**RAI Volume 3, Chapter 2.2.1.4.3, First Set, Number 1:**

Provide further information that clarifies how the dimensions of the representative volume used to address ground water protection standards were determined. In particular, describe: (1) how the traces of the particle tracks were used to define the dimensions of the cross section perpendicular to the direction of ground water flow, (2) the basis for the distance used for the dimension in the direction of ground water flow, and (3) the effect that climate change, within the first 10,000 years, has on the dimensions of the representative volume.

Basis: The dimensions of the cross section of the representative volume perpendicular to the direction of ground water are defined by particle traces (Section 2.4.4.3.2). However, the license application provides limited discussion regarding the particle traces (e.g., relationship between the number of particle traces and the number of breached waste packages, how the traces were used to determine the dimensions of the cross section, relationship between the traces and concentration in the representative volume). The dimension of the representative volume in the direction of groundwater flow is calculated to be 30 meters, but, there is limited discussion of the basis for this value (e.g., bases for the values used in the calculation).

Figure 2.3.9-14 illustrates particle tracks from beneath the repository to the southern edge of the site-scale saturated zone flow model. Plan and vertical views of these particle tracks in the figure provide limited information related to the areal extent of the plume normal to the flow direction at the accessible environment boundary. The resulting shape of the plume intersecting the accessible environment boundary is described as a rectangle 3000 m long and 200 m deep. However, if the edges, i.e., sides and bottom, of the plume are irregular, a smaller areal extent could be calculated.

The staff needs this information to determine compliance with 10 CFR 63.332, consistent with the definition of *slice of the plume* in 10 CFR 63.302.

# 1. RESPONSE

## 1.1 CROSS-SECTIONAL AREA OF THE SLICE OF THE PLUME

The total system performance assessment (TSPA) model uses the slice of the plume method and assumes complete capture of all mass passing an east-west trending vertical planar surface which is approximately normal to the flow direction. The planar surface represents the boundary of the accessible environment, which is located approximately 18 km downgradient of the repository. This approach effectively defines the edge of the slice of the plume to be where the concentration of radionuclides is negligible relative to the highest concentrations. The concentrations are then calculated by dividing the total mass flux rate (in g/yr) across the vertical plane, as determined using the TSPA model, by a water withdrawal rate of 3,000 acre-feet ($3.714 \times 10^6$ $m^3$) per year.

This is a conservative, bounding approach that is independent of the dimensions of the representative volume as defined in 10 CFR Part 63.

Although the approach taken in the TSPA model does not directly use the dimensions of the representative volume, calculating the dimensions of the representative volume is required by 10 CFR 63.332(b). To determine the dimensions of the representative volume, the cross-sectional area of the slice of the plume perpendicular to groundwater flow must be defined. The cross-sectional area as presented in SAR Section 2.4.4.3.2 is based upon a particle tracking analysis performed using the finite-element heat- and mass-transfer code (FEHM) to generate the flow paths simulated by the calibrated saturated zone site-scale flow model (SNL 2007, Section 6.5.2.3). One hundred particles were distributed randomly over the projected area of the repository at the water table and allowed to migrate until reaching the model boundary. The particle migration was based on advective transport only (dispersion was not considered). The maximum horizontal and vertical extents of the particle distribution across an east-west oriented vertical plane, which is approximately perpendicular to flow and is located at the boundary of the accessible environment, were used to circumscribe a rectangle that surrounds all the particles.

Based on the saturated zone groundwater flow modeling results presented in SAR Figure 2.3.9-14, the horizontal extent of the plume perpendicular to flow is approximately 3,000 m, and the vertical extent of the plume perpendicular to flow is approximately 200 m (SAR Section 2.4.4.3.2). The calculations presented in SAR Section 2.4.4.3.2 assume a simple rectangular approximation for the cross section of the plume, which gives a cross-sectional area of the plume perpendicular to the flow direction of 600,000 $m^2$.

The use of a simple rectangle circumscribing the simulated plume to define the cross-sectional area of the plume will always overestimate the cross-sectional area if the plume shape fits within the perimeter of the rectangle. Figure 1 presents the locations of particle traces crossing the east-west oriented vertical plane defining the accessible environment boundary derived from the base-case site-scale saturated zone transport model (SNL 2008a). Unlike the simulation used to generate SAR Figure 2.3.9-14, which does not include the influence of dispersion (SNL 2007, Section 6.5.2.3), the simulation used to generate Figure 1 includes the effect of dispersion. The simulation uses an expected value for dispersivity of 100 m (SNL 2008a, Table 6-8). Inclusion of dispersion slightly increases the spread of the particle locations, in contrast to the non-dispersive case. Although the simulation depicted in SAR Figure 2.3.9-14 differs slightly from simulation used to generate Figure 1, for the purpose of examining the implications of the shape of the plume, Figure 1 is a useful surrogate.

