in DOE/WIPP 87-005,[31] Waste Drum Fire Propagation at the WIPP, a sustained fire is expected to produce a release from only a single drum. The propagation analysis in DOE/WIPP 87-005 provides the evidence and reasoning to permit the assertion that a fire in one drum would not propagate to other drums and/or result in a loss of secondary confinement. As discussed in Section 4.4, the WHB secondary confinement system consists of the WHB structure and ventilation system which maintains static pressure differential between the primary confinement barrier and the environment and continuously high efficiency particulate air (HEPA) filters which filter exhaust air.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the no-mitigation case, the HEPA filters are assumed to be open, bypassed, or not in place. For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage HEPA.

The primary and most practical means of preventing spontaneous ignition is generator site compliance with the WAC. Given a drum conforms to the WAC, the likelihood of spontaneous ignition may be considered to be negligibly small. Therefore, drums will be susceptible to spontaneous ignition only if human error has been made during the packaging of the waste and the verification of their conformance to the WAC at the generator sites. The program designed to assure that the potential for errors will be held at the lowest feasible level is summarized in Section 5.1.2.2. Vigilant implementation and control of the Waste Analysis Plan (WAP) found in the WIPP RCRA Part B Application, the WIPP Quality Assurance Program Plan (QAPP)[36] and each generator site's Quality Assurance Project Plan (QAPjP) will provide high confidence that a sustained spontaneous combustion event will not occur at the WIPP. In the absence of an approved QAPjP from each generator site, the probability of human error during the preparation and certification of waste for shipment to the WIPP are conservatively addressed below under estimated frequency.

If a drum fire results in a release to the WHB, the release to the outside environment is mitigated by the WHB containment structure, which includes air lock entrances and a ventilation system containing on-line two-stage HEPA filters. Although the ventilation system is required to be operational during waste handling operations, active ventilation is not required to prevent a significant release of hazardous materials from the WHB. The intact HEPA filters will maintain the secondary confinement barrier, and there is only a small potential for only minor releases via leakage of air around both access doors of the air locks, or other minor leakage paths that might exist in the structure, resulting from the loss of differential pressure.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of occurrence of a spontaneous ignition in the WHB to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$). However, based on a quantitative evaluation using conservative assumptions documented in Appendix D and below, the overall frequency of release resulting from spontaneous ignition within the WHB is beyond extremely unlikely (frequency $\leq$ 1E-06/yr). Risk evaluation guidelines are not identified for events with frequency $\leq$1E-06/yr. However, the risk evaluation guidelines for the extremely unlikely range are conservatively used for evaluating the risk associated with this scenario.

The frequency of CH1 is calculated in Table D-8 for final waste forms and distributions of drum loading obtained from the BIR. The analytical model and supporting evidence that produced these results are presented in Tables D-1 through D-7, and an event tree illustrating the sequence of events resulting in consequences from sustained combustion within a waste drum in the WHB is shown in Figure D-1. This section discusses the evidence and reasoning used to develop and quantify these models.

The scenario is initiated by spontaneous ignition within a drum that does not conform to the WIPP WAC. It is sustained by the presence of both sufficient combustibles and an oxidant. Given a sustained fire breaches the drum, only the waste material within that drum is subject to release. The quantification of each of these contributors is discussed below:

1. <u>Spontaneous Ignition of Pyrophoric Material and Incompatible Mixtures</u>

Spontaneous ignition is possible when 1) a pyrophoric material of sufficient quantity and concentration is raised to its auto-ignition temperature; 2) incompatible materials chemically react in an exothermic reaction; or 3) a fuel source in an ignitible state (e.g. volatile organic compounds in the presence of an oxidant) is subjected to an ignition source, such as a discharge of static electricity. To the extent that these materials are present in the processes that directly produce TRU waste intended for long term disposal, there is a possibility for spontaneous ignition to occur in the waste containers delivered to the WIPP.

Because each of the 11 final waste form categories have their own set of processes associated with them, it is theoretically possible to establish a spontaneous ignition frequency associated with each category. Furthermore, each of the 569 waste streams listed in the BIR can be examined for the presence of potentially pyrophoric conditions in order to make more definitive conclusions regarding the absence of materials that could preclude spontaneous ignition for waste streams having high quantities of specific isotopes. The Transuranic Waste Characterization Quality Assurance Program Plan (CAO-94-1010)[36] and the generator site certification process are designed to provide this assurance. However, the detailed information needed to perform such an analysis in order to estimate the waste stream specific frequencies of spontaneous ignition for accident quantification purposes is currently not warranted, in light of the low frequency of release obtained using a generic spontaneous ignition frequency.

The quantification of the generic spontaneous ignition frequency is given in Table D-2. The frequency of spontaneous ignition in TRU waste is estimated by examining the incidents of fire within DOE facilities that generate TRU waste and comparing the conditions surrounding those incidents with the circumstances under which waste forms designated for delivery and disposal at the WIPP are generated, packaged, and stored.

- The quantity of waste at risk for spontaneous ignition is the TRU waste designated for disposal at WIPP. All the waste streams listed in the BIR[30] were included in the population estimate.

- Exposure to spontaneous ignition accumulates as waste remains in interim storage over a period of time, with the overall experience being expressed in terms of cubic meter-years (m^3-yr) of storage. The time period during which individual waste streams have been stored is not readily available. For the purposes of estimating a frequency for spontaneous ignition, TRU waste is assumed to have been placed in interim storage starting in 1970, and additional waste has been added to the stored inventory at a constant rate up to the present time. Thus, the total storage experience is estimated as one half of the current stored inventory reported in the BIR times the period of time from 1970 to the current year.

- An observed incident is counted as indication of the potential for spontaneous ignition if it occurred in a population of waste containers that could be associated with processes that result in TRU material intended for long term interim storage. An incident should be excluded if it has occurred in conjunction with process activities where potentially pyrophoric materials and mixtures are used as part of the process and the TRU waste involved was passing through the process or being temporarily stored awaiting recycling into the feed material.

Table D-3 outlines the screening rules used to judge the applicability of incidents for inclusion in the estimate of the TRU waste spontaneous ignition frequency and provides a summary of the reported incidents considered. This table addresses evidence presented in EEG-45,[32] EEG-48,[33] DOE/WIPP 91-018,[34] and DOE/NS-0013[35] to identify qualifying incidents. Additional incidents that have been examined in the past, but found to be inapplicable, are documented in DOE/WIPP 91-018.[34] In addition, the DOE Occurrence Reporting and Processing System (ORPS) online database has been queried as part of this SAR update, and no additional incidents requiring classification were identified.

- In recognition of fact that not all incidents of spontaneous ignition within a waste container may be observable, a correction factor of ten has been included in the estimate of applicable events. The correction factor multiples the observed applicable incidents to generate the total number of spontaneous ignition events for estimating the spontaneous ignition frequency used in the quantification of the release frequency. Engineering judgement is used to assess a value of ten for the correction factor based on the following evidence:

  - ♦ Waste containers have been buried at some of the generator sites for a number of years. Spontaneous ignition events in these containers would not be expected to be observable even if the containers were breached, unless the release reaches the surface and is detected by radiation monitors. Based on an estimate that less than 50 percent of the waste in interim storage is buried, a factor of two correction factor should adequately account for unobservable events in this sub-population of stored containers.

  - ♦ Spontaneous ignition events that may have occurred, but have not had either sufficient oxidant or combustibles to maintain sustained combustion, can not be observed directly. The judgement that undetected ignitions have occurred would tend to produce a larger correction factor. In the absence of definitive evidence, it is assumed that four undetected ignition events may occur for every applicable incident that has been observed, leading to an additional correction factor of five.

  - ♦ The occurrence or lack of spontaneous combustion during the repackaging and certification process will provide additional evidence to support the increase or reduction in the spontaneous ignition frequency. Evidence of internal combustion can be confirmed when containers are opened for processing or repackaging, but may be difficult to detect. To date there appear to be no reports of this type of anomalies during the repacking process. Therefore, it is reasonable to conclude that an overall correction factor that multiplies the above two factors is conservative.

2. Material at Risk in Drums Susceptible to Sustained Combustion

The BIR has been used to categorize material at risk by Final Waste Form and TRU waste loading, expressed in terms of waste stream averaged PE-Ci/drum. Table A-1 provides a consolidation of the 569 TRU waste categories from a query of the BIR in June 1996. A sort of the BIR by waste stream that provides the detail behind the consolidation is shown in Table A-2. Based on Table A-1, Table D-4 apportions the total currently stored into 78 separate bins for calculation of accident frequency and consequence. The 78 bins result from a combination of three attributes:

- Final Waste Form (13 categories) - There are eleven officially defined categories, plus two additional categories, "Unknown" and "Various Rocky Flats Residues." The "Unknown" category will not be allowed to be shipped to the WIPP for Disposal. Conservative assessments of all parameters influencing frequency and consequence are used to quantify the contribution of this waste streams to the composite risk assessment. The "Various Rocky Flats Residues" is a waste stream that is subject to specific plans for packaging, and thus enables a unique assessment.

- Plans for processing/repackaging prior to shipment to the WIPP (two categories) - The generator sites have reported their intent to process/repackage in the BIR on a waste stream basis, and this information is being used to gain a better perspective on the potential for human error during the WIPP WAC verification process. Waste that will not be processed and/or repackaged prior to shipment are subject to a higher human error probability (HEP) during verification of waste to the WIPP WAC than waste that will be processed and/or repackaged.

- Average waste stream concentration of radionuclides in terms of PE-Ci/drum (three categories) - The three bins are established to provide a better perspective on the frequency of the bounding consequence calculations required by the DOE. The reasoning for selection of the bin limits is discussed in Section 5.1.2.1.

3. Failure to Verify Conformance to the WIPP WAC

The failure to verify conformance to the WIPP WAC is modeled by considering the potential for human error at the generator sites. Drums that fall into a population that is susceptible to spontaneous ignition arise from at least two independent errors. The first involves failure to observe good practice and existing DOE/generator site controls to prevent pyrophoric mixtures when the original TRU waste was packaged and stored. The second is a failure of the WIPP WAC verification process to detect and correct potentially pyrophoric materials in the drums being certified for shipment to the WIPP. A graded approach does not warrant an investigation of the practices of individual generator sites in order to quantify these human errors. Therefore, this section makes a scoping estimate of these errors for use in this quantification.

Generator Site Control Table D-5 summarizes the evidence and reasoning used to estimate the failure to maintain control over processes, and thus create a potential for susceptibility to spontaneous ignition during long term storage at a generator site for each Final Waste Form. As spontaneous ignition has always been a safety concern, controls have existed in the past and it is reasonable to assert that susceptibility to fires result from failure of those controls. The table estimates the HEP using the definitions of the final waste forms to provide an indication of the anticipated degree of consistency within a waste stream process.

- As a baseline scoping estimate for any generic waste stream, an HEP of 1E-01 is assessed for failure to assure that pyrophoric materials or combustible mixtures are not included in waste container intended for long term storage. This corresponds to an error by a checker to detect the abnormal condition during the packaging of the waste and closure of the waste container. The source of this value is given in Table D-1 for the variable "H_check." This estimate is considered to be conservative, because it takes no credit for the waste stream process design and operational procedures to minimize the opportunity for the introduction of pyrophoric materials or combustible mixtures into the waste container. Simply stated, without further evidence, the scoping baseline estimate assumes that ten percent of stored drums have the potential of containing pyrophoric materials or combustible mixtures.

- By their physical composition, some final waste forms provide better control over the introduction of pyrophoric materials or combustible mixtures into the waste container than others. Final waste forms generated in facilities having a variety of activities have the highest potential for inadvertent mixing of pyrophoric materials with TRU waste, while waste forms generated from controlled production processes provide strong confidence of a consistent and well defined physical properties with little likelihood of violating the WIPP WAC. For the purpose of estimating susceptibility of TRU Final Waste Forms to spontaneous ignition, it is judged that containers holding waste forms which are comprised of 95 percent of a single type of non-volatile combustible material are less likely to also include incompatible materials capable of a vigorous exothermic reaction or volatile components capable of being ignited by external ignition sources. As a scoping estimate, these processes are estimated to reduce the potential for erroneous introduction of pyrophoric materials or combustible mixtures into the waste materials by an additional factor of ten. This corresponds to an independent error in checking that the materials are not introduced during the waste generation process.

Table D-5 delineates the assessment of the HEP for controlling pyrophoric materials at the generator sites. It states the assessed value of the HEP for each final waste form based on the two arguments given above. The evidence and engineering judgement used to justify each HEP is provided for each final waste form. The Final Waste Forms are defined in the BIR, and a general review of the constituents in the waste streams given in Appendix A of the BIR. It should be noted that one of the special cases mentioned earlier, Various Rocky Flats Residues, has a unique assessment that reflects the more specific plans currently made for that material.

Verification of Drum Conformance to the WIPP WAC. Prior to shipment to the WIPP, each waste container must be certified as complying to the WIPP WAC. The HEP for failing to properly verify conformance of a drum to the WIPP WAC depends on both the method by which the verification is accomplished and the final waste form.

- The highest error rate arises when stored inventory is verified without opening the drums. Verification of waste drums that have been packaged in the past by assay and records checks provide indirect confirmatory evidence, which is dependent on the quality control exerted at the time of packaging. External detection means will be used to further characterize drums that are not processed and repackaged. However, since Table A-1 indicates that the generator sites currently plan to process/repackage over 80 percent of the waste volume, no effort has been made to determine the effectiveness of these methods. Therefore, for the purpose of this quantification, no credit is taken for the detection of potentially pyrophoric materials and combustible mixtures within unopened drums.

- Verification that includes processing and/or repackaging will be able to directly observe the waste form, but the form of the waste could inadvertently conceal potentially pyrophoric mixtures. Verification by processing and/or repacking waste provides an additional independent check over and above that produced by the combination of assay and process knowledge. However, this process may not eliminate improperly verified drums, and the HEP of 1E-01 associated with checking is used to reflect this potential error.

- Finally, it is anticipated that the most confidence in conformance will be achieved by the careful control of the processes that will generate waste in the future. Measures to control future processes are anticipated to produce low error rates for the verification of all projected inventory. Errors of commission would have to be accomplished within the defined process in order to inadvertently introduce pyrophoric materials into the waste containers. For this to occur, the pyrophoric material must be physically present. Once, the container is declared ready for closure and shipment to WIPP the verification process will provide an additional check for conformance to the WIPP WAC, at which time errors can be corrected. Therefore, as a screening estimate, the combination of an HEP for an error of commission and checking, 1E-03*1E-01 = 1E-04, is used to estimate the fraction of projected waste containers that may not conform to the WIPP WAC.

4. Availability of Oxidant

For sufficient oxidant to be present to support combustion, either it must be present in the container when ignition occurs, or there must be a leak path and a means to convect oxidant to the point of combustion at a rate sufficient to sustain combustion. A model has been presented in DOE/WIPP 87-005[31] that estimates the probability that sufficient oxidant will be available either as an internal oxidant, or via in-leakage through the filter or an undetected operationally caused breach. It estimates the probability of sufficient oxygen to support sustained combustion to be 4.2E-03. The arguments presented to support this estimate are physically reasonable, and in the absence of other evidence it is used in this quantification.

It should be noted that the likelihood that sufficient oxidant to support sustained combustion may be dependent on the physical properties of the Final Waste Form. For example, some solidified material may be anticipated to have few materials having enough available oxygen to support combustion directly and also a small void fraction to provide an air pathway to the ignition site. These combination of conditions would make the frequency of sustained combustion extremely unlikely. Where waste is more loosely packed conditions may be more favorable. Based on the quantities of waste at risk and the resultant risk, this level of detail is judged to be unnecessary.

The presence of backfill within the disposal rooms is also expected to reduce the availability of oxidant to the drums once they are placed in the U/G horizon. Pathways for air flow to the burning drum will be very restricted in the drum stack. However, the impact of this is not specifically quantified in this scenario.

5. Heat of Combustion

Based on the definitions given of each waste form in Section 5.1.2.2, and the weight concentrations of materials in each specific waste stream defined in Appendix A of the BIR[30], the final waste forms could be categorized for potential of containing sufficient combustibles to support sustained combustion to breach a drum. Examination of Appendix A would lead one to infer that many of the waste streams associated with final waste forms such as salt wastes, soils, solidified inorganics, lead/cadmium metal, and uncategorized metal, would not be able to support the sustained combustion necessary to produce a breach. However, since the amount of thermal energy that must be generated to breach a drum has not been analyzed, it is assumed that any drum containing sufficient pyrophoric material to permit spontaneous ignition will also contain the materials to generate enough heat of combustion to breach the drum.

Description of Calculation for One Waste Stream

The calculation of the frequency of sustained combustion due to spontaneous ignition is illustrated by the event tree in Figure D-1. This event tree calculates the frequency of release for TRU waste categorized as combustible, having a radionuclide concentration of over 20 PE-Ci per equivalent 55- gallon drum volume, and will not be reprocessed/repackaged, one of the 78 categories of waste form bins defined for this quantification. This bin was selected for illustration, because it produces the largest consequence, given a release occurs.

Spontaneous ignition within a drum is the initiating event of the event tree. It arises from an inventory weighted time-averaged quantity of waste being stored in the Waste Handling Building, some fraction of which is susceptible to spontaneous ignition at the generic frequency. This quantity is very small, because a drum containing this waste stream will be present in the WHB very infrequently.

The calculation of the spontaneous ignition frequency is shown in Table D-6. The volume of TRU waste at risk for a spontaneous ignition is defined to be the maximum volume that can be held in the WHB at any one time. The maximum volume is assumed for CH1 because the time averaged inventory of waste that will be present in the WHB will depend on circumstances that can not now be predicted.

Given the initiating event occurs, the presence of sufficient oxidant and heat of combustion, the two other necessary conditions for sustained combustion, are questioned as top events of the tree. For this scoping quantification, sufficient heat of combustion is assumed.

The product of all events necessary for sustained combustion is then expressed as release events per year at the end point of the "no-mitigation" branch of the event tree. The frequency expressed in this event tree is for the contribution of the combustible waste form that will not be processed/repackaged before certification for shipment to the WIPP with a waste form average radionuclide content greater than 20 PE-Ci. Recall that this is just one of 78 possible combinations of waste form frequency and consequence that contribute to the overall risk of spontaneous ignition. For information purposes, a "mitigated" subtree is also included to show the impact of containment features designed into the WIPP to prevent releases offsite.

Table D-7 shows the overall calculations for all 78 possible combinations of final waste form, processing/repackaging plan, and radionuclide concentration. For simplicity, the order of calculation has been changed slightly from that represented in the event tree. The table first calculates the frequency of release for each of the 78 combinations on a per m^3-year of storage basis. The spontaneous ignition event frequency is calculated across the top row. The dot product symbol is used to indicate that cells in the same relative location of the matrices delineating each of the combinations are multiplied together to obtain the product. The second row then multiplies the spontaneous ignition frequency by the likelihood of sufficient oxidant and heat of combustion to obtain the release frequency on a per m^3-year of storage basis. This final matrix is then applied to the waste volumes at risk in Table D-8.

<u>Overall Calculation</u>

Table D-8 illustrate the calculations required to obtain an overall frequency of release due to spontaneous ignition in the WHB. The frequencies for stored non-processed/repackaged and process/repackage waste streams are repeated in the left columns for convenience. These frequencies are then multiplied by the material at risk for each waste form, which is obtained from the product of the waste form volume percent and the total stored volume. That product is in turn multiplied by the percentage of the waste form that falls into each of the radionuclide concentration bins for the non-processed/repackaged and processed/repackaged waste streams respectively. These two results are then added and listed under the composite frequency of release for that Final Waste Form.

It can be seen from Table D-8 that the overall frequencies of spontaneous ignition within the WHB is approximately 1.4E-07/year (beyond extremely unlikely). Moreover, less than two percent of this frequency (2E-09/year) involves drums containing over 20 PE-Ci of TRU waste, the consequences of which are calculated assuming a bounding content of 80 PE-Ci. Finally, over 90 percent of the frequency involves drums that will have at least an order of magnitude less consequence than the bounding case.

Source Term Development

Radiological Waste Container Inventory (CI) - Based on the postulated scenario, the radiological CI for this accident has been determined to be the maximum inventory contained in a single drum (CD=1). As discussed in Section 5.1.2, a maximum drum inventory has been established as 80.0 PE-Ci which provides the radiological CI for a spontaneous ignition within a drum.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.1.2, the solid and liquid chemical compound concentrations that would be expected to be within a waste container (Table 5.1-3) are used as the nonradiological CI.

Damage Ratio - The accident scenario involves a spontaneous ignition in a drum, therefore it is necessary to first discuss the amount of material that will burn (combustible fraction) and the amount of material that will be subjected to thermal stress (heating without ignition) (noncombustible fraction) in order to determine the amount of material that could be released to receptors of concern. The waste form within a drum (combustibles vs noncombustibles) is estimated based on information provided in the Section 5.1.2. Combustible waste is defined as consisting of paper, kimwipes, and cloth (dry and damp); various plastics such as polyethylene and polyvinyl chloride; wood; and filters contaminated with trace quantities of halogenated organic solvents.

The combustible waste distribution is conservatively assumed to be 95 percent of the waste container contents. The remainder of the material in the drum (5 percent) is assumed to be noncombustible (sludges, filters, asphalt, soil, glass, metal, other). The radioisotopes within the drum are assumed to be evenly distributed throughout the waste in the drum, therefore 95 percent of the radioactivity is assumed to be combustible material at risk and 5 percent of the radioactivity is assumed to be noncombustible material at risk.

For internal waste container fire as a result of spontaneous ignition, it is conservatively assumed that sufficient internal pressure is generated as a result of the accident phenomenon to cause a breach of the waste container. As a result of the airborne release generated by the fire phenomenon, it is conservatively assumed that the DR for this scenario is 1.0 (DR=1.0).

Airborne Release Fraction - The ARF for combustible materials in a drum is 5.0E-04 and the airborne release fraction for noncombustible materials in a drum is 6.0E-03. These values represent bounding airborne release fractions for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[5]

Respirable Fraction -The bounding RFs for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces are 1 and 1.0E-02, respectively (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[5]

Leakpath Factor - Based on the scenario description, it is not expected that the internal waste container fire will also disable the waste handling ventilation or HEPA filtration systems. If a waste container fire results in a release to the WHB, the release to the outside environment is mitigated by the permanently installed continuously on-line two-stage HEPA. Although the ventilation system is required to be operational during waste handling operations, active ventilation is not required to prevent a significant release of hazardous materials from the WHB. The intact HEPA filters will maintain the secondary confinement barrier, with a potential for only minor releases via leakage around access doors, etc. resulting from the loss of differential pressure. The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors (DF) have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook.[37] Based on the handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case, and 1.0 for the no-mitigation case.

