



# Scientific Analysis/Calculation Error Resolution Document

QA: QA  
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Complete only applicable items.

## INITIATION

1. Originator: Roger Henning / Palmer Vaughn	2. Date: 05/27/2008	3. ERD No. ANL-WIS-MD-000024 ERD 02
4. Document Identifier: ANL-WIS-MD-000024 Rev 01	5. Document Title: Postclosure Nuclear Safety Design Bases	
6. Description of and Justification for Change (Identify applicable CRs and TBVs):		

### I. Background Information Summary

CR 12112 was written to identify that colloid filtration between units in the rock matrix is an unrealized process in FEHM Version 2.24-01. The impact analysis (Section IV) in ERD No. MDL-NBS-HS-000020 ERD 02 identified that the updates to the *Particle Tracking Model and Abstraction of Transport Processes* (MDL-NBS-HS-000020 REV02 AD 02) described in the ERD have resulted in changes to several documents including the *Postclosure Nuclear Safety Design Bases* (ANL-WIS-MD-000024 REV 01). This ERD implements changes in the *Postclosure Nuclear Safety Design Bases* driven by the direct input changes from *Particle Tracking Model and Abstraction of Transport Processes* (MDL-NBS-HS-000020 REV02 AD 02) as corrected by MDL-NBS-HS-000020 ERD 02.

### II Inputs and/or Software

Direct inputs to the *Postclosure Nuclear Safety Design Bases* (referenced in this ERD as the parent document) include: the *Particle Tracking Model and Abstraction of Transport Processes* (MDL-NBS-HS-000020 REV 02 AD 02), the *Features, Events, and Processes for the Total System Performance Assessment: Analyses* (ANL-WIS-MD-000027 REV 00), and the *Total System Performance Assessment Model /Analysis for the License Application* (MDL WIS-PA-000005 REV 00 AD 01). These direct inputs are used in the *Postclosure Nuclear Safety Design Bases* analyses as documented in Appendix A and in summary descriptions in the text in the main body of the parent document. The information from the direct inputs only impacts explanatory text cited from the sources and used in *Postclosure Nuclear Safety Design Bases*. No software controlled under IM-PRO-003, Software Management, was used in this analysis.

### III Analysis Results and Conclusions

The error identified in CR 12112 is analyzed herein for potential impact on the parent report as well as on any technical products that use the information from the parent report.

## CONCURRENCE

	Printed Name	Signature	Date
7. Checker	Barry Lester	<i>[Signature]</i> for	6/10/08
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## APPROVAL

9. Originator	Roger J. Henning	<i>[Signature]</i>	6/10/2008
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### III Analysis Results and Conclusions

The error identified in CR 12112 is analyzed herein for potential impact on the parent report as well as on any technical products that use the information from the parent report. The following controlled and under development documents were evaluated for impacts:

Document Input Reference System Impact Analysis for:

DIRS 177464 SNL (Sandia National Laboratories) 2008. *Postclosure Nuclear Safety Design Bases*. ANL-WIS-MD-000024 REV 01. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080226.0002; DOC.20080314.0004.

Controlled:

- 000-30R-MGR0-00500-000-004: *Q-List*
- ANL-WIS-MD-000026 Rev. 00: Features, Events, And Processes for the Total System Performance Assessment: Methods
- MDL-NBS-HS-000006 Rev. 03: *UZ Flow Models and Submodels*
- TDR-PCS-SE-000001 Rev. 05, ACN 01, Addendum 01; *Performance Confirmation Plan*
- TDR-PCS-SE-000001 Rev. 05, Addendum 01: *Performance Confirmation Plan*
- TDR-TDIP-ES-000010 Rev. 00: Total System Performance Assessment Data Input Package for Requirements Analysis for EBS In-Drift Configuration
- TDR-TDIP-PA-000001 Rev. 00: Total System Performance Assessment Data Input Package for Requirements Analysis for Subsurface Facilities

Under Development:

- LA Safety Analysis Report

There are no open TBVs associated with this document.

The remainder of this ERD consists of revised text and tables, which address the impact evaluation for CR 12112. None of these changes result in impacts to the analyses or conclusions in ANL-WIS-MD-00024 REV 01 ACN 01 or to any downstream technical products.

