OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET

Complete Only Applicable Items

2. ☑ Analysis — Check all that apply

Type of Analysis:
- ☐ Engineering
- ☑ Performance Assessment
- ☑ Scientific

Intended Use of Analysis:
- ☐ Input to Calculation
- ☑ Input to another Analysis or Model
- ☑ Input to Technical Document
- ☐ Input to other Technical Products

Describe use:
Provides the site-scale flow and transport model component with recharge and boundaries.

3. ☐ Model — Check all that apply

Type of Model:
- ☐ Conceptual Model
- ☐ Abstraction Model
- ☐ Mathematical Model
- ☐ System Model
- ☐ Process Model

Intended Use of Model:
- ☐ Input to Calculation
- ☐ Input to another Model or Analysis
- ☐ Input to Technical Document
- ☐ Input to other Technical Products

Describe use:

4. Title:
Recharge and Lateral Groundwater Flow Boundary Conditions for the Saturated Zone Site-Scale Flow and Transport Model

5. Document Identifier (including Rev. No. and Change No., if applicable):
ANL-NBS-MD-000010 Rev. 00 ICN 01

6. Total Attachments: 7

7. Attachment Numbers - No. of Pages in Each:
I-4, II-9, III-9, IV-10, V-5, VI-3, VII-19

	Printed Name	Signature	Date
8. Originator	Bill Arnold Thomas Corbet	SIGNATURE ON FILE	12/18/01
9. Checker	Jan Bostelman	SIGNATURE ON FILE	12/18/01
10. Lead/Supervisor	Al Eddebbarh	SIGNATURE ON FILE	12/18/01
11. Responsible Manager	Bruce Robinson	SIGNATURE ON FILE	12/18/01

12. Remarks:
Rev. 00

This analysis does not affect a discipline or functional area other than the originating discipline. This analysis provides the site-scale flow and transport model flow component with recharge and boundaries. This analysis does not directly affect organizations and users outside NEPO, therefore a review is not required.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD

Complete Only Applicable Items

2. Analysis or Model Title:
Recharge and Lateral Groundwater Flow Boundary Conditions for the Saturated Zone Site-Scale Flow and Transport Model

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

ANL-NBS-MD-000010 Rev. 00 ICN 01

4. Revision/Change No.	5. Description of Revision/Change
00	Initial Issue Note: New Document Identifier (ANL-NBS-MD-000010 Rev. 00) supersedes DI: B00000000-1717-0200-00181
00 ICN 01	This ICN resolves TBVs 1249, 1250, 1251, 3105, and 4255 that were associated with previously unqualified DTNs used as direct input to the analysis. To resolve the TBVs, one DTN (GS960808312144.003) was internally qualified for use in this AMR. One unqualified DTN (LB971212001254.001) was incorporated into an assumption in this ICN. References to unqualified DTN: LB970601233129.001 were incorrect in Rev. 00 and have been deleted in this ICN; the correct citation is DTN: LB971212001254.001. Two unqualified DTNs have been replaced with qualified DTNs: GS970308312133.001 was replaced with MO0102DQRGWREC.001, MO9907YMP99025.001 was replaced with MO9906GPS98410.000. An Acronyms and Abbreviations page was added. Sections 1 and 2 were updated to refer to current technical work plans. Section 4 was modified to clarify the files from DTN GS960808312144.003 that were used to develop lateral boundary conditions. Sections 4, 5.1.2, and 6.1.2 were corrected in this ICN to clarify that the output and grid files identified in Table 4-1 were taken from DTN LB971212001254.001. Attachment VII, Internal Qualification of the Death Valley Regional Groundwater Flow Model, was added to document the internal qualification of a primary data source. Attachments I through VI of this technical product contain documentation of single-use software routines that were qualified under procedure AP-SI.1Q, Software Management, prior to the release of the current revision (Rev. 3) of said procedure. The documentation of these routines was enhanced in the attachments to this ICN as part of the corrective action for Deficiency Report LVMO-00-D-039. This ICN did not involve a change to the code of these routines and they were not used to develop additional quality affecting information, or to modify data in this technical product. Consequently, these single-use software routines will remain documented herein, in accordance with AP-SI.1Q, REV.1, ICN 0, which was in effect at the time of the approval of REV 00 of this technical product. The changes made in this ICN are identified by change bars. This ICN affects all sections and all attachments of this report, and adds Attachment VII. This ICN affects pages, 1-12, 14-17, 20, 22-32, I-1 through I-4, II-1 through II-6, III-1 through III-8, IV-1 through IV-10, V-1 through V-3, VI-1 through VI-3, and VII-1 through VII-19.

CONTENTS

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ACRONYMS AND ABBREVIATIONS

AMR	Analysis/Model Report
CRWMS	Civilian Radioactive Waste Management System
DTN	Data Tracking Number
ECN	Expedited Change Notice
GSIS	Geoscientific Information System
ICN	Interim Change Notice
M&O	Management and Operating Contractor
NWIS	National Water Information System
OCRWM	Office of Civilian Radioactive Waste Management
SZ	Saturated Zone
TBV	To Be Verified
TDMS	Technical Data Management System
TSPA-VA	Total System Performance Assessment – Viability Assessment
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UZ	Unsaturated Zone
WRIR	Water Resources Investigations Report
YMP	Yucca Mountain Site Characterization Project

1. PURPOSE

The purpose of the flow boundary conditions analysis is to provide specified-flux boundary conditions for the saturated zone (SZ) site-scale flow and transport model. This analysis is designed to use existing modeling and analysis results as the basis for estimated groundwater flow rates into the SZ site-scale model domain, both as recharge at the upper (water table) boundary and as underflow at the lateral boundaries. The objective is to provide consistency at the boundaries between the SZ site-scale flow model and other groundwater flow models. The scope of this analysis includes extraction of the volumetric groundwater flow rates simulated by the SZ regional-scale flow model to occur at the lateral boundaries of the SZ site-scale flow model and the internal qualification of the regional-scale model for use in this analysis model report (AMR). In addition, the scope includes compilation of information on the recharge boundary condition taken from three sources: 1) distributed recharge as taken from the SZ regional-scale flow model, 2) recharge below the area of the unsaturated zone (UZ) site-scale flow model, and 3) focused recharge along the Fortymile Wash channel.

Revision 00 of this analysis was governed by the OCRWM work direction and planning document entitled *Development of Flow Boundary Conditions for SZ Flow and Transport Model* (CRWMS M&O 1999a). The technical scope, content, and management of ICN 01 to this AMR is governed by Rev. 02 of the *Technical Work Plan for Saturated Zone Flow and Transport Modeling and Testing* (BSC 2001c). Addendum N to this technical work plan controls the internal data qualification included in ICN 01 to this AMR. The scope for the to be verified (TBV) resolution actions in this ICN is described in the *Technical Work Plan for: Integrated Management of Technical Product Input Department (*BSC 2001b, Addendum B, Section 4.1).

2. QUALITY ASSURANCE

The applicability of the YMP quality assurance program to the activities reported in Revision 00 of this AMR is documented in an activity evaluation (Wemheuer 1999) conducted per QAP-2-0, *Conduct of Activities*. The activity evaluation applicable to ICN 01 of this AMR is documented in Rev. 02 of the *Technical Work Plan for Saturated Zone Flow and Transport Modeling and Testing* (BSC 2001c, Addendum M). The applicable implementing procedures are defined in the OCRWM work direction and planning document *Development of Flow Boundary Conditions for SZ Flow and Transport Model* (CRWMS M&O 1999a).

3. COMPUTER SOFTWARE AND MODEL USAGE

The following industry standard software was used in this analysis and documentation:

Excel 97-SR-1

Used for spreadsheet calculations. Specific applications are discussed in Section 6 of this report. Exel 97-SR-1 is an exempt software product in accordance with AP-SI.1Q, *Software Management*.

Surfer 6.03

Used for plotting and visualization of analysis results in the figures shown in this report.

3.1. RECHARGE

No controlled software codes are used to synthesize the estimates of recharge for the boundary conditions of the SZ site-scale model. A Microsoft Excel spreadsheet is used to combine the components of the recharge model.

3.1.1. Distributed Recharge

A set of software routines is developed and used to extract the distributed recharge from the U.S. Geological Survey (USGS) SZ regional-scale flow model and write the values of recharge for input to the SZ site-scale flow model. The software routines *xread_distr_rech.f (version 1.0)* and *xread_distr_rech_-uz.f (version 1.0)* are documented in Section 6 of this report and in Attachments I and II, respectively.

3.1.2. Recharge From UZ Site-Scale Model Area

A Microsoft Excel spreadsheet is used to perform calculations and unit conversions of data extracted from the output files of the UZ site-scale flow model. In order to combine the output from the UZ site-scale flow model with the other components of the recharge model, the location coordinates from the UZ model (see Assumptions, Section 5.1.2) are converted from the Nevada State Plane coordinate system to the UTM coordinate system with the exempt routine Corpscon, Version 5.11. The accuracy of this routine is documented in Attachment VI.

3.1.3. Focused Recharge From Fortymile Wash

A software routine is used to designate the value of recharge from Fortymile Wash and superimpose this value on the distributed recharge from the USGS SZ regional-scale flow model. The software routine *xread_reaches.f (version 1.0xxx)* is documented in Section 6 of this report and in Attachment III.

A software routine is used to superimpose the values of recharge from the three recharge components for use in the SZ site-scale flow model. The software routine *xwrite_flow_new.f (version 1.0xxx)* is documented in Section 6 of this report and in Attachment IV.

3.2. LATERAL BOUNDARIES

A Microsoft Excel spreadsheet is used to compile simulated groundwater flux values from the USGS Death Valley regional-scale flow model. The regional scale model results are calculated using the MODFLOWP computer code. The executable file *Modflowp* and a set of input files were obtained from the Technical Data Management System (TDMS) directory *GS960808312144.003/milrep/finalmod/* and copied to a Sun workstation. All files needed to perform the analyses in this AMR were obtained from TDMS out of data tracking number (DTN) GS960808312144.003. As discussed in Section 4, this DTN has been internally qualified for use in this AMR. In order to extract flow terms from the output of MODFLOWP for the lateral boundaries of the SZ site-scale model, the routine *extract.f (version 1.0)* was developed. The routine is documented in Section 6 of this report and in Attachment V.

4. INPUTS

Input information used in this analysis comes from several sources that are summarized in Table 4-1. DTN GS960808312144.003, which documents inputs and outputs from the USGS Death Valley regional groundwater flow model (D'Agnese et al. 1997), was internally qualified for use in this report in accordance with AP 3.10Q, Rev. 02, ICN 04, ECN 01, *Analyses and Models.* That qualification is documented in Attachment VII of this report. Recharge data from the UZ site-scale flow model is unqualified output from a preliminary YMP model and is assumed to be reasonably representative of site conditions. This use of UZ model data is further discussed in Section 5.1.2. Focused recharge data for Fortymile Wash were separately qualified (BSC 2001a) in accordance with AP-SIII.2Q, Rev. 0, ICN 3, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*.

Table 4-1. Input Data Sources

Data Set	Data Description	Data Tracking Number	Data Type	Data Status
Distributed Recharge File: *"rchp"*	Recharge input file from USGS SZ regional-scale flow model	GS960808312144.003	Developed	Internally Qualified
Recharge from UZ Site-Scale Model Area Files: *"mnaqb_p.out"* and *"mesh_bas.2k"*	Output files from UZ site-scale flow model containing outflow to SZ and mesh location coordinates	See Assumptions Section 5.1.2	Developed	Assumption
Focused Recharge from Fortymile Wash	Estimates of recharge along four reaches of Fortymile Wash	MO0102DQRGWREC.001	Developed	Qualified

Groundwater Flow at Lateral Boundaries Files: "*modflowp",* *"aap.fix2," "baspcnst.pahdvfix 5," "bcfp2," "cnsthd1new," "cnsthd2new," "cnsthd3new," "drnp," "dvparwel14," "etmpar," "flows.new," "ghbp4," "heads.sum5.spr," "lay1str170.asc," "lay2str170.asc," "lay3str170.asc," "newfinnd.evt," "otc," "pcg2," "rchp," "rechs13fix3.asc," and "welp"*	MODFLOWP executable and input files from USGS SZ regional-scale flow model	GS960808312144.003	Developed	Internally Qualified

5. ASSUMPTIONS

5.1. RECHARGE

In the analysis presented in this report it is assumed that the three components of recharge (i.e., distributed recharge, recharge from the UZ site-scale model area, and focused recharge from Fortymile Wash) considered in the analysis provide a reasonable estimate of the magnitude and spatial pattern of recharge, when combined. In particular, it is assumed that the resulting estimate of groundwater recharge is suitable and adequate for the purposes of flow model calibration for the SZ site-scale flow model. Although the estimates of recharge for the three different components of the recharge analysis were derived by different methods, it is assumed that the results are sufficiently consistent for the purposes of the combined recharge model in the SZ site-scale flow model. This assumption is supported by the observation that the total volumetric flow rate of recharge is a relatively small fraction of the total volumetric groundwater flow rate through the SZ site-scale model domain from the lateral boundaries of the model, as shown in Sections 7.1 and 7.2 of this report.

5.1.1. Distributed Recharge

The pattern of distributed recharge is taken from the SZ regional-scale flow model (DTN GS960808312144.003), which is constructed with a grid resolution of 1500 m. It is assumed that this relatively coarse resolution is adequate for use at the higher resolution of the SZ site-scale flow model. All of the underlying assumptions embodied in the recharge model for the SZ regional-scale flow model (D’Agnese et al., 1997) apply to the results of that model as extracted in this analysis. The basis of these assumptions is that the SZ regional-scale flow model is based on measurements of groundwater discharge and is consequently constrained by the water balance of the entire groundwater system. As such, the regional-scale flow model results provide the best available estimate of the volumetric groundwater flow rate at the scale of the SZ site-scale flow model. These assumptions are used in Section 6.1.1 of this report.

5.1.2. Recharge From UZ Site-Scale Model Area

The pattern of recharge is taken from the bottom boundary of a preliminary version of the UZ site-scale flow model in the area of the UZ model. The output and grid files used in this AMR were taken from DTN LB971212001254.001. These files provided the most current estimate of recharge to the saturated zone within the area of the UZ model at the time the analysis described in Rev. 00 of this AMR was performed and it is assumed that these data are reasonably representative of site conditions. No confirmation of this assumption is required for this version of the AMR.

The UZ site-scale flow model has variable grid resolution that is generally finer than the grid resolution for the SZ site-scale flow model. It is assumed that the integration of recharge flux extracted from the UZ model for use at the grid resolution of the SZ site-scale flow model is adequate to represent the recharge pattern in this area.

The infiltration model employed in the UZ site-scale flow model differs in resolution and conceptual basis from the recharge model used in the SZ regional-scale model. It is assumed that this inconsistency is not significant for the purpose of calibrating the SZ site-scale flow model. In addition, the UZ site-scale flow model results used in this analysis are from the expected case among several alternative models that consider uncertainty in the infiltration flux and UZ flow model parameters. It is assumed that the expected case of the UZ site-scale flow model is the most representative estimate to use for the recharge analysis. The relatively small total groundwater contribution from the UZ model area relative to the distributed recharge model (see Section 7.1 of this report) indicates that these assumptions are not of large consequence for the purpose of SZ site-scale flow model calibration. These assumptions are used in Section 6.1.1 of this report.

5.1.3. Focused Recharge From Fortymile Wash

The estimates of recharge from the Fortymile Wash channel were taken from DTN MO0102DQRGWREC.001 and are based on streamflow losses during brief runoff events over a maximum of 26 years (Savard 1998). It is assumed that the observations are representative of the long-term recharge from this source. The estimates of recharge for the Fortymile Canyon reach and the Amargosa Desert reach are extrapolated and interpolated, respectively, to estimate the recharge rates for reaches of the wash within the area of the SZ site-scale model (see Section 6.1.3 of this report). It is assumed that the recharge is uniform along each of the stream reaches and that the effective width of the Fortymile Wash channel for recharge at the water table is approximately 500 m. It is also assumed that recharge is uniformly distributed over the area of the distributary channels of Fortymile Wash in the Amargosa Desert. One basis for these assumptions is the relatively small total groundwater contribution from the focused recharge along Fortymile Wash relative to the distributed recharge model (see Section 7.1 of this report). These assumptions are used in Section 6.1.3 of this report.

5.2. LATERAL BOUNDARIES

The TDMS contains an executable file of the MODFLOWP code as well as input files in DTN GS960808312144.003. It is assumed that running this executable with these input files accurately calculates the cell-by-cell flow terms of the final 1997 USGS model. In addition, it is assumed that modifying the input files, as discussed in the Analysis section below, does not alter the calculated flow terms. The basis of this assumption is that the authors of the USGS regional-scale flow model provided the executable file of

MODFLOWP in the TDMS to allow generation of the output files from the input files contained therein.

