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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET

Complete Only Applicable Items

1. QA: QA

☐ Analysis ☐ Engineering ☐ Performance Assessment ☐ Scientific

3. ☑ Model ☐ Conceptual Model Documentation ☑ Model Documentation ☑ Model Validation Documentation

4. Title:
Water Drainage Model

5. Document Identifier (including Rev. No. and Change No., if applicable):
ANL-EBS-MD-000029 REV 00

6. Total Attachments:
6

7. Attachment Numbers - No. of Pages in Each:
I-4, II-1, III-1, IV-3, V-1, VI-2

	Printed Name	Signature	Date
8. Originator	Mason Pillow	[signature]	12-16-99
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12. Remarks:
Gina Rosenburg of Lawrence Livermore National Laboratory prepared input files and executed NUFT V3.0s, and XTOOL V9.15.
Kenrick Lee of Lawrence Livermore National Laboratory developed and executed the routine Chim_Surf_TP V1.1 and Chim_wt_TP V1.1.
James Gansemer of Lawrence Livermore National Laboratory developed and executed ColumnInfiltration V1.1, Cover V1.1, and CONVERTCOORDS V1.1. James Gansimer also executed YMESH V1.53.
Mary Gokoffski of Lawrence Livermore National Laboratory developed and executed the routine rme6 V1.1.
Test cases used for routine qualification were developed by the document originator and executed by the respective routine developers.

Complete Only Applicable Items

?. Analysis or Model Title:
'ater Drainage Model

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-EBS-MD-000029 REV 00

4. Revision/Change No.	5. Description of Revision/Change
00	Initial issue.

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FIGURES

TABLES

ACRONYMS

AFC	Active Fracture Concept
DKM	Dual Permeability Model
EBS	Engineered Barrier System
TBV	To Be Verified
T-H-C	Thermal-Hydrological-Chemical
T-H-M	Thermal-Hydrological-Mechanical
UZ	Unsaturated Zone
WP	Waste Package

1. PURPOSE

The drainage of water from the emplacement drift is essential for the performance of the EBS. The unsaturated flow properties of the surrounding rock matrix and fractures determine how well the water will be naturally drained. To enhance natural drainage, it may be necessary to introduce engineered drainage features (e.g. drilled holes in the drifts), that will ensure communication of the flow into the fracture system.

The purpose of the Water Drainage Model is to quantify and evaluate the capability of the drift to remove water naturally, using the selected conceptual repository design as a basis (Wilkins and Heath, 1999). The analysis will provide input to the Water Distribution and Removal Model of the EBS.

1.1 OBJECTIVES

The objective of this modeling and analysis activity is to develop models and perform analyses and calculations, to be used in bounding the volume of water that will be removed from the emplacement drift naturally. The analysis is to address issues of uncertainties and parameter sensitivities. Thermal-Hydrological-Chemical (T-H-C) and/or Thermal-Hydrological-Mechanical (T-H-M) effects are considered.

1.2 WORK SCOPE

The scope of work includes: a) developing performance goals for water drainage; b) developing models for and performing calculations; c) considerations of uncertainties and sensitivities; and d) calculations of T-H-C/T-H-M effects. The scope of Revision 00 of this document will be limited to a complementary family of 2D NUFT calculations.

1.3 PRIMARY TASKS

The primary tasks completed in the preparation of this document are:

1. Perform Thermal-Hydrologic (T-H) calculations for drainage in the base case, including uncertainties, bounding estimates, and parameter sensitivity.
2. Extend this analysis to include possible T-H-C effects (e.g., rock flour, mineralization and possibly T-H-M effects) that may reduce drainage beneath the EBS.

2. QUALITY ASSURANCE

This document was prepared in accordance with AP-3.10Q, *Analyses and Models,* and the development plan (CRWMS M&O 1999c), which was prepared in accordance with AP-2.13Q, *Technical Product Development Plan,* and is subject to quality assurance controls. A Technical Change Request (T1999-0126) was approved in accordance with AP-3.4Q, *Level 3 Change Control.* Inputs to this document include input transmittals (in accordance with AP-3.14Q, *Transmittal of Input),* and information in the Technical Data Management System.

The activity related to preparing this document has been evaluated (CRWMS M&O 1999a) in accordance with QAP-2-0, *Conduct of Activities,* and has been determined to be subject to the requirements of the *Quality Assurance Requirements and Description* (DOE 1998a). The QAP-2-3, *Classification of Permanent Items,* evaluation *Classification of the MGR Ex-Container System* (CRWMS M&O 1999b, p. 8) has identified the ex-container system as QL-1, important to radiological safety. Water drainage is not specifically addressed, but is a characteristic of the ex-container system. For this document, it is assumed that the classification of water drainage features is QL-1, important to radiological safety. The engineered barrier system is identified on the *Q-List* (DOE 1998b, p. II-9) and is identified as QL-1, important to radiological safety; and QL-2, important to waste isolation. Water drainage is not specifically addressed in the Q-List.

Qualified and accepted input data and references have been identified. Unqualified data used in this report are tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs.* AP-3.10Q, *Analyses and Models,* requires that output resulting from unqualified software be designated as unqualified-to be verified (TBV) in accordance with AP-3.15Q, *Managing Technical Product Inputs.* Computer software and model usage is discussed in Section 3 of this report.

Model validation is discussed in Section 6.5. Software and routines used in this report are subject to AP-SI.1Q, *Software Management,* as discussed in Section 3 of this document.

As per section 5.9 of AP-3.10Q, *Analyses and Models,* the results of this model will be submitted to the Technical Data Management System in accordance with AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System* if the data developed in this document are determined to be needed by organizations outside of the Engineered Barrier Systems Operations.

3. COMPUTER SOFTWARE AND MODEL USAGE

No qualified software was used in the preparation of this document. Unqualified software that was used is outlined below (Section 3.1). AP-3.10Q, *Analyses and Models*, requires that the resulting output from the unqualified software used in the preparation of this report must be designated as unqualified-to be verified (TBV) in accordance with AP-3.15Q, *Managing Technical Product Inputs*. Further software qualification is required prior to the removal of this TBV designation.

This model is validated as documented in Section 6.2.

3.1 DESCRIPTION OF SOFTWARE USED

All unqualified software codes used in the preparation of this document are under configuration management and have associated software tracking numbers. The names and software tracking numbers for the unqualified codes used in this document are NUFT V3.0s (NUFT, STN: 10088-3.0s-00), CONVERTCOORDS V1.1 (CONVERTCOORDS, SAN: LLNL-1999-143), YMESH V1.53 (YMESH, SAN: LLNL-1999-146), and XTOOL V9.15 (XTOOL, SAN: LLNL-1999-144).

Various software packages were used in the development of the inputs to this model. Table 1 shows the sources of inputs and the actual file names of the input and output files for the various routines and software packages used in developing the model inputs. Figure 1 further illustrates the path of data through routines and software packages. The files associated with this document are in Attachment VI.

3.1.1 NUFT

NUFT is classified as an unqualified software program (per AP-SI.1Q, *Software Management*), and is under configuration management (Table 1). NUFT was run on a Sun Ultra 10 workstation with SunOS 5.6 operating system.

NUFT, specifically the USNT module of NUFT, is used in this document to model flow through a fractured porous media. The key options used for the NUFT simulations include the dual permeability model (DKM) and the active fracture concept (AFC). These modeling methods are NUFT options selected in the NUFT input files (see Attachment VI, -files: *.in).

The DKM conceptualizes the fractured rock as having two interacting materials, one representing the matrix and one representing the fractures. The interaction between the fractures and the matrix is explicitly calculated from the local temperature and pressure differences, thus allowing transient behavior to be predicted. The DKM underestimates the fracture-matrix interaction for steep temperature and pressure gradients (Birkholzer and Tsang 1998, p. 2). Simulations in this model are at ambient temperature, so there are no steep temperature or pressure gradients. Therefore, the DKM is appropriate for the model developed in this document.

Table 1. Software and Routine Usage

Name/Number	Description	Number or location of validation	Input source	Input File name	Output File Name
NUFT V3.0s	Unqualified Software	10088-3.0s-00	intermediate file	A.2.in B.2.in C.2.in D.2.in E.2.in F.2.in G.2.in H.2.in I.2.in J.2.in	A.2.m.sat B.2.m.sat C.2.m.sat D.2.m.sat E.2.m.sat F.2.m.sat G.2.m.sat H.2.m.sat I.2.m.sat J.2.m.sat
					A.2.m.ext A.2.f.ext
					F.2.m.ext F.2.f.ext
					J.2.m.ext J.2.f.ext
			Supporting Input File	vtough.pkg	
			Supporting Input File	dkm-afc-EBS_Rev10-WDR	
			Supporting Input File	dkm-afc-NBS-WDR	
rme6 V1.1	Validated Routine	Attach. V	LB99EBS1233129.001 LB99EBS1233129.001 Attachment VII	tspa99_primary_mesh UZ99_3.grd l4c3.dat	LBL99-YMESH
XTOOL V9.15	Unqualified Software	LLNL-1999-144	intermediate file	A.2.m.EBS.ext A.2.f.EBS.ext F.2.m.EBS.ext F.2.f.EBS.ext J.2.m.EBS.ext J.2.f.EBS.ext	A.2.m.ps A.2.f.ps F.2.m.ps F.2.f.ps J.2.m.ps J.2.f.ps
YMESH V1.53	Unqualified Software	LLNL-1999-146	intermediate file	LBL99-YMESH	l4c3_col.units
Chim_Surf_TP V1.1	Validated Routine	Attach. II	LB99EBS1233129.001 LB99EBS1233129.003	tspa99_primary_mesh bcs_99.dat	outpt
Chim_wt_TP V1.1	Validated Routine	Attach. II	LB99EBS1233129.001 LB99EBS1233129.003	tspa99_primary_mesh bcs_99.dat	oupt_wt
Cover V1.1	Validated Routine	Attach. IV	MO9911MWDEBSWD .000	dft1.dat	shape1.dat
Convertcoords V1.1	Unqualified Software	LLNL-1999-143	MO9911MWDEBSWD .000	9 files: *.inf	9 files: *.NV
ColumnInfiltration V1.1	Validated Routine	Attach. III	intermediate files Table V-1	9 files: *.NV column.data	9 files: *.out (infiltration rates)

The active fracture concept accounts for the contact area between the fracture and the matrix (Table 4), as well as the frequency of fractures (Table 4). The AFC is that fracture flow only occurs through some of the fractures. This is more conservative than assuming the influx flows evenly through all fractures. The flux through a fracture is greater when it has higher saturation and, therefore, focusing flow through a portion of the fractures (i.e., to active fractures) maximizes flux and results in fast pathways for flux through the mountain.

The rock properties in DTN: LB990861233129.001 were calibrated using an inverse modeling technique that assumes the properties will only be used in DKM employing AFC. Therefore, the DKM and AFC are appropriate NUFT options.

3.1.2 YMESH

YMESH is classified as an unqualified software program (per AP-SI.1Q, *Software Management*), and is under configuration management (Table 1). YMESH is used in this model to interpolate the thickness of the stratigraphic units as documented in Attachment VI (file: LBL99-YMESH) at given locations (Section 5.1.5). YMESH is appropriate software for this task. YMESH was run on a Sun Ultra 2 workstation with SunOS 5.5.1 operating system.

3.1.3 CONVERTCOORDS

CONVERTCOORDS is classified as an unqualified software program (per AP-SI.1Q, *Software Management*), and is under configuration management (Table 1). CONVERTCOORDS is used to convert from Universal Transverse Mercator coordinates to Nevada State Plane coordinates, as well as to reformat the data (see Attachment VI, files: *.inf). The desired format is columns of data, with the input files in a matrix format. CONVERTCOORDS is appropriate software for this task. CONVERTCOORDS was run on a Sun Ultra 2 workstation with SunOS 5.5.1 operating system.

3.1.4 XTOOL

XTOOL is classified as an unqualified software program (per AP-SI.1Q, *Software Management*), and is under configuration management (Table 1). The output from XTOOL is graphical (no actual data is produced with XTOOL). XTOOL is tracked in accordance with AP-SI.1Q because it is not commercial off the shelf software, and it is under configuration management (Table 1). XTOOL is used to develop graphical representations (Figures 2 through 4) of the results in the NUFT output files (VI-files: *.out). XTOOL is appropriate software for this task. Software programs used to produce figures are exempt from AP-SI.1Q requirements. XTOOL was run on a Sun Ultra 10 workstation with SunOS 5.6 operating system.

3.2 DESCRIPTION OF ROUTINES USED

All routines used in the preparation of this document are qualified within this document as follows: Chim_Surf_TP V1.1 (Chim_Surf_TP) and Chim_wt_TP V1.1 (Chim_wt_TP) are qualified in Attachment II, ColumnInfiltration V1.1 (ColumnInfiltration) is qualified in Attachment III, Cover V1.1 is qualified in Attachment IV, and rme6 V1.1 (rme6) is qualified in Attachment V.

Various validated routines were used in the development of the inputs to this model. Table 1 shows the sources of inputs and the actual file names of the input and output files for the various routines and software packages used in developing the model inputs. Figure 1 further illustrates the path of data through the routines and software packages. The files associated with this document are given in Attachment VI.