Estimated Noninvolved Worker and MEI Consequences and Comparison to Risk Evaluation Guidelines - Based on values for the source term variables as presented above, the MEI and noninvolved worker non-mitigated consequences (see Appendix E, Tables E-1, E-2, E-3, and E-4) of the Spontaneous Ignition (Drum) in the WHB (CH1) are well within the radiological and nonradiological risk evaluation guidelines (for the extremely unlikely range). Risk evaluation guidelines are not identified for events with frequency ≤ 1E-06/yr, however, the risk evaluation guidelines for the extremely unlikely range are conservatively used for evaluating the risk associated with this scenario.

Assessment of Immediate Worker Consequences - No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH1 (Table E-49) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Waste Handling Building Structure - Secondary Confinement
- WHB CH HVAC System - Secondary Confinement
- WHB HEPA Filters - Secondary Confinement
- Vented DOT Type A or equivalent Waste Container - Primary Confinement

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of the WIPP Emergency Management Program,[11] and the WIPP WAC to restrict waste elements (such as the presence of pyrophorics) that may cause the initiating event for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.2 CH2 Crane Failure in the WHB

Scenario Description - The possibility of a crane accident in the WHB was identified in the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during crane handling. Table 5.1-7 lists three crane failure/breach events which result from 1) failure of lifting equipment , 2) failure to secure load, and 3) failure to remove payload. As determined in the HAZOP each of the events involve negligible release of radioactive and nonradioactive materials and all occur within the WHB. The failure of lifting equipment during TRUDOCK crane operations bounds all other crane handling accidents in the WHB due to height of lift and total waste containers involved.

A typical TRUPACT II contains fourteen 55-gallon (208 L) drums that are stretch wrapped or banded together into seven packs or the TRUPACT II may contain up to two SWBs or a TDOP in place of the 55-gallon (208 L) drums. For this scenario, during TRUPACT unloading, the TRUDOCK crane is assumed to drop the load at the point at which the load is at its greatest height, just over the TRUDOCK railing, crushing the bottom waste containers (seven drums or one SWB). Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the WHB, it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the WHB secondary confinement consists of the WHB structure and ventilation system which maintains static pressure differential between the primary confinement barrier and the environment and continuously HEPA filters exhaust air.

Also, waste handlers are trained and qualified in safe and proper equipment operation (following accepted hoisting and rigging practices) and preoperational inspections. Additionally, the crane design provides for fail safe condition during loss of power (brake set during loss of power). Nevertheless, a release of radiological and nonradiological material is assumed to occur as a result of waste containers falling in excess of 4 ft due to equipment or human (operator) error.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the no-mitigation case, the HEPA filters are assumed to be open, bypassed, or not in place. For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage HEPA.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of occurrence of a crane dropping the load to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$).As shown in the event tree analysis for this accident scenario in Appendix D, Figure D-2, the <u>quantitative</u> evaluation of the no-mitigation annual occurrence frequency of the accident scenario is also in the unlikely range.

A fault tree analysis[38] was performed to determine the reliability of the WHB 6-ton bridge crane. The results of the analysis indicates that the dominant source of crane failure which could result in dropped loads are crane hook or wire rope failures. However, the WIPP facility has an aggressive crane test, maintenance, and inspection program including: (1) preoperational checks and inspections of the hook, wire ropes, and lifting and balancing assembly; (2) no-load test once per shift; (3) monthly inspection of the hook and wire rope; and (4) yearly non-destructive testing of the hook and wire rope. These provisions provide assurance that the analysis failure rate is a very conservative estimate of the frequency of the initiating event for this accident scenario.

As shown in the fault tree analysis,[38] scenarios involving loss of power or motor failure, and crane system brake failure are beyond extremely unlikely (frequency ≤ 1E-06/yr). Power failure may be due to loss of off-site power or coincident with the Design Basis Tornado, or Earthquake. Motor failure may be due to mechanical failure or electrical short leading to a motor fire. Regardless of the power or motor failure scenario, the crane systems brakes are designed to engage upon loss of power, and as such, hold the load, with no resulting credible waste container breach scenario.

Source Term Development

Radiological Waste Container Inventory (CI) - Based on the postulated scenario, the CD for this accident has been determined to be the inventory contained in seven drums or one SWB. As discussed in Section 5.2.1.1, it is assumed that one waste container contains the maximum radionuclide inventory (80 PE-Ci for drums, and 130 PE-Ci for SWBs), and the remaining six drums contain an average radionuclide inventory of 8 PE-Ci each. The one SWB contains the maximum CI. The waste container is conservatively assumed to contain 95 percent noncombustible material and five percent combustible material, as discussed in Section 5.2.1.1.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.2.1.1, the nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100 percent of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Damage Ratio - As discussed in Section 5.2.1.1, for drops of waste containers from the heights associated with crane failure, (from heights greater than 5 ft, and equal to or less than 10 ft ($5 \text{ ft} < h \leq 10 \text{ ft}$)), based on analyses,[10] it is conservatively assumed, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.025 (DR=0.025), and the DR for SWBs and TDOPs is 0.01 (DR=0.01).

Airborne Release Fraction and Respirable Fraction - As discussed in Section 5.2.1.1, the ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solids that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

Leakpath Factor - Based on the scenario description, it is not expected that the crane failure in the WHB will also disable the waste handling ventilation or HEPA filtration systems. If crane failure results in a release to the WHB, the release to the outside environment is mitigated by the permanently installed continuously on-line two-stage HEPA. Although the ventilation system is required to be operational during waste handling operations, active ventilation is not required to prevent a significant release of hazardous materials from the WHB. The intact HEPA filters will maintain the secondary confinement barrier, with a potential for only minor releases via leakage around access doors, etc. resulting from the loss of differential pressure.

The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors have been predicted for accident conditions in the ERDA Nuclear Air Cleaning Handbook, ERDA 76-21.[37] Based on this handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore, the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case and for the no-mitigation case an LPF of 1.0 is assumed.

Estimated noninvolved worker and MEI Consequences and Comparison to Risk Evaluation Guidelines - Based on the data provided in Table A-5 of Appendix A, considering the conditional likelihood of receiving the analyzed worst-case waste container contents and distribution (one waste container >20 PE-Ci, and the remaining at > 2.7 PE-Ci), it is concluded that the frequency for the analyzed worst-case no-mitigation scenario is extremely unlikely. Therefore, the accident risk evaluation guidelines for the extremely unlikely range are used for the comparison of the no-mitigation noninvolved worker and MEI consequences.

Based on the values for the source term variables as presented above, the worst-case, no-mitigation MEI and noninvolved worker consequences (see Appendix E, Tables E-5, E-6, E-7, and E-8) of the Crane Drop in the WHB (CH2) are well within the radiological and nonradiological risk evaluation guidelines for the extremely unlikely range

Assessment of Immediate Worker Consequences- No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH2 (Tables E-50 and E-65) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Waste Handling Building Structure - Secondary Confinement
- WHB CH HVAC System - Secondary Confinement

- WHB HEPA Filters - Secondary Confinement
- Vented DOT Type A or equivalent Waste Container - Primary Confinement
- TRUDOCK Crane - Designed to prevent failure resulting in a dropped load.
- Adjustable Center of Gravity Lift Fixture - Design to prevent load from swinging

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to configuration and document control, quality assurance, conduct of operations, preventative maintenance and inspection, waste handling procedures and training, the WIPP WAC, and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.3 CH3 Puncture of Waste Containers by Forklift in the WHB

Scenario Description - The possibility of a puncture of waste containers by a forklift in the WHB was identified in the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during waste handling. Table 5.1-7 lists one forklift mishap event which results from forklift improper engagement of the load. This scenario bounds all other puncture events involving forklift operations in the WHB due to the total number of waste containers handled during these operations.

The facility pallet is designed to carry the contents of two TRUPACT IIs, (28 drums stretch wrapped or banded together in seven packs, or four SWBs) from the TRUPACT unloading area to the underground horizon. The waste containers are placed onto the facility pallet in two stacks, each with seven drums per layer, stacked two layers high, or one SWB per layer stacked two layers high. After the facility pallet is loaded, a forklift equipped with blunt tipped tines is used to transport the facility pallet to the conveyance loading room, temporary WHB storage, or the shielded holding area. During this process, the operator may improperly engage the fork lift tines in the facility pallet, or a hardware failure prevent the operator from controlling the forklift. Either of these failures may result in the forklift tines impacting the waste containers.

The impact from the forklift tines is assumed to puncture two drums or two SWBs on the bottom layer of the stacks on the facility pallet. Operating procedures caution the operator not to disengage the forklift once the drums have been punctured, but, for the no-mitigation accident scenario, it is assumed that the forklift tines are disengaged from the drums causing material to be released. Although the waste containers are Type A packages certified through design and testing to withstand a fall from four feet without releasing the contents this analysis also assumes two drums (or two SWBs) are knocked off the stacks during impact breaching their containers in order to provide bounding consequences. Thus, a release of radiological and nonradiological material is assumed to occur as a result of two drums (or two SWBs) that are punctured and two drums (or two SWBs) that are dropped as a result of equipment or human (operator) error.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the no-mitigation case, the HEPA filters are assumed to be open, bypassed, or not in place. For the mitigated case, credit is taken for the permanently installed continuously on-line two-stage high efficiency particulate filters (HEPA).

The facility pallet design provides a wide margin for human error during the engagement before the waste containers can be penetrated. The pallet is approximately 10" thick. The two forklift tine pockets channels are located adjacent to the floor, and are approximately 7" high, so that an approximately 3" of side wall is available as a buffer to stop misaligned tines. Because the pockets are very close to the floor, vertically raising of the tines to just clear the floor is all that is required for pocket insertion. This minimizes the likelihood that the tines will be raised above the upper surface of the facility pallet during forklift engagement. Additionally, the waste containers are located in or over a circular impression at the center of the pallet, requiring the forklift to travel an additional 18" after missing the pocket and the side wall before it comes into contact with the waste containers.

Safe operation of forklifts at the WIPP is accomplished through: 1) qualified and fully trained operators that are responsible for the care and operating condition of their equipment, 2) operation of the forklifts at slow speeds within the WHB, 3) stopping operation and reporting mechanical difficulties with the equipment, and (4) the presence of a spotter. Waste handlers are trained and qualified in safe and proper equipment operation and preoperational inspections.

Given a puncture event does occur, the release will be mitigated by the permanently installed continuously on-line two-stage high efficiency particulate filters (HEPA). For the no-mitigation case, the HEPA filters are assumed to be open, bypassed, or not in place.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of occurrence of a puncture of waste containers to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$). However, since this accident evaluation indicated that most of the consequences arise from the puncture event, it is conservatively assumed that the total consequences due to both the punctured and dropped containers will occur at the frequency associated with the puncture of the containers (This is equivalent to stating that the upper drums are guaranteed to fall if the lower drums are punctured). As shown in the event tree analysis for this accident scenario in Appendix D, Figure D-3, the quantitative evaluation of the no-mitigation annual occurrence frequency of the accident scenario is also in the unlikely range.

Given the combination of the above safeguards, the frequency of human error leading to puncture events for use in this accident quantification, is judged to be an upper bound on the frequency of human error generated accidents that can be anticipated at the WIPP. As documented in Appendix D, Table D-1, the human error probability developed for forklift operations at the Savanna River Plant is used as the estimate of the frequency of the human error. In light of the discussion above, the lower value developed by Savanna River was used as the HEP for operations at the WIPP.

Source Term Development

Radiological Waste Container Inventory (CI) - Based on the postulated scenario, the CD for this accident has been determined to be the inventory contained in four drums or two SWBs. As discussed in Section 5.2.1.1, it is assumed that one waste container contains the maximum radionuclide inventory (80 PE-Ci for drums, and 130 PE-Ci for SWBs), and the remaining three drums contain an average radionuclide inventory of 8 PE-Ci each. It is conservatively assumed that of the two of four drums breached by impact, one is at the maximum CI. It is assumed that both SWBs are breached due to impact, one at the maximum of 130 PE-Ci, the second at the average of 32 PE-Ci. The waste container is conservatively assumed to contain 95 percent noncombustible material and five percent combustible material, as discussed in Section 5.2.1.1.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.2.1.1, the nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100% of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Damage Ratio - As discussed in Section 5.2.1.1, for scenarios involving the breach of waste containers due to impact with waste handling equipment, the kinetic energy associated with slow moving waste handling equipment (primarily forklifts) was evaluated[10] to determine the level of waste container damage when compared to test data. Additionally, breaches due to forklift tine impact are evaluated based on the current WIPP forklift tine design. Based on the analyses[10] of the speeds expected during waste handling and resulting possible breach mechanisms, it is considered by engineering judgement that a "puncture" of a waste container (resulting in a relatively large exit path for waste materials) may occur. It is conservatively assumed using engineering judgement, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.05 (DR=0.05), and the DR for SWBs and TDOPs is 0.01 (DR=0.01).

For the two drums not breached due to impact, which are assumed to fall from the second level of drums on the facility pallet, based on the discussion in Section 5.2.1.1, for drops of multiple Type A waste containers associated with typical forklift waste handling operations, drops are considered to occur from a height of less than or equal to five feet. This height range is associated with the height the forklift tines are above the ground, plus the height from a fall of the top waste containers that are stacked two high (as on a facility pallet). Based on analyses,[10] it is considered by engineering judgement that the DR for releases from drops of waste containers from heights less than or equal to five feet is less than 0.01 (DR $<$ 0.01). However, it is conservatively assumed, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.01 (DR=0.01), and the DR for SWBs and TDOPs is 0.001 (DR=0.001).

Airborne Release Fraction and Respirable Fraction - As discussed in Section 5.2.1.1, the ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solids that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

Leakpath Factor - Based on the scenario description, it is not expected that a forklift puncture in the WHB will also disable the waste handling ventilation or HEPA filtration systems. If forklift puncture results in a release to the WHB, the release to the outside environment is mitigated by the permanently installed continuously on-line two-stage HEPA. Although the ventilation system is required to be operational during waste handling operations, active ventilation is not required to prevent a significant release of hazardous materials from the WHB. The intact HEPA filters will maintain the secondary confinement barrier, with a potential for only minor releases via leakage around access doors, etc. resulting from the loss of differential pressure.

The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook, ERDA 76-21.[37] Based on this handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore, the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case and for the no-mitigation case a LPF of 1.0 is assumed.

Estimated Consequences and *Comparison to Risk Evaluation* Guidelines - Based on the data provided in Table A-5 of Appendix A, considering the conditional likelihood of receiving the analyzed worst-case waste container contents and distribution (1 waste container >20 PE-Ci, and the remaining at > 2.7 PE-Ci), it is concluded that the frequency for the analyzed worst-case no-mitigation scenario is extremely unlikely. Therefore, the accident risk evaluation guidelines for the extremely unlikely range are used for the comparison of the no-mitigation noninvolved worker and MEI consequences.

Based on the values for the source term variables as presented above, the worst-case no-mitigation MEI and noninvolved worker consequences (see Appendix E, Tables E-15, E-16, E-17, and E-18) of the Puncture of Waste Containers in the WHB (CH3) are well within the radiological and nonradiological risk evaluation guidelines for the extremely unlikely range.

Assessment of Immediate Worker Consequences - No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH3 (Tables E-51 and E-66) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Waste Handling Building Structure - Secondary Confinement
- WHB CH HVAC System - Secondary Confinement
- WHB HEPA Filters - Secondary Confinement
- Vented DOT Type A or equivalent Waste Container - Primary Confinement
- Forklift and Attachments - Designed to minimize waste container punctures
- Facility Pallet - Designed to minimize waste container punctures

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to configuration and document control, quality assurance, conduct of operations, preventative maintenance and inspection, waste handling procedures and training,WIPP WAC, and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6, and required in the WIPP TSR Document.

5.2.3.4 CH4 Drop of Waste Containers by Forklift in the WHB

Scenario Description - The possibility of waste container breaches due to drops in the WHB was identified in the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during waste handling. For this type of event Table 5.1-7 lists three failure/breach events which result from 1) mislocation on the conveyance car , 2) moving accidents, and 3) moving accident with payload. As determined in the HAZOP each of the events involve negligible release of radioactive and nonradioactive materials and all occur within the WHB. The drop of waste containers from a forklift during waste handling operations in the WHB bounds all other moving or forklift drops due to the total number of waste containers involved during these operations.

Once the waste containers are loaded onto the facility pallet (contents of two TRUPACT IIs, 28 drums or four SWBs), a forklift equipped with blunt tipped tines is used to transport the facility pallet to the conveyance loading room or the shielded storage room. Although the waste containers are Type A packages certified through design and testing to withstand a fall from four feet without releasing the contents it is assumed during the transport of waste containers within the WHB that waste containers are dropped and breached. A release of radiological and nonradiological material is assumed to occur as a result of four drums (or two SWBs) dropped from the facility pallet causing a breach of the waste containers due to equipment or human (operator) error. The TRUPACT-II contents of 14 drums are stretch wrapped or banded together into two seven packs. Each seven pack pair (or SWB pair) is placed on the facility pallet and held in place by tie-downs. As such, it is conservatively assumed that two drums from the top seven packs (or top SWB) of each seven pack pair (or SWB pair) fall due to failure of the tie-downs and stretch wrap (four drums or two SWBs total).

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. Safe operation of forklifts at the WIPP is accomplished through: 1) only qualified and fully trained operators are permitted to operate forklifts; 2) qualified operators will be responsible for the care and operating condition of their equipment; 3) qualified operators complete preoperational inspections; 4) forklifts shall be operated at slow speeds within the WHB; 5) in the case of mechanical difficulties, the operator is responsible to stop the equipment and report the problem; and (6) the presence of a spotter.

Given a forklift drop event does occur, the release will be mitigated by the permanently installed continuously on-line two-stage high efficiency particulate filters (HEPA). For the no-mitigation case, the HEPA filters are assumed to be open, bypassed, or not in place.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of occurrence of a drop of waste containers to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$). As shown in the event tree analysis for this accident scenario in Appendix D, Figure D-4, the quantitative evaluation of the no-mitigation annual occurrence frequency of the accident scenario is also in the unlikely range.

Source Term Development

Radiological Waste Container Inventory (CI) - Based on the postulated scenario, the CD for this accident has been determined to be the inventory contained in four drums or two SWBs. As discussed in Section 5.2.1.1, it is assumed that one waste container contains the maximum radionuclide inventory (80 PE-Ci for drums, and 130 PE-Ci for SWBs), and the remaining three drums contain an average radionuclide inventory of 8 PE-Ci each. It is assumed that one SWB contains the maximum CI of 130 PE-Ci, and the second contains an average of 32 PE-Ci. The waste container is conservatively assumed to contain 95 percent noncombustible material and five percent combustible material, as discussed in Section 5.2.1.1.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.2.1.1, the nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100% of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Damage Ratio - As discussed in Section 5.2.1.1, for drops of multiple Type A waste containers associated with typical forklift waste handling operations, drops are considered to occur from a height of less than or equal to 5 ft. This height range is associated with the height the forklift tines are above the ground, plus the height from a fall of the top waste containers that are stacked two high (as on a facility pallet). Based on analyses,[10] it is considered by engineering judgement that the DR for releases from drops of waste containers from heights less than or equal five feet is less than 0.01 (DR $<$ 0.01). However, it is conservatively assumed, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.01 (DR=0.01), and the DR for SWBs and TDOPs is 0.001 (DR=0.001).

Airborne Release Fraction and Respirable Fraction - The ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solids that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

Leakpath Factor - Based on the scenario description, it is not expected that a forklift drop in the WHB will also disable the waste handling ventilation or HEPA filtration systems. If forklift drop results in a release to the WHB, the release to the outside environment is mitigated by the permanently installed continuously on-line two-stage HEPA. Although the ventilation system is required to be operational during waste handling operations, active ventilation is not required to prevent a significant release of hazardous materials from the WHB. The intact HEPA filters will maintain the secondary confinement barrier, with a potential for only minor releases via leakage around access doors, etc., resulting from the loss of differential pressure.

The amount of material removed from the air due to the HEPA filters is predicted based on decontamination factors. Decontamination factors have been predicted for accident conditions in ERDA Nuclear Air Cleaning Handbook, ERDA 76-21.[37] Based on this handbook a DF of 5.0E+02 for the first stage and 2.0E+03 for the second stage are recommended. Therefore the total DF used in this analysis for both stages of filtration is 1.0E+06. The leakpath factor is considered as 1.0E-06 for the mitigated case, and for the no-mitigation case a LPF of 1.0 is assumed.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - Based on the data provided in Table A-5 of Appendix A, considering the conditional likelihood of receiving the worst-case analyzed waste container contents and distribution (one waste container >20 PE-Ci, and the remaining at > 2.7 PE-Ci), it is concluded that the frequency for the analyzed worst-case no-mitigation scenario is extremely unlikely. Therefore, the accident risk evaluation guidelines for the extremely unlikely range are used for the comparison of the no-mitigation noninvolved worker and MEI consequences.

Based on the values for the source term variables as presented above, the worst-case no-mitigation MEI and noninvolved worker consequences of the Drop of Waste Containers by forklift in the WHB (CH4) are well within the radiological (see Appendix E, Tables E-25 and E-26) and nonradiological (same as for CH3, Tables E-17 and E-18) risk evaluation guidelines (for the extremely unlikely range) (Table 5.2-3, 5.2-4).

Assessment of Immediate Worker Consequences- No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH4 (Tables E-52 and E-67) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Waste Handling Building Structure - Secondary Confinement
- WHB CH HVAC System - Secondary Confinement
- WHB HEPA Filters - Secondary Confinement
- Vented DOT Type A or equivalent Waste Container - Primary Confinement
- Forklift and Attachments - Minimize Waste Container drops
- Facility Pallet - Designed to minimize waste container drops

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to configuration and document control, quality assurance, conduct of operations, preventative maintenance and inspection, waste handling procedures and training,the WIPP WAC, and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.5 CH5 Waste Hoist Failure

Scenario Description - The possibility of a waste hoist failure has been identified as part of the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which may involve a breach of waste container(s) during a waste hoist failure. Table 5.1-7 lists one waste hoist drop event which results from hoist failure.

The waste hoist is a counterbalanced multi-rope friction hoist that operates a single conveyance in the waste shaft. It is used primarily to transport waste from the surface facilities to the underground repository and secondarily to transport personnel and machinery.

During transportation to the underground, it is postulated that a simultaneous break of the hoisting cables (six) or loss of power event occurs and, a failure in the hoist braking system.

Preventive and Mitigative Features - General preventive and mitigative measures were identified in the HAZOP process for this specific scenario and are listed in Table 5.1-7. These measures should be reviewed to comprehend the amount of features that are in place that either prevent and/or mitigate against this accident. For the no-mitigation case, automatic or manual shift of the underground ventilation system to HEPA filtration is assumed to not respond to mitigate a release for this scenario.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of occurrence of a hoist failure to be (beyond extremely unlikely) ($10^{-6} \geq$ frequency). This estimated frequency of occurrence has also been verified in Appendix D. As shown in the event tree analysis for this accident scenario in Appendix D, Figure D-5, the annual occurrence frequency of the no-mitigation accident scenario is confirmed to be beyond extremely unlikely. Risk evaluation guidelines are not identified for events with frequency ≤ 1E-06/yr, however, the risk evaluation guidelines for the extremely unlikely range are conservatively used for evaluating the risk associated with this scenario.