The regional model assumes that the density of water is constant, but does not specify a specific value. An arbitrary value of 1000 kg/m^3 is assumed for fluid density in this analysis to convert from volumetric [m^3/day] to mass [kg/s] flows. The mass flow rates presented by this analysis could be easily modified to represent an alternative assumption about fluid density.

6. ANALYSIS

6.1. RECHARGE

The approach taken to the analysis of recharge over the domain of the SZ site-scale flow model involves taking interpretations of recharge from three sources and combining this information into a single model for the spatial distribution of recharge. The starting point of the analysis is the model of distributed recharge used in the SZ regional-scale flow model. Within the area of the UZ site-scale flow model the estimates of distributed recharge are replaced by the simulated values of groundwater flow at the water table boundary of the UZ flow model. In the areas beneath the Fortymile Wash channel the distributed recharge estimate is replaced by the estimates of recharge based on streamflow loss measurements.

6.1.1. Distributed Recharge

The values of distributed recharge are extracted from the SZ regional-scale flow model input file for recharge. The recharge input file for the SZ regional-scale flow model is "*rchp*" and is taken from the TDMS (DTN: GS960808312144.003). The FORTRAN routine "*xread_distr_rech.f*" is used to extract the values of recharge from the "*rchp*" file and write an output file "*rech_site.dat*" that contains the UTM coordinates on 1500 m centers and the recharge in units of m/year. Electronic copies of these files are included in the electronic archive (DTN: SN9908T0581999.001) along with this report. Documentation of the software routine "*xread_distr_rech.f*" is included as Attachment I of this report.

The FORTRAN routine "*xread_distr_rech_-uz.f*" is used to convert the values of distributed recharge contained in the file "*rech_site.dat*" to a 125 m grid within the area of the SZ site-scale model and writes the output to file "*rech_distr.dat*" in units of mm/year. The 125 m grid is used because this is the finest discetization anticipated for the SZ site-scale flow model. In addition, this routine excludes any grid locations inside the area of the UZ site-scale flow model. A plot of the spatial distribution of recharge in file "*rech_distr.dat*" is shown in Figure 6.1.1-1. Electronic copies of these files are included in the electronic archive (DTN: SN9908T0581999.001) along with this report. Documentation of the software routine "*xread_distr_rech_-uz.f*" is included as Attachment II of this report.

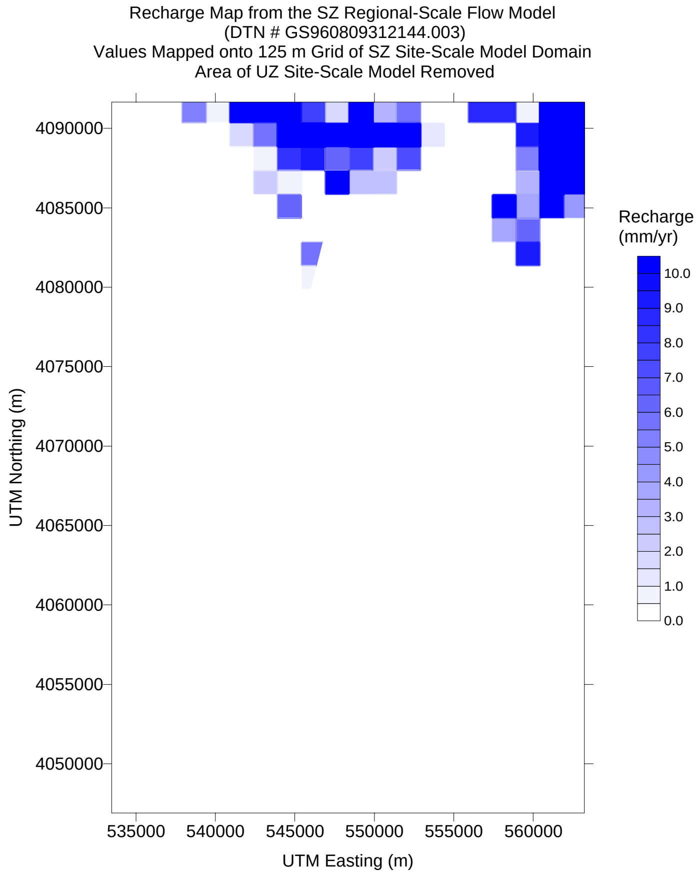

Figure 6.1.1-1. Map of distributed recharge from the SZ regional-scale flow model. Recharge within the area of the UZ site-scale model is not included. Recharge data taken from file "*rech_distr.dat*".

6.1.2. Recharge From UZ Site-Scale Model Area

The recharge in the area of the UZ site-scale flow model is taken from the output file for the UZ flow simulations "*mnaqb_p.out*", which is taken from the TDMS (see assumptions in Section 5.1.2). This TOUGH2, Version 1.11, output file corresponds to the base-case, mean alpha, present day infiltration scenario in Total System Performance Assessment – Viability Assessment (TSPA-VA) (CRWMS M&O 1998).

Elements in the UZ site-scale flow model at the bottom boundary of the model (i.e., the water table) are identified by the prefix "BT" in the input and output files. Elements that are associated with fracture flow use the prefix "F" and elements for matrix flow use the prefix "M" in this dual-permeability model. These prefixes are used to extract the 1470 elements at the water table in the UZ site-scale flow model using the UNIX "grep" command. The following two commands are used to perform the extraction:

"grep BT…..F mnaqb_p.out>extract_F.out"
"grep BT…..M mnaqb_p.out>extract_M.out"

The two output files "*extract_F.out*" and "*extract_M.out*" contain the groundwater flux at the water table boundary (in kg/s) in the fourth column of the files for the fracture and matrix components of flow, respectively.

The numerical grid file for the UZ site-scale flow model "*mesh_bas.2k*" is taken from the TDMS (see assumptions in Section 5.1.2) to obtain information on the x and y coordinates of each element and information on the connection area for each element. The following UNIX command is used to perform the extraction:

"grep "BT…..   " mesh_bas.2k>meshgrep2.out"

The output file "*meshgrep2.out*" contains the connection area of the element in column numbers 21 to 29, the x coordinate (Nevada State Plane in meters) in column numbers 51 to 60 and the y coordinate in column numbers 61 to 70.

These data are combined in an Excel spreadsheet in the file "*wt_flux_uz.xls*". This spreadsheet is constructed by taking columns from the "*extract_F.out*" , "*extract_M.out*", and "*meshgrep2.out*" files and performing additional operations to calculate total volumetric flow rate and average percolation flux. The first additional operation is to add column G of the spreadsheet (fracture flux in kg/s) to column H (matrix flux in kg/s) to get column I (total flux in kg/s). The second operation is to divide the resulting column I by column J (cell connect area in m^2) to get column K (flux per area in kg/s m^2). The final operation is to multiply the resulting column K by the constant 31557600 to convert the units of flux per area to mm/yr. This result is stored in column L. The results are plotted in Figure 6.1.2-1 and are overlain by the UZ site-scale flow model grid.

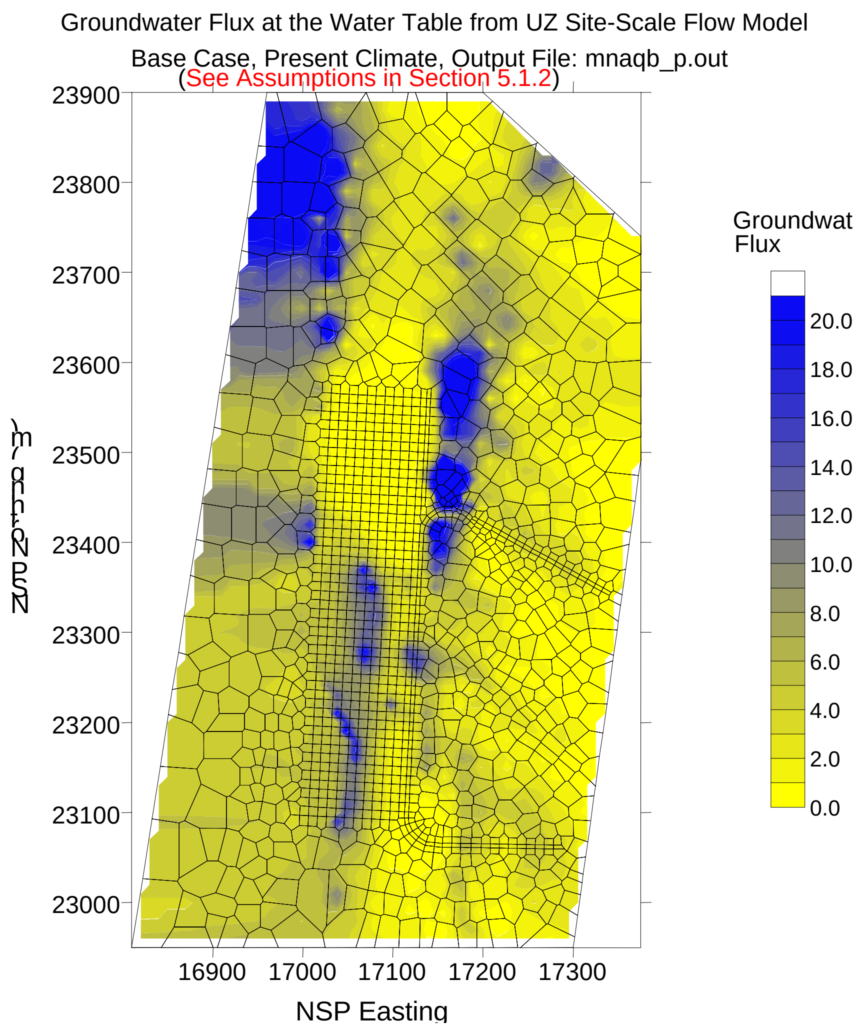

Figure 6.1.2-1. Map of groundwater flux simulated at the bottom boundary of the UZ site-scale flow model. The model grid is shown overlain on the map of simulated recharge to the SZ.

To combine the output from the UZ site-scale flow model with the other components of the recharge model, the geographical coordinates from the UZ model are converted from the Nevada State Plane coordinate system to the Universal Transverse Mercator (UTM) coordinate system. The results of this coordinate conversion are given in the spreadsheet in the file "*wt_flux_uz.xls*". The software routine "Corpscon" is used to perform the coordinate conversion. This Windows routine is included in the archive of files (DTN: SN9908T0581999.001) for this analysis. Checking and verification of the coordinate transformation was conducted by visual inspection of the plotted recharge location, as shown in Figure 6.1.3-2. In addition, confirmation of the accuracy of the Corpscon routine output for the Yucca Mountain area, with some example coordinate conversions, is contained in Attachment VI.

6.1.3. Focused Recharge From Fortymile Wash

Recharge data from infiltration along Fortymile Wash were taken from DTN MO0102DQRGWREC.001. These data are based on estimates of streamflow loss along four reaches of Fortymile Wash as described in Savard (1998). These reaches are the Fortymile Canyon reach, Upper Jackass Flats reach, Lower Jackass Flats reach, and Amargosa Desert reach, listed from north to south and shown in Figure 6.1.3-1. The estimate of recharge along the northernmost reach of Fortymile Wash (Fortymile Canyon reach) has been extrapolated to the north boundary of the SZ site-scale model domain. The lengths of the Fortymile Canyon reach within the Savard (1998) study and within the SZ site-scale model domain were estimated graphically from Figure 6.1.3-1. The estimate of recharge along the Upper Jackass Flats reach presented in Savard (1998) is anomalously low relative to the other reaches as estimated in the same report. Consequently, an interpolated value of recharge for the Upper Jackass Flats reach is applied. The volumetric groundwater recharge rates per kilometer of reach are averaged for the Fortymile Canyon reach and the Lower Jackass Flats reach and this value is applied for the Upper Jackass Flats reach. The recharge rate along the Amargosa Desert reach is scaled in proportion to the length of this reach within the SZ site-scale model area. The resulting estimates of the recharge rates are summarized in Table 6.1.3-1.

Table 6.1.3-1. Fortymile Wash Recharge Estimates

Fortymile Wash Reach	Reach Length (from Savard, 1998) (km)	Estimated Recharge (m^3/year) DTN MO0102DQRGW REC.001	Reach Length in SZ Site-Scale Model (km)	Estimated Recharge in SZ Site-Scale Model Area (m^3/year)	Estimated Recharge Flux (mm/year)
Fortymile Canyon	6.5	27000	9.5	39500[b]	5.77
Upper Jackass Flats	10.1	13600[a]	10.1	13600	2.21
Lower Jackass Flats	16.8	16400	16.8	16400	1.53
Amargosa Desert	25.0	64300	10.0	25700[b]	0.22

[a] Interpolated value.
[b] Scaled in proportion to length within the SZ site-scale model area.

The first step of the analysis is to identify those nodes that correspond to the Fortymile Wash channel for each of the reaches on a 125 m resolution grid as shown in Figure 6.1.3-1. Along most of the length of the Fortymile Wash channel, nodes within an approximately 500 m wide zone are designated to receive recharge from the wash. The nodes corresponding to a broad area of distributary channels in the Amargosa Desert are identified for the southernmost reach within the area of the SZ site-scale model domain. The results are 438 nodes in the Fortymile Canyon reach, 394 nodes in the Upper Jackass Flats reach, 687 nodes in the Lower Jackass Flats reach, and 7544 nodes in the Amargosa Desert reach.

Processing of the data is performed with the FORTRAN routine "*xread_reaches.f*", which is included as Attachment III to this report. This routine reads in the file "*digit.dat*", which contains a set of digitized points defining the stream channel location for the four reaches of Fortymile Wash within the SZ site-scale model domain and the recharge rates for those reaches as tabulated in Table 6.1.3-1. The file "*digit.dat*" was generated using the digitize function from the Surfer program from Figure 6.1.3-1. The routine also reads in the file "*rech_distr.dat*", which contains the values of distributed recharge within the SZ site-scale model domain, as described in section 6.1.1 of this report. The routine "*xread_reaches.f*" combines the estimates of distributed recharge and the estimates of focused recharge and outputs the file "*rech_distr_stream.dat*". This file contains location coordintates (UTM m) and recharge (mm/year) on a 125 m grid for all locations with nonzero values of recharge. The file "*rech_distr_stream.dat*" also excludes grid locations within the area of the UZ site-scale model.

6.1.4. Combined Recharge Model

The estimates of distributed recharge and focused recharge contained in the file "*rech_distr_stream.dat*" are combined with the simulated recharge at the water table boundary of the UZ site-scale flow model contained in file "*wt_flux_uz.xls*" in an Excel spreadsheet in the file "*rech_all_new.xls*". In the "*rech_all_new.xls*" spreadsheet, the groundwater mass flux (kg/s) into each grid node is calculated. The first 1470 entries in the spreadsheet are for the output of the UZ site-scale flow model and the remaining entries are for the distributed recharge and focused recharge components of the analysis. The result of the combined estimates is shown in the map in Figure 6.1.3-2.

These results are reformatted for input to the FEHM code using the FORTRAN routine "*xwrite_flow_new.f*", which is included as Attachment IV of this report. The "*xwrite_flow_new.f*" routine reads in the data in the "*rech_all_new.xls*" spreadsheet (saved in the text file "*rech_all_new.txt*", which has the header lines removed). The "*xwrite_flow_new.f*" routine writes output in a format suitable for input to the "flow" macro of FEHM for specified groundwater mass flux (kg/s). The resolution of the grid nodes in the output from the "*xwrite_flow_new.f*" routine is specified within the routine. The output assumes that grid nodes are numbered sequentially from the southwest corner of the SZ site-scale model domain, moving from west to east and south to north. Output files were generated for 1000 m, 500 m, 250 m, and 125 m nodal resolutions in the files "*wt_flow_1000.dat*", "*wt_flow_500.dat*", "*wt_flow_250.dat*", "*wt_flow_125.dat*", respectively.

