BSC	**Calculation/Analysis Change Notice** *Complete only applicable items.*	1. QA: QA 2. Page 1 of 12

ENG.20080828.0009

3. Document Identifier:	4. Rev.:	5. CACN:
000-00C-MGR0-00500-000-00C	00C	002

6. Title:
External Events Hazards Screening Analysis

7. Reason for Change:
Correct errors in response to Condition Report (CR) 12105.

8. Supersedes Change Notice: ☐ Yes If, Yes, CACN No.: ______ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes	☒ No	Results Impacted:	☐ Yes	☒ No
Assumptions Changed:	☐ Yes	☒ No	Design Impacted:	☐ Yes	☒ No

10. Description of Change:

1. To resolve action 015 for CR 12105, blank cells in the below Tables were modified as described:
   - Table 1 – Cell lines removed
   - Table 2 – Blank cells populated with "N/A"
   - Table 7 – Two rows of blank cells removed
   - Table 8 – Row of blank cells removed
   - Table 9 – Blank cells merged
   - Table A5 – Row of blank cells removed, and blank cells merged
   - Table A6 – Row of blank cells removed, blank cells merged, and dashes ("—") added
   - Table A7 – Row of blank cells removed, blank cells merged, and dashes ("—") added
   - Figure B5 – Image modified to add dashes ("—") to blank cells

11. REVIEWS AND APPROVAL

Printed Name	Signature	Date
11a. Originator: L.A. Plumb	[signature]	8/7/08
11b. Checker: P.E. Macheret	P. Macht.	08/07/08
11c. EGS: ~~P.T. Le~~ M. V. FRANK	[signature]	8/26/08
11d. DEM: M.V. Frank	[signature]	8/26/08
11e. Design Authority: B.E. Rusinko	B Rusinko	8/27/08

PE 8/28/08

Table 1. External Events Identification (Continued)

HAZARD			
20.	Geochemical alterations	65.	Shipwreck
21.	Glacial erosion	66.	Snow
22.	Glaciation	67.	Soil shrink-swell consolidation
23.	Hail	68.	Static fracturing
24.	High lake level	69.	Storm surge
25.	High tide	70.	Stream erosion
26.	High river stage	71.	Subsidence
27.	High summer temperature	72.	Tectonic activity-uplift and depression
28.	Hurricane	73.	Terrorist attack
29.	Ice cover	74.	Thermal loading
30.	Improper design/operation	75.	Tornado
31.	Inadvertent future human intrusion	76.	Toxic gas
32.	Industrial activity-induced accident	77.	Transportation accidents
33.	Intentional future human intrusion	78.	Tsunami
34.	Internal fire	79.	Turbine-generated missile
35.	Internal flooding	80.	Undetected past human intrusions
36.	Lahar	81.	Undetected geologic features
37.	Landslide	82.	Undetected geologic processes
38.	Lateral spread	83.	Volcanic activity
39.	Lightning	84.	Volcanism-intrusive igneous activity
40.	Liquefaction	85.	Volcanism-extrusive igneous activity
41.	Loss of offsite-onsite power	86.	Volcanism-ash fall
42.	Low lake level	87.	War
43.	Low river level	88.	Waste and rock interaction
44.	Low winter temperature	89.	Waves
45.	Mass wasting		

Source: *PRA Procedures Guide, A Guide to the Performance of Probabilistic Risk Assessment for Nuclear Power Plants* (Ref. 2.2.60), *Guidelines for Chemical Process Quantitative Risk Analysis* (Ref. 2.2.1, Section 3.3.3), and *Preclosure Radiological Safety Analysis for Accident Conditions of the Potential Yucca Mountain Repository: Underground Facilities* (Ref. 2.2.55, Section 3.2).

4.4 EXTERNAL EVENTS CATEGORIZATION

Due to the large number and common features of external events identified in Table 1, the identified external events are consolidated into categories of external events derived from six sources (Table 2). External events that exhibited similar characteristics are merged into common categories. Certain external events are identified in all of the references while other external events are unique to a particular reference. External events that are common to the references are grouped together. This grouping of external events is shown in Table 2.

