SAND2008-2136P

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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Disruptive Scenarios: Igneous Eruptive Model Abstraction

Presented to:

NRC/DOE Technical Exchange on Total System Performance Assessment (TSPA) for Yucca Mountain

Presented by:

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April 4, 2008
Las Vegas, Nevada

TSPA-LA Model Components for the Volcanic Eruption Modeling Case

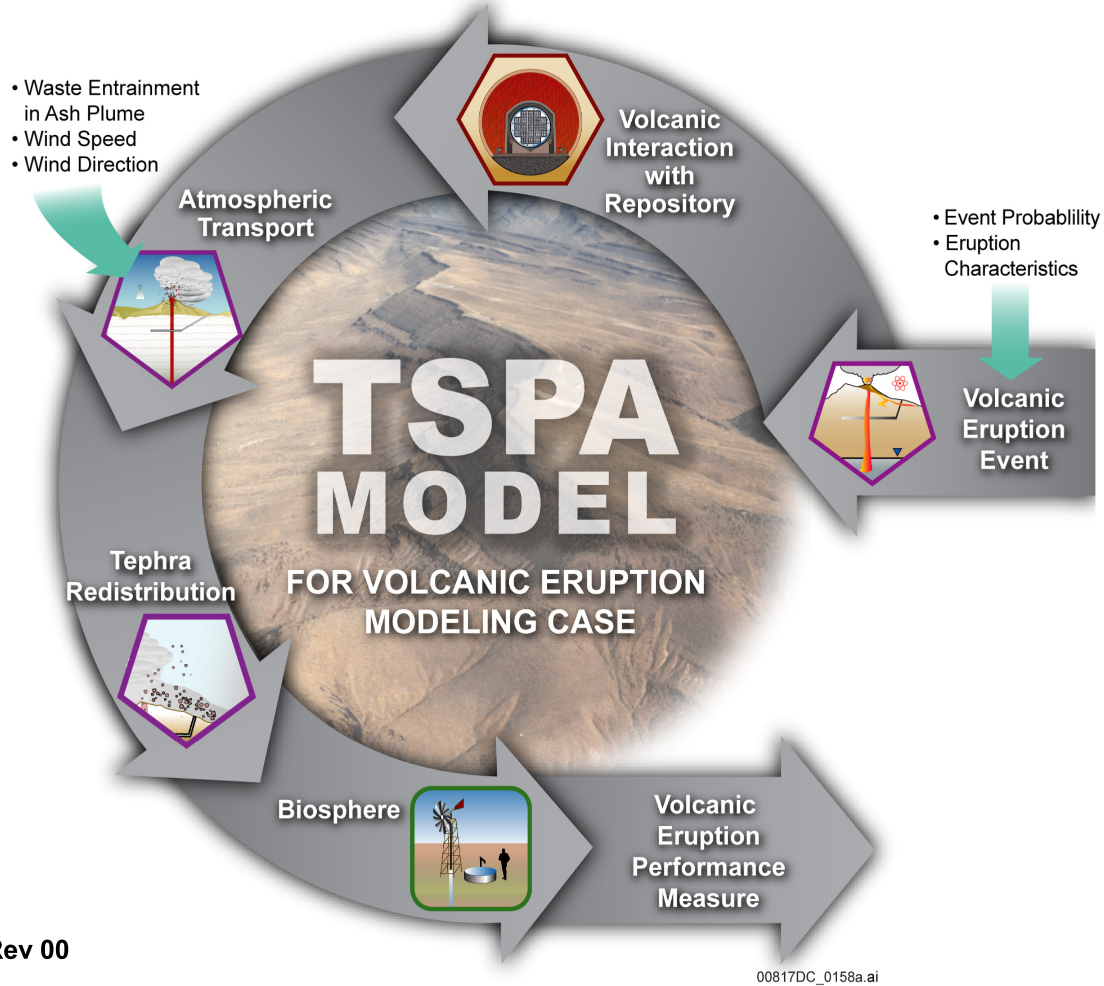

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Figure 6.5-7

Distribution of Basaltic Rocks in the Yucca Mountain Region

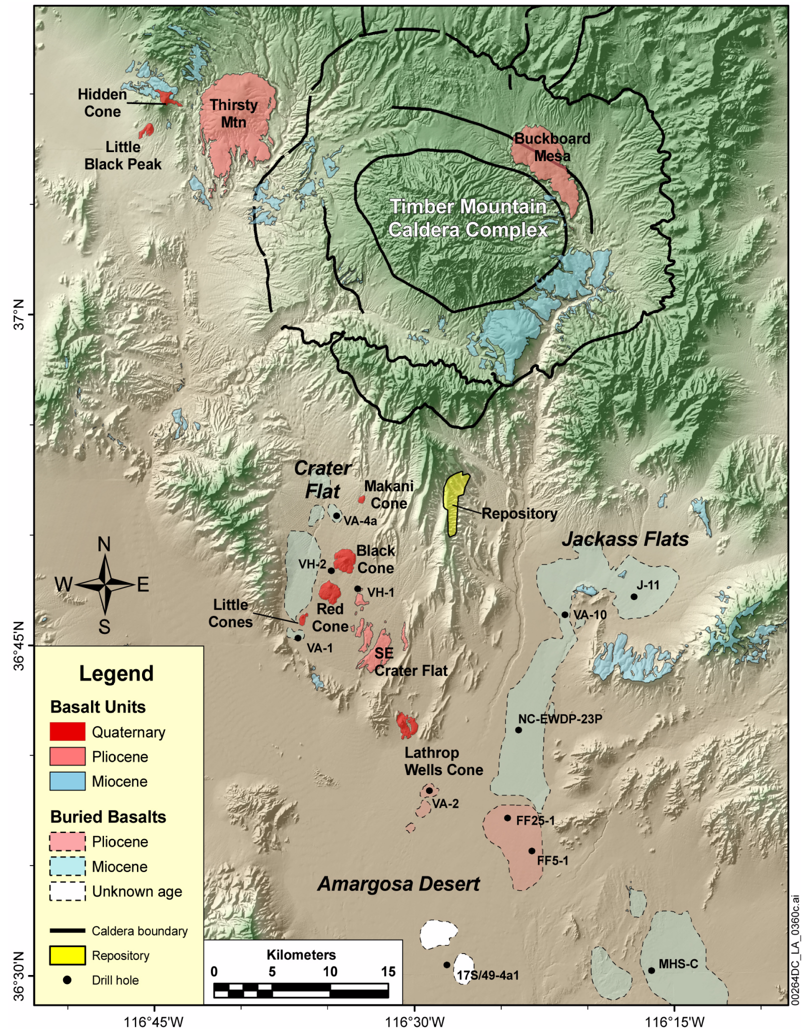

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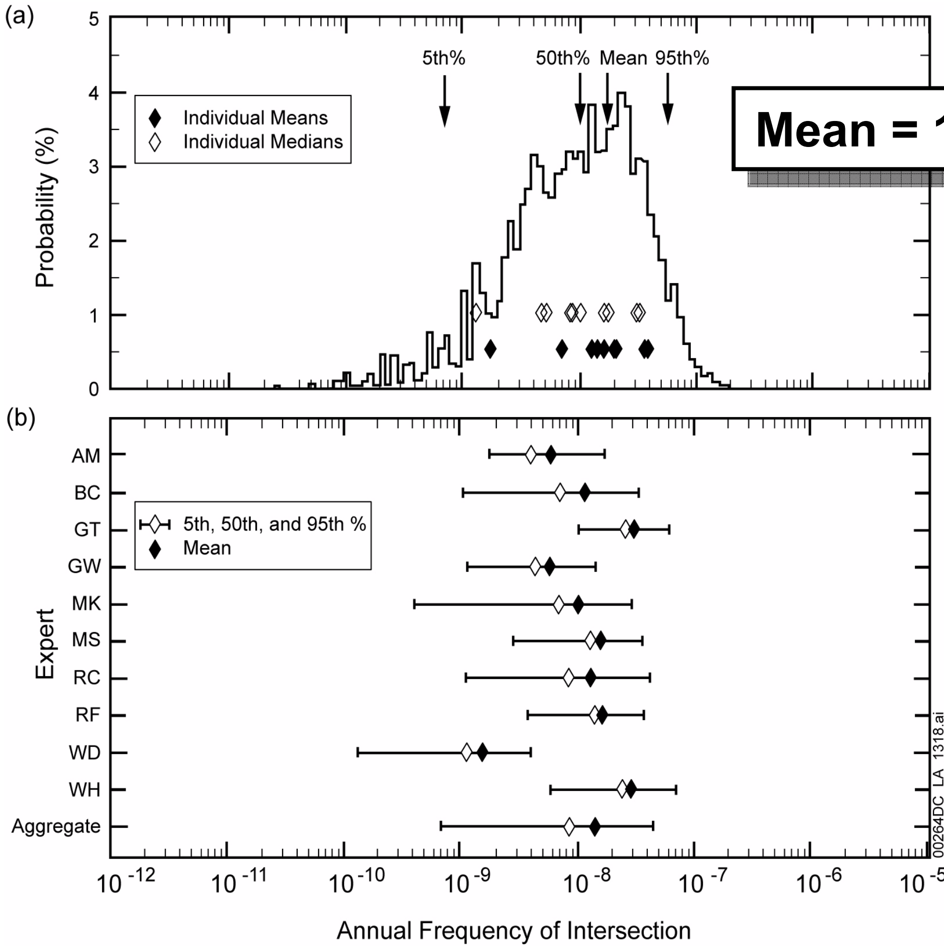
Figure 6.5-1

Annual Frequency of Intersection by Dike

Probabilistic Volcanic Hazard Analysis Expert Interpretations (1996)