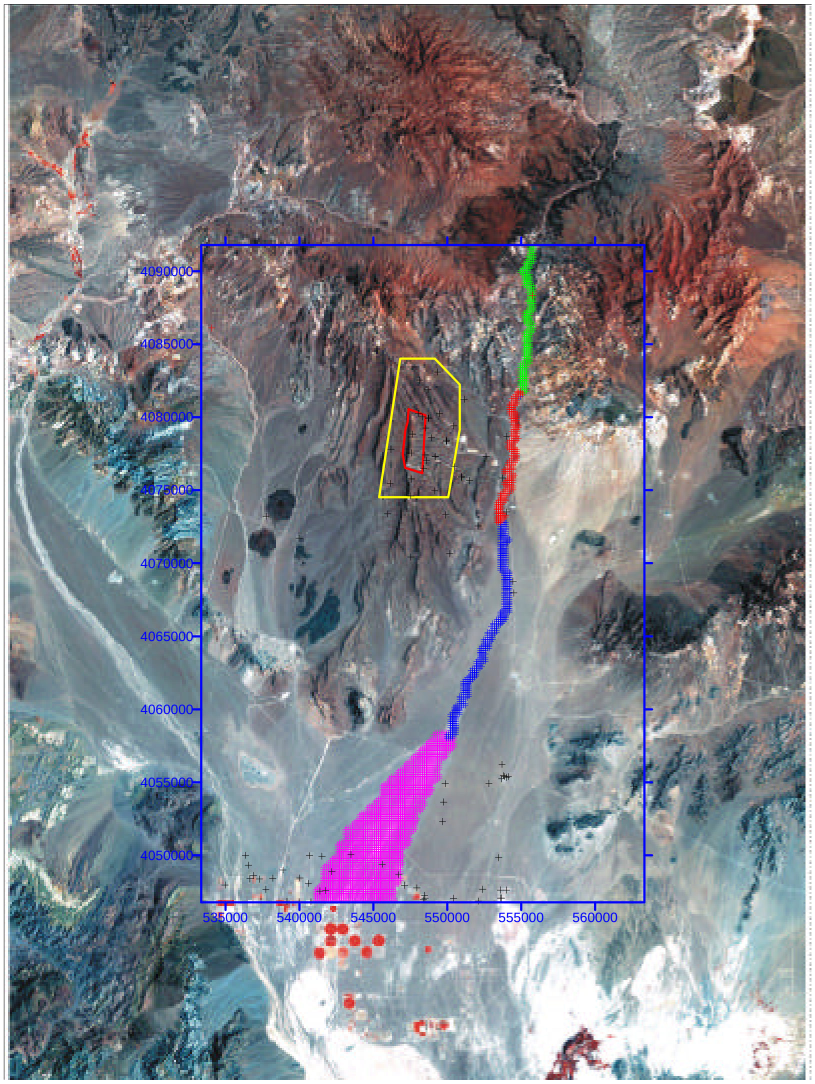

Figure 6.1.3-1. Map of recharge along the Fortymile Wash stream channel. The base image of the figure is a false-color satellite photo of the Yucca Mountain area. The four reaches of Fortymile Wash are shown by the different colors overlying the wash. The boundaries of the SZ site-scale model and the UTM coordinates (m) are shown by the blue line. The approximate outline of the repository is shown by the red line and the outline of the UZ site-scale model is shown with the yellow line.

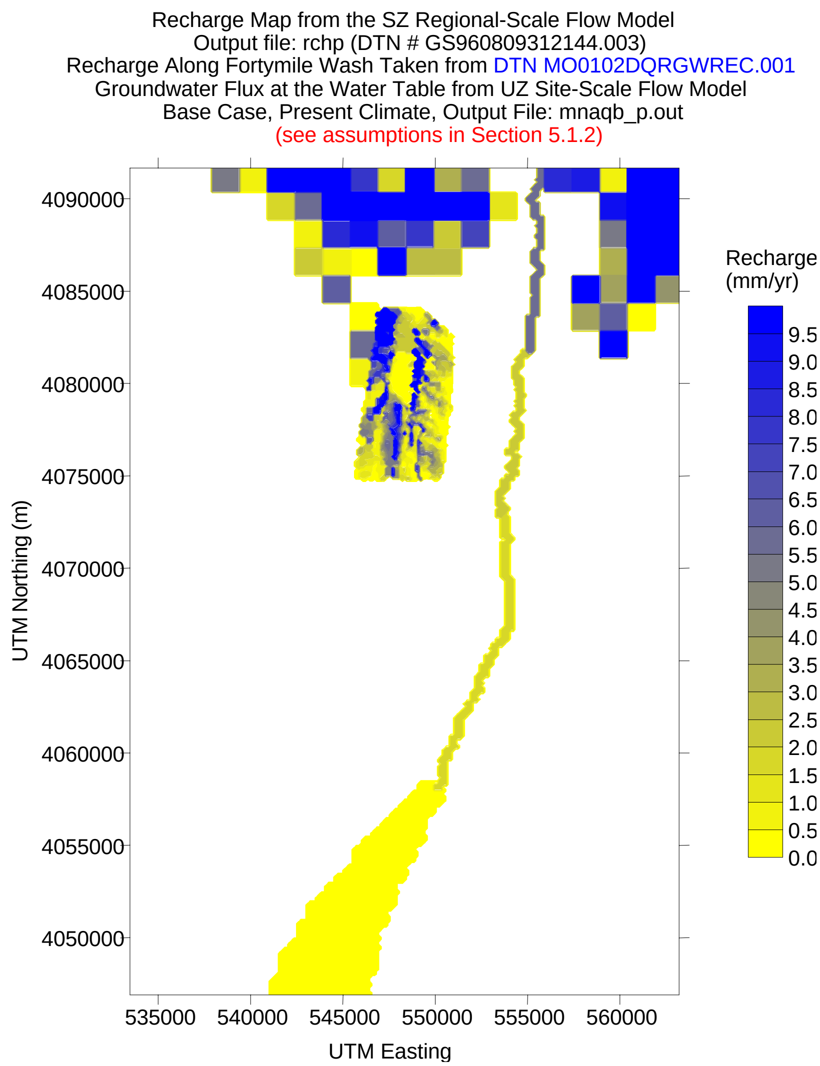

Figure 6.1.3-2. Map of recharge to the SZ site-scale flow model, combining the components of distributed recharge, recharge below the UZ site-scale flow model domain, and focused recharge along Fortymile Wash.

6.2. LATERAL BOUNDARIES

Extracting fluxes from the SZ regional-scale flow model is performed in three steps. Because the TDMS does not include output files from the 1997 U. S. Geological Survey model of the Death Valley regional ground-water flow system, the first step is to re-run the regional model to generate an unformatted output file containing cell-by-cell flow values. Second, a FORTRAN routine is used to read the unformatted file and write selected values to formatted files. Finally, an Excel spreadsheet is used to sum the flow terms for selected segments along the site-scale boundaries and convert from volumetric to mass flows.

Running the regional model:

1) The regional scale model results are calculated using the MODFLOWP computer code. An executable file (*Modflowp*) and a set of input files are obtained from the TDMS (DTN GS960808312144.003) and copied to a Sun workstation, node=Picard, with the following 4 processors:

cpu0: SUNW,UltraSPARC-II (upaid 0 impl 0x11 ver 0x11 clock 296 MHz)
cpu1: SUNW,UltraSPARC-II (upaid 1 impl 0x11 ver 0x11 clock 296 MHz)
cpu2: SUNW,UltraSPARC-II (upaid 2 impl 0x11 ver 0x11 clock 296 MHz)
cpu3: SUNW,UltraSPARC-II (upaid 3 impl 0x11 ver 0x11 clock 296 MHz).

2) The input files for the SZ regional-scale flow model in the TDMS are set up to calculate certain statistics, but the input files required for these statistics (*BEALE.DAT* and *BEALE2.DAT*) are not present. Because these statistics are not required for this analysis, two changes are made to the input files to allow MODFLOWP to run without these files. In the input file "*dvparwel14*", the 5th entry of line 7 (in columns 24 and 25) is changed from 72 to zero. This is a switch which tells MODFLOWP not to calculate the statistics that require "*BEALE.DAT"* and "*BEALE2.DAT"*. Second, the a line containing the file name "*BEALE.DAT"* and a line containing the filename "*BEALE2.DAT"* are deleted from the input file "*Files*". This file contains file names and their corresponding logical unit numbers. Deleting these file names from "*Files*" prevents MODFLOWP from trying to open a file that was not present.

3) The executable (*Modflowp*) is then run. The output file used in this analysis is the "*cbcf.new*" file, which contains cell-by-cell flow terms.

Extract cell-by-cell flow terms along the boundaries of the site-scale domain:

The coordinates of site-scale domain are:

xmin	533,340 m E
xmax	563,340 m E
ymin	4,046,780 m N
ymax	4,091,780 m N

The regional model is 163 rows by 153 columns, SW corner at 440,340; 3,944,782 (D'Agnese et al, 1997, page 75). Row 1 is to the north. Column 1 is to the west. Each model cell is 1,500 m square in the lateral directions. Then,

the x coordinates at east face of column 62 = 440340+((62)(1500))= 533,340
the x coordinates at east face of column 82 = 440340+((82)(1500))= 563,340
the y coordinates at south face of row 95 = 3,944,782+((163-95)(1500))=4,046,782
the y coordinates at south face of row 65 = 3,944,782+((163-65)(1500))=4,091,782

Thus the domain outlined by the east faces of columns 62 and 82, and the south faces of rows 65 and 95 of the regional model form a domain that is shifted 2 m north of the site-scale domain. The west boundary of the site-scale model consists of the east face of column 62 for rows 66-95. The east boundary consists of the east face of column 82 for rows 66-95. The north boundary consists of the south face of row 65 for columns 63-82. The south boundary consists of the south face of row 95 for columns 63-82.

A FORTRAN routine (*extract.f*) to extract and write the flow terms was developed and used. The routine is compiled using the FORTRAN77 compiler on the Sun workstation (WorkShop Compilers 4.2 30 Oct 1996 FORTRAN 77 4.2). Documentation of the routine is included as Attachment V. This routine writes the flow terms along each boundary to a separate file. The files are named "*west_bdy*", "*east_bdy*", "*north_bdy*", and "*south_bdy*". Details of the routine are given in comment statements in the source code of the routine.

These files were entered into an Excel workbook (electronic copy attached, file "*boundaries.xls*"). Excel is used for two calculations, to sum flow terms for segments along the site model boundaries and to convert the volumetric flows [m^3/day] to mass flows [kg/s]. The segments are selected to group fluxes of similar direction and magnitude.

7. CONCLUSIONS

7.1. RECHARGE

The results of the combined estimates of recharge from distributed recharge, focused recharge along Fortymile Wash, and recharge in the area of the UZ site-scale flow model are shown graphically in Figure 6.1.3-2 and presented in output DTN SN9908T0581999.001. Focused recharge data for Fortymile Wash were qualified in a separate data qualification report (BSC 2001a). These data were reviewed and modified for appropriate use in this AMR as described in Section 6.1.3. Distributed recharge data developed for the USGS regional flow model (DTN GS960808312144.003) were internally qualified as documented in Attachment VII to this AMR and found to be appropriate for use in this AMR. The majority of the recharge entering the system in the area of the SZ site-scale flow model occurs in the northern part of the model domain. An estimated total of 48.9 kg/s (1.55 x 10^6 m^3/year) of groundwater enters the saturated-zone system as recharge in the SZ site-scale model area. Of this total, about 6.7 kg/s recharge occurs in the area of the UZ site-scale flow model and about 3.0 kg/s recharge occurs from focused recharge along Fortymile Wash.

7.2. LATERAL BOUNDARIES

The cell-by-cell flow terms extracted from the 1997 U. S. Geological Survey model of the Death Valley regional ground-water flow system are given in Tables 7.2-1 to 7.2-4 and presented in output DTN SN9908T0581999.001. Lateral flow data developed from the USGS regional flow model (DTN GS960808312144.003) were internally qualified as documented in Attachment VII to this AMR and found to be appropriate for use in this AMR. These tables contain the flow terms as calculated by MODFLOWP, i.e. in units of m^3/day. The final column of each table is the sum of the terms for the three model layers for each row/column position. Flow terms for the west and east boundaries are for the (east) right cell faces, and terms for the north and south boundaries are for the south (front) faces. Row, column, and layer numbers are those of the regional model grid.

The total mass flux [kg/s] for segments along the west, north, and east site model boundaries follows. These boundaries are the current candidates for specified flux in the SZ site-scale flow model. The fluxes are for the boundaries of a region that is shifted 2 m north relative to the domain of the site-scale model. The coordinates of the boundary segments are in UTM (meters). Fluxes are the total flux for that boundary segment, from the water table to a depth of 2750 m (i.e., all three layers of the SZ regional-scale flow model). A positive value indicates flow into the SZ site-scale model domain.

East Boundary:

from y=4,046,780 to 4,058,780: flux = +555.45 kg/s
from y=4,058,780 to 4,081,280: flux = +5.46
from y=4,081,280 to 4,087,280: flux = -2.65
from y=4,087,280 to 4,091,780: flux = +3.07

North Boundary:

from x=533340 to 543840: flux = +101.64 kg/s
from x=543840 to 552840: flux = +18.86
from x=552840 to 560340: flux = +64.70
from x=560340 to 563340: flux = +10.63

West Boundary:

from y=4,046,780 to 4,054,280: flux = -3.45 kg/s
from y=4,054,280 to 4,063,280: flux = +71.00
from y=4,063,280 to 4,072,280: flux = +6.90
from y=4,072,280 to 4,082,780: flux = -2.73
from y=4,082,780 to 4,091,780: flux = +46.99

Table 7.2-1. Cell-by-cell flow terms [m^3/day] from the 1997 U. S. Geological Survey model of the Death Valley regional ground-water flow system along the west boundary of the site-scale model

column	row	layer1	layer2	layer3	sum
62	66	300.2210	116.4051	172.6758	589.3019
62	67	385.4388	128.9357	283.9898	798.3643
62	68	91.2969	118.8400	182.6684	392.8053
62	69	81.6321	528.7921	163.5032	773.9274
62	70	119.7977	761.6837	117.8837	999.3651
62	71	102.2948	226.3122	177.2012	505.8082
62	72	3.5854	4.5799	4.5910	12.7563
62	73	0.9552	1.5968	-0.2015	2.3505
62	74	-43.1638	-0.7436	0.2239	-43.6835
62	75	-22.9567	-0.5382	1.9569	-21.5380
62	76	-26.6496	-0.5568	2.1711	-25.0353
62	77	-132.7272	-0.6117	1.8454	-131.4935
62	78	-30.6877	-0.1970	1.3879	-29.4968
62	79	67.7964	0.1506	1.0450	68.9920
62	80	99.1461	0.2877	0.9304	100.3642
62	81	102.5495	0.2189	0.6025	103.3709
62	82	150.8397	0.5854	0.4216	151.8467
62	83	33.8089	0.4745	0.6808	34.9642
62	84	23.4775	112.0292	0.8068	136.3135
62	85	115.8098	156.8466	45.4742	318.1306
62	86	545.1091	226.8207	656.8904	1428.8202
62	87	435.0265	644.8766	799.3350	1879.2381
62	88	389.4053	582.7269	31.7153	1003.8475
62	89	339.5885	482.1666	16.0400	837.7951
62	90	63.1286	604.9294	-1.8066	666.2514
62	91	-0.7494	7.4360	-1.9344	4.7522
62	92	-51.7265	-1.1885	-2.1722	-55.0872
62	93	-59.8463	-2.5714	-2.6846	-65.1023
62	94	-80.7184	-3.5531	-3.7052	-87.9767
62	95	-86.0093	-4.1979	-4.3128	-94.5200

Table 7.2-2. Cell-by-cell flow terms [m^3/day] from the 1997 U. S. Geological Survey model of the Death Valley regional ground-water flow system along the east boundary of the site-scale model

column	row	layer1	layer2	layer3	sum
82	66	35.0744	104.1892	1.0335	140.2971
82	67	32.4961	59.5407	2.8732	94.9100
82	68	10.3283	17.9262	1.8526	30.1071
82	69	-3.4922	-6.7300	0.0019	-10.2203
82	70	-21.2585	-30.6522	0.0163	-51.8944
82	71	-31.1982	-40.6015	0.0209	-71.7788
82	72	-95.0790	-0.0151	0.0088	-95.0853
82	73	0.0957	22.1619	0.1119	22.3695
82	74	-0.0253	-4.9123	0.3112	-4.6264
82	75	5.1671	38.1532	0.3185	43.6388
82	76	5.3195	32.5464	14.2158	52.0817
82	77	23.1081	29.8514	36.8918	89.8513
82	78	21.1946	19.7791	14.2273	55.2010
82	79	5.6187	15.7595	4.4241	25.8023
82	80	1.4321	1.8868	-0.6955	2.6234
82	81	4.4139	1.3365	-0.0422	5.7082
82	82	14.2843	3.2528	0.0438	17.5809
82	83	13.3643	3.5229	-0.7694	16.1178
82	84	7.0857	2.9896	-1.4877	8.5876
82	85	6.2192	5.0456	0.1849	11.4497
82	86	29.3401	5.3988	31.3175	66.0564
82	87	1.9728	16.1808	41.1021	59.2557
82	88	0.2848	1548.8440	3119.2073	4668.3361
82	89	0.3887	2089.5090	4151.5591	6241.4568
82	90	0.4157	2228.8079	4423.1963	6652.4199
82	91	0.4114	2201.4536	4385.2954	6587.1604
82	92	3.1997	2140.7375	4301.0850	6445.0222
82	93	5.1691	2058.0015	4210.7461	6273.9167
82	94	14.4602	1854.5498	3990.9055	5859.9155
82	95	13.8338	1559.0319	3689.5305	5262.3962

