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**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT  
ANALYSIS/MODEL COVER SHEET**

1. QA: N-L 143  
Page: 1 of: 67

*Complete Only Applicable Items*

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NOTES: The DI has changed from BA0000000-01717-0200-0006 to ANL-MGR-SE-000004.  
This document is prepared per AP-3.10Q, Rev 0, ICN 0.

The following ~~DBEs~~ <sup>TBVs</sup> have been used in this analysis:

- 684
- 685
- 688
- 690
- 777
- 1034
- 1035

**FOR INFORMATION  
ONLY**

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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT  
ANALYSIS/MODEL REVISION RECORD

1. Page: 2 of: 67

*Complete Only Applicable Items*

2. Analysis or Model Title:  
MGR External Events Hazards Analysis

3. Document Identifier (including Rev. No. and Change No., if applicable):

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00

Initial Issue. This analysis supersedes the analysis of external hazards performed in *Preliminary MGDS Hazards Analysis*, B00000000-01717-0200-00130, REV 00 (Reference 8.1).

This document is prepared per AP-3.10Q, REV 0, ICN 0

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**FIGURES**

**NONE**

## 1. PURPOSE

The purpose and objective of this analysis is to apply an external events Hazards Analysis (HA) to the License Application Design Selection Enhanced Design Alternative II [(LADS EDA II design (Reference 8.32)]. The output of the HA is called a Hazards List (HL). This analysis supersedes the external hazards portion of Rev. 00 of the PHA (Reference 8.1). The PHA for internal events will also be updated to the LADS EDA II design but under a separate analysis. Like the PHA methodology, the HA methodology provides a systematic method to identify potential hazards during the 100-year Monitored Geologic Repository (MGR) operating period updated to reflect the EDA II design. The resulting events on the HL are candidates that may have potential radiological consequences as determined during Design Basis Events (DBEs) analyses. Therefore, the HL that results from this analysis will undergo further screening and analysis based on the criteria that apply during the performance of DBE analyses.

## 2. QUALITY ASSURANCE

This analysis is subject to the requirements of *Quality Assurance Requirements and Description*, DOE/RW-0333P (Reference 8.2) as determined by Quality Administrative Procedure QAP-2-0, *Conduct of Activities* (Reference 8.3). Reference 8.4 presents the QAP-2-0 Activity Evaluation addressing the analysis of MGR hazards. This analysis is performed in accordance with Procedure AP-3.10Q, *Analysis and Models* (Reference 8.5). This analysis does not directly support any construction, fabrication, or procurement activity and therefore unverified design inputs are not required to be procedurally controlled in accordance with NLP-3-15, *To Be Verified (TBV) and To Be Determined (TBD) Monitoring System* (Reference 8.6). However, use of data from this analysis for input into documents supporting construction, fabrication, or procurement is required to be controlled in accordance with the appropriate procedures. Although not required in this document, when the need for a TBV is identified the TBV is identified and assigned a TBV tracking number.

## 3. COMPUTER SOFTWARE AND MODEL USAGE

This analysis uses no computational software; therefore, this analysis is not subject to the software controls of the SI series.

## 4. INPUTS

### 4.1 PARAMETERS

Table 4-1 summarizes the inputs parameters used in this analysis.

Table 4-1 Summary of Input Parameters

SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale  (E) = existing, (A) = accepted, and (Q) = qualified
5. 2 Assumptions and 6.2 Analysis Method	100-year operational period [TBV-690]	8.14 Requirement 3.2 (H)	Accepted (A). Parameters called out in the Monitored Geologic Repository Requirements Document are considered accepted.
6.3.3.1 Aircraft crash	Crash frequency $\leq 10^{-6}$ events per year [TBV-1034 and 1035]	8.46, pages 7 and 8	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.2 Avalanche	High mountain ranges	Reference 8.17, pages 2-32 and 2-1. The required condition (high mountain ranges) does not exist. Therefore, it is not applicable to the Hazards List for the Yucca Mountain site on this basis alone. It is also noteworthy that temperature and precipitation levels at the Yucca Mountain site do not support the build up of large masses of snow, ice, or soil needed to result in an avalanche except possibly a debris avalanche discussed in Section 6.3.3.5. Reference 8.17 provides historical temperature (page 2-32) and precipitation (page 2-1) data.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.2 Avalanche	High mountain ranges	The required condition (high mountain ranges) does not exist. Therefore, it is it is not applicable to the Hazards List for the Yucca Mountain site on this basis alone. It is also noteworthy that temperature and precipitation levels at the Yucca Mountain site do not support the build up of large masses of snow, ice, or soil needed to result in an avalanche except possibly a debris avalanche discussed in Section 6.3.3.5. Reference 8.42 provides historical temperature (page 4-12) and precipitation (page 4-5) data.	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.5 Debris avalanching	Debris flow	Reference 8.20, page 1. According to Reference 8.20, page 1, rainfall-triggered debris flows occurred on the south slope of Jake Ridge, about 6 km east of the crest of the Yucca Mountain site on July 21 or 22, 1984.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.

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SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.7 Dissolution	Dissolution rate	Page 41 of Reference 8.23 predicts a maximum dissolution rate of 4 mm/year, which is too slow to affect the 100-year operational period. However, the conditions due to dissolution may create the possibility of rockfall (Reference 8.43, page 7-11, figure 7-5).	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.7 Dissolution	Rockfall	According to Reference 8.43, page 7-11, figure 7-5, the conditions due to dissolution may create the possibility of rockfall.	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.8 Eperogenic displacement	Yucca Mountain has been geomorphically stable	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.16, page 1-6 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.9 Erosion	Erosion rate = 0.19 centimeters (cm)/1000 years	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.21, page 49 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.10 Extreme wind	Occasional occurrence of extreme winds	8.17, page 2-57	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.10 Extreme wind	Occurrence of extreme winds	8.24, page 58	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.13 Flooding (storm, river diversion)	Probable maximum flood magnitude	Reference 8.19, pages 2-14 and 4-21	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.

SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale  (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.14 Fungus, Bacteria and Algae	Temperature to support fungus/bacterial growth < 100° centigrade	Reference 8.39, Section 6.3.2.6.10	Accepted (A). ANS (American Nuclear Society) is generally accepted in the nuclear power industry as a source of data and information.
6.3.3.16 Glaciation	Transition to a glacial climate	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.27, page 91 provides supporting information, the information is not required for disposition of the phenomena.	Accepted (A). The National Research Council 1995. <i>Technical Bases for Yucca Mountain Standards</i> . Washington, D.C: National Research Council, National Academy Press is considered accepted.
6.3.3.20 Hurricane	Hurricanes "shall be considered for U.S. coastline areas and areas within 100 to 200 miles..."	Section 7.2.1.1 of ANSI/ANS 2.8-92 (Section 7.2.1.1 of Reference 8.40)	Accepted (A). ANS (American Nuclear Society) is generally accepted in the nuclear power industry as a source of data and information.
6.3.3.22 Industrial activity induced accident	Occurrence of Industrial activity induced accident	8.10 page 3-27	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.24 Landslides	Occurrence of Landslides	8.16, page 1-32	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.24 Landslides	Occurrence of Landslides	8.20, page 1	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.25 Lightning	Occurrence of Lightning	8.17, page 2-24	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.25 Lightning	Occurrence of Lightning	8.42, page 4-25	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.

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SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.26 Loss of off-site/on-site power	Occurrence of Loss of off-site/on-site power	8.29	Accepted (A). NRC (Nuclear Regulatory Commission) NUREGs are generally accepted in the nuclear power industry as a source of data and information, therefore it is ("A").
6.3.3.29 Meteorite impact	Radiological impact area footprint = 624,235 ft <sup>2</sup>	8.46, Attachment II, page II-2	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.29 Meteorite impact	Meteorite impact probability < 10 <sup>-6</sup> /year	8.11, Page 6	Accepted (A). ANS (American Nuclear Society) is generally accepted in the nuclear power industry as a source of data and information.
6.3.3.29 Meteorite impact	Meteorite impact probability of 1.5 x 10 <sup>-8</sup> per year	8.30, Table 1, Column 5 (the sum of the probabilities in column 5 for meteorites greater than one pound) is 1.5 x 10 <sup>-8</sup> per year.	Accepted (A). ANS (American Nuclear Society) is generally accepted in the nuclear power industry as a source of data and information.
6.3.3.29 Meteorite impact	Meteorite weight of > 1 lb (1 pound)	8.30, Table 1, Column 5 (the sum of the probabilities in column 5 for meteorites greater than one pound) is 1.5 x 10 <sup>-8</sup> per year.	Accepted (A). Reference 8.30 is referenced in Reference 8.31 and ANS (American Nuclear Society) is generally accepted in the nuclear power industry as a source of data and information, therefore it is (A).
6.3.3.30 Military Induced Activity Accident	Occurrence of Military Activity	8.10, pages 3-17 through 3-24	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.31 Orogenic Diastrophism	Yucca Mountain has been geomorphically stable	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.16, page 1-6 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.32 Pipeline accident	Occurrence of Pipeline accidents	8.10 page 3-27	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.

SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale  (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.33 Rainstorm	Occurrence of Rainstorms	8.17, page 2-14	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.33 Rainstorm	Occurrence of Rainstorms	8.42, page xi	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.34 Sandstorm	Occurrence of Sandstorms	8.17, page 2-26	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.34 Sandstorm	Occurrence of Sandstorms	8.42, page 4-22	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.35 Sedimentation	Occurrence of Sedimentation	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.16, page 1-16 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.37 Seismic activity, uplifting (tectonic)	Slip rate = 0.001 to 0.02 mm/year	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.27, pages 92 & 93 provide supporting information, the information is not required for disposition of the phenomena.	Accepted (A). The National Research Council 1995. <i>Technical Bases for Yucca Mountain Standards</i> . Washington, D.C: National Research Council, National Academy Press is considered accepted.
6.3.3.38 Seismic activity, earthquake	Occurrence of Earthquakes	8.22, page iii, and 3-8	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.38 Seismic activity, earthquake	Occurrence of Earthquakes	8.27, page 92	Accepted (A). The National Research Council 1995. <i>Technical Bases for Yucca Mountain Standards</i> . Washington, D.C: National Research Council, National Academy Press is considered accepted.