Mean = 1.7×10^{-8} per year

ANL-MGR-GS-000001 REV 03 ACN 01
Figure 6-18

Volcanic Interaction with Repository Submodel

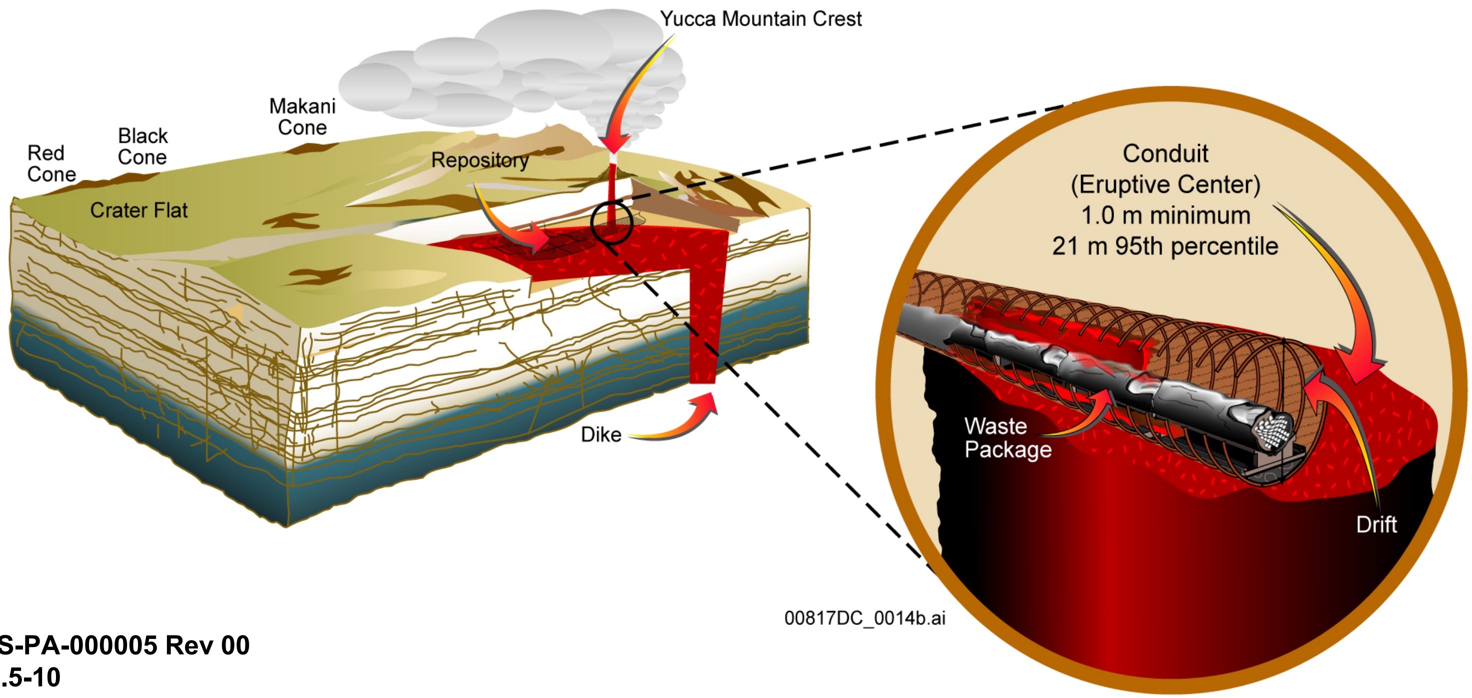


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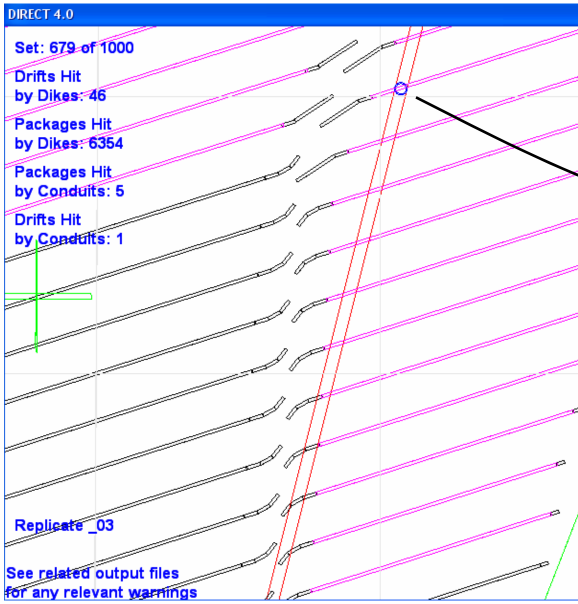
Figure 6.5-10

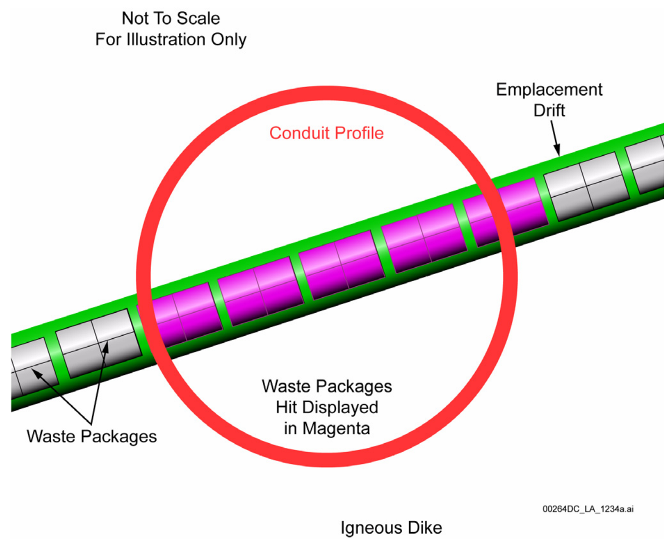
Probability of Conduit Intersecting Repository Footprint = 0.28
Probability of Intersecting Conduit Contacting Waste = 0.30

Mean Probability of Conduit Intersecting Waste $= (1.7 \times 10^{-8}) \times (0.28) \times (0.30)$
$= 1.4 \times 10^{-9}$ **per year**

Volcanic Interaction with Repository Submodel



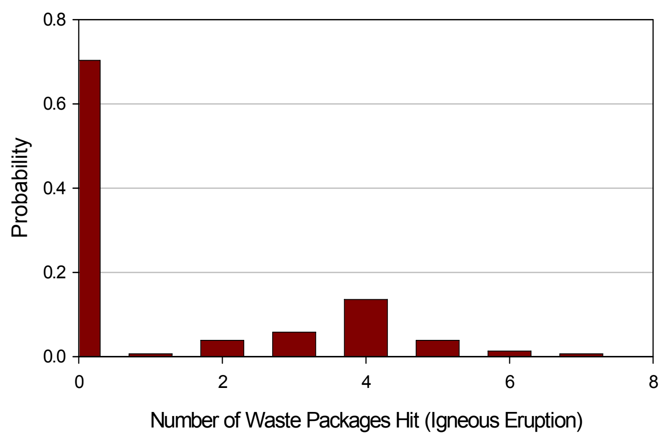
ANL-MGR-GS-000003 Rev 03 Figure 6-8



ANL-MGR-GS-000003 Rev 03 Figure 5-1

Number of dikes in a swarm: 1-5 (P of 1 = 0.40)
Dike width: normal, mean 8 m, 95th 12 m
Dike spacing: uniform, 0.5-1500 m
Number of conduits: 1-3 (P of 1 = 0.85)
Conduit diameter: normal, mean 15 m, 95th 21 m

ANL-MGR-GS-000003 Rev 03 Table 4-1



MDL-WIS-PA-000005
Rev 00 Figure 6.5-11

Atmospheric Transport of Contaminated Tephra Submodel (ASHPLUME)