Table 7.2-3. Cell-by-cell flow terms [m^3/day] from the 1997 U. S. Geological Survey model of the Death Valley regional ground-water flow system along the north boundary of the site-scale model

column	row	layer1	layer2	layer3	sum
63	65	436.7631	158.6168	88.8833	684.2632
64	65	445.4616	666.2696	126.6694	1238.4006
65	65	470.4084	705.4063	142.2845	1318.0992
66	65	496.7751	743.2569	145.7451	1385.7771
67	65	511.1288	766.8786	141.3761	1419.3835
68	65	513.3553	770.7878	131.1927	1415.3358
69	65	500.4772	703.2574	116.6735	1320.4081
70	65	90.0194	124.4723	99.4196	313.9113
71	65	94.3074	135.7408	79.1619	309.2101
72	65	81.8713	125.9834	54.6917	262.5464
73	65	79.1612	122.4325	45.4847	247.0784
74	65	81.7757	123.9266	2.4599	208.1622
75	65	78.1031	207.5337	3.3195	288.9563
76	65	71.3560	834.7631	24.5218	930.6409
77	65	77.1166	911.6486	24.9287	1013.6939
78	65	84.7914	990.1692	26.3804	1101.3410
79	65	160.8794	1060.8494	27.2710	1248.9998
80	65	166.6360	1100.9541	27.4993	1295.0894
81	65	204.6464	321.8176	38.1635	564.6275
82	65	82.4114	226.1308	45.4612	354.0034

Table 7.2-4. Cell-by-cell flow terms [m^3/day] from the 1997 U. S. Geological Survey model of the Death Valley regional ground-water flow system along the south boundary of the site-scale model

column	row	layer1	layer2	layer3	sum
63	95	-10.1696	-27.0123	-2.3935	-39.5754
64	95	-162.1753	-65.2793	-3.1454	-230.6000
65	95	-82.6131	-757.2695	-165.6998	-1005.5824
66	95	-358.8732	-600.8329	-192.5924	-1152.2985
67	95	-371.3719	-612.0051	-242.7134	-1226.0904
68	95	-511.8046	-755.4321	-249.1117	-1516.3484
69	95	-555.7947	-830.3972	-1310.7151	-2696.9070
70	95	-592.0862	-885.5881	-1346.3021	-2823.9764
71	95	-609.6418	-913.7783	-1431.5834	-2955.0035
72	95	-557.9603	-853.9814	-1365.4269	-2777.3686
73	95	-487.4033	-749.4507	-1280.9761	-2517.8301
74	95	-296.7092	-462.6852	-1192.6534	-1952.0478
75	95	-134.0494	-45.4739	-1074.3965	-1253.9198
76	95	-75.9106	-35.3944	-54.2203	-165.5253
77	95	-1.0317	16.2062	21.8088	36.9833
78	95	-10.1687	-97.8409	-152.0629	-260.0725
79	95	-6.4307	-3467.8037	-7410.0439	-10884.2783
80	95	-5.3251	-3423.5581	-7539.6074	-10968.4906
81	95	-32.0253	-3663.1204	-7828.6636	-11523.8093
82	95	-35.7936	-4120.3281	-8149.0601	-12305.1818

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8.3. SOURCE DATA, LISTED BY DATA TRACKING NUMBER

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MO0102DQRGWREC.001. Groundwater Recharge Rate Data for the Four Reaches of Fortymile Wash Near Yucca Mountain, Nevada. Submittal date: 02/26/2001.

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8.4 OUTPUT DATA, LISTED BY DATA TRACKING NUMBER

SN9908T0581999.001. Recharge and Lateral Groundwater Flow Boundary Conditions for the Saturated Zone (SZ) Site-Scale Flow and Transport Model.
Submittal date: 08/19/1999.

9. ATTACHMENTS

Attachment	**Title**
I	Documentation of the xread_distr_rech.f Version 1.0 FORTRAN Routine
II	Documentation of the xread_distr_rech_-uz.f Version 1.0 FORTRAN Routine
III	Documentation of the xread_reaches.f Version 1.0 FORTRAN Routine
IV	Documentation of Four xwrite_flow_new.f Version 1.0-XXX FORTRAN Routines
V	Documentation of the extract.f Version 1.0 FORTRAN Routine

VI	Documentation of the Corpscon Version 5.11 Routine
VII	Internal Qualification of the Death Valley Regional Groundwater Flow Model

ATTACHMENT I

DOCUMENTATION OF THE xread_distr_rech.f VERSION 1.0 FORTRAN ROUTINE

ROUTINE IDENTIFICATION

The routine *xread_distr_rech.f* is at version 1.0. This is a FORTRAN routine that was compiled using the FORTRAN 77 compiler on a Sun workstation.

INPUT AND OUTPUT FILES

The input file for *xread_distr_rech.f* v. 1.0 is the SZ regional-scale flow model file for recharge named *rchp* from (DTN GS960808312144.003). The routine *xread_distr_rech.f* extracts the values of recharge from the *rchp* file and writes an output file *rech_site.dat* that contains the UTM coordinates on 1500 m centers and the recharge in units of m/year.

DESCRIPTION

This routine begins by reading in the values of recharge from the SZ regional-scale model as a one-dimensional array with variable "rech1" in the loop ending with line 10. This array is converted to a two-dimensional array with variable "rech2" consisting of 163 rows and 153 columns in the loop ending with line 20. The rows and columns correspond to the rows and columns in the SZ regional-scale flow model (D'Agnese et al., 1997, p. 75). Output is written for those rows (66 to 95) and columns (63 to 82) that correspond to the area of the SZ site-scale model (see Section 6.2 of this report) with the loop ending with line 30. The xo and yo values defined in the routine are the UTM coordinates of the middle of the 1500 m cell in the southwest corner of the SZ site-scale model domain.

VALIDATION

Below are provided excerpts of the input and output files of the routine *xread_distr_rech.f* v. 1.0. Note that the highlighted value of recharge in m/year from the input file is correctly extracted and written to the output file in the proper location in units of m/year. The concept of a range of validation is not applicable to this routine since its purpose is to just extract values from one specified file and write them in a different format to another file. The files are specified in the code itself as can be seen in the code listing provided in this attachment. The routine is valid for all values in the specified input file.

Input file *rchp*

Following are lines 1115 through 1118 of the input file *rchp*. There are three header lines in this file. Consequently these lines correspond to lines 1112 through 1115 of the one-dimensional array of recharge values. Each line contains 9 values of recharge. Consequently, values for array indices 10,000 through 10,035 are contained in this excerpt. Values for indices 10,008 through 10,027 are highlighted. These indices correspond to the northern-most row of values in the output file *rech_site.dat*.

```
0.000000        0.000000        0.000000        0.000000
0.000000        0.000000        0.000000        0.000000
0.000000

0.000000        0.000000        0.005283        0.000576
0.013663        0.010264        0.010553        0.007710
0.001733

0.032282        0.003264        0.005660        0.000000
0.000000        0.008502        0.008533        0.000701
0.034101

0.030516        0.008270        0.032626        0.036288
0.012243        0.035966        0.000000        0.000000
0.000000
```

Output file *rech_site.dat*

Following are lines 581 through 600 of the output file *rech_site.dat.* The first two columns of each line are the UTM coordinates of the cell centers. The third column contains the recharge values corresponding to the highlighted values in the excerpt from the input file above, demonstrating correct functionality.

```
     534090.   4.09103E+06    0.
     535590.   4.09103E+06    0.
     537090.   4.09103E+06    0.
     538590.   4.09103E+06      5.28300E-03
     540090.   4.09103E+06      5.76000E-04
     541590.   4.09103E+06      1.36630E-02
     543090.   4.09103E+06      1.02640E-02
     544590.   4.09103E+06      1.05530E-02
     546090.   4.09103E+06      7.71000E-03
     547590.   4.09103E+06      1.73300E-03
     549090.   4.09103E+06      3.22820E-02
     550590.   4.09103E+06      3.26400E-03
     552090.   4.09103E+06      5.66000E-03
     553590.   4.09103E+06    0.
     555090.   4.09103E+06    0.
     556590.   4.09103E+06      8.50200E-03
     558090.   4.09103E+06      8.53300E-03
     559590.   4.09103E+06      7.01000E-04
     561090.   4.09103E+06      3.41010E-02
     562590.   4.09103E+06      3.05160E-02
```

CODE LISTING

```
C
      program xread_distr_rech
C
C     This program extracts the values of recharge in the SZ
C     regional-scale flow model input file "rchp" within the
C     domain of the SZ site-scale flow model.  The output
C     consists of x and y coordinates (UTM) on 1500 m centers and
C     the value of recharge (m/year).
C
      DIMENSION rech1(24939),rech2(153,163)

      open(file='rchp',unit=11,status='old')
      open(file='rech_site.dat',unit=12,status='new')

      xo=534090.
      yo=4091030.

      do 10 i=1,3
        READ(11,*)
   10 continue

      read (11,*) rech1

      do 20 j=1,163
        do 20 i=1,153
          nnum=((j-1)*153)+i
          rech2(i,j)=rech1(nnum)
   20 continue

      do 30 j=95,66,-1
        do 30 i=63,82
          x=xo+(i-63)*1500.
          y=yo+(66-j)*1500.
          WRITE(12,*) x,y,rech2(i,j)
   30 continue

   99 format (i6,3f12.1)

      end
```

ATTACHMENT II

DOCUMENTATION OF THE xread_distr_rech_-uz.f VERSION 1.0 FORTRAN ROUTINE

ROUTINE IDENTIFICATION

The routine *xread_distr_rech_-uz.f* is at version 1.0. This is a FORTRAN routine that was compiled using the FORTRAN 77 compiler on a Sun workstation.

INPUT AND OUTPUT FILES

The input file for *xread_distr_rech_-uz.f* v. 1.0 is *rech_site.dat* (Note that this is the output file from the previous routine documented in Attachment I.) The routine *xread_distr_rech_-uz.f* translates the values of distributed recharge in the input file to a 125 m grid within the area of the SZ site-scale model and writes the output to file *rech_distr.dat* in units of mm/year.

DESCRIPTION

This routine begins by reading in the coordinates and values of recharge from the SZ regional-scale flow model (from the input file *rech_site.dat*) within the area of the SZ site-scale model in the loop ending at line 10. The routine then loops through a 125 m grid (239 columns by 359 rows) for the SZ site-scale model domain in the loop that ends at line 100. For each fine grid location the routine finds the nearest node from the 1500 m grid of the SZ regional-scale model and assigns that value of recharge to the 125 m grid node in the loop ending at line 110. The values of recharge are converted from m/year to mm/year by multiplying by 1000 mm/m. The routine then uses a function call to the “inside” function to determine if the 125 m grid node is inside or outside of the UZ site-scale flow model area. The area of the UZ site-scale flow model is defined by the six points at the vertices of a polygon. Finally, the coordinates of the 125 m grid node and the value of recharge are written out by the routine, if the node is outside the area of the UZ site-scale flow model domain.

VALIDATION

As is apparent from the above description, the routine *xread_distr_rech_-uz.f* has three functions: 1) translating appropriate values of recharge from the 1500 m grid to the fine 125 m grid, 2) performing a simple unit conversion of m/year to mm/year, and 3) discriminating between areas and only writing output for the specified area. Validation will be by inspection of excerpts of input and output files. The concept of a range of validation is not applicable to this routine. The routine reads only one specified input file, performs the functions listed above, and writes to one specified output file. This can be confirmed by inspection of the code, which is provided in this attachment. The routine is valid for all values on the specified input file.

Input file *rech_site.dat*

Following are lines 461-480. These lines contain recharge values for the seventh row of grid cells from the northern boundary of the site-scale model domain. Only two cells have non-zero values. These are the two southern-most grid cells with non-zero recharge in Figure 6.1.3-2. As shown in this figure, only the western-most of these two grid cells intersects the domain of the UZ model domain.

```
534090.   4.08203E+06    0.
535590.   4.08203E+06    0.
537090.   4.08203E+06    0.
538590.   4.08203E+06    0.
540090.   4.08203E+06    0.
541590.   4.08203E+06    0.
543090.   4.08203E+06    0.
544590.   4.08203E+06    0.
546090.   4.08203E+06      5.71800E-03
547590.   4.08203E+06    0.
549090.   4.08203E+06    0.
550590.   4.08203E+06    0.
552090.   4.08203E+06    0.
553590.   4.08203E+06    0.
555090.   4.08203E+06    0.
556590.   4.08203E+06    0.
558090.   4.08203E+06    0.
559590.   4.08203E+06      9.81100E-03
561090.   4.08203E+06    0.
562590.   4.08203E+06    0.
```

Output file *rech_distr.dat*

Following are lines 65023 – 65140. These are the lines in *rech_distr.dat* with a Y UTM coordinate equal to 4082030 m, and an X UTM coordinate greater than 544000 m. By inspection, it is clear that the recharge values for the two cells in the excerpt of the input file are represented in the finer 125 m grid. The highlighted values in this file are one thousand times greater, showing that the conversion from m/year to mm/year works correctly. Note that there are 9 cells in the fine grid with a value of 5.72 and 12 cells with a value of 9.81. Twelve cells with a width of 125 m are required to cover the 1500-m width of a cell in the coarse grid. There are only 9 cells with a value of 5.72 because the eastern-most 3 cells corresponding to the single cell in the coarse grid with this discharge value fall within the domain of the UZ model. This shows that the routine is correctly not writing entries to the output file for cells within the domain of the UZ model.

```
544090.00      4082030.00          0.00
544215.00      4082030.00          0.00
544340.00      4082030.00          0.00
544465.00      4082030.00          0.00
544590.00      4082030.00          0.00
544715.00      4082030.00          0.00
```

544840.00	4082030.00	0.00
544965.00	4082030.00	0.00
545090.00	4082030.00	0.00
545215.00	4082030.00	0.00
545340.00	4082030.00	0.00
545465.00	4082030.00	5.72
545590.00	4082030.00	5.72
545715.00	4082030.00	5.72
545840.00	4082030.00	5.72
545965.00	4082030.00	5.72
546090.00	4082030.00	5.72
546215.00	4082030.00	5.72
546340.00	4082030.00	5.72
546465.00	4082030.00	5.72
551090.00	4082030.00	0.00
551215.00	4082030.00	0.00
551340.00	4082030.00	0.00
551465.00	4082030.00	0.00
551590.00	4082030.00	0.00
551715.00	4082030.00	0.00
551840.00	4082030.00	0.00
551965.00	4082030.00	0.00
552090.00	4082030.00	0.00
552215.00	4082030.00	0.00
552340.00	4082030.00	0.00
552465.00	4082030.00	0.00
552590.00	4082030.00	0.00
552715.00	4082030.00	0.00
552840.00	4082030.00	0.00
552965.00	4082030.00	0.00
553090.00	4082030.00	0.00
553215.00	4082030.00	0.00
553340.00	4082030.00	0.00
553465.00	4082030.00	0.00
553590.00	4082030.00	0.00
553715.00	4082030.00	0.00
553840.00	4082030.00	0.00
553965.00	4082030.00	0.00
554090.00	4082030.00	0.00
554215.00	4082030.00	0.00
554340.00	4082030.00	0.00
554465.00	4082030.00	0.00
554590.00	4082030.00	0.00
554715.00	4082030.00	0.00
554840.00	4082030.00	0.00
554965.00	4082030.00	0.00

555090.00	4082030.00	0.00
555215.00	4082030.00	0.00
555340.00	4082030.00	0.00
555465.00	4082030.00	0.00
555590.00	4082030.00	0.00
555715.00	4082030.00	0.00
555840.00	4082030.00	0.00
555965.00	4082030.00	0.00
556090.00	4082030.00	0.00
556215.00	4082030.00	0.00
556340.00	4082030.00	0.00
556465.00	4082030.00	0.00
556590.00	4082030.00	0.00
556715.00	4082030.00	0.00
556840.00	4082030.00	0.00
556965.00	4082030.00	0.00
557090.00	4082030.00	0.00
557215.00	4082030.00	0.00
557340.00	4082030.00	0.00
557465.00	4082030.00	0.00
557590.00	4082030.00	0.00
557715.00	4082030.00	0.00
557840.00	4082030.00	0.00
557965.00	4082030.00	0.00
558090.00	4082030.00	0.00
558215.00	4082030.00	0.00
558340.00	4082030.00	0.00
558465.00	4082030.00	0.00
558590.00	4082030.00	0.00
558715.00	4082030.00	0.00
558840.00	4082030.00	0.00
558965.00	4082030.00	9.81
559090.00	4082030.00	9.81
559215.00	4082030.00	9.81
559340.00	4082030.00	9.81
559465.00	4082030.00	9.81
559590.00	4082030.00	9.81
559715.00	4082030.00	9.81
559840.00	4082030.00	9.81
559965.00	4082030.00	9.81
560090.00	4082030.00	9.81
560215.00	4082030.00	9.81
560340.00	4082030.00	9.81
560465.00	4082030.00	0.00
560590.00	4082030.00	0.00
560715.00	4082030.00	0.00