Table 2. Categorization of External Events

NUREG-1804 Description (Ref. 2.2.64)	NUREG/ CR-5042 Description (Ref. 2.2.53)	NUREG-1407 Description (Ref. 2.2.62)	NUREG/ CR-2300 Description (Ref. 2.2.60)	AIChE 2000 Description (Ref. 2.2.2)	ANSI/ANS-58.21-2007 Description (Ref. 2.2.5)
Seismicity and faulting	Seismic/ earthquakes	Seismic events	Seismic activity	Seismic activity	Seismic activity
Slope instability	Others, earth movement	N/A	Avalanche, landslide	Avalanche, landslide	Avalanche, landslide
Other extreme geological conditions	Others, earth movement	N/A	Avalanche, landslide, soil shrink-swell consolidation	Avalanche, landslide, soil shrink-swell consolidation	Avalanche, landslide
Volcanic activity	Others, volcanic activity	Volcanic activity	Volcanic activity	Volcanic activity	Volcanic activity
Winds and tornadoes	High winds/ tornadoes	High winds and tornadoes	Extreme winds and tornadoes, hurricanes	Extreme winds and tornadoes, hurricanes, missile impact	Extreme winds and tornadoes, hurricanes
N/A	External floods	External floods	Coastal erosion, external flooding, high tide, high lake level, high river stage, hurricanes, intense precipitation, river diversion, seiche, storm surge, tsunami, waves	Coastal erosion, external flooding, high tide, high lake level, high river stage, hurricanes, intense precipitation, river diversion, storm surge, tsunami, waves	Coastal erosion, external flooding, high tide, hurricanes, intense precipitation, river diversion, seiche, storm surge, tsunami, waves
N/A	Others, lightning	Lightning	Lightning	Lightning	Lightning
Other extreme meteorological conditions	Others, severe temperature transients, severe weather storms, abrasive windstorms	Severe weather storms (extreme heat, extreme cold), severe weather storms	Drought, frost, hail, high summer temperatures, ice cover, low lake level, low river level, low winter temperature, sandstorm, snow	Barometric pressure, drought, frost, hail, high summer temperature, ice cover, low lake level, low river level, low winter temperature, sandstorm, snow	Drought, frost, hail, high summer temperature, ice cover, low lake level, low river, level, low winter temperature, sandstorm, snow

Table 2. Categorization of External Events (Continued)

NUREG-1804 Description (Ref. 2.2.64)	NUREG/ CR-5042 Description (Ref. 2.2.53)	NUREG-1407 Description (Ref. 2.2.62)	NUREG/ CR-2300 Description (Ref. 2.2.60)	AIChE 2000 Description (Ref. 2.2.2)	ANSI/ANS-58.21-2007 Description (Ref. 2.2.5)
Human-induced events	Transportation accidents	Transportation and nearby facility accidents	Aircraft impact, fog, transportation accidents	Aircraft impact, fog, missile impact, shipwreck, transportation accidents	Aircraft impact, fog, transportation accidents
Human-induced events	Others, nearby industrial/military facilities	Transportation and nearby facility accidents	Industrial/military facility accident, pipeline accident (gas, etc.)	Industrial/military facility accident, missile impact, pipeline accident	Industrial/military facility accident, pipeline accident
Human-induced events	Others, on-site Hazardous materials release	N/A	Onsite chemical Release, toxic gas	Onsite chemical Release, toxic gas	Onsite chemical Release, toxic gas
N/A	Others, external fires	External fires (forest fires, grass fires)	Forest fire	Forest fire	Forest fire
N/A	Others, extraterrestrial activity	Extraterrestrial activity (meteorite strikes, satellite falls)	Meteorite	Meteorite impact	Meteorite/satellite strikes
N/A	Internal fires	Internal fires	Fire	Fire	N/A
N/A	N/A	N/A	Internal flooding	Internal flooding	Internal flooding
N/A	N/A	N/A	Turbine-generated missile	Turbine-generated missile	Turbine-generated missile
N/A	N/A	N/A	N/A	N/A	Biological events
N/A	N/A	N/A	N/A	Sabotage, terrorist attack, war	N/A

