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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET

1. QA: L

Page: 1 of: 62

Complete Only Applicable Items

2. [x] Analysis [ ] Engineering [ ] Performance Assessment [ ] Scientific

3. [ ] Model [ ] Conceptual Model Documentation [ ] Model Documentation [ ] Model Validation Documentation

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Preliminary Selection of MGR Design Basis Events

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The previous DI number for this document was B00000000-01717-3300-00005 REV 00. The new DI number was assigned per AP-3.10Q Rev. 1 and AP-6.1Q Rev. 00.

Revision 00C of this analysis referenced the proposed rule 10 CFR 63 (64 FR 8640) for the definitions of design basis events (63.2), preclosure dose limits (63.111), and criticality requirements related to the Integrated Safety Analysis (ISA) (63.112). Revision 00D of this analysis referenced the Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada (Dyer 1999a) instead of 10 CFR 63 (64 FR 8640). The main difference between these sources was that Dyer (1999a) did not include the prescriptive ISA requirements under Section 63.112(e), including the requirement for analysis of criticality control. The REVISED INTERIM GUIDANCE PENDING ISSUANCE OF NEW U.S. NUCLEAR REGULATORY COMMISSION (NRC) REGULATIONS (Revision 01, July 22, 1999) FOR YUCCA MOUNTAIN, NEVADA (Dyer 1999b) includes the ISA criticality requirement in Section 63.112(e)(6), and is otherwise identical to 10 CFR 63 (64 FR 8640) and Dyer (1999a) with respect to Sections 63.2 and 63.111. Therefore, there was no impact to this analysis and Revision 00 cites the revised interim guidance (Dyer 1999b) for all references to 10 CFR 63.

The following TBD/TBV numbers are used in this analysis: TBD-414, TBD-415, TBD-416, TBD-417, TBV-245, TBV-684, TBV-688, TBV-690, TBV-1210, TBV-1212, TBV-1340, TBV-1346, TBV-1347, and TBV-1348.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD

Complete Only Applicable Items

2. Analysis or Model Title:

Preliminary Selection of MGR Design Basis Events

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4. Revision/Change No.	5. Description of Revision/Change
00	Initial release

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CONTENTS (Continued)

FIGURES

TABLES

1. PURPOSE

The purpose of this analysis is to identify the preliminary design basis events (DBEs) for consideration in the design of the Monitored Geologic Repository (MGR). For external events and natural phenomena (e.g., earthquake), the objective is to identify those initiating events that the MGR will be designed to withstand. Design criteria will ensure that radiological release scenarios resulting from these initiating events are beyond design basis (i.e., have a scenario frequency less than once per million years). For internal (i.e., human-induced and random equipment failures) events, the objective is to identify credible event sequences that result in bounding radiological releases. These sequences will be used to establish the design basis criteria for MGR structures, systems, and components (SSCs) design basis criteria in order to prevent or mitigate radiological releases. The safety strategy presented in this analysis for preventing or mitigating DBEs is based on the preclosure safety strategy outlined in *Strategy to Mitigate Preclosure Off-site Exposure* (CRWMS M&O 1998f).

DBE analysis is necessary to provide feedback and requirements to the design process, and also to demonstrate compliance with proposed 10 CFR 63 (Dyer 1999b) requirements. DBE analysis is also required to identify and classify the SSCs that are important to safety (ITS).

2. QUALITY ASSURANCE

Analysis of design basis events is a quality-affecting activity as determined by procedure QAP-2-0, *Conduct of Activities.* This work activity was evaluated in a QAP-2-0 activity evaluation titled *Design Basis Event Definition & Analysis/QA Classification Analysis (1.2.1.11) Activity Evaluation* (CRWMS M&O 1999a). That evaluation determined that DBE analysis is required for licensing of a potential repository and thus subject to the requirements of DOE/RW-0333P, *Quality Assurance Requirements and Description* (QARD) (DOE 1998b).

This analysis is quality-affecting because the results of this analysis may be used to support the analyses of repository structures, systems and components per QAP-2-3, *Classification of Permanent Items.* Therefore, as specified in NLP-3-18, *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*, this analysis shall be subject to QA controls. This analysis is documented in accordance with Procedure AP-3.10Q, *Analyses and Models.*

3. COMPUTER SOFTWARE AND MODEL USAGE

No computer software or subroutines were required to support this analysis.

4. INPUTS

This analysis is not to be used to support procurement, fabrication, or construction activities. This analysis and the results provided herein are based on a preliminary design concept (DOE 1998a) and preliminary DBE calculations (CRWMS M&O 1998c). Existing data and assumptions that provide the basis for results reported in this analysis are designated as TBV (To Be Verified) and tracked in accordance with NLP-3-15, *To Be Verified (TBV) and To Be*

Determined (TBD) Monitoring System. Effective 6/30/99, procedure AP-3.15Q Rev. 0, *Managing Technical Product Inputs*, superseded NLP-3-15 for managing TBVs/TBDs. Since this analysis was in the check process prior to 6/30/99, all TBV/TBD numbers were initiated under NLP-3-15 but will be processed to completion in accordance with AP-3.15Q (Section 2.0).

Information regarding the screening of external events for DBE analysis was received via AP-3.14Q transmittal (CRWMS M&O 1999c) and used as input to this analysis. This input was used to screen multiple external events and natural phenomena, which were previously identified in the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c), from further consideration as credible design basis events. Since this information is used to address preclosure safety issues, it is tracked as **TBV-1348**.

4.1 Parameters

No parameters, as defined by AP-3.10Q (Section 3.14), have been used as input to this analysis. Existing (i.e., unqualified) input data that provides the basis for assumptions or conclusions that impact this analysis have been identified with TBV/TBD tracking numbers and require verification/determination to support the License Application (LA).

4.2 Criteria

The design criteria applicable to this analysis are the regulatory definitions of DBEs that are provided in the proposed 10 CFR 63 (Dyer 1999b). The DBE definitions were used in the event screening and grouping process to determine whether a DBE would be identified as Category 1, Category 2, or beyond design basis.

From the proposed 10 CFR 63.2 - Definitions (Dyer 1999b), "Design basis events means:

(1) Those natural events and human-induced event sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area (referred to as Category 1 events); and

(2) (a) Other human-induced event sequences that have at least one chance in 10,000 of occurring before permanent closure of the geologic repository, and (b) appropriate consideration of natural events (phenomena) that have been historically reported for the site and the geologic setting (referred to as Category 2 events)."

4.3 Codes and Standards

10 CFR 71. *Packaging and Transportation of Radioactive Material.* Part 71.71 - Normal Conditions of Transport, and Part 71.73 - Hypothetical Accident Conditions.

10 CFR 72. *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.* Subpart F: General Design Criteria.

ANSI/ANS 1988. *Design Criteria for an Independent Spent Fuel Storage Installation (Water Pool Type)*, ANSI/ANS 57.7-1988.

ANSI/ANS 1992. *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)*. ANSI/ANS-57.9-1992.

ANSI/ASCE 1996. *Minimum Design Loads for Buildings and Other Structures*. ANSI/ASCE 7-95.

5. ASSUMPTIONS

5.1 The radiological source terms, DBE release fractions, and dose factors used to calculate off-site doses in *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository* (CRWMS M&O 1998c, pp. 6-10) are assumed to be valid and appropriate for this analysis. This assumption is used throughout Section 6.2 to identify event sequences, compare relative consequences, and determine the bounding internal events. This assumption is based on the fact that conservative release fractions and dose calculation parameters were used to calculate off-site doses in the preliminary DBE calculations (CRWMS M&O 1998c, Section 2.2). This assumption is insensitive to changes in the preliminary DBE calculations (CRWMS M&O 1998c) because event doses extracted from that document were compared on a relative basis to determine which events resulted in bounding consequences (e.g., the consequences of dropping four Pressurized Water Reactor (PWR) assemblies will bound that of dropping one PWR assembly, regardless of the parameters used to calculate the doses). As a result, this assumption does not require TBV tracking.

5.2 The preclosure period (from beginning of repository operations to permanent closure) is assumed to be 100 years **(TBV-690)**. This assumption is based on the performance requirement for retrievability in the *Monitored Geologic Repository Requirements Document* (YMP 1999, Requirement 3.2(H)). A preclosure operational period of 100 years is considered conservative since the MGR waste handling and emplacement activities are expected to span less than 40 years. The majority of potential events occur in the Waste Handling Building, which is expected to operate for less than 40 years, regardless of the time period that the repository remains open for retrievability purposes. The MGR Requirements Document (YMP 1999) requires that repository maintain the option to retrieve waste for up to 300 years, which means that subsurface events (e.g., rockfall, earthquake, early failure of a waste package, etc.) may need to be evaluated for a 300 year preclosure period instead of 100 years. However, a factor of three increase in the preclosure period is not expected to change the event frequency category (e.g., from a "Beyond Design Basis Event" to a Category 2 event) for these events (see Section 6 for a discussion of event frequency categories).

This assumption is used throughout this analysis and was used in previous supporting documents (e.g., CRWMS M&O 1998c) to calculate the event frequency ranges for Category 1 and Category 2 DBEs, consistent with the definition of "design basis events" in 10 CFR 63.2 (see Section 4.2).

5.3 Criticality analysis will demonstrate that the sequence frequency for misload, breach and moderation of a waste package (WP) is beyond design basis (i.e., less than 10^{-6} per year)**(TBV-1210)**. This assumption is based on results from *Frequency of SNF*

Misload for Uncanistered Fuel Waste Package (CRWMS M&O 1998b, p. 24), which indicates that the probability of a WP misload exceeding the criticality design basis is approximately 0.01 WPs/year. Therefore, it is assumed that facility design features will be incorporated as necessary to ensure that the probability of a WP breach and moderation is on the order of 10^{-4}, resulting in a preclosure criticality event sequence that is beyond design basis. This assumption is used in Section 6.2.5.15 to categorize criticality event sequences.

5.4 Criticality analysis will demonstrate that a preclosure criticality event in the Waste Handling Building (WHB) (e.g., in the canister staging racks or the Assembly Transfer System (ATS) pool) is beyond design basis (i.e., frequency is less than 10^{-6} per year)**(TBV-1210)**. This TBV assumes that facility design features will be incorporated as necessary to ensure that a preclosure criticality event sequence is beyond design basis. This assumption is based on the design criteria for criticality safety in the system description documents for the Assembly Transfer System (CRWMS M&O 1998e, Section 1.2.2.1.7) and the Canister Transfer System (CRWMS M&O 1998h, Section 1.2.2.1.6). This assumption is used in Sections 6.2.5.8 and 6.2.5.12.

5.5 Fire hazards analysis will identify the design criteria required to prevent or mitigate fires in the MGR surface and subsurface facilities **(TBV-688)**. It is assumed that facility design features will be incorporated as necessary to ensure that fires cannot initiate a credible radiological release scenario. This assumption is based on the requirement in 10 CFR 63.112 (Dyer 1999b) for an integrated safety analysis, which implies consideration of fire detection and appropriate suppression systems. This assumption is used in Sections 6.2.4.18, 6.2.5.1 and 6.2.5.2.

5.6 Keyblock analysis will demonstrate that the frequency of a subsurface rockfall event that could potentially breach the WP is beyond design basis (i.e., frequency is less than 10^{-6} per year)**(TBV-684)**. This assumption assumes that facility or WP design features will be incorporated as necessary to ensure that rockfall cannot initiate a credible radiological release scenario. This assumption is based on the preclosure safety strategy (CRWMS M&O 1998f, p. 5) to rely on the WP inner and outer barriers for containment of radionuclides. This assumption is used in Section 6.2.5.16.

5.7 Loss-of-Offsite Power events at the MGR are assumed to occur one or more times during the preclosure period. This assumption is based on data from nuclear power plants which indicates that loss-of-offsite power events occur with a frequency of 0.2 per year (CRWMS M&O 1998c, Assumption 3.1.14). This is a bounding assumption from a frequency category perspective and is used in Section 6.1.3.1 to categorize the Loss-of-Offsite Power event as a Category 1 DBE. Because this is a bounding assumption, it does not require TBV tracking.

5.8 The frequency of all two-block crane drops is assumed to be beyond design basis (i.e., less than 10^{-6} per year)**(TBV-1340)**, based on the availability of industry standards (e.g., NUREG-0554, *Single-Failure-Proof Cranes for Nuclear Power Plants*) that provide guidance on crane safety features to significantly reduce the probability of a two-block event (NRC 1979, p. 6). This assumption is used to evaluate the frequency of two-block crane drop events involving shipping casks (Sections 6.2.3.2.1 and

6.2.5.3), canisters (Sections 6.2.3.2.5 and 6.2.5.11) and disposal containers (DCs)/WPs (Sections 6.2.3.2.6 and 6.2.5.13).

5.9 This analysis assumes that there will not be a HEPA-filtered ventilation system in the Carrier Bay design for LA. This assumption is based on the Reference Viability Assessment (VA) design identified in *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a) and on analysis in *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository* (CRWMS M&O 1998c, pp. 10-11). This assumption is used in Sections 6.2.3.2.1 and 6.2.5.3 to evaluate event sequences that result in a radiological release. This assumption does not require TBV tracking because it does not impact the conclusions of this analysis (i.e., a shipping cask drop without impact limiters would be the bounding, credible DBE in the Carrier Bay, whether or not a ventilation system was available).

5.10 Not Used.

5.11 This analysis assumes that the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c) will be revised (issued as MGR Internal Events Hazards Analysis) to incorporate the following additional internal events **(TBV-1347)**:

- Criticality associated with small canister staging rack
- Canister drop onto another canister at the small canister staging rack
- Cladding failure in the ATS dryer
- Loss of pool water resulting in zircaloy cladding fire
- Uncontrolled pool water fill/draindown resulting in flooding
- Criticality associated with the spent fuel assembly (SFA) staging rack in the ATS pool
- Uncontrolled descent of a loaded incline basket transfer cart
- Criticality caused by the misload of the SFA dryer
- Criticality caused by the misload of a DC
- Criticality associated with DC/WP staging racks
- Preclosure "Early Failure" of a WP

This assumption is based on preliminary analysis of internal hazards associated with the MGR design. This assumption is used in Sections 6.2, 7 and 7.1 to evaluate and categorize internal event sequences.

5.12 This analysis assumes that nominal lifts (i.e., potential drops) for shipping casks in the WHB are as follows:

- Raise 4 meters **(TBV-1212)** to get casks off the truck/rail carrier and onto the floor of the Carrier Bay
- Lower 6 meters **(TBV-1212)** into the ATS Cask Preparation Pit
- Lower 15 meters **(TBV-1212)** into the ATS Pool

This assumption is based on preliminary design sketches of the Carrier Bay and Assembly Transfer System. This assumption is used in Sections 6.2.3.2.1, 6.2.3.2.2, 6.2.3.2.3 and 6.2.5.4 to evaluate events involving cask drops.

5.13 This analysis assumes that the WP is designed to withstand the following events, as described in *Waste Package Design Basis Events* (CRWMS M&O 1997c, Table 8-1)(**TBV-245**):

Table 1. WP DBE Assumptions

Event	Section Used
Impact of a 0.5 kg pressurized missile travelling at a speed of 5.7 m/s	6.2.4.17
End impact of a 2.3 metric ton (MT) object falling 2 meters	6.2.4.12
Side impact of a 25 MT rock falling 3.1 meters	6.2.5.16
Vertical drop of 2 meters	6.2.4.13
Side drop of 2.4 meters	6.2.4.14
WP tipover and slapdown onto flat surface	6.2.4.15
Puncture due to a 1.93 meter horizontal drop onto a WP support or 2.4 meter horizontal drop onto a WP pier, whichever is worse	6.2.4.20
Internal pressure of 1.01/0.72 MPa due to 100% fuel rod failure inside a WP containing 21-Pressurized Water Reactor (PWR) or 44-Boiling Water Reactor (BWR) assemblies @ gas temperature of 500°C, Safety Factor=1.5	6.2.4.21
Maintain structural integrity and prevent tip-over during an earthquake with 0.66g peak horizontal and vertical ground accelerations	6.2.4.16
WP is designed to withstand a fire with the following characteristics: exposure to heat flux of 800°C radiation environment for 30 min.; emissivity coefficient of at least 0.9; surface absorptivity of at least 0.8; and convective heat transfer rate of still air @ 800°C	6.2.4.18

This assumption is based on analysis in *Waste Package Design Basis Events* (CRWMS M&O 1997c), which formed the design basis for the waste package design presented in the VA (DOE 1998a). This assumption is used in Sections 6.2.4 and 6.2.4.12 through 6.2.4.21.

5.14 Shipping cask designs cannot be changed and the MGR must accept all Nuclear Regulatory Commission (NRC)-licensed casks. This assumption is used in *Option 1* of Section 6.2.3.2.1 to evaluate the strategy for preventing/mitigating shipping cask drops if design requirements cannot be imposed on the shipping cask vendors. This assumption is based on the fact that the existing fleet of shipping casks were designed and licensed to 10 CFR 71 requirements for transportation and not for the potential events at the MGR. This assumption does not require verification because it is used to evaluate a design option and does not constitute a design requirement.