560840.00	4082030.00	0.00
560965.00	4082030.00	0.00
561090.00	4082030.00	0.00
561215.00	4082030.00	0.00
561340.00	4082030.00	0.00
561465.00	4082030.00	0.00
561590.00	4082030.00	0.00
561715.00	4082030.00	0.00
561840.00	4082030.00	0.00
561965.00	4082030.00	0.00
562090.00	4082030.00	0.00
562215.00	4082030.00	0.00
562340.00	4082030.00	0.00
562465.00	4082030.00	0.00
562590.00	4082030.00	0.00
562715.00	4082030.00	0.00
562840.00	4082030.00	0.00
562965.00	4082030.00	0.00
563090.00	4082030.00	0.00
563215.00	4082030.00	0.00

CODE LISTING

```
C
      program xread_distr_rech_uz
C
C     This routine reads in the values of recharge (m/year) taken
C     from the SZ regional-scale flow model within the area of the
C     SZ site-scale flow model on a 1500 m grid.  The routine writes
C     out values of recharge (mm/year) on a 125 m grid over the same
C     domain with grid points inside the area of the UZ site-scale
C     flow model excluded.

      dimension x(20),y(20)
      dimension rech1(600)
      dimension x_reg(600),y_reg(600)

      open(file='rech_site.dat',unit=11,status='old')
      open(file='rech_distr.dat',unit=12,status='new')

C     Limits of the SZ site-scale model domain
      xmin=533340.
      xmax=563340.
      ymin=4046780.
      ymax=4091780.

C        Coordinates of the polygon bounding the UZ site-scale model
domain
      x(1)=545424.9
      x(2)=546891.3
```

```
      x(3)=549290.6
      x(4)=551045.7
      x(5)=551054.5
      x(6)=550323.5
      y(1)=4074660.5
      y(2)=4084163.0
      y(3)=4084171.4
      y(4)=4082578.0
      y(5)=4080078.7
      y(6)=4074677.6

      cx=548308.
      cy=4079169.

      delx=125.

      n=6

      do 10 i=1,600
        read(11,*) x_reg(i),y_reg(i),rech1(i)
   10 continue

      do 100 j=2,360
        do 100 i=2,240
          distmin=10000.
          do 110 k=1,600
            xx=(i-1)*delx+xmin
            yy=(j-1)*delx+ymin
            xdist=xx-x_reg(k)
            ydist=yy-y_reg(k)
            dist=sqrt((xdist*xdist)+(ydist*ydist))
            if(dist.lt.distmin) then
              distmin=dist
              nmin=k
            endif
  110     continue
          rech=rech1(nmin)*1000.

          nin=inside(xx,yy,n,x,y,cx,cy)
          if(nin.eq.0) then
            write(12,99) xx,yy,rech
          endif

  100 continue

   99 format(3f15.2)

C
      end


      INTEGER FUNCTION INSIDE (XX, YY, N, X, Y, CX, CY)
C
C
C    (CX,CY) is a point inside the polygon
```

```
C    (X,Y) are the vectors of the coordinates of the polygon
C      (XX,YY)  is  the  point  in  question  as  to  whether  it  is  in  the
polygon
C
C    Returns
C    0 - if outside polygon
C    1 - if inside polygon
C
      dimension x(20),y(20)
C
      INSIDE = 0
      K = N

      xmin=x(1)
      xmax=x(1)
      ymin=y(1)
      ymax=y(1)
      do 50 i=2,n
        if(x(i).le.xmin) xmin=x(i)
        if(x(i).ge.xmax) xmax=x(i)
        if(y(i).le.ymin) ymin=y(i)
        if(y(i).ge.ymax) ymax=y(i)
   50 continue

      if(xx.le.xmin) goto 100
      if(xx.ge.xmax) goto 100
      if(yy.le.ymin) goto 100
      if(yy.ge.ymax) goto 100
C
      DO 20  I = 1, N
C
        IF (X(I) .EQ. X(K) )  THEN
C
          IF ( (YY .LE. Y(I)  .AND.  YY .GE. Y(K) )  .OR.
     *         (YY .GE. Y(I)  .AND.  YY .LE. Y(K) ) )  THEN
            IF ((XX .LT. X(I)  .AND.  CX .GT. X(K) )  .OR.
     *       (XX .GT. X(I)  .AND.  CX .LT. X(K) )) GO TO 100
          END IF
C
        ELSE
          sM = (Y(K) - Y(I) ) / (X(K) - X(I) )
          Y1 = Y(K) + (XX - X(K) ) * sM
          Y2 = Y(K) + (CX - X(K) ) * sM
C
          IF ( (YY .LE. Y(I)  .AND.  YY .GE. Y(K) )  .OR.
     *         (YY .GE. Y(I)  .AND.  YY .LE. Y(K) ) ) THEN
            IF ( (YY .LT. Y1  .AND.  CY .GT. Y2)  .OR.
     *        (YY .GT. Y1  .AND.  CY .LT. Y2) ) GO TO 100
          END IF
C
      END IF
C
        K = I
C
 20   CONTINUE
```

```
      INSIDE = 1
C
 100  CONTINUE
      RETURN
      END
```

ATTACHMENT III

DOCUMENTATION OF THE xread_reaches.f VERSION 1.0 FORTRAN ROUTINE

ROUTINE IDENTIFICATION

The routine *xread_reaches.f* is at version 1.0. This is a FORTRAN routine that was compiled using the FORTRAN 77 compiler on a Sun workstation.

INPUT AND OUTPUT FILES

The input for *xread_reaches.f* v. 1.0 consists of two files, *rech_distr.dat* (note that this is the output from the previous routine documented in Attachment II) and *digit.dat*. This second file (*digit.dat*) contains a set of digitized points defining the stream channel location for the four reaches of Fortymile Wash within the SZ site-scale model domain and the recharge rates for those reaches as tabulated in Table 6.1.3-1 of this AMR. The routine *xread_reaches.f* combines the estimates of distributed recharge and the estimates of focused recharge from the two input files and outputs the file *rech_distr_stream.dat*.

DESCRIPTION

This routine begins by reading in the coordinates and values of distributed recharge on the 125 m grid within the SZ site-scale model domain (from the input file *rech_distr.dat*) in the loop ending at line 100. The routine then reads in the coordinates of digitized locations within the stream channel reaches of Fortymile Wash (from the input file *digit.dat*), finds all 125 m grid nodes within 250 m of those locations, and resets the value of recharge at those nodes to the focused recharge value assigned to that reach of Fortymile Wash in the nested loops ending at line 400. This process is repeated for the Amargosa Reach of Fortymile Wash for all nodes within a greater (500 m) distance of the digitized locations of that part of the drainage in the loops ending at line 310. The coordinates and values of recharge are then written out to the *rech_distr_stream.dat* file for the 125 m grid nodes in the loop ending at line 40.

VALIDATION

As can be seen from the above description, the routine *xread_reaches.f* performs a replacement function for grid nodes within certain specified distances of various reaches of Fortymile Wash. Distributed recharge values are replaced by focused discharge values. Validation will be by inspection of excerpts of input and output files. The concept of a range of validation is not applicable to this routine. The routine reads two specified input files, performs the replacement function described above, and writes to one specified output file. This can be confirmed by inspection of the code, which is provided in this attachment. The routine is valid for all values on the specified input files.

Input file rech_distr.dat

Following are lines 65023 – 65140. These are the lines in *rech_distr.dat* with a Y UTM coordinate equal to 4082030 m, and an X UTM coordinate greater than 544000 m. By inspection, it is clear that the recharge values for the two cells in the excerpt of the input file are represented in the finer 125 m grid. The highlighted values in this file are one thousand times greater, showing that the conversion from m/year to mm/year works correctly. Note that there are 9 cells in the fine grid with a value of 5.72 and 12 cells with a value of 9.81. Twelve cells with a width of 125 m are required to cover the 1500-m width of a cell in the coarse grid. There are only 9 cells with a value of 5.72 because the eastern-most 3 cells corresponding to the single cell in the coarse grid with this discharge value fall within the domain of the UZ model. This shows that the routine is correctly not writing entries to the output file for cells within the domain of the UZ model.

```
544090.00      4082030.00         0.00
544215.00      4082030.00         0.00
544340.00      4082030.00         0.00
544465.00      4082030.00         0.00
544590.00      4082030.00         0.00
544715.00      4082030.00         0.00
544840.00      4082030.00         0.00
544965.00      4082030.00         0.00
545090.00      4082030.00         0.00
545215.00      4082030.00         0.00
545340.00      4082030.00         0.00
545465.00      4082030.00         5.72
545590.00      4082030.00         5.72
545715.00      4082030.00         5.72
545840.00      4082030.00         5.72
545965.00      4082030.00         5.72
546090.00      4082030.00         5.72
546215.00      4082030.00         5.72
546340.00      4082030.00         5.72
546465.00      4082030.00         5.72
551090.00      4082030.00         0.00
551215.00      4082030.00         0.00
551340.00      4082030.00         0.00
551465.00      4082030.00         0.00
551590.00      4082030.00         0.00
551715.00      4082030.00         0.00
551840.00      4082030.00         0.00
551965.00      4082030.00         0.00
552090.00      4082030.00         0.00
552215.00      4082030.00         0.00
552340.00      4082030.00         0.00
552465.00      4082030.00         0.00
552590.00      4082030.00         0.00
552715.00      4082030.00         0.00
552840.00      4082030.00         0.00
552965.00      4082030.00         0.00
```

553090.00	4082030.00	0.00
553215.00	4082030.00	0.00
553340.00	4082030.00	0.00
553465.00	4082030.00	0.00
553590.00	4082030.00	0.00
553715.00	4082030.00	0.00
553840.00	4082030.00	0.00
553965.00	4082030.00	0.00
554090.00	4082030.00	0.00
554215.00	4082030.00	0.00
554340.00	4082030.00	0.00
554465.00	4082030.00	0.00
554590.00	4082030.00	0.00
554715.00	4082030.00	0.00
554840.00	4082030.00	0.00
554965.00	4082030.00	0.00
555090.00	4082030.00	0.00
555215.00	4082030.00	0.00
555340.00	4082030.00	0.00
555465.00	4082030.00	0.00
555590.00	4082030.00	0.00
555715.00	4082030.00	0.00
555840.00	4082030.00	0.00
555965.00	4082030.00	0.00
556090.00	4082030.00	0.00
556215.00	4082030.00	0.00
556340.00	4082030.00	0.00
556465.00	4082030.00	0.00
556590.00	4082030.00	0.00
556715.00	4082030.00	0.00
556840.00	4082030.00	0.00
556965.00	4082030.00	0.00
557090.00	4082030.00	0.00
557215.00	4082030.00	0.00
557340.00	4082030.00	0.00
557465.00	4082030.00	0.00
557590.00	4082030.00	0.00
557715.00	4082030.00	0.00
557840.00	4082030.00	0.00
557965.00	4082030.00	0.00
558090.00	4082030.00	0.00
558215.00	4082030.00	0.00
558340.00	4082030.00	0.00
558465.00	4082030.00	0.00
558590.00	4082030.00	0.00
558715.00	4082030.00	0.00

558840.00	4082030.00	0.00
558965.00	4082030.00	9.81
559090.00	4082030.00	9.81
559215.00	4082030.00	9.81
559340.00	4082030.00	9.81
559465.00	4082030.00	9.81
559590.00	4082030.00	9.81
559715.00	4082030.00	9.81
559840.00	4082030.00	9.81
559965.00	4082030.00	9.81
560090.00	4082030.00	9.81
560215.00	4082030.00	9.81
560340.00	4082030.00	9.81
560465.00	4082030.00	0.00
560590.00	4082030.00	0.00
560715.00	4082030.00	0.00
560840.00	4082030.00	0.00
560965.00	4082030.00	0.00
561090.00	4082030.00	0.00
561215.00	4082030.00	0.00
561340.00	4082030.00	0.00
561465.00	4082030.00	0.00
561590.00	4082030.00	0.00
561715.00	4082030.00	0.00
561840.00	4082030.00	0.00
561965.00	4082030.00	0.00
562090.00	4082030.00	0.00
562215.00	4082030.00	0.00
562340.00	4082030.00	0.00
562465.00	4082030.00	0.00
562590.00	4082030.00	0.00
562715.00	4082030.00	0.00
562840.00	4082030.00	0.00
562965.00	4082030.00	0.00
563090.00	4082030.00	0.00
563215.00	4082030.00	0.00

Input file *digit.dat*

Following are lines 1 – 37 from the input file. These lines define the first polygon in the file. This is the only polygon that extends as far north as X UTM coordinate 4082030. An excerpt from the output file showing all values with this X UTM coordinate is provided below for comparison. The routine should assign a recharge value (highlighted) of 5.77 mm/yr to all cells with centers that fall within this polygon.

5.77 36

555964, 4.09161E+006

555964, 4.09132E+006

555964, 4.09105E+006

555964, 4.09076E+006

555701, 4.09053E+006

555656, 4.0902E+006

555416, 4.08994E+006

555679, 4.08964E+006

555656, 4.08938E+006

555679, 4.0891E+006

555964, 4.08883E+006

555964, 4.08853E+006

555964, 4.08825E+006

555941, 4.08797E+006

555964, 4.08769E+006

555964, 4.08743E+006

555679, 4.08715E+006

555679, 4.08687E+006

555679, 4.08659E+006

555964, 4.0863E+006

555964, 4.08602E+006

555679, 4.08574E+006

555679, 4.08548E+006

555679, 4.0852E+006

```
555679, 4.08492E+006

555679, 4.08464E+006

555679, 4.08436E+006

555679, 4.08407E+006

555679, 4.08381E+006

555394, 4.08353E+006

555394, 4.08325E+006

555394, 4.08297E+006

555379, 4.08271E+006

555394, 4.08243E+006

555379, 4.08215E+006

555394, 4.08185E+006
```

Output file rech_distr_stream.dat

Following are lines 3875- 3911. These lines contain all entries in the file with an X UTM coordinate of 4082030 m. Note that this file only contains values for cells with non-zero recharge values. Four cells (highlighted) have been assigned the correct value of 5.77 mm/year. The other entries in this excerpt match the non-zero entries in the excerpt of file *rech_distr.dat* in Attachment II.

545465.00	4082030.00	5.72
545590.00	4082030.00	5.72
545715.00	4082030.00	5.72
545840.00	4082030.00	5.72
545965.00	4082030.00	5.72
546090.00	4082030.00	5.72
546215.00	4082030.00	5.72
546340.00	4082030.00	5.72
546465.00	4082030.00	5.72
554965.00	4082030.00	5.77
555090.00	4082030.00	5.77
555215.00	4082030.00	5.77
555340.00	4082030.00	5.77
558965.00	4082030.00	9.81
559090.00	4082030.00	9.81
559215.00	4082030.00	9.81
559340.00	4082030.00	9.81

559465.00	4082030.00	9.81
559590.00	4082030.00	9.81
559715.00	4082030.00	9.81
559840.00	4082030.00	9.81
559965.00	4082030.00	9.81
560090.00	4082030.00	9.81
560215.00	4082030.00	9.81
560340.00	4082030.00	9.81

CODE LISTING

```
program xreadreaches
C
C     This program reads approximate nodal coordinates digitized
C     from map of stream reaches.  It finds the nearest node in the
C     125 m recharge map and changes the infiltration value to
C     the value specified in the first line of the digitized
C     coordinate file.

      dimension x(83054),y(83054),rech(83054)

      open(file='digit.dat',unit=10,status='old')
      open(file='rech_distr.dat',unit=11,status='old')
      open(file='rech_distr_stream.dat',unit=12,status='new')

C     Read in values of distributed recharge on 125 m mesh.
C     This file contains "hole" where UZ flow model exists.

      do 100 i=1,83054
        read(11,*) x(i),y(i),rech(i)
  100 continue

C     Read in approximate digitized locations of nodes (on 250 m
C     centers) of the Fortymile Canyon reach, Upper Jackass Flats
C     reach and the Lower Jackass Flats reach of Fortymile Wash.
C     Loop through locations on 125 m grid and find nodes within
C     250 m of digitized channel locations.  Assign recharge (mm/year)
C     associated with that reach to the 125 m grid node.

      do 400 k=1,3

      read(10,*)rech_new,ndig

      do 300 j=1,ndig
        read(10,*) xx,yy
        distmin=5000.
        do 200 i=1,83054
          xadj=xx-250.

          dist=sqrt((xadj-x(i))*(xadj-x(i))+(yy-y(i))*
     &     (yy-y(i)))
```

```
          if(dist.lt.250.) then
            rech(i)=rech_new
          endif
  200   continue
  300 continue
  400 continue

C     Read in approximate digitized locations of nodes (on 250 m
C     centers) of the Amargosa Desert reach of Fortymile Wash.
C     Loop through locations on 125 m grid and find nodes within
C     500 m of digitized channel locations.  Assign recharge (mm/year)
C     associated with that reach to the 125 m grid node.

      read(10,*)rech_new,ndig

      do 310 j=1,ndig
        read(10,*) xx,yy
        distmin=5000.
        do 210 i=1,83054
          xadj=xx

          dist=sqrt((xadj-x(i))*(xadj-x(i))+(yy-y(i))*
     &     (yy-y(i)))
          if(dist.lt.500.) then
            rech(i)=rech_new
          endif
  210   continue
  310 continue

C     Write out locations and recharge value (mm/year) for all
C     125 m grid nodes that have nonzero recharge (for distributed
C     recharge and focused recharge along Fortymile Wash.

      do 40 i=1,83054
        if(rech(i).ne.0.) then
          write(12,99) x(i),y(i),rech(i)
        endif
   40 continue


   99 format(3f15.2)

C
      end
```

ATTACHMENT IV

DOCUMENTATION OF FOUR xwrite_flow_new.f VERSION 1.0-XXX FORTRAN ROUTINES

ROUTINE IDENTIFICATION

The routine *xwrite_flow_new.f* is actually a group of four nearly identical routines that differ by only the three lines of code that control the grid size of the output. The version designator incorporates the grid size in meters. The four versions are; 1.0-1000, 1.0-500, 1.0-250, and 1.0-125 for the 1000 m, 500 m, 250 m, and 125 m grid sizes respectively. These FORTRAN routines were compiled using the FORTRAN 77 compiler on a Sun workstation.