As shown in the event tree for this scenario, loss of power (to the hoist motor) is assumed to be the initiating event. WTSD-TME-063, Probability of a Catastrophic Hoist Accident at the Waste Isolation Pilot Plant, July, 1985,[39] identifies four dominant hoist accident scenarios, the most likely is power loss and hoist overtravel up. Power failure may be due to loss of off-site power or coincident with the Design Basis Wind, Tornado, or Earthquake. An evaluation of the off-site power loss frequency is conducted in Table D-9 of Appendix D. Comparing the frequency of the DBE (CH6) and DBT (CH10) with the frequency of off-site power loss indicates that the most likely scenario is loss of off-site power.

Regardless of the initiating event, the hoist brake system functions to prevent the uncontrolled movement of the hoist, and thus prevents the resultant waste container breach accident scenario. Due to the importance of this system, a fault tree analysis[40] on the waste hoist brake system was conducted: (1) to quantify the failure frequency on demand, (2) to verify system reliability, and (3) to identify system improvements or controls. The fault tree analysis of the current hoist configuration quantifies the frequency of failure as 1.3E-07/demand.

Additionally, an analysis has been performed by the Environmental Evaluation Group[41] of the frequency of brake system failure. The extensive uncertainty analysis performed in EEG-59, indicates that the mean frequency of 1.3E-07 corresponds to an 82 percent confidence level. At the 95 percent confidence level, the analysis indicates that the annual failure rate is 4.5E-07. The mean value of 1.3E-07 is used in the event tree in Table D-9 for the failure probability of the brake system. The EEG analysis confirms, that the no-mitigation accident scenario frequency is beyond extremely unlikely.

The primary outcome of both the previous and existing WIPP Waste Hoist Brake System fault tree analyses, and EEG-59 were design changes and identification of administrative controls which significantly enhance the system safety and reliability. As identified in EEG-59, the performance of preoperational tests is of paramount importance to system reliability (for the waste hoist, as well as other WIPP SSCs) , and as such, is a primary element of the first layer of WIPP defense-in-depth. Section 8.3.3.5 discusses the elements of preoperational checks as required by the conduct of operations program.

Source Term Development

Radiological Waste Container Inventory (CI) - Based on the postulated scenario, the CD for this accident has been determined to be 28 drums or four SWBs. As discussed in Section 5.2.1.1, it is assumed that one waste container contains the maximum radionuclide inventory (80 PE-Ci for drums, and 130 PE-Ci for SWBs), and the remaining 27 drums or three SWBs contain an average radionuclide inventory of 8 PE-Ci each and 32 PE-Ci respectively. The waste container is conservatively assumed to contain 95 percent noncombustible material and 5 percent combustible material, as discussed in Section 5.2.1.1.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.2.1.1, the nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100 percent of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Damage Ratios - As discussed in Section 5.2.1.1, a bounding DR of 0.25 for the drums and for SWBs is assumed.

Airborne Release and Respirable Fraction -The ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solids that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

Leakpath Factor - Based on the scenario description, it is not expected that a waste hoist drop in the WHB will also disable the waste handling or underground ventilation or HEPA filtration systems. Shift of the underground ventilation system may occur manually or automatically as discussed in detail in Section 4.4.2.3. However, it is assumed that automatic shift to filtration will not respond to mitigate a release for this scenario. For the mitigated case, it is assumed that the CMR operator will be notified or be aware of the accident and actuate the shift to filtration. Credit is not taken for the natural attenuation provided by the discharge path.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - Based on the values for the source term variables as presented above, the no-mitigation MEI and noninvolved worker consequences (see Appendix E, Tables E-31, E-32, and E-33) of the Waste Hoist Failure (CH5) are well within the radiological and nonradiological risk evaluation guidelines (for the extremely unlikely range). Risk evaluation guidelines are not identified for events with frequency $\leq$ 1E-06/yr, however, the risk evaluation guidelines for the extremely unlikely range are used for evaluating the risk associated with this scenario.

Assessment of Immediate Worker Consequences- No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH5 (Table E-53) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Underground Ventilation Exhaust System - Secondary Confinement
- Underground Ventilation Exhaust HEPA Filters - Secondary Confinement
- Central Monitoring System (for actuation of underground shift to filtration only) - Secondary Confinement
- Waste Hoist and Brake System - Waste Hoist design to prevent failure resulting in an uncontrolled movement of the hoist
- Vented DOT Type A or equivalent Waste Container - Primary Confinement

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to configuration and document control, quality assurance, conduct of operations (including performance of preoperational checks), preventative maintenance and inspection, waste handling procedures and training, the WIPP WAC, and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.6 CH6 Seismic Event

Scenario Description - The possibility of a seismic event has been identified as part of the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents a natural phenomena induced accident which may involve the potential breach of waste containers.

As discussed in Chapters 2 and 3 of this SAR, the Design Basis Earthquake (DBE) is the most severe credible earthquake expected to occur at the WIPP Site. The DBE is based on a 1,000-year return interval established through a site specific study. The maximum ground acceleration for the DBE is 0.1 g in both the horizontal and vertical directions, with ten maximum stress cycles.

It is postulated that as a result of the DBE, internal events within the Waste Handling Building (WHB) may cause the loss of primary confinement (e.g. process/equipment disruption resulting in waste container drops/falls and breaches) and release airborne radiological and/or nonradiological hazardous materials. The above ground WHB CH waste handling process was reviewed to determine the process step (1) most vulnerable to the DBE, and (2) bounding in terms of potential to release airborne hazardous materials.

Two process steps were identified: (1) the processes of TRUPACT unloading and movement of waste containers on the facility pallet to the conveyance loading room, and (2) waste storage in the CH Bay for a period of up to five days awaiting transfer to the underground, are considered as the most vulnerable to DBE movement, and bounding in terms of number of waste containers involved (28 drums on facility pallet or four SWBs). As discussed in Chapter 4, the 6-ton TRUDOCK cranes are designed to hold their loads in the event of the DBE. Therefore, no resultant release of hazardous materials can be postulated during TRUPACT unloading.

Design Class II DBE SSCs (see Table 4.1-1), including the WHB structure and structural components, and tornado doors are designed to withstand a DBE free-field horizontal and vertical ground acceleration of 0.1 g, based on a 1,000-year recurrence period, and retain their design function. Additionally, the main lateral force resisting members of the Support Building and Building 412 are DBE designed to protect the WHB from their structural failure.

The original design for WIPP used the 1982 Uniform Building Code and predated both DOE 6430.1A[3] and UCRL-15910.[42] An updated assessment of the DBE was performed in 1990 by Bechtel.[43] The assessment showed that the design classifications shown in the original design for WIPP either met or exceeded the newer standards for DBE for nonreactor facilities.

Based on the discussion in Section 4.3.1.1.1, up to seven facility pallets (196 drums or 28 SWBs) of waste may be stored in the CH Bay for a period of up to five days awaiting transfer to the underground. It can be postulated that drum fall/drops and breaches may occur , however, as a result of: (1) the drop height is less than or equal to 4 feet, (2) the existing process design (Type A container design, facility pallet and tie-down and lateral straps, etc.), no credible release scenario can be postulated.

Therefore, no credible release scenario could be postulated for loss of primary confinement (waste container breach) as a result of the DBE. In conclusion, there are no consequences to the MEI as a result of the WIPP DBE aboveground.

With regard to coincident power loss during a DBE, off-site power loss is analyzed in the initiating event development for the CH2, Crane Failure, and CH5 Waste Hoist Failure accident scenarios. The crane and waste hoist design provides for fail safe condition during loss of power (brake set during loss of power). Also, since the hoist system (headframe, waste shaft, and shaft furnishings) will withstand the DBE, no release scenarios are postulated involving failure of the hoist as a result of a DBE initiating event. The frequency of coincident DBT and/or DBT power loss, and failure of the crane or waste hoist brakes is beyond extremely unlikely. The analyses in CH2 and CH5 consider, in quantification of the event frequency, the more likely scenario of loss of normal off-site power, as opposed to resulting from a less likely DBE. Regardless of initiating event frequency, the consequences of CH2 and CH5, if off-site power loss and failure of the brake systems were to occur, are analyzed for the scenario, in each respective accident scenario evaluation in this section.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. These measures should be reviewed to comprehend the amount of features that are in place that either prevent and/or mitigate against this accident.

Estimated Frequency - The DBE is based on a 1,000-year return interval.

Source Term Development - No hazardous material is postulated to be released during the DBE, therefore, no source term is developed.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - No hazardous material is postulated to be released during the DBE, therefore, no consequence analysis is developed.

Safety Structures, Systems, and Components - No hazardous material is postulated to be released during the DBE, therefore Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Waste Handling Building - WHB structure (includes structure and structural components) designed to prevent failure during a DBE resulting in a loss of secondary confinement

- TRUDOCK Crane and Waste Hoist - WHB 6-ton bridge crane and waste hoist design prevent uncontrolled movement during DBE

- Vented DOT Type A or equivalent Waste Container - Primary Confinement

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

As shown in Chapter 6, based on the criteria for assigning Technical Safety Requirement (TSR) Limiting Conditions for Operation (LCOs), these equipment are not assigned TSR LCOs. However, due to the importance of DBE qualification, and programs relating to configuration and document control, quality assurance, preventative maintenance and inspection, the WIPP WAC, and the WIPP Emergency Management in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.7 CH7 Spontaneous Ignition (Drum) in the Underground

The spontaneous ignition within a drum in the underground horizon is an internally initiated accident resulting from failure to conform to the WIPP WAC,[29] which prohibits pyrophorics in a waste container. With the generic information available to it, the HAZOP team qualitatively estimated the frequency of a release as the result of spontaneous ignition to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$/year). The quantitative accident evaluation presented here makes use of the information contained in the BIR to estimate the frequency of releases of varying magnitudes resulting from a sustained drum fire based on radionuclide concentration, final waste form, and method of verification of conformance to the WIPP WAC.

Scenario Description - The HAZOP for CH TRU Waste Handling System postulates a spontaneous ignition within a drum in route to or within the waste disposal panel. The most likely area is within a panel room where drums are being emplaced. Based on DOE/WIPP 87-005,[31] Waste Drum Fire Propagation at the WIPP, the fire is not postulated to propagate to additional drums.

The frequency and magnitude of potential releases depend on the number of drums having a given quantity of TRU waste, that also contain an ignition source, as well as sufficient combustible material (heat of combustion) and oxidant to generate the energy needed to produce a breach.

Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the underground, it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the underground secondary confinement consists of the natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system. Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the Central monitoring room (CMR) operator, or automatically due to a continuous air monitor (CAM) alarm logic sequence.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the no-mitigation case: (1) automatic shift of the underground ventilation system to HEPA filtration is assumed to not respond to mitigate a release for this scenario. Additionally, a spontaneous ignition release may go undetected during nonworking hours, and thus unlike the underground waste handling scenarios, it is assumed that the CMR operator will not be notified or be aware of the accident and actuate the shift to filtration.

The primary means of preventing spontaneous ignition is compliance with the WAC. Given a drum conforms to the WAC, the frequency of spontaneous ignition is considered to be negligibly small. Therefore, drums will be part of a population of drums that is susceptible to spontaneous ignition only if an error has been made in verifying their conformance to the WAC, which involves human error at the generator sites. The potential for these errors depends on both the final waste form and the method by which verification to the WAC is achieved (see Section 5.1.2.2), both of which are discussed further under estimated frequency.

Only that portion of the panel that is being actively ventilated is capable of producing consequences to humans. A release from a drum within a room that has already been isolated from ventilation has no motive force to propagate the released material beyond the immediate vicinity of the drum.

Estimated Frequency - As part of the HAZOP[28], the team qualitatively estimated the frequency of occurrence of each event. Based on this study, the frequency of occurrence of a spontaneous ignition has been estimated to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$). However, based on a quantitative evaluation using conservative assumptions documented in Appendix D the quantification of CH7 indicates that the overall frequency of release is extremely unlikely (10^{-4}/year $\geq$ frequency $> 10^{-6}$/year) considering all final waste forms and waste drum TRU loadings. However, the frequency of release from a drum containing more than 8 PE-Ci of TRU waste is beyond extremely unlikely (frequency $\leq$ 1E-06/yr).Risk evaluation guidelines for the extremely unlikely range are used for evaluating the risk associated with this scenario.

The frequency of CH7 is calculated in Table D-15 for final waste forms and distributions of drum loading obtained from the BIR. The analytical model and supporting evidence that produced these results are presented in Tables D-1 through D-7, and an event tree illustrating the sequence of events resulting in consequences from sustained combustion within a waste drum in the underground is shown in Figure D-6. As spontaneous ignition initiates inside the drum, the model of the accident frequency is the same as CH1, with the only exception being the total volume of waste susceptible to combustion. Consequently only the aspects of the scenario that are unique to the underground will be discussed here.

The calculation of the frequency of sustained combustion due to spontaneous ignition is illustrated by the event tree in Figure D-6. As done in CH1, the event tree calculates the frequency of release for TRU waste streams categorized as combustible. The calculation of the spontaneous ignition frequency is shown in Table D-14. The volume of TRU waste at risk for a spontaneous ignition in an area where it can produce a consequence is the time averaged volume present during emplacement in a ventilated panel room. The time averaged value is used because it is anticipated that the room will be filled at a relatively constant throughput rate, with the average value being most representative of the volume that will actually be at risk.

Table D-15 calculates the overall frequency of release due to spontaneous ignition for all 78 combinations of Final Waste Form, processing/repackaging plans, and radionuclide content per drum. It can be seen from this table that the overall frequencies of sustained combustion within the ventilated U/G is approximately 5.3E-06/year, in the range of extremely unlikely accidents. However, less than two percent of this frequency (8.6E-08/year) involves drums containing over 20 PE-Ci of TRU waste, the consequences of which are calculated assuming a bounding content of 80 PE-Ci. Moreover, over 90 percent of the frequency involves drums that will have at least an order of magnitude less consequence than the bounding case. Therefore, one may conclude that releases due to spontaneous ignition in the actively ventilated U/G horizon that would involve a drum containing more than 8 PE-Ci/drum are beyond extremely unlikely.

Source Term Development

Radiological Waste Container Inventory (CI) - Based on the postulated scenario, the radiological CI for this accident has been determined to be the maximum inventory contained in a single drum(CD=1). As discussed in Section 5.1.2, a maximum drum inventory has been established as 80.0 PE-Ci which provides the radiological CI for a spontaneous ignition within a drum.

Nonradiological Waste Container Inventory (CI) - As discussed in Section 5.1.2, the solid and liquid chemical compound concentrations that would be expected to be within a waste container (Table 5.1-3) are used as the nonradiological CI.

Airborne Release Fraction - The ARF for combustible materials in a drum is 5.0E-04 and the airborne release fraction for noncombustible materials in a drum is 6.0E-03. These values represent bounding airborne release fractions for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[5]

Respirable Fraction - The bounding RFs for the burning of contaminated packaged mixed waste and the heating of noncombustible contaminated surfaces are 1 and 1.0E-02, respectively (DOE-HDBK-3010-94, subsection 5.2.1.1 and 5.3.1).[5]

Damage Ratio - The accident scenario involves a spontaneous ignition in a drum, therefore it is necessary to discuss the amount of material that will burn (combustible fraction) and the amount of material that will be subjected to thermal stress (heating without ignition) (noncombustible fraction) in order to determine the amount of material that could be released to receptors of concern. The waste form within a drum (combustibles vs noncombustibles) is estimated based on information provided in Section 5.2.1.1. Combustible waste is defined as consisting of paper, kimwipes, and cloth (dry and damp); various plastics such as polyethylene and polyvinyl chloride; wood; and filters contaminated with trace quantities of halogenated organic solvents.

The combustible waste distribution is conservatively assumed to be 95 percent of the waste container contents. The remainder of the material in the drum (five percent) is assumed to be noncombustible (sludges, filters, asphalt, soil, glass, metal, other). The radioisotopes within the drum are assumed to be evenly distributed throughout the waste in the drum, therefore 95 percent of the radioactivity is assumed to be combustible material at risk and five percent of the radioactivity is assumed to be noncombustible material at risk.

For internal waste container fire as a result of spontaneous ignition, it is conservatively assumed that sufficient internal pressure is generated as a result of the accident phenomenon to cause a breach of the waste container. As a result of the airborne release generated by the fire phenomenon, it is conservatively assumed that the DR for this scenario is 1.0 (DR=1.0).

Leakpath Factor - Based on the scenario description, it is not expected that the internal waste container fire will also disable the underground ventilation or HEPA filtration systems. Shift of the underground ventilation system may occur manually or automatically as discussed in detail in Section 4.4.2.3. However, shift to filtration is not assumed to occur in this scenario. A spontaneous ignition release may go undetected during nonworking hours, and thus unlike the underground waste handling scenarios, it is assumed that the CMR operator will not be notified or be aware of the accident and actuate the shift to filtration. Credit is not taken for the natural attenuation provided by the discharge path.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - Based on the values for the source term variables as presented above, the no-mitigation MEI and noninvolved worker consequences (see Appendix E, Tables E-34, E-35, E-36, and E-37) of a spontaneous ignition in the Underground (CH7) are well within the radiological and nonradiological risk evaluation guidelines (for the extremely unlikely range). Risk evaluation guidelines are not identified for events with frequency ≤ 1E-06/yr, however, the risk evaluation guidelines for the extremely unlikely range are used for evaluating the risk associated with this scenario.

Assessment of Immediate Worker Consequences- No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consquences to the immediate worker from CH7 (Table E-54) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Underground Ventilation Exhaust System - Secondary Confinement
- Underground Ventilation Exhaust HEPA Filters - Secondary Confinement

- Radiation Monitoring System (active waste disposal room exit alpha CAM for underground shift to filtration) - Secondary Confinement

- Central Monitoring System (for actuation of underground shift to filtration only) - Secondary Confinement

- Vented DOT Type A or equivalent Waste Container - Primary Confinement

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to configuration and document control, quality assurance, conduct of operations, preventative maintenance and inspection, waste handling procedures and training, and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

Due to the importance of the WIPP WAC to restrict waste elements (such as the presence of pyrophorics) that may cause the initiating event for this accident, a TSR AC is derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.8 CH8 Aircraft Crash

Scenario Description - The possibility of an aircraft crash into the WHB has been identified as part of the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents an external accident which may involve the potential breach of waste containers. It is postulated that a military or civilian aircraft crashes into the WHB. For the development of the frequency of aircraft crashes, the U.S. Nuclear Regulatory Commission Standard Review Plan (SRP) NUREG-0800[44] is used. This SRP provides criteria for the development of frequencies of aircraft accidents to be used in analyses for nuclear power plants. The SRP provides criteria for crash frequency contributions associated with airport operations (takeoffs and landings), and federal airway activity (overflights).

As described in Chapter 2 of this SAR, two federal ten-mile wide airways (one jet route and one low-altitude route) pass within five miles of the WIPP. Traffic data show that the combined traffic is about 28 instrument flight rule flights per day.

There are no airports or approaches within a five-mile radius of the WIPP. The nearest airstrip, 12 miles north of the site, and privately owned by Transwestern (TW) Pipeline Co. is no longer in use and TW filed for abandonment in 1990 with the Federal Aviation Administration. The nearest commercial airport is in Carlsbad (28 miles to the west).

There are no military facilities within a five mile radius of the WIPP, however, some military installations in New Mexico and Texas have operations that might affect the WIPP (the closest is Holloman Air Force Base, 138 miles NW of the site).

Using NUREG-800[44], the total aircraft hazard probability (combined airway, and airport) at the WIPP site is 1.2E-07/yr.

Preventive and Mitigative Features - Air space above facility not part of normal flight patterns and WIPP is in a remote location.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of occurrence of an aircraft crash to be beyond extremely unlikely ($10^{-6} \geq$ frequency). This estimated frequency of occurrence has also been verified in Appendix D using NUREG-0800[44], considering the total aircraft hazard probability (combined airway, airport, and military designated airspace operations probability of an aircraft crash).

Source term Development - The frequency of the accident scenario is beyond extremely unlikely therefore, source term development is unnecessary.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - The frequency of the accident scenario is beyond extremely unlikely therefore, consequence analysis is unnecessary.

Assessment of Immediate Worker Consequences- As discussed in Section 5.2.1.2, this scenario is not evaluated for immediate worker consequences.

Safety Structures, Systems, and Components - This scenario is considered beyond extremely unlikely and no hazardous material is postulated to be released during this scenario, therefore, no Safety Class or Safety Significant SSCs are required.

There are no defense-in depth SSCs applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3.

5.2.3.9 CH9 Drop of Waste Containers by Forklift in the Underground

Scenario Description - The possibility of waste container breaches due to drops in the underground was identified in the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents an internally initiated operational accident which involves a breach of waste container(s) during waste emplacement. For this type of event Table 5.1-7 lists one forklift mishap/breach event which results from the operator not observing the floor distortion which causes the forklift to tip and result in dropping of the load. Floor surveys and MSHA inspections are conducted to preclude this type of event, however it is assumed the drop could also occur not only from human error but also from equipment failure. The drop of waste containers from a forklift during waste emplacement operations in the underground bounds all other forklift drops due to the total number of waste containers involved during these operations.

Once the waste containers are at the bottom of the waste shaft, the pallet locking pins are removed and the facility pallet is pulled from the hoist to the transporter with a hydraulic driven screw hook latch. The transporter then carries the pallet to the emplacement area.

In the emplacement room, the tie-down and lateral straps are removed and a fork lift is used to place the waste containers in their final location. The fork lift uses a solid platform with a hydraulic push-pull device to handle the seven-drum arrays or a vertical tanged lifting device to engage the standard waste box lifting slots. The operator, aided by a spotter and the transporter operator, places the waste containers in the desired emplacement position (seven-drum arrays, stacked three layers high, or single SWBs stacked three layers high).

During emplacement of a seven-or 14-drum array, or one or two SWBs, the operator is assumed to improperly disengage the forklift and the waste containers drop from a height of greater than 4 ft, causing a breach of seven drums or a single SWB.

Although the primary confinement (waste container) is assumed to breach and result in a release of radiological and nonradiological material within the underground it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the underground secondary confinement consists of the natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system. Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the CMR, or automatically due to a CAM alarm logic sequence.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. For the no-mitigation case, automatic or manual shift of the underground ventilation system to HEPA filtration is assumed to not respond to mitigate a release for this scenario.

