WIPP
SAFETY ANALYSIS CALCULATION

Title:	**Calculation Number:**
Waste Isolation Pilot Plant (WIPP) Accident Analysis (AA) Calculations For Events Involving Releases From the Gamma Shielded Container	WIPP-031

Purpose and Objective:

The WIPP DSA, including both the contact-handled (CH) and remote-handled (RH) transuranic (TRU) waste processes, has been developed. As part of that analysis, a comprehensive AA was performed to assess the Total Effective Dose (TED) incurred by the Maximally Exposed Offsite Individual (MOI). This document addresses the TED incurred from a subset of events that result in a release from the gamma shielded container using the methodologies outlined in U.S. Department of Energy (DOE) Standard 5506 (DOE-STD-5506-2007 [DOE 2007]) to meet the requirements of DOE Standard 3009 Change Notice 3 (DOE-STD-3009-94 [DOE 2006]).

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	Name (printed)	Signature/Date
Calculation Author	T.C. Campbell	2/17/10
Independent Reviewer	Nicole Brown	2/18/10
Nuclear Safety Manager	J.A. McCormick	2-18-10

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Independent Review Checklist

Yes	No	N/A*	Checklist Item
✓			Previous reviews complete and outstanding comments resolved up to scope of this review.
✓			Problem completely defined.
✓			Accident scenarios developed in a clear and logical manner.
✓			Necessary assumptions explicitly stated and supported.
✓			Computer codes and data files used in the analysis documented.
✓			Data checked for consistency with original source information as applicable.
✓			Mathematical derivations checked including consistency of results.
✓			Models were appropriately used within their range of validity or used outside of their range with justification.
✓			Hand calculations or spreadsheet results checked for errors.
✓			Software input correct and consistent with document reviewed.
✓			Software output consistent with input and with results reported in document reviewed.
✓			Limits/criteria/guidelines applied to analysis results are appropriate and referenced.
✓			Safety margins consistent with good engineering practices.
✓			Conclusions consistent with calculated results and applicable limits/criteria/guidelines.
✓			Results and conclusions address all points required in defined problem statement.
✓			Format consistent with applicable guides or other standards.
	✓†		Review calculations, comments, and /or notes are attached.

* Not Applicable

Independent Reviewer: _____ 2/18/10
Nicole Brown Date

† Avaible upon request

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1.0 Introduction

The Waste Isolation Pilot Plant (WIPP) Documented Safety Analysis (DSA), including both the contact-handled (CH) and remote-handled (RH) transuranic (TRU) waste processes, has been developed. As part of that analysis, a comprehensive Accident Analysis (AA) was performed to assess the Total Effective Dose (TED) incurred by the Maximally Exposed Offsite-Individual (MOI). This document addresses the TED incurred from a subset of postulated events that result in a release from the gamma shielded container (GSC) using the methodologies outlined in U.S. Department of Energy (DOE) Standard 5506 (DOE-STD-5506-2007 [DOE 2007]) to meet the requirements of DOE Standard 3009 Change Notice 3 (DOE-STD-3009-94 [DOE 2006]). DOE-STD-3009-94 does not address quantitative analysis of on-site worker doses either inside or outside the facility. However, DOE-STD-5506-2007 does include the option for quantitative analysis of the on-site worker outside the facility (located at 100 m from the release location) for the determination of risk ranking. Therefore, the TED incurred by the on-site worker at 100 m is included in the AA for completeness. This analysis is based on the analyses previously done in WIPP-001, R1 (McCormick 2008), WIPP-017, R0 (East, 2008a), WIPP-018, R0 (East 2008b), and WIPP-019, R0 (East 2008c).

The TED values will be compared to the consequence level criteria in DOE-STD-5506-2007 (DOE 2007) for classification (see Table 1-1). Events with postulated doses incurred by the public (MOI) of 10 rem or greater may be further analyzed in the WIPP DSA as mitigated events to reduce the postulated doses. Events with a postulated public dose of less than 10 rem may also be further analyzed in the WIPP DSA as mitigated events if those events have been determined in the Hazard Analysis (HA) to have an unacceptable or marginally acceptable risk ranking (Risk Class I or II) as defined in DOE-STD-5506-2007.

Table 1-1, *DOE-STD-5506-2007 Consequence Level Criteria*

Consequence Level	On-site Worker at 100 m (rem)	MOI (rem)
High	> 100 rem	> 10 rem*
Moderate	≥ 25 rem, ≤ 100 rem	≥ 1 rem, ≤ 10 rem
Low	< 25 rem	< 1 rem

* - Events with MOI doses greater than 10 rem are specified within DOE-STD-5506-2007 as challenging of the 25 rem DOE-STD-3009-94 evaluation guide line when the dose was calculated with the methodology outlined within DOE-STD-5506-2007.

2.0 Analysis Method

For a postulated accident event the TED incurred by either the on-site worker, commonly referred to as collocated worker (CW) by DOE Standards and regulations, or the MOI is calculated by multiplying the source term (ST) or amount of plutonium-239 equivalent curies (PE-Ci) being released into the atmosphere by the unit dose per activity incurred by the receptor of interest as shown in the following:

$$D_i = ST \times TED_i \quad (1)$$

where: D_i = TED incurred by receptor i (rem)

ST = ST for event of interest (PE-Ci)

TED_i = Receptor i unit dose per activity (rem/PE-Ci)

The unit TED per PE-Ci incurred by the on-site worker at 100 m and the MOI have been calculated in another document (East 2008). This document will focus on the calculation of the individual Source Terms (STs) and their associated inputs and assumptions. DOE-STD-5506-2007 (DOE 2007) lists a number of uncertainties associated with the calculation of the ST and the resultant on-site worker (at 100 m from release location) and MOI doses. These will not be reiterated in this document.

2.1 General Source Term Analysis

In general, the ST is calculated using the five factor formula outlined in DOE-STD-5506-2007 as taken from the DOE Handbook 3010 (DOE-HDBK-3010-94) (DOE 1994). Complex postulated accident scenarios (e.g., tine puncture with collision) may employ multiple five factor formula calculations that are added together to get the ST for the event, which results in the following equation:

$$ST = \Sigma (MAR_j \times DR_j \times ARF_j \times RF_j \times LPF_j) \quad (2)$$

where: MAR_j = Material at Risk for scenario j (PE-Ci)

DR_j = Damage Ratio for scenario j

ARF_j = Airborne Release Fraction for scenario j

RF_j = Respirable Fraction for scenario j

LPF_j = Leak Path Factor for scenario j

The first two parameters are directly related to the specification of the inventory. The Material at Risk (MAR) is the amount of radioactive material available to be acted upon by a given physical stress. The Damage Ratio (DR) is the fraction of MAR that is actually acted upon by the physical stress. From these definitions, a degree of interdependence exists between the definitions of the MAR and DR as various combinations of MAR and DR values can be used to define the same product value. For the postulated AA within this document, the MAR is expressed as a product of the number of containers of TRU waste (hereafter referred to as waste containers) and/or waste container assemblies involved in the postulated event and the maximum activity associated with the waste container/waste container assembly.

The Airborne Release Fraction (ARF) is the coefficient used to estimate the amount of material that can be suspended in the atmosphere and made available for airborne transport under the specific set of induced physical stresses. The respirable (RF) is the fraction of airborne radionuclides (as particles) that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10 microns aerodynamic equivalent diameter and less. Within DOE-STD-5506-2007 (DOE 2007), the ARF and RF terms are specified as a single term ARF*RF. Additionally, an effective ARF*RF may be calculated for complex STs.

The Leak Path Factor (LPF) is the fraction of the radionuclides made airborne that challenge the interface of the facility and ambient environment (i.e., these radionuclides do not get filtered nor deposited inside the facility as result of natural mechanisms).