INPUT AND OUTPUT FILES

The input for all versions of *xwrite_flow_new.f* is *rech_all_new.txt.* This file contains the data from the Excel spreadsheet file *rech_all_new.xls* that has been saved in the text file *rech_all_new.txt*, which has the header lines removed. The output of all versions of the routine *xwrite_flow_new.f* is in a format suitable for input to the "flow" macro of FEHM for specified groundwater mass flux (kg/s). The resolution of the grid nodes in the output from the *xwrite_flow_new.f* routine is specified within the routine. The output assumes that grid nodes are numbered sequentially from the southwest corner of the SZ site-scale model domain, moving from west to east and south to north. Output files were generated for 1000 m, 500 m, 250 m, and 125 m nodal resolutions in the files *wt_flow_1000.dat*, *wt_flow_500.dat*, *wt_flow_250.dat*, and *wt_flow_125.dat*, respectively.

DESCRIPTION

All versions of this routine begin by reading in the coordinates and value of flux for all nodes from the input file *rech_all_new.txt* that includes information from *rech_distr_stream.dat* (see Attachment III) and from the UZ site-scale flow model (see section 6.1.4 of this AMR). The total flux for the output grid as defined by the number of nodes in the x direction (nx), number of nodes in the y direction (ny) and the grid spacing (delx), is calculated by finding the nearest node in the output grid for each node on the input grid, and summing the contribution to each output grid node. This is accomplished in the loops ending on line 300. The resolution of the output grid was changed to correspond to various resolution grids used in the SZ site-scale flow model by changing the values of nx, ny, and delx and recompiling the routine. Finally, the routine writes out the values of flux in the format required by the "flow" macro in the FEHM simulator for each node in the loop ending on line 40.

VALIDATION

As can be seen from the above description, all versions of the routine xwrite_flow_new.f perform two main functions: 1) find the closest node in the output grid to each entry in the input file and assign the flux associated with the entry to the identified closest node, and 2) sum the values of flux assigned to each node in the output grid. This second task is necessary because a node in the output grid can be the node closest to multiple entries in the input file. In addition, all versions calculate the node number of each node in the output grid and write this number and the associated total flux in a format that can be read as input to the FEHM code. Validation will be by inspection of input and output files and hand calculation to ensure that locating the nearest node in the output grid and summing of flux are occurring correctly. A truncated input file with only two entries will be used so that the results can be confirmed by inspection and hand calculation. The actual input file has 13,489 entries. The concept of a range of validation is not applicable to these routines. The routines all read a single specified input file, perform the formatting function and the grid size change/summing function described above, and write to one specified output file. This can be confirmed by inspection of the code, which is provided in this attachment. The routine is valid for all values on the specified input file.

Input file rech_all_new.txt (truncated)

The truncated input file was created as follows. First line 12,405 of the full input file was copied to the truncated input file. This line was selected because it is at the center of the western-most grid cell containing distributed recharge (Figure 6.1.3-2). It is located 5250 m east and 750 m south of the northwest corner of the grids. Second, an artificial entry was created that varies from line 12,405 only in that the coordinates of the original entry were shifted by 1 meter to the south and west. This provides a second value of recharge to be summed at the same node on the out put grid.

```
538590.0    4091030.0   15625.00    5.280        0.002609562
538589.0    4091029.0   15625.00    5.280        0.002609562
```

Output file wt_flow_125.dat

Each of the grids contains a node in the northwest corner (i.e. at the minimum value of X UTM and the maximum value of Y UTM). The offset of the first entry in the input file (5250 m east and 750 m south) is divisible by the 125 m spacing of this grid. It is clear that a node of the output grid will be located exactly at the location of the input entry. Also the second entry, located only about 1.4 m from the first, will have that same node as the closest on the output grid. Therefore, the correct result will be an output file containing the same location as the first entry of the input file, but with a flux twice the value of that entry.

However the output file gives locations by node number rather than position coordinates. The 125 m output grid has 241 columns and 361 rows. Column numbers increase to the east and row numbers increase from the south. By inspection of the offset from the northwest corner, it is clear that the correct node will be in column 43 and row 355. The number of this node can be calculated by hand as :

(row number –1) number columns + column number

or

(355 – 1) 241 + 43 = 85357

Consequently the correct result is a single entry in the output file with node number 85357 and flux equal to two times 0.002609562.

The entire output file follows. The node number is repeated as the first and second columns of the output entry and the flux is the fourth column, as high lighted. To match FEHM input convention, this routine reverses the sign on the flux value.

```
 85357 85357     1 -0.5219E-02      1.00      0.00
```

Output file wt_flow_250.dat

The same reasoning for the location of the nearest node in the 250 m grid holds. The node at the same location as the input entry will be in column 22, row 178. There are 121 columns and 181 rows in this grid. Consequently the correct node number is determined by the hand calculation:

$$(178 - 1)\ 121 + 22 = 21439$$

The correct result is a single entry in the output file with node number 85357 and flux equal to the negative of two times 0.002609562. The entire output file follows.

```
 21439 21439     1 -0.5219E-02      1.00      0.00
```

Output file wt_flow_500.dat

The validation of this version differs in that the offset of the location in the input file is not divisible by 500m. By inspection the closest node in the output grid will have an offset from the northwest corner of 5000 m east and 1000 m south. This node is in column 11, row 89. There are 61 columns and 91 rows in this grid. Consequently the correct node number is determined by the hand calculation:

$$(89 - 1)\ 61 + 11 = 5379$$

The correct result is a single entry in the output file with node number 5379 and flux equal to the negative of two times 0.002609562. The entire output file follows.

```
  5379  5379     1 -0.5219E-02      1.00      0.00
```

Output file wt_flow_1000.dat

The closest point on the 1000 m grid is the same as that on the 500m grid. This node is in column 6, row 45. There are 31 columns and 46 rows in this grid. Consequently the correct node number is determined by the hand calculation:

$$(45 - 1)\ 31 + 6 = 1370$$

The correct result is a single entry in the output file with node number 1370 and flux equal to the negative of two times 0.002609562. The entire output file follows.

```
  1370  1370     1 -0.5219E-02      1.00      0.00
```

CODE LISTING FOR VERSION 1.0-1000

```
program xwrite_flow_new
C
C     This program reads in the file containing the spatial distribution
C     of estimated recharge which combines distributed recharge, focused
C     recharge, and recharge from the area of the UZ site-scale model.
C     This program also loops through a regular grid and sums up the
C     groundwater mass flux (kg/s) for each grid node.  Note that the
C     grid node spacing is defined by the delx parameter below and the
C     number of nodes in the x and y directions by the parameters nx
C     and ny.  To generate output at different nodal spacings the values
C     of delx, nx, and ny must be changed accordingly and the code must
C     be recompiled.  The output file from this routine is in the
C     format required by the "flow" macro in FEHM for specified flux.
C     The node numbering in the output file assumes that nodes are
C     numbered sequentially from the southwest corner of the grid,
C     begining with node number 1 and cycling west to east and south
C     to north.

      dimension totflux(100000)

      open(file='rech_all_new.txt',unit=10,status='old')
      open(file='wt_flow.dat',unit=12,status='new')

      xmin=533340.
      xmax=563340.
      ymin=4046780.
      ymax=4091780.

      delx=1000.
      nx=31
      ny=46

      do 300 j=1,13489
        read(10,*) xx,yy,stuff1,stuff2,flux
        distmin=5000.
        do 200 i=2,ny-1
          do 200 ii=2,nx-1
          x=(ii-1)*delx+xmin
          y=(i-1)*delx+ymin
          nnode=(i-1)*nx+ii

          dist=sqrt((xx-x)*(xx-x)+(yy-y)*
     &     (yy-y))
          if(dist.lt.distmin) then
            distmin=dist
            imin=nnode
          endif
  200   continue
        totflux(imin)=totflux(imin)+flux

  300 continue
```

```
      do 40 j=2,ny-1
        do 40 i=2,nx-1
        nn=((j-1)*nx)+i
        if(totflux(nn).ne.0.) then
          write(12,99) nn,nn,1,-1*totflux(nn),1.,0.
        endif
   40 continue


   99 format(3i6,e12.4,2f10.2)

c
      end
```

CODE LISTING FOR VERSION 1.0-500

```
program xwrite_flow_new
c
c     This program reads in the file containing the spatial distribution
c     of estimated recharge which combines distributed recharge, focused
c     recharge, and recharge from the area of the UZ site-scale model.
c     This program also loops through a regular grid and sums up the
c     groundwater mass flux (kg/s) for each grid node.  Note that the
c     grid node spacing is defined by the delx parameter below and the
c     number of nodes in the x and y directions by the parameters nx
c     and ny.  To generate output at different nodal spacings the values
c     of delx, nx, and ny must be changed accordingly and the code must
c     be recompiled.  The output file from this routine is in the
c     format required by the "flow" macro in FEHM for specified flux.
c     The node numbering in the output file assumes that nodes are
c     numbered sequentially from the southwest corner of the grid,
c     begining with node number 1 and cycling west to east and south
c     to north.

      dimension totflux(100000)

      open(file='rech_all_new.txt',unit=10,status='old')
      open(file='wt_flow.dat',unit=12,status='new')

      xmin=533340.
      xmax=563340.
      ymin=4046780.
      ymax=4091780.

      delx=500.
      nx=61
      ny=91

      do 300 j=1,13489
        read(10,*) xx,yy,stuff1,stuff2,flux
        distmin=5000.
        do 200 i=2,ny-1
          do 200 ii=2,nx-1
```

```
          x=(ii-1)*delx+xmin
          y=(i-1)*delx+ymin
          nnode=(i-1)*nx+ii

          dist=sqrt((xx-x)*(xx-x)+(yy-y)*
     &     (yy-y))
          if(dist.lt.distmin) then
            distmin=dist
            imin=nnode
          endif
  200   continue
        totflux(imin)=totflux(imin)+flux

  300 continue


      do 40 j=2,ny-1
        do 40 i=2,nx-1
        nn=((j-1)*nx)+i
        if(totflux(nn).ne.0.) then
          write(12,99) nn,nn,1,-1*totflux(nn),1.,0.
        endif
   40 continue


   99 format(3i6,e12.4,2f10.2)

C
      end
```

CODE LISTING FOR VERSION 1.0-250

```
program xwrite_flow_new
C
C     This program reads in the file containing the spatial distribution
C     of estimated recharge which combines distributed recharge, focused
C     recharge, and recharge from the area of the UZ site-scale model.
C     This program also loops through a regular grid and sums up the
C     groundwater mass flux (kg/s) for each grid node.  Note that the
C     grid node spacing is defined by the delx parameter below and the
C     number of nodes in the x and y directions by the parameters nx
C     and ny.  To generate output at different nodal spacings the values
C     of delx, nx, and ny must be changed accordingly and the code must
C     be recompiled.  The output file from this routine is in the
C     format required by the "flow" macro in FEHM for specified flux.
C     The node numbering in the output file assumes that nodes are
C     numbered sequentially from the southwest corner of the grid,
C     begining with node number 1 and cycling west to east and south
C     to north.

      dimension totflux(100000)

      open(file='rech_all_new.txt',unit=10,status='old')
```

```
      open(file='wt_flow.dat',unit=12,status='new')

      xmin=533340.
      xmax=563340.
      ymin=4046780.
      ymax=4091780.

      delx=250.
      nx=121
      ny=181

      do 300 j=1,13489
        read(10,*) xx,yy,stuff1,stuff2,flux
        distmin=5000.
        do 200 i=2,ny-1
          do 200 ii=2,nx-1
          x=(ii-1)*delx+xmin
          y=(i-1)*delx+ymin
          nnode=(i-1)*nx+ii

          dist=sqrt((xx-x)*(xx-x)+(yy-y)*
     &     (yy-y))
          if(dist.lt.distmin) then
            distmin=dist
            imin=nnode
          endif
  200   continue
        totflux(imin)=totflux(imin)+flux

  300 continue


      do 40 j=2,ny-1
        do 40 i=2,nx-1
        nn=((j-1)*nx)+i
        if(totflux(nn).ne.0.) then
          write(12,99) nn,nn,1,-1*totflux(nn),1.,0.
        endif
   40 continue


   99 format(3i6,e12.4,2f10.2)

C
      end
```

CODE LISTING FOR VERSION 1.0-125

```
program xwrite_flow_new
C
C     This program reads in the file containing the spatial distribution
C     of estimated recharge which combines distributed recharge, focused
C     recharge, and recharge from the area of the UZ site-scale model.
C     This program also loops through a regular grid and sums up the
```

```
C     groundwater mass flux (kg/s) for each grid node.  Note that the
C     grid node spacing is defined by the delx parameter below and the
C     number of nodes in the x and y directions by the parameters nx
C     and ny.  To generate output at different nodal spacings the values
C     of delx, nx, and ny must be changed accordingly and the code must
C     be recompiled.  The output file from this routine is in the
C     format required by the "flow" macro in FEHM for specified flux.
C     The node numbering in the output file assumes that nodes are
C     numbered sequentially from the southwest corner of the grid,
C     begining with node number 1 and cycling west to east and south
C     to north.

      dimension totflux(100000)

      open(file='rech_all_new.txt',unit=10,status='old')
      open(file='wt_flow.dat',unit=12,status='new')

      xmin=533340.
      xmax=563340.
      ymin=4046780.
      ymax=4091780.

      delx=125.
      nx=241
      ny=361

      do 300 j=1,13489
        read(10,*) xx,yy,stuff1,stuff2,flux
        distmin=5000.
        do 200 i=2,ny-1
          do 200 ii=2,nx-1
          x=(ii-1)*delx+xmin
          y=(i-1)*delx+ymin
          nnode=(i-1)*nx+ii

          dist=sqrt((xx-x)*(xx-x)+(yy-y)*
     &     (yy-y))
          if(dist.lt.distmin) then
            distmin=dist
            imin=nnode
          endif
  200   continue
        totflux(imin)=totflux(imin)+flux

  300 continue


      do 40 j=2,ny-1
        do 40 i=2,nx-1
        nn=((j-1)*nx)+i
        if(totflux(nn).ne.0.) then
          write(12,99) nn,nn,1,-1*totflux(nn),1.,0.
        endif
   40 continue
```

```
   99 format(3i6,e12.4,2f10.2)
c
      end
```

ATTACHMENT V

DOCUMENTATION OF THE extract.f VERSION 1.0 FORTRAN ROUTINE

ROUTINE IDENTIFICATION

The routine *extract.f* is at version 1.0. This is a FORTRAN routine that was compiled using the FORTRAN 77 compiler on a Sun workstation.

INPUT AND OUTPUT FILES

The input file for *extract.f* v. 1.0 is *cbcf.new* which is an unformatted output file from MODFLOWP containing flow terms. The routine writes the flow terms along each boundary of the SZ site-scale model to four separate output files named *west_bdy*, *east_bdy*, *north_bdy*, and *south_bdy*. A fifth output file named *headers* is also written. The *headers* file contains an echo of the header line for each of the four data arrays.

DESCRIPTION

This routine first reads a header line (first read statement) and then a block of data (second read statement). This first block of data is not used. This process is repeated three times (next six read statements). The final three blocks of data contain the values of fluxes across the right, front, and lower face of each model cell, respectively.

Values of flux across the right faces are written to output files along column 62 (loop ending at statement number 20), and along column 82 (loop ending at statement number 40). Values of flux across the front faces are written to output files along row 65 (loop ending at statement number 60), and along row 95 (loop ending at statement number 80). The sign of flux is reversed in loops ending in statements 40 and 60 so that, in the output files, flux into the model domain has a positive sign.