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	Parameter	Reference	Qualification Status and Rationale (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.39 Seismic activity, surface fault displacement	Occurrence of surface fault displacement	8.22, pages v, 4-3, and 4-5	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.39 Seismic activity, surface fault displacement	Occurrence of surface fault displacement	8.27, page 92	Accepted (A). The National Research Council 1995. <i>Technical Bases for Yucca Mountain Standards</i> . Washington, D.C: National Research Council, National Academy Press is considered accepted.
6.3.3.40 Seismic activity, subsurface fault displacement	Occurrence of subsurface fault displacement	8.18, pages 1.2, 1.12, and 11.1-11.5	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.40 Seismic activity, subsurface fault displacement	Occurrence of subsurface fault displacement	8.22, pages 4-3 and 4-5	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.42 Stream Erosion	Erosion rate = 222 cm/ka (1000 years)	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.21, Page 52 of Section 3.3.3.3 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.43 Subsidence	The emplacement level must be at least 200 meters below the directly overlying ground surface.	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.14, page 3-4, Section 3.3 C provides supporting information, the information is not required for disposition of the phenomena.	Qualified (Q). The data was developed under the Office of Civilian Radioactive Waste Management QA program.

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SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale  (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.43 Subsidence	Rock bolts, steel mesh, and steel sets for the emplacement drifts	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.32, page 5-13 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.43 Subsidence	Surface handling facilities not located directly overlying the emplacement drifts.	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although Reference 8.32, page 5-10, figure 5-2 provides supporting information, the information is not required for disposition of the phenomena.	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.44 Tornado	Occurrence of Tornadoes	8.17, 2-68	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.44 Tornado	Occurrence of Tornadoes	8.31	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.44 Tornado	Occurrence of Tornadoes	8.42, page 4-26	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.46 Undetected past intrusions (man-made)	Undetected past intrusions (man-made)	8.18	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.47 Undetected Geologic features	Undetected Geologic features	8.18	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.

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SECTION IN THIS ANALYSIS	INPUT PARAMETER/REFERENCE/QUALIFICATION STATUS		
	Parameter	Reference	Qualification Status and Rationale (E) = existing, (A) = accepted, and (Q) = qualified
6.3.3.48 Undetected Geologic processes	Undetected Geologic processes	8.18	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.49 Volcanic Eruption	Occurrence of Volcanic Eruptions	8.33, page 1-9	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.49 Volcanic Eruption	Occurrence of Volcanic Eruptions	8.34, page 4-14	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.50 Volcanism, magmatic activity (extrusive and intrusive)	Subsurface repository area = 1050 acres	8.32, page 5-7	Existing (E). It has not been confirmed that the data from this reference are qualified, therefore the data are treated as existing.
6.3.3.50 Volcanism, magmatic activity (extrusive and intrusive)	Magmatic activity disruption area = 6 km <sup>2</sup> (Square kilometers)	8.33, Page 7-94	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.50 Volcanism, magmatic activity (extrusive and intrusive)	Probability of magmatic disruption is 2 x 10 <sup>-8</sup> /year	8.33, page 9-12, paragraph 14	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.51 Volcanism, ashflow (extrusive magmatic activity)	2 x 10 <sup>-8</sup> /year	8.33, page 9-12, paragraph 14	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.
6.3.3.52 Volcanism, ashfall	Density of solid Basalt = 2.95 gm (gram) /cm <sup>3</sup>	8.41, Page 6-9	Accepted (A). The data is from established fact (Marks' Standard Handbook for Mechanical Engineers).
6.3.3.52 Volcanism, ashfall	The worst case ashfall depth = 3 cm	8.36, Page 12	Existing (E). The data was not acquired and developed in accordance with an approved quality assurance program (i.e., qualified from the origin) or has not undergone the qualification process.

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## 4.2 CRITERIA

4.2.1 The MGR-RD shall comply with the applicable provisions of 10 CFR (Code of Federal Regulations) 20, "Standards for Protection Against Radiation." [MGR-RD 3.1.B](Reference 8.14)

4.2.2 In addition to meeting the preliminary requirements above, the MGR-RD shall comply with other laws, statutes, U.S. Codes, treaties, CFRs, Executive Orders, NUREGs, state and local codes and regulations, DOE Orders, and other directives applicable to the mined geologic disposal of spent nuclear fuel (SNF) and high level waste (HLW), including those related to environmental protection and radiological health and safety, as identified through analyses of the MGR. [MGR-RD 3.1.G](Reference 8.14)

## 4.3 CODES, STANDARDS, AND REGULATIONS

10 CFR 20 1999. Energy: Standards for Protection Against Radiation.

UBC (Uniform Building Code) 1997. Volumes 1 and 2. *Structural Engineering Design Provisions*.

ANS (American Nuclear Society) 1988. *Design Criteria for an Independent Spent Fuel Storage Installation (Water Pool Type)*.

ANS 1992. *Determining Design Basis Flooding at Power Reactor Sites, an American National Standard*.

NRC (Nuclear Regulatory Commission) 1974. *Design Basis Tornado for Nuclear Power Plants*. Regulatory Guide 1.76.

NRC 1988. *Evaluation of Station Blackout Accidents at Nuclear Power Plants*. NUREG-1032.

NRC 1983. *A Guide to the Performance of Probabilistic Risk Assessment for Nuclear Power Plants*. NUREG/CR-2300.

NRC 1987. *The Standard Review Plan for Nuclear Power Plants* NUREG-0800.

ANSI (American National Standards Institute) 1996. *Minimum Design Loads for Buildings and other Structures*. ANSI/ASCE 7-95.

## 5. ASSUMPTIONS

5.1 The capability for orderly facility shutdown due to HEPA filter clogging from sandstorms is assumed [TBV-685] (See Section 6.3.3.34). This assumption is based on the assumed availability of the Technical Specifications specifically addressing filter clogging.

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* (Reference 8.14, 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 MGR Requirements Document requires that the 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 for these events (e.g., from a "Beyond Design Basis Event" to a Category 2 event) (Reference 8.47). Furthermore, the vast majority of 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. This assumption is used throughout this analysis.

## 6. ANALYSIS

This analysis was performed using a generic checklist consisting of external events as described in Section 6.3.2. This HA addresses external events that could, as determined by other analyses, result in a radioactive release during the 100-year operational period.

### 6.1 GENERIC EVENTS CHECKLIST

The analysis begins with the development of a comprehensive list of events that, if determined to be applicable, could result in a radioactive release. These generic lists are not project specific but provide a starting point for the systematic approach that is intended to identify all potentially hazardous external events. The intent is to provide the most comprehensive list to ensure thorough treatment of possible hazards. The development of generic events for external events uses existing project documents where similar work has been performed.

The HL is the result of applying a generic checklist for external events to the MGR design and determining which of those external events require further study. As discussed in Section 1, the HL will be used to identify potential DBEs.

### 6.2 ANALYSIS METHOD

For each generic external event, the analysis establishes a definition, required conditions, performs an evaluation, and determines the applicability of each generic external event. The following format is used in Section 6.3.3 to document the applicability of each external event.

Definition: Establishes the explanation of the event to be analyzed.

Required Condition: States what has to occur for the event or events to exist.

**Evaluation:** States what has to occur for the event to be considered a potential DBE for the 100-year operational period [TBV-690] design basis.

The event is considered a potential DBE if all of the following are determined to be true:

1. The potential exists and is applicable to the Yucca Mountain site.

Note: If the event in its entirety is included in another event then the statement is false and this fact is so noted. For example, 6.3.3.11 Extreme Weather Fluctuations are included in other weather-related events.

2. The rate of the process is sufficient to affect the 100-year operational period.

Note: Long-term phenomena are defined as those that require thousands of years for perceptible changes to take place. Sections 6.3.3.9 Erosion, 6.3.3.16 Glaciation, 6.3.3.15 Glacial Erosion, 6.3.3.31 Orogenic Diastrophism, 6.3.3.35 Sedimentation, 6.3.3.37 Seismic Activity, Uplifting [Tectonic], and 6.3.3.42 Stream Erosion are such phenomena. These phenomena are not applicable to the repository during the 100-year operational period even if it's extended to 300 years. Although supporting information may be included, the information is not required for disposition of the phenomena.

3. The consequence of the process is significant enough to affect the 100-year operational period.

4. The event frequency  $\geq 10^{-6}$  events per year.

The event cutoff frequency of  $10^{-6}$  events per year [TBV-690] is adjusted for the 100-year operational period (See Assumption 5.2). Therefore, an event that has a 1/10,000 probability of occurring in a 100-year period has a lower cutoff frequency of  $1/10,000 \div 100$ , which equals  $10^{-6}$  events per year.

5. The event is not included in another analysis (such as safeguards and security) or is not a subset of other DBE analyses [i.e., rainstorms that are initiators for floods or sandstorms (types of extreme winds)].

**Applicability:** States applicability (yes or no)

**Yes.** If all of the above statements are true for any external event, then the event is considered applicable to the Hazards List for the Yucca Mountain site. Note that if any statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (cannot be screened out at that point).

**No.** If, for any external event, any one of the above statements is false then the event is not considered applicable to the Hazards List for the Yucca Mountain site and all statements following the false statement are not applicable (NA).

### **6.3 THE ANALYSIS OF EACH GENERIC EXTERNAL EVENT**

This section contains the analysis that determines the applicability of each of the external events. The impact of each TBV is discussed in Section 7.2.