5.15 A shipping cask drop and breach that results in a radiological release is a credible design basis event. This assumption is used in *Option 2* of Section 6.2.3.2.1 to evaluate the strategy for preventing/mitigating credible shipping cask drops that result in a radiological release. This assumption implies that lifts above the cask design basis cannot be prevented by design and that radiological releases must be mitigated by the facility design. This assumption is based on a lack of available information on shipping cask design basis drop heights. This assumption does not require verification because it is used to evaluate a design option and does not constitute a design requirement.

5.16 This analysis assumes that an event sequence involving the drop of a commercial spent fuel assembly (SFA) basket onto another commercial SFA basket and subsequent failure or unavailability of the ventilation system to function after the event is beyond design basis (i.e., less than 10^{-6} per year). This assumption is based on the improbable likelihood that three concurrent failures will occur, including: (1) control system failure or operator error that results in suspending one basket above another, (2) mechanical failure or operator error that results in a drop of the suspended basket onto another basket in the Assembly Transfer System (ATS) dryer, and (3) failure of the ventilation system to function on demand. This assumption is used in Sections 6.2.5 and 6.2.5.6.

5.17 This analysis assumes that it is impossible for a zircaloy cladding fire to be initiated by a total loss of pool water or partial drain down in the ATS pool **(TBV-1346)**. This assumption is used in Section 6.2.5.9 to evaluate the potential for a zircaloy cladding fire sequence and classify the event as beyond design basis. The basis for this assumption is the SECY-96-256 report published by the NRC which indicates that the spent fuel cladding temperature must exceed 565 °C before a zircaloy fire sequence is possible (NRC 1996b).

6. ANALYSIS/MODEL

This analysis used qualitative frequency screening and consequence grouping techniques to identify the preliminary list of DBEs for the MGR. The result of this qualitative screening and grouping is a list of bounding events that will be further evaluated in future DBE analyses. Bounding DBEs are important in that they provide the design basis for the MGR, as well as the basis for demonstrating preclosure safety in Chapter 7 of the MGR License Application.

The overall process for implementing an Integrated Safety Analysis for preclosure repository operations is graphically illustrated in Figure 1. The work performed in this analysis is represented by the box titled "Preliminary Selection of DBEs" in Figure 1.

As the facility design evolves and matures, the potential DBEs and/or the strategy to prevent or mitigate them may also be updated to reflect the design. The event prevention/mitigation strategy presented in this analysis is generally based on the *Strategy to Mitigate Preclosure Off-site Exposure* (CRWMS M&O 1998f), which established a prioritization of facility safety features (i.e., primary, secondary and defense-in-depth) for each operational function of the MGR.

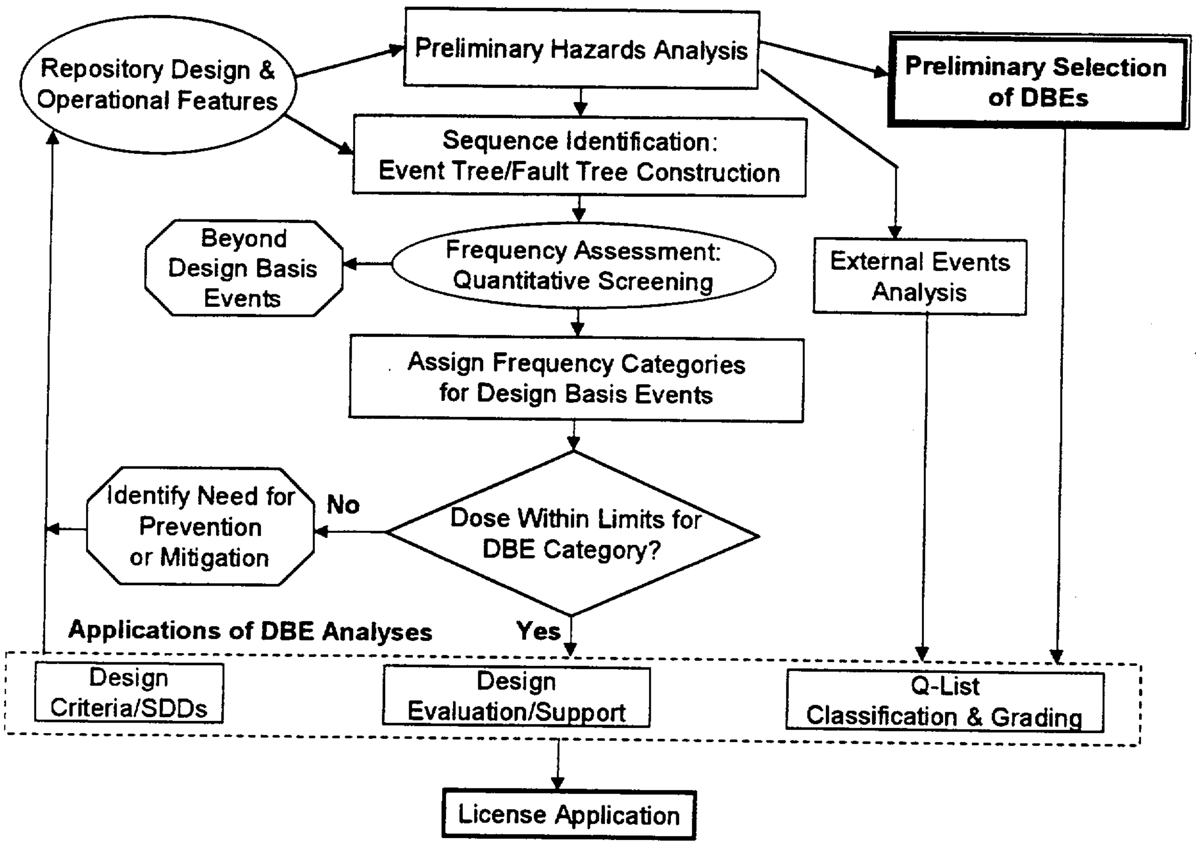

Figure 1. Integrated Safety Analysis Process (Preclosure)

DBEs are classified as Category 1 or Category 2 based on the frequency of the entire event sequence (also known as the scenario frequency), as shown in Table 2 below:

Table 2. DBE Frequency Categories

DBE Category	Frequency of Occurrence	10 CFR 63.2 Definition (Dyer 1999b)
Category 1	Greater than, or equal to, once every 100 years	"Those natural events and human-induced event sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area."
Category 2	Less than once every 100 years, but greater than, or equal to, once every 1 million years	"(a) Other human-induced event sequences that have at least one chance in 10,000 of occurring before permanent closure of the geologic repository, and (b) appropriate consideration of natural events (phenomena) that have been historically reported for the site and the geologic setting."
Beyond Design Basis Event (BDBE)	Less than once every 1 million years	Not Applicable (N/A)

The frequency ranges shown above for each DBE category correlate with the probability-based definitions from the proposed 10 CFR 63.2 (Dyer 1999b), adjusted for the 100-year preclosure period (Assumption 5.2). For example, an event that has a 1/10,000 probability of occurring before permanent closure (Category 2 DBE definition), which is assumed to be 100 years, has a lower cutoff frequency of 1/10,000 ÷ 100 years, or 10^{-6} per year. For Category 1 DBEs, the event frequency is based on the probability that an event will occur at least once before permanent closure and an assumed preclosure period of 100 years (Assumption 5.2), or 10^{-2} per year (i.e., 1/100 years). Events expected to occur less than once per million years are categorized as Beyond Design Basis Events (BDBEs).

6.1 External Design Basis Event Selection

External events, including natural phenomena, that could potentially occur at the MGR and lead to a radioactive release were selected and screened using the methodology described in this section.

Potential external initiating events considered in this analysis are based on the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c, Section 7.1.3) and *Screening of External Events for DBE Analysis* (CRWMS M&O 1999c)**(TBV-1348)**. These events were reviewed in conjunction with the reference VA design (DOE 1998a, Section 4). In addition, the external event and/or accident analysis sections from the following sources were reviewed for completeness:

- *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste* (10 CFR 72)
- *Design Criteria for an Independent Spent Fuel Storage Installation* (ISFSI)*(Dry Type)* (ANSI/ANS 1992)
- *Standard Review Plan for Spent Fuel Dry Storage Systems* (NRC 1996a)
- *Standard Review Plan for Dry Cask Storage Systems* (NRC 1997)
- *Waste Isolation Pilot Plant (WIPP) Safety Analysis Report* (DOE 1997b)
- *Safety Evaluation Report for the Prairie Island Independent Spent Fuel Storage Installation* (NRC 1993a)
- *Rancho Seco Independent Spent Fuel Storage Installation (ISFSI): Revision 1 to the Rancho Seco Independent Spent Fuel Storage Installation License Application and Safety Analysis Report.* (NRC 1993b)
- *The Safety Analysis Report for the INEL TMI-2 Independent Spent Fuel Storage Installation* (INEL 1996)

Subpart F of *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste* (10 CFR 72) contains general design criteria and prescribes the overall requirements that a storage site must satisfy in order to be licensed. These requirements include protection against extreme environmental conditions, natural phenomena, fires, and explosions.

Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type) (ANSI/ANS 1992) contains the standard design criteria for an independent spent fuel dry storage installation. This standard defines design events and the general conditions of design for SSCs of a spent fuel storage installation.

Chapter 12 of *Standard Review Plan for Spent Fuel Dry Storage Systems* (NRC 1996a) contains NRC guidance for protection against environmental conditions and natural phenomena. Section 12.3 states that "SSCs important to safety must be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lightning, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform safety functions."

Chapter 2 of *Standard Review Plan for Dry Cask Storage Systems* (NRC 1997) presents design basis events which could significantly effect structures, systems and components important to safety.

The *Waste Isolation Pilot Plant (WIPP) Safety Analysis Report* (DOE 1997b) presents the design criteria and requirements for the receiving, handling, and emplacement of transuranic waste. These requirements include protection against extreme weather, flooding, seismic activity, and fires.

The remaining sources reviewed are safety evaluation reports (SERs) or safety analysis reports (SARs) for Independent Spent Fuel Storage Installations (ISFSIs) at the Northern States' Prairie Island nuclear power plant (NRC 1993a), the Sacramento Municipal Utility District's Rancho Seco site (NRC 1993b), and the Idaho National Engineering Laboratory ISFSI for Three Mile Island Unit-2 fuel (INEL 1996), respectively.

Based upon review of the above-listed documents, the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c, Section 7.1.3), the MGR design, and *Screening of External Events for DBE Analysis* (CRWMS M&O 1999c), it was concluded that the potential external events and natural phenomena listed in Table 3 below would be the starting point for additional screening in this analysis.

Table 3. Potential External Events and Natural Phenomena

1.	Debris Avalanching
2.	Extreme Wind
3.	Floods (storm, river diversion)
4.	Industrial Activity - Induced Accident
5.	Landslide
6.	Lightning
7.	Loss of Off-site/On-site Power
8.	Military Activity - Induced Accident
9.	Seismic Activity, Earthquake
10.	Seismic Activity, Surface Fault Displacement
11.	Seismic Activity, Subsurface Fault Displacement
12.	Tornado

6.1.1 Screening of External Events

The first step was to establish a set of screening criteria that would identify the bounding external events to be considered in detailed design basis event analyses for the MGR. Once established, the screening criteria were applied to the list of events in Table 3.

The following screening criteria were used in this analysis:

- The event will be eliminated if the phenomena does not exist at the MGR site.
- The event will be screened out if it is included in the analysis of another event.
- The event will be screened out if its effects are bounded by the effects of another credible event of similar nature.
- The event will be screened out if its initiating frequency is determined to be less than 1×10^{-6} per year.

6.1.2 Events Screened Out from Additional Analysis

Table 4 lists the three (3) events from Table 3 that were screened out from additional analysis based on the criteria identified in Section 6.1.1. The purpose of this screening analysis is to identify the preliminary bounding design basis external events and natural phenomena that will establish design criteria for the MGR. A detailed discussion of each event is provided in the subsections that follow Table 4 (note that Industrial and Military Accidents are discussed in the same subsection due to similarities).

Table 4. External Events Screened Out from Additional Analysis

Event	Location	Rationale	Discussion Section
Lightning	Surface Facilities	Lightning is addressed as an initiating event for the "Loss-of-Offsite Power" event (Section 6.1.3.1). *DBE/Scenario Analysis for Preclosure Repository Subsurface Facilities* (CRWMS M&O 1997a, p. 87) concluded that a release scenario associated with a direct lightning strike on a WP transporter is beyond design basis.	6.1.2.1
Industrial Activity-Induced Accident	Surface Facilities	An evaluation is in progress to identify potential hazards in the vicinity of the proposed repository site from industrial or military activity-induced accidents. NUREG-0800 (NRC 1987, Sections 2.2.1.III.1 and 2.2.2.III.1) states that all identified facilities and activities within five miles of the plant should be reviewed and facilities at greater distances may be considered if they have the potential to affect facility safety-related features. The preliminary results from the analysis in progress indicate that there are no credible industrial/military activity-induced event sequences that could cause a radiological release at the MGR.	6.1.2.2
Military Activity-Induced Accident	Surface Facilities	Same rationale as Industrial Activity-Induced Accident	6.1.2.2

6.1.2.1 Lightning

Event Description: Lightning is a large-scale high-tension natural electric discharge in the atmosphere. When lightning strikes a building, a transporter, or an electrical component, the consequences may be a localized temperature increase, a loss-of-offsite power, or a short circuit. In addition, a lightning strike may initiate a fire.

Screening Rationale: Lightning will be analyzed as a potential initiator for a loss-of-offsite power event and an internal fire. The analysis for the loss-of-offsite power event is discussed in Section 6.1.3.1 and the fire event is discussed in Section 6.2.5.1. Analysis of lightning-initiated event sequences in these sections is expected to demonstrate that there are no credible release scenarios that result from a lightning strike.

The potential for lightning to initiate a radionuclide release scenario associated with the WP and WP transporter was analyzed in CRWMS M&O 1997a (pp. 86-87). That analysis concluded that the frequency of such a release scenario is beyond design basis, based on the areal strike frequency, transporter exposure time, and exposure area.

6.1.2.2 Industrial/Military Activity-Induced Accident

Event Description: This event involves potential hazards in the vicinity of the proposed repository site resulting from industrial or military activity-induced accidents that are not under direct control of the MGR operations. Military activities which must be evaluated include, but are not limited to, weapons testing, planned explosions and ordnance dropped from military aircraft. Also included in this category of events are activities related to potential future uses of the Nevada Test Site, such as commercial, rocket-launched satellites. This event excludes aircraft crashes, which are screened out from further consideration based on *Screening of External Events for DBE Analysis* (CRWMS M&O 1999c).

Screening Rationale: NUREG-0800 (NRC 1987) was used to determine guidelines for use in screening this event. NUREG-0800 (Sections 2.2.1.III.1 and 2.2.2.III.1) states that all identified facilities and activities within five miles of the plant should be reviewed. Facilities and activities at greater distances may be considered if they have the potential for affecting MGR SSCs important to safety.

Because the proposed repository site is currently located on land within federal control, it is anticipated that the land withdrawal area will exceed the five mile radius criterion and no non-repository facilities or activities will be allowed within this area. The potential for objects to be dropped from military aircraft flying in the vicinity of the surface facilities is currently being analyzed. The analysis in progress also addresses military and industrial facilities and activities at distances beyond five miles. These include activities ongoing or planned at the Nevada Test Site, transportation-related activities, and commercial activities such as mining in the region. However, due to the remoteness of the site, no impact to the MGR is anticipated.

6.1.3 Preliminary External DBEs

The events listed in Table 5 are the remaining external initiating events that could not be eliminated by the screening criteria in Section 6.1.1. Events which are similar in nature have been grouped together (see Event Group column of Table 5) for evaluation purposes.

The external events and natural phenomena in Table 5 are currently considered credible initiating events that could potentially lead to a radiological release. The general MGR strategy for external DBEs, which is based on nuclear facility licensing precedence, is to design the SSCs important-to-safety to withstand these events, such that a radiological release scenario (e.g., earthquake resulting in a canister drop, breach and radionuclide release) that exceeds regulatory dose limits is beyond design basis.

Table 5. External Events and Natural Phenomena Subject to Additional Analysis

External Event or Natural Phenomena	Event Group
1. Debris Avalanching	Flood
2. Extreme Wind	Tornado Wind
3. Flooding (storm, river, diversion)	Flood
4. Landslide	Flood
5. Loss of Off-site/On-site Power	Loss-of-Offsite Power
6. Seismic Activity, Earthquake	Earthquake – Vibratory Ground Motion
7. Seismic Activity, Surface Fault Displacement	Earthquake – Fault Displacement
8. Seismic Activity, Subsurface Fault Displacement	Earthquake – Fault Displacement
9. Tornado	Tornado Missiles and Tornado Wind

Table 6 contains the preliminary list of external DBEs, the initiating event frequency category, and potential design features to prevent or mitigate the event. The bases for the initiating event frequency categories are described in the discussion sections cited in Table 6. The potential design features discussed in Table 6 and the sections that follow are based on the current MGR design, best-available information, and discussions with MGR Surface and Subsurface Design. However, it should be noted that not all of these features are included in the current VA design (DOE 1998a). The design features discussed herein are presently not design requirements – they are potential design solutions that are subject to change as the MGR design matures.