VALIDATION

As can be seen from the above description, the routine *extract.f* performs three functions. It reads flux terms from a binary input file, writes values along selected rows and columns that correspond to the boundaries of the site-scale model, and performs a sign reversal function for the east and south boundaries so that all lateral flows into the model domain are positive and all lateral flows out of the model domain are negative. Validation by inspecting excerpts of input and output files is not possible because the input file is binary. Any routine used to generate or display a non-binary version of the input file would be essentially the same as this routine. Instead validation was achieved by two methods. First, by detailed inspection of the source code to ensure that information from the correct rows and columns was being extracted from the input file, and second by checking that the distribution of flux values corresponds correctly to known rock properties during calibration of the site-scale model. Both of these methods demonstrated that the code was performing correctly.

The concept of a range of validation is not applicable to this routine. The routine reads a single specified input file, performs the extraction and sign reversal functions described above, and writes to the four specified boundary output files, plus the header file. This can be confirmed by inspection of the code, which is provided in this attachment. The routine is valid for all values on the input file.

CODE LISTING

```
      program extract
c
c     T. Corbet
c     5 May 1999
c
c     This program extracts cell-by-cell flow values from a
c     Modflowp binary output file (cbcf.new).  This output
c     file was generated by running the executable and input
c     files contained in the Technical Data Management
c     System DTN GS960808312144.003 for the USGS 1997
c     flow model of the Death Valley regional ground-water
c     flow system.  The flow terms extracted are for the
c     latteral boundaries of the site-scale model. The
c     following values are extracted:
c       west boundary:  east (right) face of column 62 for rows 66-95
c       east boundary: east (right) face of column 82 for rows 66-95
c       north boundary: south (front) face of row 65 for columns 63-82
c       south boundary: south (front) face of row 95 for columns 63-82
c
c     The Modflowp output is written in arrays dimensioned
c     (number columns, number rows, number layers) or
c     (153,163,3).  Four arrarys are in the file.  The first
c     records flows due to constant head nodes and is read
c     but not written by this program.  The next three arrays contain
c     flows across the right (xcomp), front (ycomp), and lower (zcomp)
c     faces of each model cell,respectively. Values for flow
c     across the lower face are also read but not written.
c
c      Values are for volumetric flows with units of cubic meters per
day.
c
c     This program reads the unformatted file cbcf.new and
c     writes to formatted files west_bdy, east_bdy, north_bdy,
c     south_bdy, and headers.  The headers file contains an
c     echo of the header line for each of the four data
c     arrays.
c
c     Modflowp writes flows such that positive values are in
c     the direction of increasing index value, i.e positive
c     to the east (right), south (front), and downward.
c     This progarm reverses the sign for flows on the east
c     and south boundaries so that flows into the
c     site-scale domain are positive inward on all
c     boundaries.
c
      character*4 text
      character*4 textx
```

```
      character*4 texty
      character*4 textz
c
      dimension text(4)
      dimension textx(4)
      dimension texty(4)
      dimension textz(4)
      dimension dummy(153,163,3)
      dimension xcomp(153,163,3),ycomp(153,163,3),zcomp(153,163,3)
c
      open (10,file='cbcf.new',status='old',form='unformatted')
      open (11,file='west_bdy',status='unknown')
      open (12,file='east_bdy',status='unknown')
      open (13,file='north_bdy',status='unknown')
      open (14,file='south_bdy',status='unknown')
      open (15,file='headers',status='unknown')
c
c     read Modflowp cell-by-cell flow terms from binary file
      read (10) kstp,kper,text,ncol,nrow,nlay
      read (10) dummy
      read (10) kstpx,kperx,textx,ncolx,nrowx,nlayx
      read (10) xcomp
      read (10) kstpy,kpery,texty,ncoly,nrowy,nlayy
      read (10) ycomp
      read (10) kstpz,kperz,textz,ncolz,nrowz,nlayz
      read (10) zcomp
c
c     echo header information
      write (15,*) kstp,kper,text,ncol,nrow,nlay
      write (15,*) kstpx,kperx,textx,ncolx,nrowx,nlayx
      write (15,*) kstpy,kpery,texty,ncoly,nrowy,nlayy
      write (15,*) kstpz,kperz,textz,ncolz,nrowz,nlayz
c
c     write new headers
      write (11,*) ' col  row     layer1     layer2      layer3'
      write (12,*) ' col  row     layer1     layer2      layer3'
      write (13,*) ' col  row     layer1     layer2      layer3'
      write (14,*) ' col  row     layer1     layer2      layer3'
c
c     extract flows on west boundary
      i=62
      do 20 j=66,95
        write (11,1) i,j,(xcomp(i,j,k), k=1,3)
   20 continue
c
c     extract flows on east boundary, reverse sign
      i=82
      do 40 j=66,95
        write (12,1) i,j,(-xcomp(i,j,k), k=1,3)
   40 continue
c
c     extract flows on north boundary
      j=65
      do 60 i=63,82
        write (13,1) i,j,(ycomp(i,j,k), k=1,3)
```

```
   60 continue
c
c     extract flows on south boundary, reverse sign
      j=95
      do 80 i=63,82
        write (14,1) i,j,(-ycomp(i,j,k), k=1,3)
   80 continue
c
    1 format (2i5,3f12.4)
c
      stop
      end
```

ATTACHMENT VI

DOCUMENTATION OF THE Corpscon VERSION 5.11 ROUTINE

ROUTINE IDENTIFICATION

The Corpscon routine used in the AMR is at version 5.11. It is a public domain routine developed by and available through the U. S. Army Corps of Engineers.

DESCRIPTION

The Corpscon Windows-based routine is for performing simple geographical coordinate conversions from state plane coordinates to UTM coordinates. The routine is considered to be exempt software since its only function is to perform coordinate conversions in a manner analogous to a hand calculator performing metric to English conversions. The executable file and supporting files for this routine are contained in the electronic archive for this report in the TDMS (DTN SN9908T0581999.001).

VALIDATION

Though the Corpscon routine is considered exempt, it was deemed prudent to check the accuracy of the routine in the Yucca Mountain area. For the purpose of this AMR, an agreement to within one meter (1.0 m) between the results of Corpscon and published values was considered acceptable. Validation is performed by using the routine to calculate the UTM coordinates for some example locations, given the coordinates in the Nevada State Plane coordinate system. The results are compared to published values of the UTM coordinates for those example locations. The example locations used in the validation are for borehole locations taken from the Yucca Mountain Project Geographical Information database. The coordinates of the boreholes in the Nevada State Plane coordinate system used to validate the Corpscon routine are contained in a table (DTN MO9906GPS98410.000, file *bores2.xls*) and the coordinates of the same boreholes in the UTM system are contained in another table (DOE 1997, Table YMP97-05-04). The results of the validation exercise are shown in Table VI-1.

Table VI-1. Validation Results for the Corpscon Software Routine.

Borehole Identifier	Nevada State Plane Northing (ft) [a]	Nevada State Plane Easting (ft) [a]	UTM Northing (m) [b]	UTM Easting (m) [b]	UTM Northing (m) (Corpscon)	UTM Easting (m) (Corpscon)
WT-10	748771.56	553302.31	4073388.6	545976.0	4073388.8	545976.1
WT-12	739726.69	567011.81	4070647.0	550162.9	4070647.2	550163.1
WT-14	761651.38	575210.19	4077336.5	552638.0	4077336.7	552638.0
WT-15	766117.00	579806.25	4078702.2	554033.6	4078702.4	554033.8

[a] Source: DTN: MO9906GPS98410.000.
[b] Source: DOE 1997, Table YMP97-05-04.

Comparison of the UTM coordinate values from the published source (DOE 1997, Table YMP97-05-04) and from the Corpscon routine indicates a maximum discrepancy of 0.2

m. This degree of accuracy is well within the 1.0 m acceptance criterion and is therefore sufficient for the application of the routine in this analysis.

ATTACHMENT VII

INTERNAL QUALIFICATION OF THE DEATH VALLEY REGIONAL GROUNDWATER FLOW MODEL

EXECUTIVE SUMMARY

This Internal Data Qualification Report uses technical assessment methods to evaluate the appropriateness of unqualified inputs and outputs from the Death Valley regional groundwater flow model (D'Agnese et al. 1997) for use in Analysis/Model Report S0010, *Recharge and Lateral Groundwater Flow Boundary Conditions for the Saturated Zone Site-Scale Flow and Transport Model,* ANL-NBS-MD-000010 (CRWMS M&0 1999b). This qualification report was prepared as an attachment to this document in conformance with AP-3.10Q, Rev. 2, ICN 4, ECN 1, *Analyses and Models.* The Death Valley regional groundwater flow model was prepared by the U.S. Geological Survey and has been published by the U.S. Geological Survey as a Water Resources Investigations Report. Inputs to the regional model were used to identify groundwater recharge across the upper surface of the Yucca Mountain Site Characterization Project's saturated zone site-scale flow and transport model, and outputs from the regional model were used to identify groundwater flow across the lateral boundaries of the site-scale model.

The Data Qualification Team found the Death Valley regional flow model database to be well researched, the model to be appropriately constructed, and the resulting output to provide a reasonable simulation of regional groundwater flow. Several approaches to estimating recharge from precipitation were evaluated by the regional model's authors before deciding on a modification of an empirical relationship developed by Maxey and Eakin (1950). Shortcomings of other, more recent techniques were identified, particularly for application to desert areas where small amounts of recharge were ignored. Within the area of the saturated zone site-scale model, the recharge fluxes from the regional model are consistent with similar magnitude fluxes independently estimated from the unsaturated zone flow model and from focused recharge from Fortymile Wash. The Maxey-Eakin method is widely used and accepted by the technical community and is appropriate for use in the regional model.

The effective residual between actual and simulated heads was determined to be 45 m for most wells in the regional model. The Data Qualification Team considers this overall goodness-of-fit to be not good but acceptable. Because the goodness-of-fit is a measure of the model's accuracy, a degree of uncertainty must be associated with the regional model outputs used to identify lateral flux boundary conditions for the site-scale model. These uncertainties were adequately addressed by using the regional model fluxes not as absolute values but as targets during site-scale model calibration.

The Data Qualification Team has concluded that the Death Valley regional flow model provides a qualified source of data for establishing recharge and lateral flux boundary conditions for the saturated zone site-scale flow and transport model. In accordance with AP-3.10Q, this finding qualifies these data only for their intended uses in this document. The regional model's source DTN GS960808312144.003 will remain unqualified for other uses.

CONTENTS

TABLES

VII-1. INTRODUCTION

VII-1.1 PURPOSE

This Internal Data Qualification Report evaluates the appropriateness of unqualified inputs and outputs from the U.S. Geological Survey (USGS) flow model of the Death Valley regional groundwater system for use in this Analysis/Model Report (AMR), *Recharge and Lateral Groundwater Flow Boundary Conditions for the Saturated Zone Site-Scale Flow and Transport Model,* ANL-NBS-MD-000010, Rev. 00 (CRWMS M&O 1999b). This qualification report also evaluates the methods used in this AMR to develop boundary conditions from the regional modeling results.

The regional model was developed in part to support site-scale modeling for the Yucca Mountain Site Characterization Project (YMP). Inputs to the regional model were used in this AMR to identify groundwater recharge across the upper surface of the site-scale model and outputs from the regional model were used to identify groundwater flow across the lateral boundaries of the site-scale model. This evaluation was performed in accordance with the internal data qualification requirements of AP-3.10Q, Rev. 2, ICN 4, ECN 1, *Analyses and Models.* A limited finding that the regional model is internally qualified means that it is qualified to support the Site Recommendation and may also be used to support the License Application, but only for the uses made in this AMR. The appropriateness and limitations of the data with respect to intended use are addressed in this attachment.

In accordance with Attachment 1 of AP-3.15Q, Rev. 3, *Managing Technical Product Inputs*, it has been determined that the unqualified data evaluated in this attachment are not used in the direct calculation of Principal Factors for postclosure safety or disruptive events. Therefore, in accordance with AP-SIII.2Q, Rev. 0, ICN 3, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*, Section 5.1.1, concurrence by the U.S. Department of Energy Assistant Manager, Office of Project Execution, is not required.

VII-1.2 SCOPE

This attachment was prepared according to the internal data qualification plan presented in Addendum N of the *Technical Work Plan for Saturated Zone Flow and Transport Modeling and Testing* (BSC 2001c). The Internal Data Qualification Plan identifies one data tracking number (DTN GS960808312144.003) containing unqualified, developed hydrogeological data associated with the Death Valley regional groundwater flow model. This DTN is identified in Table VII-1. These data consist of the groundwater flow model and its input database. The model and database are archived in the YMP's Model Warehouse directory *GS960808312144.003/milrep/finalmod/* and can be accessed through the aforementioned DTN. The USGS WRIR 96-4300, *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (D'Agnese et al. 1997), is cited in the Model Warehouse Dataset as providing information on the model.

Table VII-1. Unqualified DTN Considered in this Attachment

DTN	Title
GS960808312144.003	Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California, Using Geoscientific Information Systems.

DTN GS960808312144.003 is unqualified because it contains data collected prior to implementation of a YMP-approved USGS quality assurance program. In addition to the recharge and lateral flow data used in this AMR, the data set contains other information that was not directly used in the AMR and is not within the scope of this qualification activity. This qualification report focuses on the specific data selected to support the saturated zone site-scale groundwater flow model in this AMR. To the extent that only subsets of data within this DTN were used, only those data are evaluated for qualification.

VII-1.3 DATA QUALIFICATION TEAM

Chairperson. The Chairperson for this internal data qualification, Bill Arnold, is the originator of this AMR.

Team Member. The team member for this internal data qualification, Jan Bostelman, is the checker for the ICN to this AMR.

VII-1.4 BACKGROUND

Development of the data from DTN GS960808312144.003 that were used in this AMR is described in USGS WRIR 96-4300, *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California* (D'Agnese et al. 1997). Although the regional groundwater flow model is unqualified because its database does not fully meet the YMP quality assurance requirements, the model construction and review were performed in accordance with YMP quality assurance procedures, the model was developed and reviewed in accordance with USGS policy, and the model results were formally published in a WRIR after receiving the USGS Director's approval (D'Agnese et al. 1997, p. 4).

The domain of the YMP saturated zone site-scale flow and transport model lies entirely within the larger domain of the regional flow model. Three sources of information were used in this AMR to develop estimates of groundwater recharge across the upper surface of the site-scale model. The first of these was the regional model's input database, which contains estimates of recharge across the entire Death Valley region including the area of the site-scale model. The second information source for recharge was the flow across the lower, water table boundary of the YMP unsaturated zone site-scale flow model. The domain of the unsaturated zone site-scale model lies entirely within the larger domain of the saturated zone site-scale model. Within the unsaturated zone model domain, recharge from the unsaturated zone model replaces recharge from the regional model. The third information source was a USGS WRIR that provided an estimate of focused recharge along Fortymile Wash (Savard 1998). Within the area of Fortymile Wash, recharge to the saturated zone site-scale model is equal to the estimated recharge from flow in the wash. Only the first of these data sources, the regional model, is addressed in this attachment. Outflow from the unsaturated zone model is technical product output, and the estimates of recharge from Fortymile Wash have been separately qualified (BSC 2001a).

Output from the regional model was used in this AMR to develop estimates of groundwater flow across the lateral boundaries of the saturated zone site-scale model. The AMR uses a nested model approach, where uncertainties in boundary conditions for the smaller model are reduced by developing them from internal flow patterns calculated within a larger model. The increased precision and accuracy required in a site-specific study, such as at Yucca Mountain, requires fine gridding. To increase computational efficiency, the site model is reduced in size with the consequence that the model boundaries are often not optimally located where groundwater flow conditions are well understood. To increase the accuracy of the assigned boundary conditions, it is common to develop them from a larger, coarser gridded model that allows boundaries to be more optimally located, for example, at groundwater divides. This is the process followed in this AMR by using the regional model to develop boundary conditions for the saturated zone site-scale model.

VII-2. QUALIFICATION APPROACH

VII-2.1 QUALIFICATION METHODS

The regional model is unqualified because its input data are unqualified. The regional hydrologic and geologic data required for the model were collected outside the YMP because no other data were available (D'Agnese et al. 1997, p. 4). However, model construction and review were performed in accordance with accepted YMP quality assurance procedures and USGS policy (D'Agnese et al. 1997, p. 4). In view of these conditions and the essentially unique status of the model in depicting regional groundwater flow, the data were evaluated for their intended use in this AMR by technical assessment.

An evaluation was performed of the appropriateness and accuracy of the methods used by the USGS to develop the regional model inputs and outputs used in this AMR. Technical assessments focused on the methodology used to prepare the model inputs and perform the modeling. The assessments also considered the appropriateness of the model results for the applied uses in this AMR and the accuracy requirements associated with those uses. Because the modeling was performed on a regional basis in an area with unevenly distributed data and complex hydrogeology, the modeling results were expected to be approximate. Such results can be appropriately used so long as consideration is given to limitations on their accuracy, precision, and representativeness for an intended use.