#### **6.3.1 General Description of the Yucca Mountain Site**

The following description is taken from Volume 1 of the Viability Assessment (Reference 8.28, Section 2.2, and page 2-7):

Yucca Mountain is located in southern Nevada approximately 100 miles (160 km) northwest of Las Vegas. The mountain is an irregularly shaped volcanic upland varying in elevation at its crest from 1,500 meters (m) to 1,930 m (4,921 ft to 6,332 ft) and characterized by approximately 650 m (2,132 ft) of relief. The area surrounding the site includes Nye, Lincoln, Esmeralda, and Clark counties in Nevada and Inyo County in California. The site occupies land controlled by three federal agencies: the U.S. Air Force (Nellis Air Force Range), DOE (Nevada Test Site), and the U.S. Bureau of Land Management (BLM) . . . . Nearly all the area surrounding Yucca Mountain is federally owned, and very little is developed or urban land . . . . A large percentage of the land around Yucca Mountain is anticipated to remain federally owned or withheld from public use in the future.

#### **6.3.2 Summarized Results**

A comprehensive checklist of natural and man-induced events was prepared through a review of information provided in References 8.7, page 3-82, 8.9, pages 251 and 252, 8.12, page 10-8, and 8.13, page 3-9. Identification of natural events was based on known or predicted geologic, seismologic, hydrologic, and meteorological characteristics. Man-induced events include surface, subsurface, and airborne activities that occurred in the past, are currently ongoing, or could occur during the 100-year operational period. The SECTION/EVENT IN THIS ANALYSIS column of Table 6-1 contains the composite generic checklist and the section in this document that addressed the applicability of the event. The remaining columns summarize the results of the evaluation contained in the analyses of Section 6.3.3. The numbers in the applicability column indicate the number of events that appear on the Hazards List of Section 7.1.

Table 6-1 Summary of External Events Hazards Analysis Results

SECTION/ EVENT IN THIS ANALYSIS	EVALUATION/APPLICABILITY					
	1. Potential exists and the event is applicable to the Yucca Mountain site.	2. The rate of the process is sufficient to affect the 100-year operational period.	3. The consequence of the process is significant enough to affect the 100-year operational period.	4. The event frequency is $\geq 10^{-6}$ events per year.	5. The event is not included in another analysis.	Applicability (Applicable to the Hazards List for the Yucca Mountain site?)
6.3.3.1 Aircraft crash	TRUE	TRUE	TRUE	FALSE	NA(not applicable)	NO
6.3.3.2 Avalanche	FALSE	NA	NA	NA	NA	NO
6.3.3.3 Coastal erosion	FALSE	NA	NA	NA	NA	NO
6.3.3.4 Dam failure	FALSE	NA	NA	NA	NA	NO
6.3.3.5 Debris avalanching	TRUE	TRUE	TRUE	TRUE	TRUE	(1)YES
6.3.3.6 Denudation	TRUE	FALSE	NA	NA	NA	NO
6.3.3.7 Dissolution	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.8 Eperogenic displacement	TRUE	FALSE	NA	NA	NA	NO
6.3.3.9 Erosion	TRUE	FALSE	NA	NA	NA	NO
6.3.3.10 Extreme wind	TRUE	TRUE	TRUE	TRUE	TRUE	(2)YES
6.3.3.11 Extreme weather fluctuations	FALSE	NA	NA	NA	NA	NO
6.3.3.12 Range fire	TRUE	TRUE	TRUE	TRUE	FALSE	NO

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SECTION/ EVENT IN THIS ANALYSIS	EVALUATION/APPLICABILITY					
	1. Potential exists and the event is applicable to the Yucca Mountain site.	2. The rate of the process is sufficient to affect the 100-year operational period.	3. The consequence of the process is significant enough to affect the 100-year operational period.	4. The event frequency is $\geq 10^{-6}$ events per year.	5. The event is not included in another analysis.	Applicability (Applicable to the Hazards List for the Yucca Mountain site?)
6.3.3.13 Flooding (storm, river diversion)	TRUE	TRUE	TRUE	TRUE	TRUE	(3)YES
6.3.3.14 Fungus, bacteria, and algae	TRUE	TRUE	FALSE	NA	NA	NO
6.3.3.15 Glacial erosion	FALSE	NA	NA	NA	NA	NO
6.3.3.16 Glaciation	FALSE	NA	NA	NA	NA	NO
6.3.3.17 High Lake Level	FALSE	NA	NA	NA	NA	NO
6.3.3.18 High Tide	FALSE	NA	NA	NA	NA	NO
6.3.3.19 High river stage	FALSE	NA	NA	NA	NA	NO
6.3.3.20 Hurricane	FALSE	NA	NA	NA	NA	NO
6.3.3.21 Inadvertent future intrusions (man-made)	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.22 Industrial activity induced accident	TRUE	TRUE	TRUE	TRUE	TRUE	(4)YES
6.3.3.23 Intentional future intrusions (man-made)	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.24 Landslides	TRUE	TRUE	TRUE	TRUE	TRUE	(5)YES

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SECTION/ EVENT IN THIS ANALYSIS	EVALUATION/APPLICABILITY					
	1. Potential exists and the event is applicable to the Yucca Mountain site.	2. The rate of the process is sufficient to affect the 100-year operational period.	3. The consequence of the process is significant enough to affect the 100-year operational period.	4. The event frequency is $\geq 10^{-6}$ events per year.	5. The event is not included in another analysis.	Applicability (Applicable to the Hazards List for the Yucca Mountain site?)
6.3.3.25 Lightning	TRUE	TRUE	TRUE	TRUE	TRUE	(6)YES
6.3.3.26 Loss of off-site/ on-site power	TRUE	TRUE	TRUE	TRUE	TRUE	(7)YES
6.3.3.27 Low lake level	FALSE	NA	NA	NA	NA	NO
6.3.3.28 Low river level	FALSE	NA	NA	NA	NA	NO
6.3.3.29 Meteorite impact	TRUE	TRUE	TRUE	FALSE	NA	NO
6.3.3.30 Military activity induced accident	TRUE	TRUE	TRUE	TRUE	TRUE	(8)YES
6.3.3.31 Orogenic Diastrophism	TRUE	FALSE	NA	NA	NA	NO
6.3.3.32 Pipeline accident	FALSE	NA	NA	NA	NA	NO
6.3.3.33 Rainstorm	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.34 Sandstorm	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.35 Sedimentation	TRUE	FALSE	NA	NA	NA	NO
6.3.3.36 Seiche	FALSE	NA	NA	NA	NA	NO
6.3.3.37 Seismic activity, uplifting (tectonic)	TRUE	FALSE	NA	NA	NA	NO

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SECTION/ EVENT IN THIS ANALYSIS	EVALUATION/APPLICABILITY					
	1. Potential exists and the event is applicable to the Yucca Mountain site.	2. The rate of the process is sufficient to affect the 100-year operational period.	3. The consequence of the process is significant enough to affect the 100-year operational period.	4. The event frequency is $\geq 10^{-6}$ events per year.	5. The event is not included in another analysis.	Applicability (Applicable to the Hazards List for the Yucca Mountain site?)
6.3.3.38 Seismic activity, earthquake	TRUE	TRUE	TRUE	TRUE	TRUE	(9)YES
6.3.3.39 Seismic activity, surface fault displacement	TRUE	TRUE	TRUE	TRUE	TRUE	(10)YES
6.3.3.40 Seismic activity, subsurface fault displacement	TRUE	TRUE	TRUE	TRUE	TRUE	(11)YES
6.3.3.41 Static Fracturing	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.42 Stream Erosion	TRUE	FALSE	NA	NA	NA	NO
6.3.3.43 Subsidence	TRUE	TRUE	TRUE	TRUE	FALSE	NO
6.3.3.44 Tornado	TRUE	TRUE	TRUE	TRUE	TRUE	(12)YES
6.3.3.45 Tsunami	FALSE	NA	NA	NA	NA	NO
6.3.3.46 Undetected past intrusions (man-made)	FALSE	NA	NA	NA	NA	NO
6.3.3.47 Undetected Geologic features	FALSE	NA	NA	NA	NA	NO
6.3.3.48 Undetected Geologic processes	FALSE	NA	NA	NA	NA	NO

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SECTION/ EVENT IN THIS ANALYSIS	EVALUATION/APPLICABILITY					
	1. Potential exists and the event is applicable to the Yucca Mountain site.	2. The rate of the process is sufficient to affect the 100-year operational period.	3. The consequence of the process is significant enough to affect the 100-year operational period.	4. The event frequency is $\geq 10^{-6}$ events per year.	5. The event is not included in another analysis.	Applicability (Applicable to the Hazards List for the Yucca Mountain site?)
6.3.3.49 Volcanic Eruption	FALSE	NA	NA	NA	NA	NO
6.3.3.50 Volcanism, intrusive magmatic activity	TRUE	TRUE	TRUE	FALSE	NA	NO
6.3.3.51 Volcanism, ashflow (extrusive magmatic activity)	FALSE	NA	NA	NA	NA	NO
6.3.3.52 Volcanism, ashfall	TRUE	TRUE	FALSE	NA	NA	NO
6.3.3.53 Waves (aquatic)	FALSE	NA	NA	NA	NA	NO

**6.3.3 Generic External Event Analysis**

The determinations of applicability to the Yucca Mountain site are in accordance with methodology described in Section 6.2. The disposition in terms of applicability for each event is discussed below in alphabetical order.

**6.3.3.1 Aircraft Crash**

Definition: Accidental impact of an aircraft on the site.

Required Condition: Periodic presence of aircraft over or near the site.

