BSC

Scientific Analysis Administrative Change Notice

Complete only applicable items.

QA: QA

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1. Document Number:	ANL-MGR-GS-000003	**2. Revision:**	01	**3. ACN:**	01
4. Title:	Number of Waste Packages Hit by Igneous Intrusion				
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6. Approvals:			
Preparer:	Paul E Sanchez Print Name and Sign	SIGNATURE ON FILE	5-25-2005 Date
Checker:	Cheryl Hastings Print name and sign	SIGNATURE ON FILE	5/31/05 Date
QER:	Judy Gebhart Print name and sign	SIGNATURE ON FILE	6/1/05 Date
Responsible Manager:	Mike Cline Print name and sign	SIGNATURE ON FILE	6/1/05 Date

7. Affected Pages	**8. Description of Change:**
4-1	Editorial update associated with TBV-6014. Page 4-1, paragraph 3, sentence 1, Table # callout for DIRS 169989 updated as shown: *Characterize Framework for Igneous Activity at Yucca Mountain* (BSC 2004 [DIRS 169989], ~~Table 19~~ <u>Table 6-11</u>) develops the final composite conditional probability distribution for number of eruptive centers, also known as conduits.
4-1	Editorial update associated with TBV-6014. Page 4-1, paragraph 4, sentence 1, Figure # callout for DIRS 169989 updated as shown Independent probabilities for the distribution of dike azimuth angles are also developed in *Characterize Framework for Igneous Activity at Yucca Mountain* (BSC (2004 [DIRS 169989]), highlighted by ~~Figure 22~~ <u>Figure 6-20</u> of that report and the pertinent section shown in Figure 6-3 of this report. The data source for this information is DTN: LA0303BY831811.001 [DIRS 163985].
5-2	Editorial update associated with TBV-6766: Page 5-2, paragraph 1, sentence 2, additional section callout added for reference to [DIRS 169183] as shown: Such drift degradation is expected to occur as a result of seismic ground motion at estimated frequencies (approximately 106 to 107 per year) much greater than the estimated frequency of dike intersection (approximately 108 per year) (BSC 2004 [DIRS 169183], Section<u>s 6.1.3 and</u> 6.5.5).
6-6	Editorial update associated with TBV-6014. Page 6-6, Numbered Paragraph 2, sentence 3, Figure # callout for DIRS 169989 updated as shown 2. Dike azimuth angle. One value is sampled for each realization. Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (BSC 2004 [DIRS 169989], <u>Figure 6-20</u> ~~Figure 22~~) developed the distributions of possible azimuth angles through the repository that is used in this analysis (Table 4-1, row 3).

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6-7	Editorial update associated with TBV-6014. Page 6-7, Figure 6-3, Figure # callout for DIRS 169989 updated in "Data Source" note Data Source: <u>Figure 6-20</u> ~~Figure 22~~ (BSC 2004, [DIRS 169989]). Data in DTN: LA0303BY831811.001 [DIRS 163985].
6-22	Editorial update associated with TBV-6014. Page 6-22, paragraph 1, sentence 2, Table # callout for DIRS 169989 updated as shown *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989], <u>Table 6-11</u> ~~Table 19~~) contains various distributions based on different approaches for the number of conduits associated with a dike system intersecting the repository.
6-22	Editorial update associated with TBV-6014. Page 6-22, Table 6-2, Table # callout for DIRS 169989 updated in "Data Source" note as shown: Source: BSC 2004 [DIRS 169989], <u>Table 6-11</u> ~~Table 19~~; DTN: LA0307BY831811.001 [DIRS 164713].
6-22	Editorial update associated with TBV-6014. Page 6-22, paragraph 2, sentence 1, Figure # callout for DIRS 169989 updated in "Data Source" note as shown: As documented in *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989], <u>Figure 6-13</u> ~~Figure 19~~ and accompanying text), the results of the PVHA generally specify that less than five eruptive centers…
E-7	Editorial correction to address CR 4734-005. New stand-alone numbered paragraph # 4 from existing text. Last 2 sentences of existing numbered paragraph #3 moved to new numbered paragraph # 4 as shown below. Changed from: 3. Uncertainty is adequately represented in parameter development for conceptual models, … … Conservatism adopted in the analyses ensures that the risk is not under-represented and that they are discussed in Sections 6.3.3, 6.4, and 6.5. Where sufficient data do not exist, the definition of parameter values and conceptual models is based on appropriate use of expert elicitation, conducted in accordance with NUREG-1563 (Kotra et al 1996 [DIRS 100909]). If other approaches are used, the U.S. Department of Energy adequately justifies their use. Expert elicitation was not directly used in the development of the analysis … To: 3. Uncertainty is adequately represented in parameter development for conceptual models, … … Conservatism adopted in the analyses ensures that the risk is not under-represented and that they are discussed in Sections 6.3.3, 6.4, and 6.5. 4. Where sufficient data do not exist, the definition of parameter values and conceptual models is based on appropriate use of expert elicitation, conducted in accordance with NUREG-1563 (Kotra et al 1996 [DIRS 100909]). If other approaches are used, the U.S. Department of Energy adequately justifies their use. Expert elicitation was not directly used in the development of the analysis …