Table 6. Preliminary External DBEs

Design Basis Event	Location	Initiating Event Frequency Category†	Potential Design Features‡	Discussion Section
Loss-of-Offsite Power	Surface and Subsurface Facilities	1	Primary: • Protect against initiators of loss-of-offsite power event, including lightning strike • Emergency backup power system Defense-In-Depth: • Heating, ventilation and air conditioning (HVAC) confinement – High efficiency particulate air (HEPA) filters in hot cells • Incorporate fail-safe design features on cranes and lifting machines	6.1.3.1
Earthquake - Vibratory Ground Motion	Surface and Subsurface Facilities	1, 2	Primary: • Design SSCs important to safety to withstand the applicable design basis earthquake (Frequency-Category-1 or Frequency-Category-2) Defense-In-Depth: • Seismically qualify other SSCs not important to safety	6.1.3.2
Earthquake - Fault Displacement	Surface and Subsurface Facilities	1, 2	Primary: • Avoid "Type I" faults when practicable in designing the layout, placement and operation of SSCs important to safety. Defense-In-Depth: None	6.1.3.3
Flood	Surface and Subsurface Facilities	2	Primary: • SSCs important to safety are either protected from floods, landslides, and debris avalanches, or designed to withstand the static and dynamic loadings caused by the probable maximum flood Defense-In-Depth: • Procedures to suspend operations in the event of extreme weather/rainstorm • Installation of underground utilities • Hardened buildings	6.1.3.4
Tornado Missiles	Surface Facilities	2	Primary: • Design important to safety SSCs to withstand the impact of tornado-generated missiles Defense-In-Depth: • Administrative controls to suspend operations in the event of tornado or extreme weather warning • Installation of underground utilities • Hardened buildings	6.1.3.5

Table 6. Preliminary External DBEs (Continued)

Design Basis Event	Location	Initiating Event Frequency Category†	Potential Design Features‡	Discussion Section
Tornado Wind	Surface Facilities	2	Primary: • Design important-to-safety SSCs to withstand the impact of tornado wind loadings Defense-In-Depth: • Administrative controls to suspend operations in the event of tornado or extreme weather warning • Installation of underground utilities • Hardened buildings	6.1.3.6

† For external events, the initiating event (e.g., earthquake) frequency is considered instead of the event sequence (e.g., earthquake→waste form breach→radiological release) frequency.

‡ Potential design features are not necessarily reflective of the current design concept.

6.1.3.1 Loss-of-Offsite Power

Event Description: This event results in the total loss of external AC power, short term and long term, to the MGR. This event is postulated to occur as a result of an external event (e.g., lightning) or an internal event (e.g., a fire in the WHB, or random equipment failure). A Loss-of-Offsite Power event will, at a minimum, temporarily halt the receiving and transferring of waste.

Technical Strategy: Loss-of-Offsite Power events at the MGR are assumed to occur one or more times during the preclosure operations (Assumption 5.7). Therefore, Loss-of-Offsite Power is a Category 1 initiating event. The strategy for this event is to prevent credible release scenarios by design. MGR SSCs important to safety will be designed to fail safe during a Loss-of-Offsite Power event. Important-to-safety cranes may also be designed in accordance with NUREG-0554 (NRC 1979) to preclude single point failures.

Emergency backup power sources and redundant off-site power lines/sources may be used to ensure continuous power is supplied to SSCs important to safety. The MGR design may also include features such as external lightning rods to protect against a lightning-initiated Loss-of-Offsite Power event.

6.1.3.2 Earthquake - Vibratory Ground Motion

Event Description: This is a natural event involving trembling and shaking of the earth due to the shifting of tectonic plates. It is defined by a fraction of gravitational acceleration and design response criteria. This event can potentially impact SSCs in the surface and subsurface facilities and lead to a radiological release. The possible consequences of this event include a collapse of structures, concrete cracking, loss-of-offsite power, ground displacement, and subsurface rockfall.

Technical Strategy: The safety strategy for the surface facilities is to design the SSCs important to safety to withstand the effects of a design basis earthquake (DBEQ). *DOE Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (DOE 1997a, p.3-1) defines two DBEQ categories: Frequency-Category-1 (recurring frequency of 1.0×10^{-3} per year) and Frequency-Category-2 (recurring frequency of 1.0×10^{-4} per year). The 10,000 year return period for the Category-2 DBEQ is conservatively based on the mean annual probability of exceeding the safe shutdown earthquake (2.0×10^{-4}) at licensed commercial nuclear power plants in the western U.S. (DOE 1997a, pp.3-4 and 3-5).

Future classification analyses will establish which DBEQ category is appropriate for designing SSCs that are determined to be important to safety (e.g., Frequency-Category-2 for the Waste Handling Building Ventilation System). Development of seismic design criteria for each DBEQ category will be documented in the third seismic topical report (DOE 1997a, p. iii). *DOE Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (DOE 1997a) also invokes NUREG-0800 (NRC 1987, Sections 3.7.1, 3.7.2, 3.7.3, and 3.10) for guidance and potential use in repository seismic design.

For defense-in-depth, SSCs not important to safety (but important for other reasons such as operational throughput or cost) may also be designed to withstand the Frequency-Category-1 or Frequency-Category-2 DBEQ.

6.1.3.3 Earthquake - Fault Displacement

Event Description: A fault displacement is a fracture or a zone of fractures along which there is potential for displacement of the sides relative to one another, parallel to the fracture. Because several faults intersect the designated repository area, this event is applicable to Yucca Mountain.

Technical Strategy: *DOE Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (DOE 1997a, p. 4-3) stipulates that fault avoidance is the preferred approach to mitigating fault displacement hazards. Furthermore, a hazard is judged to be significant when an explicit fault displacement design may be necessary to accommodate the hazard. Conversely, the hazard is judged to be negligible – and fault avoidance is deemed to have been achieved – when the hazard is so low that there is clearly no need for the SSC in question to have an explicit fault displacement design (DOE 1997a, p. 4-3). Faults that are capable of impacting the design of an SSC are defined as Type I faults – those "*subject to displacement and of sufficient length and located such that they may affect repository design and/or performance*" of SSCs important to safety, containment, or waste isolation (CRWMS M&O 1998g, p. A-1).

The primary fault displacement engineering concern for an emplaced WP is shear loading by the displaced drift walls. However, analysis in *Waste Package Design Basis Events* (CRWMS M&O 1997c, p. 32) concluded that shear loading of the WP by fault displacement is not a credible event.

6.1.3.4 Flood

Event Description: An external flood may be initiated by intense precipitation, runoff, landslide, avalanche, or storm surge. Floods can potentially produce heavy loads on buildings, WPs, or transporters containing WPs. The consequences of a design basis flood are expected to bound the rainstorm, landslide, and debris avalanche events identified in the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c, Section 7.1).

Technical Strategy: The primary safety strategy for the design basis flood event is to preclude a radiological release by placement, layout and design of the surface facilities. The Waste Handling Building (WHB), Waste Treatment Building (WTB), and Carrier Preparation Building (CPB) will be designed to withstand the probable maximum flood (PMF); all other surface facilities will be designed to withstand the 100-year flood, based on standard industrial design practice (CRWMS M&O 1998d, p. 8). In addition, the WHB, WTB and CPB structures will be designed to withstand the roof loads resulting from 24 hours of rainfall associated with the 100-year flood. Since the return period of the design basis flood is 100 years, the design basis flood is a borderline Category 2 initiating event.

The North Portal site is adjacent to Midway Valley Wash, which is estimated to receive 9-12 feet of water during a PMF with a 2-times bulking factor (CRWMS M&O 1998d, p. 8). The North Portal is located above the maximum probable flood elevation to ensure that subsurface SSCs important to safety are not impacted by the PMF. The 24-hour rainfall associated with the 100-year flood is 2.6 inches (CRWMS M&O 1998d, p. 8).

For defense-in-depth, the following surface facility characteristics and/or design features may also be used for flood protection:

- "Hardened" foundations and structures
- Sandbags, flood doors & bulkheads
- WHB hot cells located within interior walls
- Administrative controls to suspend operations during such an event

6.1.3.5 Tornado Missiles

Event Description: This event involves the impact of a tornado-generated missile on the MGR.

Technical Strategy: The primary safety strategy is to preclude a radiological release by designing the important to safety SSCs that are potentially vulnerable to a tornado missile to withstand the design basis tornado.

SSCs that are vulnerable to tornado missile impact must either be protected from the missiles, designed to withstand a missile impact, or shown to not interact with a missile based on probabilistic analysis. The WP transporter must be designed to not overturn or allow penetration that could breach a WP as a result of the impact of a tornado missile. In addition, the surface facility foundations and structures must be designed to protect the wasteforms inside.

Sections 3.5.1.4 and 3.5.2 of NUREG-0800 (NRC 1987) provide NRC guidance on missiles generated by natural phenomena and externally-generated missiles, respectively. The design basis tornado (missile spectrum) criterion for missile size, weight, and impact velocity (horizontal and vertical) are to be determined **(TBD-414)**. As noted in the Tornado Wind event (Section 6.1.3.6), the design basis tornado is a Category 2 DBE.

Potential defense-in-depth safety strategy features could include administrative controls to suspend operations in the event of a tornado warning or extreme weather conditions, hardened buildings, and the installation of underground utilities.

6.1.3.6 Tornado Wind

Event Description: Tornado winds are high winds generated during a tornado. This event is associated only with the effects produced by these winds (i.e., pressure drop and wind loading). Extreme wind is defined as the 100-year wind with a duration of 6 hours (CRWMS M&O 1996c, Section 7.1.3.10). The extreme wind, "fastest mile" wind, and "basic" wind criteria (discussed below) are all bounded by the design basis tornado wind for Yucca Mountain (PNL 1986, p. 51). The consequence of this event will be a pressure load on the surface facilities, WP transporter, and transportation cask surfaces.

Technical Strategy: Important-to-safety SSCs that are potentially vulnerable to a tornado will be designed to withstand the static loading and pressure drops associated with the design basis tornado. This strategy includes designing the WP transporter to prevent a transporter tipover or derailment accident due to tornado wind conditions.

The following NRC documents related to design basis tornadoes will be considered in the MGR design process:

- Regulatory Guide 1.76, *Design Basis Tornado for Nuclear Power Plants* (NRC 1974)
- Regulatory Guide 1.117, *Tornado Design Classification* (NRC 1978)
- NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition* (NRC 1987), Sections 2.3.1 (*Regional Climatology*), 3.3.1 (*Wind Loadings*), and 3.3.2 (*Tornado Loadings*)
- NUREG/CR-4461, *Tornado Climatology of the Contiguous United States* (PNL 1986).

The design basis tornado wind criterion, including wind velocity, pressure drop, and rate of pressure drop are to be determined **(TBD-415)**. This event is a Category 2 initiating event based on data presented in *Tornado Climatology of the Contiguous United States* (PNL 1986, p. 51). The design basis tornado wind for the Yucca Mountain region is 189 mph, with a 10^{-6} probability of occurrence and a 90% strike probability confidence interval (PNL 1986, p. 51). This wind speed bounds both the 100-year return period "Fastest Mile" wind (100-year, 1-minute gust) referenced in NUREG-0800 (NRC 1987, Section 2.3.1) and the "Basic" wind (50-year, 3-second gust) calculated from methodology in ANSI/ASCE 7.95 (ANSI/ASCE 1996, p. 13).

As with the tornado-generated missile event, potential defense-in-depth safety features to protect against tornado winds may include administrative controls to suspend operations in the event of a tornado warning or extreme weather conditions, hardened buildings, and the installation of underground utilities.

6.2 Internal Design Basis Event Selection

Internal event sequences were postulated based on a review of the preliminary internal events identified in the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c, Section 7.2.3), as modified by Assumption 5.11. Whereas the *Preliminary MGDS Hazards Analysis* (PHA)(CRWMS M&O 1996c) is based on the *Mined Geologic Disposal System Advanced Conceptual Design (ACD)*(CRWMS M&O 1996a), the event screening in this analysis is based on the MGR reference design identified in *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a).

The PHA (CRWMS M&O 1996c, Section 3) used a systematic methodology to evaluate potential generic hazards with respect to the MGR design. The output from the PHA, relative to internal events, was a list of preliminary hazards for each functional area of the repository that could potentially lead to a radiological release (CRWMS M&O 1996c, Section 7.2.3). The screening process for identifying bounding DBEs in this analysis assumed the preliminary hazards (events) from the PHA as a starting point, including the additional events listed in Assumption 5.11 **(TBV-1347)**, and evaluated sequences of events that could potentially result in a radiological release. The following sections discuss the methodology used to evaluate, screen and group the internal events considered in this analysis.

Figure 2 graphically illustrates the decision process for binning DBEs by frequency and consequence.

6.2.1 Frequency Assessment of Internal Events

Event sequence frequencies were not explicitly calculated in this analysis. Rather, event frequencies from previous DBE calculations (CRWMS M&O 1998c) and analyses (CRWMS M&O 1997a and CRWMS M&O 1997c) were used as applicable. Frequencies were used to bin event sequences into either Category 1 or Category 2. Internal events with a scenario frequency less than once per million years are considered to be "Beyond Design Basis Events" (per Table 2) and screened out from further consideration.

A complete frequency and consequence analysis of internal events that could potentially result in a radiological release (Table 7) will be performed in subsequent analyses. In the follow-up work, fault tree and event tree techniques will be used to develop potential sequences of events, including sequence probabilities and consequences. From these event sequences, Category 1 and Category 2 events can be segregated and appropriately evaluated. Once categorized and quantified, the bounding event sequences (from an off-site dose perspective) for Category 1 and Category 2 can be determined. These will be the DBEs that are evaluated in the LA, and which provide the basis for classifying SSCs as important-to-safety.

Beyond design basis event sequences that rely on facility SSCs to achieve their low frequency of occurrence can also provide the basis for classifying SSCs as important-to-safety. For example, if a "two-block" crane drop having consequences that exceed the off-site dose limit is normally a Category 2 event, but is reduced to a BDBE by taking credit for design features that prevent "two-blocking," the crane and/or components that are relied on may be classified as important-to-safety. BDBE sequences that fall into this category are identified in Table 10.

In event sequences where the conditional probability of HVAC failure is considered, conservative values of 2.5×10^{-5} and 4.8×10^{-4} were used for the HVAC unavailability in the primary and secondary confinement zones, respectively (CRWMS M&O 1998c, Section 2.2.9). A more recent calculation, *Reliability Assessment of Waste Handling Building HVAC System*, which is based on the WHB HVAC design for VA, concludes that the probability of an unfiltered release from a primary confinement area is 1.72×10^{-7} (CRWMS M&O 1999b, p. 19). In this analysis, the more conservative values were used to evaluate event sequence frequencies including HVAC failure, consistent with the *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Section 2.2.9).

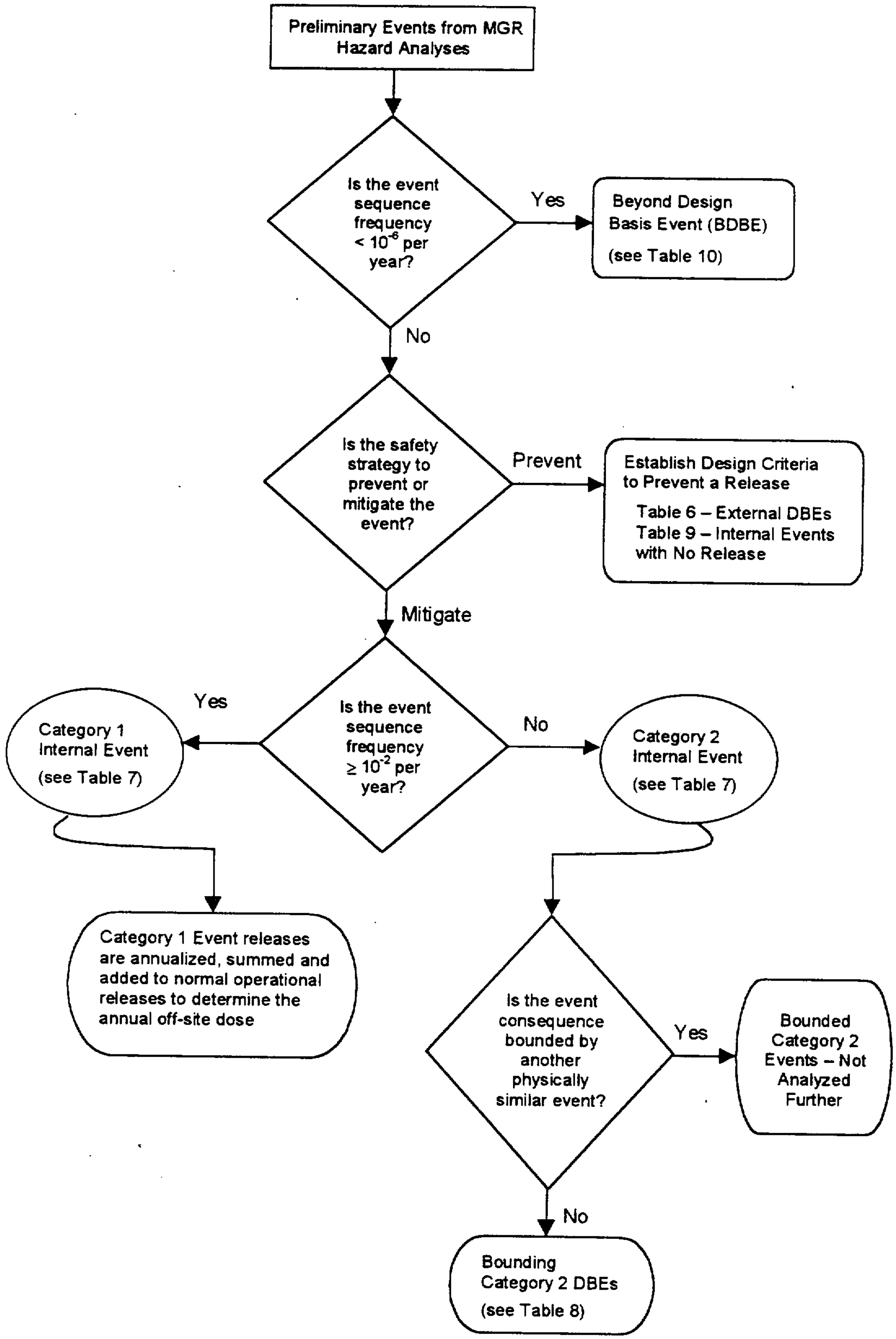

Figure 2. DBE Decision Flowchart

6.2.2 Consequence Assessment and Grouping of Internal Events

Consequences for most internal event sequences were evaluated quantitatively in the *Preliminary Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c). In cases where events had not been quantitatively evaluated by previous calculations and analyses, event consequences were qualitatively analyzed by comparison with similar events. Bounding DBEs are considered by this analysis to be those event sequences that result in the maximum radiological consequences to a member of the public at the preclosure controlled area boundary, for a group of similar events. Collectively, the design basis events establish constraints or limits on the facility design to ensure that the facility SSCs will perform their intended function during a design basis event, and that any radiological releases are within the regulatory limits specified by 10 CFR 63.111 (Dyer 1999b).