The changes to the following four pages in the parent document are made to resolve issues in CR12112:

Page 6-94: deleted “colloid filtration” from list in 1<sup>st</sup> paragraph of section 6.2.2.3.1.

Page 6-95 deleted “and colloid filtration” in two places in 3rd paragraph of section 6.2.2.3.1, and changed “are” to “is” because it now needs to say “and sorption is weaker”.

Page 6-96 deleted “and colloid filtration” from 6th paragraph of section 6.2.2.3.1, and changed “are” to “is” because it now needs to say “and sorption is weaker”.

Page A-168: added additional explanatory information to the discussion of Effect on Barrier Capability for FEP 1.2.02.01.0A, by adding “in fractures as simulated using a retardation factor”, after “colloid filtration”.

As a separate issue, as noted during checking of this ERD, an error was discovered in Table 4-1 and the DIRS report related to reference SNL (Sandia National Laboratories) 2007. UZ Flow Models and Submodels. MDL-NBS-HS-000006 REV 03 AD 01. [DIRS 184614]. Change is made to page 4-8 of the parent document, and to the DIRS entry (item 70) by replacing “transport” with “flow”, deleting sorption and colloid filtration” and inserting “and” before “matrix diffusion coefficient”.

#### **IV Impact Evaluation**

From the analysis of results in ERD No. MDL-NBS-HS-000020 ERD 02 there is no detrimental impact to the conclusions of the *Particle Tracking Model and Abstraction of Transport Processes* (MDL-NBS-HS-000020 REV 02 AD 02). In all cases, the conclusions of the downstream documents are unchanged, but the descriptions of the colloid filtration process are revised to be consistent with the no colloid filtration case at interfaces with rock units. The corrected information is consistent with the implementation of the UZ transport model in the TSPA-LA and removal of colloid filtration from the model results in more conservative estimates of the dose. The changes as documented in this ERD are only modifications of text, and do not impact any of the conclusions of output DTNs from the parent document. The pages that required changes only apply to the parent document, not the subsequent ACN 01 or the ERD 01. There are no impacts to the analyses or conclusions in ANL-WIS-MD-00024 REV 01 or to any downstream technical products.

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#### **CHANGES TO THE DOCUMENT SHOWN ON IMAGES OF THE ORIGINAL DOCUMENT**

Copies of the five pages from the parent document with corrections and a page illustrating the corrections to DIRS 184614 are included on the following six pages.

sorption. Field scale in situ tracer tests at the C-Wells demonstrated matrix diffusion as an important transport mechanism in fractured volcanic formations in the saturated zone. Matrix diffusion is included in the saturated zone transport model abstraction (SNL 2008 [DIRS 183750], Section 6.3.1 and Table 6-8).

- **Sorption in the Saturated Zone**—Radionuclides released from the repository have varying retardation characteristics. Several radionuclides that are the dominant contributors to the total inventory are significantly retarded in the saturated zone. These include  $^{90}\text{Sr}$ ,  $^{230}\text{Th}$ ,  $^{226}\text{Ra}$ ,  $^{137}\text{Cs}$ ,  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$ ,  $^{242}\text{Pu}$ ,  $^{241}\text{Am}$ , and  $^{243}\text{Am}$ . The sorption behavior of these radionuclides significantly reduces the rate of movement of these radionuclides from the repository to the accessible environment. Sorption effects are included in the TSPA models presented in *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008 [DIRS 183750], Section 6).

The bases for the models used in the analysis of unsaturated zone flow are described in *UZ Flow Models and Submodels* (SNL 2007 [DIRS 184614], Sections 6). The flow fields are generated using the three-dimensional site-scale unsaturated zone flow model with input parameters based on unsaturated zone calibrated properties (SNL 2007 [DIRS 179545], Section 6.3). These flow fields are developed for spatially varying net-infiltration maps for the present-day, monsoon, and glacial-transition climate states and the post-10,000-year climate. The bases for the model used in the analysis of radionuclide transport in the unsaturated zone are described in *Particle Tracking Model and Abstraction of Transport Processes* (SNL 2008 [DIRS 184748], Section 6). The processes incorporated into the unsaturated zone transport model include sorption, fracture-matrix interaction, colloid-facilitated radionuclide transport, radioactive decay and ingrowth, and dispersion. The bases for the process models used to assess the capability of the unsaturated zone component of the LNB are the same as the bases contained in the TSPA abstraction.