3.2.1 Chim_Surf_TP and Chim_wt_TP

Chim_Surf_TP and Chim_wt_TP are classified as routines per AP-SI.1Q, and are qualified in Attachment II. The purpose of these routines is to interpolate the temperature and pressure at the ground surface and at the water table for a given X-Y location using the inverse distance method (Section 4.1.1). These routines execute the expected mathematical operations accurately (see Attachment II, p. II-1), and are therefore appropriate. Chim_Surf_TP and Chim_wt_TP were run on a Sun Ultra 2 workstation with SunOS 5.5.1 operating system.

3.2.2 ColumnInfiltration

ColumnInfiltration is classified as a routine per AP-SI.1Q, and is qualified in Attachment III. The purpose of ColumnInfiltration is to interpolate the infiltration at a given X-Y location using a Gaussian weighting function (Section 4.1.2). This routine executes the required mathematical operations accurately (see Attachment III, p. III-1), and is therefore appropriate. ColumnInfiltration was run on a Sun Ultra 2 workstation with SunOS 5.5.1 operating system.

3.2.3 Cover V1.1

Cover V1.1 is classified as a routine per AP-SI.1Q, and is qualified in Attachment IV. The purpose of Cover V1.1 is to develop a block model of the plan view of the repository that approximates the area and location of emplacement. The results of this routine meet the objectives (see Attachment IV, p. IV-1) and, therefore, the routine is appropriate. Cover V1.1 was run on a Sun Ultra 2 workstation with SunOS 5.5.1 operating system.

3.2.4 Rme6

Rme6 is classified as a routine per AP-SI.1Q, and is qualified in Attachment V. The purpose of rme6 is to reformat and combine specific files (VI-files: tspa99_primary_mesh, UZ99_3.grd, l4c3.dat). The resulting file, LBL00_YMESH is used by a subsequent software program, YMESH (see Section 3.1.2; Figure 1 and Table 1). The results of this routine meet the objectives (see Section V, p. V-1) and, therefore, the routine is appropriate. Rme6 was run on a Sun Ultra 10 workstation with SunOS 5.6 operating system.

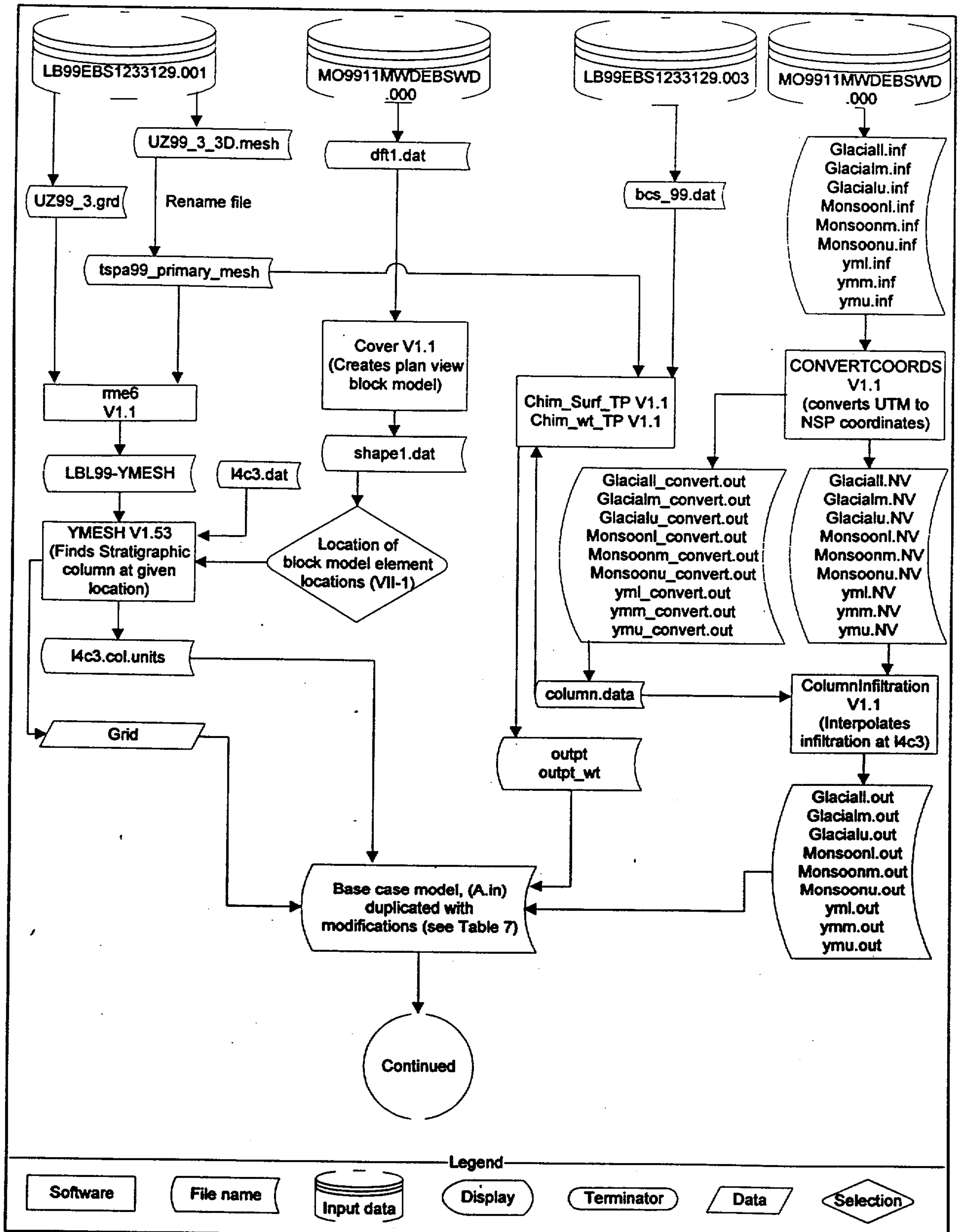

Figure 1. Input Data Manipulation Flowchart

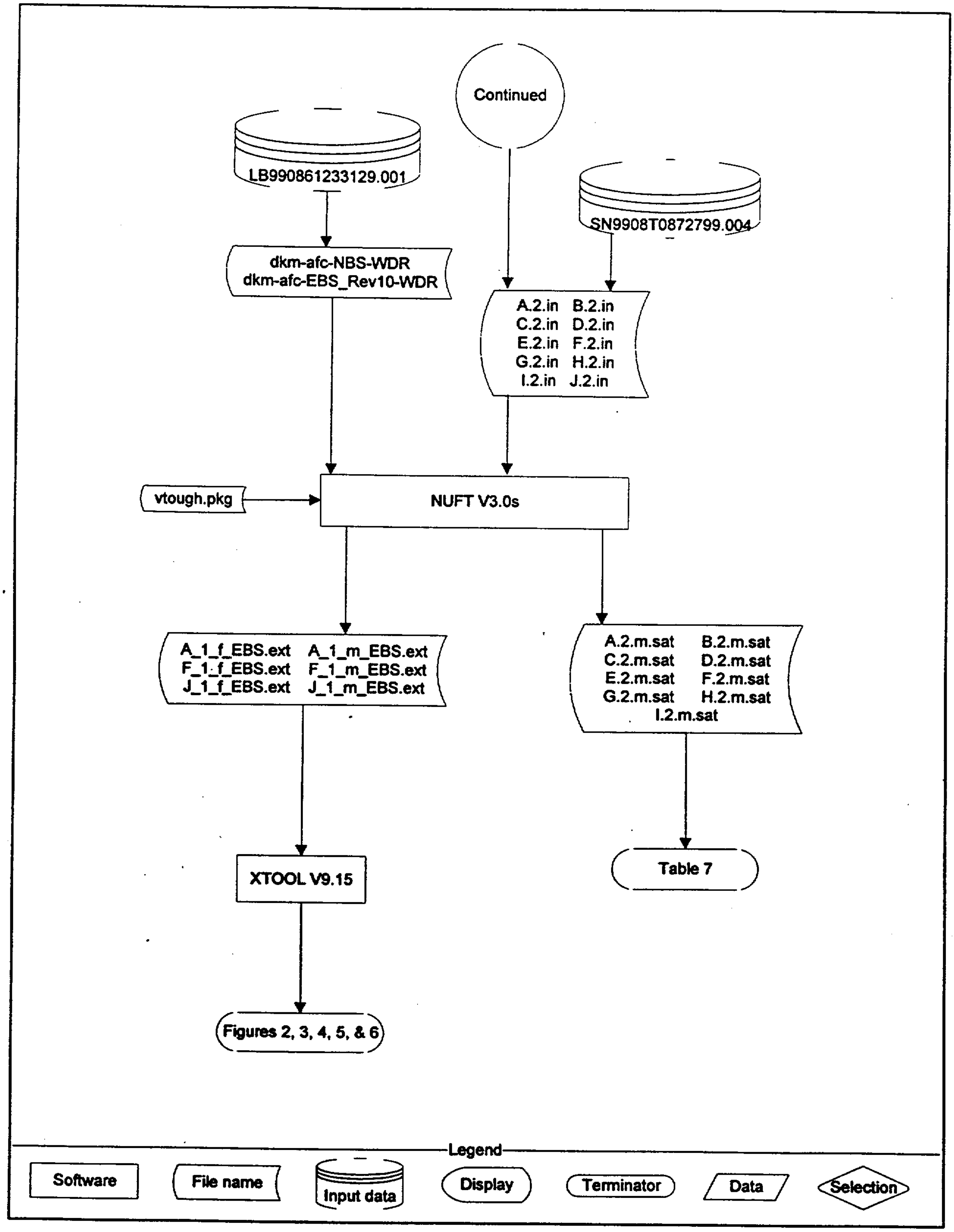

Figure 1. Input Data Manipulation Flowchart (Continued)

4. INPUTS

The inputs to the Water Drainage Model are presented in the following sections: Section 4.1 Data and Parameters, Section 4.2 Criteria, and Section 4.3 Codes and Standards.

4.1 DATA AND PARAMETERS

The data and parameter inputs to the Water Drainage Model are based on information from AP-3.14Q, *Transmittal of Input*, and information in the Technical Data Management System. Modification of inputs by routines and/or software is outlined in the following sections.

4.1.1 Inverse Distance Cubed Function

The inverse distance cubed function is:

$$V = \frac{\sum_{i=1}^{n} V_i \cdot \frac{1}{d_i^3}}{\sum_{i=1}^{n} \frac{1}{d_i^3}} \qquad \text{(Eq. 1)}$$

where:

- V -Value of interest at a given point
- V_i -Value at point i, d_i meters away
- d_i -Plan distance between points.
- n -Number of points in data set

Source: (Isaaks and Srivastava 1989, p. 258)

4.1.2 Gaussian Weighting Function

The Gaussian weighting function is:

$$I = \sum_{i=1}^{n} I_i \cdot W_i \qquad \text{(Eq 2)}$$

where

$$W = e^{-\left[\left(\frac{D}{Scale}\right)^2\right]} \qquad \text{(Eq. 3)}$$

where:

- I -Interpolated infiltration
- I_i -Value at point i, D meters away
- D -Plan distance between points.
- n -Number of points in data set
- W -Calculated weight assigned to each value ($W=W_i$)

Scale -Effective radius of influence (Scale = 50ft)
Source: (Isaaks and Srivastava 1989, p. 208) and (Kitanidis 1997, p. 54)

4.1.3 Drift Diameter

The diameter of the emplacement drifts is 5.5m (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.4 Angle of Repose of Backfill

The angle of repose of the backfill is 26° (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.5 Properties of Backfill and Invert Materials

Backfill and invert material properties are given in Table 2. (TBV).

Table 2. Backfill and Invert Material Properties

Property	Units	Backfill Value	Invert Value
Permeability	m^2	$1.43x10^{-11}$	$6.152x10^{-10}$
Porosity		0.41	0.545
Van Genuchten a	1/Pa	$2.7523x10^{-4}$	$1.2232x10^{-3}$
Van Genuchten b		2	2.7
Residual Saturation		0.024	0.092
Grain Density	Kg/m^3	2700	2530
Grain Specific Heat	J/Kg K	795.492	948
Conductivity	W/m-K	0.33	0.66

Source: (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc)

4.1.6 Minimum Depth of Backfill Cover

The minimum depth of the backfill cover (occurs at an angle equivalent to the angle of repose measured off the vertical drawn from the WP centerline) is 1.495m (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.7 Location of Backfill Peak

The backfill peak crosses the drift centerline 2.25m above the drift springline (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.8 Intersection Between Backfill and Drift Wall

The backfill profile intersects the drift wall 1.0m above the drift springline (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.9 Drip Shield Thickness

The drip shield is 0.02m thick (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.10 Drip Shield Radius

The portion of the drip shield above the centerline of the WP has an inside radius of 1.231m (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.11 Location of Waste Package

The WP centerline is 1.945m above the bottom of the drift and 0.805m below the springline (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.12 Waste Package Diameter

The WP outer diameter is 1.67m (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.13 Waste Package Spacing

There is a 0.1-m gap between WPs (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.14 Gap Between Waste Package and Drip Shield

The gap between the top half of the WP and the drip shield is 0.396m (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.15 Gap Between Waste Package and Invert

The gap between the bottom of the WP and the invert is 0.504m (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.16 Invert Height

The top of the invert is 0.606m above the bottom of the drift (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.17 Drift Spacing

Emplacement drifts will have an 81-m centerline to centerline spacing (DTN: SN9908T0872799.004, File: indriftgeom_rev01.doc). (TBV).