Estimated Frequency - The HAZOP team qualitatively estimated the frequency of a drop of waste containers to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$). As shown in the event tree analysis for this accident scenario in Appendix D, Figure D-7, the quantitative evaluation of the no-mitigation annual occurrence frequency of the accident scenario is also in the unlikely range.

Source Term Development

Radiological Waste Container Inventory (CI)- Based on the postulated scenario, the CD for this accident has been determined to be the inventory contained in seven drums or one SWB. As discussed in Section 5.2.1.1, it is assumed that one waste container contains the maximum radionuclide inventory (80 PE-Ci for drums, and 130 PE-Ci for SWBs), and the remaining six drums contain an average radionuclide inventory of 8 PE-Ci each. The SWB is assumed to be at the maximum CI. The waste container is conservatively assumed to contain 95 percent noncombustible material and 5 percent combustible material, as discussed in Section 5.2.1.1.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.2.1.1, the nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100 percent of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes. *Damage Ratio*- As discussed in Section 5.2.1.1, for drops of waste containers from the heights associated with drops from the third layer of the waste stack (from heights equal to or less than 10 ft (5 ft $<$ h $\leq$ 10 ft)), based on analyses,[10] it is conservatively assumed using engineering judgement, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent) in this class of accident is 0.025 (DR=0.025), and the DR for SWBs and TDOPs is 0.01 (DR=0.01).

Airborne Release and Respirable Fraction - The ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solid that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

Leakpath Factor - Based on the scenario description, it is not expected that a waste container drop in the underground will also disable the underground ventilation or HEPA filtration systems. Shift of the underground ventilation system may occur manually or automatically as discussed in detail in Section 4.4.2.3. However, it is assumed that an automatic shift to filtration will not respond to mitigate a release for this scenario. For the mitigated case, it is assumed that the CMR operator will be notified or be aware of the accident and actuate the shift to filtration. Credit is <u>not</u> taken for the natural attenuation provided by the discharge path.

Estimated Consequences and Comparison to Risk Evaluation Guidelines -Based on the data provided in Table A-5 of Appendix A, considering the conditional likelihood of receiving the analyzed worst-case waste container contents and distribution (1 waste container >20 PE-Ci, and the remaining at > 2.7 PE-Ci), it is concluded that the frequency for the analyzed worst-case no-mitigation scenario is extremely unlikely. Therefore, the accident risk evaluation guidelines for the extremely unlikely range are used for the comparison of the no-mitigation noninvolved worker and MEI consequences.

Based on the values for the source term variables as presented above, the worst-case no-mitigation MEI and noninvolved worker consequences (see Appendix E, Tables E-38, E-39, and E-40) of a drop of waste containers from a forklift in the underground (CH9) are well within the radiological and nonradiological risk evaluation guidelines (for the extremely unlikely range) (Table 5.2-3, 5.2-4).

Assessment of Immediate Worker Consequences- No current risk evaluation guidelines exist for the assessment of <u>accident</u> consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH9 (Tables E-55 and E68) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Underground Ventilation Exhaust System - Secondary Confinement
- Underground Ventilation Exhaust HEPA Filters - Secondary Confinement
- Radiation Monitoring System (active waste disposal room exit alpha CAM for underground shift to filtration) - Secondary Confinement

- Central Monitoring System (for actuation of underground shift to filtration only) - Secondary Confinement

- Vented DOT Type A or equivalent Waste Container - Primary Confinement

- Forklift and Attachments - Designed to minimize waste container drops

- Facility Pallet - Designed to minimize waste container drops

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to configuration and document control, quality assurance, conduct of operations, preventative maintenance and inspection, waste handling procedures and training, the WIPP WAC, and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.10 CH10 Tornado Event

The processes at WIPP have been examined for the need to protect against high wind, tornado, and wind blown missiles. Underground facilities are inherently protected against these phenomenon, and as such, the examination deals only with surface facilities. Areas of concern for the release of radiological and nonradiological hazardous materials associated with TRU waste are: (1) TRUPACT-II transporter parking and unloading area; (2) TRUPACT-II and waste handling areas within the WHB, the waste hoist, and WHB and underground ventilation systems. These are described below:

- The TRUPACT-II container is designed to withstand the effects of high wind, tornado, tornado driven missiles, and overturning without the release of waste contents as part of the TRUPACT-II Safety Analysis Report for Packaging (SARP).

- The WHB and waste hoist are protected by the WHB steel frame structure with insulated steel siding, and the tornado doors. The structure, and doors, passively withstand the winds, pressure change, and missile forces to ensure that the waste and waste hoist are not subjected to unacceptable forces.

- The WHB exhaust system and HEPA filters are contained within the WHB and are protected from wind forces and missiles by the tornado hardened features of the building structure and the tornado hardened closures (doors). The ventilation system is not required to remain operating during and after the tornado, but rather is protected against dispersal of minor contamination on HEPA filters. No tornado coincident need for confinement active ventilation is postulated due to the extremely low tornado frequency and the absence of common cause events since all crane and hoisting mechanisms are protected (with braking systems that <u>actuate</u> upon loss of power) from accident conditions due to loss of power.

- Underground ventilation is designed to function through DBE/DBT phenomenon, however, as discussed above, is not required to function during the extremely unlikely DBT. Since coincident events such as radionuclide release in the underground and DBT are not coincident or common cause design basis conditions, the function or protection of the intake or exhaust equipment is not required.

Scenario Description - The possibility of a tornado event has been identified as part of the HAZOP[28] performed for the CH TRU Waste Handling system. This scenario represents a natural phenomena induced accident which may involve the potential breach of waste containers.

As discussed in Chapters 2 and 3 of this SAR the Design Basis Tornado (DBT) is the most severe credible tornado that could occur at the WIPP Site. The DBT used for the WIPP has a maximum wind speed of 183 mi/hr (including effects of suction vortices), translational velocity of 41 mi/hr, tangential velocity of 124 mi/hr, a 325 ft radius of maximum wind, pressure drop of 0.5 lb/in^2, and rate of pressure drop of 0.09 $lb/in^2/sec$, with a mean recurrence interval of 1,000,000 years.

Design Class II DBT SSCs (see Table 4.1-1) are designed to withstand winds generated by this tornado (183 mi/h), based on a 1,000,000-year recurrence period, and retain their safety function. The WHB structure and structural components, including tornado doors are designed to withstand the DBT.

Therefore, no credible internal events within the WHB can be postulated to cause the loss of primary confinement (e.g. process/equipment disruption resulting in waste container drops/falls and breaches) and release airborne radiological or nonradiological hazardous materials as a result of the DBT.

With regard to coincident power loss during a DBT, off-site power loss is analyzed in the initiating event development for the CH2, Crane Failure, and CH5 Waste Hoist Failure accident scenarios in this section. The crane and waste hoist design provides for fail safe condition during loss of power (brake set during loss of power). The frequency of coincident DBT caused power loss and failure of the crane or waste hoist brakes is beyond extremely unlikely. The analyses in CH2 and CH5 consider, in quantification of the event frequency, the more likely scenario of loss of normal off-site power, as opposed to resulting from a less likely DBT. The consequences of CH2 and CH5, if off-site power loss and failure of the brake systems were to occur, are analyzed in each respective accident scenario evaluation in this section.

With regard to the effects of missiles generated by the DBT, the WIPP is designed on a single failure basis. It is considered incredible that two or more failure events (breach of waste handling building and breach of waste container by a DBT missile which results in a release of significant quantities of radionuclides that require confinement) can occur simultaneously, therefore, the effects of missiles are not evaluated.

Table 4.1-1, identifies those Design Class II and IIIA DBT SSCs, Table 3.1-2 identifies the applicable design code requirements, and Section 3.2 identifies the applicable DBT structural design criteria for WIPP DBT SSCs. Detailed design information may be found in the respective System Design Description.

Design Class II and IIIA SSCs from Table 4.1-1 applicable to the DBT aboveground are the:

- WHB structure and structural components including tornado doors - Design Class II (Provides physical confinement)

Additionally, the Auxiliary Air Intake Shaft and Tunnel (Bldg. 465) is DBT, and the main lateral force resisting members of the support building and building 412 are DBT designed to protect the WHB from their structural failure.

As shown in Table 3.1-2, Design Class II, and IIIA structures and supports necessary for the confinement of radioactivity are DBT designed. The function provided is to prevent tornado forces or missiles from causing failure of the primary confinement boundaries (waste containers). Therefore, no releases of hazardous materials are postulated as a result of the WIPP DBT designed mitigative/preventative SSCs.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7.

Estimated Frequency - The Design Basis Tornado (DBT) is the most severe credible tornado (183 mi/hr) that could occur at the WIPP site, based on a 1,000,000-year recurrence period.

The DBT was developed by a site specific study SMRP No. 155, "A Site-Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico," Department of Geophysical Sciences, T. Fujita, University of Chicago, February 1978 and its Supplement of August 1978.[45]

Source Term Development - No hazardous material is postulated to be released as a result of the DBT, therefore, the source term development is not required.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - No hazardous material is postulated to be released as a result of the DBT, therefore, consequence analysis is not required.

Assessment of Immediate Worker Consequences- As discussed in Section 5.2.1.2, this scenario is not evaluated for immediate worker consequences.
Safety Structures, Systems, and Components - No hazardous material is postulated to be released during the DBT; therefore, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Waste Handling Building - WHB structure (includes structure and structural components) designed to prevent failure during a DBT resulting in a loss of secondary confinement

Additionally, the main lateral force resisting members of the support building and building 412 are DBT designed to protect the WHB from their structural failure.

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Due to the importance of DBT qualification, and programs relating to configuration and document control, quality assurance, preventative maintenance and inspection, the WIPP WAC, and the WIPP Emergency Management Program, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.3.11 CH11 Underground Roof Fall

Scenario Description - The possibility of waste container breaches due to a roof fall in the underground was identified in the HAZOP[28] performed for the CH TRU Waste Handling system. Given the evidence available to it, the HAZOP team qualitatively estimated the frequency of releases from roof fall events to be in the unlikely range ($10^{-2} \geq$ frequency $> 10^{-4}$), indicating that further evidence should be collected to gain a better quantitative estimate of the frequency.

Roof fall is a natural event that has the potential to breach drums through either direct damage to the drums or by causing drums to fall from the storage stack. Table 5.1-7 lists two nodes where roof fall events can occur: in a disposal panel and in the life of facility area.

A roof fall event in an actively ventilated storage room during emplacement operations in the underground bounds all other roof falls because waste containers are present in the area during these operations and there is a mechanism present to transport hazardous material to the external environment. The CH11 scenario described in this section quantifies the anticipated frequency and consequences of this event.

The following scenarios related to other areas in an active panel or life of facility area are not quantified for the reasons given:

- A roof fall in a room of an active panel that has been filled with waste containers and isolated by the room ventilation barriers is expected to produce no consequences because of the lack of a significant motive force. There is a possibility of an initial pressure pulse due to the disruption, but a majority of the displaced air is expected to flow into the voids in the roof (back) created by the falling salt. Unless a roof fall event occurs on a barrier, the room ventilation barriers are expected to prevent a significant puff release of hazardous material into the ventilated portion of the repository. In addition, if the roof fall occurs in anywhere but the most recently filled room, there will be multiple ventilation barriers in place with emplaced drums on both sides of the barrier to provide additional assurance that material will not reach the ventilated area. PLG-1167, Analysis of Roof Falls and Methane Gas Explosions in Closed Rooms and Panels,[11] judged the conditional likelihood that the chain-link/brattice cloth ventilation barrier system will fail to continue to isolate ventilation to a closed room to no greater than 1E-4.

- PLG-1167,[11] also concluded that, that a breach of waste drums due to expected energy absorption mechanisms is highly unlikely. The anticipated crushing action will tend to fold over the sides of the drums as a result of plastic deformation, rather than splitting them open. In addition, it is judged that the falling salt will tend to crush lids into the drums rather than dislodge them. Thus, two of the primary failure mechanisms leading to releases should have a minimal impact. The analysis did not take into account failure mechanisms due to irregularities in the falling salt and the support system that may have been emplaced in the roof prior to waste emplacement. These mechanisms can not be completely discounted, but by their very nature they should produce localized effects that do not involve many drums. Accounting for the uncertainties involved in actual roof fall events, the likelihood that a significant release from drums may occur as a result of a roof fall is assessed to be 1E-3. This likelihood is considered to be a conservative but reasonable upper bound because the material must be released from the drums but not entombed by the salt. Hazardous material will be available for transport to the actively ventilated portion of the mines only if both these conditions are met.

- Combining the above two likelihoods with the likelihood of a roof fall in a closed room, (PLG-1167 [11]) the overall frequency of a release from drums to the ventilated area of the mine is 1E-7 per year.

- After a panel has been filled, the panel closure is designed to provide isolation of that panel from the rest of the mine.

- Although roof falls in the active life of facility areas of the mine could potentially injure personnel or damage equipment within the affected area, the frequency that such a roof fall could damage drums is extremely remote, because of the small amount of time that a facility pallet is in transit in the underground.

The roof fall accident analysis focuses on panel 1, as it is considered the most susceptible to roof fall. Panels 2 through 8 will be mined, filled with waste, and closed before a roof fall in these panels becomes a concern. Each panel can be mined in about two years. Based on the throughput described in Chapter 4, an individual panel will be filled in approximately 2.5 years, yielding a total open life of approximately 4.5 years. Newly mined rooms are expected to remain stable against roof fall for the expected length of time to completely fill and close a panel at the expected throughput. As evidence to support this, Room 1 in the Site and Preliminary Design Validation (SPDV) was eight years old when the roof fall occurred in 1991 (DOE/WIPP 93-033).[46] In addition, ground control operations will be conducted in each panel room segment prior to the emplacement of waste to provide high confidence that a roof fall will not occur during emplacement.[48,49]

The events necessary for a roof fall in an actively ventilated room containing drums are shown in the fault tree given in Appendix D, Figure D-9. For completeness, the analysis considers roof fall due to:

- Anticipated/Observable Failure Mechanisms. This event addresses the failure mechanisms characterized and discussed by the Geotechnical Expert Panel in DOE/WIPP 91-023.[47] DOE/WIPP 93-033[46] provides very strong arguments for the assertion that the progression of salt instabilities that lead to roof fall due to known mechanisms is very gradual, occurring on the order of months to years after the precursor instability is revealed by monitoring. WIPP/WID-94-2027[48] describes the WIPP program to characterize, monitor, and trend salt behavior that might result in roof fall in Panel 1 due to these mechanisms, so that remedial actions may be formulated as deemed necessary.

- Unanticipated/Unobservable Failure Mechanisms. This event assesses the likelihood that, despite all the efforts to characterize, prevent, and monitor salt behavior that might result in roof fall, a surprise roof fall could occur with no prior observable indications.

Should a roof fall occur, it is postulated that it would be of size equivalent to the roof fall that occurred in the Site and Preliminary Design Validation (SPDV) Room 1 on February 4, 1991 (DOE/WIPP 93-033).[46] The section that fell was in the shape of an elongated pyramid approximately 33 ft wide by seven ft high by 180 ft long, and weighed about 700 tons. The roof fall is expected to produce a static force in the vertical direction of approximately 143 lb_m/ft.[3]

Waste containers may be breached by either being directly damaged by the falling salt, or by being knocked from the waste container stack by lateral forces generated by the stack matrix recoiling from the impact of the fall. An engineering evaluation of the response of the waste container stack to forces generated directly by the falling salt indicate that it is highly unlikely to produce a breach in the drum stack.[10] Even if some of the containers are breached by the falling salt, the material is expected to provide a natural barrier against the transport of the waste, and the material available to be released will be minimal. Therefore, the scenario produced by lateral displacement of the drums is assumed to be bounding for the purposes of calculating consequences.

As a bounding case for consequence analysis, it is hypothesized that up to seven 7-packs may fall from the third level at the edge of the stack. This is equivalent to every 7-pack at the leading edge of the waste container stack. Furthermore, as a result of the fall an average of three drums per 7-pack are breached, producing a source term involving release from a total of 21 drums.

Although the primary confinement (waste container) may breach and result in a release of radiological and nonradiological material within the underground it is not expected to result in a loss of secondary confinement. As discussed in Section 4.4, the underground secondary confinement consists of the natural barrier formed by the salt in the underground disposal areas or the underground bulkheads, separating the disposal and mining areas, and the underground ventilation system. Shifting of the exhaust system to the filtration mode can be accomplished manually either locally at the exhaust filtration building or by the central monitoring room (CMR) operator, or automatically due to a CAM alarm logic sequence.

Preventive and Mitigative Features - General preventive and mitigative measures identified in the HAZOP process for this specific scenario are listed in Table 5.1-7. Evidence available to the WIPP regarding salt mechanics indicates that a roof fall will result from instabilities that progress very gradually and can be observed.[46,47] A vigorous geotechnical monitoring and ground control program is in place to provide high confidence that instabilities will be detected and corrected through resupport operations long before they progress to roof fall.

It is important to recognize that if a roof instability is detected and recognized within as little as a few minutes of an impending roof fall, WIPP personnel will have the time to evacuate the affected area of the mine and take action to prevent a discharge of any materials released by the collapse to the accessible environment. An immediate action available to prevent the possibility of transport of material to the accessible environment is transferring to the filtered ventilation mode. Once personnel are evacuated, plant management has the option to terminate ventilation of the underground horizon until the roof fall event has occurred, thus limiting the spread of hazardous material to that which can be displaced as a result of the shock of the fall.

With a few days prior notice, there will be sufficient time to isolate the affected area and install emergency barriers to cut off air flow to and from the area. Materials are readily available at the WIPP to construct an emergency barrier having sufficient strength and integrity to greatly reduce the potential for transport of material released from the waste containers beyond the barriers, and a monitoring program can be set up to verify that containment integrity is maintained. This will enable evaluation of the stability of the remainder of the underground horizon while minimizing the potential for a release of hazardous materials from the roof fall zone. With these response capabilities, the success criteria for avoiding a roof fall due to anticipated/observable failure mechanisms is defined to be the failure to recognize an impending roof fall up to two days prior to the event.

If necessary for safety, further emplacement activities in the panel can be abandoned. The emergency barrier will inhibit ventilation of the roof fall zone sufficiently to enable safe construction of the panel closure system. As described in Section 4.2.3.4, the panel closure system is designed to maintain acceptable containment of hazardous materials within the panel following a wide variety of postulated disruptive events as the panel progresses to its final disposal configuration. When combined with a stability assessment for the remainder of the underground horizon, this is judged to provide adequate confidence that an unanticipated roof fall in one panel will not impact emplacement operations in other portions of the repository. For the no-mitigation case, automatic or manual shift of the underground ventilation system to HEPA filtration is assumed to not respond to mitigate a release for this scenario.

Estimated Frequency - The overall accident sequence is modeled with the event tree for CH11 given in Appendix D, Figure D-8. Roof fall is the initiating event of the event tree. As shown in the event tree analysis for this accident scenario, the annual occurrence frequency of the no-mitigation accident scenario, evaluated as unlikely by the HAZOP, is quantitatively evaluated to be beyond extremely unlikely (less than 1E-06/yr). Risk evaluation guidelines are not identified for events with frequency ≤ 1E-06/yr, however, the risk evaluation guidelines for the extremely unlikely range are used for evaluating the risk associated with this scenario.

Roof Fall Initiating Event. The frequency of a roof fall is quantified as 4.7E-07 per year using the logic developed in Table D-19 and illustrated in the fault tree following it. This section describes the reasoning used to develop and quantify the table.

Either anticipated/observable or unanticipated/unobservable failure mechanisms may cause the roof fall.

Known and Observable Failure Mechanisms. As shown in the fault tree, roof collapse due to known and observable failure mechanisms during emplacement would require the coincident failure of a number of activities, which are discussed below.

- First, the ground control operations done prior to emplacement of waste in a specific room must be done improperly. These operations are designed to provide high confidence that major roof fall events will not occur for at least four years after the room is declared ready for waste, and if done properly would virtually assure that a major roof fall event would not occur in an actively ventilated room. The fault tree is developed for Panel 1, where bolts will be installed to provide this confidence.

  The quantification took a graded approach that used the collective engineering judgement of safety analysis, ground control, and geotechnical engineering personnel to hypothesize both the number of errors required for an improper installation and the number of opportunities for these errors. To create sufficient unsupported length for propagation to exceed the strength of adjacent bolts, geotechnical engineering have estimated that three or four closely located bolts would have to fail. This can happen due to either hardware failures or human error during installation. In addition, the torque testing of the adhesion of the hardened resin to the bolt and salt must fail to reveal the improper installation.

  - As a screening estimate, a likelihood of 10^{-3} was assigned to installing flawed hardware. This likelihood encompasses both the delivery of out-of-specification bolts or resin and the failure of acceptance inspections to detect the anomalies. As the bolts and resin system represents a straightforward and mature technology, a screening value on the same order of magnitude as an error of omission is judged to bound the likelihood of installing flawed hardware.

- Human error that could lead to the improper insertion of the bolts was quantified using the THERP methodology, which has been widely applied to routine actions during nuclear power plant operations. Improper insertion of bolts is judged to be an error of commission. As bolts are inserted close enough to provide mutual support, a series of adjacent bolts must be improperly inserted to provide a potential for an instability to propagate. However, once an error of commission is accomplished, the likelihood of the same installation personnel repeating that error is high. Conversely, once the proper procedure is set during a given shift, the installation personnel have a high likelihood of continuing with a proper installation. Using these arguments, the opportunity for errors was judged to occur once per shift, with one error of commission being sufficient to leave the room with an unsupported span large enough to propagate to the entire room, e.g. cause the failure of the remaining bolts as the instability spreads. The quantification of these events is documented in Appendix D.

- After the resin has had an opportunity to attain its full strength, the bond between the bolt and the salt is verified with a torque test. Although this is a formal independent check, as a screening estimate, the likelihood of an error in accomplishing this test that would result in a poor bond being undetected is assessed as a checking error, which is quantified in the basic event table in Appendix D with a likelihood of 1E-01.

- Throughout the emplacement operations, the measurements collected by geotechnical engineering to monitor the creep of the salt formation to predict its stability will have to be either errantly reported by the installed instruments or improperly evaluated by the geotechnical engineers. The installation of the geomechanical instrumentation is documented and the initial data from each instrument is reviewed to ensure proper operation. The installation and monitoring of the geomechanical instrumentation are governed by approved procedures. An assessment of the convergence measurements and geotechnical observations are made after each round of measurements, and a complete analysis is performed on an annual basis, as a minimum. The likelihood of these assessments may be changed as warranted by changing ground conditions. The geotechnical monitoring program is further described in Section 4.3.5.5 of this SAR.

  The likelihood that the instability will not be detected because of a failure in the monitoring equipment is judged to be negligible compared to the potential for human error. The monitoring system consists of multiple sensors that would have to fail in a mode that provides false stable readings while giving no other indication of malfunction.