The flow and radionuclide transport model for the saturated zone is discussed in detail in *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008 [DIRS 183750], Section 6). The analysis of the capability of the saturated zone component of the LNB is derived from the same models used as the basis for the TSPA calculations. Key uncertainty parameters (i.e., groundwater flux, sorption coefficients, and matrix-imbibition and matrix diffusion transport parameters) are varied, subject to uncertainty distributions based on the available data and observations, and these uncertainties are reflected in the model results.

#### **6.2.2.3.1 Capability of the Unsaturated Zone below the Repository to Prevent or Substantially Reduce the Rate of Movement of Radionuclides to the Water Table**

The unsaturated zone below the repository prevents or substantially reduces the rate of movement of radionuclides from the repository horizon to the water table. The radionuclides take time to move through the unsaturated zone. As water percolates down, sorption, ~~colloid filtration~~, matrix imbibition, and matrix diffusion cause the movement of radionuclides to be slower relative to the general movement of the percolating water. The existence of perched-water bodies introduces three-dimensional lateral flow within the unsaturated zone below the repository level. Below the northern half of the repository block, low-permeability layers and perched water bodies in the CHn unit channel a large fraction of flow laterally to

faults that act as conduits for water flow to the water table (SNL 2007 [DIRS 184614], Section 6.6.2.2). Radionuclides are also dispersed during movement in the unsaturated zone because of variability in radionuclide transport times and in the retardation characteristics of the various volcanic units.

The data and analyses supporting models of radionuclide transport in the unsaturated zone that are summarized below are described in detail in *Particle Tracking Model and Abstraction of Transport Processes* (SNL 2008 [DIRS 184748], Section 6). Figure 6-8 shows the sequence of tuffs comprising the unsaturated zone below the repository. This figure shows that these features include the lower part of the TSw and Calico Hills nonwelded (CHn) units and tuffs of the Crater Flat Group, including the Prow Pass welded tuff. These units together provide a feature ranging from about 200-m to 400-m-thick, under present-day climate conditions. The TSw unit is characterized by very low matrix permeability and well-connected, steeply dipping fracture networks. The CHn unit underlies the TSw unit. Below the southern part of the repository, the CHn unit is vitric, composed of unaltered glassy shards of volcanic ash and characterized by relatively high matrix permeability. Fractures are rare to nonexistent in the vitric CHn unit and flow through this unit is predominantly through the matrix. Below the vitric CHn unit are the devitrified and zeolitized tuffs of the Prow Pass welded tuff unit. These tuffs have lower matrix permeability than the vitric CHn unit, and flow down through such tuffs is primarily in fractures. The fracture networks in these nonwelded tuffs are generally bed-confined and not well connected.

The movement of radionuclides carried by water in the matrix of the TSw unit is slow because of sorption ~~and colloid filtration~~ processes in the rock matrix. The rate of movement of radionuclides carried by water in the fractures is more rapid than in the matrix, and sorption ~~and colloid filtration are~~ is weaker. Consequently, the matrix of the TSw unit more effectively retards the migration of the radionuclides than the fracture system. Matrix diffusion and imbibition transfers radionuclide mass from fractures into the matrix.

As shown in Figure 6-8, downward-moving radionuclides encounter the CHn unit at the base of the TSw unit. Because of the low permeability and infrequency of connected fractures of the zeolitic CHn unit beneath the northern part of the repository block and because the flow down from the overlying TSw unit is primarily in the fractures, perched-water zones form at the TSw-CHn contact. A significant fraction of the downward-percolating flux is diverted laterally to the east in this region. The present age of the perched water ranges from several thousand years old to as much as 11,000 years old.

Beneath the northern part of the repository, the radionuclides either enter the zeolitic CHn unit or are diverted to the east in the perched water. The zeolitic CHn unit is strongly altered to a mixture of minerals, including zeolites and clays. The minerals have precipitated in the pores of the rock so that the matrix permeability of the zeolitic CHn unit is low. Most of the downward flow that reaches the zeolitic CHn is diverted laterally through perched water zones at the TSw-CHn contact, bypassing this unit and flowing through faults or connected fractures, which leads to short radionuclide transport times to the saturated zone.