4.1.18 Matrix Parameters of Stratigraphic Units

The matrix parameters of the stratigraphic units are given in Table 3. (TBV).

4.1.19 Fracture Parameters of Stratigraphic Units

The fracture parameters of the stratigraphic units are given in Table 4. (TBV).

4.1.20 Thermal Parameters of Stratigraphic Units

The thermal parameters of the stratigraphic units are given in Table 5. (TBV).

4.1.21 Tortuosity of Stratigraphic Units

The tortuosity of all stratigraphic units is 0.7 (DTN: LB997141233129.001). (TBV).

4.1.22 UZ Site Scale Model

The UZ (unsaturated zone) site scale model (DTN: LB99EBS1233129.001) is a three-dimensional model used to estimate the thickness of stratigraphic units. Temperature and pressure for the UZ site scale model are in the file bcs99.dat (DTN: LB99EBS1233129.002). This information is used throughout this document. (TBV).

4.1.23 Drift Locations

The drift locations are given in the file dft1.dat (DTN: MO9911MWDEBSWD.000). (TBV).

4.1.24 Infiltation

The infiltration for current and future climates is given in the *.inf files in Attachment VI (DTN: MO9911MWDEBSWD.000). (TBV).

4.2 CRITERIA

No criteria were used in the preparation of this document.

4.3 CODES AND STANDARDS

No codes and standards were used in the preparation of this document.

Table 3. Matrix Parameters of Stratigraphic Units

Unit	Permeability	Porosity	Van Genuchten α	Van Genuchten β	Residual Saturation	Satiated Saturation
	(m^2)	(Fraction)	(Pa^{-1})		(Fraction)	(Fraction)
tcw11	3.86E-15	0.253	4.00E-05	0.47	0.07	1
tcw12	2.74E-19	0.082	1.81E-05	0.241	0.19	1
tcw13	9.23E-17	0.203	3.44E-06	0.398	0.31	1
ptn21	9.90E-13	0.387	1.01E-05	0.176	0.23	1
ptn22	2.65E-12	0.439	1.60E-04	0.326	0.16	1
ptn23	1.23E-13	0.254	5.58E-06	0.397	0.08	1
ptn24	7.86E-14	0.411	1.53E-04	0.225	0.14	1
ptn25	7.00E-14	0.499	5.27E-05	0.323	0.06	1
ptn26	2.21E-13	0.492	2.49E-04	0.285	0.05	1
tsw31	6.32E-17	0.053	3.61E-05	0.303	0.22	1
tsw32	5.83E-16	0.157	3.61E-05	0.333	0.07	1
tsw33	3.08E-17	0.154	2.13E-05	0.298	0.12	1
tsw34	4.07E-18	0.11	3.86E-06	0.291	0.19	1
tsw35	3.04E-17	0.131	6.44E-06	0.236	0.12	1
tsw36	5.71E-18	0.112	3.55E-06	0.38	0.18	1
tsw37	4.49E-18	0.094	5.33E-06	0.425	0.25	1
tsw38	4.53E-18	0.037	6.94E-06	0.324	0.44	1
tsw39	5.46E-17	0.173	2.29E-05	0.38	0.29	1
ch1z	1.96E-19	0.288	2.68E-07	0.316	0.33	1
ch1v	9.90E-13	0.273	1.43E-05	0.35	0.03	1
ch2v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch3v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch4v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch5v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch2z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch3z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch4z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch5z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch6	4.23E-19	0.266	3.38E-07	0.51	0.37	1
pp4	4.28E-18	0.325	1.51E-07	0.676	0.28	1
pp3	2.56E-14	0.303	2.60E-05	0.363	0.1	1
pp2	1.57E-16	0.263	2.67E-06	0.369	0.18	1
pp1	6.40E-17	0.28	1.14E-06	0.409	0.3	1
bf3	2.34E-14	0.115	4.48E-06	0.481	0.11	1
bf2	2.51E-17	0.259	1.54E-07	0.569	0.18	1

DTN: LB990861233129.001

Table 4. Fracture Parameters of Stratigraphic Units

Unit	Permeability	Porosity	Van Genuchten α	Van Genuchten β	Residual Saturation	Satiated Saturation	Active Fracture Parameter	Frequency	Fracture to matrix area
	(m^2)		(Pa^{-1})		(Fraction)	(Fraction)			
tcw11	2.41E-12	0.028	3.15E-03	0.627	0.01	1	0.30	0.92	1.56
tcw12	1.00E-10	0.02	2.13E-03	0.613	0.01	1	0.30	1.91	13.39
tcw13	5.42E-12	0.015	1.26E-03	0.607	0.01	1	0.30	2.79	3.77
ptn21	1.86E-12	0.011	1.68E-03	0.58	0.01	1	0.09	0.67	1.00
ptn22	2.00E-11	0.012	7.68E-04	0.58	0.01	1	0.09	0.46	1.41
ptn23	2.60E-13	0.0025	9.23E-04	0.61	0.01	1	0.09	0.57	1.75
ptn24	4.67E-13	0.012	3.37E-03	0.623	0.01	1	0.09	0.46	0.34
ptn25	7.03E-13	0.0062	6.33E-04	0.644	0.01	1	0.09	0.52	1.09
ptn26	4.44E-13	0.0036	2.79E-04	0.552	0.01	1	0.09	0.97	3.56
tsw31	3.21E-11	0.0055	2.49E-04	0.566	0.01	1	0.06	2.17	3.86
tsw32	1.26E-12	0.0095	1.27E-03	0.608	0.01	1	0.41	1.12	3.21
tsw33	5.50E-13	0.0066	1.46E-03	0.608	0.01	1	0.41	0.81	4.44
tsw34	2.76E-13	0.01	5.16E-04	0.608	0.01	1	0.41	4.32	13.54
tsw35	1.29E-12	0.011	7.39E-04	0.611	0.01	1	0.41	3.16	9.68
tsw36	9.91E-13	0.015	7.84E-04	0.61	0.01	1	0.41	4.02	12.31
tsw37	9.91E-13	0.015	7.84E-04	0.61	0.01	1	0.41	4.02	12.31
tsw38	5.92E-13	0.012	4.87E-04	0.612	0.01	1	0.41	4.36	13.34
tsw39	4.57E-13	0.0046	9.63E-04	0.634	0.01	1	0.41	0.96	2.95
ch1z	3.40E-13	0.00017	1.43E-03	0.631	0.01	1	0.10	0.04	0.11
ch1v	1.84E-12	0.00069	1.09E-03	0.624	0.01	1	0.13	0.10	0.30
ch2v	2.89E-13	0.00089	5.18E-04	0.628	0.01	1	0.13	0.14	0.43
ch3v	2.89E-13	0.00089	5.18E-04	0.628	0.01	1	0.13	0.14	0.43
ch4v	2.89E-13	0.00089	5.18E-04	0.628	0.01	1	0.13	0.14	0.43
ch5v	2.89E-13	0.00089	5.18E-04	0.628	0.01	1	0.13	0.14	0.43
ch2z	3.12E-14	0.00043	4.88E-04	0.598	0.01	1	0.10	0.14	0.43
ch3z	3.12E-14	0.00043	4.88E-04	0.598	0.01	1	0.10	0.14	0.43
ch4z	3.12E-14	0.00043	4.88E-04	0.598	0.01	1	0.10	0.14	0.43
ch5z	3.12E-14	0.00043	4.88E-04	0.598	0.01	1	0.10	0.14	0.43
ch6	1.67E-14	0.00017	7.49E-04	0.604	0.01	1	0.10	0.04	0.11
pp4	3.84E-14	0.00043	5.72E-04	0.627	0.01	1	0.10	0.14	0.43
pp3	7.60E-12	0.0011	8.73E-04	0.655	0.01	1	0.46	0.20	0.61
pp2	1.38E-13	0.0011	1.21E-03	0.606	0.01	1	0.46	0.20	0.61
pp1	1.12E-13	0.00043	5.33E-04	0.622	0.01	1	0.10	0.14	0.43
bf3	4.08E-13	0.0011	9.95E-04	0.624	0.01	1	0.46	0.20	0.61
bf2	1.30E-14	0.00043	5.42E-04	0.608	0.01	1	0.10	0.14	0.43

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Table 5. Thermal Parameters of Stratigraphic Units

Model Layer	Rock Grain Density Kg/m^3	Rock Grain Specific Heat (J/Kg K)	Dry Conductivity W/m K	Wet Conductivity W/m K
tcw11	2550	823	1.6	2
tcw12	2510	851	1.24	1.81
tcw13	2470	857	0.54	0.98
ptn21	2380	1040	0.5	1.07
ptn22	2340	1080	0.35	0.5
ptn23	2400	849	0.44	0.97
ptn24	2370	1020	0.46	1.02
ptn25	2260	1330	0.35	0.82
ptn26	2370	1220	0.23	0.67
tsw31	2510	834	0.37	1
tsw32	2550	866	1.06	1.62
tsw33	2510	882	0.79	1.68
tsw34	2530	948	1.56	2.33
tsw35	2540	900	1.2	2.02
tsw36	2560	865	1.42	1.84
tsw37	2560	865	1.42	1.84
tsw38	2360	984	1.69	2.08
tsw39	2360	984	1.69	2.08
ch1z	2310	1060	0.7	1.31
ch1v	2310	1060	0.7	1.31
ch2v	2240	1200	0.58	1.17
ch3v	2240	1200	0.58	1.17
ch4v	2240	1200	0.58	1.17
ch5v	2240	1200	0.58	1.17
ch2z	2350	1150	0.61	1.2
ch3z	2350	1150	0.61	1.2
ch4z	2350	1150	0.61	1.2
ch5z	2350	1150	0.61	1.2
ch6	2440	1170	0.73	1.35
pp4	2410	577	0.62	1.21
pp3	2580	841	0.66	1.26
pp2	2580	841	0.66	1.26
pp1	2470	635	0.72	1.33
bf3	2570	763	1.41	1.83
bf2	2410	633	0.74	1.36

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5. ASSUMPTIONS

5.1 MODELING ASSUMPTIONS

5.1.1 Thermal-Hydrological-Chemical and Thermal-Hydrological-Mechanical Effects

The T-H-C and T-H-M effects are evaluated by eliminating the fractures below the invert and then below the engineered barrier segment (see Section 6.2). Removing these fractures represents fracture plugging. This is a bounding approach.

5.1.2 Infiltration Rate Focusing

The focused infiltration rate is defined as the rate of flux into the drift, assuming all flux at the model boundary is distributed spatially above the drift. This rate is applied across the entire top boundary of the model. A "focused glacial" infiltration rate is defined as follows: a glacial infiltration rate is concentrated spatially such that the entire flux between adjacent pillar centerlines is focused into the intervening drift, and then that rate is applied across the top boundary of the model (ground surface) (see Section 6.1.6).

Rationale: The focused infiltration rate approach is conservative because it represents the highest local infiltration rate into the drift that could occur due to focusing, for each average infiltration rate at the model boundary. This is a bounding approach.

5.1.3 Inverse Distance Cubed Method

The inverse distance cubed method (Section 4.1.1) is used to interpolate the temperature and pressure at the surface and at the level of the water table. This assumption is used in Attachment II and in all NUFT input files.

Rationale: The inverse distance cubed method strongly weights the closest points. The inverse distance power chosen was three. A power of two does not assign strong enough weights to the closest points, and higher powers do not significantly change the weighting. For a given point, the temperature and pressure at relatively close points are the best indicators.

5.1.4 Gaussian Interpolation for Infiltration

Gaussian interpolation (Section 4.1.2) is used to find the infiltration at given reference locations. Values are interpolated at the given location from data contained in Attachment VI (tspa99_primary_mesh, bcs99.txt), as modified by the routine CONVERTCOORDS (Attachment V). This assumption is used in Attachment III and in all NUFT input files.

Rationale: The Gaussian method strongly weights the closest points. For a given point, the infiltration rates at relatively close points are the best indicators.

5.1.5 Location of Model

Inputs that vary with location are found by using an assumed location of the l4c3 block element, 170717.1'E, 233796.7'N (Attachment V). This assumption is used in Attachment V and in all YMESH and NUFT input files.

Rationale: This point is near the center of the proposed repository. Since edge effects are not considered in this model the center of the repository is used as the representative location. This model is not sensitive to this input.

5.1.6 Relative Humidity at Ground Surface

The relative humidity at the ground surface is assumed to be 100%. This assumption is used in Section 6.1.4, and impacts all NUFT input files.

Rationale: This bounds humidity effects by minimizing evaporation.

5.1.7 Tortuosity of Backfill and Invert Materials

The assumed value for tortuosity of the backfill and invert materials is 0.7. This assumption is used in all NUFT input files. (TBV).

Rationale: This value is consistent with the tortuosity values in Section 4.1.21.

5.1.8 Satiated Saturation of Invert and Backfill Materials

The assumed value for satiated saturation of the invert and backfill materials is 1.0. This assumption is used in all NUFT input files. This is an upper bound for this parameter.