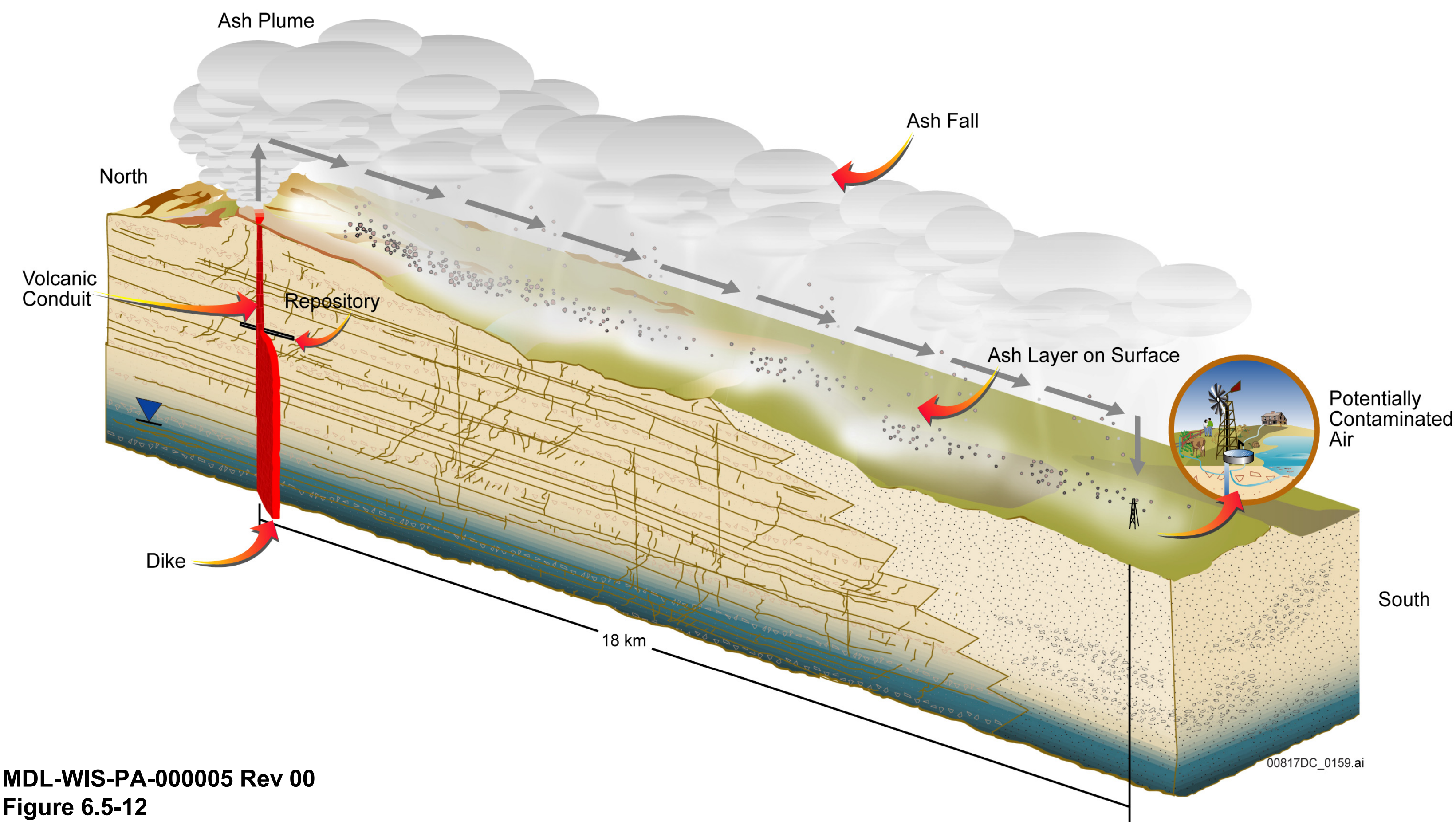


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Figure 6.5-12

Atmospheric Transport of Contaminated Tephra Submodel - Key Parameters

TSPA Parameter	Parameter Description	Uncertainty Type	Value(s)
C	Constant relating eddy diffusivity and particle fall time ($cm^2/s^{5/2}$)	Fixed value	400
Erupt Power	Eruptive power (W)	Aleatory	1.0×10^9 – 1.0×10^{12} (log uniform)
Erupt Velocity	Initial Rise Velocity (cm/s)	Aleatory	1.0 – 1.0×10^4 (uniform)
Beta Dist	Column diffusion constant	Epistemic	0.01 – 0.5 (uniform)
Dash Mean	Mean ash particle diameter (cm)	Epistemic	0.001 – 0.01 – 0.1 (log Tri.)
Dash sigma	Ash particle diameter standard deviation (log cm)	Epistemic	0.301 – 0.903 (uniform)
D_min	Minimum waste particle diameter (cm)	Fixed value	0.0001
D_mode	Mode of waste particle diameter (cm)	Fixed value	0.0013
D_max	Maximum waste particle diameter (cm)	Fixed value	0.2
Rhocut	Waste incorporation ratio	Fixed value	0.0
Erupt Time	Eruption duration (seconds)	Aleatory	DTN: LA0702PADE03GK.002
Wind Direction	Wind direction (degrees)	Aleatory	DTN: MO0408SPADRWSD.002
Wind Speed	Wind speed (cm/s)	Aleatory	DTN: MO0408SPADRWSD.002
Magma Partitioning	Fractional multiplier on waste mass to account for waste-containing magma erupted in scoria cone and lava flows	Aleatory	0.1 – 0.5 (uniform)

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Table 6.5-4

Tephra Redistribution Submodel
(FAR – Fortymile Wash Ash Redistribution)

Two Model Domains

1) **Drainage Basin**
   – **Mobilization from hill slopes**
   – **Channel transport – mixing/dilution**
2) **Alluvial Fan (RMEI location)**
   – **Diffusion into soil column**
   – **Channel and Divides**