Beneath the southern part of the repository, the radionuclides are transferred into the vitric CHn unit matrix where groundwater velocity is low relative to the velocity in the fractures and where

sorption ~~and colloid filtration are~~ ~~is~~ strong. Below the vitric CHn unit, the radionuclides move predominantly in the fractures of the underlying devitrified and zeolitized tuffs of the Prow Pass Tuff. Because the fracture flow pathways are not continuous, the alternating layers of welded, nonwelded, and zeolitized tuffs delay the movement of radionuclides, which leads to long transport times to the saturated zone compared to release locations in the northern repository region.

The combination of slow water movement from the repository to the water table and processes that retard the rate of movement of radionuclides in the unsaturated zone results in a reduction in the activity of the radionuclides and their release to the saturated zone.

#### **6.2.2.3.2 Capability of the Saturated Zone to Prevent or Substantially Reduce the Rate of Movement of Radionuclides to the Accessible Environment**

Radionuclides that migrate through the unsaturated zone to the water table are transported through the saturated zone before they can reach the accessible environment. The data and analyses supporting models of radionuclide transport in the saturated zone that are summarized below are described in detail in *Saturated Zone Site-Scale Flow Model* (SNL 2007 [DIRS 177391], Section 6); and *Saturated Zone Flow and Transport Model Abstraction* (SNL 2008 [DIRS 183750], Section 6). Groundwater below Yucca Mountain is part of the Alkali Flat–Furnace Creek groundwater subbasin within the Death Valley regional groundwater system. Groundwater flow is generally to the south and east near Yucca Mountain. The southeasterly flow from the site is incorporated into the stronger southward flow in western Jackass Flats. The expected pathway for movement of radionuclides through the saturated zone is southeast from the repository site, transitioning to southerly flow to the accessible environment in the Amargosa Desert.

The pathways for radionuclide movement, in the saturated zone, for the first 12 to 14 km downgradient from Yucca Mountain, occur in fractured volcanic rocks. This portion of the saturated zone is affected by the faulting and tilting of the volcanic rocks and is represented in an equivalent continuum model in terms of two aquifers: an upper volcanic aquifer associated with the Topopah Spring Tuff units, and a lower volcanic aquifer associated with the Prow Pass, Bullfrog, and Tram Tuff units.

The schematic shown in Figure 6-8 is located along the approximate pathways for radionuclide movement as the radionuclides encounter alluvial sediments approximately 12 to 14 km from Yucca Mountain. These alluvial sediments are generally represented as a single porous medium with equivalent continuum properties to represent heterogeneity in the flow and transport characteristics of these sediments.

The saturated zone feature of the LNB includes the fractured volcanic rocks from below the repository to approximately 12 to 14 km southeast and south of Yucca Mountain and the saturated alluvium at the water table from the volcanic aquifer to the accessible environment. The movement of radionuclides in the saturated zone is slow because the velocity of water that can carry such radionuclides is low. In addition, processes discussed below cause the rate of movement of radionuclides to be slower compared to the rate of movement of the water. The data and models for saturated zone flow and transport that support this analysis are discussed in