Rationale: This is consistent with the satiated saturation in Section 4.1.18.

6. ANALYSIS / MODEL

The model developed below is used to quantify and evaluate the capability of the drift to remove water naturally. Additionally, parameter sensitivities, uncertainties, T-H-Chemical effects, and T-H-M effects are considered. The results of this model include the development of performance goals.

6.1 INPUT MANIPULATION AND INTERPOLATION

The alteration or interpolation of inputs given in Section 4.1 is documented in the following sections.

6.1.1 Elevation of Repository

The elevation of the proposed repository at coordinates 170717.1'E, 233796.7'N (Section 5.1.5) is 1,073.1m (VI-l4c3.col.units). This elevation is based on Attachment VI (UZ99_3.grd, tspa99_primary_mesh) as modified by rme6 V1.1, and YMESH V1.53. The intermediate input and output file names are given in Table 1.

6.1.2 Temperature at Domain Boundaries

The temperature at the top of the model domain (ground surface) is 16.5 °C. The temperature at the bottom of the model domain (water table) is 32.39 °C. These temperatures are interpolated at the point 170717.1'E, 233796.7'N (column.data, Section 5.1.5) from values in bcs_99.txt and tspa99_primary_mesh (Attachment VI). The interpolation at the ground surface is done by the routine Chim_Surf_TP (Attachment II) and the interpolation at the water table is done by the routine Chim_wt_TP (Attachment II). The routines Chim_Surf_TP and Chim_wt_TP are appropriate for estimating the temperature at the repository domain boundaries (Section 5.1.3).

6.1.3 Pressure at the Domain Boundaries

The pressure at the top of the model domain (ground surface) is 0.85×10^5 Pascal. The pressure at the bottom of the model domain (water table) is 0.92×10^5 Pascal. These pressures are interpolated at the point 170717.1'E, 233796.7'N (column.data, Section 5.1.5) from values in bcs_99.txt and tspa99_primary_mesh (Attachment VI). The interpolation at the ground surface is done by the routine Chim_Surf_TP (Attachment II) and the interpolation at the water table is done by the routine Chim_wt_TP (Attachment II). The routines Chim_Surf_TP and Chim_wt_TP are appropriate for estimating the pressure at the repository domain boundaries (Section 5.1.3)

6.1.4 Air Mass Fraction at Ground Surface

The air mass fraction at the ground surface is 0.986. This is found using the temperature (Section 6.1.2), pressure (Section 6.1.3), and relative humidity (Section 5.1.6) at the ground surface. The relating equation is given below.

$$W = 0.622 \cdot \frac{p_v}{p_b - p_v} \left(\frac{kg}{kg} \right) \quad \text{(Eq. 4)}$$

where:

W - Specific humidity, weight of water per unit weight of dry air

p_v - Partial pressure of water vapor

p_b - Barometric pressure

Source: (Hartman et al 1997, p. 15).

6.1.5 Thickness of Stratigraphic Units

The thickness of the stratigraphic units is based on Attachment VI (UZ99_3.grd, tspa99_primary_mesh) as modified by rme6 V1.1, and YMESH V1.53. The intermediate input and output file names are given in Table 1. The stratigraphic thickness used to develop the block model is given in Table 6.

6.1.6 Focused Infiltration Rate

Given the glacial infiltration rate of 38.66mm/yr (results of ColumnInfiltration, see Figure 1), drift diameter of 5.5m (Section 4.1.3) and a drift spacing of 81m (Section 4.1.17), the focused glacial infiltration rate is calculated as follows (Section 5.1.2):

38.66mm/yr * 81m/5.5m = 570mm/yr

6.1.7 Infiltration Rates

The present day, monsoon, and glacial infiltration rates are calculated in Attachment I. The mean present day infiltration rate is 10.14mm/yr. The mean monsoon infiltration rate is 24.09mm/yr. The mean glacial infiltration rate is 38.66mm/yr. The 2x glacial infiltration rate is 77mm/yr (=2 * 38.66), and the 3x glacial is 116mm/yr (=3 * 38.66) . The focused glacial infiltration rate is 570mm/yr (6.1.6).

6.2 BLOCK MODEL

The in-drift geometry from Sections 4.1.3, 4.1.4, and 4.1.6 through 4.1.16 is simplified in two ways. First, the area under the drip shield is modeled as an impermeable solid. Second, the area above the backfill is modeled as host rock. This is conservative because no credit is taken for the potential capillary barrier above the host rock and the air above the backfill.

This simplified two dimensional model was used to represent the proposed repository. The simplified in-drift geometry is shown in Figure 2. The model domain and boundary conditions are shown in Figure 3. Figures 2 and 3 are output from NUFT V3.01s (VI-file: NUFT_OUTPUT) as interpreted by XTOOL V9.15 (VI-file: AMR-fig1.eps). The dimensions and grid spacing represented in Figures 2 and 3 can by verified by visual inspection of the NUFT input files (VI-file: /NUFT_INPUT_FILES/*.in). To account for T-H-C and T-H-M effects, two cases are considered (Section 5.1.1). First, the fractures in the grid blocks below the invert are given properties similar to the host rock matrix (i.e., the blocks are assigned rock matrix properties to simulate fracture plugging). An "x" in Figure 2 denotes the grid blocks below the invert. Next, the fractures in the grid blocks below the engineered barrier segment are removed in the same manner. The grid blocks in the engineered barrier segment are those denoted by "x" or "y" in Figure 2.

6.3 SIMULATIONS

Ten cases were considered. Case A is the base case with a glacial infiltration rate of 38.66mm/yr (Section 6.1.7). Case B is the base case with a focused glacial infiltration rate of 570mm/yr. The sensitivity of the performance to backfill and invert permeability is evaluated by decreasing the permeability of each by a factor of 10 (Case C for the backfill, Case D for the invert, and case E for both). Next, T-H-C and T-H-M effects are considered by plugging fractures (Section 5.1.1) below the invert and then the EBS (each defined in Section 6.2) and elevating influx rates until the invert becomes saturated. Glacial, 2xGlacial, and 3xGlacial infiltration rates were considered (with the invert plugged) as Cases F, G, and H, respectively. Cases I and J have fractures in the EBS plugged, as defined in Section 6.2. The infiltration rates for Cases I and J are the present day infiltration rate and the monsoon infiltration rate (Section 6.1.7).

6.4 PERFORMANCE GOALS

The minimum performance goal for the EBS is to allow the invert to remain unsaturated. With this goal, the performance of the EBS is evaluated over a range of infiltration rates and a range of EBS properties. The EBS meets this goal for infiltration rates up to 570 mm/yr. If the host rock below the invert becomes plugged, then the EBS remains unsaturated for the glacial infiltration rate of 38.66 mm/yr. If the entire area below the EBS becomes plugged, then the EBS barely meets this minimum requirement for infiltration rates of up to 3/4 current climate, or 7.6 mm/yr.

6.5 MODEL VALIDATION

The water drainage model is performed using industry standard finite element method that includes mass balance and energy balance. The results from finite element models are only as good as the inputs. All inputs into this model are TBV, and therefore the results are TBV. The model validation includes the documentation of: parameter input, assumptions, simplifications, initial and boundary conditions; explanation of how the software are used; expected source of uncertainty (TBV tracking); and computer data files to allow independent repetition of the model simulation. The standard validation techniques used for this finite element model include visual inspection of the computer input files and comparison of inputs using different computer programs. The XTOOL output (Figure 3) and the stratigraphic thickness in Table 6 are arrived at by independent methods and the total grid depth is the same (669.774m in Table 6 vs. approximately 670m in Figure 3). Independent checking of the computer files verifies their accuracy. It is determined that the model is validated for its intended use of evaluating the capability of the EBS to drain water.

Table 6. Stratigraphic Column

Model Unit	Thickness (m)
tcw11	0
tcw12	83.086
tcw13	5.391
ptn21	4.893
ptn22	3.193
ptn23	2.754
ptn24	7.061
ptn25	15.41
ptn26	14.619
tsw31	2.021
tsw32	46.318
tsw33	87.412
tsw34	31.586
tsw35	108.981
tsw36	31.348
tsw37	15.674
tsw38	21.035
tsw39	2.871
ch1VI	0
ch2VI	0
ch3VI	0
ch4VI	0
ch5VI	0
ch1Ze	14.004
ch2Ze	16.523
ch3Ze	16.523
ch4Ze	16.523
ch5Ze	16.523
ch6	18.896
pp4	9.932
pp3	30.732
pp2	16.846
pp1	29.619
bf3	0
bf2	0
Total:	669.774

Source: VI-file: l4c3.col.units

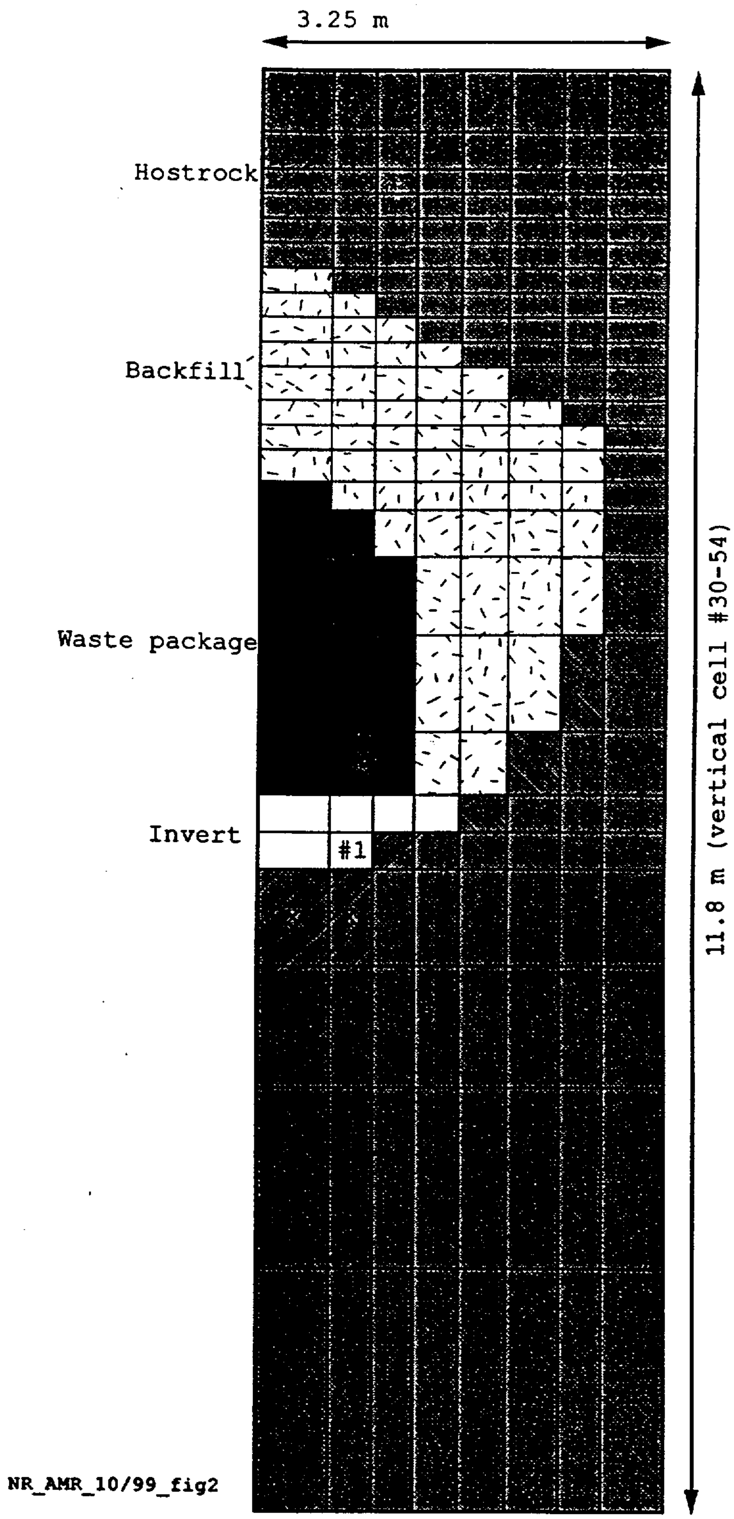
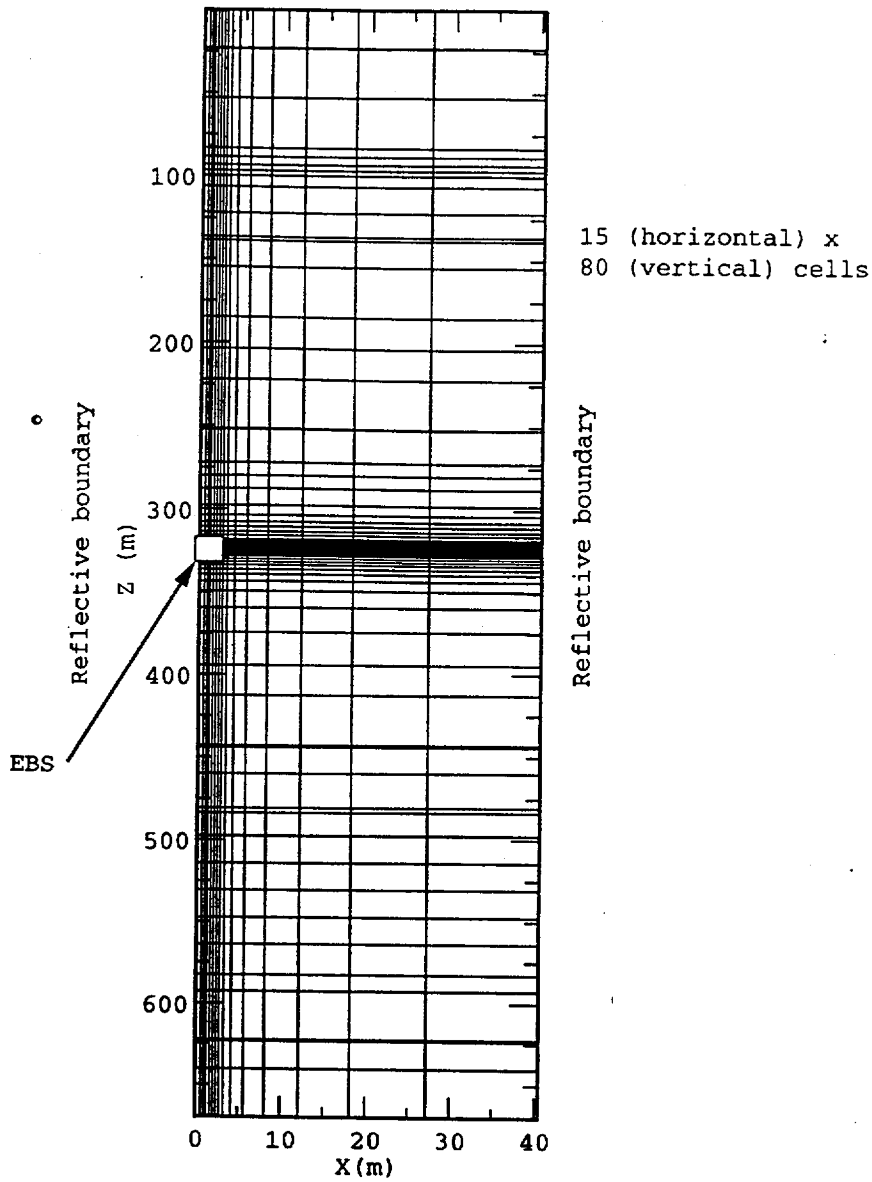