2.2 Postulated Event Source Term Analysis

In order for the gamma shielded container to be adopted as a WIPP compliant container for disposition of TRU waste it must be analyzed in the AA for the WIPP DSA. The gamma shielded container is in essence two containers in one. The inner container is a 30 gallon steel drum, similar to the Type A CH drums utilized throughout WIPP. Surrounding this inner container is a robust outer container comprised of 1 inch of lead shielding contained between the 7-gauge inner shell, and 11-gauge outer shell. The outer shells are connected to an upper flange with a bolted lid and a 3-inch thick solid steel bottom. The shielded container has a similar configuration to that of a 55-gal Type A drum with an SWB overpack. Because of this similarity in configuration, the damage ratios provided for overpacked containers in DOE-STD-5506-2007 (DOE 2007) are considered bounding for the shielded container for events involving mechanical insults. In *Fire Analysis of the Shielded Container for the Waste Isolation Pilot Plant* (Sprankle 2009), it was determined that shielded containers are not susceptible to damage and release due to short duration engulfing fires. Long duration engulfing fires, and severe exposure fires, which includes the burning solids portion of postulated vehicle fires, could cause a release due to the uneven heating, melting, and expansion of the lead liner.

Even though the shielded containers are susceptible to a release due to severe exposure fires, the low combined DR and ARF x RF (6.1E-8) associated with this container type (Sprankle 2009), as compared to a DR of 0.5 and ARF x RF of 5.0E-04 (combined DR and ARF x RF, 2.5E-4) for direct loaded TRU drums exposed to a severe exposure fire (DOE, 2007), indicates that on a per container basis the consequences for a direct loaded TRU drum will bound the consequences for a shielded container. For fires, 55 gal TRU drums currently result in the highest consequence. The shielded container was compared to the 55 gal TRU drum to ensure that there is no increase in consequence beyond what is already analyzed in the WIPP DSA. In addition, the configuration for the shielded containers has smaller numbers (i.e., three shielded containers/ waste assembly compared to seven 55 gal TRU drums/ waste assembly). Because the MAR for the shielded container is identical to that of a 55 gal TRU drum, and the other factors listed prior, it is determined that the consequences for 55 gal TRU drums bound the consequences for

shielded containers for exposure fires. Due to this qualitative determination, it was decided that instead of analyzing the shielded container in all events for which the shielded container could be affected, or experience a release of radiological material, a subset of the worst case accident scenarios would be analyzed with the shielded container as the container of concern. This subset of postulated events is carried forth from analyses WIPP-001 (McCormick 2008), WIPP-017 (East 2008a), WIPP-018 (East 2008b), and WIPP-019 (East 2008c) and is analyzed for consequence determination with shielded containers. A complete accident analysis will be completed, which will include the shielded container, during the next DSA update.

Even though the shielded containers are able to be affected by fire and mechanical insults, a criticality involving the TRU waste at WIPP during waste handling or disposal has been determined to be an incredible event *Nuclear Criticality Safety Evaluation for Contact-Handled Transuranic Waste at the Waste Isolation Pilot Plant* [Larson 2008].

3.0 Input Data & Assumptions

3.1 Dose per Unit Activity

For the WIPP CH/RH DSA, the on-site worker at 100 m and the MOI (at 2.9 km) TED was calculated with the MACCS2 Code Version 1.13.1 (Chanin 1998 and Radiation Safety Information Computational Center 2006) in accordance with the methodology outlined in DOE-STD-5506-2007. The model utilizes a single curie of plutonium-239 released over a three-min period from ground-level and includes the effects of dry deposition. The resultant 95th quantile dose (TED) per unit activity values were calculated to be 680 rem/PE-Ci for the on-site worker at 100 m and 1.2 rem/PE-Ci for the MOI at 2.9 km (East 2008).

For the analyzed Natural Phenomena Hazard (NPH) events involving high winds, the MACCS2 calculated 95th quantile dose (TED) per unit activity values are reduced by a factor of 10 to account for the greater dispersion associated with these NPH events. The resultant 95th quantile dose (TED) per unit activity values are then calculated to be 68 rem/PE-Ci for the on-site worker at 100 m and 0.12 rem/PE-Ci for the MOI at 2.9 km.

3.1.1 Dose per Unit Activity Key Inputs and Assumptions

The inputs and assumptions used in the calculation of the dose (TED) per unit activity are in accordance with the methodology outlined in DOE-STD-5506-2007. No additional inputs or assumptions were employed in the calculation of the dose per unit activity that are considered key to the AA and should be considered for protection in the WIPP CH/RH DSA or its associated Technical Safety Requirements (TSRs).

3.2 Material at Risk

As noted in the Analysis Method Section, the MAR is expressed as a product of the number of waste containers or waste container assemblies involved in the postulated event and the maximum activity associated with the waste container/waste container assembly. The waste

container and waste container assembly is dependent on the type of TRU waste (CH or RH) and the form of the waste. The MAR for each individual postulated accident event is given in the event description in Section 4 of this document including any reduction in MAR due to mitigation of the event.

WIPP receives waste containers from various generators throughout the DOE complex. The waste containers are assembled by the generator in standard waste assembly configurations and placed in U.S. Department of Transportation (DOT) Type B shipping containers for Over the Road transportation to WIPP. The DOT Type B shipping containers that transport gamma shielded containers are HalfPACTs that hold one waste assembly (three gamma shielded containers).

The generator limits the radiological inventory of each individual waste container being packaged. The gamma shielded container has a radiological inventory limit of 80 PE-Ci. Once inside the WIPP Waste Handling Building (WHB), the waste containers are removed from the shipping containers and transported to the UG. The gamma shielded containers are transported to the UG on facility pallets, which are limited to two waste assemblies (in two one-tier stacks). This limit of two gamma shielded container waste assemblies is based on the load rating of the facility pallet.

The determination of TED associated with each postulated event scenario will only be analyzed for waste configurations applicable to the gamma shielded container. Additional waste configurations are analyzed in WIPP-001 (McCormick 2008), WIPP-017 (East 2008a), WIPP-018 (East 2008b), and WIPP-019 (East 2008c). The waste configuration for the gamma shielded container is as follows: The gamma shielded containers are assumed to be in a 3-pack arrangement since this configuration results in the maximum PE-Ci per waste assembly for the shielded container. Each container has a radiological inventory limit of 80 PE-Ci per container. The MAR for each of the analyzed events is taken from the original calculations and modified to reflect the container radiological inventory limit, and the waste configuration associated with the shielded container.

3.2.1 Material at Risk Key Inputs and Assumptions

The following inputs and assumptions are made in the AA with respect to the MAR used in the analysis. These inputs and assumptions are considered key to the AA and should be considered for worker and public protection in the WIPP CH/RH DSA and its associated TSRs.

MAR Assumption Number 1: The inventory of waste containers is within the limits specified in Section 3.2: Material at Risk.

This assumption is predicated on the TRU waste generator facilities shipping TRU waste to WIPP in accordance with the WIPP Waste Acceptance criteria (WAC). Since dose is directly proportional to ST, which in turn is directly proportional to waste container inventory, a waste container or waste assembly having an inventory greater than the limits specified in Section 3.2 would result in postulated on-site worker and MOI doses greater than the doses calculated for an accident event that includes a single waste container or waste assembly. For accident events that involve more than one waste assembly, a single container or assembly being out of compliance may or may not result in a higher potential dose than analyzed in the AA since this analysis is being developed as if all waste containers and waste assemblies are at their maximum allowable inventory and in their worst possible form.

MAR Assumption Number 2: The shielded container waste assemblies within the WHB CH Bay inventory are stacked one high.

This assumption is predicated on normal operational practices and limits. Normal operational practices involve unloading the HalfPACT and placing the waste assembly on a facility pallet for transport around the WHB and into the UG. The load rating for the facility pallet is such that only two waste assemblies can be supported (two one high stacks). Stacking the shielded container waste assemblies two high would exceed the load rating of the facility pallet.