Sources: *Guidelines for Chemical Process Quantitative Risk Analysis* (Ref. 2.2.2, Section 3.3.3), *External-Events PRA Methodology.* ANSI/ANS-58.21-2007 (Ref. 2.2.5, Appendix A); *Evaluation of External Hazards to Nuclear Power Plants in the United States*, NUREG/CR-5042 (Ref. 2.2.53, Section 2.1), *PRA Procedures Guide, A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants.* NUREG/CR-2300 (Ref. 2.2.60, Table 10-1), *Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities, Final Report.* NUREG-1407 (Ref. 2.2.62, Section 2), *Yucca Mountain Review Plan, Final Report.* NUREG-1804 (Ref. 2.2.64, Section 2.1.1.3).

2. Can the external event occur at the repository with a frequency greater than 10^{-6}/yr, that is, have a 1 in 10,000 chance of occurring in the 100-year preclosure period? **NO.**

Meteorites: The number of meteorites entering the earth's atmosphere annually as a function of mass at initial atmospheric entry is found in Table 1 of Ref. 2.2.8. Multiplying the total number of meteorites striking the Earth's atmosphere of a particular mass by the fraction of iron meteorites (5%, Ref. 2.2.69, p. 480), the number of iron meteorites striking the earth's atmosphere as a function of mass is obtained. Dividing the number of iron meteorites striking the earth's atmosphere by the earth's surface area yields the earth atmospheric iron meteorite flux. The mean radius of the earth is 6,371 km and the mean surface area of 5.1×10^8 km^2 (Ref. 2.2.72, p. F-193). Multiplying the earth atmospheric meteorite flux by the GROA protected area of 2.7 km^2 (Ref. 2.2.39) yields the iron meteorite impact frequency to the GROA. A similar calculation is done for hard stone meteorites except the fraction of hard stone meteorites of 4-18% is taken from Ref. 2.2.44, Figure 2. For soft stone and ice meteorites, their fraction is obtained by subtracting the iron and hard stone meteorite fraction from one. The results of this calculation are shown Table 7.

Table 7. Earth Atmospheric Meteorite Flux and Impact Frequency

Iron Meteorites						
Mass (kg)	**No. of Earth Atmospheric Events/yr N_{total} (Ref. 2.2.8, Table 1)**	**Iron Meteorites Fraction (Ref. 2.2.69, p. 408)**	**No. of Earth Atmospheric Iron Meteorite Events/yr N_{Iron} (Calculated)**	**Earth Atmospheric Iron Meteorite Flux (calculated) (events/ km^2-yr)**	**GROA Protected Area (Ref. 2.2.39) (km^2)**	**Iron Meteorite Impact Frequency (calculated) (/yr)**
0.1	111,800	5%	5,590	1.09×10^{-5}	2.7	2.95×10^{-5}
1	37,020	5%	1,851	3.62×10^{-6}	2.7	9.78×10^{-6}
10	6,497	5%	325	6.35×10^{-7}	2.7	1.72×10^{-6}
100	770	5%	39	7.53×10^{-8}	2.7	2.03×10^{-7}
1,000	91	5%	4.55	8.90×10^{-9}	2.7	2.40×10^{-8}
10,000	11	5%	0.55	1.08×10^{-9}	2.7	2.90×10^{-9}
100,000	1.3	5%	0.065	1.27×10^{-10}	2.7	3.43×10^{-10}
1,000,000	0.152	5%	0.0076	1.49×10^{-11}	2.7	4.01×10^{-11}

Table 7 Earth Atmospheric Meteorite Flux and Impact Frequency (Continued)