  Based on the above information, the following screening assessments have been made for the likelihood of human error that would lead to a failure of that program. These assessments are combined in Table D-19 to produce a geotechnical monitoring failure rate of 5.0E-05 for each room in which waste will be emplaced:

  - The likelihood of the initial geotechnical evaluation of the data failing to detect an instability trend as it progresses within a panel room is assessed to be equivalent to the median likelihood of an error of commission (H_com = 1E-03) related to the misinterpretation of the data. It is highly unlikely that geotechnical engineering will fail to monitor the room in a timely fashion, and without more detailed evaluation the basic failure rate for an error of commission is considered to be an upper bound. Trends from a number of monitors will be collected and compared, so there is ample opportunity for the detection of errors and inconsistencies. Moreover, the evaluation process is not done under a strict time constraint.

- Because more than one person will have the opportunity to examine the data, an error in checking (H_check = 0.1) is hypothesized to reflect the fact that the initial failure to detect a trend will be identified by these reviewers. Only one opportunity to detect the error is hypothesized for a given round of measurements, reflecting an assumed total dependency among multiple reviewers. In other words, if one reviewer will also misinterpret the data, so will all the other reviewers.

- Despite the fact that the current understanding of salt mechanics predicts that an instability will progress over months, high dependency (H_High_dep = 0.5) is assessed for the misinterpretation of the next set of measurements detecting the trend. Trend data tend to become one body of information, and this assessment of dependency allows for the possibility that some yet unknown systemic problem could lead to the continuing failure to detect the trend. If the second set of measurements fails to detect the trend, all subsequent assessments are assumed to also fail.

- For roof fall incidents that might occur near the edge of the emplaced waste stack in a region that can be observed by ground control, surface indications of impending roof fall may provide sufficient warning. However, because roof falls may occur within the stack where ground control personnel no longer have access, the likelihood that they will not detect some indication of the precursor to a large roof fall is accessed to 0.5. This corresponds to a high dependency with the non-detection of instabilities by geotechnical engineering.

Unanticipated/Unobservable Mechanisms. The roof fall accident analysis recognizes that, despite all the efforts to characterize, prevent, and monitor salt behavior that might result in roof fall, a surprise roof fall could occur with no prior observable indications. The frequency assessment of unanticipated/unobservable roof fall mechanisms has considered the following evidence:

- As documented in DOE/WIPP-91-023,[47] the current geotechnical engineering program has been found to be sound and appropriate for both predicting and preventing roof fall by an international panel of mine experts with considerable experience. A surprise event would indicate the combined expertise and experience of this group, together with the active and continuing geotechnical monitoring and ground control program at the WIPP, was insufficient to predict an imminent roof fall.

- The time frame in which the failure mechanisms would be required to develop into a roof fall is very short compared to the known behavior of salt instabilities, which develop over a period of months. A surprise failure mechanism would have to develop at a rate that is almost two orders of magnitude faster than those that are currently understood.

- In order to produce the consequences hypothesized for this accident, the roof fall is assumed to laterally displace up to seven 7-packs that have been placed on the third level at the edge of the stack, which then fall and breach an average of three drums per 7-pack. This would require a large roof fall relatively close to the edge of the stack. For this to occur as a surprise, no prior indications would have to be observed on all the monitoring equipment in the affected zone, and the weight of the material involved would have to overwhelm any support systems that had been placed in the room prior to the start of emplacement.

- Salt mines are common and have been in operation for a long time. As part of their professional duties, ground control and geotechnical engineering personnel at the WIPP review current industrial experience regarding the performance of salt mines and analyze it for similarities with conditions at WIPP. They are not aware of any events that would be indicative of failure mechanisms that could occur at the WIPP other than those for which they have accounted.

The variable representing unobservable/undetectable failure mechanisms is quantified by interpreting the uncertainty in the above evidence using the following line of reasoning:

- The evidence provides high confidence that unknown mechanisms have only an extremely small chance to develop at a rate that would not be detected, but they do not necessarily make a surprise roof fall incredible. Therefore, it was judged that the frequency of an undetected roof fall anywhere within the actively monitored portion of the mine should be above 1E-06/year.

- Although considerable experience has been accumulated to support the technical understanding of the behavior of salt, WIPP ground control and geotechnical engineering personnel recognize that salt is not homogeneous, production mines are not monitored as well as the WIPP, and incidents that have occurred, but did not result in injury, may not be reported. Consequently, it was judged that the frequency of an undetected roof fall anywhere within the actively monitored portion of the mine could be as high as 1E-04 per year, but the combined experience and engineering knowledge of the salt formation would make higher frequencies very unlikely.

- To encompass both the upper and lower values, the frequency is modeled as a lognormal distribution with a median value of 1E-05/year and a range factor of ten. The range factor of ten relates a 95 percent confidence that the frequency is above 1E-06/year, and a 95 percent confidence that the frequency is below 1E-04/year. The mean value of this distribution is 2.6E-05/year, which is used for this quantification.

- A roof fall can occur in any part of the active underground; however, only a fall in the fraction of the underground having both CH and active ventilation will produce hazardous material consequences. On the average ½ of a room will be filled.

Source Term Development

Radiological Waste Container Inventory (CI)- Based on the postulated scenario, the CD for this accident has been determined to be the inventory contained in twenty one drums or five SWBs. It is conservatively assumed that of the 21 drums breached, one is at the maximum CI of 80 PE-Ci, and the remaining 20 drums are at the average of 8 PE-Ci each. Of the five SWBs breached, one is assumed to be at the maximum CI of 130 PE-Ci, the remaining four are at the average of 32 PE-Ci. The waste container is conservatively assumed to contain 95 percent noncombustible material and 5 percent combustible material, as discussed in Section 5.2.1.1.

Nonradiological Waste Container Inventory (CI)- As discussed in Section 5.2.1.1, the nonradiological CI development process for events which involve a breach of a waste container is simplified by assuming that 100 percent of the VOC headspace inventory is released instantaneously. VOCs selected for consideration for accidental releases are listed in Table 5.1-2. These values were scaled for estimating concentrations in the SWBs based on container volumes.

Damage Ratio -

Two evaluations of the roof fall event were performed:

1) Bottom layer of drums subjected to axial loads caused by the weight of overlying drums, backfill supersacks and mini-sacks, and 7 feet of roof fall.

2) Roof fall dislodges drums from upper stack and they fall to floor (drop accident with the potential for additional loading due to additional drums and debris).

(1) <u>Damage to Drums due to Impact of Falling Salt</u>

The following evidence provides confidence that the inherent strength of the drum matrix and its backfill has a high likelihood of preventing a significant release from the drums due to direct damage from falling salt.

For the static axial loading case, the crush force on the bottom seven-pack of drums is equal to the sum of the following:

- Weight of the 14 overlying drums (each containing the maximum weight of 1,000 lb) plus 12 mini-sacks (each weighing approximately 25 lb)

- Weight of the supersacks acting on the reinforcement sheet (equal to approximately 133 lb/ft^2 of reinforcement sheet surface).

- Weight of the fallen roof acting over the supersacks (equal to approximately 1000 lb/ft^2 of reinforcement sheet surface assuming a roof thickness of 7 ft)

Based on the emplacement configuration, the total crush force acting on the bottom seven-pack of drums is approximately 41,000 lb or 5900 lb/drum. Based on the Sandia tests[7] for "new" DOT-17C drums, plastic deformation did not begin in axial crush tests until the load reached approximately 15,000 lb. No lid separation was observed in these tests and no contents were released. Lateral crush tests indicated no lid separation at loads below 17,100 lb. If the results for the DOT-17C drums are scaled by the wall thickness for the DOT-17H drums, the allowable axial load per drum would be approximately 10,000 lb. Clearly, the maximum crush force is substantially less than the capacity of the drums if they are in a "new condition."

Considering the conservatism in the roof fall and drum weight loading, and the apparent margin between maximum loading and the crush capacity of new drums, it is assumed that the conclusion applies to slightly corroded and damaged drums as well. Based on minimum wall thickness, the DOT-17C and DOT-17H drums could lose approximately 61 percent and 41 percent, respectively, of their original thickness before the apparent allowable load would be exceeded. Consequently, one may conclude that even slightly degraded drums have a high likelihood of not being breached by the static loading induced by the fallen salt.

The ability of the drums to maintain their integrity was also examined from a limiting energy perspective[10] and was updated in PLG-1167, Analysis of Roof Falls and Methane Gas Explosions in Closed Rooms and Panels.[11] The report cited experimental evidence that drum deformations of up to 15 inches produced no breach of the crushed drums. Since there was no data on deformations greater than 15 inches, these were assumed to result in a release of material from the drums. The report concluded that the axial crush energy required to displace a Type 17C drum 15 inches for content weights of 0 to 640 pounds are 186,500 to 650,000 in-lb. A roof fall of 53 inches (including 15 inches of compression) for three layers of drums and the supersack, would produce a potential energy release of 182,000 in-lb. A roof fall of 74 inches (including 15 inches of compression) for three layers of drums and without supersack, would produce a potential energy release of 254,000 in-lb.

The duration of time during which only one or two layers of drums are emplaced is very small compared to the duration of storage. These configurations will exist only at the leading edge of the stack for one or two seven-packs that may be stacked one or two high until the next facility pallet is unloaded. Therefore, these configurations do not pose any significant risk. The results for the remaining two configurations indicate that only modest levels of drum contents are required to ensure that the drums will not be compressed more than 15 inches. Thus, based on the available evidence, Type 17C drums should retain their radioactive material contents following a roof fall event once three layers of drums are emplaced.

Based on axial buckling considerations, it has been shown[10] that the Type 17C drums are approximately 50 percent stronger than the Type 17H drums. If it is argued that the energy range for Type 17C drum lid separation is a factor of 1.5 times higher than that for Type 17H drums, then the corresponding limit for the latter drums lies in the range of 124,955 to 435,500 in-lb. The potential energy associated with a roof slab thickness falling 53 inches has been determined[77] to be of the order of 182,000 in-lb.

Type 17H drums must contain more waste than the Type 17C drums to ensure that they will not be compressed more than 15 inches during a roof fall event. Nevertheless, for the emplacement configurations of interest, the Type 17H drums require only modest content amounts to survive the fall. For the long-term configuration, the drums must contain only 110 lbs to prevent compressions greater than 15 inches, the arbitrary limit in this evaluation. It is unlikely that drums will be shipped to WIPP with such a small amount of contents.

The following factors combine to ensure that the estimate of drum damage is conservative:

- The conclusions reached in PLG-1167, [11] for Type 17H Type 17C drums, assume that all of the potential energy of the roof fall is absorbed by only one of the drums in the vertical stack. If some of this energy is absorbed by the remaining drums in the vertical stack, the drums will require less contents than those indicated above.

- The roof will "sag" significantly before it actually falls, reducing the potential energy available for crushing the drums. It must also be emphasized that no lid separation or drum splitting was actually observed when the drums were compressed by 15 inches. The anticipated crushing action will tend to fold over the sides of the drums as a result of plastic deformation, rather than splitting them open. In addition, it is judged that the falling salt will tend to crush lids into the drums rather than dislodge them. Thus, two of the primary failure mechanisms leading to releases should have a minimal impact. The above analysis did not take into account failure mechanisms due to irregularities in the falling salt and the support system that may have been emplaced in the roof prior to waste emplacement. These mechanisms can not be completely discounted, but by their very nature they should produce localized effects that do not involve many drums.

- If drums were breached by the roof fall event, the reinforcing sheets and stretch wrap will tend to minimize the degree of lid separation. These features were not included in any of the cited tests. The fallen roof itself may provide a barrier against the release of drum contents to the underground room and subsequent entrainment of this material by the ventilation stream.

(2) Drum Damage Due to an Induced Fall from the Waste Stack

As discussed in Section 5.2.1.1, for drops of waste containers from the heights associated with drops from the third layer of the waste stack (from heights equal to or less than 10 ft ($5 \text{ ft} < h \leq 10 \text{ ft}$)), based on analyses,[10] it is conservatively assumed using engineering judgement, to encompass the uncertainty in the application of test data and the variation in waste forms, that the DR for Type A drums (or equivalent)in this class of accident is 0.025 (DR=0.025), and the DR for SWBs and TDOPs is 0.01 (DR=0.01).

Airborne Release and Respirable Fraction - The ARF for contaminated combustible materials which are subjected to impact and breach of the waste container is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.2.3.2).[5] The bounding RF is 0.1 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

The ARF for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solids that do not undergo brittle fracture is 0.001. This value represents a bounding ARF for packaged material in a container which fails due to impact (DOE-HDBK-3010-94, subsection 5.3.3.2.2).[5] The bounding RF is 1.0 (DOE-HDBK-3010-94, subsection 5.2.3.2).[5]

Leakpath Factor - Based on the scenario description, it is not expected that the roof fall in the underground will also disable the underground ventilation or HEPA filtration systems. Shift of the underground ventilation system may occur manually or automatically as discussed in detail in Section 4.4.2.3. However, it is assumed that an automatic shift to filtration will not respond to mitigate a release for this scenario. For the mitigated case, it is assumed that the CMR operator will be notified or be aware of the accident and actuate the shift to filtration. Credit is not taken for the natural attenuation provided by the discharge path.

Estimated Consequences and Comparison to Risk Evaluation Guidelines - Based on the values for the source term variables as presented above, the no-mitigation MEI and noninvolved worker consequences (see Appendix E, Tables E-45, E-46, and E-47) of a roof fall in the underground (CH11) are well within the radiological and nonradiological risk evaluation guidelines (for the extremely unlikely range). Risk evaluation guidelines are not identified for events with frequency ≤ 1E-06/yr, however, the risk evaluation guidelines for the extremely unlikely range are used for evaluating the risk associated with this scenario.

Assessment of Immediate Worker Consequences - No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines are used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The worst-case consequences to the immediate worker from CH11 (Table E-56) are well within the risk evaluation guidelines. Therefore, no specific additional worker protection engineering or administrative controls beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results.

Safety Structures, Systems, and Components - Based on the estimated worst-case no-mitigation MEI and noninvolved worker consequences and comparison to the risk evaluation guidelines, Safety Class or Safety Significant SSCs are not required.

The defense-in-depth SSCs which are applicable to this scenario, per the criteria provided in Chapter 3, Section 3.1.3 are assigned as follows:

- Underground Ventilation Exhaust System - Secondary Confinement
- Underground Ventilation Exhaust HEPA Filters - Secondary Confinement
- Radiation Monitoring System (active waste disposal room exit alpha CAM for underground shift to filtration) - Secondary Confinement
- Central Monitoring System (for actuation of underground shift to filtration only) - Secondary Confinement
- Vented DOT Type A or equivalent Waste Container - Primary Confinement
- Underground Disposal Area - Designed to minimize failure resulting in a breach container

Section 5.2.4.1, Evaluation of the Design Basis, discusses in greater detail: (1) the evaluation of safety SSCs, and (2) the applicability of functional and performance requirements (system evaluation) and controls (TSRs). Detailed design descriptions for the above defense-in-depth SSCs may be found in Chapter 4 and the applicable Systems Design Descriptions.

Due to the importance of WIPP programs relating to geotechnical monitoring, configuration and document control, quality assurance, conduct of operations (including ground control), preventative maintenance and inspection, waste handling procedures and training, the WIPP WAC and the WIPP Emergency Management Program[54] and associated procedures, in the WIPP defense-in-depth strategy for this accident, TSR ACs are derived in Chapter 6 and required in the WIPP TSR Document.

5.2.4 Assessment of WIPP CH Facility Design Basis and Waste Acceptance Criteria

5.2.4.1 Assessment of WIPP CH Facility Design Basis

Accident Analysis Frequency Results

As shown in Section 5.2.3, the quantitative frequency analysis for each accident produced the following grouping of accidents:

Unlikely Range (10^{-2}/year $\geq$ frequency $>10^{-4}$/year)

CH2, Crane Failure in the Waste Handling Building (WHB)

CH3, Puncture of Waste Containers in the Waste Handling Building

CH4, Drum Drop in WHB

CH9, Drum Drop in the Underground

Extremely Unlikely Range (10^{-4}/year $\geq$ frequency $>10^{-6}$/year)

CH7, Spontaneous Ignition in the Underground (For the population of drums $<$ 8 PE-Ci)

Beyond Extremely Unlikely Range (10^{-6}/year $\geq$ frequency)

CH1, Spontaneous Ignition in The Waste Handling Building

CH5, Waste Hoist Failure

CH7, Spontaneous Ignition in the Underground (For the population of drums $>$ 8 PE-Ci)

CH11, Roof Fall

For all accidents, the quantitative frequency analysis has verified that the qualitative frequency ranges assigned for these scenarios in the Hazard and Operability Study (HAZOP) were either correctly or conservatively assigned.

Additional quantitative frequency analyses in the form of event/fault tree analyses were performed to identify systems, structures, components (SSCs), or processes that contribute most to the accident phenomena frequency for the purposes of verifying their adequacy or identifying improvements to reduce the accident frequency and therefore risk to immediate workers (as well as noninvolved worker and MEI). Specific accidents evaluated in this manner were: (1) CH1 and CH7, Spontaneous Ignition in the WHB and Underground; (2) CH2, Crane Failure in the WHB; (3) CH5, Waste Hoist Failure; and (4) CH11, Roof Fall in the Underground. With the exception of the Waste Handling Building 6-ton bridge crane (CH2) and spontaneous ignition in drums containing $<$8 PE-Ci/ drum in the underground (CH7), the event tree/fault tree analyses indicate that the no-mitigation frequency of the identified accidents occurring are beyond extremely unlikely (frequency $\leq$ 1E-06/yr).

Accident Analysis Consequence Results

Based on the CH accident source term and release mechanism analyses presented in Section 5.2.3, for worst-case scenarios with a frequency greater than 1E-06/yr (CH2, CH3, CH4, and CH9), the calculated worst-case no-mitigation accident consequences to the noninvolved worker and MEI, and immediate worker were found to be well below the selected accident risk evaluation guidelines for the extremely unlikely range. The highest consequences are obtained from CH3, with an estimated 3.8 rem (38 mSv) to the noninvolved worker (100 m) (four percent of 100 rem (1 Sv) guideline), 440 mrem (4.4 mSv) to the MEI at the exclusive use area (two percent of 25 rem (250 m Sv) guideline), and 32 rem (0.32 Sv) (32 percent of 100 rem guideline) to the immediate worker. It should be noted that: (1) the MEI consequences for worst-case scenarios with a frequency greater than 1E-06/yr (CH2, CH3, CH4, and CH9), are also well within the value of 500 mrem (5 mSv) temporary annual dose limit **for normal operations** derived from DOE Order 5400.5, and (2) the noninvolved worker consequences are within the 5 rem (50 mSv) annual dose limit for workers for normal operations.

The worst-case consequences to the immediate worker from CH3 are estimated to be 32 rem (320 mSv). No current risk evaluation guidelines exist for the assessment of accident consequences to immediate workers. Therefore, in the absence of guidelines, and for conservatism, the noninvolved worker radiological guidelines were used as a reference point for the assessment of consequences to immediate workers and the evaluation of the adequacy of the WIPP defense-in-depth features. The consequences to the immediate worker from CH3 are also well within the on-site risk evaluation guidelines. Therefore, no specific additional worker protection, engineering, or administrative controls (such as respiratory protection, more stringent maximum waste container inventory, or additional WAC controls such as immobilization) beyond those already qualitatively identified as providing defense-in-depth for the immediate worker, are needed based on the quantitative consequence assessment results

For scenarios with a frequency less than 1E-06/yr (CH1, CH5, CH7, and CH11), the calculated no-mitigation accident consequences to the noninvolved worker, and MEI were also found to be below the selected accident risk evaluation guidelines. The worst-case noninvolved worker and MEI consequences are obtained from CH5, with an estimated 60 rem (600 mSv) to the noninvolved worker (100 m [328 ft]) (60% of 100 rem [1 Sv] on-site guideline) and 9 rem (90 mSv) to the MEI at the exclusive use area (36% of 25 rem [250 mSv] off-site guideline). Risk evaluation guidelines are not identified for events with frequency < 1E-06/yr, however, the 25 rem (250 mSv) risk evaluation guideline for the extremely unlikely range (25 rem siting criteria in DOE Order 6430.1A) is used for evaluating the risk associated with these scenarios.

It should be noted that the MEI (exclusive use area) no-mitigation consequences for all accidents analyzed, regardless of frequency, were found to be well below 25 rem (250 mSv) risk evaluation guideline. The worst-case calculated dose to an immediate worker is from CH5 with an estimated 500 rem (5 Sv). Although the immediate worker dose for CH5 exceeds the on-site risk evaluation guidelines for the extremely unlikely range, no specific additional worker protection engineering or administrative controls are identified. The risk associated with this potential exposure is deemed acceptable for the following reasons:

- The conservatism in the risk evaluation guidelines as discussed in Section 5.2.2, as well as the application of the on-site guidelines to the immediate worker,

- The very low frequency of this scenario, primarily due to the design changes and identification of administrative controls which significantly enhance the system safety and reliability. As identified in EEG-59, the performance of preoperational tests are of paramount importance to system reliability (for the waste hoist, as well as other WIPP SSCs), and as such, is a primary element of the first layer of WIPP defense-in-depth. Section 8.3.3.5 discusses the elements of preoperational checks as required by the conduct of operations program, and a TSR AC is derived in Chapter 6 for inclusion in the WIPP Technical safety Requirements,

- The conservatism inherent in all of the accident analysis source term variables used to estimate the above consequences,

- The existing elements for protection of the worker discussed in detail in Section 5.1.7.

Evaluation of the Design Basis

The accident analyses indicate that Design Class I (Safety Class) SSCs are not required for the WIPP to mitigate any MEI accident radiological and nonradiological consequence to below risk evaluation guideline levels. Secondary confinement is required to remain functional (following DBAs) to the extent that the guidelines in DOE Order 6430.1A, Section 1300-1.4.2,[3] Accidental Releases, are not violated. The risk evaluation guidelines developed in this safety analysis report were used in the absence of definitive criteria in DOE Order 6430.1A and DOE safety analysis orders or guidance documents for evaluation of secondary confinement. As stated above, the MEI (exclusive use area) noninvolved worker no-mitigation consequences were found to be well below the selected risk evaluation guidelines, including accidents whose frequency is < 1E-06/yr, and as such, secondary confinement is not required. However, existing Design Class II and IIIA secondary confinement SSCs, while not required to mitigate the consequences of an accident from exceeding the risk evaluation guidelines, support the second layer of the WIPP defense-in-depth philosophy.