3.3 Damage Ratio

Due to the nature of this calculation, and the fact that all of the events in this calculation have been incorporated from WIPP-001 (McCormick 2008), WIPP-017 (East 2008a), WIPP-018 (East 2008b), and WIPP-019 (East 2008c), the damage ratios utilized in this analysis will be the same ones that were used in the previously mentioned calculations. The damage ratios used in this analysis for mechanical insults are given in Table 3-2 of WIPP-017 (East 2008a) and are taken from DOE-STD-5506-2007 (Section 4.4.4 and Table 4.4.4-1). The damage ratios for external explosions impacting waste are given in Table 3-2 of WIPP-018 [East 2008b]. The only DRs of concern for the analysis completed in this calculation are those for the overpacked containers. This is based on the assumption stated in Section 3.3.1 that the gamma shielded container has a similar configuration, and is as robust, if not more so, as an overpacked container.

3.3.1 Damage Ratio Key Inputs and Assumptions

The inputs and assumptions that were made in the AA with respect to the DR used in the analysis are in accordance with the methodology outlined in DOE-STD-5506-2007 (DOE 2007). The following additional inputs or assumptions were employed with respect to the DR and are considered key to the AA. These assumptions should be considered for protection in the WIPP CH/RH DSA or its associated TSRs.

DR Assumption Number 1: TRU waste within the WIPP facility is in waste containers that are of sound integrity and the lids remain closed.

This assumption is predicated on the TRU waste generator facilities shipping TRU waste to WIPP in accordance with the WIPP WAC. A higher DR would be assumed if the waste containers were not of sound integrity or the lids were removed. As a result, higher on-site worker and MOI doses would be calculated for all postulated events within this document.

DR Assumption Number 2: The damage ratios provided for Overpack Containers in DOE-STD-5506-2007 are considered bounding for the shielded containers.

This assumption is based on the information in the Memorandum – Nuclear Safety Assessment of Shielded Containers in the WIPP System of Operations (McCormick 2008a). The gamma shielded container is in essence two containers in one. The inner container is a 30 gallon steel drum, similar to the Type A CH drums utilized throughout WIPP. Surrounding this inner container is a robust outer container comprised of 1 inch of lead shielding contained between the 7-gauge inner shell, and 11-gauge outer shell. The outer shells are connected to an upper flange with a bolted lid and a 3-inch thick solid steel bottom. The shielded container has a similar configuration to that of a 55-gal Type A drum with an SWB overpack. A higher DR would be assumed if the shielded container were not as robust as an overpacked container. As a result, higher on-site worker and MOI doses would be calculated for all postulated events within this document.

3.4 Airborne Release Fraction and Respirable Fraction

The Airborne Release Fraction and Respirable Fraction (ARF*RF) values that were used in the analysis of postulated events carried forth to this document were taken directly from DOE-STD-5506-2007 (DOE 2007) (Section 4.5, Table 4-5.1) and are give in Table 3-1. The values were selected based on the postulated event scenario, and waste container contents. For all events analyzed in this calculation, TRU waste is all treated as contaminated combustible solids.

Table 3-1, *ARF*RF from DOE-STD-5506-2007*

Stress	Contaminated Combustible Solid ARF*RF
Mechanical - Spill or Low Stress Impact (not reducing the volume by greater than 25%)	1E-4
Mechanical - High Stress Impact (reducing the volume by greater than 25%)	2E-3
Thermal – Unconfined burning	1E-2
Thermal – Confined burning	5E-4

3.4.1 Airborne Release Fraction and Respirable Fraction Key Inputs and Assumptions

The inputs and assumptions that were made in the AA with respect to the ARFs and RFs used in the analysis are in accordance with the methodology outlined in DOE-STD-5506-2007. There were no additional inputs or assumptions employed with respect to the ARFs or RFs that are considered key to the AA and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs.

3.5 Leak Path Factor

For the unmitigated analysis, a LPF of 1 was conservatively assumed as directed by DOE-STD-5506-2007 (Table 6.3-1).

3.5.1 Leak Path Factor Key Inputs and Assumptions

The inputs and assumptions that were made in the AA with respect to the LPFs used in the analysis are in accordance with the methodology outlined in DOE-STD-5506-2007. There were no additional inputs or assumptions employed with respect to the LPFs that are considered key to the AA and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs.

4.0 Postulated Accident Event Scenario Calculations

4.1 Event E-04C-CH/RH-WHB, Large Fire in Waste Hoist Tower results in Waste Conveyance Drop

4.1.1 Unmitigated Analysis

The combustibles in the waste hoist tower accumulate during maintenance and abnormal operational activities. The combustibles include rags, oil, lubricants, hydraulic fluids, cleaners,

and miscellaneous hazardous materials. The combustibles are subject to ignition from external sources such as, hot work, maintenance, electrical failures, or spontaneous ignition of materials.

The analyzed scenario for this event is a large combustible fire in the waste hoist tower causing a catastrophic structural failure of the hoist resulting in a waste conveyance free fall down the waste shaft.

The analyzed ST for this event involves 6 Shielded Containers. The Shielded Containers are given a DR of 1.0 with an effective ARF*RF of 2E-3 for the high energy impact. An LPF of 1 is assumed for the unmitigated analysis. The resultant source term for this postulated event is calculated as follows:

$$ST = ST_{damage} = 0.96 \text{ PE-Ci}$$

ST_{damage} = (80 PE-Ci/Shielded Container × 6 Shielded Containers × 1.0 × 2E-3 × 1) = 0.96 PE-Ci

The resultant TED incurred by the on-site worker at 100 m is 6.5E+2 rem. The resultant TED incurred by the MOI is 1.2E+0 rem. The on-site worker dose is classified as *High*, and the MOI dose is classified as *Moderate* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is not considered to exceed the DOE-STD-3009-94 evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-001 (McCormick 2008) for the bounding case.

4.1.2 Event E-04C-CH/RH-WHB Initial Conditions and Key Assumptions

The following initial conditions were employed in the analysis of Event E-04C-CH/RH-WHB accident analysis and should be considered for inclusion in the WIPP CH/RH DSA or its associated TSRs:

The waste container inventories are within the limits identified in Section 3.2

Only two waste assemblies are transported on the waste conveyance at one time.

4.2 Event E-09B-CH/RH-UG – UG Vehicle Collides with Waste Array

4.2.1 Unmitigated Analysis

The UG disposal waste array is vulnerable to vehicle impacts from vehicles emplacing waste, other waste handling equipment, electric carts, and mining equipment. The bounding event involves a CH transporter colliding into the disposal array while carrying a loaded facility pallet (two waste assemblies). The event is postulated to be a moderate impact to three columns (three waste assemblies tall) of the waste disposal array. The waste containers on the CH transporter are also assumed to experience a moderate impact.

This calculation assumes all waste containers involved are shielded containers even though they may not be stacked three high in the waste array. The ST for the event involves one facility pallet (two waste assemblies) and three waste disposal array columns (nine waste assemblies). The gamma shielded containers are assumed to not be secured to the facility pallet nor are they assumed to be secured together. The waste assemblies are assumed to be subjected to a moderate impact. The analyzed waste configuration for this event is the shielded container (80 PE-Ci per drum or 240 PE-Ci per waste assembly). The shielded container DR is 0.05 for moderate impact. The ARF*RF for this scenario is 1E-4 for spill/ low stress impact to contaminated combustible solid waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST_{impact} = (240 \text{ PE-Ci/WA} \times 11 \text{ WA} \times 0.05 \times 1E\text{-}4 \times 1) = 1.32E\text{-}2 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 9E+0 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 1.6E-2 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-017 (East 2008a) for the bounding case.