Figure 2. Engineered Barrier Segment Block Model

Top boundary (ground surface) held at constant temperature, pressure, liquid saturation and air mass fraction:
T=16.5¡C, P=0.85 Pa, S_1 = 0, Xair = 98.6%



Bottom boundary (water table) held at constant temperature, pressure, liquid saturation and air mass fraction:
T=32.39¡C, P=0.92 Pa, S_1 = 1, Xair = 1e-6%

Figure 3. Model Domain and Boundary Conditions

6.6 RESULTS

The results of this model are presented in Table 7 and Figures 4 through 6. The results of the ten cases summarized in Section 6.3 are given in Table 7. The ten cases presented in Table 7 support the following observations.

- For the base case (unplugged) property set, the EBS performs well for infiltration rates of up to 570mm/yr.
- The ability of the EBS to drain water is not affected by reductions in the permeability of the invert or backfill materials (for at least a factor of ten reduction in permeability).
- If the fractures below the invert become plugged, portions of the EBS approach saturation at infiltration rates of 38.66mm/yr.
- If the fractures below the entire EBS become plugged, the EBS approaches failure from a drainage standpoint at 3/4 of the current climate infiltration rate, 7.6 mm/yr.
- If fracture plugging is expected below the invert or EBS, then engineered drainage features, such as gravel-packed boreholes, should be evaluated. Minor modifications of the model developed in this report could show the effectiveness of engineered drainage features. The flow vectors in Figures 4 through 6 provide insight on where these engineered drainage features could be located.

The ten cases are represented by Figures 4, 5, and 6. These figures represent the unplugged case, plugging below the invert, and plugging of the entire EBS.

Figure 4 shows the flow paths and relative magnitude of flux in the matrix and in the fractures for Case A. This figure illustrates the focusing effect of the backfill and the invert. However, it is reiterated that the flow was focused into the backfill by assuming the host rock is in intimate contact with the backfill, thus eliminating the capillary barrier that would exist in a partially open drift. A capillary barrier on top of the backfill would mitigate the focusing effect that could occur when the drift collapses onto the backfill.

Figure 5 shows the flow paths and relative magnitude of flow in the matrix and in the fractures for Case F. The flow vectors illustrate the ability of the EBS to drain if a portion of fractures become plugged. In addition, the flow vectors show that if the fractures below the invert are plugged, then a large portion of the infiltration is diverted away from the invert.

Figure 6 shows the flow paths and relative magnitude of flow in the matrix and in the fractures for Case J. The flow vectors suggest that some ponding may occur if the entire EBS becomes plugged.

Table 7. Saturation of Key Block Elements

	Infiltration Rate		Changes to EBS properties	Changes to NBS properties	Saturation Cell #1 (see Fig. 2) at steady-state	Saturation Cell #2 (see Fig. 2) at steady-state
A	Glacial	38.66 mm/yr			0.196	0.150
B	Focused Glacial	570 mm/yr			0.319	0.220
C	Focused Glacial	570 mm/yr	Decrease backfill permeability by 10x		0.307	0.213
D	Focused Glacial	570 mm/yr	Decrease invert permeability by 10x		0.295	0.280
E	Focused Glacial	570 mm/yr	Decrease invert and backfill permeability by 10x		0.284	0.270
F	Glacial	38.66 mm/yr		fractures plugged below invert	0.979	0.182
G	2xGlacial	77 mm/yr		fractures plugged below invert	1.000	0.216
H	3xGlacial	116 mm/yr		fractures plugged below invert	1.000	0.246
I	1/2 Current Climate	5.07 mm/yr		fractures plugged below EBS	0.817	0.166
J	3/4 Current Climate	7.6 mm/yr		fractures plugged below EBS	0.939	0.175