4. INPUTS

This section identifies data, parameters, criteria, and codes and standards associated with the scientific analysis. Uncertainties in input data and parameters are addressed in Section 6.5.

4.1 DIRECT INPUTS

Table 4-1 summarizes the inputs and input sources used for this analysis. Conditional probabilities for dike length, azimuth angle, and number of eruptive centers (conduits) on a dike (DTN: LA0302BY831811.001 [DIRS 162670]) are used as input to this analysis. The file consists of 4032 points in a parameter space for dike length and azimuth angle. The data cover angles from 0 degrees (north) to 175 degrees (south-southeast) in 5 degree increments and lengths from 0 km to 5.55 km in 0.05 km increments. Details of this parameter development are discussed in *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989], Section 6.5.3). That analysis summarizes and builds upon the *Probabilistic Volcanic Hazards Assessment for Yucca Mountain, Nevada* (CRWMS M&O 1996 [DIRS 100116]), in which the interpretations of 10 members of an expert panel were used to compute a probability distribution of the annual frequency of intersection of a basaltic dike or dike set with the repository footprint. The analysis assumes an origin for the igneous event (also called a volcanic event) and a dike with a given length and direction extending away from the origin. Points of origin have been used throughout the region around the repository based on the probabilistic volcanic hazards assessment experts' interpretations. Although similar in concept, these points of origin are not to be confused with anchor points described later in this report. This input information is used in the calculations for the number of waste packages hit for both the igneous intrusion scenario (Section 6.3) and the volcanic eruption scenario (Section 6.4). However, the points of origin in this case should not be confused with descriptions of dike swarm origin points in Section 6.3, which are focused on implementation of the dike geometry on a local scale.

Characterize Framework for Igneous Activity at Yucca Mountain (BSC 2004 [DIRS 169989], Table 6-11) develops the final composite conditional probability distribution for number of eruptive centers, also known as conduits. The data source for this information is DTN: LA0307BY831811.001 [DIRS 164713]. That distribution is used as input to this calculation for determining the cumulative distribution function (CDF) for number of waste packages hit, given a maximum of 13 eruptive centers associated with a volcanic event.

Independent probabilities for the distribution of dike azimuth angles are also developed in *Characterize Framework for Igneous Activity at Yucca Mountain*, BSC (2004 [DIRS 169989]), highlighted by Figure 6-20 of that report and the pertinent section shown in Figure 6-3 of this report. The data source for this information is DTN: LA0303BY831811.001 [DIRS 163985].

Repository design input information is taken from several information exchange drawings (IED):

D&E / PA/C IED Subsurface Facilities (BSC 2004 [DIRS 164519]), Figure 6-1 provides information on the underground layout configuration.

D&E / PA/C IED Subsurface Facilities (BSC 2004 [DIRS 168370]) provides several important parameters. Figure 2 and Table 7 from this source provide information on the underground

Finally, no credit is taken for the presence of rockfall in the drifts. Such drift degradation is expected to occur as a result of seismic ground motion at estimated frequencies (approximately 10^{-6} to 10^{-7} per year) much greater than the estimated frequency of dike intersection (approximately 10^{-8} per year) (BSC 2004 [DIRS 169183], Sections 6.1.3 and 6.5.5).

No further confirmation is necessary.

Use Within the Analysis: This assumption set is used in Section 6.3.