Internal event sequences were screened into one of the following three groups based on their frequency of occurrence and potential to result in a radiological release:

1. Internal Events with Potential Releases – These events could potentially result in a release of radioactivity and, therefore, will be mitigated by the facility design. Internal events with potential radiological releases (either Category 1 or Category 2 events) are identified in Table 7 and discussed in Section 6.2.3. These events were grouped by similar waste form (i.e., shipping cask, spent fuel assembly, canister or disposal container) and location. The events with bounding off-site dose consequences (shown as bold in Table 7) are identified as bounding events in Table 8 and discussed in Section 6.2.3.2.

2. Internal Events with No Release – These events will be prevented by design, such that no radiological release will occur. In this case, design features function to either prevent the event sequence from occurring or to prevent a release, should the event occur. Design features to prevent the event sequence can either physically prevent the event from occurring (e.g., use of passive design features or process controls such as eliminating cask/canister lifts) or reduce the event sequence frequency below the credible cutoff frequency of 10^{-6} per year (e.g., use of active design features such as redundant cranes and control systems). Design features that prevent a release are based on the premise that credible events will occur and that affected SSCs must be designed to protect the wasteform from releasing radioactivity during such an event. Prime examples of this include the WP DBEs, which establish design bases for the WP to ensure that the WP will not breach as a result of credible DBEs. The preclosure safety analysis for LA will ensure that the original assumptions and design constraints (e.g., maximum drop heights, equipment dimensions, WP mass, etc.) relative to these events are still valid for the final LA design. These events are identified in Table 9 and discussed in Section 6.2.4.

3. Beyond Design Basis Events – BDBEs that have the potential to exceed off-site dose limits and that credit facility SSCs for their low frequency of occurrence are identified in Table 10.

Internal events (Category 1 and 2) with potential releases are listed in Table 7 below.

Table 7. Internal Events with Potential Releases

Event Group	Event Number - Design Basis Event[a]	Location	Scenario Frequency Category[b]
Shipping Cask-Related	**(1)-Shipping Cask Drop (no impact limiters)**	**Carrier Bay**	**2**
	(2)-Shipping Cask Tipover/Slapdown (no impact limiters)	Carrier Bay	2
	(3)-Shipping Cask Drop into Cask Preparation Pit	**Cask Preparation Pit**	**2**
	(4)-Shipping Cask Drop into Cask Unloading Pool	**ATS Pool**	**2**
Spent Fuel Assembly (SFA)-Related	SFA Events:		
	(5)-SFA drop onto Pool Floor	ATS Pool	1
	(6)-SFA drop onto another SFA in Pool Staging Rack	ATS Pool	1
	(7)-SFA Collision	ATS Pool or Hot Cell	1
	(8)-Handling Equipment Drops onto SFA	ATS Pool or Hot Cell	2
	(9)-SFA Drop onto Hot Cell Floor	ATS Hot Cell	1
	(10)-SFA drop into empty DC	ATS Hot Cell	1
	(11)-SFA drop onto another SFA in DC or dryer	ATS Hot Cell	1
	SFA Basket Events:		
	(12)-SFA Basket Drop Onto Pool Floor	ATS Pool	1
	(13)-SFA Basket Collision	ATS Pool or Hot Cell	1
	(14)-Uncontrolled Descent of Loaded Incline Basket Transfer Cart	ATS Pool	1
	(15)-SFA Basket Drop Onto Hot Cell Floor	ATS Hot Cell	1
	(16)-Handling Equipment Drops Onto SFA Basket	ATS Pool or Hot Cell	2
	(17)-SFA Basket Drop Onto Another SFA Basket in Dryer	**ATS Hot Cell**	**2**
Canister-Related	**(18)-Canister Drop onto Floor**	**Canister Transfer System (CTS) Hot Cell**	**2**
	(19)-Handling Equipment Drop onto Canister		2
	(20)-Canister Tipover/Slapdown	CTS Hot Cell	2
	(21)-Canister Drop onto Sharp Object	CTS Hot Cell	2
	(22)-Canister Drop onto Disposal Container	CTS Hot Cell	2
	(23)-Canister Collision	CTS Hot Cell	2
	(24)-Small Canister Drop onto Another Small Canister	CTS Hot Cell Canister Staging Rack	2
DC/WP-Related	**(25)-Unsealed DC Drop and Slapdown**	**DC Hot Cell**	**2**
	(26)-Handling Equipment Drop onto Unsealed DC	DC Hot Cell	2
	(27)-Unsealed DC Tipover/Slapdown	DC Hot Cell	2
	(28)-Preclosure "Early Failure" of a WP	**Subsurface**	**2**

(a) Credible events (Category 1 or 2) with bounding off-site dose consequences, for each location, are shown in **bold-face type**.
(b) Scenario frequencies are based on frequency analysis from *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository* (CRWMS M&O 1998c, Section 6).

6.2.3 Internal Events with Potential Releases

Events which could potentially occur and result in a release of radioactivity were evaluated in this section. Events were first grouped by the waste container (e.g., shipping cask, bare spent fuel assembly, canister, DC or WP) and then by location. Events involving the same container but different locations are considered separately. Events that are estimated to result in the largest off-site dose (for a physically similar group of events) and, therefore, establish the basis for design criteria are identified as bounding DBEs.

Frequency categories for most events shown in Table 7 are based on the *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Attachments II-V). For events not specifically evaluated in CRWMS M&O 1998c (e.g., SFA basket collision), event frequencies were based on a qualitative comparison with similar events in the same functional location, having the same or similar fuel handling rates.

6.2.3.1 Category 1 DBEs

Category 1 DBEs are those event sequences expected to "occur one or more times before permanent closure of the geologic repository operations areas," per 10 CFR 63.2 (Dyer 1999b). All of the Category 1 events identified in Table 7 are internal events that occur during handling of bare commercial spent fuel assemblies (SFAs) or SFA baskets in the Assembly Transfer System (ATS). Each of these events are postulated to occur in either a primary (e.g., ATS Hot Cell) or secondary (e.g., ATS Pool) HVAC confinement zone with HEPA filtration (CRWMS M&O 1998c, p. 11) functional during the event.

In accordance with 10 CFR 63.111 (Dyer 1999b), Category 1 DBEs (including normal operation releases) must meet the annualized (rem per year) dose limit of 25 mrem to any real member of the public located beyond the preclosure controlled area boundary. As such, the annual release due to all Category 1 events must be combined with normal operation releases for comparison to the limits. From a consequence perspective, the Category 1 events in the ATS are bounded by the Category 2 event involving a SFA basket drop onto another SFA basket in the assembly dryer.

Category 1 event dose calculations to determine compliance with the 10 CFR 63.111 (Dyer 1999b) dose criteria were not performed in this analysis. The MGR design for the ATS shall ensure that the annualized (sum of all Category 1 events and normal operations) off-site dose to the public is below 25 mrem/year. The ATS design should incorporate defense-in-depth features to the extent practical to minimize the frequency of Category 1 events and/or mitigate the consequences. For example, the consequences of underwater drops and collisions can be mitigated by the pool water, which acts to cushion the impact and confine the release of radionuclide particulates. For defense-in-depth, single-failure-proof cranes, the site radiological monitoring system, the ATS decontamination system, waste handling control systems, and facility administrative controls may be credited to minimize or mitigate Category 1 events.

<u>Single SFA Events</u>: Bare, unconfined SFAs are individually handled underwater, during transfer from the cask to the ATS wet staging rack, and in a dry environment during transfer from the ATS dryer to the DC.

While underwater, SFAs can potentially be dropped or impacted as a result of mechanical failure or control system failure of the Wet Assembly Transfer Machine, or as a result of operator error. These events occur in the ATS pool area, which is a secondary confinement zone with HEPA filtration.

During transfer from the ATS Dryer to the DC, individual SFAs can potentially be dropped or impacted as a result of mechanical failure or control system failure of the Dry Assembly Transfer

Machine, or as a result of operator error. These events occur in the ATS Hot Cell, which is a primary confinement zone with HEPA filtration.

SFA Basket Events: SFA baskets are handled underwater during transfer out of the wet staging rack and into the incline transfer cart. From there, the SFA baskets are transported out of the pool, via the Inclined Transfer Canal, and into the Assembly Drying Station, where up to six SFA baskets may be loaded into each of the two assembly dryers.

SFA baskets can potentially be dropped or impacted in the pool during transport up the Inclined Transfer Canal as a result of mechanical failure or control system failure of the transfer canal/transfer cart, or operational error. In addition, SFA baskets can potentially be dropped or impacted onto the floor or into one of the assembly dryers as a result of mechanical failure or control system failure of the Dry Assembly Transfer Machine, or operational error. These events (except for the drop back into the pool) occur in the ATS Hot Cell, which is a primary confinement zone with HEPA filtration.

6.2.3.2 Bounding Category 2 DBEs

This section describes in further detail the bounding Category 2 events from Table 7 (bounding events are highlighted in bold). Each bounding event, including the primary preclosure safety strategy and potential defense-in-depth features to mitigate the events, are discussed in Table 8 and the subsections that follow. It can be reasonably stated that if the facility is designed to prevent or mitigate the bounding Category 2 DBEs in Table 8, the facility will be adequately designed to prevent or mitigate the other (non-bold-face type) Category 2 DBEs listed in Table 7 and ensure that off-site doses are kept within the allowable limits.

These events and strategies are based on best available information to date. In some cases there are alternative design strategies that could provide the same end result – a facility design that ensures public and worker safety, and meets the applicable dose limits for worker and public safety prescribed in 10 CFR 63 (Dyer 1999b). One example is the spent fuel assembly basket drop event (occurs in a hot cell), in which HEPA filtration is the primary strategy to ensure compliance with radiological limits. There may be other more effective design solutions that prevent, minimize or mitigate the event. The preclosure safety strategies, like the DBEs, are subject to change as the design process evolves and additional design detail becomes available.

The potential defense-in-depth features identified in Table 8 and the following subsections are also subject to change, and by no means represent a comprehensive list of potential design features. The features identified are assumed to provide defense-in-depth for radiological safety, but may be essential to satisfy other goals such as maximizing throughput, minimizing total lifecycle cost, minimizing worker exposures for event recovery and/or ALARA, or minimizing facility downtime for event recovery. Administrative controls and operational procedures are not specifically identified for each event in Table 8, but are expected to be implemented prior to the operational phase of the MGR. Trade studies and design analyses are currently ongoing to assess potential design alternatives and determine the optimal facility design for meeting safety requirements and balancing other factors such as cost, throughput and maintainability.

Table 8. Bounding Category 2 Events

Event Group	Design Basis Event	Location	Mitigation Features	Discussion Section
Shipping Cask-Related	# 2-01 Shipping Cask Drop (no impact limiters)	Carrier Bay	Primary: Cask Containment (Option-1 or Option-3) [see Section 6.2.3.2.1 for Options 1-3] - Prevent drops or other impacts which exceed cask's certified design bases Defense-In-Depth: - HVAC confinement (Option-2) - Shock absorbing floor	6.2.3.2.1
	# 2-02 Shipping Cask Drop into Cask Preparation Pit	ATS Cask Preparation Pit	Primary: HVAC Confinement Defense-In-Depth: - Do not completely unbolt the lid - Shock absorbing floor in pit - Design features/solutions to prevent or minimize drops (e.g., standardized grapples) - Redundant controls and/or cable restraints	6.2.3.2.2
	# 2-03 Shipping Cask Drop into Cask Unloading Pool	ATS Cask Unloading Pool	Primary: HVAC Confinement Defense-In-Depth: - Pool designed to withstand the impact of the maximum load that could potentially drop into the pool, per ANSI/ANS 57.7 (ANSI/ANS 1988, pp. 2-8). - Design features/solutions to prevent or minimize drops (e.g., standardized grapples) - Redundant controls and/or cable restraints - Operator training and procedures	6.2.3.2.3
Spent Fuel Assembly (SFA)-Related	# 2-04 SFA Basket Drop onto Another SFA Basket	ATS Dryer	Primary: HVAC confinement Defense-In-Depth: - Design features/solutions to prevent or minimize drops (e.g., standardized grapples, redundant cables, physical restraints, etc.). - Controlled load path. - Administrative controls. - Operator training and procedures.	6.2.3.2.4
Canister-Related	# 2-05 Canister Drop onto Floor	CTS Hot Cell	Primary: Canister Containment Defense-In-Depth: - HVAC confinement. - Design solutions to prevent impacts exceeding canister design bases.	6.2.3.2.5
Disposal Container (DC)-Related	# 2-06 Unsealed DC Drop and Slapdown	DC Hot Cell	Primary: HVAC confinement Defense-In-Depth: - Design features/solutions to prevent dropping unsealed DCs. - Design features to prevent radiological release.	6.2.3.2.6
Waste Package (WP)-Related	# 2-07 Preclosure "Early Failure" of a WP	Subsurface	Primary: Radiological monitoring system Defense-In-Depth: - WP confinement. - Quality controls on WP manufacturing, welding & inspection. - Subsurface ventilation system.	6.2.3.2.7

6.2.3.2.1 DBE 2-01: Shipping Cask Drop (no impact limiters)

Event Description: A shipping cask without impact limiters is dropped by the Carrier Bay bridge crane from the normal handling height of 4 meters (Assumption 5.12)**(TBV-1212)** onto the floor of the Carrier Bay. It is assumed that a HEPA-filtered ventilation system is not present in the design and thus unavailable to mitigate potential releases (Assumption 5.9).

Sources: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Table 6.1-1, Events CH07 and CH43).

Note: The referenced source for this event identified the two-block drop of a 61-BWR cask and a 26-PWR cask as bounding Category 2 internal events for the Carrier Bay (CRWMS M&O 1998c, Table 6.1-1, Events CH10 and CH46). However, this analysis assumes that all potential two-block drop events will be shown by analysis to be beyond design basis (Assumption 5.8) (**TBV-1340**). Refer to Section 6.2.5.3 for information on the two-block cask drop.

Technical Strategy: To establish a safety strategy, it is necessary to determine the design bases of the shipping casks that will be handled at the MGR **(TBD-416)**. If it is decided that requirements will not be imposed on cask vendors and that the MGR will accept any of the shipping casks currently licensed by the NRC, then design of the cask handling system must ensure that casks are not vulnerable to events (e.g., drops) that exceed their certified design bases (*Option-1*). This scenario would be representative of a preventive strategy to ensure that casks do not breach as a result of credible design basis events. An alternative approach is to allow casks to breach, but design the facility to mitigate the release such that off-site dose limits are not exceeded (*Option-2*). Another alternative strategy is to provide design requirements on both the shipping casks and the waste handling facilities that will achieve a balance between cask design/facility design and ensure that casks do not breach as a result of credible design basis events (*Option-3*). Options 1 and 3 are both consistent with the *Strategy to Mitigate Preclosure Off-Site Exposure* (CRWMS M&O 1998f) which recommends a safety strategy of primary containment by the transportation cask. Each option is discussed below.

Option-1: This option assumes that cask designs are fixed and the MGR must accept all NRC-licensed casks (Assumption 5.14). In this case, the primary safety strategy is to design the surface facilities to prevent cask drops or other energetic events that exceed the cask's certified design bases. Design basis impacts for shipping casks are TBD **(TBD-416)**. Design features such as shock-absorbing floors and recessed receiving bays could be incorporated to reduce impact forces or limit cask lift heights, respectively. HVAC confinement may be provided for defense-in-depth.

Note: The design basis drop heights for casks currently in use are unknown and not disclosed in the applicable safety analysis reports.