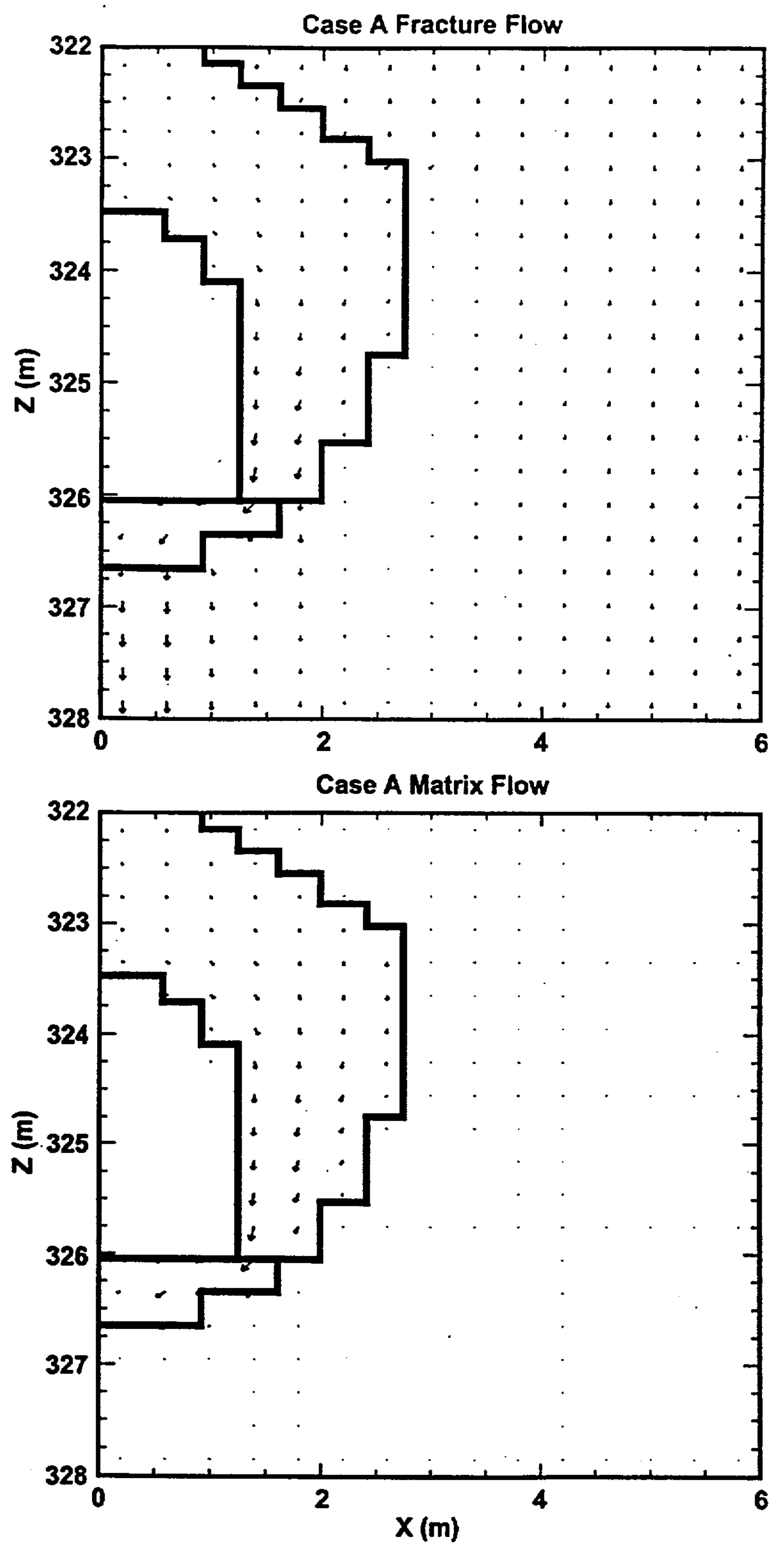


Figure 4. Matrix and Fracture Flow for Case A

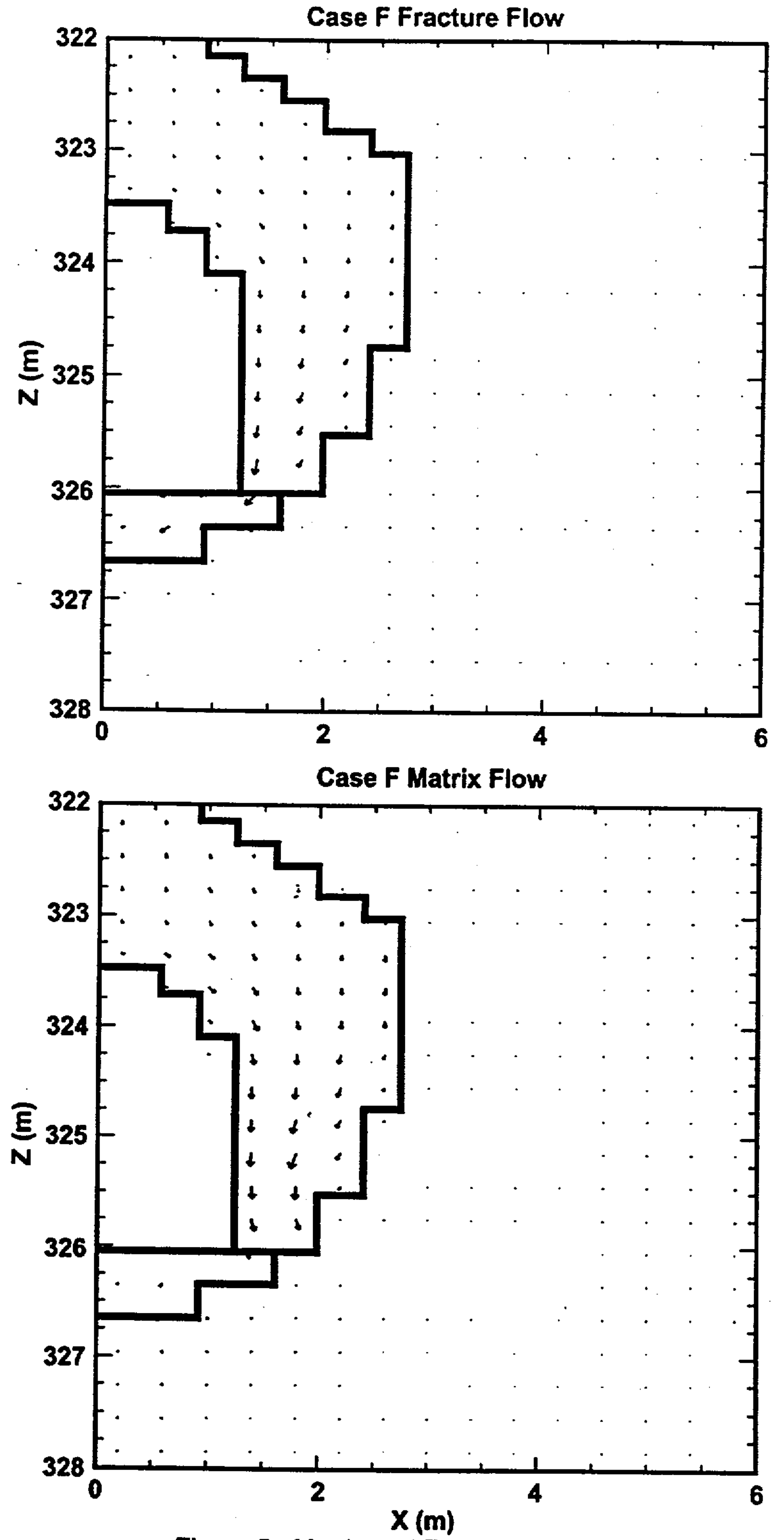


Figure 5. Matrix and Fracture Flow for Case F

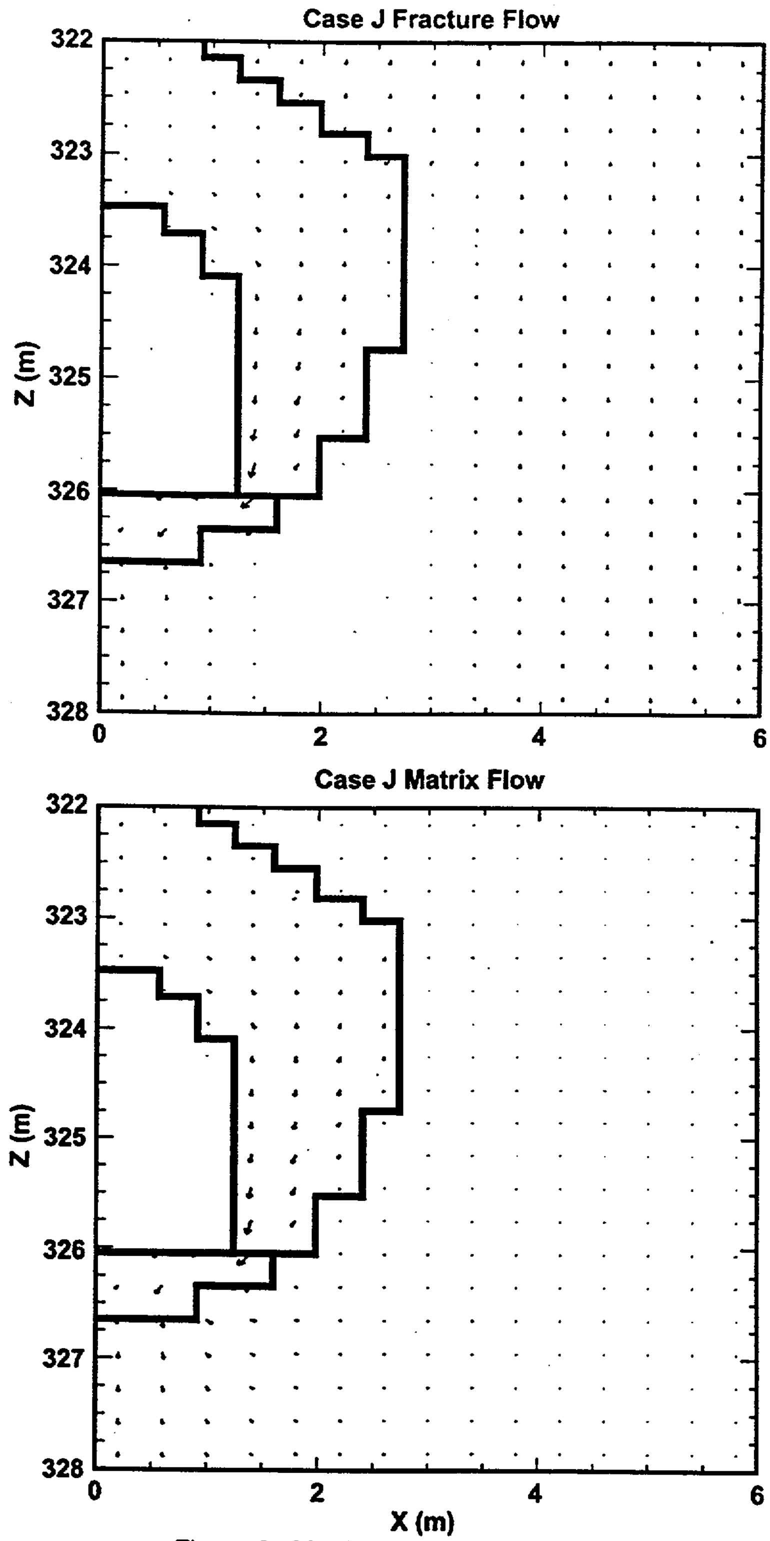


Figure 6. Matrix and Fracture Flow for Case J

7. CONCLUSIONS

The results of processes that plug the fracture system below the invert or below the EBS were modeled. The ability of the EBS to drain water and the sensitivity of the model to backfill and invert permeability was evaluated. Subsequent use of the model presented in this document requires alteration of the NUFT input files. Any changes to this model would require the development of a new model and the associated documentation.

The purpose of this document was to quantify and evaluate the capability of the drift to remove water naturally. This included the tasks outlined below.

a) Developing performance goals for water drainage

b) Considerations of uncertainties and sensitivities, and

c) Calculations of T-H-C/T-H-M effects.

The completion of these tasks led to the following, which are supported by the results in Table 7.

- The minimum performance goal for the EBS is to remain unsaturated (Section 6.4). If the fractures below the invert become plugged, portions of the EBS approach saturation at infiltration rates of 38.66mm/yr. If the fractures below the entire EBS become plugged, the EBS approaches failure from a drainage standpoint at 3/4 of the current climate infiltration rate, 7.6 mm/yr.

- A sensitivity study shows that the ability of the EBS to drain water is not affected by reductions in the permeability of the invert or backfill materials (Table 7-Cases C, D, and E). Uncertainties are introduced in the inputs, as discussed in Section 6.6.

- T-H-C/T-H-M effects are substantial, and are illustrated in Table 7-cases F, G, H, and I.

- For the base case (unplugged) property set, the EBS performs well (with respect to drainage) for infiltration rates of up to 570mm/yr.

If fracture plugging is expected below the invert or EBS, then engineered drainage features, such as gravel-packed boreholes, should be evaluated. Minor modifications of the model developed in this report could show the effectiveness of engineered drainage features. The flow vectors in Figures 4 through 6 provide insight on where these engineered drainage features could be located.

Inputs to this model are unqualified and along with the unqualified software used, all results from this model are unqualified and cannot be used for procurement, fabrication, construction, or used in a verified design package without being tracked in accordance with applicable procedures.

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

Birkholzer, J.T. and Tsang, Y.W. 1998. *Numerical Analysis of Thermal-Hydrological Conditions in the Single Heater Test at Yucca Mountain.* Technical Report TPM# 826. Berkeley, California: Lawrence Berkeley National Laboratory. ACC: MOL.19980715.0257.

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1999a. *Engineered Barrier System Performance Modeling (WP# 12012383MX).* Activity Evaluation. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990719.0317.

CRWMS M&O 1999b. *Classification of the MGR Ex-Container System.* ANL-XCS-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0221.

CRWMS M&O 1999c. *Development Plan for Water Drainage Model.* TDP-EBS-MD-000013 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991005.0222.

DOE (U.S. Department of Energy) 1998a. *Quality Assurance Requirements and Description.* DOE/RW-0333P Rev 8. Washington, D.C.: DOE Office of Civilian Radioactive Waste Management (OCRWM). ACC: MOL.19980601.0022.

Hartman, H.L.; Mutmansky, J.M.; Ramani, R.V.; and Wang, Y.J. 1997. *Mine Ventilation and Air Conditioning, 3rd Edition.* New York, New York: John Wiley and Sons, Inc. TIC: 236391.

Hartman, H.L. sr. ed. 1992. *SME Mining Engineering Handbook, 2nd Edition, Volume 2.* Littleton, Colorado: Society for Mining, Metallurgy, and Exploration, Inc. TIC: 206894.

Isaaks, E. H. and Srivastava, R. M. 1989. *Applied Geostatistics.* New York, New York: Oxford University Press. TIC: 200301.

Kitanidis, P. K. 1997. *Introduction to Geostatistics: Applications in Hydrogeology.* New York, New York: Cambridge University Press. TIC: 236758.

Wilkins, D.R. and Heath, C.A. 1999. "Direction to Transition to Enhanced Design Alternative II." Letter from D.R. Wilkins and C.A. Heath (CRWMS M&O) to Distribution, June 15, 1999, LV.NS.JLY.06/99-026, with enclosures, "Strategy for Baselining EDA II Requirements" and "Guidelines for Implementation of EDA II." ACC: MOL.19990622.0126; MOL.19990622.0127; MOL.19990622.0128.

YMP (Yucca Mountain Project) 1998. *Q-List.* YMP/90-55Q Rev 5. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19980513.0132.

8.2 PROCEDURES CITED

AP-2.13Q, Rev 0, ICN 1. *Technical Product Development Plan.* Washington, D.C.: DOE OCRWM. ACC: MOL.19991115.0230.

AP-3.4Q, Rev 1, ICN 1. *Level 3 Change Control.* Washington, D.C.: DOE OCRWM. ACC: MOL.19991117.0140.

AP-3.10Q, Rev 1, ICN 1. *Analyses and Models.* Washington, D.C.: DOE OCRWM. ACC: MOL.19991019.0467.

AP-3.14Q, Rev 0, ICN 0. *Transmittal of Input.* Washington, D.C.: DOE OCRWM. ACC: MOL.19990701.0621.

AP-3.15Q, Rev 0, ICN 2. *Managing Technical Product Inputs.* Washington, D.C.: DOE OCRWM. ACC: MOL.19991123.0068.

AP-SI.1Q, REV 2, ICN 1. *Software Management.* Washington, D.C.: DOE OCRWM. ACC: MOL.19991101.0212.

AP-SIII.3Q, Rev 0, ICN 2. *Submittal and Incorporation of Data to the Technical Data Management System.* Washington, D.C.: DOE OCRWM. ACC: MOL.19991214.0632.

QAP-2-0, Rev 5. *Conduct of Activities.* Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0209.

QAP-2-3, Rev 10. *Classification of Permanent Items.* Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990316.0006.

8.3 SOURCE DATA

LB990861233129.001. Drift Scale Calibrated 1-D Property Set, FY99. Submittal Date: 08/06/1999.

LB99EBS1233129.001. Natural Environment Data for Engineered Barrier System (EBS) Basecase. Submittal Date: 11/29/1999.

LB99EBS1233129.003. Natural Environment Data for Engineered Barrier System (EBS) Basecase. Submittal Date: 11/29/1999.

MO9911MWDEBSWD.000. EBS Water Drainage Model. Submittal Date: 11/29/1999.

SN9908T0872799.004. Tabulated In-drift Geometric and Thermal Properties Used in Drift-scale Models for TSPA-SR (Total System Performance Assessment-Site Recommendation). Submittal Date: 08/30/1999.

9. ATTACHMENTS

ATTACHMENT I NORMALIZED INFILTRATION RATES

The repository block model developed in Attachment IV, shape1.dat (see Figure I-1), is divided into 31 sections. The block model is composed of a rectangle with a smaller rectangle attached to the southern half of the west boundary of the repository. The 31 sections of the block model are derived by divided the block model into 4 columns with seven rows, plus one additional column (3 rows) in the extension on the southwest side of the repository (Table I-1 and Figure I-1). The location of the 31 elements (Table I-1) is easily checked with coordinate geometry. One example is given:

The Northern row of elements are L1c1-L1c4, as shown in the example below.. To check their spacing simply find the distance between the points and then verify that the slope of the line segments between points is similar. The similar distances and slopes between points verifies that the first row of points represent block elements of similar size. Calculations presented in Table I-1 verify that the repository block elements are similarly sized. The information in Table I-1 is in the file column.data (Attachment VI).

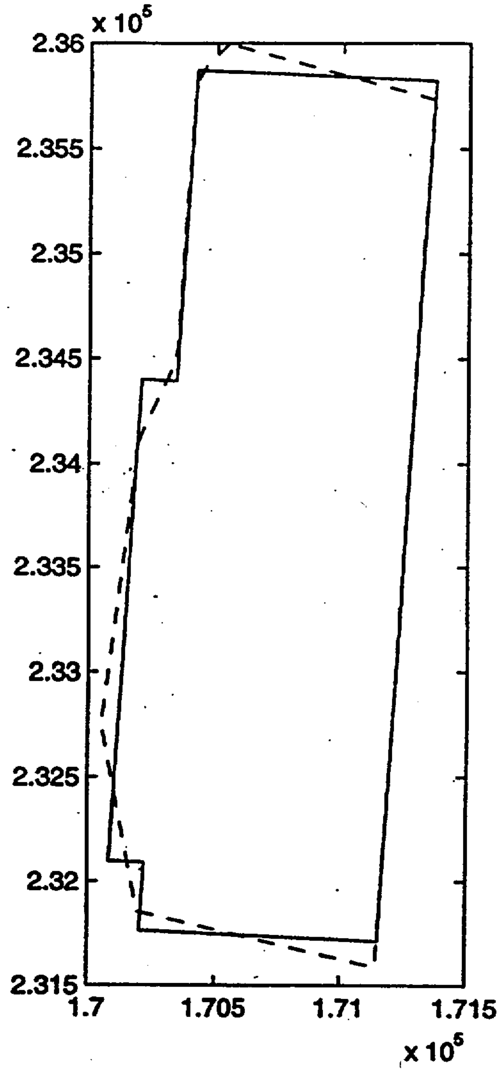
ID	Easting (ft)	Northing (ft)	Points	Distance (ft)	Slope (radians)
l1c1	171234.3	235534.8	c1-c2	236.7	-0.053
l1c2	170997.9	235547.3	c2-c3	236.7	-0.053
l1c3	170761.5	235559.9	c3-c4	236.7	-0.053
l1c4	170525.1	235572.4			

(Portion of Table I-1)

Note: Slope is the quotient of ΔY and ΔX.