5.2 CONSTANT CONDUIT DIAMETER PER REALIZATION (VOLCANIC ERUPTION SCENARIO)

Assumption: It is assumed that all conduits have the same diameter for any particular realization.

Rationale: This is a simplifying assumption. A distribution of conduit diameters is sampled in this analysis. The assumption only refers to the fact that for each realization, the conduit diameter that is sampled from the distribution is held constant. In other words, conduit diameters do vary from one realization to the next, but within any particular realization, the diameter is held constant.

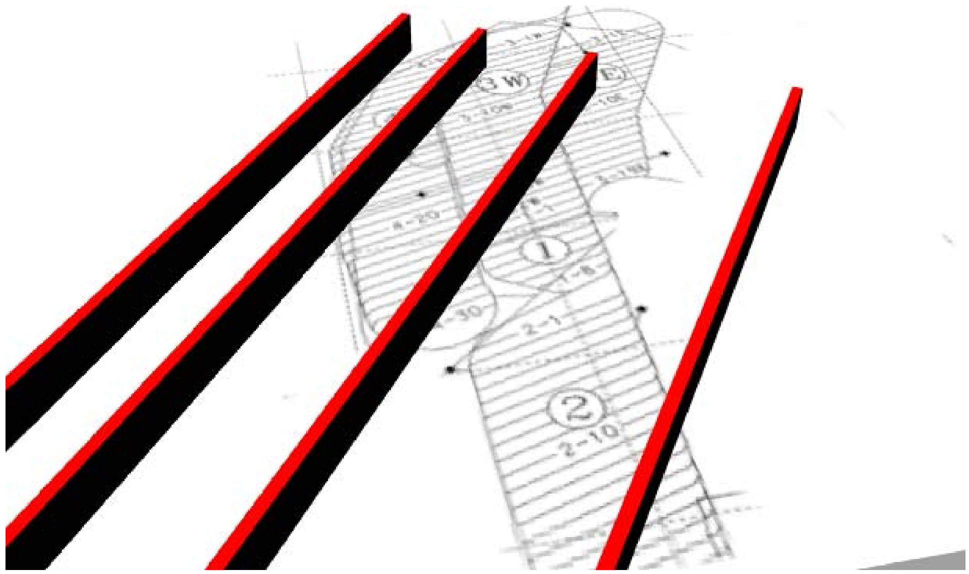
Confirmation Status: No additional work is planned to verify this assumption.

Use within the Analysis: This assumption is used in Section 6.4 to simplify the calculation of the number of waste packages hit by an eruptive conduit.

5.3 WASTE PACKAGES DAMAGED BY A CONDUIT (VOLCANIC ERUPTION SCENARIO)

Assumption: The number of waste packages within an eruptive conduit is assumed to be simply a function of conduit area and the average waste package density within the repository. No attempt is made to specifically determine or assign where a conduit occurs in the repository. If the conduit occurs in the repository, the number of waste packages hit is determined by multiplying the conduit area by the calculated waste package density factor, which is the total number of waste packages divided by the total repository area. Although magma associated with an eruption may contact other packages along the drift, the magma moving with sufficient vertical velocity to entrain waste in an eruption is assumed to be located only within the conduit because if additional waste packages outside of the conduit profile fail, then this simplified calculation approach would not be viable.

Rationale: The average waste package density is calculated by dividing the total planned number of waste packages by the total planned active repository area, including pillars. That approach is supported in part by the facts that the waste packages are uniformly distributed along each emplacement drift and those emplacement drifts are evenly spaced within the repository footprint. In other words, the waste packages are relatively evenly spaced in two different directions throughout the repository. Considered over the scale of the entire repository, this leads to a relatively uniform waste package density, which supports the use of an average value.



NOTE: For illustration purposes only. Not to scale. Oblique view.

Figure 6-2. Conceptualization of a Swarm of Dikes Penetrating the Repository Footprint

An input file was prepared for LHS (SNL 2004 [DIRS 167794]) (Appendix A; file *lhs2_uif$input.dat*) that contains the following distribution parameter sets:

1. Dike length within repository. Sampled dike lengths can range from near 0 m to over 5,000 m (Table 4-1, row 3). One value is sampled for each realization. However, the length of each dike in that realization can vary from this value according to the rules described in Appendix D (part A). These rules are intended to prevent logical inconsistencies when the sampled dike lengths are incorporated with the multiple dike distributions and overlaid onto the repository plan.