Option-2: This option assumes that a cask drop and breach that results in radioactive release is a credible design basis event (Assumption 5.15). In this case, the primary safety strategy is to perform all cask handling operations in an area with HVAC confinement and design the HVAC system to mitigate the maximum radiological releases that could occur.

For defense-in-depth, cranes and lifting fixtures may be designed to NUREG-0554 (NRC 1979) or other crane-related codes and standards, as appropriate.

Option-3: Under this option, MGR designers would work in concert with the cask manufacturers to determine acceptable facility/cask designs and ensure that credible cask drop events will not result in breach of the casks. HVAC confinement may be provided for defense-in-depth.

The shipping cask drop (no impact limiters) bounds the radiological consequences of the cask tipover/slapdown event in the Carrier Bay.

6.2.3.2.2 DBE 2-02: Shipping Cask Drop into Cask Preparation Pit

Event Description: A shipping cask, without impact limiters and with the lid unbolted, is dropped from a normal lift height of 6 meters (Assumption 5.12)**(TBV-1212)** into the Cask Preparation Pit in the ATS Pool Area, with HEPA filters available.

Source: N/A - Event has not been analyzed.

Technical Strategy: The primary safety strategy is to confine particulate releases within the Waste Handling Building using HEPA filters.

The defense-in-depth strategy is to prevent cask drops by providing design features that prevent or minimize drops (e.g., limit switches, interlocks, redundant control circuitry and/or cable restraints) or reduce the impact of a drop (e.g., shock absorber at base of pit). Administrative controls and procedures may also be employed to prevent the cask lid from being completely unbolted during the lift out of the Cask Preparation Pit and into the Unloading Pool.

This is the only credible event in the ATS Cask Preparation area that is expected to result in a radiological release.

6.2.3.2.3 DBE 2-03: Shipping Cask Drop into Cask Unloading Pool

Event Description: A shipping cask is dropped by the cask bridge crane approximately 15 meters into the ATS cask unloading pool, with HEPA filters available (Assumption 5.12)**(TBV-1212)**.

Source: ANSI/ANS 57.7, *Design Criteria for an Independent Spent Fuel Storage Installation (Water Pool Type)* (ANSI/ANS 1988, pp. 2-8).

Technical Strategy: The primary strategy is to confine potential radiological particulates in the pool water. To achieve this, the pool will be designed in accordance with ANSI/ANS 57.7 (ANSI/ANS 1988) which includes, among others, the following design requirements to prevent damage to the pool liner and/or a loss of pool water:

- "The cask unloading pool shall be designed such that a dropped cask shall not impact on stored fuel or result in a loss of functional integrity." (ANSI/ANS 1988, Section 6.1.2.2)

- "The fuel unit storage pool shall be designed to withstand, without loss of functional integrity, the impact of the maximum load over the pool, dropped into the pool from the highest position attainable by the load." (ANSI/ANS 1988, Section 6.1.2.3)

- "The design should include a system of gates between adjacent pools so that any one pool may be isolated from the other pools in order to minimize the spread of contaminants in case of an accident in one pool, or a pool may be emptied without affecting the water level in adjacent pools." (ANSI/ANS 1988, Section 6.1.2.4)

- "...There shall be no permanently installed piping which could serve as a syphon to lower the water level below the minimum level [for proper shielding]." (ANSI/ANS 1988, Section 6.1.2.6)

- "...Means shall be provided for detection and control of leakage from the pools." (ANSI/ANS 1988, p. 7, Para. 6.1.4)

- "The fuel unit storage racks shall be designed for the design earthquake." (ANSI/ANS 1988, Section 6.2.2.2)

- "The crane structures and their support systems shall be designed to withstand all design loadings including the Design Earthquake, while remaining in place...[and] not result in a loss of load incident." (ANSI/ANS 1988, Section 6.4.2.5)

For defense-in-depth, particulate mitigation in the ATS pool area is provided by the secondary HVAC confinement ventilation system. Analysis may also show that a radiological release is improbable because the maximum potential impact forces resulting from a cask drop into the pool are insufficient to cause a breach of the cask and/or spent fuel rod cladding.

This is the only credible event in the ATS Cask Unloading Pool that is expected to result in a radiological release.

6.2.3.2.4 DBE 2-04: SFA Basket Drop onto Another SFA Basket

Event Description: A SFA basket is dropped by the assembly transfer machine onto another SFA basket in the ATS drying vessel, with HEPA filters available. For this event to occur, two concurrent failures are required: (1) control system failure or operator error results in the Dry Assembly Transfer Machine suspending a basket above another basket, and; (2) mechanical failure or operator error results in a drop of the suspended basket onto another basket in the assembly dryer. This event sequence is credible and in the Category 2 frequency range due to the large number of assembly baskets that are handled at the MGR in any given year.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Table 6.3-1).

Note: In CRWMS M&O 1998c (Table 6.3-1, ATS001 & ATS003), the ATS event with bounding dose consequences is a 4-PWR basket drop onto another 4-PWR basket. This event was conservatively identified as a Category 1 event based on limited available information. The re-classification of this event in this analysis, from Category 1 to

Category 2, was based on a more realistic interpretation of the ATS design, which credited the function of the control system to prevent an assembly basket from travelling over or being suspended above another basket in the assembly dryer.

Technical Strategy: The primary safety strategy is to confine particulate releases to within the Waste Handling Building using HEPA filters. This event results in the bounding dose consequence for the ATS.

The defense-in-depth strategy is to provide design features (e.g., limit switches, interlocks, redundant controls, redundant cables, physical restraints, etc.) that lower the probability of a radiological release. Other credible SFA-related events, shown in Table 7, are bounded by the consequences of this event, but may provide a basis for unique defense-in-depth design features. These events include:

- SFA drop onto pool floor
- SFA drop onto another SFA in pool staging rack
- SFA collision
- Handling equipment drop onto SFA
- SFA drop onto hot cell floor
- SFA drop into empty DC
- SFA drop onto another SFA in DC or dryer
- SFA basket drop onto pool floor
- SFA basket collision
- Uncontrolled descent of loaded incline basket transfer cart
- SFA basket drop onto hot cell floor
- Handling equipment drop onto SFA basket

6.2.3.2.5 DBE 2-05: Canister Drop onto Floor

Event Description: A disposable canister is dropped by the CTS bridge crane onto the floor of the CTS hot cell, with HEPA filters available. The drop height for this event is the normal handling height in the Canister Transfer Cell.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, p. 37).

Note: The referenced source for this event identified the normal drop of a multi-canister overpack (MCO) containing N-Reactor fuel and the two-block drop of a CSNF canister (multipurpose canister (MPC) with 44-BWR assemblies) as the bounding Category 2 internal events for the CTS (CRWMS M&O 1998c, Table 6.2-1, CTS-107 and CTS-006). However, this analysis assumes all potential two-block drop events will be shown by analysis to be beyond design basis (Assumption 5.8) (**TBV-1340**). It is also noted that the preliminary DBE calculations (CRWMS M&O 1998c) did not evaluate the consequences of canisters containing DOE spent nuclear fuel (other than the MCO). Refer to Section 6.2.5.11 for information on the two-block canister drop.

Technical Strategy: The primary safety strategy is to prevent canister breaches by ensuring that the design basis handling constraints of the canister are not exceeded by the handling system. This may be accomplished by designing the canisters to withstand the maximum credible drops at the MGR, by providing facility design features (e.g., single-failure-proof crane, limit switches, interlocks, redundant controls, physical restraints, etc.) that prevent canisters from being impacted beyond their design bases, or by providing design features that reduce the scenario frequency of a canister breach to beyond design basis (i.e., less than 10^{-6} per year). To ensure that a canister will not breach as a result of potential handling events, it is necessary to determine the design basis impact loads for the following canister events:

- End drop **(TBD-417)**
- Side drop **(TBD-417)**
- Edge drop followed by slapdown **(TBD-417)**

The defense-in-depth strategy is to confine particulate releases within the Waste Handling Building using HEPA filters. Other credible canister-related events, shown in Table 7, are bounded by the consequences of this event, but may serve as a basis for unique defense-in-depth design features. These events include:

- Handling equipment drops onto a canister
- Canister tipover/slapdown
- Canister drop onto a sharp object
- Canister drop onto DC
- Canister collision
- Small canister drop onto another small canister

6.2.3.2.6 DBE 2-06: Unsealed DC Drop and Slapdown

Event Description: A loaded, unsealed DC is dropped by the DC bridge crane onto a welding fixture, staging fixture, or onto the DC Tilting Station. After dropping, the DC is postulated to slap down onto the floor and spill its contents, with functional HEPA filters available to mitigate the release. The drop height for this event is the normal handling height in the DC Handling Cell.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, p. 29).

Note: The referenced source for this event identified the vertical DC drop from the two-block height (6 m) as the bounding Category 2 internal event for the DC Handling System (CRWMS M&O 1998c, Table 6.4-1, Event DC-01). However, this analysis assumes that all potential two-block drop events will be shown by analysis to be beyond design basis (Assumption 5.8) **(TBV-1340)**. Refer to Section 6.2.5.13 for information on the two-block DC/WP drop.

Technical Strategy: The primary safety strategy is to confine particulate releases within the Waste Handling Building using a HEPA-filtered ventilation system. This event results in the bounding credible dose consequence for the DC Handling System.

The defense-in-depth strategy is to provide design features (e.g., single-failure-proof crane, limit switches, interlocks, redundant controls, redundant cables, physical restraints, etc.) that prevent unsealed DC drops or minimize radiological releases from such an event. Other credible DC-related events, shown in Table 7, are bounded by the consequences of this event, but may serve as a basis for unique defense-in-depth design features. These events include:

- Handling equipment drop onto unsealed DC
- Unsealed DC tipover/slapdown
- Preclosure "early" failure of a WP

6.2.3.2.7 DBE 2-07: Preclosure "Early Failure" of a WP

Event Description: An emplaced WP breaches during the preclosure phase due to a manufacturing defect or improper weld, combined with failure to detect the defect, corrosion, or a combination thereof. The breached WP is postulated to release its gaseous and volatile radionuclide contents to the subsurface environment.

Source: This event has not been analyzed.

Technical Strategy: Although this event has not been analyzed, it is expected to result in negligible consequences to subsurface workers or to the public at the preclosure controlled area boundary. The primary safety strategy is to confine radioactive particulates within the WP and demonstrate by analysis that potential radiological releases (gases and volatiles) will result in negligible doses that are well within the limits established by 10 CFR 63.111 (Dyer 1999b).

In all likelihood, the probability of any release due to this event is very low. In addition to the WP breach, a fuel rod cladding breach within the WP would also have to occur between the time that the WP was sealed and closure of the repository (Note: A fuel rod cladding breach that occurs prior to WP sealing would have already resulted in release of the fission product gasses and volatiles to the environment). This event is expected to occur gradually over time and, therefore, would not possess the energy to drive out the radioactive particulates within the WP. In addition, the breach is expected to be similar to a pinhole leak and the pressure build-up within the WP during the preclosure phase is expected to be minimal.

6.2.4 Internal Events with No Release

Internal events in this category are not expected to result in a radiological release because they are prevented by design (i.e., either the event sequence frequency is less than 10^{-6} per year, or the event is insufficient to cause a release because the appropriate SSCs have been designed to withstand the event). Since the design features for preventing these events are design specific (e.g., WP design bases were based on evaluation of the *Mined Geologic Disposal System (MGDS) Functional Analysis Document* [CRWMS M&O 1996b]), these events will be carried forward and re-evaluated as the MGR design matures to ensure that the original assumptions and inputs are valid. Table 9 includes a summary of these events and the applicable preclosure safety strategy or design bases.

Bounding, credible Waste Package DBEs for the surface and subsurface, shown in Table 9, were evaluated in *Waste Package Design Basis Events* (CRWMS M&O 1997c, p. 68) and

DBE/Scenario Analysis for Preclosure Repository Subsurface Facilities (CRWMS M&O 1997a, pp. 197-199), respectively. For a list of other WP events that were considered and found to be bounded, refer to CRWMS M&O 1997c (Table 7.3-1, pp. 64-66). The bounding Waste Package DBEs may be updated, as necessary, to reflect the repository design and waste package design dimensions (CRWMS M&O 1998a, p. 3) as the design matures. As a result, all criteria that are associated with WP DBEs are identified as TBV **(TBV-245)** until the calculations to support the final LA design are performed and the TBV data/parameters can be verified.

Table 9. Internal Events with No Release

Event Group	Design Basis Event	Location	Preclosure Safety Strategy	Discussion Section
Shipping Cask-Related	Cask Carrier/Railcar Accident (with impact limiters)	Between Fence and Carrier Preparation Building (CPB)	Rely on robust shipping cask design in accordance with 10 CFR 71. Design features to prevent and/or mitigate this event include: • Impact limiters • Speed controls • Redundant brake system	6.2.4.1
	Shipping Cask Collision (no impact limiters)	CPB, Carrier Bay, or En-Route Between	Prevent or minimize collisions by use of design features and administrative controls: • Speed controls on cranes and transfer carts • Procedures and training	6.2.4.2
	Handling Equipment Drops onto Cask (no impact limiters)	CPB or Carrier Bay	Cask handling system will be designed not to exceed the design constraints of the cask.	6.2.4.3
	Shield Door Closes on Cask	ATS or CTS Airlock	Cask handling system will be designed not to exceed the design constraints of the cask.	6.2.4.4
	Cask Cooldown System Overpressurization	ATS Cask Preparation Pit	Prevent cask overpressurization with design features and administrative controls. • Pressure regulators, sensors & guages • Electronic and manual pressure relief valves • Procedures & training	6.2.4.5
SFA-Related	Flooding Due to Uncontrolled Pool Water Fill/Draindown	ATS Pool & Surrounding Area	Prevent flooding with administrative controls and design features such as flow meters and shutoff valves.	6.2.4.6
Canister-Related	None	N/A	N/A	N/A
DC-Related	System Generated Missile Impacts DC	DC Hot Cell	Design facility to prevent pressure missiles that could breach a DC. DC (WP) designed to withstand the impact of a 0.5 kg missile traveling at 5.7 m/s.	6.2.4.7
	Unsealed DC Collision	DC Hot Cell or DC Staging Area	Insufficient energy to cause a release; prevent or minimize collisions by use of design features and administrative controls: • Speed controls on cranes and transfer carts • Operator procedures and training	6.2.4.8
	Shield Door Closes on DC	DC Hot Cell	Insufficient energy to cause a release.	6.2.4.9

Table 9. Internal Events with No Release (Continued)

Event Group	Design Basis Event	Location	Preclosure Safety Strategy	Discussion Section
DC-Related (continued)	*** Deleted ***	N/A	N/A	6.2.4.10
	Welding Burnthrough	DC Hot Cell	Prevent welding burnthrough with design, process, and administrative controls: • Electronic and manual shutoff switches • Limit exposure time (turntable and/or welding robot) Operator procedures and training	6.2.4.11
WP – Surface	Falling Objects – End Impact	DC Hot Cell	WP design basis established to withstand 2.3 MT object falling 2-m onto end without breaching WP.	6.2.4.12
	WP Vertical Drop or End Collision	DC Hot Cell	WP design basis established to withstand 2-m end drop without breaching.	6.2.4.13
	WP Horizontal Drop or Side Collision	WP Transfer/Decon	WP design basis established to withstand 2.4-m side drop without breaching.	6.2.4.14
	WP Tipover and Slapdown	DC Hot Cell	WP and/or facility design bases established to withstand a tipover from vertical position and slapdown onto unyielding surface without breaching. Design features include restraints on carts and fixtures to prevent tipovers.	6.2.4.15
	Seismic-Initiated Tipover	DC Hot Cell	WP design basis established to maintain structural integrity and prevent tipover for peak horizontal and peak vertical ground accelerations for the design basis earthquake.	6.2.4.16
	Pressurized System Missile	DC Hot Cell	Design facility to prevent a missile that could breach a WP. WP designed to withstand the impact of a 0.5-kg missile travelling at 5.7 m/s.	6.2.4.17
	WP Fire	DC Hot Cell	Demonstrate by Fire Hazards Analysis (FHA) that fire cannot cause a radiological release. WP designed to withstand 30 min. exposure to heat flux not less than radiation environment of: • 800°C • Emissivity coefficient of at least 0.9 • Surface absorptivity of at least 0.8 Convective heat transfer rate of still air @ 800°C	6.2.4.18
WP – Subsurface	Uncontrolled Transporter Descent	Subsurface North Ramp	Design and demonstrate by analysis that the frequency of an uncontrolled descent and subsequent WP breach is below 10^{-6} per year.	6.2.4.19
	WP Horizontal Drop onto Sharp Object (Puncture Hazard)	Subsurface Emplacement Drift	WP design basis established to withstand either a 1.93-m horizontal drop onto a WP support or a 2.4-m horizontal drop onto a pier, whichever is worse, without breaching	6.2.4.20
	Fuel Rod Rupture/Internal Pressurization	Subsurface Emplacement Drift	WP designed to withstand pressure due to 100% rod breach @ gas temperature of 500°C, with safety factor of 1.5.	6.2.4.21

6.2.4.1 Cask Carrier/Railcar Accident (with impact limiters)

Event Description: A carrier or railcar carrying shipping casks derails and impacts the shipping casks.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent a cask breach by cask design and use of impact limiters. This event is not expected to result in a radiological release because a) shipping casks are designed to withstand normal and hypothetical accident conditions during transportation, per 10 CFR 71 (§71.71 and §71.73, respectfully), b) the cask impact limiters will not yet have been removed and, c) the travel speed between the fence and the CPB will be much less than that experienced during transportation. Additional design controls to mitigate this event may include operational speed limits, electronic speed controls, and redundant braking systems.