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Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** The statement is true because of the potential for commercial aircraft over-flights and because of the proximity of the Yucca Mountain site to the flight path of military aircraft flying from Nellis Air Force Base to their practice range (Reference 8.10, page 3-23).
2. The rate of the process is sufficient to affect the 100-year operational period. **True** (The impact of the crash is immediate).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** A study on the consequence of this event was performed in 1990 and reported in Reference 8.15.
4. The event frequency  $\geq 10^{-6}$  events per year. **False.** The crash frequency is  $\leq 10^{-6}$  events per year is based on Reference 8.46, [TBVs 1034 and 1035] on pages 7 and 8 respectively.
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.2 Avalanche

Definition: A large mass of snow, ice, soil, or rock, or mixtures of these materials, falling, sliding, or flowing under the force of gravity.

Required Condition: Steeply sloped terrain found in high mountain ranges must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** The required condition (high mountain ranges) does not exist. Therefore, it is false on this basis alone. It is also noteworthy that temperature and precipitation levels at the Yucca Mountain site do not support the build up of large masses of snow, ice, or soil needed to result in an avalanche except possibly a debris avalanche discussed in Section 6.3.3.5. Reference 8.42 provides historical temperature (page 4-12) and precipitation (page 4-5) data. Reference 8.17 provides historical temperature (page 2-32) and precipitation (page 2-1) data. Conditions for forming of glaciers is discussed in Section 6.3.3.16.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**

5. The event is not included as a part of another analysis. NA

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.3 Coastal Erosion

Definition: The wearing away of soil and rock by waves and tidal action. (Also see Section 6.3.3.9 Erosion)

Required Condition: A coastline must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False**. This event requires a coastline, which does not exist at Yucca Mountain; therefore, the event was eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. NA
3. The consequence of the process is significant enough to affect the 100-year operational period. NA
4. The event frequency  $\geq 10^{-6}$  events per year. NA
5. The event is not included as a part of another analysis. NA

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.4 Dam Failure

Definition: Failure of a large man-made barrier that creates and restrains a large body of water.

Required Condition: A dam must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False**. This event requires a dam of sufficient size and proximity to the Yucca Mountain site. Since the required condition does not exist at the Yucca Mountain site, this event is eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. NA
3. The consequence of the process is significant enough to affect the 100-year operational period. NA
4. The event frequency  $\geq 10^{-6}$  events per year. NA
5. The event is not included as a part of another analysis. NA

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Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.5 Debris Avalanching** (also see Section 6.3.3.33 Rainstorm)

Definition: The sudden and rapid movement of debris (soil, vegetation and weathered rock) down steep slopes resulting from intensive rainfall.

Required Condition: Steep slopes and debris must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (Reference 8.19, page 2-11).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** According to Reference 8.20, page 1, rainfall-triggered debris flows occurred on the south slope of Jake Ridge, about 6 km east of the crest of the Yucca Mountain site on July 21 or 22, 1984.
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Volumetric calculations indicate that 7,000 cubic meters of debris was redistributed on the 49,000 square meter hillslope study area (Reference 8.20, page 1).
4. The event frequency  $\geq 10^{-6}$  events per year. **True** (See 2. above).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.6 Denudation** (also see Erosion, Section 6.3.3.9)

Definition: The sum of the processes that result in the wearing away or the progressive lowering of the earth's surface by weathering, mass wasting, and transportation.

Required Condition: Weathering, mass wasting, and transportation must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (See 2. below).
2. The rate of the process is sufficient to affect the 100-year operational period. **False.** This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Denudation is a process that occurs over geologic time much greater than the 100-year operational period. Therefore, the event is too

slow to cause a potential hazard during the 100-year operational period (See Section 6.3.3.9).

3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

**Applicability:** **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.7 Dissolution**

**Definition:** A process of chemical weathering by which mineral and rock material passes into solution.

**Required Condition:** The weathering process, minerals, rocks, and fluids must exist at the site.

**Evaluation:**

1. Potential exists and is applicable to the Yucca Mountain site. **True** (Reference 8.10, page 2-82 and see 2. below).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Although page 41 of Reference 8.23 predicts a maximum dissolution rate of 4 mm/year, which is too slow to affect the 100-year operational period, the conditions due to dissolution may create the possibility of rockfall (Reference 8.43, page 7-11, figure 7-5).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **False.** A final Key Block analysis report [TBV-684] is planned for completion in September of 1999 that will address the issue of rockfall. Rockfall has been identified as an internal event (Reference 8.1).

**Applicability:** **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.8 Epeirogenic Displacement (See 6.3.3.43 Subsidence)**

Definition: Geomorphic processes of uplift and subsidence that have produced the broader features of the continents and oceans.

Required Condition: Geomorphic processes must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (See 2. Below).
2. The rate of the process is sufficient to affect the 100-year operational period. **False**. This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. This process applies to postclosure. The process is too slow to affect the 100-year operational period. According to Reference 8.16, page 1-6, the data suggests that the region surrounding Yucca Mountain has been geomorphically stable during much of the middle and late Quaternary (the last 3 million years) and that the rates of geomorphic processes are likely to remain generally low during the next 10,000 years.
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No**. This event is not applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.9 Erosion (includes 6.3.3.6 Denudation)**

Definition: The slow wearing-away of soil and rock by weathering, mass wasting, and the action of streams (denudation), glaciers, waves, wind.

Required Condition: Evidence of weathering and mass wasting must exist at the site

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True**.
2. The rate of the process is sufficient to affect the 100-year operational period. **False**. This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Reference 8.16, page 1-6 has determined that erosion at the Yucca Mountain site is minimal for the 10,000-year time frame and is

negligible during the 100-year operational period. Long-term hillslope erosion rates for the Yucca Mountain site were determined to be 0.19 cm/1000 years (Reference 8.21, page 49). Therefore, although the condition exists at the site, it is too slow to have an effect during the 100-year operational period.

3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.10 Extreme Wind**

Definition: Wind is a meteorologic term for that component of air that moves parallel to the earth's surface. Sections 2.3.1 and 3.3.1 of NUREG-0800, *The Standard Review Plan for Nuclear Power Plants* (refer to Section 4.3) states that the 100-year return period "fastest mile of wind" including vertical velocity distribution and gust factor should be used and be based on the standard published by the American National Standards Institute (ANSI) with suitable corrections for local conditions. The current standard published by the American National Standards Institute is ANSI/ASCE 7-95, *Minimum Design Loads for Buildings and other Structures* (refer to Section 4.3). The basic wind speed defined on page 13 of ANSI/ASCE 7-95 is a 3 second gust with annual probability of 0.02 of being equaled or exceeded (50 year mean recurrence interval).

Required Condition: Meteorologic conditions conducive to wind generation must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** According to References 8.17, page 2-57 and 8.24, page 58 extreme winds do occasionally occur in southern Nevada making this event applicable for consideration during the 100-year operational period.
2. The rate of the process is sufficient to affect the 100-year operational period. **True** (The impact is immediate.)
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True** (See 2. above).
5. The event is not included as a part of another analysis. **True.**

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Applicability: Yes. This event is applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.11 Extreme Weather Fluctuations** (See Sections 6.3.3.6 Denudation, 6.3.3.9 Erosion, 6.3.3.10 Extreme wind, 6.3.3.13 Flooding (storm, river diversion), 6.3.3.15 Glacial erosion, 6.3.3.16 Glaciation, 6.3.3.20 Hurricane, 6.3.3.33 Rainstorm, 6.3.3.34 Sandstorm, 6.3.3.35 Sedimentation, 6.3.3.42 Stream erosion, and 6.3.3.44 Tornado)

Definition: Various types of weather fluctuations.

Required Condition: Evidence of weather fluctuations at the site that pose unusual design challenges.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** The required condition is not met. Any extreme weather fluctuation is covered in Sections 6.3.3.6 Denudation, 6.3.3.9 Erosion, 6.3.3.10 Extreme wind, 6.3.3.13 Flooding (storm, river diversion), 6.3.3.15 Glacial erosion, 6.3.3.16 Glaciation, 6.3.3.20 Hurricane, 6.3.3.33 Rainstorm, 6.3.3.34 Sandstorm, 6.3.3.35 Sedimentation, 6.3.3.42 Stream erosion, and 6.3.3.44 Tornado.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: No. These events are not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.12 Fire (Range)**

Definition: The combustion of natural vegetation external to the repository that propagates to combustible materials within the MGR operations area.

Required Condition: Combustible materials must exist on the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Since vegetation is present and at least one source of range fires (lightning - see Section 6.3.3.25) then range fires are possible.

2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **False.** This event will be included in the Fire Hazards Analyses. This event includes fires that occur externally to the repository system, such as a range fire. Fires can be man-made or initiated by other external events such as lightning. For the purpose of this evaluation, if fire-initiating events occur away from the repository and cause a fire to start that eventually reaches the repository boundary, it would be considered a fire event. The frequency of a range fire as an initiating event will be further analyzed as a part of a Fire Hazards Analysis. Range fires are bounded by and will be considered in Fire Hazards Analyses [TBV-688].

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.13 Flooding (Storm, River Diversion) - (See Section 6.3.3.33 Rainstorm)**

Definition: The covering or causing to be covered with water.

Required Condition: Source of water and topography that does not allow adequate drainage

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (Reference 8.11, page 4).
2. The rate of the process is sufficient to affect the 100-year operational period. **True** (See 4. below).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Although flooding can occur over an extensive area, floods at the Yucca Mountain site are generally restricted to relatively small areas as the result of rainstorms and occur as flash floods of short duration. Reference 8.19, pages 2-14 and 4-21, defines the probable maximum flood magnitude
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Reference 8.25, page 31 provides additional input on flood potential.

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5. The event is not included as a part of another analysis. **True**.

Applicability: **Yes**. This event is applicable to the Hazards List for the Yucca Mountain site.

#### 6.3.3.14 Fungus, Bacteria, and Algae

Definition: Fungus and bacteria are part of a general class of microorganisms that may be present in the subsurface environment. Algae are an aquatic plant that may be present in Assembly Transfer System (ATS) pools.

Required Condition: The proper environment and the existence of nutrients to support these organisms must exist at the site.

#### Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (See definition).
2. The rate of the process is sufficient to affect the 100-year operational period. **True**. Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **False**. This event, as a subsurface postclosure issue has been addressed as part of the waste package development effort (Reference 8.37, page 3-26). Thus, it was eliminated from further consideration in the 100-year operational period DBE analysis because the temperature must be less than 100 degrees centigrade to support microbiologically induced corrosion. Reference 8.26, page 3-36 (figure 3-21) shows that the surface temperature of the waste packages exceeds 100 degrees centigrade during the 100-year operational period.

As a surface 100-year operational period issue, in the Assembly Transfer System (ATS) where water is normally present, the problem of fungus, bacteria and algae is being addressed as a part of the ATS pool study due as a deliverable during the 1999 fiscal year. There are three reasons this event is eliminated. First, in the pool study there are plans to provide ultra violet light treatment to eliminate fungus, bacteria and algae when the water is recirculated. Second, the presence of radiation and elevated temperatures that exist after drying the spent fuel assemblies will also eliminate fungus, bacteria and algae. Third, performance criterion for filtration for the pool area to limit biological growth in accordance with requirements for clarity per ANSI 57.7 (Reference 8.39, Section 6.3.2.6.10) will also eliminate fungus, bacteria and algae. Any of the above three reasons are sufficient to eliminate fungus, bacteria and algae from further consideration.

4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No**. This event is not applicable to the Hazards List for the Yucca Mountain site.

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### **6.3.3.15 Glacial Erosion (See Section 6.3.3.16 Glaciation)**

**Definition:** Reduction of the earth's surface as a result of grinding and scouring by glacier ice armed with rock fragments.

**Required Condition:** Glaciers must exist at the site.

**Evaluation:**

1. Potential exists and is applicable to the Yucca Mountain site. **False.** This process requires the presence of glaciation (See Section 6.3.3.16).
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

**Applicability:** **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.16 Glaciation**

**Definition:** The formation, movement, and recession of glaciers or ice sheets.

**Required Condition:** Glaciers and climate change must be present at the site.

**Evaluation:**

1. Potential exists and is applicable to the Yucca Mountain site. **False.** This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. According to Reference 8.16, pages 5-89 to 5-90, alpine glaciers did form in the higher portions of the Sierra Nevada and in other Great Basin mountain ranges; however, there is no evidence suggesting that glacial activity occurred on Yucca Mountain. Reference 8.27, page 91 confirms that "a transition to a glacial climate during the next few hundred years is highly unlikely..." and therefore is not applicable for consideration during the 100-year operational period.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**

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5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.17 High Lake Level

Definition: Any inland body of standing water occupying a depression in the earth's surface, generally of appreciable size and too deep to permit vegetation to take root completely across the expanse of water with potential for overflow or flooding.

Required Condition: Lakes must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Since the required condition does not exist at the Yucca Mountain site, this event is eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.18 High Tide

Definition: Tides are the rhythmic, alternate rise and fall of the surface of the ocean, and bodies of water connected with the ocean with the potential for flooding inland areas.

Required Condition: An ocean or coastal area must be present at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Since the required condition does not exist at the Yucca Mountain site, this event is eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**

5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.19 High River Stage** (See Flooding, Section 6.3.3.13)

Definition: A river is a natural freshwater permanent or seasonal surface stream of considerable volume with potential for flooding.

Required Condition: Permanent or seasonal flow of considerable volume must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** This event is included in Flooding, Section 6.3.3.13.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.20 Hurricane** (See Rainstorm; Section 6.3.3.33)

Definition: An intense cyclone that forms over the tropical oceans and ranges 100 to 1000 km in diameter.

Required Condition: The site must be within 200 miles of the Pacific Ocean.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Section 7.2.1.1 of ANSI/ANS 2.8-92 (Section 7.2.1.1 of Reference 8.40) states that hurricanes "shall be considered for U.S. coastline areas and areas within 100 to 200 miles bordering the Pacific Ocean, Atlantic Ocean, Gulf of Mexico, and possessions within the Caribbean Sea. In addition, influence along estuaries and rivers connecting with these bodies of water should also be considered because hurricane storm surges will be transmitted upstream to some degree." The Yucca Mountain site is located approximately 225 miles to the northeast of Santa Monica Bay near Los Angeles, California, the nearest feature defined in the standard. Hurricanes, therefore, are not applicable to the Hazards List for the Yucca Mountain site.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**

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3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No**. This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.21 Inadvertent Future Intrusions (man-made)**

Definition: Man-made inadvertent future intrusions with regard to the 100-year operational period involve undetected surface access into repository facilities.

Required Condition: Potential for human access to surface facilities must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (See definition and required condition. The site borders the Nuclear Test Site (NTS) and highways exist in the area.)
2. The rate of the process is sufficient to affect the 100-year operational period. **True**. Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True**. Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True**. Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **False**. This event will be considered in future Safeguards and Security analyses [TBV-777], therefore is not a part of DBE analyses. Inadvertent future intrusions will be prevented by active Safeguards and Security measures. These measures will remain in effect through the 100-year operational period.

Applicability: **No**. This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.22 Industrial Activity Induced Accident**

Definition: An accident resulting from industrial or transportation activities unrelated to the MGR.

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Required Condition: Activity in the vicinity of the Yucca Mountain site must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** The Yucca Mountain site borders the Nevada Test Site. Nuclear weapon testing is on hold and alternate uses are now being considered for the Nevada Test Site including launch pads for satellite launching rockets. Reference 8.10 concludes on page 3-27 that information is not likely to show significant adverse effects from nearby industrial, transportation, and military installations and operations that cannot be accommodated by engineering measures.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.23 Intentional Future Intrusion (man-made)**

Definition: Man-made intentional future intrusions with regard to preclosure involve undetected surface access and/or sabotage to repository facilities.

Required Condition: Potential for intentional access to surface facilities at the site must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** The potential exists for intentionally bypassing active barriers to surface or subsurface analysis facilities with intent to sabotage a system important to radiological safety.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its

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validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).

4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **False.** This event will be considered in future Safeguards and Security analyses [TBV-777]. Also note that the repository would not represent an attractive target to potential saboteurs due to its remote location and the low population density in the area. Furthermore, security measures DOE would use to protect the waste material from intrusion, sabotage, and theft would make such attempts unlikely to succeed. At all times, the waste material would be either in robust shipping or disposal containers or inside the Waste Handling Building.

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.24 Landslides** (See Debris Avalanching; Section 6.3.3.5 and Rainstorm; Section 6.3.3.33)

Definition: A general term covering a wide variety of mass-movement land forms and processes involving the downslope transport, under gravitational influence, of soil and rock material.

Required Condition: Soil, rocks, and down slopes must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Some evidence of debris avalanching has been reported in Reference 8.20, page 1 (See Debris Avalanching in Section 6.3.3.5).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** According to Reference 8.16, page 1-32, large scale rapid mass wasting (e.g., rock slides, debris avalanches, earth flows) does not play a significant role at the Yucca Mountain site. However, the rate of the process is indeterminant. Since this statement is indeterminant (its validity in terms of significance cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).

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5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.25 Lightning**

Definition: The flashing of light produced by a discharge of atmospheric electricity between an electrically charged cloud and the earth.

Required Condition: Potential for discharge of atmospheric electricity between an electrically charged cloud and the earth within the site boundary.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** This event is anticipated at the Yucca Mountain site. Reference 8.17, page 2-24 and 8.42, page 4-25 report that lightning strikes of some consequence occur in Nevada. Data on frequency is provided in the reference.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.26 Loss of Off-Site/On-Site Power**

Definition: The loss of electrical power either generated or controlled by persons outside the Yucca Mountain site repository system or loss of power within the repository.

Required Condition: The need and provision for electrical power at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Any facility requirement to sustain off-site/on-site power is susceptible; therefore, this event is

applicable to the Hazards List for the Yucca Mountain site. Reference 8.29 provides the basis for consideration of loss of power events.

2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.27 Low Lake Level**

Definition: A lake is any inland body of standing water occupying a depression in the earth's surface, generally of appreciable size and too deep to permit surface vegetation to take root completely across the expanse of water where the lake level must be maintained for cooling purposes.

Required Condition: A lake must exist at the site as well as the need for a minimum level.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** This event is of concern to power facilities where water is needed for cooling purposes. The Yucca Mountain site has neither the need nor the required conditions. Since the required conditions do not exist at the Yucca Mountain site, the event was eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.28 Low River Level

Definition: A river is a natural freshwater permanent or seasonal surface stream of considerable volume where river level must be maintained for cooling purposes.

Required Condition: A river must exist at the site as well as the need for a minimum level.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** This event is of concern to power facilities where water is needed for cooling purposes. The Yucca Mountain site has neither the need nor the required conditions. Since the required conditions do not exist at the Yucca Mountain site, the event was eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.29 Meteorite Impact

Definition: The impact of any meteoroid that has reached the earth's surface without being completely vaporized.

Required Condition: Potential meteorite impact at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** According to page 69 of Reference 8.30, meteorites fall randomly throughout the surface of the earth.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).

4. The event frequency  $\geq 10^{-6}$  events per year. **False.** Reference 8.11, page 6 in referring to Reference 8.30 states that its probability is less than  $10^{-6}$  per year. Reference 8.30, page 70, Table 1, Column 5 (the sum of the probabilities greater than one pound) predicts probabilities of approximately  $1.5 \times 10^{-8}$  per year for a meteorite  $> 1$  pound (0.001 tons) impacting on a  $10^5$  ft<sup>2</sup> area. Based on Attachment II, page II-2 of Reference 8.46, the bounding case MGR footprint containing waste forms is 624,235 ft<sup>2</sup>. This means that the MGR footprint is approximately 6.24 times as large as  $10^5$  ft<sup>2</sup> cited in Reference 8.30. The probability of impact on the footprint area would then be  $6.24 \times 1.5 \times 10^{-8}$  per year or  $9.36 \times 10^{-8}$  per year. The 1 lb parameter has the potential to damage the containment building of a commercial nuclear power plant. Even if the probabilities for meteorites  $< 1$  lb are included (sum of all Column 5 probabilities) the total probability is  $4.5 \times 10^{-8}$  per year for  $10^5$  ft<sup>2</sup> area. Thus for the same area the probability of impact on the MGR footprint would then be  $6.24 \times 4.5 \times 10^{-8}$  per year or  $0.28 \times 10^{-6}$  per year.