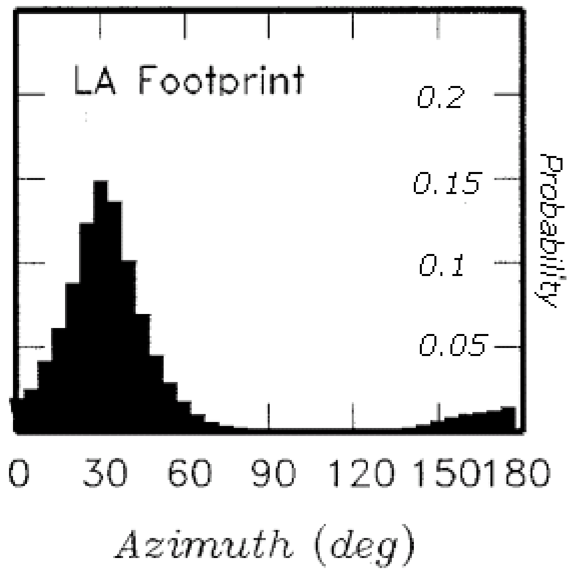
2. Dike azimuth angle. One value is sampled for each realization. *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989], Figure 6-20) developed the distributions of possible azimuth angles through the repository that is used in this analysis (Table 4-1, row 3). Azimuth angles are measured in degrees, going clockwise, from due north. Figure 6-3 shows a relatively narrow distribution clustered around the modal value of 30 degrees. The sampled angle applies to all dikes in that realization.

3. Number of dikes per realization. This is a truncated log-normal distribution with a minimum value of 1 and a modal value of 3. The 95th percentile is set at 6 (Table 4-1, row 11). Given the LHS (SNL 2004 [DIRS 167794]) setting to produce 1000 realizations, this distribution leads to a small population of cases where the number of dikes can run from 7 to roughly 15.

4. Spacing between dikes. Dike spacing ranges from 1 m to 1490 m (Table 4-1, row 13). The range used in this analysis has a minimum value of 100 m and a maximum possible spacing of 690 m. This range is demonstrated to be conservative and is

discussed further in Section 6.5.1. The spacing values are calculated independently for each pairing of adjacent dikes. In other words, for any given realization, there can be many unique inter-dike spacing values. The total width of the swarm will be the sum of the dike spacings.

5. Central dike swarm entry location. This position is termed an 'anchor point'. The anchor point is assigned to a random location along the repository perimeter for each realization. The variable position of entry locations is assigned a uniform distribution.



Data Source: Figure 6-20 (BSC 2004, [DIRS 169989]). Data in DTN: LA0303BY831811.001 [DIRS 163985].

Figure 6-3. Mean Probability Distribution for Dike Intersection Azimuth Angle

Parameters that are not treated as uncertain variables include dike thickness and repository layout and dimensions. The repository is treated as a configuration that does not change. Dike thicknesses do vary, but the maximum expected thickness of 4.5 m (DTN: LA0407DK831811.001 [DIRS 170768]) at Yucca Mountain is still small compared to the 81 m spacing between repository emplacement drifts and the average drift length of over 600 m (800-IED-MGR0-00201-000-00B BSC 2004 [DIRS 168489]). A maximum dike thickness is hard-coded into DIRECT (SNL 2004 [DIRS 167795]) by bounding box algorithms with additional thickness above the maximum value of 4.5 m. This additional thickness adds an element of conservatism because the greater the thickness of each dike, the greater the area occupied by each dike. Within the limited repository area, these greater dike areas proportionately increase the opportunities for intersections with drifts. This increased thickness treatment is discussed in more detail in Section 6.3.3.

Figures 6-4 and 6-5 illustrate the basic conceptual rules, and the type and variety of outcomes that can be realized. After conducting an LHS (SNL 2004 [DIRS 167794]) run with the proper sampling and distribution criteria, a set of 1000 parameter combination realizations is produced (this set is captured in the file *LHS.dat*, which is input to the DIRECT code (SNL 2004 [DIRS 167795])). This set is called a replicate and it contains its own unique random seed to

The number of waste packages damaged by a system of eruptive conduits is treated as a joint probability, dependent on both the number of conduits and the diameter of the conduits. *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989], Table6-11) contains various distributions based on different approaches for the number of conduits associated with a dike system intersecting the repository. The approaches differ in several respects, including the degree of randomness versus the tendency toward a constant conduit spacing and the degree of correlation between conduit number and dike characteristics. The distribution for the mean hazard, final composite conditional probability represents a composite of these different approaches, and is used in this analysis. The term, hazard, is a term of art, that simply means probability. Table 6-2 shows this distribution, which has 14 bins ranging from 0 to 13 conduits and a maximum at 1 conduit.