The average infiltration rate in the modeled repository is different than the average infiltration rate in the actual repository. To offset this difference, the infiltration rates at the 31 locations are normalized (Table I-2). The normalized infiltration rate is the product of the estimated infiltration rate and a normalization factor. The normalization factor is the quotient of the average normalized infiltration and the actual infiltration. The average normalized infiltration is the average of the estimated infiltration at the 31 block element locations (Attachment VI, *.out). The average actual infiltration is included in the output from Columninfiltration (Attachment VI, *.out).

(NORTHINGS)



(EASTINGS)

Figure I-1. Repository and Repository Block Model

Note: The dotted line is from the drift endpoints in the file dft1.dat (Attachment VI) and the solid line is from the file shape1.dat (Attachment VI).

Table I-1. Repository Block Model Element Locations

Block ID	Easting ft	Northing ft	Points	Distance (ft)	Slope (radians)
I7c4	170338	232049.4	c4-c3	236.6	-0.053
I7c3	170574.3	232036.8	c3-c2	236.7	-0.053
I7c2	170810.7	232024.3	c2-c1	236.7	-0.053
I7c1	171047.1	232011.7			
I6c5	170221.2	232644.4	c5-c4	217.0	-0.053
I6c4	170437.9	232632.9	c4-c3	217.1	-0.053
I6c3	170654.7	232621.4	c3-c2	217.0	-0.053
I6c2	170871.4	232609.9	c2-c1	217.0	-0.053
I6c1	171088.1	232598.4			
I5c5	170252.4	233231.6	c5-c4	217.0	-0.053
I5c4	170469.1	233220.1	c4-c3	217.1	-0.053
I5c3	170685.9	233208.6	c3-c2	217.0	-0.053
I5c2	170902.6	233197.1	c2-c1	217.0	-0.054
I5c1	171119.3	233185.5			
I4c5	170283.6	233818.8	c5-c4	217.0	-0.053
I4c4	170500.3	233807.3	c4-c3	217.1	-0.054
I4c3	170717.1	233795.7	c3-c2	217.0	-0.053
I4c2	170933.8	233784.2	c2-c1	217.0	-0.053
I4c1	171150.5	233772.7			
I3c4	170462.7	234398.1	c4-c3	236.7	-0.053
I3c3	170699.1	234385.5	c3-c2	236.7	-0.053
I3c2	170935.5	234373	c2-c1	236.7	-0.053
I3c1	171171.9	234360.4			
I2c4	170493.9	234985.3	c4-c3	236.7	-0.053
I2c3	170730.3	234972.7	c3-c2	236.7	-0.053
I2c2	170966.7	234960.1	c2-c1	236.7	-0.053
I2c1	171203.1	234947.6			
I1c4	170525.1	235572.4	c4-c3	236.7	-0.053
I1c3	170761.5	235559.9	c3-c2	236.7	-0.053
I1c2	170997.9	235547.3	c2-c1	236.7	-0.053
I1c1	171234.3	235534.8			

Table I-2. Interpolated and Normalized Infiltration Rates

	INTERPOLATED									NORMALIZED								
	Glacial			Monsoon			YM			Glacial			Monsoon			YM		
	Low	Mean	Hi	Low	Mean	Hi	Low	Mean	Hi	Low	Mean	Hi	Low	Mean	Hi	Low	Mean	Hi
I7c4	0.278	3.684	7.090	1.025	2.256	3.487	0.000	1.025	2.559	0.392	5.211	10.031	1.493	3.252	5.014	0.000	1.493	3.60
I7c3	1.511	13.020	24.530	3.212	7.432	11.651	0.006	3.212	7.559	2.131	18.418	34.705	4.677	10.710	16.751	0.010	4.677	10.65
I7c2	1.731	15.849	29.967	3.814	9.524	15.235	0.057	3.814	8.961	2.442	22.420	42.398	5.554	13.726	21.904	0.101	5.554	12.63
I7c1	0.848	4.958	9.067	1.168	3.184	5.200	0.030	1.168	3.839	1.196	7.013	12.829	1.700	4.588	7.476	0.053	1.700	5.41
I6c5	7.645	21.725	35.804	6.462	12.314	18.165	3.594	6.462	13.185	10.785	30.732	50.657	9.410	17.746	26.117	6.423	9.410	18.58
I6c4	1.476	33.842	66.208	7.761	22.656	37.551	0.000	7.761	19.471	2.082	47.872	93.674	11.302	32.651	53.989	0.000	11.302	27.44
I6c3	2.623	11.716	20.810	2.870	7.149	11.427	0.088	2.870	6.790	3.700	16.574	29.442	4.180	10.303	16.429	0.158	4.180	9.57
I6c2	1.824	7.766	13.708	2.161	4.970	7.780	0.333	2.161	4.950	2.573	10.986	19.395	3.147	7.163	11.186	0.596	3.147	6.97
I6c1	1.617	10.660	19.702	2.663	6.545	10.426	0.043	2.663	6.385	2.281	15.079	27.875	3.879	9.432	14.990	0.076	3.879	9.00
I5c5	6.474	21.117	35.760	5.787	11.980	18.172	1.947	5.787	12.368	9.134	29.872	50.594	8.428	17.265	26.127	3.479	8.428	17.436
I5c4	2.157	42.583	83.009	9.896	28.430	46.963	0.000	9.896	24.717	3.043	60.237	117.443	14.412	40.972	67.522	0.000	14.412	34.845
I5c3	4.065	14.103	24.140	3.900	9.104	14.308	0.690	3.900	8.635	5.735	19.949	34.154	5.680	13.120	20.571	1.233	5.680	12.173
I5c2	3.604	19.155	34.706	5.078	12.287	19.495	0.451	5.078	11.730	5.085	27.097	49.103	7.395	17.707	28.029	0.807	7.395	16.537
I5c1	0.084	0.577	1.071	0.455	0.303	0.150	0.000	0.455	1.302	0.118	0.816	1.515	0.663	0.436	0.216	0.000	0.663	1.835
I4c5	2.536	14.289	26.043	3.742	10.042	16.342	0.471	3.742	8.728	3.577	20.214	36.847	5.449	14.472	23.496	0.842	5.449	12.305
I4c4	1.412	29.690	57.967	6.957	20.036	33.115	0.000	6.957	17.227	1.992	41.998	82.014	10.132	28.876	47.611	0.000	10.132	24.286
I4c3	3.915	27.330	50.745	6.966	16.716	26.467	0.029	6.966	16.737	5.523	38.660	71.795	10.144	24.091	38.053	0.052	10.144	23.595
I4c2	1.910	19.740	37.570	4.744	11.727	18.710	0.001	4.744	11.278	2.694	27.923	53.155	6.909	16.900	26.900	0.003	6.909	15.899
I4c1	2.349	13.348	24.346	3.292	8.391	13.491	0.098	3.292	7.791	3.314	18.881	34.446	4.794	12.093	19.396	0.176	4.794	10.983
I3c4	3.505	45.970	88.435	10.902	30.526	50.151	0.000	10.902	26.916	4.944	65.028	125.120	15.877	43.993	72.104	0.000	15.877	37.945
I3c3	0.636	2.965	5.293	0.895	1.830	2.765	0.059	0.895	2.106	0.897	4.194	7.489	1.304	2.637	3.975	0.105	1.304	2.969
I3c2	0.163	0.899	1.634	0.333	0.341	0.350	0.006	0.333	0.836	0.230	1.271	2.312	0.485	0.492	0.503	0.012	0.485	1.179
I3c1	1.269	19.091	36.912	4.350	13.093	21.837	0.085	4.350	11.005	1.791	27.005	52.224	6.335	18.869	31.395	0.151	6.335	15.514
I2c4	6.417	41.445	76.473	10.985	29.341	47.696	1.105	10.985	25.800	9.052	58.627	108.195	15.998	42.285	68.574	1.974	15.998	36.372
I2c3	2.955	44.655	86.354	8.247	28.275	48.303	0.380	8.247	25.791	4.169	63.168	122.176	12.011	40.749	69.448	0.680	12.011	36.359
I2c2	0.054	16.541	33.029	0.973	6.352	11.731	0.000	0.973	6.517	0.076	23.399	46.730	1.416	9.154	16.866	0.001	1.416	9.188
I2c1	0.092	0.518	0.944	0.278	0.174	0.069	0.000	0.278	0.692	0.130	0.733	1.336	0.406	0.250	0.099	0.000	0.406	0.975
I1c4	0.174	13.472	26.770	2.071	8.032	13.993	0.001	2.071	7.583	0.245	19.057	37.875	3.015	11.575	20.119	0.002	3.015	10.690
I1c3	1.702	22.932	44.162	5.363	15.164	24.965	0.130	5.363	13.144	2.400	32.439	62.482	7.809	21.854	35.894	0.232	7.809	18.530
I1c2	0.390	1.506	2.622	0.602	0.652	0.703	0.119	0.602	1.419	0.550	2.130	3.709	0.877	0.940	1.010	0.212	0.877	2.001
I1c1	0.189	9.560	18.931	0.394	6.941	13.489	0.027	0.394	4.094	0.266	13.523	26.784	0.574	10.004	19.393	0.047	0.574	5.772
Avg Int.	2.116	17.571	33.026	4.108	11.154	18.200	0.315	4.108	10.326	2.985	24.856	46.726	5.982	16.074	26.166	0.562	5.982	14.558
Actual Avg	2.985	24.856	46.726	5.982	16.074	26.166	0.562	5.982	14.558	2.985	24.856	46.726	5.982	16.074	26.166	0.562	5.982	14.558

(Normalized value)=(Interpolated value * Actual avg/Avg of interpolated values). All values ar in mm/yr.

Avg. Int. = Average of Interpolated values, or the average of each column.

Actual Avg = actual average of infiltration values that occur within the repository footprint. This value is included in the *_convert.out files (Attachment VI).

ATTACHMENT II ROUTINE TO INTERPOLATE USING INVERSE DISTANCE

ROUTINE IDENTIFICATION

Chim_Surf_TP Version 1.1 and Chim_wt_TP Version 1.1, Initial issue of routines. These routines were developed and compiled using Version Fortran 77 SC4.2. The source codes are chim_surf_TP.f and chim_wt_TP.f (Attachment VI)

ROUTINE PURPOSE AND VALIDATION

The purpose of this routine is to calculate the temperature and pressure at a given location using the inverse distance cubed method (Sections 4.1.1, 5.1.3) The specific input files used for this calculation are: tspa99_primary_mesh, bcs99.txt, and column.data (Attachment VI)

Documentation of the accuracy of this routine is in the form of a test case. The test case is the interpolation of temperature at an arbitrary location (170000N, 230000E) given five temperatures at various locations. The hand calculation that verifies the accuracy of the test case is in Table II-1. Due to the reduction in file size and format minor changes were made to chim_surf_TP in order to execute the test case. The modified source code (chim_surf_bc_tst.f) is in Attachment VI and is used to execute the test case for chim_surf_TP.f and chim_wt_TP.f. The input file for the test case is chim_test and the output file is chim_out.

Table II-1. Calculation of Temperature Using Inverse Distance Method.

Reference Northing:	170000			
Reference Easting:	230000			
Data				
Northing	Easting	1/(distance^3)	Temperature	T_i / (distance^3)
169398.601	236623.643	3.39908E-12	14.27	4.85048E-11
172705.438	230904.031	4.30854E-11	18.62	8.0225E-10
168909.656	233244.625	2.49348E-11	17.00	4.23892E-10
171465.906	237975.359	1.87545E-12	16.89	3.16763E-11
172320.452	237217.733	2.29468E-12	17.53	4.02258E-11
	Sum:	7.55894E-11	Sum:	1.34655E-09
Estimated Temperature:				
17.8140	(= quotient of the sums)			

Note: The Northings and Eastings were randomly selected from tspa99_primary_mesh (Attachment VI).
The Temperatures were randomly selected from bcs99.txt (Attachment VI).
The distance is between each point and the reference location.

The test case was run and the predicted temperature is 17.8140 °C (Attachment VI-chim_out). This documents the accuracy of this routine for predicting temperature and pressure at given points.

ATTACHMENT III ROUTINE TO INTERPOLATE USING A GAUSSIAN MODEL

ROUTINE IDENTIFICATION

ColumnInfiltration V1.1. Initial issue of routine. This routine was developed and compiled using C. The source code for this routine is columninfiltration.c (Attachment VI).

ROUTINE PURPOSE AND VALIDATION

The purpose of this routine is to calculate the infiltration at a given location using Gaussian interpolation method (Sections 4.1.2 and 5.1.4). The specific files used for this calculation are: Glaciall.NV, Glacialm.NV, Glacialu.NV, Monsoonl.NV, Monsoonm.NV, Monsoonu.NV, Yml.NV, Ymm.NV, Ymu.NV, and column.data (Attachment VI).