The 624,235 ft<sup>2</sup> footprint area is conservative because all of the footprint is not completely filled with waste forms and the area would have to be ten times larger to increase the frequency to  $> 10^{-6}$  per year. Even during peak years, only a fraction of the area will be occupied by waste forms. This, therefore, reduces the potential impact area. Furthermore, the waste forms will not be on the surface for the entire 100-year operational period. Therefore, meteorite impact is not considered credible for consideration during the 100-year operational period.

5. The event is not included as a part of another analysis. **NA**

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.30 Military Activity Induced Accident

Definition: An accident resulting from military activities on the Nevada Test Site or Nellis Air Force Range.

Required Condition: Military activity in the vicinity of the Yucca Mountain site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Reference 8.10, pages 3-17 through 3-24 identifies potential effects that could be credible for the 100-year operational period including ground motion, facility accidents, missile firings, and objects dropped from aircraft.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its

validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).

4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.31 Orogenic Diastrophism

Definition: Movement of earth's crust produced by tectonic processes in which structures within fold-belt mountainous areas were formed, including thrusting, folding, and faulting.

Required Condition: Large-scale mountain ranges must exist at or near the site.

#### Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (See definition and required condition above).
2. The rate of the process is sufficient to affect the 100-year operational period. **False.** This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. According to Reference 8.16, page 1-6, the data suggests that the region surrounding the Yucca Mountain site has been geomorphically stable during much of the middle and late Quaternary (the last 3 million years) and that the rates of geomorphic processes are likely to remain generally low during the next 10,000 years.
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.32 Pipeline Accident

Definition: Industrial pipeline containing hazardous materials (oil, gas, etc.).

Required Condition: Industrial pipeline containing hazardous materials must exist at the site.

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Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Reference 8.10 page 3-27 has not identified any industrial activities (implying pipelines containing hazardous materials) existing or planned to be located in the area of Yucca Mountain. This event was eliminated from further consideration.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.33 Rainstorm**

Definition: A rainstorm of concern is one that produces the 100-year or greater maximum rainfall rate occurring for one day.

Required Condition: Potential for rainstorms at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** According to Reference 8.17, page 2-14 and 8.42, page xi, the Nevada Test Site averages less than 10 inches of precipitation per year. The maximum-recorded level of rainfall at the Yucca Mountain site in one day was 2.13 inches as of the date of Reference 8.17.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True** (based on a 100-year flood).
5. The event is not included as a part of another analysis. **False.** This is a mechanism enabling debris avalanching, flooding, and landslides to occur. Therefore, it is included in those (debris avalanching, flooding, and landslides) DBE analyses (See Sections 6.3.3.5, 6.3.3.13, and 6.3.3.24 respectively). The design of roof loads due

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to rainfall and snow are covered in Volume 2, Section 1506.1, page 1-1146 and Section 1611.7, page 1-159 of the UBC (See Section 4.3).

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.34 Sandstorm**

Definition: Extreme wind capable of transporting sand and other unconsolidated surficial materials.

Required Condition: Potential for wind and loose surficial materials must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** The southern Nevada desert region experiences the highest incidence of dust storms in the state. However, according to Reference 8.17, page 2-26 and 8.42, page 4-22, relatively strong winds needed for severe sandstorms occur only a fraction of the time during dry periods.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True** (See 1. above).
5. The event is not included as a part of another analysis. **False.** This event is a subset of DBE analyses related to Extreme Winds and Tornadoes (See Sections 6.3.3.10 and 6.3.3.44 respectively), since wind loading from sandstorms are by definition an extreme wind conditions. Without the sand component a sandstorm is equivalent to an extreme wind or tornado condition. Therefore, the event is included as a part of another analysis and is not considered further.

Potential for filter clogging from sandstorms is possible but given the capability for orderly facility shutdown through Technical Specification [TBV-685] the potential filter clogging due to sandstorms is screened from further consideration.

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.35 Sedimentation**

Definition: The process of forming or accumulating sediment (solid fragmental material that originates from weathering of rocks) in layers.

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Required Condition: Potential for weathering of rocks.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** (Weathered rocks already exist at the site.).
2. The rate of the process is sufficient to affect the 100-year operational period. **False.** This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. According to Reference 8.16 page 1-31 this process occurs slowly over many years and is too slow to have a significant effect on operations and is therefore not applicable for consideration during the 100-year operational period.
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.36 Seiche

Definition: A free or standing-wave oscillation of the surface of water in an enclosed or semi-enclosed basin (as a lake, bay, or harbor).

Required Condition: Large body of water must exist at or near the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Required condition does not exist.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.37 Seismic Activity, Uplifting [Tectonic]

Definition: A structurally high area in the crust, produced by positive movements over a long period of time that result in faults giving rise to the upthrust of rocks.

Required Condition: Rock upthrusts must exist at or around the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** (Rock upthrusts already exist at or around the site.)
2. The rate of the process is sufficient to affect the 100-year operational period. **False.** This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Reference 8.27, pages 92 and 93, states that measured slip rates of faults at Yucca Mountain range from 0.001-0.02 mm/year making this a long-term event and therefore not applicable for consideration during the 100-year operational period.
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site. However, events related to seismic activity such as in Sections 6.3.3.38, 6.3.3.39, 6.3.3.40 and 6.3.3.41 must be considered.

### 6.3.3.38 Seismic Activity, Earthquake

Definition: Pertaining to earthquake or earth vibrations, including those that are artificially induced.

Required Condition: Natural seismic activity or man-induced events such as weapons testing on Nevada Test Site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Earthquakes have occurred as recently as 1993 in the region as noted in Reference 8.27, page 92, making this event applicable for consideration during the 100-year operational period. Reference 8.22 describes the strategy for the 100-year operational period seismic design methodology. Note that nuclear weapon testing is no longer performed at the site.

2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Per Reference 8.22, page iii, the MGR will use mean annual probabilities of  $1 \times 10^{-3}$  and  $1 \times 10^{-4}$  as reference values in determining the Frequency-Categories -1 and -2 design basis vibratory ground motions. Structures, systems, and components important to safety will be designed to withstand a design basis earthquake (Frequency-Category -1 or -2), as appropriate (Reference 8.22, page 3-8).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

#### 6.3.3.39 Seismic Activity, Surface Fault Displacement

Definition: 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.

Required Condition: Surface faults in the area of planned surface facilities must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Earthquakes have occurred as recently as 1993 in the region as noted in Reference 8.27, page 92, making surface displacement a possibility. Therefore, this event is applicable for consideration during the 100-year operational period. Reference 8.22 describes the strategy for the 100-year operational period seismic design methodology. Note that Reference 8.22 replaces the *Preliminary Seismic Design Cost-Benefit Assessment of the Tuff Repository Waste Handling Facilities*. (SAND88-1600) cited in the Work Plan for the MGR External Events Hazards Analysis.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).

4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Per Reference 8.22, page v, that fault displacements having mean annual probabilities of  $1 \times 10^{-4}$  and  $1 \times 10^{-5}$  are appropriate for the Frequency-Category -1 and -2 design basis fault displacements. Structures, systems, and components important to safety will be designed to avoid (Reference 8.22, page 4-3) or withstand (Reference 8.22, page 4-5) design basis fault displacements of Frequency-Category -1 or -2).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

#### 6.3.3.40 Seismic Activity, Subsurface Fault Displacement

Definition: 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.

Required Condition: Subsurface faults in the area of planned subsurface facilities must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** Several faults intersect the designated subsurface repository area (Reference 8.18 pages 1.2, 1.12, 11.1-11.5). This event is applicable for consideration during the 100-year operational period. A probabilistic seismic hazard assessment will provide annual probabilities of accidents for various levels of fault displacement at locations throughout the Geologic Repository Operations Area. Reference 8.22 describes the strategy for the 100-year operational period seismic design methodology.
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Per Reference 8.22, page vi, fault displacements having mean annual probabilities of  $1 \times 10^{-4}$  and  $1 \times 10^{-5}$  are appropriate for the Frequency-Category -1 and -2 design basis fault displacements. Structures, systems, and components important to safety will be designed to avoid (Reference 8.22, page 4-3) or withstand (Reference 8.22, page 4-5) design basis fault displacements of Frequency-Category -1 or -2).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

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#### 6.3.3.41 Static Fracturing

Definition: Any break in a rock due to mechanical failure by stress (includes cracks, joints, and faults).

Required Condition: Evidence of stress (including cracks, joints, and faults) must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** The subsurface repository area is potentially susceptible to rock mechanical failure from stress due to seismic activity (Reference 8.27 page 92).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** The consequence of this process is one that leads to rockfall. Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **False.** A final Key Block analysis report [TBV-684] is planned for completion in September of 1999 that will address the issue of rockfall.

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

#### 6.3.3.42 Stream Erosion

Definition: The progressive removal, by a stream, of bedrock, overburden, soil, or other exposed matter, from the surface of its channel.

Required Condition: Intermittent or continuous flowing streams at or near the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (Reference 8.21 page 52).
2. The rate of the process is sufficient to affect the 100-year operational period. **False.** This is defined as a long-term process. Therefore, this phenomenon is not applicable

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to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Studies performed in Reference 8.21 page 52 indicate that this is a long-term event that cycles between erosion and deposition. The average erosion rate for Fortymile Wash was found in Reference 8.21 page 52 to be 222 cm/ka (1000 years). Therefore, stream erosion is too slow to have an effect during the 100-year operational period.