Table 6-2 . Mean Hazard, Final Composite Conditional Probability for Number of Eruptive Centers

Number of Eruptive Centers within Repository	Final Composite Conditional Probability
0	0.218
1	0.567
2	0.108
3	0.0430
4	0.0238
5	0.0163
6	0.0101
7	0.00699
8	0.00335
9	0.00144
10	0.00092
11	0.00080
12	0.00045
13	0.00005

Source: BSC 2004 [DIRS 169989], Table 6-11;
DTN: LA0307BY831811.001 [DIRS 164713].

As documented in *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989], Figure 6-13 and accompanying text), the results of the PVHA generally specify that less than five eruptive centers would form during a single volcanic event, regardless of the number of associated dikes (CRWMS M&O 1996, *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada* [DIRS 100116]. To capture the full range of uncertainty, the distribution shown in Table 6-2 allows as many as 13 conduits to penetrate the repository.

The distribution for conduit diameters is taken from the DTN LA0407DK831811.001 [DIRS 170768]. It is described as a triangular distribution with a most-likely (mode) value of 50 m, a minimum value equal to the host dike thickness of 4.5 m, and a maximum value of 150 m. The development of this distribution is detailed in the work area titled Auxiliary 1, starting on row 75 in the auxiliary worksheet of the *ANL-MGR-GS-000003_results.xls* spreadsheet. Appendix B of this document explains how to acquire this spreadsheet from the dike length and orientation, and the CDF for number of conduits that could form within the repository) are described in the analysis report, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989]). Table 8 presents a mapping of CDF technical product outputs from this report to the results spreadsheet. Table 9 presents a similar mapping for alternative CDF results and Table 10 presents a mapping of auxiliary CDF outputs for the two previously identified spreadsheets. This analysis does not evaluate failure modes for engineered barrier components or damage that could result from exposure of waste packages and waste forms to magmatic conditions. Assessments of damage to waste packages and waste forms associated with intrusion of a dike into the repository or eruption of a volcano through the repository are provided in the model report, *Dike/Drift Interactions* (BSC 2004 [DIRS 170028]).

3. Uncertainty is adequately represented in parameter development for conceptual models, process-level models, and alternative conceptual models considered in developing the assessment abstraction of mechanical disruption of engineered barriers. This may be done either through sensitivity analyses or use of conservative limits.

   Uncertainties in the current analysis have been intrinsically accounted for by the nature of the Latin Hypercube Sampling approach. Additionally, conservative assumptions have been included to bound uncertainties associated with parameters used in the analysis as described in Section 6.5. Alternate analyses, and sensitivity and uncertainty studies that were included to examine sensitivities to specific parameters are described in Section 6.5. Conservatism adopted in the analyses ensures that the risk is not under-represented and that they are discussed in Sections 6.3.3, 6.4, and 6.5.

4. Where sufficient data do not exist, the definition of parameter values and conceptual models is based on appropriate use of expert elicitation, conducted in accordance with NUREG-1563 (Kotra et al 1996 [DIRS 100909]). If other approaches are used, the U.S. Department of Energy adequately justifies their use.

   Expert elicitation was not directly used in the development of the analysis of number of waste packages hit by igneous intrusion into the repository. However, expert elicitation was used in *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (BSC 2004 [DIRS 169989]) and data resulting from that elicitation are used in this report.

Acceptance Criterion 4: Model uncertainty is characterized and propagated through the model abstraction

1. Alternative modeling approaches of features, events, and processes are considered and are consistent with available data and current scientific understanding, and the results and limitations are appropriately considered in the abstraction.

   Features, events, and processes that are included in this report are described in Section 6.2 and summarized in Table 6-1. Table 6-1 also summarizes the TSPA-LA description of each included FEP and includes references to sections of the report in which the TSPA-LA disposition is described. Analysis of alternates and sensitivity