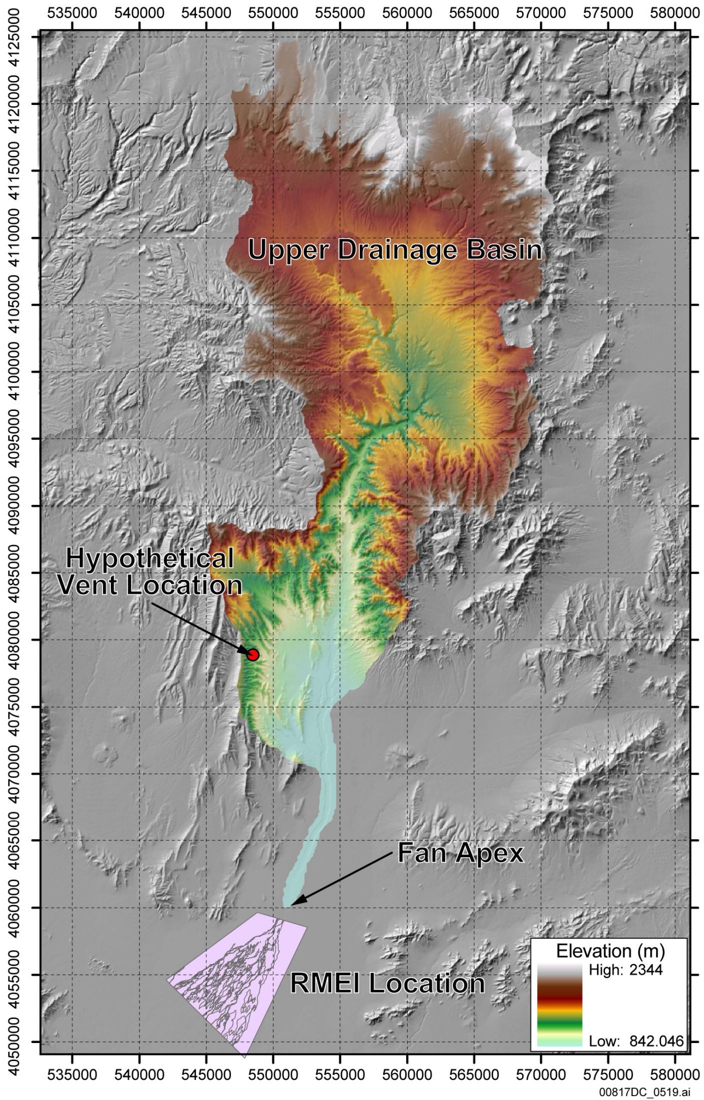

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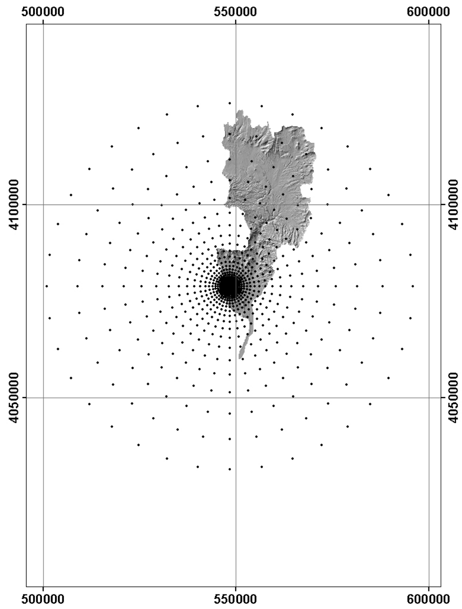
Figure 6.5-13

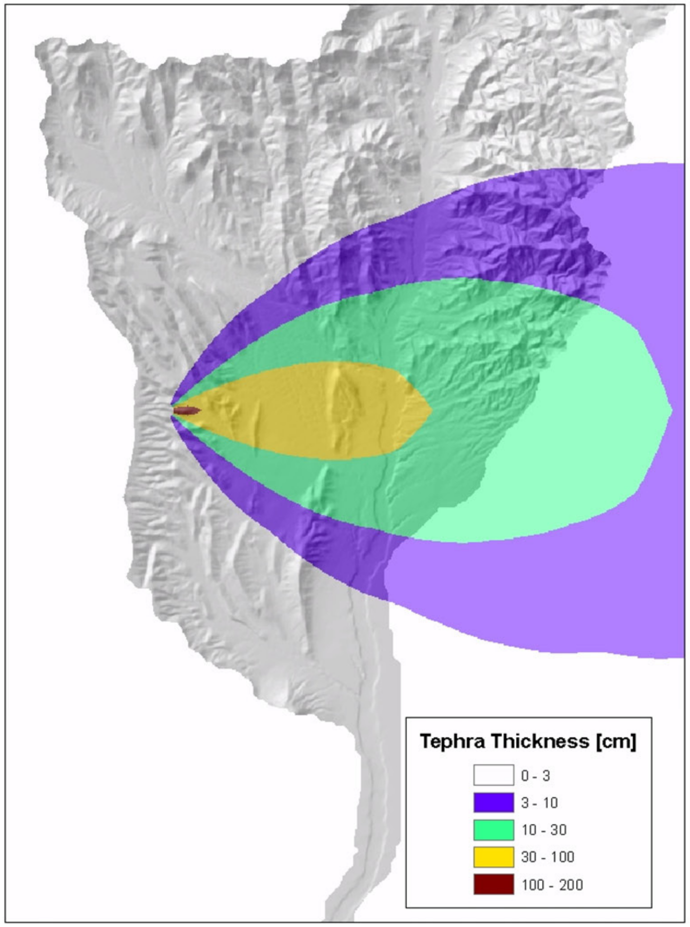
Tephra Redistribution Submodel (continued)

ASHPLUME results calculated for a hypothetical vent located at YM and superimposed on FAR domain

(Example shown with wind to east)



MDL-MGR-GS-000006 Rev 00 Figure 6.3.3-2



MDL-MGR-GS-000006 Rev 00 Figure 6.3.3-9

Tephra Redistribution Submodel
Vertical Transport of Radionuclides in Soil

Surface transport of contaminated tephra assumed to be instantaneous

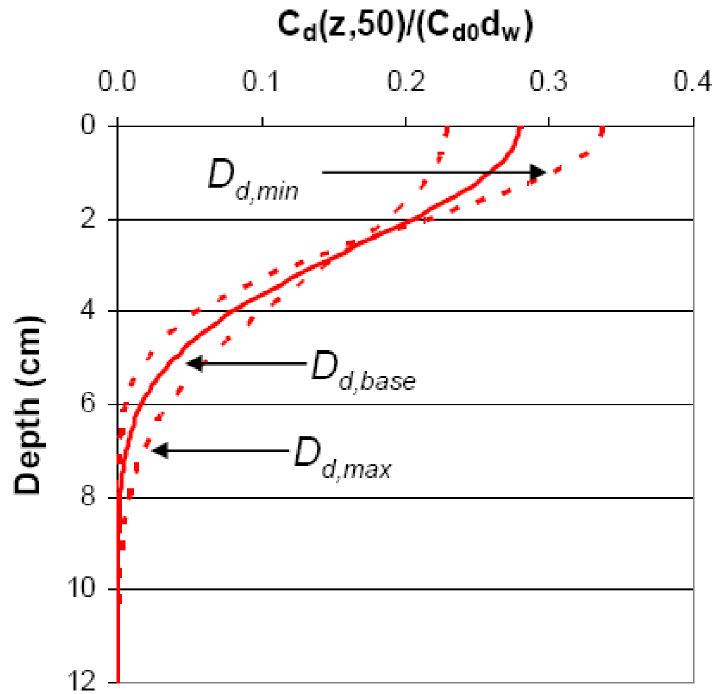
Subsequent vertical migration in soil estimated assuming bulk transport from all processes can be represented by diffusion (Fick's Law)

$$\frac{\partial C(z,t)}{\partial t} = D\frac{\partial^2 C(z,t)}{\partial z^2}; z \geq 0, \quad t \geq 0$$

Rate of transport depends on effective diffusivity and layer thickness

Effective diffusivity constants are uncertain parameters based on field measurements of ^{137}Cs