4.2.2 Event E-09B-CH/RH-UG Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-09B-CH/RH-UG (UG vehicle collides with waste array) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.
- A facility pallet holds a maximum of 2 Gamma Shielded Container (GSC) waste assemblies in a single tier array.
- A single facility pallet is transported by a single CH vehicle in the UG.
- Waste assemblies are stacked in the disposal array no more than three high.

4.3 Event E-09C-CH/RH-UG Forklift Tines Puncture Waste Containers in UG

4.3.1 Unmitigated Analysis

Waste containers are vulnerable to punctures from forklift tines during the waste disposal process. The shielded container is moved within the UG using a forklift and; therefore, has a potential for forklift tine puncture. Additionally, because of the honeycomb configuration of the waste disposal array (every other waste disposal array column protrudes a half waste assembly); the CH waste disposal array has the potential to be impacted by the CH forklift during some forklift tine puncture scenarios. Therefore, the bounding event involving a forklift tine puncture in the UG is a puncture of the CH waste containers with the forklift tines following a collision into the waste face. The event is postulated to be a moderate impact to three columns (three waste assemblies tall) of the waste disposal array and a puncture of two waste containers (one for each tine).

This calculation assumes all waste containers involved are shielded containers even though they may not be stacked three high in the waste array. The ST for the event involves three waste disposal array columns (nine waste assemblies). The waste containers are assumed to not be secured together. The waste assemblies are assumed to be subjected to a moderate impact. The analyzed waste configuration for this event is the shielded container (80 PE-Ci per drum or 240 PE-Ci per waste assembly). The shielded container DR is 0.05 for forklift tine puncture and 0.05 for moderate impact. The ARF*RF for this scenario is 1E-4 for spill/ low stress impact to contaminated combustible solid waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{impact} + ST_{puncture} = 1.08E\text{-}2 \text{ PE-Ci} + 8.0E\text{-}4 \text{ PE-Ci} = 1.16E\text{-}2 \text{ PE-Ci}$$

$$ST_{impact} = (240 \text{ PE-Ci/WA} \times 9 \text{ WA} \times 0.05 \times 1E\text{-}4 \times 1) = 1.08E\text{-}2 \text{ PE-Ci}$$

$$ST_{puncture} = (80 \text{ PE-Ci/drum} \times 2 \text{ drums} \times 0.05 \times 1E\text{-}4 \times 1) = 8.0E\text{-}4 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 7.9E+0 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 1.4E-2 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-017 (East 2008a) for the bounding case.

4.3.2 Event E-09C-CH/RH-UG Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-09C-CH/RH-UG (forklift tines puncture waste containers in UG) and should be considered for inclusion in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.
- Waste assemblies are stacked in the disposal array no more than three high.

4.4 Event E-10A-CH-WHB – Pressurized Container Impacts CH Waste Containers

4.4.1 Unmitigated Analysis

Within the WHB CH Bay, pressurized gas cylinders are used to support radiation protection and maintenance activities. These cylinders can become airborne missiles that can impact the waste containers in the CH Bay. The bounding event is postulated to be a cylinder missile hitting three drums.

This calculation assumes all waste containers involved are shielded containers. The ST for the event involves three waste containers. The waste containers are assumed to be subjected to an impact by a cylinder missile. The analyzed waste configuration for this event is the shielded container (80 PE-Ci per drum). The shielded container DR is 0.5 for a high speed crush. The ARF*RF for this scenario is 1E-4 for spill/ low stress impact to contaminated combustible solid waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST_{impact} = (80 \text{ PE-Ci/drum} \times 3 \text{ drum} \times 0.5 \times 1E\text{-}4 \times 1) = 1.2E\text{-}2 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 8.2E+0 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 1.4E-2 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See calculation WIPP-017 (East 2008a) for the bounding case.

4.4.2 Event E-10A-CH-WHB Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-10A-CH-WHB (pressurized container impacts CH waste containers) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.

4.5 Event E-10B-CH-WHB – Drop of Waste Containers in CH Bay

4.5.1 Unmitigated Analysis

Within the WHB CH Bay, there are numerous opportunities to drop waste containers. The waste containers are moved from the shipping containers by the TRUDOCK crane. The containers are moved by forklift or Automatic Guided Vehicles (AGV) throughout the CH Bay and loaded on the waste conveyance using either the conveyance car or an AGV. All these pieces of equipment can fail and result in a drop of waste containers. Additionally, a structural failure of the waste pallet stand or the waste conveyance chair could result in a container drop. The bounding event of this type is a drop of the waste containers from the TRUDOCK crane onto containers below.

The event is modeled as the full HalfPACT payload (one waste assembly) dropping from a fourth/fifth tier height (moderate stress impact) onto one waste assembly directly below. The bottom waste assembly is subjected to a vertical crush. The dropped/crushed waste containers fall and knock the adjacent six waste assemblies over (modeled as a first and second tier drop only).

This calculation assumes all waste containers involved are shielded containers. The ST for the event involves eight waste assemblies. The analyzed waste configuration for this event is the shielded container (80 PE-Ci per drum or 240 PE-Ci per waste assembly). The shielded container DR is 0.05 for a drop from the 4th tier (one waste assembly), 0.25 for a vertical crush (one waste assembly), and zero for a first/second tier drop (six waste assemblies). The ARF*RF for this scenario is 1E-4 for impact to contaminated combustible solid waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{moderate} + ST_{vertical} + ST_{1st/2nd} = 1.2E\text{-}3 \text{ PE-Ci} + 6.0E\text{-}3 \text{ PE-Ci} + 0 \text{ PE-Ci} = 7.2E\text{-}3 \text{ PE-Ci}$$

$$ST_{moderate} = (240 \text{ PE-Ci/WA} \times 1 \text{ WA} \times 0.05 \times 1E\text{-}4 \times 1) = 1.2E\text{-}3 \text{ PE-Ci}$$

$$ST_{vertical} = (240 \text{ PE-Ci/WA} \times 1 \text{ WA} \times 0.25 \times 1E\text{-}4 \times 1) = 6.0E\text{-}3 \text{ PE-Ci}$$

$$ST_{1st/2nd} = (240 \text{ PE-Ci/WA} \times 6 \text{ WA} \times 0 \times 1E\text{-}4 \times 1) = 0 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 4.9E+0 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred

by the MOI is 8.6E-3 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-017 (East 2008a) for the bounding case.

4.5.2 Event E-10B-CH-WHB Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-10B-CH-WHB (drop of waste containers in CH Bay) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.

4.6 Event E-10C-CH-WHB – Elevated Material Falls or Drops on Waste Containers

4.6.1 Unmitigated Analysis

Within the WHB CH Bay, there are numerous opportunities for objects to drop and impact waste containers. These objects include overhead equipment (ventilation ducts, sprinkler system, lights, TRUDOCK crane) and tools used in the maintenance of the equipment as well as waste containers. The bounding event of this type is a drop of the shipping container lid from the TRUDOCK crane onto waste containers below.

The event is modeled as a shipping container lid dropping onto two waste assemblies below. The lid is assumed to crush an equivalent of one waste assembly on the facility pallet below (vertical crush). The remaining waste containers on the facility pallet are knocked over (lower tier drop). The shipping lid then rolls and impacts a facility pallet (two waste assemblies) with a low stress impact.

The ST for the event involves four waste assemblies. The analyzed waste configuration for this event is the shielded container (240 PE-Ci per waste assembly). The shielded container DR is 0.25 for a vertical crush (one waste assembly), zero for a first/second tier drop (one waste assembly), and 0.005 for a low stress impact (two waste assemblies). The ARF*RF for this scenario is 1E-4 for impact to contaminated combustible solid waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{vertical} + ST_{1st/2nd} + ST_{low\ impact} = 6.0E\text{-}3\ PE\text{-}Ci + 0\ PE\text{-}Ci + 2.4E\text{-}4\ PE\text{-}Ci = 6.24E\text{-}3\ PE\text{-}Ci$$

$$ST_{vertical} = (240\ PE\text{-}Ci/WA \times 1\ WA \times 0.25 \times 1E\text{-}4 \times 1) = 6.0E\text{-}3\ PE\text{-}Ci$$

$$ST_{1st/2nd} = (240 \text{ PE-Ci/WA} \times 1 \text{ WA} \times 0 \times 1E\text{-}4 \times 1) = 0 \text{ PE-Ci}$$

$$ST_{low\ impact} = (240 \text{ PE-Ci/WA} \times 2 \text{ WA} \times 0.005 \times 1E\text{-}4 \times 1) = 2.4E\text{-}4 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 4.2E+0 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 7.5E-3 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-017 (East 2008a) for the bounding case.