Hard Stone Meteorites						
Mass m (kg)	No. of Earth Atmospheric Events/yr N_{total} (Ref. 2.2.8, Table 1)	Hard Stone Meteorites Fraction (Ref. 2.2.44, Figure 2)	No. of Earth Atmospheric Hard Stone Meteorite Events/yr N_{Iron} (Calculated)	Earth Atmospheric Hard Stone Meteorite Flux (calculated) (events/ km^2-yr)	GROA Protected Area (Ref. 2.2.39) (km^2)	Hard Stone Meteorite Impact Frequency (calculated) (/yr)
0.1	111,800	16%	17,888	3.50×10^{-5}	2.7	9.45×10^{-5}
1	37,020	16%	5,923	1.16×10^{-5}	2.7	3.13×10^{-5}
10	6,497	18%	1,169	2.29×10^{-6}	2.7	6.18×10^{-6}
100	770	14%	108	2.11×10^{-7}	2.7	5.69×10^{-7}
1,000	91	10%	9.1	1.78×10^{-8}	2.7	4.81×10^{-8}
10,000	11	8%	0.88	1.72×10^{-9}	2.7	4.65×10^{-9}
100,000	1.3	6%	0.978	1.53×10^{-10}	2.7	4.12×10^{-10}
1,000,000	0.152	4%	0.00608	1.19×10^{-11}	2.7	3.21×10^{-11}
Soft Stone, Ice Meteorites						
Mass m (kg)	No. of Earth Atmospheric Events/yr N_{total} (Ref. 2.2.8, Table 1)	Soft Stone, Ice Meteorites Fraction (1-iron-hard stone calc.)	No. of Earth Atmospheric Ice Meteorite Events/yr N_{Iron} (Calculated)	Earth Atmospheric ice Meteorite Flux (calculated) (events/ km^2-yr)	GROA Protected Area (Ref. 2.2.39) (km^2)	Ice Meteorite Impact Frequency (calculated) (/yr)
0.1	111,800	79%	88,322	1.73×10^{-4}	2.7	4.66×10^{-4}
1	37,020	79%	29,246	5.72×10^{-5}	2.7	1.54×10^{-4}
10	6,497	77%	5,003	9.79×10^{-6}	2.7	2.64×10^{-5}
100	770	81%	624	1.22×10^{-6}	2.7	3.29×10^{-6}
1,000	91	85%	77	1.57×10^{-7}	2.7	4.09×10^{-7}
10,000	11	87%	9.57	1.87×10^{-8}	2.7	5.05×10^{-8}
100,000	1.3	89%	1.157	2.26×10^{-9}	2.7	6.11×10^{-9}
1,000,000	0.152	91%	0.13832	2.71×10^{-10}	2.7	7.31×10^{-10}

Sources: See heading row.

The process that a meteorite undergoes in its journey through the earth's atmosphere is a very complex process. Ablative friction heating of the meteorite results in the outside heating up and compressing the inner parts of the meteorite. For meteorites larger than a few kilograms, the breaking up and fragmenting of the meteorite typically occurs (Ref. 2.2.8, p. 609). Discussion in "Meteorites and their Properties" (Ref. 2.2.54) and Ref. 2.2.70 indicates that iron and hard stone meteorites smaller than about 10 kg in mass tend to burn up (ablative melting) in their journey through the

Table 8. Earth Ground Impact Meteorite Flux and Impact Frequency

Iron Meteorites						
Mass m (kg)	No. of Earth Atmospheric Events/yr N_{total} (Ref. 2.2.8, Table 1)	Iron Meteorites Fraction (Ref. 2.2.69, p. 408)	No. of Earth Atmospheric Iron Meteorite Events/yr N_{iron} (Calculated)	Earth Atmospheric Iron Meteorite Flux (calculated) (events/ km^2-yr)	GROA Protected Area (Ref. 2.2.39) (km^2)	Iron Meteorite Impact Frequency (calculated) (/yr)
10	674	5%	34	6.59×10^{-8}	2.7	1.78×10^{-7}
100	40	5%	2	3.91×10^{-9}	2.7	1.06×10^{-8}
1,000	2.2	5%	0.11	2.15×10^{-10}	2.7	5.81×10^{-10}
Hard Stone Meteorites						
Mass m (kg)	No. of Earth Atmospheric Events/yr N_{total} (Ref. 2.2.8, Table 1)	Hard Stone Meteorites Fraction (Ref. 2.2.44, Figure 2)	No. of Earth Atmospheric Hard Stone Meteorite Events/yr N_{iron} (Calculated)	Earth Atmospheric Hard Stone Meteorite Flux (calculated) (events/ km^2-yr)	GROA Protected Area (Ref. 2.2.39) (km^2)	Hard Stone Meteorite Impact Frequency (calculated) (/yr)
10	674	18%	121	2.37×10^{-7}	2.7	6.41×10^{-7}
100	40	14%	6	1.10×10^{-8}	2.7	2.96×10^{-8}
1,000	2.2	10%	0.22	4.30×10^{-10}	2.7	1.16×10^{-9}