As discussed in the accident scenarios in Section 5.2.3, there is no credible physical mechanism by which the operational accidents analyzed in the WHB or the underground will also disable the respective ventilation or HEPA filtration systems. Again, no releases are postulated requiring ventilation or HEPA filtration for the DBE and DBT scenarios. If waste container breach occurs in the WHB during a credible operational accident (CH2, CH3, CH4), the release to the outside environment is mitigated by the permanently installed continuously on-line two-stage HEPA filter. For credible accident scenarios in the underground (CH9), shift of the underground ventilation system may occur manually (it is assumed that the CMR operator will be notified or be aware of the accident and actuate the shift to filtration), or automatically. With regard to DBE and DBT scenarios, no release scenarios are expected to be initiated during the DBE or DBT, primarily due to the DBE/DBT design of the WHB structure including tornado doors and specific waste handling equipment such as the WHB 6-ton bridge crane and waste hoist. As such, the WHB ventilation and filtration systems are not required to mitigate the consequences of the DBE or DBT scenarios.

Based on criteria in Chapter 3, Section 3.1.3.2, the factors that lead to designation of a component as Safety Significant are:

- SSCs whose preventive or mitigative function is necessary to keep hazardous material exposure to the noninvolved worker below on-site risk evaluation guidelines,

- SSCs that prevent acute worker fatality or serious injury from hazardous material release that is outside the protection of standard industrial practice, OSHA regulation, or mine safety regulation (MSHA) (e.g. potentially explosive waste containers).

As concluded from the WIPP SAR Section 5.2, Accident Analysis, none of the worst-case analyzed scenarios (note: all scenarios are analyzed without regard for occurrence frequency) resulted in noninvolved worker consequences exceeding the risk evaluation guidelines. Therefore, there are no SSCs that are considered Safety Significant due to need to prevent or mitigate noninvolved worker consequence.

The HAZOP identified two potential scenarios related to WIPP waste handling operations, that could result in worker fatality: (1) potentially explosive waste containers, and (2) waste hoist failure while transporting personnel. With regard to explosive waste containers, SAR Section 5.2.3.1 evaluates such scenarios as beyond extremely unlikely. These events are effectively controlled through rigorous application of the preventive function provided by the WAC administrative control, and as such, preventive or mitigative SSCs are not evaluated or required.

With regard to the waste hoist failure scenario, the consequences involving waste hoist failure while transporting waste containers were evaluated in SAR Chapter 5. Based on the analysis, Safety SSCs are not applicable for that scenario. Personnel **and** waste containers will not be transported simultaneously. Failure of the waste hoist while transporting personnel does not constitute a process related accident involving radioactive materials and as such is considered a standard industrial hazard associated with standard mining operations. Hoisting operations are required to comply with the requirements of 30 CFR 57 and the New Mexico Safety Code for all Mines. As such, Safety Significant SSCs are not designated for failure of the waste hoist while transporting personnel.

Specific SSCs that fulfill a defense-in-depth safety function are: (1) the waste handling equipment such as the WHB 6-ton TRUDOCK bridge crane, adjustable center of gravity lift fixture (ACGLF), electric forklifts, facility pallets (including tie-downs and stretchwrap), waste-hoist, underground transporter, the Loron/BRUDI attachments, and (2) WIPP confinement SSCs including waste containers, Waste Handling Building (WHB) and underground structure, and WHB and underground ventilation and filtration systems. With regard to waste handling equipment, in each instance their reliability and functionality are important to the prevention of damage to the waste containers (first layer of defense in depth). As such, their designation as defense-in-depth SSCs ensures that they are designed, maintained, and operated to prevent failure resulting in an accident. WIPP confinement SSCs (WHB and underground ventilation and filtration systems, and WHB and underground structure) support the second layer of defense in depth. All other WIPP SSCs are considered as balance of plant.

DOE-STD-3009-94, requires that for Safety (Safety Class or Safety Significant) SSCs, a SAR define the SSC safety function and functional requirements, performance requirements (system evaluation), and controls (TSRs). Since Safety SSCs are not defined for WIPP, these requirements are not applicable to the WIPP SAR.

Specific WIPP SSCs are classified as Defense-in-Depth SSCs, based on the above functional classification results. Rather than the WIPP SAR specify functional requirements and performance criteria for those defense-in-depth SSCs, the applicable System Design Descriptions (SDDs) describe their intended safety functions, and specify the requirements for design, operation, maintenance , testing, and calibration.

As discussed in detail in SAR Chapter 6, based on application of the criteria in DOE Order 5480.22 for the selection of safety and operational limits, and the fact that Safety Class and Safety Significant SSCs are not selected for WIPP, TSR Safety Limits (SLs), Limiting Conditions for Operation (LCOs), and Surveillance Requirements are not required. TSR ACs assigned for features discussed above that play a role in supporting the WIPP defense-in-depth approach are derived in SAR Chapter 6. Table 6-1 provides a summary of defense-in-depth safety features and applicable TSR controls.

Based on the fact that TSR Operational Limits and Surveillance Requirements are not defined for WIPP, operability definitions for Defense-in-Depth SSCs are not required in the SAR. SSCs are required in the TSR to be as operated as required during each facility mode as described in Table 6-2, to support the overall WIPP defense-in-depth strategy.

Evaluation of Human Factors

A systematic inquiry of the importance to safety of reliable, correct, and effective human-machine interactions, considering the mission of the WIPP facility and the physical nature of the radioactive wastes that it will receive was conducted. The specific human errors that can contribute to accidental releases of hazardous materials were evaluated as an integral part of each hypothesized accident. Based on the analysis of those accidents and the discussion below, it can be concluded that the WIPP waste acceptance criteria for transuranic wastes, facility design, and operational controls provide high confidence that all potential releases can be contained with passive safety features that eliminate the need for human actions requiring sophisticated human-machine interfaces.

To provide additional support for the conclusion that no detailed human factor evaluation of human-machine interfaces is required, a scoping assessment of the effectiveness of the human-machine interfaces that support important design functions of the Table 4.1-1 Design Class II and IIIA systems was performed. It can be seen in Table 4.8-1 that most of the Design Class II and IIIA WIPP systems and equipment do not require human actions to initiate or sustain their function relative to the release of radiological or nonradiological waste materials. In most cases these functions are accomplished with automatic passive mechanisms designed to provide containment for the waste materials.

Functions allocated to automatic passive mechanisms or automatic active systems may be influenced by human error during maintenance. However, using the graded approach, human-machine interfaces for maintenance activities at WIPP are judged to be adequate because they are deliberate, and there is ample opportunity to discover errors and correct them with no adverse safety consequences.

The ability of the staff to accomplish their responsibilities in potential accident environments was evaluated. The limited magnitude of the hazard and the lack of dispersal driving forces provide very high confidence that the staffing and training presented in those sections will enable the staff to perform their responsibilities in potential accident environments.

The magnitude of hazardous materials that can be involved in an accident leading to a release is very limited. The radioactive material is delivered to the site in closed containers, and the waste handling operations are designed to maintain that integrity throughout the entire process required to safely emplace those containers in the site's underground waste disposal rooms. Inventory limits on individual containers ensure that heat generated by radioactive decay can be easily dissipated by passive mechanisms. Finally, only a limited number of waste containers have the possibility of being breached as a result of any one accident initiating event. As a result, the consequences of unmitigated releases from all accidents hypothesized in Chapter 5, including those initiated by human error, do not produce significant offsite health consequences.

The facility has no complex system requirements to maintain an acceptable level of risk. The facility is designed to minimize the presence and impact of other energy sources that could provide the heat or driving force to disperse hazardous materials. When something unusual happens during normal operations, such as support systems becoming unavailable, **waste handling can be simply stopped** and personnel evacuated until an acceptable operating condition is reestablished.

Should an initiating event occur that breaches the waste containers, **the plant design permits the immediate cessation of activity and isolation of the area where the breach occurs.** Once isolation is achieved, there is no driving force within the waste or waste handling area that could result in a release of the waste material. Consequently, **sufficient time is available to thoroughly plan and prepare for the remediation process prior to initiating decontamination and recovery actions.**

Human factors considered in this SAR is limited to that time necessary to properly emplace the transuranic waste designated for disposal at WIPP. The operations will be straightforward, proceduralized, and consistent. Moreover, they will continue for only the period of time needed to complete the disposal process. Once a panel is filled and sealed off, the natural properties of the salt and the location of the mine combine to provide passive isolation of the waste from the environment. The potential for human intrusion after the facility closure is beyond the scope of the human factors evaluation considered here.

Conclusion

It is therefore concluded from the hazards and accident analyses in this SAR that the design basis of the WIPP CH TRU waste handling system is adequate in response to postulated range of CH TRU normal operations and accident conditions for the facility.

5.2.4.2 Analysis of Beyond the Design Basis

Operational Events

An evaluation of operational accidents "beyond" the derivative design basis accident (BDBA) is conducted to provide perspective of the residual risk associated with the operation of the facility. As discussed in DOE-STD-3009-94,[1] beyond DBAs are simply those accidents with more severe conditions or equipment failure. The operational scenarios analyzed in this section as "beyond the design basis" take into consideration the effect of the WIPP Waste Acceptance Criteria Pu-239 Equivalent Activity, and Thermal Power Criteria on the assumed accident scenario material at risk (MAR) and accident consequences of the most credible accident sequences. Based on the analyses in Section 5.2.3, the operational accident scenarios involving potential consequences to the noninvolved worker individual, MEI, and immediate worker, whose frequency is greater than 1E-06/yr are: (1) CH2, Crane Failure in the Waste Handling Building (WHB); (2) CH3, Puncture of Waste Containers in the Waste Handling Building; (3) CH4, Drum Drop in WHB; and (4) CH9, Drum Drop in the Underground.

The source term MAR developed in Section 5.2.3 is based on the waste container inventory derived in Section 5.1.2.1.2. The analyses assumed that based on the data in Appendix A, that: (1) one waste container contains a maximum radionuclide inventory, and (2) the remaining waste containers contain an average radionuclide inventory of 8 PE-Ci (Table A-1 lowest bin upper cutoff). The 8 PE-Ci average bounds 86 percent of the volume for all waste forms, including the predominant heterogeneous, uncategorized metal, and combustible waste forms, and bounds over 96 percent of the volume of uncategorized metals, chosen in Section 5.2.1.1 as the waste form for waste container breach/impact analyses. For accident scenarios which involve single waste containers, it was conservatively assumed that the waste container contains a maximum radionuclide inventory.

As discussed in Section 5.1.2.1.2, the WIPP WAC Thermal Power TRUPACT-II requirements, limit the decay heat from all CH-TRU waste to 40 watts per TRUPACT-II. Using the Pu-238 “heat source” distribution in Table A-4 of Appendix A, calculations indicate that the maximum total PE-Ci for a shipment of Pu-238 waste is approximately 1,117 PE-Ci. The analyses of beyond the design basis considers the effect, and thus the residual risk, on the accident consequences evaluated for CH2, CH3, CH4, and CH9 of a hypothetical TRUPACT-II shipment of **untreated** (not solidified or vitrified) Pu-238 waste with each drum at 80 PE-Ci. Receipt of fourteen drums each at 80 PE-Ci is plausible, considering the above thermal wattage limit PE-Ci equivalent of 1,117 PE-Ci (14 drums x 80 PE-Ci approximately equals 1,117 PE-Ci). However, based on the data presented in Table A-5 of Appendix A, as a result of the conditional likelihood of receiving such a shipment, the on-site and off-site risk evaluation guidelines for the extremely unlikely range are used for the consequence evaluation.

As shown in Appendix E Tables E-13, E-14, E-23, E-24, E-29, E-30, E-43, and E-44, the analysis of CH2, CH3, CH4, and CH9 with each damaged drum at 80 PE-Ci, indicates that the highest immediate worker consequences are obtained from CH3 and CH9.

The radiological consequences of CH3 are discussed here assuming that each drum involved in the scenario is at 80 PE-Ci. The same assumptions regarding waste form combustible and noncombustible composition, damage ratio, airborne release fraction, and respirable fraction are assumed. Substitution of these values into the consequence calculations for CH3, indicate doses of approximately 12 rem (120 mSv) to the noninvolved worker individual (12 percent of the 100 rem noninvolved worker risk evaluation guideline for the extremely unlikely range), and 1.4 rem (14 mSv) (six percent of 25 rem MEI risk evaluation guideline for the extremely unlikely range) to the MEI. The noninvolved worker and MEI doses therefore remain well within the risk evaluation guidelines. The estimated dose to an immediate worker for the CH3 beyond design basis scenario approaches 70 rem (700 mSv), but does not exceed the noninvolved worker risk evaluation guideline of 100 rem (1 Sv) for the extremely unlikely range (Table E-62).

Thus, no significant risk is incurred to the immediate worker, noninvolved worker, or MEI considering the beyond design basis most credible operational accident scenarios above involving a maximally loaded TRUPACT-II shipment of untreated Pu-238 heat source waste, with each drum at 80 PE-Ci.

Natural Phenomenon

As discussed in Section 3.4.3 of DOE-STD-3009, natural phenomenon beyond design basis accidents are defined by a frequency of occurrence less than that assumed for the DBA. Since the DBT is defined with a 10^6 yr return period, and the DBE as a 10^3 yr return period, the most credible beyond DBA natural phenomenon event is an earthquake with a vertical ground acceleration of greater than 0.1 g (considered extremely unlikely). DBE SSCs: (1) the WHB structure, and (2) WHB 6-ton bridge crane, are assumed to fail resulting in a release of radioactive material.

It is assumed that the bridge crane fails while removing a load from a TRUPACT II (CH2). The WHB structure is also assumed to fail resulting in some damage to the seven facility pallets (196 drums or 28 SWBs) of waste that may be stored in the CH Bay for a period of up to five days awaiting transfer to the underground. It is conservatively assumed that one-half of the drums in storage are breached by the falling WHB structure debris, with a DR equivalent to that from the heights associated with drops from the third layer of the waste stack (DR=0.025). This equivalent to 14 times the consequences of the CH2 accident (0.31 rem) or 4.3 rem (43 mSv) to the MEI. Combining this with the MEI consequences of CH2 (0.3 rem), the total MEI (exclusive use area) consequence from the postulated beyond DBE is 4.6 rem (46 mSv) (20 percent of 25 rem MEI risk evaluation guideline for the extremely unlikely range). For the noninvolved worker, the combined consequences are 41 rem (410 mSv) (41 percent of the 100 rem noninvolved worker guideline). Therefore, the radiological risk associated with a greater than 0.1 g earthquake is considered acceptable.

5.2.4.3 Assessment of WIPP Waste Acceptance Criteria (WAC)

WAC Pu-239 Equivalent Activity Operations and Safety Requirement

Based on the beyond design basis accident analysis results in Section 5.2.4.2 above (using conservative assumptions, and in conjunction with elimination of the WAC Revision 4.0 Immobilization Criteria), the estimated radiological consequences for CH3, Puncture in the Waste Handling Building, to the immediate worker, approach the selected accident risk evaluation guidelines. Therefore, the 80 PE-Ci for drums and 130 PE-Ci for SWBs derived in Section 5.1.2.1.2, are established as the WAC Pu-239 Equivalent Activity Operations and Safety maximum allowable waste container radionuclide inventories for untreated CH TRU waste. The establishment of the 80 and 130 PE-Ci values, provides a defense-in-depth based approach to ensure that the estimated immediate worker accident consequences from untreated CH TRU waste remain acceptable.

Waste containers exceeding these values must be overpacked or treated (solidified, or vitrified) prior to acceptance at WIPP. Such a defense-in-depth approach, focuses on the prevention of potential higher dose consequences to the immediate worker from high PE-Ci untreated waste containers by reducing: (1) the conditional likelihood of waste container breach, and the damage ratio (DR) term of the source term equation (Equation 5-1) for overpacked containers (drums overpacked in SWBs or ten-drum overpacks); and (2) the combined airborne release fraction (ARF) and respirable fraction (RF) for solidified or vitrified waste containers. The CH1 and CH7 sustained internal waste container fire scenarios were evaluated in Section 5.2.3 to be beyond extremely unlikely. Therefore, for the evaluation of solidification, vitrification, and overpacking options, these scenarios are not evaluated.

The WIPP WAC Thermal Power TRUPACT-II requirements, limit the decay heat from all CH-TRU waste to 40 watts per TRUPACT-II. Using the Pu-238 "heat source" distribution in Table A-4 of Appendix A, calculations indicate that the maximum total PE-Ci for a TRUPACT-II shipment of Pu-238 waste is approximately 1,117 PE-Ci.

The acceptability of the WAC Pu-239 Equivalent Activity Operations and Safety maximum allowable waste container radionuclide inventory of 1,100 PE-Ci for overpacked and 1,800 PE-Ci for solidified/vitrified waste, established in Section 5.1.2.1.2 is verified by evaluating the most credible worst-case accident scenarios involving the largest potential consequences for each scenario of interest to the noninvolved worker, MEI, and immediate worker.

However, the consequences of accident scenarios CH2 and CH3 are evaluated in Appendix E (Tables E-9, E-10, E-11, E-12, E-19, E-20, E-21, E-22, E-57, E-58, E-59, and E-60) assuming that the accidents involve highly loaded (1,100 PE-Ci) overpacked (untreated waste within a 55-gallon (208 L) drum overpacked within a SWB or TDOP) and (1,800 PE-Ci) solidified/vitrified waste containers. The consequences of CH2 and CH3 for solidified/vitrified waste, are discussed here due to the differences in breaching mechanisms, and the release fractions identified in Section 5.2.1.1. It is conservatively assumed that seven solidified waste containers are breached as a result of crane failure (CH2), and two are breached as a result of puncture (CH3), with one drum in each scenario at 1,800 PE-Ci. As discussed in Section 5.2.1.1, the damage ratio for CH2 scenario is conservatively assumed to be the same as for untreated waste (DR = 1E-02), and for CH3, DR = 1E-02. The ARF x RF for solids that undergo brittle fracture (e.g. aggregate, glass) due to crush-impact forces is given by Equation 5-1 of DOE-HDBK-3010-94.[5] Applying this equation for solidified waste forms to the drop of waste container from heights equal to or less than 10 ft (5 ft $< h \leq$ 10 ft), the calculated ARF x RF = 1.64E-05. Comparing this factor with that obtained for contaminated noncombustible materials which are subjected to impact and breach of the waste container for solid that do not undergo brittle fracture (Section 5.2.1.1), solidification offers a two order magnitude reduction in respirable airborne radioactive material for the bounding scenarios analyzed in this SAR.

Substitution of these values into the consequence calculations for CH2 and CH3 (Tables E-9, E-11, E-19, E-21, E-57, and E-59), indicate worst-case consequences to the immediate worker for CH3, and are thus summarized here. The doses to the immediate worker (2.1 rem [21 mSv]), noninvolved worker (0.25 rem [2.5 mSv]), and MEI (0.03 rem [0.3 mSv]), are well within the risk evaluation guidelines (for the extremely unlikely range) <u>despite the higher PE-Ci loading</u>. Based on the data presented in Table A-5 of Appendix A, as a result of the conditional likelihood of receiving such a shipment, the risk evaluation guidelines for the extremely unlikely range are used for the consequence evaluation. Therefore, although a higher PE-Ci limit is allowed, the effects of vitrifying, or solidifying waste containers results in a significant reduction in the release of respirable airborne radioactivity and thus risk to the receptors of concern.

To determine the acceptability of overpacking a drum of untreated waste within a SWB, the radiological consequences of CH2 and CH3 are again evaluated assuming that multiple drums are breached, one in each scenario at 1,100 PE-Ci (Tables E-10, E-12, E-20, E-22, E-58, and E-60). As discussed in Section 5.2.1.1, the DR for overpacked noncombustible solids (drum within a SWB) for drops less than 10 ft is 2.5E-04, and the DR for punctures of overpacked noncombustible solids (drum within a SWB or TDOP) is 1E-02. CH3 therefore results in a worst-case source term and as such, the consequences of CH3 are analyzed here. The ARF and RF for noncombustible solids are 1E-03 and 1.0 respectively. Substitution of these values into the consequence calculations for CH3, indicate doses of approximately 9 rem (90 mSv) to the noninvolved worker, 1 rem (10 mSv) to the MEI, and 77 rem (770 mSv) to the immediate worker. The immediate worker, noninvolved worker, and MEI doses therefore remain well within the risk evaluation guidelines (for the extremely unlikely range). Based on the data presented in Table A-5 of Appendix A, as a result of the conditional likelihood of receiving such a shipment, the risk evaluation guidelines for the extremely unlikely range are used for the consequence evaluation.

The WAC Pu-239 Equivalent Activity Operations and Safety limits defined above, when analyzed in conjunction with conservative safety analysis assumptions, and existing stored waste information: (1) provides a reasonable degree of assurance that the safety envelop of the facility has been defined, and (2) ensures that the risk to immediate workers, noninvolved worker, and the MEI remain well within the risk evaluation guidelines.

WAC Revision 4.0 Immobilization Criteria

Section 3.3.1.6 of WAC Rev.4[50] stated that immobilization will minimize the quantity of radioactive material that is available for dispersion or inhalation in event of the failure of a waste package.

The types of accidents of SAR concern involve contaminated combustible and non-combustible material packaged in robust containers (drums and standard waste boxes), that are opened and/or fail due to drops and/or punctures. The release fractions for drops and/or punctures of drums used in the SAR analyses for the case of surface contamination on solid, noncombustible surfaces are obtained from DOE-HDBK-3010-94. Section 5.1, page 5-4 of DOE-HDBK-3010-94 states, “the airborne release fractions and respirable fractions for these types of accidents are based on reasoned judgement that suspension under these circumstances will be bounded by suspension postulated for debris impacting powders in cans.”

Therefore, in conjunction with the use of conservative waste container radionuclide inventories and damage ratios for heterogeneous or uncategorized metals, conservatism is provided in the calculation of potential radiological consequences from untreated CH TRU waste to the MEI, onsite worker, and immediate worker. The estimated consequences were found to be within the accident risk evaluation guidelines for all receptors of concern. As such, based on the accident consequence analysis in this SAR, no additional criteria are required to immobilize **untreated** (not solidified or vitrified) waste forms (up to a maximum allowable value of 80 PE-Ci for drums and 130 PE-Ci for SWBs) to minimize the quantity of radioactivity available for release.

Section 5.0 of DOE-HDBK-3010-94[5] discusses the difficulty in characterizing the size distribution of deposited radionuclide contamination. The handbook states that for surface contamination of combustible and noncombustible materials, it is not expected that defensible bases exist for assuming an original source respirable fraction, as the WAC Rev 4 criteria required. Therefore, (1) since the use of 80 PE-Ci for a drum radionuclide inventory and the inherent conservatism in the derivation and use of the bounding release fractions produce acceptable dose consequences to the worker, noninvolved worker, and MEI, and (2) considering the difficulty in characterizing waste particle size distributions for the waste forms identified in the BIR, the elimination of the WAC immobilization criteria for “untreated waste” up to the values of 80 PE-Ci for drums and 130 PE-Ci for SWBs is warranted. As discussed in the preceding discussion on maximum allowable waste container radionuclide inventories, however, waste containers exceeding these values will be overpacked, solidified, or vitrified (thus immobilized) as a defense-in-depth approach to limiting the consequences of potential accidents. Immobilization is therefore based on a more readily quantifiable variable (PE-Ci) (i.e., it is measurable and verifiable in all waste forms) than on the percentage of respirable particulates.