Table A-3. ITBC Analysis of Lower Natural Barrier FEPs

Feature / Component	FEP Number Name, and Screening Decision	Discussion of Effect on Barrier Capability	Relates to ITBC <sup>1</sup>	Core Parameter Characteristic <sup>2</sup>	Control Parameter Characteristic <sup>3</sup>
Unsaturated Zone Below the Repository	1.2.02.01.0A Fractures <b>Included</b>	Fractures below the repository still conduct the majority of the percolation flux through the unsaturated zone, although the low-matrix-permeability zeolitic rocks of the CHn, cause increased lateral diversion toward the faults, and the vitric CHn is dominated by matrix flow. In addition, the fractures have a significant effect on the rate of radionuclide transport through the unsaturated zone through their influence on transport properties. Important fracture-related transport processes/properties include fracture permeability, porosity, frequency, active fracture model, matrix diffusion coefficient, sorption, and colloid filtration <b>in fractures as simulated using a retardation factor</b> (SNL 2007 [DIRS 184614], Section 6.1.2); SNL 2007 [DIRS 177396], Sections 6.1.1 and 6.1.2). <b>FEP Source:</b> SNL 2008 [DIRS 183041] – 1.2.02.01.0A	Yes	<b>ITBC:</b> Unsaturated Zone Properties Unsaturated Zone Flow Unsaturated Zone Transport	<b>Non-ITBC:</b> Repository Geographic and Geologic Location
Unsaturated Zone Below the Repository	1.2.02.02.0A Faults <b>Included</b>	A significant fraction of percolation flux below the repository occurs through faults (on average over 30% at the water table location). In addition, faults are important to unsaturated zone transport because they provide fast pathways for radionuclide transport to the water table (SNL 2007 [DIRS 177396], Section 6.7.5). The Drill Hole Wash fault and the Pagany Wash fault act as the main transport conduits, from the repository horizon to the water table (SNL 2007 [DIRS 177396], Section 6.8.1.2). <b>FEP Source:</b> SNL 2008 [DIRS 183041] – 1.2.02.02.0A	Yes	<b>ITBC:</b> Unsaturated Zone Properties Unsaturated Zone Flow Unsaturated Zone Transport	<b>Non-ITBC:</b> Repository Geographic and Geologic Location Repository Standoff from Quaternary Fault

Table 4-1. Source of Inputs (Continued)

Citation	Source Title	Specifically Used From	Specifically Used In (this AMR)	Input Description
SNL 2007 [DIRS 184614]	UZ Flow Models and Submodels	Section 7.7.4.2	Table A-1	Perched-water conditions do not presently exist in the unsaturated zone above the repository, and are not expected even under future climate changes
		Sections 6.1.2, 6.2.4, 6.1.2; Table 4.1-1	Table A-3	Fracture-related <del>transport-flow</del> processes/properties include fracture permeability, porosity, frequency, active fracture model, and matrix diffusion coefficient, <del>desorption, and colloid filtration</del>
SNL 2007 [DIRS 180506]	In-Package Chemistry Abstraction	Section 6.3.1.3.4	Table A-2	The different characteristics of these waste forms (in particular the hygroscopic nature of the HLW glass) have been considered in the waste form alteration models and is not found to substantially impact barrier capability of this feature
		Section 6.3.1.1	Table A-2	Chemistry effects of voids in the waste package internals are included in models of in-package chemistry
		Sections 6.10.8 and 8.1	Table A-2	The chemical characteristics of the water in contact with the waste package internals, including void spaces, and the waste form, affect the degradation characteristics of the waste form, the solubility of radionuclides in the dissolved phase, and the stability of colloidal particles
		Table 6-1a	Table A-2	The in-package redox state is assumed to be set by the oxidation state in the emplacement drifts once the waste package is breached and therefore set to 0.2
		Section 6.3.1.3.3	Table A-2	The chemistry of the water that comes into contact with the waste form and waste package internals is altered by reaction with the exposed metallic and waste form surfaces inside the waste package. Results of analyses indicate that the chemistry is more affected by the rate and amount of water interacting with the waste package internals than the chemistry of this water



Change required in DIRS consistent with use in Table 4-1. (page 4-8 in parent document).

2a.	2. Technical Product Input Source Title and Identifier (s) with Version	3. Specifically Used From:	4. Specifically Used In:	5. Input Description	6. Input Description	7. Input Category	8. Q Status	9. TBV/TBD Status
70	SNL (Sandia National Laboratories) 2007. <i>UZ Flow Models and Submodels</i> . MDL-NBS-HS-000006 REV 03 AD 01. (update on: 21-jan-2008 14:52:03) <a href="#">184614</a> Verified	Sections 6.2.4, 6.1.2; Table 4.1-1	Table 4-1, Table A-3	Fracture-related <del>transport flow</del> processes/properties include fracture permeability, porosity, frequency, active fracture model, and matrix diffusion coefficient; <del>desorption, and colloid filtration</del>	Direct Input	Data	Qualified	N/A