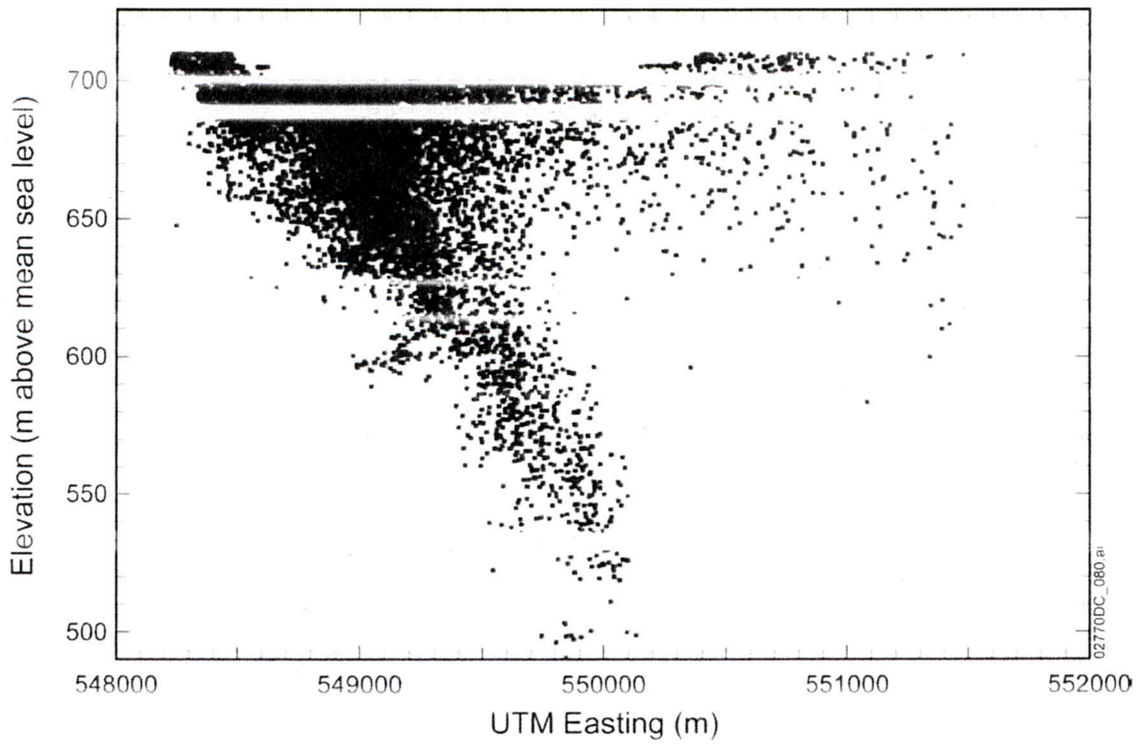


Figure 1. Locations of Particles Released from below the Repository and Tracked with FEHM's Streamline Particle Tracking Routine (SPTR) at the Accessible Environment Boundary

As can be seen in Figure 1, the horizontal extent of the plume is approximately 3,300 m and the vertical extent of the plume is about 220 m. For this simulation, a rectangular cross section defined by the horizontal and vertical extent of the plume would be approximately 726,000 $m^2$. This figure also shows that based on the particle traces, roughly 40% of a rectangular cross section defined by the horizontal and vertical extent of the plume would be outside the plume as described by the particle traces. The estimate of 40% is based on the assumption that the plume is not found in an approximately 1,600 m × 160 m triangular area located in the bottom-western part of the rectangular cross section and in an approximately 1,400 m × 95 m rectangular area located in the bottom-eastern part of the rectangular cross section. This would mean that the plume is not found in 261,000 $m^2$ of a 726,000 $m^2$ rectangular cross section or in 40% of the rectangular cross section if the ratio is rounded to one significant figure. If the plume is irregular, a smaller areal extent could be calculated. Taking into consideration the irregularities in the plume depicted in the simulation results presented in Figure 1, a calculation of the plume cross-sectional area would produce a cross-sectional area of 435,000 $m^2$ (726,000 $m^2$ × 60%). Although a smaller plume area could be calculated, since the dimensions of the representative volume are not used in the TSPA model, a simple 600,000 $m^2$ rectangular approximation of the cross section of the plume is a reasonable and conservative approach to defining the representative volume.