References for Section 5.2

1. DOE-STD-3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports, July 1994.

2. DOE/WIPP 94-026, Waste Isolation Pilot Plant Land Management Implementation Plan, August 1994.

3. DOE Order, 6430.1A, U.S. Department of Energy, General Design Criteria, 1989.

4. Guidance for the Implementation of EPA's Standards for management and Storage of Transuranic Waste (40 CFR Part 191, Subpart A) at the Waste Isolation Pilot Plant ("WIPP Subpart A Guidance"), Draft, August 23, 1996.

5. DOE-HDBK-3010-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities, December 1994.

6. WPS-88-001, Full-Scale Drop-Impact Tests with DOT Specification 7A Waste Containers, Rockwell International, Rocky Flats Plant, December 9, 1988.

7. SAND80-2517, Analysis, Scale Modeling, and Full-Scale Tests of Low-Level Nuclear Waste Drum Response to Accident Environments.

8. MLM-3245, U.S. DOE Evaluation Document for DOT Type A Packaging, EG&G Mound, March 1987.

9. WHC-SD-WM-TRP-231, Drum Drop Test Report, Westinghouse Hanford Corporation, February 27, 1995.

10. PLG-1121, Damage Assessment of Waste Containers Involved in Accidents at the Waste Isolation Pilot Plant, PLG, Inc., August, 1996.

11. PLG-1167, Analysis of Roof Falls and Methane Gas Explosions in Closed Rooms and Panels

12. TRUPACT-II SAR, Revision 16, Appendix 1.3.11, Description of Pipe Overpack Payload Container, February 1997.

13. DOE/EIS-0026-FS, Final Supplement Environmental Impact Statement, Waste Isolation Pilot Plant, U.S. Department of Energy, Carlsbad, N.M., 1990.

14. Nuclear Regulatory Commission Regulatory Guide 1.145, Rev 1, Atmospheric Dispersion Models for the Potential Accident Consequence Assessments at Nuclear Power Plants, United States Nuclear Regulatory Commission, Washington, DC, November 1982.

15. WHC-SD-GN-SWD-30002, GXQ Users Guide, Westinghouse Hanford Company, Rev 0., June 8, 1993.

16. ICRP Report No. 23, Report of the Task Group on Reference Man, International Commission on Radiological Protection, Pergamon Press, NY, 1974.

17. DOE/EH-0071, Internal Dose Conversion Factors for Calculation of Dose to the Public, July 1988.

18. Letter from R. Neill, Environmental Evaluation Group, New Mexico, to G. Dials, dated January 9, 1996.

19. ANSI/ANS-51.1-1983, American National Standards Institute, Standard Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants.

20. ANSI/ANS-52.1-1983, American National Standards Institute, Standard Nuclear Safety Criteria for the Design of Stationary Boiling Water Reactor Plants.

21. 10 CFR 835, Occupational Radiation Protection, December 14, 1993.

22. 10 CFR 100, Reactor Site Criteria.

23. DOE Emergency Management Guide for Hazards Assessment, June 2, 1996.

24. Craig, DK et al., Toxic Chemical Hazard Classification and Risk Acceptance Guidelines for the use in DOE Facilities, May 1993.

25. American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances, ACGIH, Cincinnati, Ohio, ISBN:1-882417-06-2, 1994.

26. Federal Emergency Management Agency, Handbook of Chemical Hazards Analysis Procedures, 1989.

27. American Conference of Government Industrial Hygienists, Guide to Occupational Exposures Values-1993, ISBN:1-882417-07-0, 1994.

28. WCAP 14312, Hazard and Operability Study for CH TRU Waste Handling System, Waste Isolation Pilot Plant, Westinghouse Waste Isolation Division, April, 1995.

29. WIPP-DOE-069, Rev. 5, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, April 1996.

30. DOE/CAO-95-1121, U.S. Department of Energy Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report (BIR), Revision 03, December 1995.

31. DOE\WIPP 87-005, Waste Drum Fire Propagation at the WIPP, April 1987.

32. EEG-45, Preliminary Investigation Into the Explosion Potential of Volatile Organic Compounds in WIPP CH-TRU Waste, Environmental Evaluation Group, New Mexico, June, 1990.

33. EEG-48, An Assessment of the Flammability Potential of Transuranic Waste, Environmental Evaluation Group, New Mexico, June, 1991.

34. DOE/WIPP-91-018, Position Paper on Flammability Concerns Associated with TRU Waste Destined for WIPP, April, 1991.

35. DOE/NS-0013, Fire, Explosion, and High-Pressure Hazards Associated with Waste Drums and Containers, DOE Office of Nuclear Safety, Safety Notice Issue No. 93-1, February, 1993.

36. CAO-94-1010, Revision 0, Transuranic Waste Characterization Quality Assurance Program Plan, U.S. Department of Energy, Carlsbad, N.M., 1995.

37. ERDA 76-21, Energy Research and Development Administration, Nuclear Air Cleaning Handbook.

38. WIPP/WID-96-2196, Rev. 0, Waste Isolation Pilot Plant TRUDOCK Crane System Analysis, September, 1996.

39. WTSD-TME-063, Probability of a Catastrophic Hoist Accident at the Waste Isolation Pilot Plant, July, 1985.

40. DOE/WID-96-2178, Rev. 0, Waste Isolation Pilot Plant Waste Hoist Brake System Analysis, July, 1996.

41. EEG-59, An Analysis of the Annual Probability of Failure of the Waste Hoist Brake System at the Waste Isolation Pilot Plant, Environmental Evaluation Group, New Mexico, November, 1995.

42. UCRL-15910, Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards, June 1990.

43. Bechtel Interoffice Memorandum, J.J. Litehiser to H.G. Taylor, DOE Order 6430.1A Review of the WIPP Site, Job No. 20585-001, September 27, 1990.

44. NUREG-0800, U.S. Nuclear Regulatory Commission. Standard Review Plan, 3.5.1.6, Aircraft Hazards, Rev 2, July, 1981.

45. SMRP No. 155, A Site-Specific Study of Wind and Tornado Probabilities at the WIPP Site in Southeast New Mexico, Department of Geophysical Sciences, T. Fujita, University of Chicago, February 1978 and its Supplement of August 1978.

46. DOE/WIPP 93-033, The Current Basis for Roof Fall Prediction at WIPP and the Preliminary Prediction for SPDV Room II, August 1993.

47. DOE/WIPP-91-023, U.S. Department of Energy, Report of the Geotechnical Panel on the Effective Life of Rooms in Panel 1, DOE/WIPP 91-023, Waste Isolation Pilot Plant, Carlsbad, NM, 1991.

48. DOE/WIPP-94-2027, Westinghouse Electric Corporation, Waste Isolation Division, 1994 Panel 1 Utilization Plan, .WIPP/WID-94-2027.

49. DOE/WIPP-96-2180, Westinghouse Geotechnical Engineering, 1996 Long-Term Ground Control Plan for the Waste Isolation Pilot Plant, WIPP/WID-95-2180, June 1996.

50. WIPP-DOE-069, Rev. 4, TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, December 1991.

51. 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes, Subpart A, Environmental Standards for Management and Storage.

52. 40 CFR 61, Environmental Protection Agency Regulations on National Emission Standards for Hazardous Air Pollutants, Subpart H, National Emission Standard for Radionuclide Emissions from Department of Energy (DOE) Facilities.

53. Working Agreement for Consultation and Cooperation, signed by the U.S. DOE and the State of New Mexico, July 1981 and subsequent revisions.

54. WP 12-9, WIPP Emergency Management Program

55. DOE/WIPP-91-005, Waste Isolation Pilot Plant RCRA Part B Permit Application, Revision 6, U.S. Department of Energy, Carlsbad, N.M.

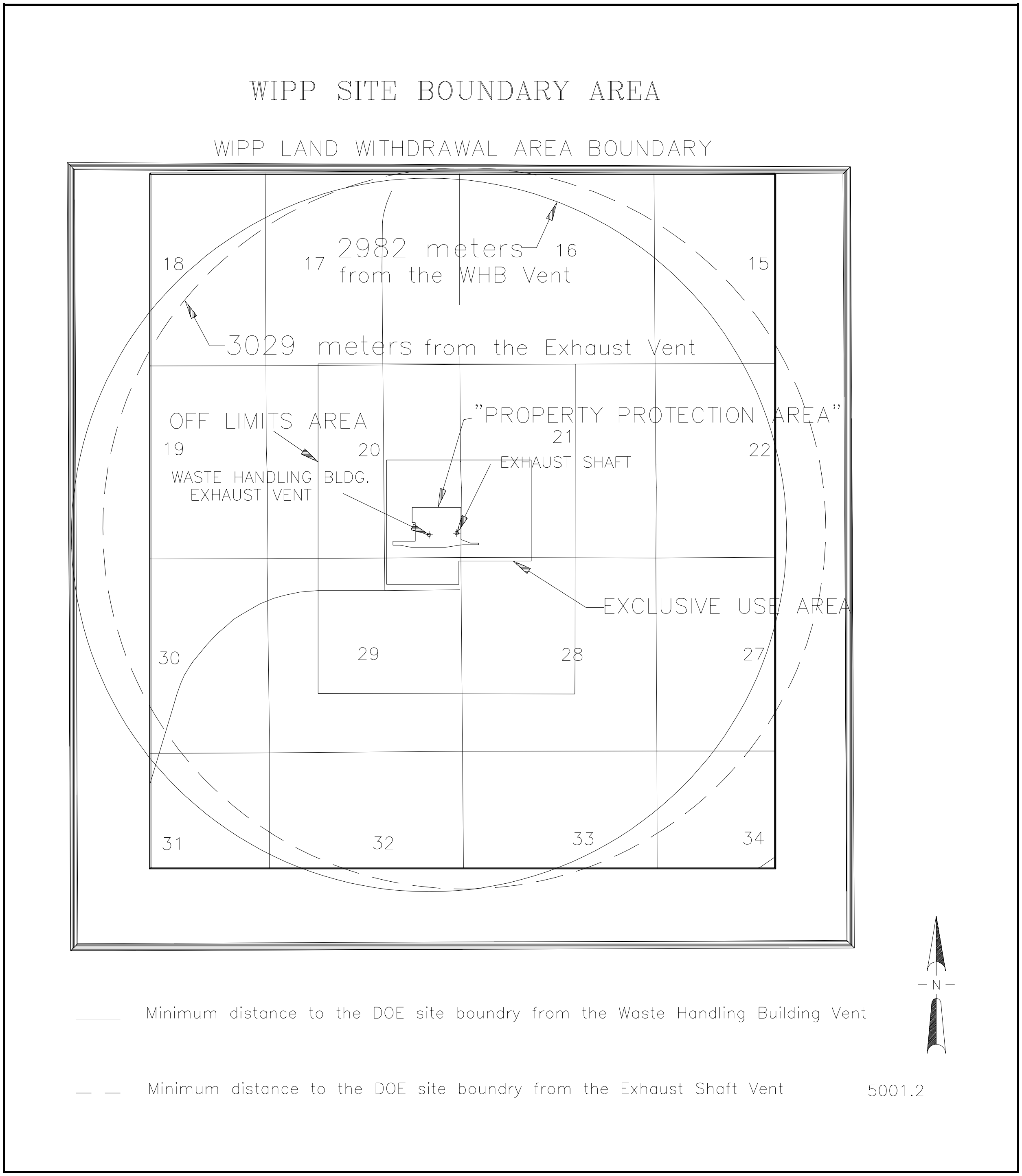

Figure 5.2-1, WIPP Site Boundary Area

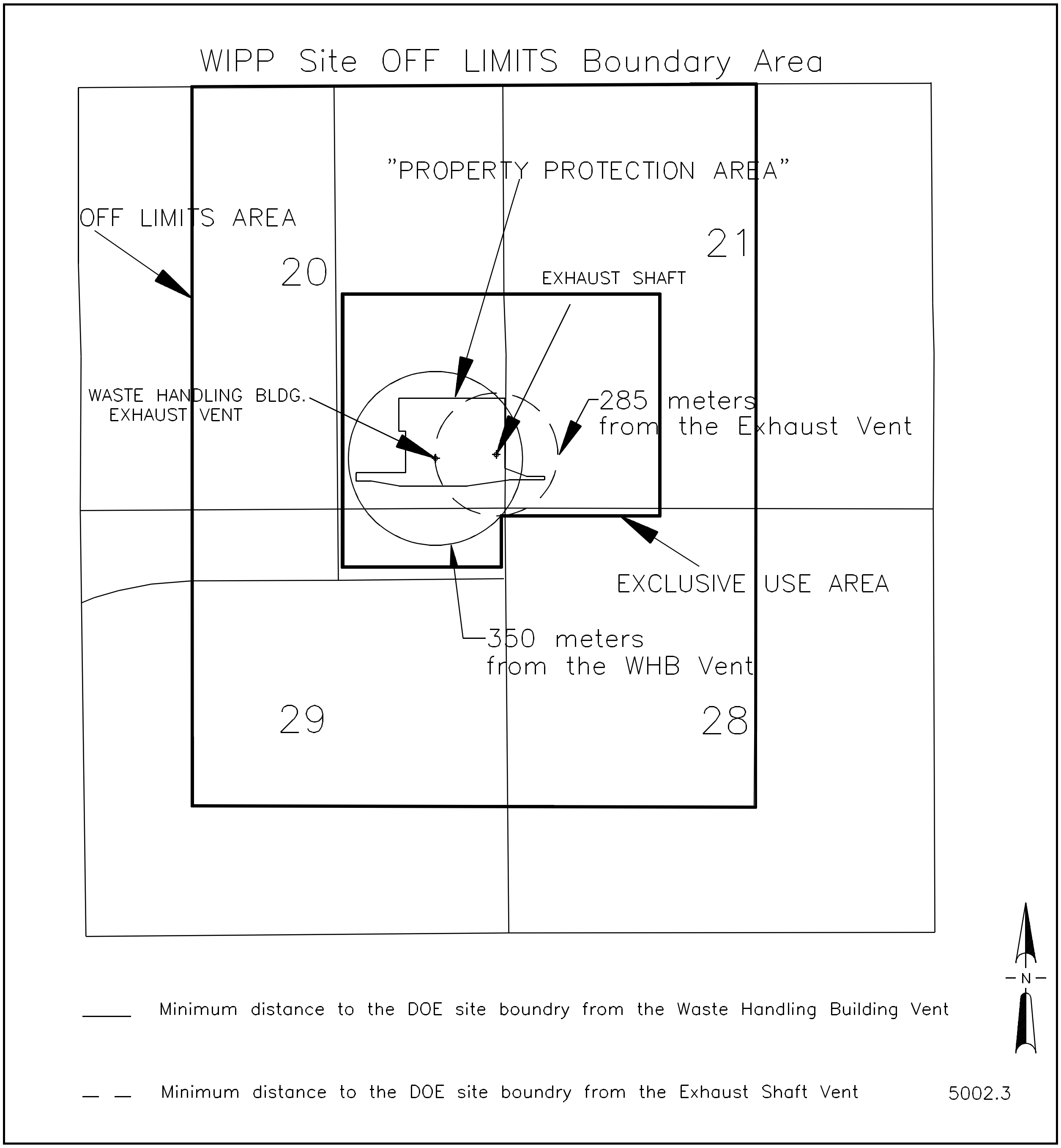

Figure 5.2-2, WIPP Site Off-Limits Boundary Area

Table 5.2-1a, MEI Risk Evaluation Guidelines

Description	Estimated Annual Frequency of Occurrence	Description	Radiological Guidelines	Nonradiological Guidelines
Normal operations	$1 \geq f\ 10^{-1}$			
Anticipated	$10^{-1} \geq f \geq 10^{-2}$	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur)	≤ 2.5 rem (25 mSv)	≤ PEL-TWA or TLV-TWA
Unlikely	$10^{-2} \geq f > 10^{-4}$	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this class include: Uniform Building Code-level earthquake, 100-year flood, maximum wind gust, etc.	≤ 6.5 rem (65 mSv)	≤ TOX-1[(1)]
Extremely Unlikely	$10^{-4} \geq f > 10^{-6}$	Accidents that will probably not occur during the life cycle of the facility.	≤ 25 rem (250 mSv)	≤ TOX-2[(2)]
Beyond Extremely Unlikely	$10^{-6} \geq f$	All other accidents.	No Guidelines	No Guidelines

(1) **TOX-1 Alternative** Guidelines
ERPG1
PEL-STEL
TLV-STEL
TLV-TWA*3

(2) **TOX-2 Alternative** Guidelines
ERPG2
EEGL (60 min.)
PEL-C
TLV-C
TLV-TWA*5

Table 5.2-1b, Noninvolved Worker Risk Evaluation Guidelines

Description	Estimated Annual Frequency of Occurrence	Description	Radiological Guidelines	Nonradiological Guidelines
Normal operations	$1 \geq f\ 10^{-1}$			
Anticipated	$10^{-1} \geq f \geq 10^{-2}$	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur)	≤ 5 rem (50 mSv)	TOX 1
Unlikely	$10^{-2} \geq f > 10^{-4}$	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this class include: Uniform Building Code-level earthquake, 100-year flood, maximum wind gust, etc.	≤ 25 rem (250 mSv)	TOX 2
Extremely Unlikely	$10^{-4} \geq f > 10^{-6}$	Accidents that will probably not occur during the life cycle of the facility.	≤ 100 rem (1 Sv)	TOX 3
Beyond Extremely Unlikely	$10^{-6} \geq f$	All other accidents.	No Guidelines	No Guidelines

(1) TOX-1 Alternative Guidelines
ERPG1
PEL-STEL
TLV-STEL
TLV-TWA*3

(2) TOX-2 Alternative Guidelines
ERPG2
EEGL (60 min.)
PEL-C
TLV-C
TLV-TWA*5

(3) TOX-3 Alternative Guidelines
EEGL (30 minute)
IDLH

Table 5.2-2, Toxicological Guidelines for Derivation of TOXs Page 1 of 2

Substance	TLV - TWA (mg/m^3)	TLV - STEL/C (mg/m^3)	PEL - TWA (mg/m^3)	PEL - STEL/C (mg/m^3)	IDLH (mg/m^3)	EEGL (mg/m^3)	ERPG 1 - 2 - 3 (mg/m^3)
Asbestos	2 f/cc	n/a	.2 f/cc	1 f/cc (30min)	n/a	n/a	n/a
Beryllium	0.002	n/a	0.002	0.005	10	n/a	1 - 0.005 2 - 25 3 - 100
Cadmium	0.002	n/a	0.005	n/a	50	n/a	n/a
Lead	0.15	n/a	0.05	n/a	700	n/a	n/a
Butyl Alcohol	n/a	152	300	150	24,640	n/a	n/a
Carbon Tetrachloride	31	63	12.6	n/a	1,917	n/a	1 - 95 2 - 159 3 - 1917
Mercury	0.025	n/a	0.05	0.1	28	.2 (24 hour)	1 - 0.15 2 - 0.2 3 - 28
Methyl Alcohol	262	328	260	310	33,250	266	1 - 266 2 - 266 3 - 532
Methylene Chloride	174	n/a	500	1,000	21,000	n/a	n/a
Chloroform	10	n/a	2	50	5,000	500	1-100 2-1,000 3-5,000
1,1,2,2-Tetrachloroethane	6.9	n/a	35	n/a	1,505	n/a	n/a
Trichloroethylene	n/a	n/a	50	200	1,000	n/a	1-100 2-500 3-1,000
Polychlorinated Biphenyl (PCB)	0.5	n/a	0.5	n/a	10	n/a	n/a

Notes to Table 5.2-2:

EEGL is a concentration of a substance in air that has been judged by the Department of Defense to be acceptable for the performance of specific tasks by military personnel during emergency conditions lasting 1 to 24 hours. EEGL dosages may produce transient central nervous system effects and eye or respiratory irritation, but nothing serious enough to prevent response to emergency conditions.

Threshold limit values (TLVs) have been defined to include various levels of exposure to worker populations. TLVs are published by the American Conference of Governmental Industrial Hygienists (ACGIHs).

TLV-TWA: Threshold limit value-Time-weighted average for a specific substance defines the limit of acceptable concentration to which most workers can be exposed for up to a normal eight-hour day and a 40-hour week without adverse effect. As with other TLV values, the population that comprises the general public differs from the population defined for TLVs in that the general public includes additional groups such as children, elderly persons, and hospitalized patients.

TLV-STEL: Threshold limit value-Short-term exposure limit is a time weighted average concentration to which workers should not be exposed for longer than 15 minutes and which should not be repeated more than four times per day, with at least 60 minutes between successive exposures. Whereas the TLV-TWA is useful for chronic exposure effects, the TLV-STEL addresses effects of Short-term, high-level exposures. As with other TLV values, the population that comprises the general public differs from the population defined for TLVs in that the general population includes additional groups such as children, elderly persons, and hospitalized patients.

Table 5.2-2, Toxicological Guidelines for Derivation of TOXs Page 2 of 2

TLV-C: Threshold Limit Value-Ceiling is the concentration in air that should not be exceeded during any part of the working exposure, for the work population. Ceiling limits may be used with other TLVs or independently. As for other TLV values, the population that comprises the general public differs from the working population since it includes additional groups such as children, elderly persons, and hospitalized patients.

PELs have been developed by the Occupational Safety and Health Administration (OSHA) as a measure for safe and healthful working conditions for men and women employed in any business engaged in commerce in the United States. As with other exposure limits developed for industrial applications, limitations exist with respect to applicability to the general population. PEL is an exposure limit established by OSHA. PEL-C is the concentration that shall not be exceeded during any part of the workday exposure.

SPEGL-Short-term Public Emergency Guidance Level is an acceptable ceiling concentration for a single, unpredicted short-term exposure to the public. The exposure period is usually calculated to be one hour or less and never more than 24 hours. Five SPEGLs have been developed by the USNRC Committee on Toxicology and are generally set at between 0.1 and 0.5 of EEGL values.

IDLH levels have been developed to define concentrations of materials from which workers should evacuate within 30 minutes without escape-impairing symptoms or any irreversible health effect. As IDLH values were developed by the National Institute for Occupational Safety & Health (NIOSH) for industrial application, their usefulness for application to the general population is limited. IDLH is a NIOSH definition.