6.2.4.2 Shipping Cask Collision (no impact limiters)

Event Description: A shipping cask without impact limiters collides with a wall, shield door, another cask or other heavy object in the CPB, Carrier Bay, or between the CPB and the Carrier Bay.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent or minimize the consequences of cask collisions by use of speed controls on cranes and transfer carts, operator training and procedural controls.

6.2.4.3 Handling Equipment Drops onto Cask (no impact limiters)

Event Description: A lifting yoke or crane fixture falls on the cask in the CPB or Carrier Bay.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to design the cask handling system such that a credible handling equipment drop onto a cask will not breach the cask. This event is not expected to result in a radiological release because shipping casks are designed to withstand the following hypothetical accident conditions per 10 CFR 71.73(c), which are judged to be more restrictive than a heavy object falling on a cask in the CPB or Carrier Bay:

> "(1) Free Drop. A free drop of the specimen through a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.
>
> (2) Crush. Subjection of the specimen to a dynamic crush test by positioning the specimen on a flat, essentially unyielding, horizontal surface so as to suffer maximum damage by the drop of a 500-kg (1100 pound) mass from 9-m (30 ft) onto the specimen. The mass must consist of a solid mild steel plate 1 m (40 in) by 1 m and must fall in a horizontal attitude. The crush test is required only when the specimen has a mass not greater than 500 kg (1100 lbs), an overall density not greater than 1000 kg/m3 (62.4 lbs/ft^3) based on external

dimensions, and radioactive contents greater than 1000 A2 not as special form radioactive material.

(3) Puncture. A free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 in), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical."

6.2.4.4 Shield Door Closes on Cask

Event Description: A shield door closes on the cask in the ATS or CTS airlock.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent a cask breach by designing the cask handling system not to exceed the design basis constraints of the cask. For example, the shield doors may be designed to retract in the event of contact with a cask.

6.2.4.5 Cask Cooldown System Overpressurization

Event Description: An uncontrolled, pressurized release occurs from a shipping cask, while being cooled in the Cask Preparation Pit, prior to placement into the Cask Unloading Pool.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent cask overpressurization by use of design features (e.g., pressure guages, electronic/manual pressure relief valves) and administrative controls (e.g., procedures and training).

6.2.4.6 Flooding Due to Uncontrolled Pool Water Fill/Draindown

Event Description: Failure of the pool system to control the filling or draining of the ATS pool results in flooding of the surrounding areas and potential radiological exposure of workers.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent flooding, the spread of radioactive contaminants, and direct radiation to workers (loss of shielding) by designing the pool system to prevent such events from occurring. Although, it is assumed that this is a credible Category 2 event, there is not expected to be any off-site release; any radioactive contaminants generated by this event would be bound to the water and confined within the Waste Handling Building.

6.2.4.7 System Generated Missile Impacts DC

Event Description: See "Pressurized System Missile" event in Section 6.2.4.17.

6.2.4.8 Unsealed DC Collision

Event Description: An unsealed, fully loaded DC collides with a wall, shield door, another DC, or other heavy object in the DC Hot Cell or DC Staging Area.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent or minimize the consequences of an unsealed DC collision by use of speed controls on cranes and transfer carts, operator training and procedural controls.

6.2.4.9 Shield Door Closes on DC

Event Description: A shield door closes on the DC in the ATS Decon Cell or the CTS loading cell.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent a fuel cladding or canister breach by relying on the robust DC design to absorb the maximum impact of a shield door inadvertently closing on a DC. Although the DC is not permanently sealed in this event, the spent fuel assemblies or canisters contained inside the DC are not expected to be impacted. Consequently, this event is not expected to result in a radiological release.

6.2.4.10 Not Used.

6.2.4.11 Welding Burnthrough

Event Description: The DC inner lid is burned through and the enclosed spent fuel is damaged during the DC inner lid welding operation.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, p. 29).

Technical Strategy: The primary strategy is to prevent a welding burnthrough by incorporating design, process and administrative controls on the welding process. Such controls may include:

- Welding process that is physically incapable of burnthrough
- Limit exposure time (e.g., use turntable or CNC welding robot)
- Operator controls & training
- Electronic and manual shutoff switches
- Detailed work instructions

Design controls will ensure that the frequency of occurrence for this event is estimated to be less than 10^{-6} per year, making it beyond design basis. This event was initially postulated due to the use of a laser welder to weld the DC lid. However, non-laser welding processes can be used that physically preclude the occurrence of this event.

6.2.4.12 Falling Objects – End Impact

Event Description: A large, heavy object falls onto a horizontally-oriented WP on the surface.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 38-39).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand a 2.3 MT object falling 2m onto its end without breaching **(TBV-245)**. These design criteria are based on the largest potential mass that could fall onto a WP from the greatest potential height in the subsurface.

6.2.4.13 WP Vertical Drop or End Collision

Event Description: A loaded WP is dropped by the DC bridge crane vertically onto end or has an end-collision with an unyielding object in the DC Cell or WP Transfer/Decon area.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, p. 41).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand an end drop from the maximum normal lift height, 2m **(TBV-245)**, without breaching. This design criteria is based on the maximum height the shortest WP can fall in the WHB.

6.2.4.14 WP Horizontal Drop or Side Collision

Event Description: A loaded WP is dropped by the WP Horizontal Lift System onto its side or has a side-collision with an unyielding object in the WP Transfer/Decon area.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 41-43).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand a 2.4m **(TBV-245)** side drop without breaching. This design criteria is based on the maximum height the WP can fall from a horizontal position at the WP Transfer/Decon station.

6.2.4.15 WP Tipover and Slapdown

Event Description: A loaded WP tips over from the vertical position and slaps down onto its side in the DC Cell.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, p. 44).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand a tipover and slapdown onto the floor without breaching **(TBV-245)**.

6.2.4.16 Seismic-Initiated Tipover

Event Description: A seismic event causes a loaded WP to tipover from the vertical position and slap down onto its side in the DC Cell.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 31-32).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP and facility to withstand a design basis earthquake without tipping over **(TBV-245)**. Internal events (e.g., drops and tipovers) that are initiated by an external design basis event such as an earthquake or loss-of-offsite power will be prevented by designing ITS SSCs to withstand the external DBE. Credible external DBEs are identified in Table 6 and discussed in Sections 6.1.3.1 through 6.1.3.6.

6.2.4.17 Pressurized System Missile

Event Description: An internal system-generated missile impacts a WP in the WP Decontamination area.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 50-51).

Technical Strategy: The primary strategy is to design the facility to prevent system missiles that could breach a WP.

The WP is designed to withstand the impact of a 0.5 kg missile travelling at 5.7 m/s **(TBV-245)**. This design criteria is based the maximum velocity of a 0.5 kg valve stem at a pressure of 2.1 MPa. This event was postulated to occur with CO_2 decontamination equipment during decontamination of the WP. Design controls for the WHB and Waste Treatment Building (WTB) will ensure that only low to moderate pressure gas systems will be used, which do not have the potential to generate a missile that could breach a WP.

6.2.4.18 WP Fire

Event Description: A WP is exposed to fire in the DC Handling Cell.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 52-55).

Technical Strategy: The primary strategy is to prevent fires from occurring. A detailed fire hazards analysis of the MGR will establish the appropriate design criteria to prevent or mitigate fires in the Waste Handling Building (WHB) (see Section 6.2.5.1) and ensure that a fire-initiated release scenario is beyond design basis (Assumption 5.5) **(TBV-688)**.

The WP is designed to withstand the fire specified in 10 CFR 71.73 for transportation cask accidents, including (see Assumption 5.13):

- Exposure of WP to heat flux of 800°C radiation environment for 30 minutes **(TBV-245)**
- Emissivity coefficient of at least 0.9 **(TBV-245)**
- Surface absorptivity of at least 0.8 **(TBV-245)**
- Convective heat transfer rate of still air @ 800°C **(TBV-245)**

For defense-in-depth, additional design features may be provided to mitigate the fire or protect the WP in case a fire does occur.

6.2.4.19 Uncontrolled Transporter Descent

Event Description: A human failure and/or mechanical control failure to limit the transporter speed below the maximum speed limit results in a transporter derailment and WP impact at the bottom of the North Ramp.

Sources: *Waste Package Design Basis Events* (CRWMS M&O 1997c), *DBE Scenario Analysis for Preclosure Repository Subsurface Facilities* (CRWMS M&O 1997a, pp. 98-109).

Technical Strategy: The primary strategy is to design the Subsurface Transportation System to prevent a high-speed, uncontrolled transporter descent that could impact and breach a WP. If the event cannot be prevented (i.e., demonstrated to have a frequency of occurrence less than 10^{-6} per year), design features will be incorporated to ensure that a WP breach is not possible.

Analysis in *Waste Package Design Basis Events* (CRWMS M&O 1997c, p. 49) estimated that the transporter could attain a maximum velocity of approximately 63 km/hr **(TBV-245)** if loss of control occurred at the top of the North Ramp and the transporter was allowed to coast unimpeded down the entire length (2250 m) of the North Ramp. The Uncontrolled Transporter Descent is potentially the most energetic event associated with the transporter. Other transporter events such as a "WP rail car rolling out of the transporter" and a "Transporter Derailment" were considered in establishing the WP design bases and, therefore, have insufficient energy to breach a WP (CRWMS M&O 1997c, Sections 7.2.2.2.3 and 7.2.2.4.2).

6.2.4.20 WP Horizontal Drop onto Sharp Object (Puncture Hazard)

Event Description: A horizontal, loaded WP falls onto a steel support in the emplacement drift or onto a emplacement drift pier.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 43-44).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand the more limiting of a 1.93m **(TBV-245)** drop onto a steel WP support or a 2.4m **(TBV-245)** drop onto a emplacement drift pier. These design criteria are based on potential hazards identified during review of the *MGDS Advanced Conceptual Design* (CRWMS M&O 1996a) and the *Waste Handling Systems Configuration Analysis* (CRWMS M&O 1997b), and an estimate of the maximum WP drop heights in the subsurface emplacement drift.

6.2.4.21 Fuel Rod Rupture/Internal Pressurization

Event Description:. The failure of multiple fuel rods inside a WP pressurizes the WP.

Source: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 56-57).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand the maximum potential internal pressure that would result from the highly unlikely event of a rupture of 100% of the fuel rods in a WP containing 21-PWR or 44-BWR commercial SFAs. The maximum internal pressure, including a safety factor of 1.5, for a 21-PWR and 44-

BWR WP at 500°C gas temperature is 1.01 and 0.72 MPa, respectively **(TBV-245)** (CRWMS M&O 1997c, Table 7.2.2.7-1, p. 57).

6.2.5 Beyond Design Basis Events

Beyond design basis events (BDBEs) are those internal event sequences that could potentially have consequences that exceed the 10 CFR 63.111 off-site dose limits but are expected to occur less than once per million years (i.e., frequency<10^{-6} per year). This section of the analysis considers event sequences that have been intentionally designed to have a beyond design basis frequency as opposed to a natural event such as a meteorite impact that is expected to occur less than once per million years at the Yucca Mountain Site (CRWMS M&O 1996c, p. 27). This section focuses on event sequences that would be Category 2 events if the initiating event results in a release. These events have been reduced to BDBEs by incorporating design features, physical barriers, administrative controls, or a combination thereof to ensure that the sequence of events necessary to result in a radiological release is beyond design basis (i.e., less than 10^{-6} per year). For example, a SFA basket drop onto another basket (e.g., with a drop frequency of 10^{-3} drops/year) followed by failure of the HVAC system to mitigate the release (e.g., probability=10^{-4}) represents an event sequence that is beyond design basis (i.e., scenario frequency of an unmitigated release is 10^{-3} drops/year x 10^{-4} = 10^{-7}/year)(see Assumption 5.16). Table 10 and the subsections that follow identify the BDBEs considered in this analysis.

Table 10. Beyond Design Basis Events

Event Group	Event†	Location	Section Discussed
Fire	Fire in Surface Facilities	Waste Handling Building or Waste Treatment Building	6.2.5.1
	Fire in Subsurface Facilities	Subsurface	6.2.5.2
Shipping Cask-Related	Two-Block Shipping Cask Drop (no impact limiters), No Filtration	Carrier Bay	6.2.5.3
	Cask Drop into Cask Preparaton Pit, No Filtration	ATS Cask Preparation Pit	6.2.5.4
	Diesel Fire/Explosion	Outside CPB	6.2.5.5
Spent Fuel Assembly (SFA)-Related	SFA Basket Drop onto Another SFA Basket, No Filtration	ATS Dryer	6.2.5.6
	Catastrophic Pool Failure	ATS Pool	6.2.5.7
	Criticality Event in Pool	ATS Pool	6.2.5.8
	Loss of Pool Water Resulting in Zircaloy Cladding Fire	ATS Pool	6.2.5.9
	Cladding Failure in the ATS Dryer	ATS Dryer	6.2.5.10
Canister-Related	Two-Block Canister Drop	CTS Hot Cell	6.2.5.11
	Criticality Associated with Small Canister Staging Rack	CTS Hot Cell	6.2.5.12

Table 10. Beyond Design Basis Events (Continued)

Event Group	Event†	Location	Section Discussed
DC/WP-Related	Two-Block DC/WP Drop	DC Hot Cell	6.2.5.13
	Unsealed DC Drop (from normal handling height) onto Hot Cell Floor, No Filtration	DC Hot Cell	6.2.5.14
	DC/WP Preclosure Criticality	ATS Hot Cell	6.2.5.15
	Rockfall Exceeding WP Design Basis (Falling Objects – Side Impact)	Subsurface	6.2.5.16

† Unless "No Filtration" is denoted, HEPA filters are assumed to be available in the event sequence

6.2.5.1 Fire in Surface Facilities

Event Description: A fire starts inside the Waste Handling Building or Waste Treatment Building and results in failure of safety systems necessary to prevent or contain the release of radioactivity.

Source: N/A – Fire Hazards Analyses for the Waste Handling Building and Waste Treatment Building are due to be completed in FY99 by Surface Design

Technical Strategy: The primary strategy is to prevent fires by minimizing the use of combustibles, fuel sources and ignition sources in the Waste Handling Building and Waste Treatment Building. A fire-initiated event sequence that results in the release of radioactivity is assumed to be beyond design basis (i.e., frequency of occurrence less than 10^{-6} per year)(Assumption 5.5)**(TBV-688)**.

For defense-in-depth, fire-prevention and/or mitigation design features may be incorporated to detect and suppress fires if they occur.

6.2.5.2 Fire in Suburface Facilities

Event Description: A fire starts in the subsurface and results in failure of safety systems necessary to prevent or contain the release of radioactivity.

Source: N/A – Fire Hazards Analysis for the Subsurface facilities is expected to be completed in FY00 by Subsurface Design.

Technical Strategy: The primary strategy is to prevent fires by minimizing the use of combustibles, fuel sources and ignition sources in the subsurface. A fire-initiated event sequence that results in the release of radioactivity is expected to be beyond design basis (i.e., frequency of occurrence less than 10^{-6} per year) (Assumption 5.5)**(TBV-688)**.

For defense-in-depth, the WP is designed to withstand a fire similar to that required by 10 CFR 71.73 for transportation casks (see Section 6.2.4.18). In addition, fire-prevention and/or mitigation design features may be incorporated to detect and suppress fires if they occur.

6.2.5.3 Two-Block Shipping Cask Drop (no impact limiters), No Filtration

Event Description: The Carrier Bay bridge crane drops a shipping cask from the two-block position (above the design basis drop height), resulting in breach of a cask. It is assumed that a HEPA-filtered ventilation system is not present in the design and thus unavailable to mitigate the release (Assumption 5.9).

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Table 6.1-1).

Technical Strategy: The primary safety strategy is to ensure by design (e.g., incorporation of single-failure-proof and redundant safety features) and verify by fault-tree analysis that the frequency of this sequence of events is beyond design basis (i.e., less than 10^{-6} per year)(Assumption 5.8)**(TBV-1340)**.

6.2.5.4 Cask Drop into Cask Preparation Pit, No Filtration

Event Description: A shipping cask, without impact limiters and with the lid unbolted, is dropped from a normal lift height of 6 meters into the Cask Preparation Pit in the ATS Pool Area (Assumption 5.12)**(TBV-1212)**, with HEPA filters unavailable. In normal operating circumstances, primary reliance is placed on the availability of the HEPA-filtered ventilation system and on the ventilation system's ability to function and mitigate the release of particulates to the environment. In this scenario, the conditional probability of failure of the ventilation system is included in the scenario frequency.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary safety strategy is to ensure by design and verify by fault-tree analysis that the frequency of this sequence of events is beyond design basis (i.e., less than 10^{-6} per year).

The defense-in-depth strategy is to prevent cask drops by providing design features that prevent or minimize drops (e.g., limit switches, interlocks, redundant control circuitry and/or cable restraints) or reduce the impact of a drop (e.g., shock absorber at base of pit). Administrative controls and procedures may also be employed to prevent the cask lid from being completely unbolted during the lift out of the Cask Preparation Pit and into the Unloading Pool.