Sources: See heading row.

Iron meteorites (8000 kg/m^3) greater than 10 kg to 1000 kg have an impact frequency that ranges from 1.78×10^{-7} to 5.81×10^{-10}/yr from Table 8. Based on impact frequency, iron meteorites will not be evaluated further because smaller meteorites tend to burn up before hitting the ground. Hard stone meteorites (3700 kg/m^3) greater than 10 kg to 1000 kg will tend to breakup or burst apart high in the earth's atmosphere with the fragments impacting the surface with near atmospheric entry velocities of km/sec based on the discussion in Ref. 2.2.54 and Ref. 2.2.70. Hard stone meteorites greater than 10 kg to 1000 kg have an impact frequency that ranges from 6.41×10^{-7} to 1.16×10^{-9}/yr from Table 8, which is less than 10^{-6}/yr and thus stone meteorites will not be evaluated further.

Satellites: According to Ref. 2.2.74 (p. 1), roughly 17,000 tracked objects have re-entered the earth atmosphere between 1957 and 1999, where most of these objects burnt up without posing a risk on the ground. Ref. 2.2.74 (p. 1) goes on to state that about one object re-enters the earth's atmosphere per day and 1 to 2 objects of 1 m^2 radar cross section re-enter per week, which is approximately equivalent to 17,000 objects over a 42-year period. Those objects greater than 1 m^2 radar cross section are monitored more closely until their atmospheric entry due to the higher potential of

Table 9. Surface Area of Facilities

Building/Area	Length (ft)	Width (ft)	Total (ft^2)	References
Aging Pad 17P	1030 (=1180-75-75)	1155 (1302 rounded up to 1305; =1305-75-75)	1,189,650	Ref. 2.2.29
Aging Pad 17R	1525 (1661 rounded up to 1675; -1675-75-75)	750 (900-75-75)	1,143,750	Ref. 2.2.30
Wet Handling Facility	400 (385 rounded up to 400)	400 (349' 6" + 45' 8" rounded up to 400)	160,000	Ref. 2.2.31
Initial Handling Facility	400 (386' 2" rounded up to 400)	265 (222' 6" + 40' rounded up to 265)	106,000	Ref. 2.2.32
Canister Receipt and Closure Facility 1	420 (419 rounded up to 420)	400 (392 rounded up to 400)	168,000	Ref. 2.2.15
Canister Receipt and Closure Facility 2	420	400	168,000	(Assumption 3.2.2)
Canister Receipt and Closure Facility 3	420	400	168,000	(Assumption 3.2.2)
Receipt Facility	315	320 (318 rounded up to 320)	100,800	Ref. 2.2.33
Railcar staging area (railcar buffer area 33A)	800	150	120,000	Ref. 2.2.40
Truck staging area (truck buffer area 33B)	300	150	45,000	Ref. 2.2.40 and Ref. 2.2.16, Section 9.8.2.1.3
TOTAL			3,369,200	

Sources: See Reference column.

Should the external event be retained for further evaluation? **NO.**

IHF sheet metal exterior wall. While the sheet metal wall is not as strong as reinforced concrete, it is less susceptible to tornado damage than the overhead door, as described later in this analysis.