ERPGs are published by the AIHA These are intended to provide airborne concentration levels to which most individuals (in a community) could be exposed for periods up to one hour without experiencing adverse effects as defined by the ERPG level. These guidelines are intended for emergency response applications. ERPG designations are:

ERPG-3: The maximum airborne concentration below which, it is believed, nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

ERPG-2: The maximum airborne concentration below which, it is believed, nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible adverse health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-1: The maximum airborne concentration to which nearly all individuals could be exposed for up to one hour without experiencing or developing health effects (i.e., more severe than sensory perception or mild irritation, if relevant).

a. There is no IDLH identified for asbestos. TLV for asbestos is set by the number of asbestos fibers. The TLV-TWA (per OSHA permissible exposure limits) is 0.2 fibers longer than 5 micrometers and with a length to diameter ratio of at least 3:1.

b. Conversion to fibers/cc and calculation of fraction of TLV: The asbestos release is assumed to be chrysotile, the most common form of asbestos. The density of chrysotile is 1.55 gm/cc (or 1.55E+09 mg/m^3). Fibers of respirable size would be approximately 10 microns long by 3.3 microns in diameter. Using the expression that volume equals (π/4)x(diameter squared) x (length), the volume of a fiber is then 8.5E-17 m^3. The volume multiplied by the density gives the mass as 1.3E-07 mg per fiber. Using the concentration in mg/m^3 at each receptor and converting to fibers/cc will allow a comparison of the asbestos released to the appropriate TLV.

   Fibers/cc = (Asbestos concentration mg/m^3)(1 fiber/1.3 x 10^{-7}mg)($1m^3$/1.0 x 10^6cc)

c. C denotes ceiling value.

$1mg/m^3$ * 1.6E7 = $1lb/ft^3$

Table 5.2-3a, Summary of Noninvolved Worker and MEI Estimated Radiological Dose and Comparison to Guidelines[1] Page 1 of 1

Accident	No-mitigation Release Freq/yr[2]	Noninvolved Worker /MEI Guidelines (rem)	Type of Release	Receptor Dose (CEDE-rem)			Receptor Dose % of Guidelines [(Dose/Guidelines)*100]		
				On-site (Noninvolved Worker)	Exclusive Use Area Boundary (MEI)	Site Boundary	On-site (Noninvolved Worker)	Exclusive Use Area Boundary (MEI)	Site Boundary
CH2 Crane Failure in WHB	Extremely Unlikely	100/25	Drums/mitigated	2.7E-06	3.1E-07	2.1E-08	<1%	<1%	<1%
			Drums/no-mitigation	2.7E+00	3.1E-01	2.1E-02	2.7%	1.2%	<1%
			SWBs/mitigated	1.1E-06	1.3E-07	8.5E-09	<1%	<1%	<1%
			SWBs/no-mitigation	1.1E+00	1.3E-01	8.5E-03	1.1%	<1%	<1%
CH3 Puncture in WHB	Extremely Unlikely	100/25	Drums/mitigated	3.8E-06	4.4E-07	3.0E-08	<1%	<1%	<1%
			Drums/no-mitigation	3.8E+00	4.4E-01	3.0E-02	3.8%	1.8%	<1%
			SWBs/mitigated	1.3E-06	1.6E-07	1.1E-08	<1%	<1%	<1%
			SWBs/no-mitigation	1.3E+00	1.6E-01	1.1E-02	1.3%	<1%	<1%
CH4 Drop in WHB	Extremely Unlikely	100/25	Drums/mitigated	8.6E-07	1.0E-07	6.8E-09	<1%	<1%	<1%
			Drums/no-mitigation	8.6E-01	1.0E-01	6.8E-03	<1%	<1%	<1%
			SWBs/mitigated	1.3E-07	1.6E-08	1.1E-09	<1%	<1%	<1%
			SWBs/no-mitigation	1.3E-01	1.6E-02	1.1E-03	<1%	<1%	<1%
CH9 Drop in U/G	Extremely Unlikely	100/25	Drums/mitigated	2.7E-06	4.4E-07	2.1E-08	<1%	<1%	<1%
			Drums/no-mitigation	2.7E+00	4.4E-01	2.1E-02	2.7%	1.8%	<1%
			SWBs/mitigated	1.1E-06	1.8E-07	8.4E-09	<1%	<1%	<1%
			SWBs/no-mitigation	1.1E+00	1.8E-01	8.4E-03	1.1%	<1%	<1%

Notes: (1) Listed accidents are those whose no-mitigation frequency, as derived in Appendix D, is $>10^{-6}$/yr. The consequences of beyond extremely unlikely accidents may be found in the respective accident scenario.

(2) The no-mitigation release frequency is as derived from the event tree (Appendix D) and includes: (a) the likelihood of the initiating event, (b) the conditional likelihood of waste container damage/failure as derived from test data, and (c) the conditional likelihood of the worst-case CI from Table A-5 of Appendix A.

1 REM = .01 Sv **1mg/m^3 * 1.6E7 = 1lb/ft^3**

Table 5.2-3b, Summary of Immediate Worker Estimated Radiological Dose and Comparison to Guidelines[1] **Page 1 of 1**

Accident	No-Mitigation Release Freq/yr[2]	Type of Release	Noninvolved Worker Guidelines (rem)	Receptor Dose (CEDE-rem)	Receptor Dose % of Guidelines
CH2 Crane Failure in WHB	Extremely Unlikely	Drums/no-mitigation	100	1.1E+01	11.0%
		SWBs/no-mitigation	100	4.5E+00	4.5%
CH3 Puncture in WHB	Extremely Unlikely	Drums/no-mitigation	100	3.2E+01	32.0%
		SWBs/no-mitigation	100	1.1E+01	11.0%
CH4 Drop in WHB	Extremely Unlikely	Drums/no-mitigation	100	3.6E+00	3.6%
		SWBs/no-mitigation	100	5.6E-01	<1.0%
CH9 Drop in U/G	Extremely Unlikely	Drums/no-mitigation	100	2.2E+01	22.0%
		SWBs/no-mitigation	100	8.8E+00	8.8%

Notes: (1) Listed accidents are those whose no-mitigation frequency, as derived in Appendix D, is $>10^{-6}$/yr. The consequences of beyond extremely unlikely accidents may be found in the respective accident scenario.

(2) The no-mitigation release frequency is as derived from the event tree (Appendix D) for the associated scenario, and includes: (a) the likelihood of the initiating event, (b) the conditional likelihood of waste container damage/failure as derived from test data, and (c) the conditional likelihood of the worst-case CI from Table A-5 of Appendix A.

1 REM = .01 Sv

Table 5.2-4a, Summary of Noninvolved Worker and MEI Estimated Nonradiological Concentrations and Comparison to Guidelines

Accident	No-mitigation Release Freq./yr	Type of Release	Compound	Concentrations (mg/m3)			% of Guidelines	% of Guidelines
				Noninvolved Worker Area	Exclusive Use Area	Noninvolved Worker/MEI Guidelines (mg/m^3) (Table 5.2-2)	Noninvolved Worker Area	Exclusive Use Area
CH2 Crane Failure in WHB	Unlikely	Drums/no-mitigation	Methylene Chloride	7.3E+00	8.6E-01	21,000/870	<1.0%	<1.0%
			Carbon Tetrachloride	1.4E+01	1.6E+00	1,917/63	<1.0%	2.50%
			Chloroform	7.10E-01	8.3E-02	5,000/50	< 1.0%	<1.0%
			1,1,2,2-Tetrachloroethane	3.70E-01	4.34E-02	1,505/35	<1.0%	<1.0%
		SWBs/no-mitigation	Methylene Chloride	4.2E+00	4.9E-01	21,000/870	<1.0%	<1.0%
			Chloroform	4.1E-01	4.7E-02	5,000/50	<1.0%	<1.0%
			1,1,2,2-Tetrachloroethane	2.12E-01	2.5E-02	1,505/35	<1.0%	<1.0%
			Carbon Tetrachloride	7.7E+00	9.0E-01	1,917/63	<1.0%	1.40%
CH3 Puncture in WHB	Unlikely	Drums/no-mitigation	Methylene Chloride	4.2E+00	4.9E-01	21,000/870	<1.0%	<1.0%
			Carbon Tetrachloride	7.8E+00	9.0E-01	1,917/63	<1.0%	1.40%
			Chloroform	4.10E-01	4.7E-02	5,000/50	<1.0%	<1.0%
			1,1,2,2-Tetrachloroethane	2.10E-01	2.5E-02	1,505/35	<1.0%	<1.0%

Table 5.2-4a, Summary of Noninvolved Worker and MEI Estimated Nonradiological Concentrations and Comparison to Guidelines

Accident	No-mitigation Release Freq./yr	Type of Release	Compound	Concentrations (mg/m3)			% of Guidelines	% of Guidelines
				Noninvolved Worker Area	Exclusive Use Area	Noninvolved Worker/MEI Guidelines (mg/m^3) (Table 5.2-2)	Noninvolved Worker Area	Exclusive Use Area
		SWBs/no-mitigation	Methylene Chloride	8.4E+00	9.8E-01	21,000/870	<1.0%	<1.0%
			Chloroform	8.1E-01	9.5E-02	5,000/50	<1.0%	<1.0%
			1,1,2,2-Tetrachloroethane	4.2E-01	4.9E-02	1,505/35	<1.0%	< 1.0%
			Carbon Tetrachloride	1.6E+01	1.8E+00	1,917/63	<1.0%	2.9%
CH4 Drop in WHB	Unlikely	Consequences same as CH3	-	-	-	-	-	-
CH9 Drop in U/G	Unlikely	Drums/no-mitigation	Methylene Chloride	7.3E+00	1.2E+00	21,000/870	<1.0%	<1.0%
			Chloroform	7.1E-01	1.2E-01	5,000/50	<1.0%	<1.0%
			1,1,2,2-Tetrachloroethane	3.7E-01	6.1E-02	1,505/35	<1.0%	<1.0%
			Carbon Tetrachloride	1.36E+01	2.2E+00	1,917/63	<1.0%	3.5%
		SWBs/no-mitigation	Methylene Chloride	4.2E+00	6.9E-01	21,000/870	<1.0%	<1.0%
			Chloroform	4.1E-01	6.7E-02	5,000/50	<1.0%	<1.0%
			1,1,2,2-Tetrachloroethane	2.1E-01	3.5E-02	1,505/35	<1.0%	<1.0%
			Carbon Tetrachloride	7.7E+00	1.3E+00	1,917/63	<1.0%	2.1%

NOTE: No credit is taken for mitigation of solid, liquid chemicals or VOCs by HEPA filtration.

1mg/m^3 * 1.6E7 = 1lb/ft^3

Table 5.2-4b, Summary of Immediate Worker Estimated Nonradiological Dose and Comparison to Guidelines Page 1 of 1

Accident	No-mitigation Freq/yr	Compound	Noninvolved Worker Guidelines (mg/m^3)	Drum Concentration (mg/m^3)	Drum % 0f Guidelines	SWB Concentration (mg/m^3)	SWB % of Guidelines
CH2	Unlikely	Methylene Chloride	21,000	5.49E+00	<1.0%	3.14E+00	<1.0%
		Chloroform	5,000	5.30E-01	<1.0%	3.03E-01	<1.0%
		Carbon Tet	1,917	1.01E+01	<1.0%	5.79E+00	<1.0%
		1,1,2,2-Tetrachlor.	1,505	2.78E-01	<1.0%	1.58E-01	<1.0%
CH3 Puncture in WHB	Unlikely	Methylene Chloride	21,000	3.14E+00	<1.0%	6.27E+00	<1.0%
		Chloroform	5,000	3.03E-01	<1.0%	6.06E-01	<1.0%
		Carbon Tet	1,917	5.79E+00	<1.0%	1.16E+01	<1.0%
		1,1,2,2-Tetrachlor.	1,505	1.59E-01	<1.0%	3.16E-01	<1.0%
CH4	Unlikely	Same as CH3		Same as CH3		Same as CH3	
CH9	Unlikely	Methylene Chloride	21,000	5.99E+01	<1.0%	3.42E+01	<1.0%
		Chloroform	5,000	5.78E+00	<1.0%	3.30E+00	<1.0%
		Carbon Tet	1,917	1.11E+02	5.8%	6.31E+01	3.3%
		1,1,2,2-Tetrachlor.	1,505	3.03E+00	<1.0%	1.73E+00	<1.0%

1mg/m^3 * 1.6E7 = 1lb/ft^3

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5.3 Remote Handled (RH) Transuranic (TRU) Hazard Analysis

TBD

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5.4 RH TRU Accident Analysis

TBD

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5.5 Long-Term Waste Isolation Assessment

Applicable regulations require the DOE to demonstrate the ability of the WIPP repository to isolate TRU wastes for a 10,000-year period (40 CFR 191[1]). To evaluate the long-term performance of the disposal system, the DOE uses a technique developed especially for predicting the behavior of geologic repositories over the thousands of years required for waste isolation. This technique is performance assessment. Performance assessment is a multi disciplinary, iterative, analytical process that begins by using available information that characterizes the waste and the disposal system (the design of the repository, the repository seals, and the natural barriers provided by the host rock and the surrounding formations). The DOE uses performance assessment to estimate the releases of radionuclides, based on the probabilities of these relevant features, events, and processes (FEPs) occurring. Sensitivity analyses are used by the DOE to determine which characteristics of the disposal system exert the greatest effect on performance. The results of performance assessment are used by the DOE in the 40 CFR Part 191 compliance program to assess the disposal system's behavior and the possible environmental releases.

The DOE's methodology for performance assessment uses relevant information about the disposal system and the waste to simulate performance over the regulatory time periods. This process is schematically represented by the flow diagram in Figure 5.5-1, which shows how information describing the disposal system is used by the DOE to develop scenarios, scenario probabilities, and the consequence models used to estimate performance. The WIPP performance assessment methodology has been reviewed by the NAS, the EEG, and experts in and outside the United States. Initially, the DOE used the process in Figure 5.5-1 with a feedback line from the Uncertainty Analysis block to the System Description block. In this way, the DOE used performance assessment to identify important parameters and the programs needed to better define the parameters and to obtain relevant information.

Uncertainty and how it is handled in the analysis plays a major role in the formulation of a performance assessment strategy. The EPA anticipates that uncertainty in long-term predictions will be inevitable and substantial (see 40 CFR § 191.13(b)). Because of this, the Agency applies a reasonableness test to the outcome of performance assessments. In other words, the uncertainty that is inherent in modeling the behavior of natural and engineered system is such that there is likely no single correct set of models and assumptions. Instead, there are those models and assumptions that lead to a "reasonable expectation" that compliance will be achieved.

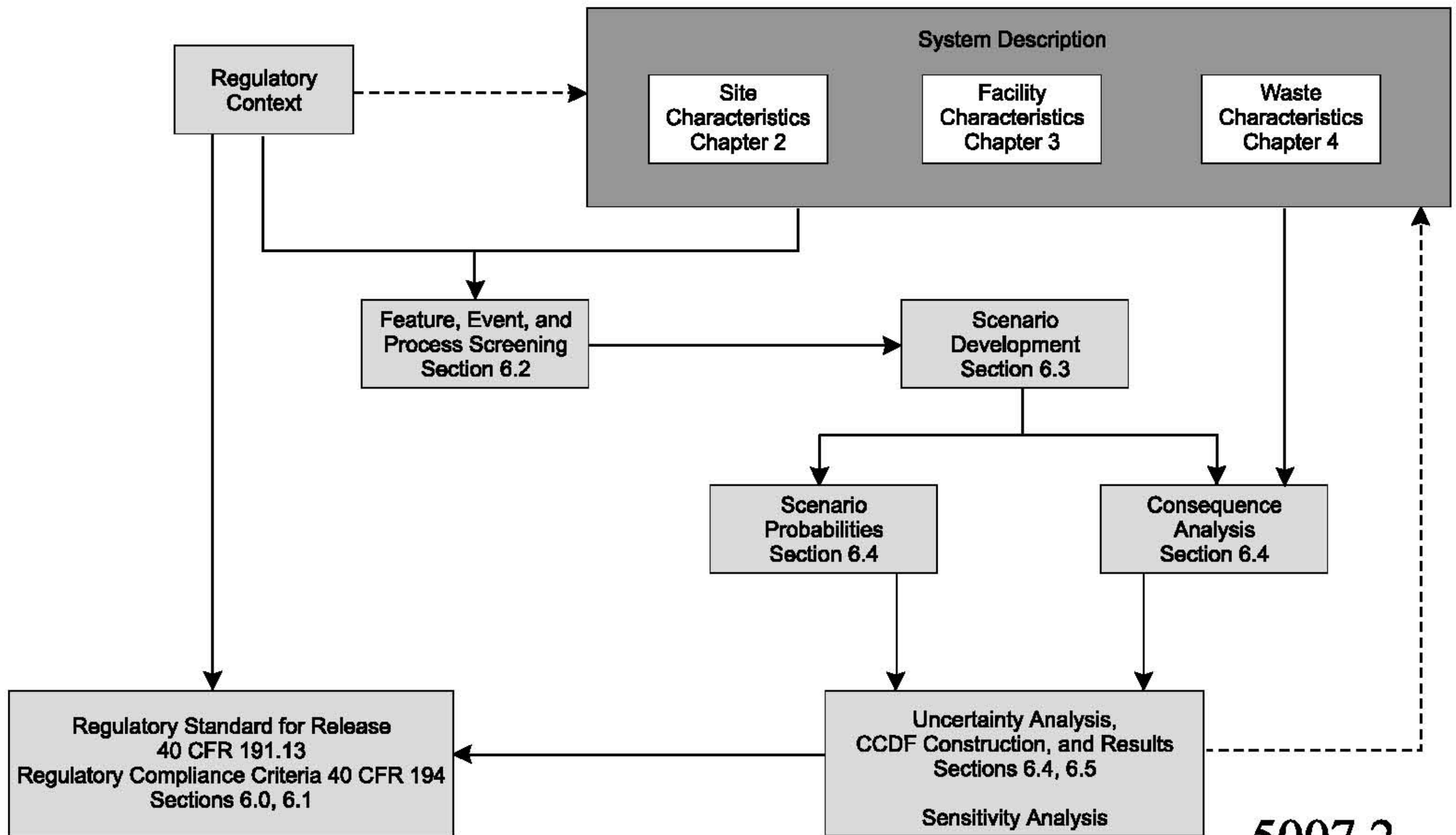
The DOE has addressed uncertainty associated with the WIPP disposal system through careful site, facility, and waste characterization. Uncertainty remaining after these characterizations is incorporated into the performance assessment through the use of reasonable assumptions about models and parameter distributions.

In general, the DOE has not attempted to bias the performance assessment toward a conservative outcome. The mean complimentary cumulative distribution function (CCDF) represents a best estimate of the expected, and in the case of human intrusion, prescribed performance of the disposal system. However, where realistic approaches to incorporating uncertainty are unavailable or impractical, and where the impact of the uncertainty on performance is small, the DOE has chosen to simplify the analysis by implementing conservative assumptions. The conservatism in the analysis does not significantly affect the location of the mean CCDF in Figure 5.5-2 (DOE/CAO-1996-2184, Title 40 CFR Part 191, Compliance Certification Application for the Waste Isolation Pilot Plant, October 1996[2]).

References for Section 5.5

1. 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes, Subpart A, Environmental Standards for Management and Storage.

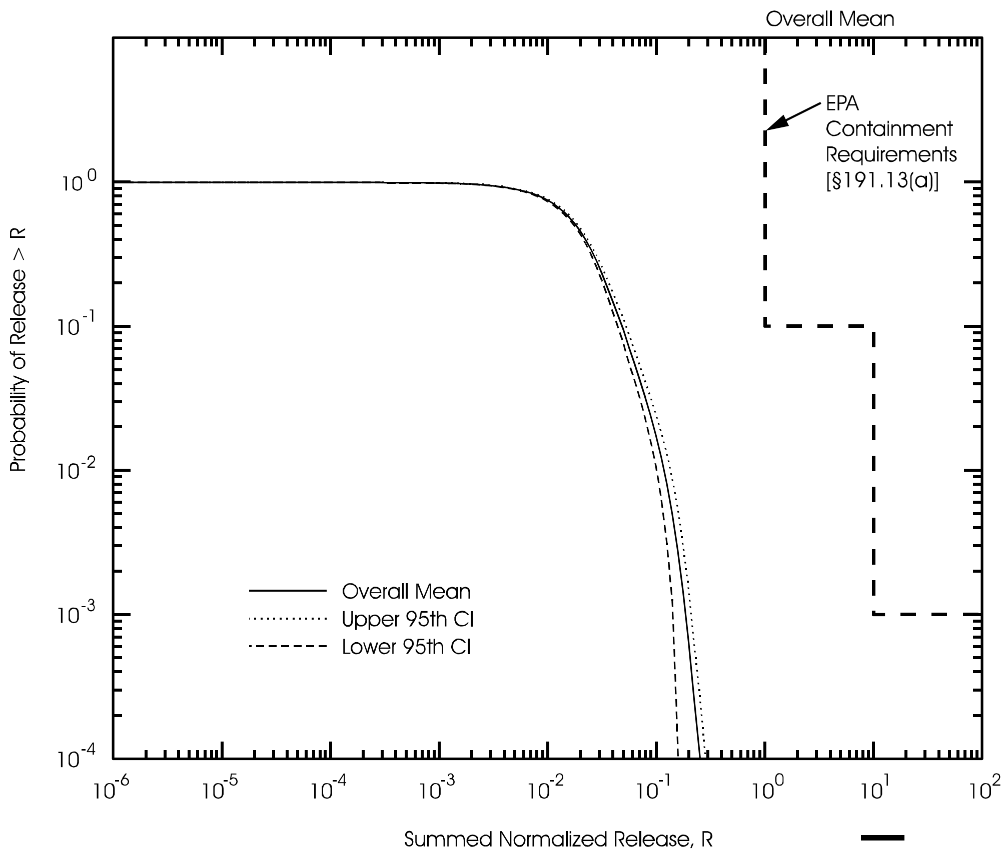
2. DOE/CAO-1996-2184, Title 40 CFR Part 191, Compliance Certification Application for the Waste Isolation Pilot Plant, October 1996.



5007.2

Note: Solid lines indicate those relationships most relevant to this application.
Section numbers in this figure refer to sections in the CCA.

Figure 5.5-1 Methodology for Performance Assessment for the WIPP



Fugure 5.5-2 Final WIPP CCDF

5.6 Conclusions

The analyses in this chapter provide a detailed review of the potential hazards associated with CH TRU waste handling operations. The methodologies used in this process included a qualitative hazard analysis and a quantitative evaluation of the potential consequences of postulated accidents. The hazard analysis process indicated that eleven potential accident scenarios required further review and quantitative evaluation. Based on bounding container inventory and release estimates, the calculated accident consequences were compared to accident risk evaluation guidelines for the public and found to be significantly below the guidelines.

Additionally, (1) the analysis indicated safety class or safety significant SSCs are not required for the WIPP to mitigate any accident radiological and nonradiological consequence to below risk evaluation guidelines, and (2) per the discussion in Section 4.4.1, secondary confinement is not required. SSCs while not required to prevent or to mitigate the consequences of an accident from exceeding the risk evaluation guidelines support the WIPP defense-in-depth philosophy.

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