Validated by comparison to data from Chernobyl and Harwell



Example calculation: normalized concentration versus depth for a divide sample point 50 years after deposition MDL-MGR-GS-000006 Rev 00 Figure 7.1.3-3

Tephra Redistribution Submodel Key Parameters

TSPA Parameter Name	Parameter Description	Distribution type	Uncertainty Type	Value (s)
Critical_Slope_a	Critical gradient for tephra mobilization from hillslopes	Uniform	Epistemic	0.21 – 0.47
Drainage_Density_a	Average drainage density for the Fortymile Wash drainage basin	Uniform	Epistemic	20 – 33 km^{-1}
Scour_Depth_a	Scour depth in Fortymile Wash at the fan apex	Uniform	Epistemic	73 – 122 cm
RMEI_Area	Area of the Fortymile Wash fan	Constant	fixed value	33 km^2
Fraction_Channel_a	Fraction, *F*, of the Fortymile Wash fan subject to fluvial activity	Uniform	Epistemic	0.09 – 0.54
L_Channels_a	Depth of permeable soil on channels, L_c, of the Fortymile Wash fan (RMEI location)	Constant	fixed value	200 cm
L_Divides_a	Depth of permeable soil on divides, L_d. of the Fortymile Wash fan (RMEI location)	Uniform	Epistemic	102 – 140 cm
D_Channels_a	Diffusivity of waste in channels, D_c, of the Fortymile Wash fan (RMEI location)	Uniform	Epistemic	0.035 – 0.266 cm^2/yr
D_Divides_a	Diffusivity of waste in divides, D_d, of the Fortymile Wash fan (RMEI location)	Uniform	Epistemic	0.001 – 0.095 cm^2/yr
Ash_Density_a	Tephra settled density	Truncated normal	Epistemic	300 – 1,500 kg/m^3 mean = 1,000 kg/m^3 std. dev. = 100 kg/m^3
b_Tillage	Tillage depth	Uniform	Epistemic	0.05 – 0.30 m

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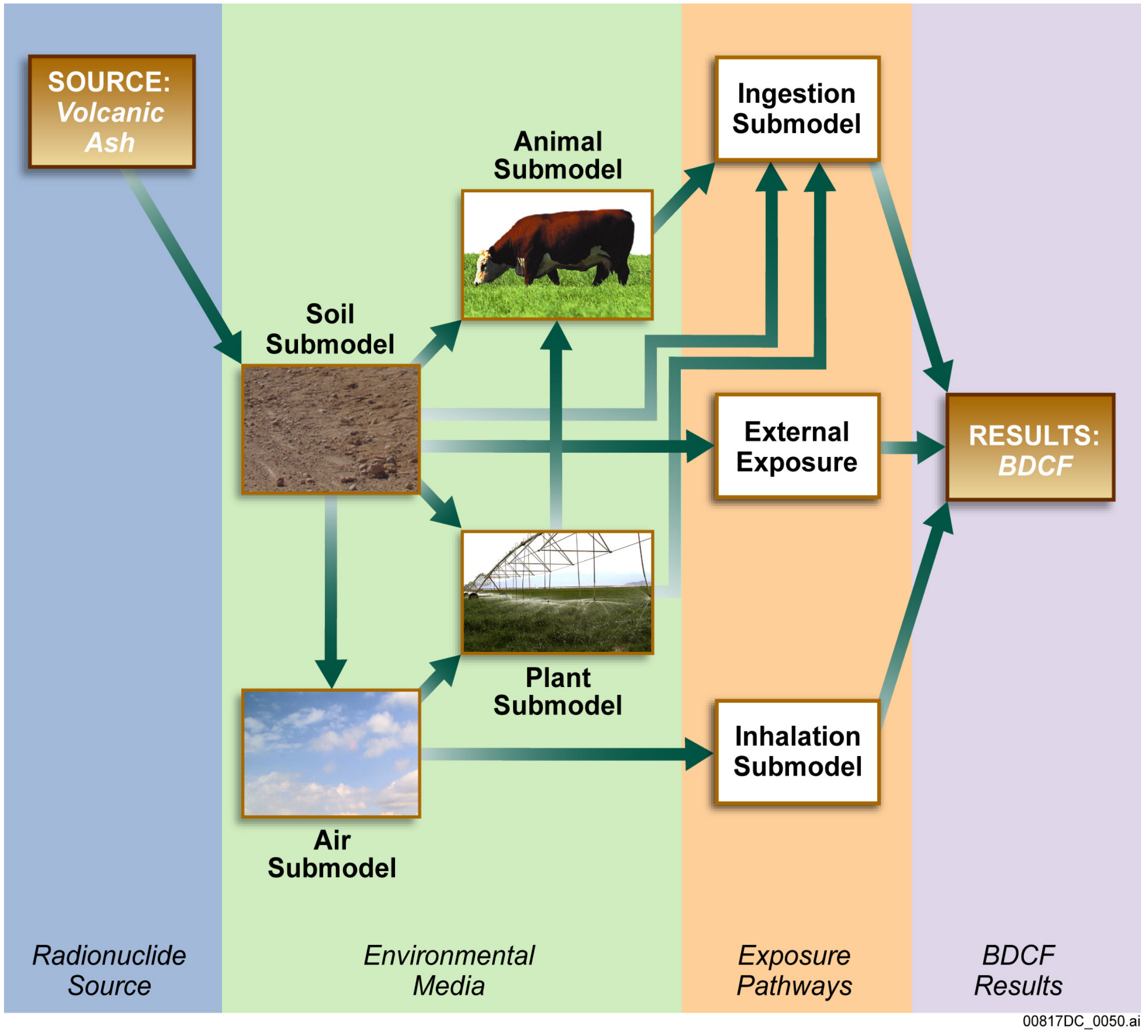
Table 6.5-5

Biosphere Submodel for the Volcanic Eruption Modeling Case



Biosphere Dose Conversion Factors (BDCFs) for Volcanic Eruption Case

- **Ingestion pathway**
- **External exposure pathway**
- **Inhalation pathway**
  - **Accounts for high air mass loading following eruption and longer-term soil stabilization**

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Figure 6.3-11-6

Calculation of Annual Dose to the RMEI for the Volcanic Ash Exposure Case

$$D_{all\ pathway,i}(t,T) = BDCF_{ext,ing,Rn,i}\ Cs_i(t) + \left(BDCF_{inh,v,i}\, f(t-T) + BDCF_{inh,p,i}\right) Cs_{mc,i}(t)$$