6.2.5.5 Diesel Fire/Explosion

Event Description: A diesel-powered site prime mover or truck carrying shipping casks explodes or catches on fire.

Source: N/A – Event has not been analyzed.

Technical Strategy: 10 CFR 71.73(c) criteria (see Section 6.2.4.3) are intended to prevent a cask breach in transportation-related fires. The primary strategy is to prevent a diesel fire/explosion by limiting the available ignition sources and protecting the fuel sources to the extent practical (e.g., lightning rods on nearby buildings and physical separation from potential internal ignition sources).

6.2.5.6 SFA Basket Drop onto Another SFA Basket, No Filtration

Event Description: A SFA basket is dropped by the assembly transfer machine onto another SFA basket in the ATS drying vessel, with HEPA filters unavailable. For this event sequence to occur, three concurrent failures are required: (1) control system failure or operator error results in the Dry Assembly Transfer Machine suspending a basket above another basket; (2) mechanical failure or operator error results in a drop of the suspended basket onto another basket in the assembly dryer; and (3) the HEPA-filtered ventilation system is unavailable on demand.

In normal operating circumstances, primary reliance is placed on the availability of the HEPA-filtered ventilation system and on the ventilation system's ability to function and mitigate the release of particulates to the environment. In this scenario, the conditional probability of failure of the ventilation system is included in the scenario frequency.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Table 6.3-1).

Technical Strategy: The primary safety strategy is to ensure by design and verify by fault-tree analysis that the frequency of this sequence of events is beyond design basis (i.e., less than 10^{-6} per year) (Assumption 5.16).

The defense-in-depth strategy is to provide design features (e.g., limit switches, interlocks, redundant controls, redundant cables, physical restraints, etc.) that prevent or minimize drops.

6.2.5.7 Catastrophic Pool Failure

Event Description: Catastrophic failure of the pool liner results in in controlled draining of the water and exposure of the spent fuel in storage racks. Catastrophic failure is postulated to occur because of an earthquake or a cask drop into the pool.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to prevent a catastrophic failure by designing the pool to withstand the design basis earthquake and designing the pool in accordance with ANSI/ANS-57.7 (ANSI/ANS 1988, Section 6.1.2.2 and 6.1.2.3) to ensure that it will withstand the maximum dropped load over the pool without loss of functional integrity (see Section 6.2.3.2.3)..

Assuming the appropriate design controls are incorporated, the frequency of occurrence for this event is, by definition, beyond design basis.

6.2.5.8 Criticality Event in Pool

Event Description: Spent fuel assemblies in the ATS pool staging racks go critical due to failure of a design feature (e.g., staging racks collapse), design basis event (e.g., earthquake), or operator error (e.g., fuel misload or maintaining inadequate levels of boron or other neutron absorber in the pool water), which causes the fuel to be rearranged into a critical configuration.

Source: N/A – Criticality analysis of the Waste Handling Building will be completed prior to LA submittal.

Technical Strategy: Criticality control is required per the integrated safety analysis requirements of 10 CFR 63.112 (Dyer 1999b). The primary strategy is to prevent criticality by design of the facility structures, systems and components. *Standard Review Plan for Spent Fuel Dry Storage Systems* (NRC 1996a, Section 10.4.1) contains design criteria and features that are acceptable to the NRC for criticality control at ISFSI facilities and may be applicable to the MGR. Provided that appropriate design controls are incorporated, the frequency of occurrence for this event is expected to be less than 10^{-6} per year, making it beyond design basis (Assumption 5.4)**(TBV-1210)**.

6.2.5.9 Loss of Pool Water Resulting in Zircaloy Cladding Fire

Event Description: Inadvertent loss of pool water (cooling) initiates a zircaloy cladding fire that results in a release of radioactivity in the ATS pool area.

Source: N/A – Event has not been analyzed by the M&O. The potential for zircaloy cladding fires in spent fuel storage pools was addressed in the NRC SECY-96-256 rule making (NRC 1996b).

Technical Strategy: The primary strategy is to prevent a loss of pool water by design of the ATS pool systems. For defense-in-depth, it may be shown by analysis that (a) air ventilation in the ATS pool area (secondary confinement zone) is sufficient to ensure that the zircaloy cladding will not ignite; and/or (b) the decay heat generated by the maximum potential source term in the ATS pool is insufficient to ignite the zircaloy cladding.

The SECY-96-256 report indicates that in order to avoid a potential zircaloy cladding fire, the rod cladding temperature must not exceed 565 °C. Future analysis is expected to confirm that an event where spent fuel cladding temperatures exceed 565 °C and initiate a zircaloy fire is not credible, even with a loss of pool water or partial drain down (Assumption 5.17)**(TBV-1346)**.

6.2.5.10 Cladding Failure in the ATS Dryer

Event Description: The heat generated by stacking up to 24 PWR assemblies in a basket drying vessel (a concrete-insulated enclosure) causes spent fuel cladding to fail (i.e., breach) and release radioactivity in the ATS hot cell. The heat generation is a result of the heat introduced into the dryer, the decay heat from the spent fuel, or a combination of both.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary strategy is to demonstrate by analysis that, even with the maximum loading of the hottest fuel assemblies that could be handled at the MGR, there is insufficient energy to ignite (see Section 6.2.5.9 – zircaloy cladding fire) or otherwise breach the fuel cladding and cause a release. For defense-in-depth, administrative controls and procedures will ensure that fuel assemblies are not left inside the dryers for extended lengths of time.

6.2.5.11 Two-Block Canister Drop

Event Description: The CTS bridge crane drops a disposable canister from the two-block position (above the design basis drop height), resulting in breach of a canister.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Table 6.2-1).

Technical Strategy: The primary safety strategy is to ensure by design (e.g., incorporation of single-failure-proof and redundant safety features) and verify by fault-tree analysis that the frequency of this sequence of events is beyond design basis (i.e., less than 10^{-6} per year) (Assumption 5.8)**(TBV-1340)**.

6.2.5.12 Criticality Associated with Small Canister Staging Rack

Event Description: Small canisters stored in the CTS staging racks achieve criticality due to a design failure (e.g., staging racks collapse) or design basis event (e.g., earthquake, canister drop onto staging rack).

Source: N/A - Criticality analysis of the Waste Handling Building is expected to be completed prior to LA submittal.

Technical Strategy: Criticality control is required per the integrated safety analysis requirements of 10 CFR 63.112 (Dyer 1999b). The primary strategy is to prevent criticality by design of the facility structures, systems and components. *Standard Review Plan for Spent Fuel Dry Storage Systems* (NRC 1996a, Section 10.4.1) contains design criteria and features that are acceptable to the NRC for criticality control at ISFSI facilities and may be applicable to the MGR. Provided that appropriate design controls are incorporated, the frequency of occurrence for this event is expected to be less than 10^{-6} per year, making it beyond design basis (Assumption 5.4)**(TBV-1210)**.

6.2.5.13 Two-Block DC/WP Drop

Event Description: The CTS bridge crane drops a disposable canister from the two-block position (above the design basis drop height), resulting in breach of a canister.

Source: *Preliminary Preclosure Design Basis Event Calculations for the MGR* (CRWMS M&O 1998c, Table 6.4-1).

Technical Strategy: The primary safety strategy is to ensure by design (e.g., incorporation of single-failure-proof and redundant safety features) and verify by fault-tree analysis that the frequency of this sequence of events is beyond design basis (i.e., less than 10^{-6} per year) (Assumption 5.8)**(TBV-1340)**.

6.2.5.14 Unsealed DC Drop (from normal handling height) onto Hot Cell Floor, No Filtration

Event Description: A loaded, unsealed DC is dropped by the DC bridge crane onto a welding fixture, staging fixture, or onto the DC Tilting Station. After dropping, the DC is postulated to slap down onto the floor and spill its contents, with HEPA filters unavailable to mitigate the release. The drop height for this event is the normal handling height in the DC Handling Cell.

Primary reliance is placed on the availability of the HEPA-filtered ventilation system and on the ventilation system's ability to function and mitigate the release of particulates to the environment. In this scenario, the conditional probability of failure of the ventilation system is included in the scenario frequency.

Source: N/A – Event has not been analyzed.

Technical Strategy: The primary safety strategy is to ensure by design and verify by fault-tree analysis that the frequency of this sequence of events is beyond design basis (i.e., less than 10^{-6} per year).

The defense-in-depth strategy is to certify disposable canisters within the DC to withstand the normal drop without breaching and show by analysis that the releasable fraction of unconfined commercial spent fuel is insufficient to exceed the off-site dose limits in 10 CFR 63.111 (Dyer 1999b).

6.2.5.15 DC/WP Preclosure Criticality

Event Description: A DC/WP criticality event occurs due to accidental misloading of commercial spent nuclear fuel assemblies into a DC and exceeding the DC's/WP's criticality design basis, followed by accidental flooding of the DC/WP (Note: a sealed WP would also have to be breached for this event sequence to occur, whereas an unsealed DC would only need to be misloaded and then flooded).

Sources: *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 57-58); *Frequency of SNF Misload for Uncanistered Fuel Waste Package* (CRWMS M&O 1998b).

Technical Strategy: The primary safety strategy for a DC misload that leads to criticality is to demonstrate by analysis that the event sequence frequency is beyond design basis (i.e., less than 10^{-6} per year) (Assumption 5.3)**(TBV-1210)**. For criticality to potentially occur in a WP, it would have to be misloaded, breached and adequately moderated (e.g., flooded with water). Part of the design strategy will be to ensure that no water sources are present in the areas where unsealed DCs are handled.

Misload of a DC/WP with fuel that exceeds its criticality design basis was analyzed in *Frequency of SNF Misload for Uncanistered Fuel Waste Package* (CRWMS M&O 1998b, p. 11) and postulated to result from human error. Results from this analysis (CRWMS M&O 1998b, p. 24) indicate that the probability of a WP misload exceeding the criticality design basis is approximately 0.01 WPs/year. Therefore, facility design features must be incorporated to ensure that the probability of a WP breach and moderation is less than 10^{-4}, resulting in a preclosure criticality event sequence that is beyond design basis.

Defense-in-depth features may include administrative controls (e.g., strict adherence to procedures and training), additional inspections and HVAC confinement.

6.2.5.16 Rockfall Exceeding WP Design Basis (Falling Objects – Side Impact)

Event Description: A large rock block or other heavy object falls onto a horizontally-oriented WP in the subsurface.

Sources: *DBE/Scenario Analysis for Preclosure Repository Subsurface Facilities* (CRWMS M&O 1997a, pp. 121-134), *Waste Package Design Basis Events* (CRWMS M&O 1997c, pp. 33-34).

Technical Strategy: The primary strategy is to prevent a WP breach by designing the WP to withstand the impact of the maximum credible rock block that could potentially fall from the maximum height onto the side of a WP in an emplacement drift.

Analysis from *Waste Package Design Basis Events*, which was based on preliminary keyblock data, indicates that a 25 MT rock could fall 3.1 meters onto a WP (CRWMS M&O 1997c, pp. 33-34). An ongoing probabilistic keyblock analysis, scheduled for completion in FY99, is expected to demonstrate that the frequency of a rockfall event that could potentially breach the WP is beyond design basis, i.e., less than 10^{-6} per year (Assumption 5.6)**(TBV-684)**. Potential design options for limiting the impact of a rockfall event include (i) orientation of the emplacement drifts to minimize the maximum rock block size, (ii) placement of the WPs to minimize impact, (iii) reliance on dripshields or other structural features to absorb the impact of a rockfall, and (iv) credit for ground support such as steel sets and rock bolts to reduce the probability of a rockfall.

7. CONCLUSIONS

This analysis is not to be used to support procurement, fabrication, or construction activities. This analysis and the results provided herein are based on a preliminary design concept (DOE 1998a) and preliminary DBE calculations (CRWMS M&O 1998c).

The external and internal DBEs are summarized in Tables 11 and 12, respectively. These events must be considered in the MGR design process and in the selection of important-to-safety SSCs for the MGR.

Table 11. External DBEs/Natural Phenomena

Design Basis Event	Location	DBE Frequency Category†	Discussion Section
Loss-of-Offsite Power	Surface and Subsurface Facilities	1	6.1.3.1
Earthquake - Vibratory Ground Motion	Surface and Subsurface Facilities	1, 2	6.1.3.2
Earthquake -Fault Displacement	Surface and Subsurface Facilities	1, 2	6.1.3.3

Table 11. External DBEs/Natural Phenomena (Continued)

Design Basis Event	Location	DBE Frequency Category†	Discussion Section
Flood	Surface and Subsurface Facilities	2	6.1.3.4
Tornado Missiles	Surface Facilities	2	6.1.3.5
Tornado Wind	Surface Facilities	2	6.1.3.6

† DBE frequency categories for external events and natural phenomena are based on the initiating event and not the sequence of events required to cause a radiological release.

Table 12. Bounding Internal Events

Event Group	Event	Location	Section Discussed
Shipping Cask-Related	# 2-01 - Shipping Cask Drop (no impact limiters)	Carrier Bay	6.2.3.2.1
	# 2-02 - Shipping Cask Drop into Cask Preparation Pit	ATS Cask Preparation Pit	6.2.3.2.2
	# 2-03 - Shipping Cask Drop into Cask Unloading Pool	ATS Cask Unloading Pool	6.2.3.2.3
Spent Fuel Assembly (SFA)-Related	# 2-04 - SFA Basket Drop onto Another SFA Basket	ATS Dryer	6.2.3.2.4
Canister-Related	# 2-05 - Canister Drop onto Floor	CTS Hot Cell	6.2.3.2.5
Disposal Container (DC)-Related	# 2-06 - Unsealed DC Drop and Slapdown	DC Hot Cell	6.2.3.2.6
Waste Package (WP)-Related	# 2-07 - Preclosure "Early Failure" of a WP	Subsurface	6.2.3.2.7

The analysis of external events and natural phenomena is provided in Section 6.1. The lightning event (Section 6.1.2.1) was screened out because it is considered as an initiating event for the loss-of-offsite power event (Section 6.1.3.1) and the industrial/military activity-induced accidents were screened out due to their low probability of causing a radiological release at the MGR (Section 6.1.2.2). The events in Table 11 are those external events that were not screened out by *Screening of External Events for DBE Analysis* (CRWMS M&O 1999c) or the screening analysis in Sections 6.1.1 and 6.1.2.

The events in Table 12 are the bounding internal DBEs based on the preliminary events identified in the *Preliminary MGDS Hazards Analysis* (CRWMS M&O 1996c, Section 7.2.3), as modified by Assumption 5.11, and the consequence grouping in Section 6.2.2 of this analysis. The bounding internal DBEs are Category 2 DBEs which potentially result in the largest dose to the public at or beyond the preclosure controlled area (i.e., off-site) boundary. As such, they establish the limiting design criteria for mitigation features (e.g., HEPA filters) that are credited to meet 10 CFR 63.111 off-site dose limits (Dyer 1999b). A brief description and technical strategy for preventing or mitigating each event is provided in Section 6.2.3.2.

The DBEs identified in Table 9 are those internal events that the MGR is expected be designed to withstand and therefore are not expected to result in a radiological release. However, they do provide a basis for design features that are credited to ensure that no radiological release occurs.

The BDBEs identified in Table 10 are events that the MGR is expected to design for and, as a result, have event sequence frequencies less than 10^{-6} per year, classifying them as beyond design basis. Similar to the internal events with no release in Table 9, these events (e.g., two-block crane drops) establish design criteria that must be satisfied to demonstrate preclosure safety.

In summary, the purpose of this analysis is to identify the potential DBEs that will be considered in the MGR design process and used to identify design criteria (implemented through system description documents) and SSC quality level classifications for the MGR. The potential impact of these internal and external events on the MGR design, and the basis for preclosure safety of the MGR, will be further evaluated in future design analyses. As the MGR design is updated, a more detailed review of MGR operations will be conducted and additional events may be selected for consideration as potential DBEs.

7.1 Impact of Input Parameters and Uncertainty

The uncertainty in this analysis is primarily due to the preliminary nature of the MGR design that was used as the basis for DBE evaluation and selection. The unqualified and unverified input data (TBVs) are also a source of uncertainty that could affect many of the events discussed in this analysis. The bounding internal and external DBEs, however, are not likely to be impacted unless the MGR design is dramatically changed. As a result of these uncertainties, this analysis should only be used as a preliminary input to design and will be updated as necessary to reflect the evolving MGR design.

A number of TBDs were identified in this analysis where information voids existed. Table 13 lists the TBDs identified in this analysis and the sections where they were used. Table 14 identifies the TBV parameters used in this analysis and the impact of each.

Table 13. Impact of TBDs

Parameter	Section Used	TBD Number	Impact
Design basis tornado missile criterion, including size, weight, and impact velocity (horizontal and vertical).	6.1.3.5	TBD-414	This information is needed to establish design criteria for MGR SSCs important to safety to ensure that they can withstand a design basis tornado missile.
Design basis tornado wind criterion, including wind velocity, pressure drop, and rate of pressure drop.	6.1.3.6	TBD-415	This information is needed to establish design criteria for MGR SSCs important to safety to ensure that they can withstand a design basis tornado.
Shipping cask design bases for end drop, side drop, and drop onto edge & slapdown – include all casks to be handled at the MGR.	6.2.3.2.1	TBD-416	This information is needed to evaluate event sequences initiating with a cask drop.