The screening estimate for the CRCFs, RF and WHF was developed by establishing a probability distribution for overhead door failure at different wind speeds and then convolving this distribution with the frequency of a tornado strike as a function of wind speed. The probability of the surrogate overhead door failing is developed from data included in Ref. A5.8. This reference addresses the inward or outward collapse of an overhead door that is part of a Metal Building System (e.g., warehouses and industrial facilities) during a tornado. In developing Ref. A5.8, six experts provided estimates of the wind speed at which door failure will occur (Ref. A5.8, pp 4 – 6 and Appendix B). The six experts included two meteorologists, two engineers, one architect and one individual with both a meteorological and engineering background. Column 1 of Table A5 is a distribution of the experts' estimates of the tornado wind speeds at which an overhead door will fail due to direct tornado effects at the wind speed shown in Column 2 of Table A5 (Ref. A5.8, p. B-8).

The probability of door failure at the wind speeds shown in Table A5 were combined with the frequencies of a tornado strike at the same wind speeds to estimate an overall frequency of overhead door failure due to a tornado at the repository site. The total failure frequency is the sum of the strike frequency at each wind speed weighted by the conditional probability of failure at that wind speed.

The CRCF was chosen for this calculation because it has a slightly higher tornado strike frequency than the RF and WHF. The results of the calculation will therefore bound the frequency of overhead door failure for the other two facilities:

Table A5. CFCF Surrogate Failure Probability at Different Wind Speeds and Surrogate Failure Frequency

Overhead Door (Surrogate) Failure Probability	Overhead Door (Surrogate) Failure Wind Speed (mph)	Strike Frequency (yr^{-1}) at Wind Speed	Surrogate Failure Frequency (yr^{-1})
0.167	80	1.8×10^{-6}	3.0×10^{-7}
0.167	85	1.4×10^{-6}	2.3×10^{-7}
0.500	90	1.2×10^{-6}	6.0×10^{-7}
0.167	100	7.3×10^{-7}	1.2×10^{-7}
Total			1.2×10^{-6}

Source: Original.

The results of the calculation are shown in columns 3 and 4 of Table A5. The strike frequency at each wind speed is estimated using equation A12. The overall frequency of surrogate failure is estimated at 1.2×10^{-6}/yr. This corresponds to a failure probability in the preclosure period of 6.0×10^{-5}, which is below the 1.0×10^{-4} screening probability. Since this is true for the weakest part of the structure it is also true for the rest of the structure and therefore the CRCF, and hence and aging pads) could be screened out from detailed analysis based on the probability of tornado-caused structural damage. The total probability is well below the 1.0×10^{-4} screening probability.

An assessment of the potential for structural damage from tornado missiles results in a similar conclusion. At the low tornado wind speeds expected at the repository site, no heavy (typically damaging) tornado missiles would be generated. Construction materials can generate light-weight missiles; however, construction materials are expected to be at the site for limited periods of time once the facility is in operation. These short time periods preclude such material as potential missiles at probabilities above the screening probability. However, an assessment was made on the effect of a missile, which shows that the penetration depth is much less than the wall thicknesses of structures, aging overpacks, transportation casks and the TEV.

Based on this quantitative screening analysis, tornadoes and their potential for structural damage from direct effects and missiles are eliminated from further detailed analysis.

Table A6. Tornado Point Strike Frequency Data for Four-Degree Box Surrounding Yucca Mountain