$D_{all\ pathway,i}(t,T)$	=	**all-pathway annual dose for primary radionuclide *i* at time *t-T* after a volcanic release of radionuclides from the repository at time *t* after repository closure (Sv/yr)**
$BDCF_{ext,ing,Rn,i}$	=	**BDCF component for external exposure, ingestion, and inhalation of radon decay products for primary radionuclide *i* (Sv/yr per Bq/m^2)**
$Cs_i(t)$	=	**areal radionuclide concentration in a specified depth of surface soil at time *t* (year) after the repository closure (Bq/m^2) calculated in TSPA-LA model**
$BDCF_{inh,v,i}$	=	**BDCF component representing average early-time increase in inhalation exposure in the first year after a volcanic eruption; used in calculation of short-term inhalation exposure at post-eruption level of mass loading in excess of nominal mass loading for primary radionuclide *i* (Sv/yr per Bq/kg)**
$BDCF_{inh,p,i}$	=	**BDCF component for long-term inhalation at nominal level of mass loading for primary radionuclide *i* (Sv/yr per Bq/kg)**
$f(t-T)$	=	**decay function describing reduction of the annual average mass loading with time at time *t-T* following a volcanic eruption**
$Cs_{mc,i}(t)$	=	**activity concentration of radionuclide *i* per unit mass of soil in the resuspendable layer of surface soil (critical thickness [1-3 mm uniform]) at time t (year) after the repository closure (Bq/kg).**

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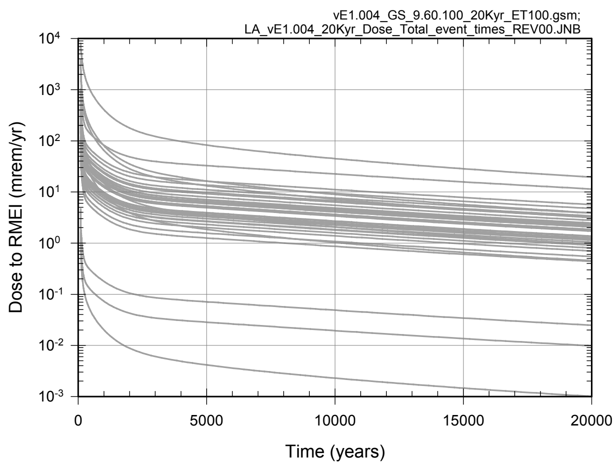
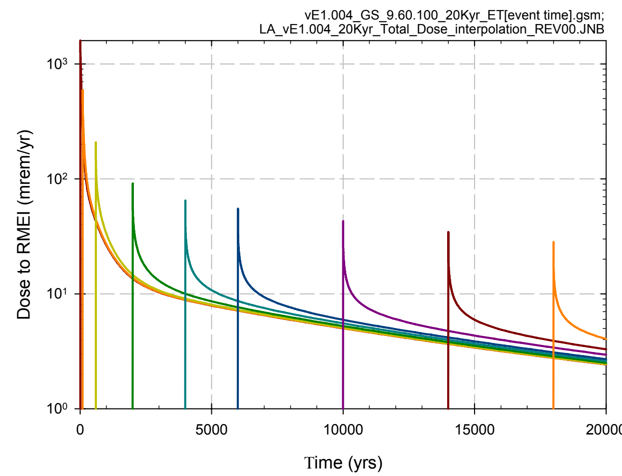
Section 6.3.11.2

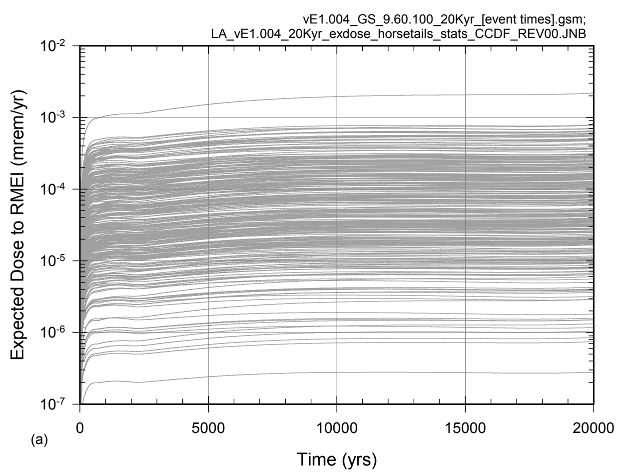
Conditional and Expected Eruptive Dose



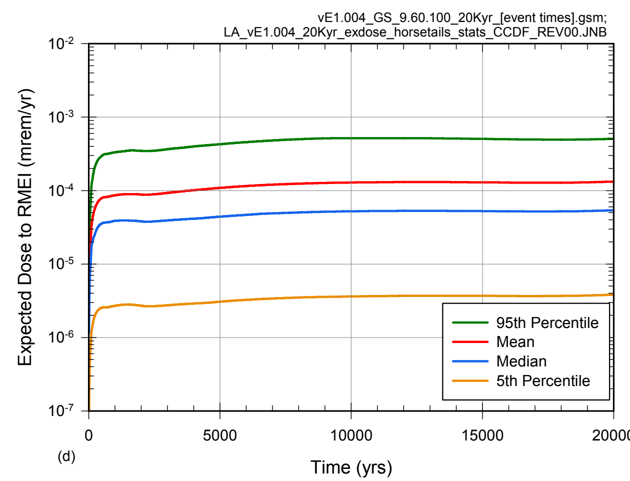
Conditional dose: 40 realizations of aleatory uncertainty conditional on a single eruption of 1 WP at time zero



Mean over aleatory uncertainty associated with a single eruption of 1 WP, eruptions at multiple times