4.6.2 Event E-10C-CH-WHB Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-10C-CH-WHB (elevated material falls or drops on waste containers) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.
- A facility pallet holds a maximum of two shielded container waste assemblies in a one tier array.

4.7 Event E-10D-CH/RH-UG – Waste Shaft Conveyance Failure Leads to Conveyance/Waste Containers Dropping Down Shaft

4.7.1 Unmitigated Analysis

Both CH and RH waste containers are moved from the WHB to the UG using the waste conveyance. The waste conveyance moves its payload from the waste collar area in the WHB down 2150 ft to the waste shaft station in the UG. During this movement, there is a possibility for waste conveyance to fail and drop the load to the bottom of the shaft (2325 ft from the surface). The bounding event involves a failure in the waste conveyance system resulting in a 2325 ft free fall of a facility pallet (two waste assemblies) of shielded containers.

The ST for the event involves a full facility pallet (two shielded container waste assemblies). The waste assemblies are assumed to be subjected to a free fall drop of 2325 ft. The analyzed waste configuration for this event is shielded containers (240 PE-Ci per waste assembly). The shielded container DR is 1.0 for the fall down the shaft. The ARF*RF for this scenario is 2E-3 for free fall drop of a shielded container containing contaminated combustible solids. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST_{shaft\ frcc\ fall} = (240\ PE\text{-}Ci/WA \times 2\ WA \times 1.0 \times 2E\text{-}3 \times 1) = 9.6E\text{-}1\ PE\text{-}Ci$$

The resultant TED incurred by the on-site worker at 100 m is 6.5E+2 rem, which is classified as *High* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 1.2E+0 rem, which is classified as *Moderate* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-017 (East 2008a) for the bounding case.

4.7.2 Event E-10D-CH/RH-UG Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-10D-CH/RH-UG (waste shaft conveyance failure leads to conveyance/waste containers dropping down shaft) and should be considered for inclusion in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.
- A facility pallet holds a maximum of two shielded container waste assemblies in a single tier array.
- A single facility pallet is placed on the waste conveyance.

4.8 Event E-05B-CH/RH-UG – BLEVE/VCE of Liquefied Gas Cylinder in the UG at the Waste Face

4.8.1 Unmitigated Analysis

Pressurized gas cylinders including liquefied gas cylinders are used to support operations and maintenance activities throughout the UG. Under the right conditions, these cylinders can explode violently resulting in a pressure wave and shrapnel that can impact waste containers in the waste disposal array. The bounding event of this type is a BLEVE/VCE explosion involving a single liquefied gas cylinder at the waste face (six columns by three tiers; total 18 waste assemblies). The cylinder is assumed to be located somewhere close to the waste face with a RH canister present. The front face of the waste assemblies and the RH canister are subjected to a pressure wave and shrapnel from a single cylinder explosion. The pressure wave is modeled as high stress impact that could reduce the volume of the waste containers by greater than 25%.

This calculation assumes that all CH waste containers involved are shielded containers, even though they may not be stacked three high in the waste array. The ST for the event involves the

waste face (18 waste assemblies) and a RH canister. The analyzed CH waste configuration for the event is the shielded container (80 PE-Ci per drum). The RH canister (240 PE-Ci) is assumed to contain contaminated combustible solids. The explosion is assumed to directly impact the front face of the waste assemblies or two shielded containers per assembly (36 total drums) and the RH canister with shrapnel (modeled as a puncture, DR of 0.05) and a high stress impact (DR of 0.5 for the shielded containers and DR of 1 for the RH canister). The remaining drums (18 total drums) are assumed to have no impact (DR of 0). The ARF*RF for this scenario is 2E-3 for impact of contaminated combustible solids, and 1E-4 for the shrapnel puncture involving contaminated combustible solids. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{CH\ shrapnel} + ST_{CH\ high\ impact} + ST_{RH\ shrapnel} + ST_{RH\ high\ impact}$$
$$= 1.44E\text{-}2\ PE\text{-}Ci + 2.88E{+}0\ PE\text{-}Ci + 1.2E\text{-}3\ PE\text{-}Ci + 4.8E\text{-}1\ PE\text{-}Ci = 3.4E{+}0\ PE\text{-}Ci$$

$$ST_{CH\ shrapnel} = (80\ PE\text{-}Ci/drum \times 36\ drums \times 0.05 \times 1E\text{-}4 \times 1) = 1.44E\text{-}2\ PE\text{-}Ci$$

$$ST_{CH\ high\ impact} = (80\ PE\text{-}Ci/drum \times 36\ drums \times 0.5 \times 2E\text{-}3 \times 1) = 2.88E{+}0\ PE\text{-}Ci$$

$$ST_{RH\ shrapnel} = (240\ PE\text{-}Ci/RH\ canister \times 1\ RH\ canister \times 0.05 \times 1E\text{-}4 \times 1) = 1.2E\text{-}3\ PE\text{-}Ci$$

$$ST_{RH\ high\ impact} = (240\ PE\text{-}Ci/RH\ canister \times 1\ RH\ canister \times 1 \times 2E\text{-}3 \times 1) = 4.8E\text{-}1\ PE\text{-}Ci$$

The resultant TED incurred by the on-site worker at 100 m is 2.3E+3 rem, which is classified as *High* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 4.1E+0 rem, which is classified as *Moderate* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See calculation WIPP-018 (East 2008b) for the bounding case.

4.8.2 Event E-05B-CH/RH-UG Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-05B-CH/RH-UG (BLEVE/VCE of liquefied gas cylinder in the UG at the waste face) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.
- Waste assemblies are stacked in the disposal array no more than three high.

4.9 Event E-21A-CH/RH-WHB – High Wind Impacts WHB

4.9.1 Unmitigated Analysis for Design Basis High Wind Event

The WHB is vulnerable to NPH events that can in turn have an impact on the waste containers within the WHB. This event postulates the design basis ("code of record") high wind event that results in equipment impacting waste. In this event, the building is of medium construction and is designed not to collapse under the "code of record" wind load.

The ST for the event involves the entire WHB inventory (80 waste assemblies and 2 RH shipping container payloads). The analyzed CH waste configuration for this event is the shielded container (240 PE-Ci per waste assembly); and the analyzed RH shipping container payload is a 72B (240 PE-Ci). The DR for a "code of record" building collapse is 0.0005 for the shielded container and 0.0 for shipping containers. The ARF*RF for this scenario is 1E-4 for an impact to contaminated combustible solid waste and 1E-4 for the RH waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{CH} + ST_{RH} = 9.6E\text{-}4 \text{ PE-Ci} + 0 \text{ PE-Ci} = 9.6E\text{-}4 \text{ PE-Ci}$$

$$ST_{CH} = (240 \text{ PE-Ci/WA} \times 80 \text{ WA} \times 0.0005 \times 1E\text{-}4 \times 1) = 9.6E\text{-}4 \text{ PE-Ci}$$

$$ST_{RH} = (240 \text{ PE-Ci/RH payload} \times 2 \text{ RH payloads} \times 0 \times 1E\text{-}4 \times 1) = 0 \text{ PE-Ci}$$

The exposure TED for the collocated worker and MOI are calculated using the reduced dose per unit activity value as defined in Section 3.1. The resultant TED incurred by the on-site worker at 100 m is 6.5E-2 rem, which is classified as *Low* by the DOE-STD-5506-2007 (doe 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 1.2E-4 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-019 (East 2008c) for the bounding case.