Latitude	Longitude	Area of 1° Square[1] (mi^2)	Number of Observed Tornadoes[1]	Tornado Area[1] (Median) (mi^2)	Tornado Area[2] (5^{th} percent) (mi^2)	Tornado Area[2] (95^{th} percent) (mi^2)	Tornado Area[3] (mean) (mi^2)	Weighted Tornado Area[3] (mean) (mi^2)
35	114	3.887×10^3	6	1.151×10^{-1}	6.619×10^{-3}	2.002	5.196×10^{-1}	1.006×10^{-1}
35	115	3.887×10^3	1	1.136×10^{-2}	—	—	1.138×10^{-2}	3.665×10^{-4}
35	116	3.887×10^3	0	0	—	—	0	0
35	117	3.887×10^3	2	8.533×10^{-4}	5.569×10^{-4}	1.307×10^{-3}	8.823×10^{-4}	5.692×10^{-5}
36	114	3.887×10^3	6	5.773×10^{-3}	7.853×10^{-4}	4.244×10^{-2}	1.204×10^{-2}	2.331×10^{-3}
36	115	3.887×10^3	5	1.681×10^{-1}	1.721×10^{-2}	1.642	4.389×10^{-1}	7.079×10^{-2}
36	116	3.887×10^3	2	8.533×10^{-4}	5.569×10^{-4}	1.307×10^{-3}	8.823×10^{-4}	5.692×10^{-5}
36	117	3.887×10^3	0	0	—	—	0	0
37	114	3.887×10^3	1	1.136×10^{-3}	—	—	1.136×10^{-3}	3.665×10^{-5}
37	115	3.887×10^3	4	1.321×10^{-2}	2.668×10^{-4}	6.544×10^{-1}	2.203×10^{-1}	2.843×10^{-2}
37	116	3.887×10^3	1	5.682×10^{-4}	—	—	5.682×10^{-4}	1.833×10^{-5}
37	117	3.887×10^3	0	0	—	—	0	0
38	114	3.887×10^3	1	3.977×10^{-2}	—	—	3.977×10^{-2}	1.283×10^{-3}
38	115	3.887×10^3	0	0	—	—	0	0
38	116	3.887×10^3	1	1.705×10^{-4}	—	—	1.705×10^{-4}	5.500×10^{6}
38	117	3.887×10^3	1	1.136×10^{-3}	—	—	1.136×10^{-3}	3.665×10^{-5}
Total		6.100×10^4	31	—	—	—	—	2.040×10^{-1}

Notes: [1] Data from Ref. A5.7, Appendix C.
[2] Data from Ref. A5.7, Appendix C. For latitude and longitude boxes with 0 or 1 observed tornado, the point estimate was utilized as the median and the 5^{th} and 95^{th} percentiles were not estimated.
[3] See Section A3.1 for the approach used to estimate the mean and weighted mean. For boxes with 0 or 1 observed tornado, the point estimate was used as the mean.

Source: See Notes.

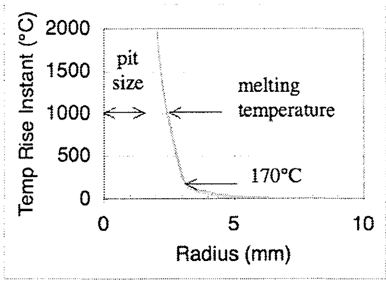
Table A7. Tornado Life-Line Frequency Data for Four-Degree Box Surrounding Yucca Mountain

Latitude	Longitude	Area of 1° Square[1] (mi^2)	Number of Observed Tornadoes[1]	Tornado Length[1] (Median) (mi^2)	Tornado Length[2] (5th percent) (mi^2)	Tornado Length[2] (95th percent) (mi^2)	Tornado Length[3] (mean) (mi^2)	Weighted Tornado Length[3] (mean) (mi^2)
35	114	3.887×10^3	6	8.043×10^{-1}	2.049×10^{-1}	3.158	5.196×10^{-1}	2.200×10^{-1}
35	115	3.887×10^3	1	1.000	—	—	1.000	3.226×10^{-2}
35	116	3.887×10^3	0	0	—	—	0	0
35	117	3.887×10^3	2	1.502×10^{-1}	9.802×10^{-2}	2.301×10^{-1}	1.553×10^{-1}	1.002×10^{-2}
36	114	3.887×10^3	6	2.170×10^{-1}	1.341×10^{-1}	3.512×10^{-1}	2.265×10^{-1}	4.384×10^{-2}
36	115	3.887×10^3	5	1.512	8.261×10^{-1}	2.769	1.618	2.610×10^{-1}
36	116	3.887×10^3	2	1.502×10^{-1}	9.802×10^{-2}	2.301×10^{-1}	5.233×10^{-2}	3.376×10^{-3}
36	117	3.887×10^3	0	0	—	—	0	0
37	114	3.887×10^3	1	1.000×10^{-1}	—	—	1.000×10^{-1}	3.226×10^{-3}
37	115	3.887×10^3	4	1.828	2.170×10^{-1}	1.539×10^{1}	4.228	5.456×10^{-1}
37	116	3.887×10^3	1	1.000×10^{-1}	—	—	1.000×10^{-1}	3.226×10^{-3}
37	117	3.887×10^3	0	0	—	—	0	0
38	114	3.887×10^3	1	1.000	—	—	1.000	3.226×10^{-2}
38	115	3.887×10^3	0	0	—	—	0	0
38	116	3.887×10^3	1	1.000×10^{-1}	—	—	1.000×10^{-1}	3.226×10^{-3}
38	117	3.887×10^3	1	2.000×10^{-1}	—	—	2.000×10^{-1}	6.452×10^{-3}
Total		6.100×10^4	31	—	—	—	—	1.164