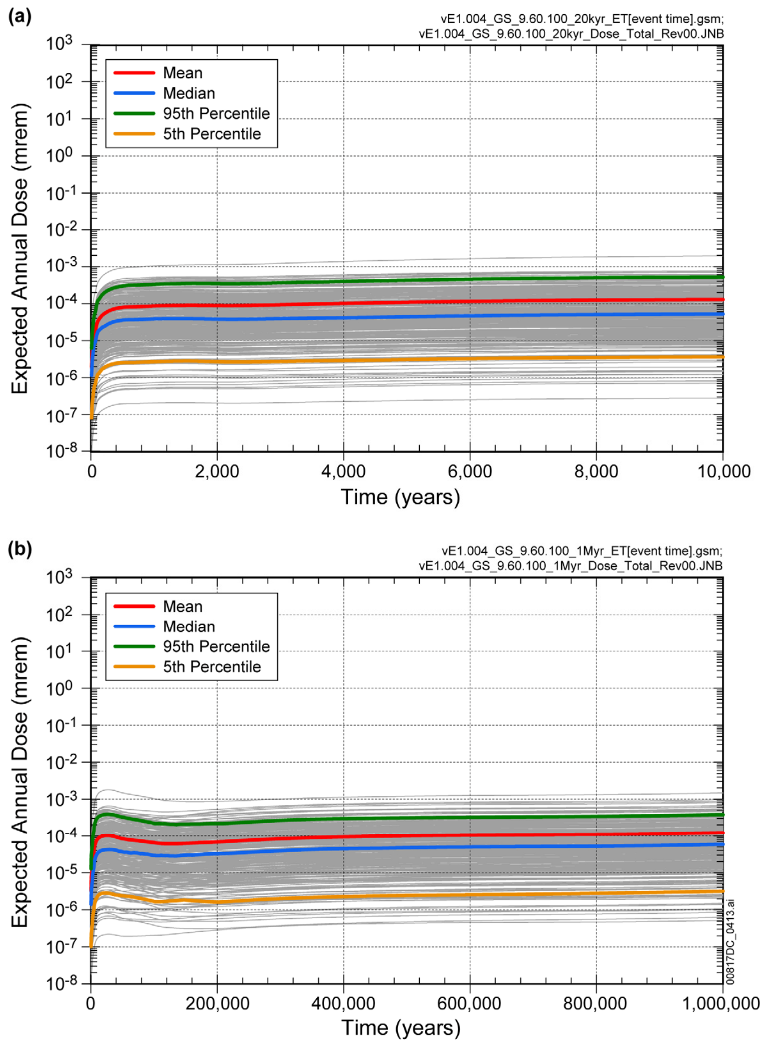
300 realizations, each showing expected dose from a single sampling of epistemic uncertainty with events at all times



Summary curves showing overall expected dose from eruption

MDL-WIS-PA-000005 Rev 00, Figures J7.3-1, 2,&4

Expected Annual Dose for the Volcanic Eruption Modeling Case



0 to 10,000 years

0 to 1,000,000 years

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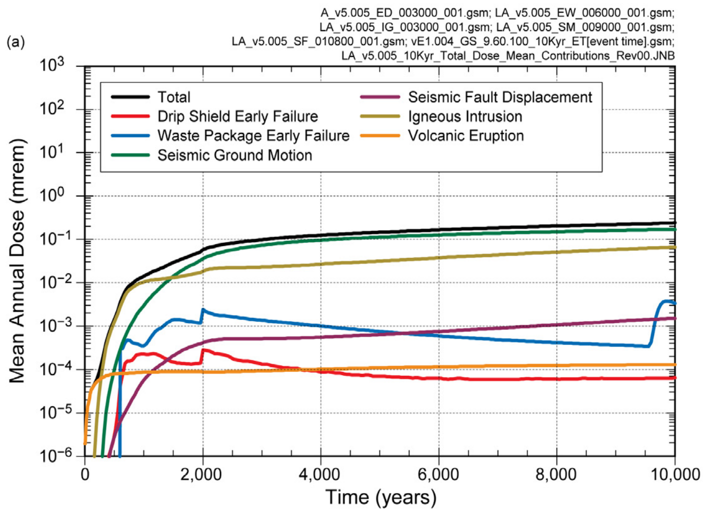
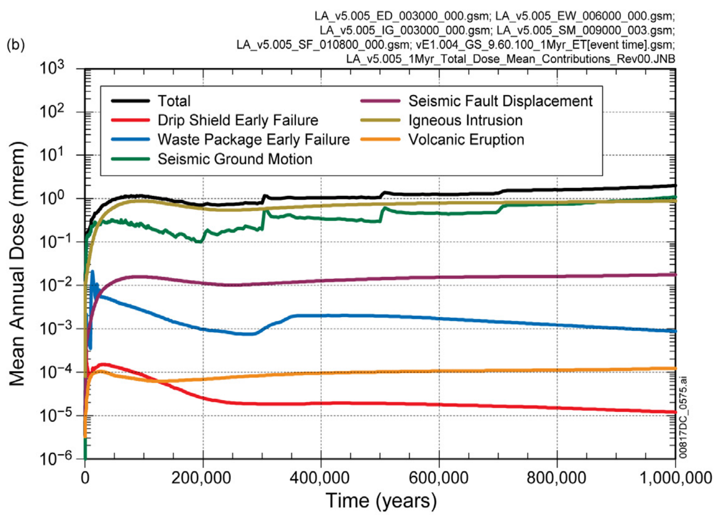
Figure 8.2-9

Relative Contributions of Modeling Cases to Total Mean Annual Dose



0 to 10,000 years



0 to 1,000,000 years

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Figure 8.1-13[a]

Conclusions

- Four components to the TSPA implementation of igneous
  - Volcanic interaction with the repository
    - Event probability, quantity of waste available for transport
  - Atmospheric transport
    - ASHPLUME model
  - Tephra redistribution
    - FAR model
  - Volcanic ash exposure
    - Biosphere dose conversion factors
- Overall, igneous eruption is a minor contributor to total mean annual dose

References

- **Bechtel SAIC 2004 and 2005, *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada,* ANL-MGR-GS-000001 Rev 02 and Rev 02 ACN 01.**
- **Sandia National Laboratories (SNL) 2007. *Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada*, MDL-MGR-GS-000002 Rev 03.**
- **SNL 2007. *Biosphere Model Report*, MDL-MGR-MD-000001 Rev 02.**
- **SNL 2007. *Characterize Eruptive Processes at Yucca Mountain, Nevada.* ANL-MGR-GS-000002 Rev 03.**
- **SNL 2007. *Number of Waste Packages Hit by Igneous Events,* ANL-MGR-GS-000003 Rev 03.**
- **SNL 2007. *Redistribution of Tephra and Waste by Geomorphic Processes Following a Potential Volcanic Eruption at Yucca Mountain, Nevada,* MDL-MGR-GS-000006 Rev 00.**
- **SNL 2008. *Total System Performance Assessment Model/Analysis for the License Application*, MDL-WIS-PA-000005 Rev 00 and Rev 00 AD01.**