4.9.2 Event E-21A-CH/RH-WHB Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-21A-CH/RH-WHB (high wind impacts WHB) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- RH shipping containers prevent a release of radionuclides from a building collapse.
- Waste containers are of sound integrity.
- The WHB is of medium construction.
- The WHB will not collapse when subjected to the "code of record" wind load.

- High wind events reduce the dose per unit activity by a factor of ten.

4.10 Event E-24-CH/RH-WHB – Design Basis Earthquake

4.10.1 Unmitigated Analysis

The WHB is vulnerable to NPH events that can in turn have an impact on the waste containers within the WHB. This event postulates a design basis ("code of record") seismic event that impacts the building but does not collapse the roof. In this event, the building is of medium construction and is designed not to collapse under the "code of record" seismic event.

The ST for the event involves the entire WHB inventory (80 waste assemblies and 2 RH shipping container payloads). The analyzed CH waste configuration for this event is the shielded container (240 PE-Ci per waste assembly); and the analyzed RH shipping container payload is a 72B (240 PE-Ci). The DR for a "code of record" building collapse is 0.0005 for the shielded container and 0.0 for shipping containers. The ARF*RF for this scenario is 1E-4 for an impact to contaminated combustible solid waste and 1E-4 for the RH waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{CH} + ST_{RH} = 9.6E\text{-}4 \text{ PE-Ci} + 0 \text{ PE-Ci} = 9.6E\text{-}4 \text{ PE-Ci}$$

$$ST_{CH} = (240 \text{ PE-Ci/WA} \times 80 \text{ WA} \times 0.0005 \times 1E\text{-}4 \times 1) = 9.6E\text{-}4 \text{ PE-Ci}$$

$$ST_{RH} = (240 \text{ PE-Ci/RH payload} \times 2 \text{ RH payloads} \times 0 \times 1E\text{-}4 \times 1) = 0 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 6.5E-1 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 1.2E-3 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-019 (East 2008c) for the bounding case.

4.10.2 Event E-24-CH/RH-WHB Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-24-CH/RH-WHB (Design basis earthquake) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- RH shipping containers prevent a release of radionuclides from a building collapse.
- Waste containers are of sound integrity.
- The WHB is of medium construction.

- The WHB will not collapse when subjected to the "code of record" seismic event.

4.11 Event E-28-CH/RH-WHB – Loss of Power

4.11.1 Unmitigated Analysis

The CH and RH waste containers are handled by electric powered cranes in the WHB. In a loss of power event, these cranes could drop their loads. The bounding event is postulated to have all three cranes (two TRUDOCK cranes and the RH hot cell crane) drop their loads simultaneously. The TRUDOCK cranes are modeled as dropping a HalfPACT payload (one waste assembly) onto the ground. The payload drop is modeled as a moderate stress impact. The RH hot cell crane is modeled as dropping a RH canister from the upper hot cell onto the transfer cell room floor. The RH canister is modeled as being subjected to the high stress impact.

The ST for this event involves two HalfPACT payloads (two waste assemblies) and one RH canister (240 PE-Ci). The analyzed CH waste configuration is shielded container (240 PE-Ci per waste assembly). The shielded container DRs for the TRUDOCK crane drop are 0.05 for the moderate impact involving shielded containers. The DR for the RH hot cell crane drop is 1. The ARF*RF is 1E-4 for an impact to contaminated combustible solid waste and 1E-4 for an impact to RH waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST = ST_{CH\ moderate} + ST_{RH\ drop} =$$
$$2.4E\text{-}3\ PE\text{-}Ci + 2.4E\text{-}2\ PE\text{-}Ci = 2.64E\text{-}2\ PE\text{-}Ci$$

$$ST_{CH\ moderate} = (240\ PE\text{-}Ci/WA \times 2\ WA \times 0.05 \times 1E\text{-}4 \times 1) = 2.4E\text{-}3\ PE\text{-}Ci$$

$$ST_{RH\ drop} = (240\ PE\text{-}Ci/RH\ canister \times 1\ RH\ canister \times 1 \times 1E\text{-}4 \times 1) = 2.4E\text{-}2\ PE\text{-}Ci$$

The resultant TED incurred by the on-site worker at 100 m is 1.8E+1 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 3.2E-2 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-019 (East 2008c) for the bounding case.

4.11.2 Event E-28-CH/RH-WHB Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-28-CH/RH-WHB (loss of power) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.

- Waste containers are of sound integrity.

4.12 Event E-30-CH/RH-UG – Roof fall

4.12.1 Unmitigated Analysis

In the UG disposal rooms, there is a potential for localized sections of the roof to fall and impact disposed waste containers. From the top of the waste disposal array to the bottom of the roof is approximately 3 ft. While the roof does not have far to fall before reaching the waste disposal array, the height of the slab that could impact the array could be quite large. The impacted drums will experience a vertical crush but not to the extent they would if they were not a part of the tightly packed waste disposal array. The array will work together as a single unit and the resulting impact is modeled as a moderate impact. This event is postulated to impact 30 waste assemblies in the waste stack (ten columns in three tier stacks).

The calculation assumes all waste containers involved are shielded containers even though they may not be stacked three high in the waste array. The ST for this event involves 30 waste assemblies. The analyzed CH waste configuration is the shielded container (240 PE-Ci per waste assembly). The DR is 0.05 for the moderate impact involving the shielded container. The ARF*RF is 1E-4 for a moderate stress impact to contaminated combustible solid waste. A LPF of 1 is assumed for the unmitigated analysis. The resultant ST for this postulated event is calculated as follows:

$$ST_{\text{moderate impact}} = (240 \text{ PE-Ci/WA} \times 30 \text{ WA} \times 0.05 \times 1\text{E-}4 \times 1) = 3.6\text{E-}2 \text{ PE-Ci}$$

The resultant TED incurred by the on-site worker at 100 m is 2.4E+1 rem, which is classified as *Low* by the DOE-STD-5506-2007 (DOE 2007) criteria (Table 1-1). The resultant TED incurred by the MOI is 4.3E-2 rem, which is classified as *Low* by the DOE-STD-5506-2007 criteria (Table 1-1). The facility worker consequences were qualitatively assessed to be low. The DSA assumes the facility worker will observe the event and has a reasonable opportunity to exit the scene of the event and take self-protective actions that will limit exposure. The MOI dose is considered not to challenge the DOE-STD-3009-94 (DOE 2006) evaluation guideline. Thus, there is no new control necessary. See Calculation WIPP-019 (East 2008c) for the bounding case.

4.12.2 Event E-30-CH/RH-UG Key Inputs and Assumptions

The following inputs were employed as initial conditions of the HA/AA for Event E-30-CH/RH-UG (Roof fall) and should be considered for protection in the WIPP CH/RH DSA or its associated TSRs:

- The waste container inventories are within the limits identified in Section 3.2.
- Waste containers are of sound integrity.

5.0 Results and Conclusions

The resultant TED incurred by the on-site worker at 100 m and MOI have been calculated for the postulated events in Section 4. The unmitigated resultant TED for each postulated event analyzed for the shielded container is listed in Table 5-1. Consequences that were determined to challenge the High EG are highlighted red, and consequences that were determined to challenge the Moderate EG are highlighted yellow. Even though several events were determined to result in consequences that challenge the EGs, the consequences for the other waste configurations analyzed in WIPP-001 (McCormick 2008), WIPP-017 (East 2008a), WIPP-018 (East 2008b), and WIPP-019 (East 2008c) bound the consequences for all events analyzed in this calculation; therefore these events do not require any controls in addition to those already in place for CH waste.