Documentation of the accuracy of this routine is in the form of a test case. The test case involves the interpolation of the infiltration rate at an arbitrary reference location (242000N, 168000E) given infiltration rates at five various points. The input files for the test case are columninfiltration_tst.NV and columninfiltration_tst.dat (Attachment VI). The output file from this test case is columninfiltration_tst.out (Attachment VI). The hand calculation that verifies the accuracy of the test case is in Table III-1.

Table III-1. Calculation of Infiltration Using the Gaussian Method.

Reference Northing:	242000			
Reference Easting:	168000			
Data				
Northing	Easting	Weight	Infiltration	W_i * $Infiltraiton_i$
168192.021	242645.935	1.300E-79	1.94718	2.532E-79
168222.029	242645.830	9.530E-82	1.23309	1.17517E-81
168252.037	242645.725	3.399E-84	0.00	0
168282.045	242645.621	5.899E-87	0.45	2.67267E-87
168312.053	242645.516	4.981E-90	0.54	2.68959E-90
	Sum:	1.30968E-79	Sum:	2.54331E-79
Estimated Infiltration				
1.941933	(= quotient of the sums)			

Note: The Northings, Eastings, and infiltration rates were selected from Glaciall.NV (Attachment VI). The weight is found using Equation 3.

The test case was run and the predicted infiltration rate is 1.941933 (Attachment VI-columninfiltration_tst.out). This documents the accuracy of this routine for predicting infiltration rates at given points.

ATTACHMENT IV ROUTINE TO DEVELOP A BLOCK MODEL

ROUTINE IDENTIFICATION

Cover Version 1.1. Initial issue of routine. This routine was developed using MatLAB.

ROUTINE PURPOSE AND VALIDATION

The purpose of this routine is to develop a block model of the repository from information contained in dft1.dat (Attachment VI), which is listed in Table IV-2. The output of this routine contains the edges of the block model in the file shape1.dat (Attachment VI), which is listed in Table IV-1. The resulting repository block model is intended to have a similar area to the original layout. The block model is used to develop infiltration rates over the repository footprint.

Range of validation: this routine is limited to developing a block model from information in the file shape1.dat (Attachment VI). Validation is achieved by verifying that the objective of the code (i.e., similar footprint area) was achieved. The area outlined in dft1.dat (Attachment VI) is calculated and compared to the area contained in the block model (shape1.dat).

Table IV-1. Area of Repository Block Model

Easting	Northing	Equation IV-1
171368.06	235822.06	4303909
170422.51	235872.29	-121804376
170343.91	234392.62	-125402076
170205.80	234399.95	-195258392
170083.53	232098.24	-196365687
170221.63	232090.90	-28610852
170204.16	231762.08	-32257943
171149.71	231711.85	347432200
171368.06	235822.06	352179357
	Total area:	4216139

The exact area of a solid by coordinates is found by the following equation:

$$Area = \frac{1}{2} \cdot [x_1(y_2 - y_{(n)}) + x_2(y_3 - y_1) + \ldots + x_{(n)}(y_1 - y_{(n-1)})] \qquad \text{(Eq. IV-1)}$$

where:

Area -area enclosed by coordinates
x -x coordinate
y -y coordinate
n -last point of figure
Source: (Hartman, H. L. 1992, p. A-37)

The routine is verified by finding the area of the repository using equation IV-1. The routine predicted an area of 4,216,139 ft^2 (see Table IV-1), and the actual area is 4,310,041 ft^2 (see Table IV-2). This is an error of less than three percent. This documents the accuracy of the output of this routine. The source code for this routine is cover.m (Attachment VI).

Table IV-2. Actual Area of Repository in Ft^2

East Boundary		West Boundary		from Equation IV-1		
Northing	Easting	Northing	Easting	East pts	West pts	
235997.80	170544.61	235732.05	171362.51	19825810.91	26327279.22	
235964.55	170515.90	235690.53	171359.24	-8505333.09	10680821.43	
235898.04	170458.47	235607.39	171353.01	-12019879	14298551.92	
235823.52	170425.70	235523.64	171348.62	-13295761	14349590.18	
235742.01	170414.44	235439.90	171344.23	-14059191.3	14348365.82	
235658.52	170409.28	235356.16	171339.84	-14227470.8	14347998.2	
235575.03	170404.11	235272.42	171335.46	-14227039.1	14348488.1	
235491.54	170398.95	235188.67	171331.07	-14226608.3	14348120.46	
235408.05	170393.78	235104.93	171326.68	-14226176.7	14346896.18	
235324.56	170388.62	235021.19	171322.29	-14225745.9	14346528.56	
235241.07	170383.45	234937.45	171317.90	-14238944.9	14347017.54	
235157.42	170378.77	234853.70	171313.51	-14259851.2	14346649.89	
235073.68	170374.38	234769.96	171309.12	-14267150.6	14345425.71	
234989.94	170369.99	234686.22	171304.73	-14267634.8	14345058.09	
234906.19	170365.60	234602.48	171300.35	-14267267.2	14345547.81	
234822.45	170361.21	234518.73	171295.96	-14266047.7	14345180.17	
234738.71	170356.83	234434.99	171291.57	-14265680.9	14343956.07	
234654.97	170352.44	234351.25	171287.18	-14266165.1	14343588.45	
234571.22	170348.05	234267.51	171282.79	-14120149.9	14344077.25	
234489.19	170338.41	234183.76	171278.40	-13495060.5	14343709.61	
234412.77	170311.48	234100.02	171274.01	-12918977.3	14342485.6	
234337.48	170281.06	234016.28	171269.62	-12819609.6	14342117.98	
234262.20	170250.64	233932.54	171265.24	-12817319.4	14342607.52	
234186.91	170220.23	233848.79	171260.85	-12985250.2	14342239.88	
234109.63	170195.95	233765.05	171256.46	-13568021.1	14341015.96	
234027.47	170186.69	233681.31	171252.07	-13998706.2	14340648.34	
233945.12	170178.03	233597.57	171247.68	-14015011.7	14341136.96	
233862.76	170169.37	233513.82	171243.29	-14014298.5	14340769.32	
233780.41	170160.72	233430.08	171238.90	-14013586.1	14339545.49	
233698.05	170152.06	233346.34	171234.51	-14013723.7	14339177.87	
233615.69	170143.41	233262.60	171230.13	-14012160.5	14339667.24	
233533.34	170134.75	233178.85	171225.74	-14011447.3	14339299.6	
233450.98	170126.10	233095.11	171221.35	-14010735	14338075.85	
233368.63	170117.44	233011.37	171216.96	-14010021.8	14337708.23	
233286.27	170108.78	232927.63	171212.57	-14010159.1	14338196.67	
233203.91	170100.13	232843.88	171208.18	-14008596.2	14337829.03	
233121.56	170091.47	232760.14	171203.79	-14007883	14336605.37	
233039.20	170082.82	232676.40	171199.40	-14007170.6	14336237.76	
232956.85	170074.16	232592.66	171195.02	-14006457.4	14335870.97	
232874.49	170065.50	232508.92	171190.63	-14006594.6	14336359.31	
232792.13	170056.85	232425.17	171186.24	-14317086.2	14335991.67	
232706.11	170059.48	232341.43	171181.85	-14949078.6	14334768.12	
232616.32	170073.70	232257.69	171177.46	-15270917.5	14334400.5	
232526.53	170087.93	232173.95	171173.07	-15272195.2	14334888.75	
232436.74	170102.15	232090.20	171168.68	-15273472	14334521.11	
232346.95	170116.37	232006.46	171164.29	-15274748.9	14333297.64	
232257.16	170130.59	231922.72	171159.91	-15276025.7	14332930.86	
232167.37	170144.81	231838.98	171155.52	-15277302.5	14333419.02	
232077.58	170159.03	231755.23	171151.13	-15277728.5	14333051.38	
231987.80	170173.25	231671.49	171146.74	-15279005.3	14331828.01	
231898.01	170187.47	231587.75	171142.35	-11461275.2	10748595.29	
231853.11	170194.58	231545.88	171140.16	-29965308.7	-22706876.4	Total Area
			SUM:	-709051221	713361261.6	4310040.8

ATTACHMENT V ROUTINE TO REFORMAT AND COMBINE FILES

ROUTINE IDENTIFICATION

Rme6 V1.1. Initial issue of routine. This routine was developed and compiled using C. The source code for this routine is rme6.c (Attachment VI).

ROUTINE PURPOSE AND VALIDATION

The purpose of this routine is to reformat and combine the files tspa99_primary_mesh and UZ99_3.grd (Attachment VI). The output of this routine is the file LBL99-YMESH (Attachment VI), an input file to YMESH. This routine is verified by visually inspecting the file LBL99-YMESH file.

ATTACHMENT VI ELECTRONIC FILES

All files generated in the development of this document were placed on a CD and are available through the records processing center. The files located on the CD and their sources are listed below. Figure 1 and Table 1 show the source for electronic files.

A.2.f.ps	XTOOL output
A.2.in	Developed, NUFT input
A.2.m.ps	XTOOL output
A.2.m.sat	NUFT output
A.2.f.EBS.ext	NUFT output
A.2.m.EBS.ext	NUFT output
B.2.in	Developed, NUFT input
B.2.m.sat	NUFT output
bcs_99.dat	4.1.22
C.2.in	Developed, NUFT input
C.2.m.sat	NUFT output
chim_out	Test case output for Attachment II
chim_surf_bc_tst	Test case executable for Attachment II
chim_surf_bc_tst.f	Test case source code for Attachment II
chim_surf_TP	Routine executable
chim_surf_TP.f	Routine source code
chim_test	Test case for Attachment II
column.data	Attachment I
columninfiltration.c	Routine source code
columninfiltration_tst.dat	Test case for Attachment III
columninfiltration_tst.NV	Test case for Attachment III
columninfiltration_tst.out	Test case for Attachment III
cover.m	Routine source code
D.2.in	Developed, NUFT input
D.2.m.sat	NUFT output
dft1.dat	4.1.23
dkm-afc-EBS_Rev10-WDR	Developed from 4.1.5, 5.1.7, and 5.1.8
dkm-afc-NBS-WDR	Developed from 4.1.18 through 4.1.21
E.2.in	Developed, NUFT input
E.2.m.sat	NUFT output
F.2.f.ps	XTOOL output
F.2.in	Developed, NUFT input
F.2.m.ps	XTOOL output
F.2.m.sat	NUFT output
F.2.f.EBS.ext	NUFT output
F.2.m.EBS.ext	NUFT output
G.2.in	Developed, NUFT input
G.2.m.sat	NUFT output
Glaciall.inf	4.1.24
Glaciall.NV	Output from CONVERTCOORDS
Glaciall._convert.out	Output from CONVERTCOORDS
Glaciall.out	Output from ColumnInfiltration
Glacialm.inf	4.1.24
Glacialm.NV	Output from CONVERTCOORDS
Glacialm._convert.out	Output from CONVERTCOORDS
Glacialm.out	Output from ColumnInfiltration
Glacialu.inf	4.1.24

Glacialu.NV	Output from CONVERTCOORDS
Glacialu._convert.out	Output from CONVERTCOORDS
Glacialu.out	Output from ColumnInfiltration
H.2.in	Developed, NUFT input
H.2.m.sat	NUFT output
I.2.in	Developed, NUFT input
I.2.m.sat	NUFT output
J.2.f.ps	XTOOL output
J.2.in	Developed, NUFT input
J.2.m.ps	XTOOL output
J.2.m.sat	NUFT output
J.2.f.EBS.ext	NUFT output
J.2.m.EBS.ext	NUFT output
l4c3.dat	Attachment I
l4c3_col.units	Output from YMESH
LBL99-YMESH	Output from rme6
Monsoonl.inf	4.1.24
Monsoonl.NV	Output from CONVERTCOORDS
Monsoonl._convert.out	Output from CONVERTCOORDS
Monsoonl.out	Output from ColumnInfiltration
Monsoonm.inf	4.1.24
Monsoonm.NV	Output from CONVERTCOORDS
Monsoonm._convert.out	Output from CONVERTCOORDS
Monsoonm.out	Output from ColumnInfiltration
Monsoonu.inf	4.1.24
Monsoonu.NV	Output from CONVERTCOORDS
Monsoonu._convert.out	Output from CONVERTCOORDS
Monsoonu.out	Output from ColumnInfiltration
rme6	Routine executable
rme6.c	Routine source code
shape1.dat	Output from MatLAB
tspa99_primary_mesh	Renamed file from 4.1.22
UZ99_3.grd	4.1.22
vtough.pkg	Part of NUFT program
yml.inf	4.1.24
yml.NV	Output from CONVERTCOORDS
yml._convert.out	Output from CONVERTCOORDS
yml.out	Output from ColumnInfiltration
ymm.inf	4.1.24
ymm.NV	Output from CONVERTCOORDS
ymm._convert.out	Output from CONVERTCOORDS
ymm.out	Output from ColumnInfiltration
ymu.inf	4.1.24
ymu.NV	Output from CONVERTCOORDS
ymu._convert.out	Output from CONVERTCOORDS
ymu.out	Output from ColumnInfiltration