Notes: [1] Data from Ref. A5.7, Appendix C.
[2] Data from Ref. A5.7, Appendix C. For latitude and longitude boxes with 0 or 1 observed tornado, the point estimate was utilized as the median and the 5th and 95th percentiles were not estimated.
[3] See Section A3.1 for the approach used to estimate the mean and weighted mean. For boxes with 0 or 1 observed tornado, the point estimate was used as the mean.

Source: See Notes.

Parameters	Values	Reference / Notes
Action - $i^2 t$	$3\ 10^6\ A^2\ s$	Sandia [7]
Attenuation	1	Worst case
Resistivity - ρ @ 20°C	$7.2\ 10^{-5}$ Ω cm	CRC [8] 304 Stainless
Resistivity Temp Coeff - α	0.001 /C°	CRC [9] steel manganese
Specific Heat - c_p	502 J/kg-K°	Rosebury [10] 304 Stainless
Density	7.9 g/cm^3	CRC [8] 304 Stainless
Area	6.28 mm^2	—
Shell thickness	1 mm	—
Melting Temperature	1425°C	CRC [8] 304 Stainless
Max Normal Temperature	400°C	Design Criteria [4, 5]



Notes: Reference Sandia [7] refers to Ref. B6.7, CRC [8] refers to Ref. B6.8 (provided for temperature at 20°C), CRC [9] refers to Ref. B6.9, p. E-91, Rosebury [10] refers to Ref. B6.10, p. 502, and Design Criteria [4, 5] refers to Ref. B6.4, pp. 2-3, and Ref. B6.5

Source: Original

Figure B5. Physical Parameters Used in Lightning Temperature Rise Calculation

The thermal rise calculations start at 400°C, the peak normal temperature. The resistivity is also increased from the value at 20°C to $1.0\ 10^{-4}$ Ω cm using the temperature coefficient. At the strike point, the temperature is very high and the metal is vaporized, leaving a pit. Based on the thermal calculations, the pit has a radius of approximately 1 to 2 mm. The melting temperature of 304 stainless steel is about 1425°C, and this temperature occurs between the 2 mm and 3 mm shells. The instantaneous temperature drops quickly with increasing radius, and the wall temperature is less than 570°C (170°C plus 400°C) beyond the 3 mm shell (plot in Figure B5).

The instantaneous heating occurs extremely fast, in much less than a second. Later, heat will radiate into the air and dissipate into the cooler metal at a much slower rate. A conservative method to incorporate this diffusion effect is to calculate an average temperature for different hemispheres by adiabatic heating, (i.e., no heat is lost outside the hemisphere). The average temperature of a hemisphere is calculated by adding the temperature of all the sections and dividing by the total number of sections. The hemispherical pit represented by the first section is not included in the average temperature calculation. The maximum average temperature rise of 170°C is the difference between the abnormal maximum temperature (570°C) and the normal maximum temperature (400°C).

$$\Delta Temperature_{avg}(radius) = \frac{1}{\text{total section (radius)}} \sum_{\text{total section}} \Delta Temperature_{section} \quad \text{(Eq. B4)}$$

$$\Delta Temp_{avg\text{-}max} = Temp_{max\text{-}abnormal} - Temp_{max\text{-}normal}$$
$$= 570°C - 400°C = 170°C$$