Table 5-1, *Postulated Accident Resultant TEDs*

Event Number	On-site TED (rem)	MOI (rem)
E-04C-CH/RH-WHB	[redacted]	1.2E+00
E-09B-CH/RH-UG	9.0E+00	1.6E-02
E-09C-CH/RH-UG	7.9E+00	1.4E-02
E-10A-CH-WHB	8.2E+00	1.4E-02
E-10B-CH-WHB	4.9E+00	8.6E-03
E-10C-CH-WHB	1.6E-01	2.9E-04
E-10D-CH/RH-UG	[redacted]	1.2E+00
E-05B-CH/RH-UG	[redacted]	4.1E+00
E-21A-CH/RH-WHB	6.5E-02	1.2E-04
E-24-CH/RH-WHB	6.5E-01	1.2E-03
E-28-CH/RH-WHB	1.8E+01	3.2E-02
E-30-CH/RH-UG	2.4E+01	4.3E-02

6.0 References

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Appendix A: Excel Worksheets for Postulated Events

Source Term/Dose Consequence Summary		Unmitigated			
Events	**Description**	**Container**	**MAR**	**CW rem**	**MOI rem**
E-04C-CH/RH-WHB	Large fire in waste hoist tower results in waste conveyance drop	Gamma Shielded Container	480		1.2E+00
E-09B-CH/RH-UG	Underground vehicle collides with waste array	Gamma Shielded Container	2640	9.0E+00	1.6E-02
E-09C-CH/RH-UG	Forklift tines puncture waste containers in UG	Gamma Shielded Container	2320	7.9E+00	1.4E-02
E-10A-CH-WHB	Pressurized container impacts CH waste containers	Gamma Shielded Container	240	8.2E+00	1.4E-02
E-10B-CH-WHB	Drop of waste containers in CH Bay	Gamma Shielded Container	1920	4.9E+00	8.6E-03
E-10C-CH-WHB	Elevated material falls or drops on waste containers	Gamma Shielded Container	480	1.6E-01	2.9E-04
E-10D-CH/RH-UG	Waste shaft conveyance failure leads to conveyance/waste containers dropping down shaft	Gamma Shielded Container	480		1.2E+00
E-05B-CH/RH-UG	BLEVE/ VCE of liquefied gas cylinder in the UG at the waste face	Gamma Shielded Container	3120		4.1E+00
E-21A-CH/RH-WHB	High wind impacts WHB	Gamma Shielded Container	19680	6.5E-02	1.2E-04
E-24-CH/RH-WHB	Design basis earthquake	Gamma Shielded Container	19680	6.5E-01	1.2E-03
E-28-CH/RH-WHB	Loss of power	Gamma Shielded Container	720	1.8E+01	3.2E-02
E-30-CH/RH-UG	Roof fall	Gamma Shielded Container	7200	2.4E+01	4.3E-02

WIPP Specific MACCS2 rem/PE-Ci values:

REM_CW	680	collocated worker receptor at 100 m {See WIPP-002}
REM_MOI	1.2	MOI receptor at 2900 m {See WIPP-002}
REM_CW_wind	68.0	collocated worker receptor at 100 m (conservatively estimated to be 10% of 95th value)
REM_MOI_wind	0.1	MOI receptor at 2900 m (conservatively estimated to be 10% of 95th value)

Source Term and Consequence Inputs:

The following damage ratio values are derived from DOE-STD-5506:

Punctures		
DR_TINE_SV_OP	0.05	Damage ratio used for SV and OP during a forklift puncture
Low Impact Stress (<10 mph)		
DR_SV_OP_C_LS	0.005	Over-packed containers and SV waste
Moderate Impact Stress		
DR_SV_OP	0.05	Over-packed containers and SV waste
High Impact Stress		
DR_SV_OP_HI	0.50	Over-packed containers and SV waste
Drop from less than 4 ft		
DR_SV_OP_D	0.0	Over-packed containers and SV waste
Drop from 3rd tier or 2nd tier being moved		
DR_SV_OP_S	0.005	Over-packed containers and SV waste
Drop from 4th tier		
DR_4th_TIER_SV_OP	0.05	Over-packed containers and SV waste
Vertical Drop - Bottom Tier Crush		
DR_Bot_Crush_SV_OP	0.25	Over-packed containers and SV waste
Drop down Shaft		
DR_SHAFT	1.0	Direct loaded drums, SWBs, RH canisters, and Over-packed containers
Punctures		
DR_TINE_SWB	0.05	Direct Loaded SWBs and RH Canisters
High Impact Stress		
DR_C_HI	1.0	Direct loaded drums, SWBs, and RH canisters.
COR Building Collapse		Note: Building collapse DRs are based on the WHB being of Medium Construction
DR_Bldg_SV_OP	0.0005	Over-packed containers and SV waste

The following ARF*RF values are derived from DOE-STD-5506:

ARF_RF_LOC	1.00E-04	Combustible Cellulose and Plastics (Flexing/Overpressure/Spill/Low and Moderate Impact)
ARF_RF_LOC_HIGH	2.00E-03	Combustible Cellulose and Plastics (High Stress Impact)
ARF_RF_SV	7.00E-05	SV drums (Spill/Low and Moderate Impact)
ARF_RF_SV_HIGH	7.00E-04	SV (High stress impact)
ARF_RF_OP	7.00E-02	Powder (Over-pressurization)
ARF_RF_SHAFT	2.00E-03	Bounding ARF for high stress impact to drums, SWBs, canisters, and overpacked drums.
Note:		In Table 4.4.4-1 of DOE-STD-5506-2007 High Impact ARF/RFs only to containers with >~25% volume reduction and is not applicable to cylinders or missiles

The following LPF used for the LOC analysis.

LPF	1.0	LPF for Unmitigated events

Waste Container Inventories PE-Ci Limits

Inv_drum	80	Direct loaded CH or RH waste drum including shielded containers
Inv_RH_wc	240	RH waste canister or 72B DOT Type B Shipping Cask.
Inv_Shield	240	PE-Ci limit for a three-pack of gamma shielded waste containers

E-04C-CH/RH-WHB Fire in waste hoist tower

UNMITIGATED

Bounding event: MAR - 2 Shielded Container waste assemblies
Qualitative assessed as fire resulting in a catastropic failure of the waste hoist system with subsequent dropping of the waste conveyance down the waste shaft
Release is from high energy impact only with no burning

UNMITIGATED

Gamma Shielded Container

Waste Assemblies	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)
2	480	1.0	2.00E-03	1.0	9.60E-01	[redacted]	1.2E+00

E-09B-CH/RH-UG Underground vehicle collides with waste array

UNMITIGATED

Bounding event: MAR - 11 waste assemblies (1 FP and 9 WA at the waste face)
Modeled as - Moderate impact (all containers subjected to moderate speed crush)

Gamma Shielded Container

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Puncture
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Low Speed Crush
33	2640	0.05	1.00E-04	1.0	1.32E-02	9.0E+00	1.6E-02	Moderate Speed Crush
	0	0.5	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	High Speed Crush
	0	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from lower tier
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 3rd tier
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 4th tier
33	2640				1.32E-02	9.0E+00	1.6E-02	

E-09C-CH/RH-UG Forklift tines puncture waste containers in UG

UNMITIGATED

Bounding event: MAR - 9 WA
Modeled as - FL tine puncture to 2 waste containers with subsequent moderate collision to 9 waste assemblies

Gamma Shielded Container

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
2	160	0.05	1.00E-04	1.0	8.00E-04	5.4E-01	9.6E-04	Puncture
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Low Speed Crush
27	2160	0.05	1.00E-04	1.0	1.08E-02	7.3E+00	1.3E-02	Moderate Speed Crush
	0	0.5	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	High Speed Crush
	0	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from lower tier
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 3rd tier
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 4th tier
29	2320				1.16E-02	7.9E+00	1.4E-02	