## 1.2 DIMENSION OF THE SLICE OF THE PLUME PARALLEL TO FLOW

As defined in 10 CFR 63.302, the "[s]*lice of the plume*" is a cross section of the plume of contamination with sufficient thickness parallel to the prevalent direction of flow of the plume that it contains the representative volume. The dimension of the representative volume parallel to flow may be based on the ratio of the annual water demand of 3,000 acre-feet to the area of the slice perpendicular to flow, taking into account the porosity of the aquifer. The third dimension that is necessary to define the representative volume of rock containing the 3,000 acre-feet of water is defined as:

$$L_{flow} = \frac{V_{water}}{\phi P_{area}} \quad \text{(Eq. 1)}$$

where $L_{flow}$ is the length of the representative volume in the flow direction, $V_{water}$ is the volume of water in the representative volume, $\phi$ is the average effective porosity in the representative volume, and $P_{area}$ is the plume slice cross-sectional area.

Once the cross-sectional area of the plume perpendicular to the flow direction is determined, the length of the representative volume (which is the rock volume that contains the 3,000 acre-feet of water) parallel to the flow direction can then be determined from Equation 1. Assuming the volume of water in the representative volume ($V_{water}$) is $3.714 \times 10^6$ m$^3$, the average effective porosity ($\phi$) in the representative volume is 0.18 (see SAR Table 2.3.9-2), and the plume slice cross-sectional area ($P_{area}$) is 600,000 m$^2$, the length of the representative volume in the flow direction ($L_{flow}$) is approximately 34.4 m (30 m if rounded to one significant figure), as stated in SAR Section 2.4.4.3.2. Similarly, a length of the representative volume in the flow direction of 47.4 m (50 m if rounded to one significant figure) could be developed based on the simulation presented in Figure 1 taking into consideration the irregularities in the plume depicted in Figure 1. Note that since the concentration calculations in the TSPA model are calculated by dividing the mass flux rate across an unbounded vertical plane at the boundary of the accessible environment by 3,000 acre-feet of water, the choice of dimensions for the representative volume would have no influence on dose calculations.

## 1.3 INFLUENCE OF CLIMATE STATES ON THE SLICE OF THE PLUME

By defining the length in the direction of the flow dimension of the representative volume based on the definition of *slice of the plume* in 10 CFR 63.302 (see Section 1.2 above), the dimension of the representative volume that is parallel to flow is not based on the specific discharge. Because the dimension of the representative volume that is parallel to flow is based on the cross-sectional area of the plume (which is not considered to be dependent on climate state) and the rock volume that contains the 3,000 acre-feet of water, the geometry of the representative volume is independent of the climate state. Not considering climate state in the development of the cross section is consistent with the conceptualization of the saturated zone flow and transport submodel of the TSPA model, where a change of climate states is represented by a scaling of the time-axes on the breakthrough curves, thus influencing only the transport rates and not the lateral distribution of particle traces across a plane perpendicular to flow.

## 1.4 SUMMARY

The cross-sectional area used to define the representative volume is based upon a particle tracking analysis performed to generate the flow paths simulated by the calibrated saturated zone site-scale flow model. Based on the intersection of flow paths with an east-west oriented vertical plane defining the boundary of the accessible environment, the maximum horizontal and vertical extent of the particle distribution were approximated and used to define a rectangle that circumscribed all the particles. A cross section from a similar particle tracking simulation was used to show that a smaller cross-sectional area would be calculated if a more refined cross section of the plume were considered.

Consistent with the definition of *slice of the plume* found in 10 CFR 63.302, the dimension of the representative volume, which is the rock volume that contains the 3,000 acre-feet of water, parallel to flow, can be based on the ratio of the annual water demand of 3,000 acre-feet to the area of the slice perpendicular to flow, taking into account the porosity of the rock mass.

The dimension of the representative volume parallel to flow is based on the cross-sectional area of the plume and the rock volume that contains the 3,000 acre-feet of water; the geometry of the representative volume is independent of the climate state.

# 2. COMMITMENTS TO NRC

None.

# 3. DESCRIPTION OF PROPOSED LA CHANGE

None.

# 4. REFERENCES

SNL (Sandia National Laboratories) 2007. *Saturated Zone Site-Scale Flow Model.* MDL-NBS-HS-000011 REV 03. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070626.0004; DOC.20071001.0013

SNL 2008a. *Site-Scale Saturated Zone Transport.* MDL-NBS-HS-000010 REV 03 AD 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080121.0003.

SNL 2008b. *Saturated Zone Flow and Transport Model Abstraction.* MDL-NBS-HS-000021 REV 03 AD 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080107.0006; LLR.20080408.0256.