3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.43 Subsidence**

Definition: The sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion.

Required Condition: Potential natural geologic processes or man-induced activity that results in a large consolidated subsurface void space must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (Reference 8.16 page 1-6).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
5. The event is not included as a part of another analysis. **False.** Naturally occurring events that could potentially lead to subsidence such as subsurface fault displacement (Section 6.3.3.40) resulting in collapse of underground excavations have been included in Section 6.3.3.40. Furthermore, the MGR-RD (Reference 8.14, page 3-4, Section 3.3 C) requires that the emplacement level be at least 200 meters

below the directly overlying ground surface. EDA II (Reference 8.32, page 5-13) calls out rock bolts, steel mesh, and steel sets for the emplacement drifts. EDA II also does not have the surface handling facilities directly overlying the emplacement drifts (Reference 8.32, page 5-10, Figure 5-2). Therefore, subsidence is not considered a candidate for DBE analysis.

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.44 Tornado (See Section 6.3.3.10)**

Definition: A small scale cyclone generally less than 500 meters (m) in diameter and with very strong winds. Intense thunderstorms that are present in the desert southwest have the capability of producing tornados.

Required Condition: The potential for tornados must exist at the site.

#### Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** This event is applicable to the Hazards List for the Yucca Mountain site. According to Reference 8.17, page 2-68 and 8.42, page 4-26 tornado activity in Nevada is a rare occurrence because conditions conducive to tornado formation are generally absent.
2. The rate of the process is sufficient to affect the 100-year operational period. **True** (See 1. above).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **True.** Following licensing precedents for the design of nuclear facilities, structures, systems and components important to safety must be design to withstand the wind loading and missile penetration potential associated with a design basis tornado (i.e., a credible tornado that is established for the site of the facility). For example, see Regulatory Guide 1.76, *Design Basis Tornado for Nuclear Power Plants* (Reference 8.31).
5. The event is not included as a part of another analysis. **True.**

Applicability: **Yes.** This event is applicable to the Hazards List for the Yucca Mountain site.

#### **6.3.3.45 Tsunami**

Definition: A gravitational sea wave produced by a large-scale, short-duration disturbance on the ocean floor. Wave heights of up to 30 m may impact coastal regions.

Required Condition: A coastal region must exist at the site.

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Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** This by definition is a coastal event and is impossible to affect the Yucca Mountain site.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.46 Undetected Past Intrusions (Man-made)**

Definition: Past intrusions involve mining activities where deep shafts, drill holes, or tunnels may have been excavated.

Required Condition: Potential for undetected past human activity (intrusions) must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Site characterization (Reference 8.18) has provided sufficient assurance that these types of activities would have been detected.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.47 Undetected Geologic Features**

Definition: Geologic features of concern to the 100-year operational period include natural event such as faults and volcanoes.

Required Condition: Potential for undetected geologic features at the site.

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Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Site characterization (Reference 8.18) provides sufficient assurance that these types of activities would have been detected.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.48 Undetected Geologic Processes**

Definition: Geologic processes of concern to the 100-year operational period include natural events such as erosion, tectonic and seismic processes.

Required Condition: Potential for undetected geologic processes must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Site characterization (Reference 8.18) has provided sufficient assurance that these types of activities would have been detected.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.49 Volcanic Eruption**

Definition: The process by which magma and its associated gases rise into the crust and are extruded onto the earth's surface and into the atmosphere.

Required Condition: The potential for a volcanic center at the site must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** (See Sections 6.3.3.50, 6.3.3.51, and 6.3.3.52).
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

**6.3.3.50 Volcanism, Intrusive Magmatic Activity**

Definition: The development and movement of magma and mobile rock material underground.

Required Condition: The potential for volcanism and subsurface intrusion into the site must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True** (See Reference 8.33 pages 7-94, 9-12).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
4. The event frequency  $\geq 10^{-6}$  events per year. **False.** Page 5-7 of Reference 8.32 has determined that subsurface repository emplacement area covers 1050 acres. Magmatic disruption either during or at any time while the volcano may be active, has a potential for future activity; however, according to Reference 8.33 (page 9-12, paragraph 14) the area-related probability of this event is  $2 \times 10^{-8}$ /year per  $6 \text{ km}^2$  (1483 acres) which is the median estimate for Cima and Lunar crater. The frequency is based on  $6 \text{ km}^2$  (1483 acres) as determined in Reference 8.33, page 7-94. Since the EDA II design covers 1050 acres (Reference 8.32, page 5-7) which is approximately 70.8 % of the referenced  $6 \text{ km}^2$  (1483 acres). This results in a frequency reduction of 1050/1483 of the annual probability. Thus, 1050/1483 times  $2 \times 10^{-8}$  per year results in a new value of  $1.4 \times 10^{-8}$  per year.

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5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.51 Volcanism, Ash Flow (Extrusive Magmatic Activity)**

Definition: A highly heated mixture of volcanic gases, magma, mobile rock material and ash traveling down the flank of a volcano or along the surface of the ground (silicic volcanism).

Required Condition: The potential for volcanism and surface intrusion into the site must exist.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** Reference 8.33 page 1-9, paragraph 1 states that the risk of silicic volcanism is insignificant for the Yucca Mountain site.
2. The rate of the process is sufficient to affect the 100-year operational period. **NA**
3. The consequence of the process is significant enough to affect the 100-year operational period. **NA**
4. The event frequency  $\geq 10^{-6}$  events per year. **NA**
5. The event is not included as a part of another analysis. **NA**

Applicability: **No.** This event is not applicable to the Hazards List for the Yucca Mountain site.

### **6.3.3.52 Volcanism, Ash Fall**

Definition: Airborne volcanic ash falling from an eruption cloud.

Required Condition: Ashfall potential must exist at the site.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **True.** (See References 8.35 page 577, 8.36 pages 3 and 12, and, 8.41 page 6-9).
2. The rate of the process is sufficient to affect the 100-year operational period. **True.** Note that since this statement is indeterminant (its validity cannot be determined at this time) then the statement is treated as equivalent to true (See Section 6.2).
3. The consequence of the process is significant enough to affect the 100-year operational period. **False.** According to Reference 8.35 (page 577), the density for ash compacted by rain (wet ashfall) is  $1.25 \text{ g/cm}^3$ . The worst case ashfall depth from (Reference 8.36, page 12) is 3 cm; therefore, in this case the loading would be  $3 \text{ cm} \times 1.25 \text{ g/cm}^3$  or  $3.75 \text{ g/cm}^2$  ( $7.68 \text{ lbs/ft}^2$ ). The 1997 Uniform Building Code (UBC), Table 16-C, page 2-27 (Reference 8.38), states a worst-case minimum flat roof live

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load design requirement of 20 lbs/ft<sup>2</sup>. If, as a more conservative case, the density of solid Basalt (2,950 kg/m<sup>3</sup> or 2.95 g/cm<sup>3</sup>, from Reference 8.41, page 6-9) is used in place of wet ash, the roof load for a 3 cm depth would only be 18.14 lbs/ft<sup>2</sup>. Since in both cases (solid Basalt and wet ash) the roof loading is less than the minimum UBC load requirements then roof loading due to ashfall is screened from further consideration.

Due to the higher frequency of sandstorms, filter clogging due to ashfall is bounded by filter clogging due sandstorms (See Section 6.3.3.34).

4. The event frequency  $\geq 10^{-6}$  events per year. NA
5. The event is not included as a part of another analysis. NA

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

### 6.3.3.53 Waves (Aquatic)

Definition: An oscillatory movement of water manifested by an alternate rise and fall of the waters surface.

Required Condition: A body of water must exist at the site large enough to provide a source of wave action.

Evaluation:

1. Potential exists and is applicable to the Yucca Mountain site. **False.** The Yucca Mountain site is located in a desert environment that is not near a body of water large enough to provide a source of wave action. Therefore, the event was eliminated.
2. The rate of the process is sufficient to affect the 100-year operational period. NA
3. The consequence of the process is significant enough to affect the 100-year operational period. NA
4. The event frequency  $\geq 10^{-6}$  events per year. NA
5. The event is not included as a part of another analysis. NA

Applicability: No. This event is not applicable to the Hazards List for the Yucca Mountain site.

## 7. CONCLUSIONS

The PHA (Reference 8.1) identified 53 generic external events for evaluation as to applicability in the design of the MGR. The 53 external events that were considered in the PHA were reduced down to 22 based on the information available at that time. This HA reanalyzed all 53 including

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the 22 previously identified external events. Based on current information 12 of the 22 external events need further analysis as DBEs as shown in Section 7.1 and are applicable for consideration in the 100-year operational period DBEs. The remaining 10 of the original list of 22 have either been included in another analysis or screened out in this analysis (See Section 7.2).

## **7.1 HAZARDS LIST**

A summary of the HA results is found in Table 6-1. The Hazards List containing the events that are potential candidates for the 100-year operational period MGR DBEs are shown below.

1. Debris Avalanching
2. Extreme Wind
3. Flooding (storm, river diversion)
4. Industrial-Activity-Induced Accident
5. Landslide
6. Lightning
7. Loss of Offsite/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

## **7.2 DISPOSITION OF PREVIOUSLY IDENTIFIED HAZARDS**

Ten of the original 22 potential external hazards that were identified in the PHA (Reference 8.1) are not included in the above HL because they are either included in another analysis or screened out in this analysis. For details regarding the disposition of any specific hazard listed below, refer to the respective analysis in Section 6.3.

The 10 external not listed in the above HA are:

1. Aircraft Crash
2. Dissolution
3. Fungus, Bacteria, and Algae
4. Fires (Range)
5. Inadvertent Future Intrusions (Man-made)
6. Intentional Future Intrusions (Man-made)
7. Rainstorm
8. Sandstorm
9. Static Fracturing
10. Subsidence

7.3 IMPACT OF TBVs

Table 7-1 describes the impact of TBVs including a discussion of uncertainties and restrictions as well as citing TBV tracking numbers.