E-10A-CH-WHB Pressurized container impacts CH waste containers

UNMITIGATED

Bounding event: MAR - 1 Facility Pallet (Only 3 drums)
Modeled as - High energy impact with cylinder (High Impact ARF*RF does not apply per 5506)

Gamma Shielded Container

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Puncture
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Low Speed Crush
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Moderate Speed Crush
3	240	0.5	1.00E-04	1.0	1.20E-02	8.2E+00	1.4E-02	High Speed Crush
	0	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from lower tier
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 3rd tier
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 4th tier
3	240				1.20E-02	8.2E+00	1.4E-02	

E-10B-CH-WHB Drop of waste containers in CH Bay

UNMITIGATED

Bounding event: MAR - 8 waste assemblies
Modeled as - Dropping 1 waste assembly (4th Tier Drop/moderate impact) and crushes 1 waste assembly stacked below (Vertical Crush) remaining 6 waste assemblies are knocked over from 1st and 2nd tier

Gamma Shielded Container

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Puncture
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Low Speed Crush
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Moderate Impact
3	240	0.25	1.00E-04	1.0	6.00E-03	4.1E+00	7.2E-03	Vertical Impact
18	1440	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from lower tier
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 3rd tier
3	240	0.05	1.00E-04	1.0	1.20E-03	8.2E-01	1.4E-03	Drop from 4th tier
24	1920				7.20E-03	4.9E+00	8.6E-03	

E-10C-CH-WHB Elevated material falls or drops on waste containers

UNMITIGATED

Bounding event: MAR - 2 Facility Pallets
Modeled as - Shipping container crushes an equivalent of 1 WA on FP (vertical crush), 1 WA lower tier drop. 2nd FP low stress impact

Gamma Shielded Container

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Puncture
6	480	0.005	1.00E-04	1.0	2.40E-04	1.6E-01	2.9E-04	Low Speed Impact
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Moderate Impact
3	240	0.25	1.00E-04	1.0	6.00E-03	4.1E+00	7.2E-03	Vertical Crush
3	240	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from lower tier
	0	0.005	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 3rd tier
	0	0.05	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Drop from 4th tier
12	960				6.24E-03	4.2E+00	7.5E-03	

E-10D-CH/RH-UG Waste shaft conveyance failure leads to conveyance/waste containers

UNMITIGATED

Bounding event: MAR - 1 Facility Pallet
Modeled as - High energy impact (Bounding High Impact ARF*RF used for all but S/V which uses its High Impact Stress ARF*RF)

Gamma Shielded Containers

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
6	480	1	2.00E-03	1.0	9.60E-01		1.2E+00	Drop down shaft
6	480				9.60E-01		1.2E+00	

E-05B-CH/RH-UG BLEVE/VCE of liquefied gas cylinder in the underground at the waste face

UNMITIGATED

Bounding event: MAR - 18 Waste assemblies (waste face)
Modeled as - 18 WA (2 shielded containers/WA) subjected to BLEVE/VCE (modeled as High Impact) and shrapnel (modeled as forklift tine puncture)

Shielded Containers

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
36	2880	0.05	1.00E-04	1.0	1.44E-02	9.8E+00	1.7E-02	Shrapnel Puncture
36	2880	0.5	2.00E-03	1.0	2.88E+00		3.5E+00	VCE (Modeled as High Impact w/ higher ARF*RF)
36	2880				2.89E+00		3.5E+00	

RH Canister

RH Canister	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
1	240	0.05	1.00E-04	1.0	1.20E-03	8.2E-01	1.4E-03	Shrapnel Puncture
1	240	1	2.00E-03	1.0	4.80E-01		5.8E-01	VCE (Modeled as High Impact w/ higher ARF*RF)
1	240				4.81E-01		5.8E-01	

Conf.	CH	Type	RH	Type	Total	Type
MAR	2880	GSC	240	Canister	3120	GSC & Canister
CW		GSC		Canister		GSC & Canister
MOI	3.5E+00	GSC	5.8E-01	Canister	4.1E+00	GSC & Canister

E-21A-CH/RH-WHB High wind impacts WHB

UNMITIGATED
Code of Record Event

Bounding event: MAR - Entire WHB MAR (80 waste assemblies and 2 RH Shipping Containers)
Modeled as - High Wind or Tornado results in elevated materials falling and impacting waste containers. Calculation includes a reduction in the estimate of dose for greater dispersion associated with high wind and tornado events.

Conf.	CH	Type	RH	Type	Total	Type
MAR	19200	GSC	480	72B	19680	GSC & 72B
CW	6.5E-02	GSC	0.0E+00	72B	6.5E-02	GSC & 72B
MOI	1.2E-04	GSC	0.0E+00	72B	1.2E-04	GSC & 72B

Shielded Containers

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
240	19200	0.0005	1.00E-04	1.0	9.60E-04	6.5E-02	1.2E-04	Building Collapse
240	19200				9.60E-04	6.5E-02	1.2E-04	

RH Shipping Container (72B)

RH Canister	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
2	480	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Building Collapse
2	480				0.00E+00	0.0E+00	0.0E+00	

E-24-CH/RH-WHB Design basis earthquake

UNMITIGATED

Bounding event: MAR - Entire WHB MAR (80 waste assemblies and 2 RH Shipping Containers)
Modeled as - Snow/hail buildup or DBE that results in dropping of elevated materials onto CH and RH waste

Code of Record Event

Conf.	CH	Type	RH	Type	Total	Type
MAR	19200	GSC	480	72B	19680	GSC & 72B
CW	6.5E-01	GSC	0.0E+00	72B	6.5E-01	GSC & 72B
MOI	1.2E-03	GSC	0.0E+00	72B	1.2E-3	GSC & 72B

Shielded Containers

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
240	19200	0.0005	1.00E-04	1.0	9.60E-04	6.5E-01	1.2E-03	Building Collapse
240	19200				9.60E-04	6.5E-01	1.2E-03	

RH Shipping Container (72B)

RH Canister	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
2	480	0	1.00E-04	1.0	0.00E+00	0.0E+00	0.0E+00	Building Collapse
2	480				0.00E+00	0.0E+00	0.0E+00	

E-28-CH/RH-WHB Loss of power

UNMITIGATED

Bounding event: MAR - Two HalfPACT Payloads and RH Canister
Modeled as - Crane drop of two TRUPACT-II payloads (2 WA moderate impact) and a RH canister from an unspecified height (high impact not expected to reduce the volume >25%)

Conf.	CH	Type	RH	Type	Total	Type
MAR	480	GSC	240	72B	720	GSC & 72B
CW	1.6E+00	GSC	1.6E+01	72B	1.8E+01	GSC & 72B
MOI	2.9E-03	GSC	2.9E-02	72B	3.2E-2	GSC & 72B

Shielded Containers

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
6	480	0.05	1.00E-04	1.0	2.40E-03	1.6E+00	2.9E-03	Moderate Impact
6	480				2.40E-03	1.6E+00	2.9E-03	

RH Canister

RH Canister	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
1	240	1	1.00E-04	1.0	2.40E-02	1.6E+01	2.9E-02	High Impact (lower ARF x RF used)
1	240				2.40E-02	1.6E+01	2.9E-02	

E-30-CH/RH-UG Roof fall

UNMITIGATED

Bounding event: MAR - 30 Waste Assemblies
Modeled as - Modeled as a localized slab of roof impacts 30 waste assemblies. A DR of 0.1 or 0.05 (same as substantial building collapse or moderate stress impact) was used to account for the encapsulation of the roof after falling ~3 feet.

Shielded Containers

GSCs	MAR (PE-Ci)	DR	ARFxRF	LPF	ST (PE-Ci)	CW CED (rem)	MOI CED (rem)	
90	7200	0.05	1.00E-04	1.0	3.60E-02	2.4E+01	4.3E-02	Moderate Impact
90	7200				3.60E-02	2.4E+01	4.3E-02	