Table 13. Impact of TBDs (Continued)

Parameter	Section Used	TBD Number	Impact
Minimum canister design basis drop heights for end drop, side drop, and drop onto edge & slapdown – include all disposable canisters to be handled at the MGR, except for defense high-level waste (DHLW) and Navy canisters.	6.2.3.2.5	TBD-417	This information is needed to evaluate event sequences initiated by a canister drop. DHLW and Navy canisters are exempted from this TBD because DHLW canisters already have certified design bases and Navy canisters will have negligible releases due to the robust structure of Naval fuel.

Table 14. Impact of TBVs

TBV Description	Section Used	Source	TBV Number	Impact
100-year preclosure time period	Section 6	Assumption 5.2	TBV-690	Any change in the preclosure time period will change the frequency ranges for DBE categories and may change the category level for existing events.
Criticality analysis to demonstrate that the sequence frequency for misload and preclosure moderation of a DC/WP is beyond design basis (i.e., less than 10^{-6} per year).	6.2.5.15	Assumption 5.3	TBV-1210	Analysis is necessary to demonstrate that a criticality event sequence is beyond design basis. Analysis will also identify SSCs credited to ensure that this event sequence is less than 10^{-6} per year.
Criticality analysis to demonstrate that a criticality event in the WHB (e.g., in the canister staging racks or the ATS pool) is beyond design basis (i.e., frequency is less than 10^{-6} per year).	6.2.5.12 and 6.2.5.8	Assumption 5.4	TBV-1210	Analysis is necessary to demonstrate that a criticality accident is beyond design basis. Analysis will also identify SSCs credited to ensure that these event sequences are less than 10^{-6} per year.
Fire hazards analysis to identify the design criteria required to prevent or mitigate fires in the WHB.	6.2.4.18, 6.2.5.1, 6.2.5.2	Assumption 5.5	TBV-688	Analysis is necessary to demonstrate that a release sequence initiated by a fire is beyond design basis. If necessary, analysis will identify SSCs credited to ensure that these event sequences are less than 10^{-6} per year. If Assumption 5.5 cannot be confirmed, fire-initiated events will be considered as credible DBEs.
Keyblock analysis demonstrating that the frequency of a rockfall that could potentially breach the WP is beyond design basis (i.e., less than 10^{-6} per year).	6.2.5.16	Assumption 5.6	TBV-684	Probabilistic analysis is necessary to demonstrate that a release scenario initiated by rockfall is beyond design basis. If Assumption 5.6 cannot be confirmed, rockfall will be considered a credible, Category 2 DBE.

Table 14. Impact of TBVs (Continued)

TBV Description	Section Used	Source	TBV Number	Impact
Two-block drop frequency for overhead cranes.	6.2.3.2.1, 6.2.3.2.5, 6.2.3.2.6 6.2.5.3, 6.2.5.11, 6.2.5.13	Assumption 5.8	TBV-1340	Analysis is necessary to demonstrate that two-block crane drops in the WHB are beyond design basis events. If Assumption 5.8 cannot be verified, two-block drops will be considered as credible, Category 2 DBEs.
Screening of external events and natural phenomena that are no longer considered credible.	4, 6.1	CRWMS M&O 1999c	TBV-1348	If TBV-1348 is not confirmed by external hazards analysis, additional external events and natural phenomena may require consideration in future DBE analysis.
Preliminary MGDS Hazards Analysis (CRWMS M&O 1996c) will be revised to include the additional internal events listed in Assumption 5.11.	6.2	Assumption 5.11	TBV-1347	If TBV-1347 is not confirmed by internal hazards analysis, the list of potential internal events that will be considered in future DBE analysis may change.
Nominal lift height for cask in Carrier Bay is 4 meters.	6.2.3.2.1	Assumption 5.12	TBV-1212	Raising or lowering the potential drop height could affect whether a cask is likely to breach if dropped. This could affect the frequency and consequence of release scenarios initiated by a cask drop.
Nominal lift height for cask in ATS Cask Preparation Pit is 6 meters.	6.2.3.2.2 and 6.2.5.4	Assumption 5.12	TBV-1212	Raising or lowering the potential drop height could affect whether a cask is likely to breach if dropped. This could affect the frequency and consequence of release scenarios initiated by a cask drop.
Nominal height for a cask to be dropped into the ATS pool is 15 meters.	6.2.3.2.3	Assumption 5.12	TBV-1212	Raising or lowering the potential drop height could affect whether a cask is likely to breach itself or damage the pool if dropped. This could affect the frequency and consequence of release scenarios initiated by a cask drop.
Waste Package is designed to withstand, without breaching, the following design basis events:		Assumption 5.13	TBV-245	WP design basis events may be adversely affected by a change in WP design, facility design, or facility operations. WP DBEs must be confirmed relative to SR/LA design. If these criteria cannot be confirmed, new design criteria for the WP will be established and the WP DBE analysis will be redone.
• Impact of a 0.5 kg pressurized missile travelling at a speed of 5.7 m/s	6.2.4.17			
• End impact of a 2.3 MT object falling 2 meters	6.2.4.12			
• Vertical drop of 2 meters	6.2.4.13			
• Side drop of 2.4 meters	6.2.4.14			
• Prevention of WP tipover and slapdown onto flat surface	6.2.4.15			

Table 14. Impact of TBVs (Continued)

TBV Description	Section Used	Source	TBV Number	Impact
Waste Package is designed to withstand, without breaching, the following design basis events: (continued)		Assumption 5.13	TBV-245	WP design basis events may be adversely affected by a change in WP design, facility design, or facility operations. WP DBEs must be confirmed relative to SR/LA design. If these criteria cannot be confirmed, new design criteria for the WP will be established and the WP DBE analysis will be redone.
• Puncture due to a 1.93 meter horizontal drop onto a WP support or 2.4 meter horizontal drop onto a WP pier, whichever is worse.	6.2.4.20			
• Internal pressure due to 100% fuel rod failure inside the WP @ gas temperature of 500°C, Safety Factor=1.5.	6.2.4.21			
• WP is designed not to tip over during a design basis earthquake with peak horizontal and vertical ground accelerations.	6.2.4.16			
• WP is designed to with-stand a fire with the following characteristics: exposure to heat flux of 800°C radiation environment for 30 min.; emissivity coefficient of at least 0.9; surface absorptivity of at least 0.8; and convective heat transfer rate of still air @ 800°C.	6.2.4.18			
Maximum potential transporter velocity in North Ramp is 63 km/hr.	6.2.4.19	CRWMS M&O 1997c, p. 49	TBV-245	This parameter provides bounding impact criteria for a WP. Since the strategy is to design the WP to withstand this event without breaching, a change in the maximum potential speed could change the WP design criteria.
Potential zircaloy cladding fire in the ATS pool .	6.2.5.9	Assumption 5.17	TBV-1346	Analysis is necessary to demonstrate that a zircaloy cladding fire resulting from a partial or total loss of pool water is beyond design basis. If this assumption cannot be confirmed, this event sequence will be considered as a credible DBE.

8. REFERENCES

8.1 Documents Cited

CRWMS M&O 1996a. *Mined Geologic Disposal System Advanced Conceptual Design (ACD) Report, Volume III – Engineered Barrier Segment/Waste Package*. B00000000-01717-5705-00027. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960821.0186.

CRWMS M&O 1996b. *Mined Geologic Disposal System Functional Analysis Document*. B00000000-01717-1708-00006, Revision 1. Las Vegas, NV: CRWMS M&O. ACC: MOL.19970124.0397.

CRWMS M&O 1996c. *Preliminary MGDS Hazards Analysis*. B00000000-01717-0200-00130 Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19961230.0011.

CRWMS M&O 1997a. *DBE/Scenario Analysis for Preclosure Repository Subsurface Facilities*, BCA000000-01717-0200-00017 Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980218.0237.

CRWMS M&O 1997b. *Waste Handling System Configuration Analysis*, BCBD00000-01717-0200-00001 Rev 00. Las Vegas, Nevada. CRWMS M&O. ACC: MOL.19970415.0399.

CRWMS M&O 1997c. *Waste Package Design Basis Events*. BBA000000-01717-0200-00037 Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971006.0075.

CRWMS M&O 1998a. *Preliminary List of Waste Package Designs for VA*, BBA000000-01717-3300-00008 Rev 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980311.0284.

CRWMS M&O 1998b. *Frequency of SNF Misload for Uncanistered Fuel Waste Package*, BBA000000-01717-0210-00011 Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980806.0604.

CRWMS M&O 1998c. *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository*, BC0000000-01717-0210-00001 Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981002.0001.

CRWMS M&O 1998d. *Repository Surface Design Site Layout Analysis*. BCB000000-01717-0200-00007 Rev 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980410.0136.

CRWMS M&O 1998e. *Assembly Transfer System Description Document*. BCB000000-01717-1705-00023 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981111.0035.

CRWMS M&O 1998f. *Strategy to Mitigate Preclosure Off-site Exposure*. June 24, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980916.0360.

CRWMS M&O 1998g. *Seismic Design Basis Inputs For A High-Level Waste Repository At Yucca Mountain, Nevada*. B00000000-01727-5700-00018 Rev 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990319.0318.

CRWMS M&O 1998h. *Canister Transfer System Description Document*. BCB000000-01717-1705-00024 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980505.0087.

CRWMS M&O 1999a. *Activity Evaluation for Design Basis Event Definition & Analysis/QA Classification Analysis (1.2.1.11)*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990325.0008.

CRWMS M&O 1999b. *Reliability Assessment of Waste Handling Building HVAC System*. BCBD00000-01717-0210-00008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990621.0155.

CRWMS M&O 1999c. *Screening of External Events for DBE Analysis*. RSO-RSO-99258.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990826.0076.

DOE (U.S. Department of Energy) 1997a. *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain*. Topical Report YMP/TR-003-NP, Revision 2. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971009.0413.

DOE 1997b. *Waste Isolation Pilot Plant (WIPP) Safety Analysis Report*. Rev. 2. DOE/WIPP 95-2065. Washington DC: U.S. Department of Energy. TIC: 235209.

DOE 1998a. *Viability Assessment of a Repository at Yucca Mountain*. Volume 2: Preliminary Design Concept for the Repository and Waste Package. DOE/RW-0508/V2. Las Vegas, Nevada: U.S. DOE, Office of Civilian Radioactive Waste Management. TIC: 241999.

DOE 1998b. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 8. Washington D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19980601.0022.

Dyer, J.R. 1999a. *Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada*. Letter from J.R. Dyer (DOE) to D.R. Wilkins (CRWMS M&O), June 18, 1999, with enclosure. OL&RC:AVG:1435. ACC: MOL.19990623.0026, MOL.19990623.0027.

Dyer, J.R. 1999b. *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999) for Yucca Mountain, Nevada*. Letter from J.R. Dyer (DOE) to D.R. Wilkins (CRWMS M&O), September 3, 1999, with enclosure. OL&RC:SB-1714. ACC: MOL.19990910.0079.

INEL 1996. *The Safety Analysis Report for the INEL TMI-2 Independent Spent Fuel Storage Installation*. Rev. 0. Docket No. 72-20. Idaho Falls, ID: Idaho National Engineering Laboratory (INEL). TIC: 233637.

NRC (Nuclear Regulatory Commission) 1974. *Design Basis Tornado for Nuclear Power Plants*. Regulatory Guide 1.76, Rev. 0. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 2717.

NRC 1978. *Tornado Design Classification*. Regulatory Guide 1.117, Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 4628.

NRC 1979. *Single-Failure-Proof Cranes for Nuclear Power Plants*. NUREG-0554. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 232978.

NRC 1987. *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition*. NUREG-0800. Washington, D.C.: Nuclear Regulatory Commission. TIC: 203894.

NRC 1993a. *Safety Evaluation Report for the Prairie Island Independent Spent Fuel Storage Installation*. Washington, DC: U.S. Nuclear Regulatory Commission. TIC: 10123.

NRC 1993b. *Rancho Seco Independent Spent Fuel Storage Installation (ISFSI) : Revision 1 to the Rancho Seco Independent Spent Fuel Storage Installation License Application and Safety Analysis Report*. DAGM NUC 93-135. Washington, DC: U.S. Nuclear Regulatory Commission. NRC Docket Number 72.11. TIC: 226550.

NRC 1996a. *Standard Review Plan for Spent Fuel Dry Storage Systems*. NUREG-1567. Draft Report for Comment. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 226657.

NRC 1996b. *Changes to the Financial Protection Requirements for Permanently Shutdown Nuclear Power Reactors, 10 CFR 50.54 (W) AND 10 CFR 140.11*. SECY-96-256. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 231084.

NRC 1997. *Standard Review Plan for Dry Cask Storage Systems*. NUREG-1536. Final Report. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 232373.

PNL (Pacific Northwest Laboratory) 1986. *Tornado Climatology of the Contiguous United States*. NUREG/CR-4461. Richland, WA: Pacific Northwest Laboratory. TIC: 236705.

YMP (Yucca Mountain Site Characterization Project) 1999. *Monitored Geologic Repository Requirements Document*, YMP/CM-0025, Revision 3 DCN 01. Las Vegas, Nevada: Yucca Mountain Site Characterization Project. ACC: MOL.19990429.0228.

8.2 Codes, Standards, and Regulations

10 CFR (Code of Federal Regulations) 71. *Packaging and Transportation of Radioactive Material. Part 71.71 - Normal Conditions of Transport, and Part 71.73 - Hypothetical Accident Conditions*. Washington, D.C.: National Archives and Records Administration. TIC: 242776.

10 CFR Part 72, Subpart F (1999). *Energy: Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste*. General Design Criteria. Washington, D.C.: National Archives and Records Administration. TIC: 242777.

64 FR (Federal Register) 8640. *Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada*. Proposed rule: 10 CFR 63. TIC: 240509.

ANSI/ANS (American National Standards Institute/American Nuclear Society) 1988. *Design Criteria for an Independent Spent Fuel Storage Installation (Water Pool Type)*, ANSI/ANS 57.7-1988. La Grange Park, Illinois: American National Standards Institute and American Nuclear Society. TIC: 238870.

ANSI/ANS 1992. *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)*. ANSI/ANS-57.9-1992. La Grange Park, IL: American Nuclear Society. TIC: 3043.

ANSI/ASCE (American National Standards Institute/American Society of Civil Engineers) 1996. *Minimum Design Loads for Buildings and Other Structures*. ANSI/ASCE 7-95. New York, NY: American Society of Civil Engineers. TIC: 236611.

8.3 Procedures

AP-3.10Q, Rev. 0, ICN 0. *Analyses and Models*. ACC: MOL.19990225.0335.

AP-3.14Q, Rev. 0, ICN 0. *Transmittal of Input*. ACC: MOL.19990701.0621.

AP-3.15Q, Rev. 0, ICN 0. *Managing Technical Product Inputs*. ACC: MOL.19990702.0315.

NLP-3-15, Rev. 5. *To Be Verified (TBV) and To Be Determined (TBD) Monitoring System*. ACC: MOL.19981117.0148.

NLP-3-18, Rev. 04. *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*. ACC: MOL.19960611.0170.

QAP-2-0, Rev. 5. *Conduct of Activities*. ACC: MOL.19980826.0209.

QAP-2-3, Rev. 10. *Classification of Permanent Items*. ACC: MOL.19990316.0006.

9. ATTACHMENTS

Attachment	Title
I	ACRONYMS
II	UNITS & DEFINITIONS

ATTACHMENT I

ACRONYMS

ACD	Advanced Conceptual Design
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ATS	Assembly Transfer System
BDBE	Beyond Design Basis Event
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
CPB	Carrier Preparation Building
CRWMS	Civilian Radioactive Waste Management System
CTS	Canister Transfer System
DBE	Design Basis Event
DBEQ	Design Basis Earthquake
DC	Disposal Container
DHLW	Defense High-Level Waste
DOE	Department of Energy
FHA	Fire Hazards Analysis
FR	Federal Register
HA	Hazards Analysis
HEPA	High Efficiency Particulate Air (Filter)
HVAC	Heating, Ventilation and Air Conditioning
INEL	Idaho National Engineering Laboratory
ISFSI	Independent Spent Fuel Storage Installation
ITS	Important To Safety
LA	License Application
M&O	Management & Operating Contractor
MCO	Multi-Canister Overpack
MGDS	Mined Geologic Disposal System
MGR	Monitored Geologic Repository
MPC	Multi-Purpose Canister

N/A	Not Applicable
NRC	Nuclear Regulatory Commission
PHA	Preliminary Hazards Analysis
PMF	Probable Maximum Flood
PWR	Pressurized Water Reactor
SAR	Safety Analysis Report
SDD	System Description Document
SER	Safety Evaluation Report
SFA	Spent Fuel Assembly
SSCs	Structures, Systems, and Components
TBD	To Be Determined
TBV	To Be Verified
TMI	Three Mile Island
VA	Viability Assessment
WHB	Waste Handling Building
WIPP	Waste Isolation Pilot Plant
WP	Waste Package
WTB	Waste Treatment Building

ATTACHMENT II

UNITS & DEFINITIONS

°C	Degrees Celsius
K_{eff}	Effective Multiplication Factor
kg	Kilogram
km	Kilometer
m	Meters
m/s	Meters per second
MPa	Mega-Pascale
MT	Metric Tons