Table 7-1 Impact of TBVs

SECTION IN THIS ANALYSIS	Potential TBV ITEM	TBV Tracking Number	Impact of Potential TBV
5.2 Assumptions and 6.2. Analysis Method	100-year operational period	690	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 <i>Monitored Geologic Repository Requirements Document</i> (Reference 8.14, 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 MGR Requirements Document 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 for these events (e.g., from a "Beyond Design Basis Event" to a Category 2 event) (Reference 8.47). Furthermore, the vast majority of 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.
6.3.3.1 Aircraft crash	< 10 <sup>-6</sup> events per year	1034 and 1035	Any increase in the aircraft crash frequency to greater than 10 <sup>-6</sup> events per year would add the potential for aircraft crash as a DBE.
6.3.3.5 Debris Avalanching	Steep slopes and debris	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.7 Dissolution	Dissolution rate ≤ 4 millimeters (mm)/year	NA	The conditions due to dissolution may create the possibility of rockfall (Reference 8.43, page 7-11, figure 7-5). This event is therefore covered in 6.3.3.41 Static Fracturing and TBV - 684. Therefore, there is no need for a TBV.

SECTION IN THIS ANALYSIS	Potential TBV ITEM	TBV Tracking Number	Impact of Potential TBV
6.3.3.8 Epeirogenic Displacement	Geomorphic stability during the last 3 million years	NA	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Therefore, there is no need for a TBV.
6.3.3.10 Extreme Wind	Extreme Wind	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.12 Fire (Range)	Plans for Fire Hazards Analyses (FHA)	688	The surface and subsurface repository areas are potentially susceptible to fires. The FHAs will consider range fires as a potential contributor to the potential for fires on-site.
6.3.3.13 Flooding (Storm, River Diversion)	Flooding	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.14 Fungus, bacteria, and algae	Plans for ultra violet light treatment	NA	The absence of ultra violet light treatment would promote the survival of fungus, bacteria, and algae. However, the presence of radiation and elevated temperatures that exist after drying the spent fuel assemblies will eliminate fungus, bacteria and algae. This is also true of the performance criterion for filtration for the pool area to limit biological growth in accordance with requirements for clarity per ANSI 57.7 (Reference 8.39, Section 6.3.2.6.10). Either of the above two reasons is sufficient to eliminate fungus, bacteria and algae from further consideration. Therefore, there is no need for the ultra violet light treatment. Therefore there is no need for a TBV.
6.3.3.16 Glaciation	Transition to a glacial climate	NA	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Therefore, there is no need for a TBV.

<b>SECTION IN THIS ANALYSIS</b>	<b>Potential TBV ITEM</b>	<b>TBV Tracking Number</b>	<b>Impact of Potential TBV</b>
6.3.3.20 Hurricanes	Hurricanes within 100 to 200 miles of the U.S. coastline	NA	Any residual effects of hurricanes are covered under rainfall, flooding, extreme winds, tornados, etc. Therefore, there is no need for a TBV.
6.3.3.21 Inadvertent Future Intrusions (man-made)	Plans for Safeguards and Security Analyses	777	The inclusion of this event in Safeguards and Security Analyses eliminates the need for a separate DBE analysis.
6.3.3.22 Industrial Activity induced Accident	Industrial Activity	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.23 Intentional Future Intrusion (man-made)	Plans for Safeguards and Security Analyses	777	The inclusion of this event in Safeguards and Security Analyses eliminates the need for a separate DBE analysis.
6.3.3.24 Landslides	Soil, rocks, and down slopes	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.25 Lightning	Lightning	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.29 Meteorite impact	624,235 ft <sup>2</sup> footprint area	NA	The 624,235 ft <sup>2</sup> footprint area is conservative because all of the footprint area is not completely filled with waste forms and the area would have to be ten times larger to increase the frequency to > 10 <sup>-6</sup> . Even during peak years only a fraction of the area will be occupied by waste forms, thus reducing the potential impact area. Furthermore, the waste forms will not be on the surface for the entire 100-year operational period. Therefore, there is no need for a TBV.

<b>SECTION IN THIS ANALYSIS</b>	<b>Potential TBV ITEM</b>	<b>TBV Tracking Number</b>	<b>Impact of Potential TBV</b>
6.3.3.30 Military Induced Activity Accident	Occurrence of Military Activity	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.31 Orogenic Diastrophism	Geomorphic stability during the last 3 million years	NA	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Therefore, there is no need for a TBV.
6.3.3.32 Pipeline accident	The existence of pipelines	NA	Reference 8.10 page 3-27 has not identified any industrial activities (implying pipelines containing hazardous materials) existing or planned to be located in the area of Yucca Mountain. Ongoing site investigation activities would also disclose any new pipelines. The addition of above ground pipelines would have been detected visually as would underground pipeline due to the associated surface excavation required. Therefore, there is no need for a TBV.
6.3.3.35 Sedimentation	Forming or accumulating sediment	NA	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Therefore, there is no need for a TBV.
6.3.3.34 Sandstorms	Technical Specification for orderly shutdown due to filter clogging	685	Lack of proper Technical Specification for filter clogging could interfere with orderly shutdown.
6.3.3.38 Seismic Activity, Earthquake	Seismic Activity	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.39 Seismic Activity, Surface Fault Displacement	Seismic Activity	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential</u> hazard that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.

<b>SECTION IN THIS ANALYSIS</b>	<b>Potential TBV ITEM</b>	<b>TBV Tracking Number</b>	<b>Impact of Potential TBV</b>
6.3.3.40 Seismic Activity, Subsurface Fault Displacement	Seismic Activity	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential hazard</u> that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.41 Static Fracturing	Key Block Analysis Report and Rockfall Analysis	684	The subsurface repository area is potentially susceptible to rock mechanical failure by stress (Static Fracturing) as well as dissolution and possible subsequent rockfall. The Key Block Analysis Report will address rockfall potential.
6.3.3.44 Tornado	Occurrence of Tornadoes	NA	Note that this event is listed as a hazard in Section 7 and, therefore is considered a <u>potential hazard</u> that will require further analysis either as DBEs or as a part of another analysis. Any TBVs associated with further analyses will be determined on a case by case basis in those analyses. Therefore, there is no need for a TBV in this case.
6.3.3.46 Undetected Past Human Activity (intrusions)	Undetected Past Human Activity (intrusions)	NA	Site characterization (Reference 8.18) has provided sufficient assurance that these types of activities would have been detected. Ongoing site investigation activities would also disclose any undetected past human activity. Therefore, there is no need for a TBV.
6.3.3.47 Undetected geologic features	Undetected geologic features	NA	Site characterization (Reference 8.18) provides sufficient assurance that these types of activities would have been detected. Ongoing site investigation activities would also disclose any undetected geologic features. Therefore, there is no need for a TBV.
6.3.3.48 Undetected geologic processes	Undetected geologic processes	NA	Site characterization (Reference 8.18) has provided sufficient assurance that these types of activities would have been detected. Ongoing site investigation activities would also disclose any undetected geologic features. Therefore, there is no need for a TBV.
6.3.3.50 Volcanism, magmatic activity (extrusive and intrusive)	Probability of magmatic disruption = $2 \times 10^{-8}$ /year per 6 km <sup>2</sup> (Square kilometers)	NA	The magmatic activity disruption area of 6 km <sup>2</sup> (Square kilometers) is for a reference point only. Areas greater or less than 6 km <sup>2</sup> would change the disruption probability proportionately. The area would have to increase 10 to 100 times to increase the probability to less than $10^{-6}$ events per year. EDA II, (Reference 8.32) for example, is less than 6 km <sup>2</sup> . Therefore, there is no need for a TBV.

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SECTION IN THIS ANALYSIS	Potential TBV ITEM	TBV Tracking Number	Impact of Potential TBV
6.3.3.50 Volcanism, magmatic activity (extrusive and intrusive)	Magmatic activity disruption area = 1050 acres	NA	Since the EDA II design (Reference 8.32) covers 1050 acres which is approximately 70.8 % of the referenced 6 km <sup>2</sup> (1483 acres). This results in a frequency reduction of 1050/1483 of the annual probability. Thus, 1050/1483 times 2 x 10 <sup>-8</sup> per year is still less 10 <sup>-6</sup> per year. Therefore, there is no need for a TBV.
6.3.3.51 Volcanism, ashflow (extrusive magmatic activity)	Risk of silacic volcanism	NA	Reference 8.33 page 1-9, paragraph 1 states that the risk of silacic volcanism is insignificant for the Yucca Mountain site. Therefore, there is no need for a TBV.
6.3.3.52 Vocanism, ashfall	3 cm ashfall depth	NA	According to Reference 8.35 (page 577), the density for ash compacted by rain (wet ashfall) is 1.25 g/cm <sup>3</sup> . The worst case ashfall depth from (Reference 8.36, page 12) is 3 cm ; therefore, in this case the loading would be 3 cm x 1.25 g/cm <sup>3</sup> or 3.75 g/cm <sup>2</sup> (7.68 lbs/ft <sup>2</sup> ). The 1997 Uniform Building Code (UBC), Table 16-C, page 2-27 (Reference 8.38), states a worst-case minimum flat roof live load design requirement of 20 lbs/ft <sup>2</sup> . Ashfall depth would have to more than double over worst case to be considered for a TBV. Therefore, there is no need for a TBV.
6.3.3.37 Seismic activity, uplifting (tectonic)	Slip rate = 0.001 to 0.02 mm/year	NA	This is defined as a long-term process. Therefore, this phenomenon is not applicable to the repository during the 100-year operational period (See Section 6.2, Evaluation step 2). Although supporting information is included, the information is not required for disposition of the phenomena. Therefore, there is no need for a TBV.

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## 9. ATTACHMENTS

None