VII-2.2 EVALUATION CRITERIA

Evaluation Criteria: The unqualified data were evaluated for use in this document based on consideration of the following evaluation criteria. These criteria were selected to incorporate the considerations in AP-SIII.2Q, Attachment 2, the applicable qualification process attributes listed in AP-SIII.2Q, Attachment 3, and the data-specific considerations identified in Section VII-3.

1. Are the methods used to develop the Death Valley regional groundwater model reasonable and generally accepted by the technical community?
2. Are the methods used in this AMR to develop boundary conditions from the regional modeling results reasonable and generally accepted by the technical community?
3. Are there more appropriate sources of information for developing the boundary conditions required in this AMR?
4. Are the boundary condition data and their associated uncertainties acceptable for their intended use?

Recommendation Criteria: A recommendation for internal qualification is based on the satisfactory resolution of the evaluation criteria. Although these criteria are considered in determining whether the data are appropriate for their intended use in this AMR, the final conclusions of the Data Qualification Team are based on a preponderance of evidence, and not all of the evaluation criteria may be applied.

VII-3. EVALUATION RESULTS

A technical assessment of the Death Valley regional flow model (D’Agnese et al. 1997) was performed by evaluating the approach used to develop the model's input database, the code selection and model development processes, and the assessment of the model output. Each of these elements of the review is discussed in the following sections of this attachment.

VII-3.1 INPUT DATABASE

The methods used to compile the regional model’s input database were reviewed with special emphasis on the recharge data that were directly used in this AMR. The model was constructed using methods that have been widely accepted within the technical community. The model was based primarily on existing data, accompanied by extensive analysis and synthesis. In compiling the input database, heavy reliance was placed on the USGS National Water Information System (NWIS) database and on formal USGS publications, such as Professional Papers, Water Resources Investigations Reports, and Water Supply Papers. These are considered accepted data sources by the YMP. Accepted data from NWIS include data collected before May 27, 1986, as well as data collected after that date that were not funded through the YMP (Mellington 2001).

Accepted data from formal USGS publications include data collected prior to May 3, 1989, as well as data collected after that date that were not collected as part of site characterization activities for the YMP (Mellington 2000).

New methods of storage, retrieval, and analysis of the complex input database were used that take advantage of recent advances in the technology of Geoscientific Information Systems (GSIS). Emphasis on the input database focused on identifying regional discharge, recharge including interbasin flows, the regional hydrogeologic framework, and the regional patterns of groundwater movement.

VII-3.1.1 Discharge Component

The discharge component of groundwater movement within the region was quantified by measuring spring flows, estimating evapotranspiration by phreatophytes and wet playas, and estimating groundwater pumping (D'Agnese et al. 1997, p. 43). The greatest discharges were found to be evaporation from wet playas and evapotranspiration by plants. Detailed maps of the distributions of specific phreatophytes were developed for this study that included all areas in the region where significant groundwater discharges may occur from vegetation or moist, bare soil. Springs that discharge from the regional groundwater flow system were included in this study (D'Agnese et al. 1997, p. 44). These springs typically emerge from the valley fill and carbonate aquifer at low elevations along the borders or on the floor of some valleys. Groundwater pumping was estimated based on average annual consumptive use for the various commercial, irrigation, mining, and domestic applications in the region. These average rates were assumed based on best estimate information and were believed to offer the best available data on pumping rates (D'Agnese et al. 1997, p. 47).

VII-3.1.2 Recharge Component

The recharge component of groundwater movement was quantified from precipitation data and estimates of interbasin flows at the model boundaries. Because of the uncertainty in some significant elements of the water balance, such as evapotranspiration rates and interbasin flows, the smaller contributions of surface water runoff and irrigation return flows were ignored in the study. Several approaches to estimating recharge from precipitation were evaluated by D'Agnese et al. (1997) before deciding on a modification of an empirical relationship developed by Maxey and Eakin (1950). Shortcomings of other, more recent techniques were discussed, particularly for application to desert areas where small amounts of recharge, such as the amount that probably occurs at Yucca Mountain, were ignored (D'Agnese et al. 1997, p. 51). Although acknowledged to provide an empirical estimate, the Maxey-Eakin method is widely used and accepted by the technical community and was also used in preparing the YMP AMR, *Simulation of Net Infiltration for Modern and Potential Future Climates* (USGS 2000).

The Maxey-Eakin method was modified in the regional model to make it more sensitive to the four critical potential recharge indicators within the region: altitude, slope-aspect, relative rock and soil permeability, and vegetation (D'Agnese et al. 1997, p. 52).

Regional maps were prepared for each of these indicators and the recharge potential for each area was classified on a six-point scale. The four maps were then overlaid to produce a single map that combined the recharge ratings and a final recharge database, reclassified into six zones, was prepared. As with the Maxey-Eakin method, these recharge potential classes were assigned distinctive percentages of mean annual precipitation that are expected to contribute to recharge. Within the study area, these percentages ranged from zero in areas of no (or very low) recharge potential to 30 percent in areas of highest potential.

The accuracy and suitability of the refined Maxey-Eakin method were evaluated by D'Agnese et al. (1997, p. 55). The locations of low-temperature springs (indicative of shallow groundwater flow) were compared with uphill area recharge potentials. Areas uphill from low temperature springs, regardless of altitude, were found to coincide with predicted regional recharge areas. Also, because of the vegetation constraints imposed, all predicted recharge areas were restricted to zones classified as either coniferous forests, pinon-juniper woodlands, or mixed transition shrublands. The suitability of the method was also evaluated by comparing total recharge volumes in individual hydrographic basins with those estimated in previous investigations. Generally higher rates were estimated for the regional model in higher elevation basins and generally lower rates were estimated in the central and southern parts of the region. Overall, the D'Agnese et al. (1997, p. 55) estimates were 30 percent higher than if the unmodified Maxey-Eakin method had been used. Reasons forwarded for this difference include a slightly higher estimated average annual rainfall, greater recharge potential in high elevation areas than previously estimated, and a reduced accuracy of the Maxey-Eakin method outside the area of the northern Great Basin where the empirical relationships of Maxey and Eakin (1950) were developed (D'Agnese et al. 1997, p. 55). D'Agnese et al. (1997, p. 55) conclude that while the prepared maps may not exactly describe recharge locations on a local scale, they appear to be appropriate for delineating large-scale zones of recharge. They note, however, that even with the better defined potential recharge areas, the rates are still based on empirical estimates rather than actual measurements and reflect a significant unknown flux in the regional modeling (D'Agnese et al. 1997, p. 55).

The recharge fluxes from the regional model are consistent with similar magnitude fluxes independently estimated from the unsaturated zone site-scale flow model and from the focused recharge from Fortymile Wash. This consistency is illustrated in Figure 6.1.3-2 of this AMR, which shows recharge rates from all three sources on the same map. The correlation between topography and recharge is similar in the regional and the unsaturated zone models, both of which show decreasing recharge with decreasing elevations to the south. The magnitudes of recharge are also similar, although the range of values is larger at the more-refined site- scale. Figure 6.1.2-1 shows localized regions within the domain of the UZ site-scale model in which simulated recharge exceeds 20 mm/year. Simulated values approach 100 mm/year in several model cells and the maximum value is 729 mm/year.

The more refined site-scale and Fortymile Wash analyses supplement the coarser, regional-scale analysis. The regional model focuses on broad topographical and vegetal considerations. It does not account for the refined topography of Yucca Mountain captured in the site-scale model, nor does it specifically account for localized recharge from runoff in Fortymile Wash. Although residual uncertainties affect all three sources of recharge data, the total recharge mass flux of about 49 kg/s into the saturated zone site-scale flow and transport model is small compared to the total mass flux of about 870 kg/s calculated for the lateral boundaries of the model. Residual uncertainties in the recharge will therefore have relatively little impact on the overall modeling results. The recharge data developed from the regional model input files were directly used in the saturated zone site-scale flow and transport model but were redistributed prior to use to avoid artificially high heads in areas of high recharge rates (CRWMS M&O 2000, Section 6.1.4). Beneath the potential repository site, where vertical seepage may be an important transport mechanism for migrating radionuclides, the recharge is comprehensively defined and integrated into the upper boundary of the saturated zone site-scale flow and transport model.

Although lateral flow is expected across all boundaries of the saturated zone site-scale flow model, most lateral boundaries of the regional model are located where no groundwater flow occurs. Most of these boundaries result from the presence of low-permeability bedrock. Interbasin flows occur where the permeability of the bedrock is high enough to allow significant groundwater flow and where a hydraulic gradient exists across the boundary. Significant inflows may occur into the modeled region at ten different locations, most of which have little of the data needed to estimate flow rates (D'Agnese et al. 1997, p. 59). No significant discharge from the region is thought to occur through interbasin flow. Although flows were estimated for each of these areas based on available information and the uncertainties in these estimates are high (D'Agnese et al. 1997, p. 71), the recharge from these sources is small compared to infiltration from precipitation and the effects of boundary condition uncertainties on the regional model are therefore also assessed to be small. The practice of determining boundary conditions for a smaller, nested model from the internal flow patterns of a larger model with better-defined boundary conditions is appropriately used to reduce uncertainty in the smaller model.

VII-3.1.3 Regional Hydrogeologic Framework

The regional hydrogeologic framework accounts for the influences of stratigraphy and geologic structure on groundwater movement, the hydrologic properties of the hydrogeologic units, and the regional potentiometric surface. The framework is a geometrical configuration of the regional hydrogeologic structure designed to support the regional model. A regional digital elevation model was combined with geologic maps to provide a three-dimensional series of points locating the outcrops of individual geologic formations, geologic cross sections and borehole lithologic logs. The surface and subsurface data were then interpolated to define the tops of hydrogeologic units

(D'Agnese et al. 1997, p. 33). Minor faults and other structures that were not considered to influence regional hydrology were not generally included in the model.

The distribution of hydraulic conductivity values was defined as part of the hydrogeologic framework. The conductivities initially assigned to each model cell were varied by rock type, depth, degree of faulting, degree of weathering, grain size, and degree of welding, as appropriate to the rock type (D'Agnese et al. 1997, p. 42).

A new potentiometric surface was constructed for this study using regional water level data from wells, boundaries of perennial marshes and ponds, topographic elevations, regional spring locations, the locations of recharge and discharge areas, and hydrogeologic information (D'Agnese et al. 1997, p. 56). In this sparsely-populated area, well data are concentrated in alluvial valleys and data are generally lacking in consolidated bedrock. Supplemental information was developed from other sources such as the elevations of perennial marshes and ponds, and the elevations of regional springs and playa discharge areas. Manual adjustments to the potentiometric surface were made to reflect the steeper hydraulic gradients in lower permeability rocks and the development of groundwater highs in regional recharge areas.

GSIS methods were used to represent the considerable array of three-dimensional data used in constructing the regional model. The GSIS is a relatively new, three-dimensional extension of the traditional two-dimensional Geographic Information System (GIS), and its development and application to the Death Valley regional modeling is extensively described by D'Agnese et al. (1997, pp. 22 through 33).

VII-3.1.4 Regional Groundwater Movement

For purposes of discussing groundwater movement, the regional system was divided into three subregional flow systems. Conceptual descriptions of groundwater movement in each of these systems are presented by D'Agnese et al. (1997, p. 62) and are used to help evaluate the modeling results. Compilations of inflows and outflows from these subregions were used by D'Agnese et al. (1997, p. 71) to prepare an estimated water budget for the region. D'Agnese et al. (1997, p. 71) are correct in stating that, because of the uncertainties involved, water budgets generally provide only gross indications of the accuracy of the major flow components. Based only on the aforementioned estimates of inflows and outflows and not on modeling results, regional outflows (about 374,000 m^3/day) were found to exceed regional inflows (about 344,000 m^3/day) by about 30,000 m^3/day (D'Agnese et al. 1997, Table 13). Not included in the water budget is an estimated 89,000 m^3/day groundwater pumping which is represented as a change in storage. However, because the regional model is steady-state, changes in storage cannot be accommodated because they represent nonequilibrium conditions (D'Agnese et al. 1997, p. 72). The pumping was treated as a groundwater discharge in the final modeling.

VII-3.1.5 Discussion

The regional model's input database was diligently compiled using appropriate methodologies that take into account the difficulties of handling large amounts of data for a large and complex region, as well as the uncertainties that are present in much of the developed information. The care taken in developing the regional hydrogeologic framework was appreciated, as was the use of the new GSIS techniques for managing the data.

Discharges from evapotranspiration, playa evaporation, spring flow, and pumping were well researched, particularly the evapotranspiration component which constituted the largest single source of discharge. Recharge was dominated by infiltration of precipitation, which remained somewhat uncertain despite the large effort put into its quantification. The effort expended by D'Agnese et al. (1997) to corroborate the various model inputs lent credibility to their results. Given that the average estimated regional recharge from infiltration of 312,300 m^3/day (D'Agnese et al. 1997, Table 13) amounts to over 90 percent of the total regional inflow, it is not surprising that the model should be quite sensitive to this parameter (D'Agnese et al. 1997, Figure 43). D'Agnese et al. (1997, p. 55) make the statement that the "...recharge rates are still based on empirical estimates rather than actual measured rates and reflect a significant unknown flux in modeling this region." This statement is overly cautious. While the uncertainty associated with this parameter is certainly high, its value is far from being *unknown.* Although a high degree of uncertainty is also associated with interbasin flow at the model boundaries, the volumes involved are estimated to be small relative to the total water budget in the model, and the modeling results are not expected to be sensitive to this parameter.

D'Agnese et al. (1997, p. 72) are appropriately concerned about the inability of a steady state model to adequately incorporate changes in the volume of groundwater in storage from pumping. Incorporating such withdrawals as discharges in a steady state model results in other discharges being proportionately reduced so that a balance between recharge and discharge is maintained. While this may, in part, explain the model's tendency to underestimate current discharges from the larger springs, including pumping as a constant discharge in the model will tend to make it more representative of long term, developed conditions that are of primary interest to performance assessment at Yucca Mountain.

VII-3.2 CODE SELECTION AND MODEL DEVELOPMENT

The MODFLOWP code was used for the Death Valley regional flow study. MODFLOWP is an adaptation of the USGS MODFLOW code that allows nonlinear regression to be used in the calibration process (D'Agnese et al. 1997, p. 72). Although more refined interim databases were developed, the final model was constructed with three vertical layers (D'Agnese et al. 1997, p.75) and a 1,500 m grid spacing (D'Agnese et al. 1997, p. 37). D'Agnese et al. (1997, p. 37) found this configuration to be sufficiently detailed to support the regional modeling effort and allowed the entire area to be displayed as a single model using available computers. The two upper model layers simulate local and subregional flow mostly within valley-fill alluvium, volcanic rocks, and shallow carbonate rocks. The third and deepest layer simulates regional flow in volcanic, carbonate and clastic rocks (D'Agnese et al. 1997, p. 75). Each model layer contains several hydrogeologic framework model units (D'Agnese et al. 1997, p. 77). The bottom of the model is located 2,750 m below the interpreted water table (D'Agnese et al. 1997, p. 75).

The mapped input databases were resampled to a 1,500 m lateral grid spacing and reclassified to simplify the final model. For example, simplification of the hydraulic conductivity database in the final model resulted in the definition of four hydraulic conductivity zones representing very small to large conductivity values and the 50th percentile conductivity values were used as initial estimates in the model (D'Agnese et al. 1997, p. 77). This simplified the number of parameters that were varied in the calibration process. The model was calibrated by varying the locations and types of boundary conditions and the interpretation of the hydrogeologic framework until acceptable matches were made with measured hydraulic heads and spring flows. Nonlinear regression methods were used to estimate parameter values that produced the best fit to observed heads and flows (D'Agnese et al. 1997, p. 72). Hydraulic conductivities, vertical anisotropy ratios, recharge potentials, spring conductance, and groundwater pumping were varied during the calibration process (D'Agnese et al. 1997, p. 84). No modifications were made to conceptual models during calibration simply to improve the model fit (D'Agnese et al. 1997, p. 86) and the parameter values estimated by the regression process remained reasonable. Supporting independent hydrogeologic criteria were needed before modifications were made (D'Agnese et al. 1997, p. 86). Detailed analysis of the calibration results identified previously overlooked spurious data, such as head observations from perched zones, incorrectly recorded head data, springs that issued from local instead of regional groundwater, and incorrect spring altitudes.

Use of the MODFLOWP code in constructing the model is appropriate. The MODFLOW code has become an industry standard and the advantages of the MODFLOWP adaptation in simplifying the calibration process and evaluating the model results are clearly explained by D'Agnese et al. (1997, p. 95). It is always regretful when a detailed model database has to be simplified to accommodate operational constraints, but the reasons for such simplification are understood. The restraint exercised by D'Agnese et al. in not modifying the model without supporting hydrogeologic criteria and in maintaining the hydraulic parameter values within reasonable bounds is also appreciated.

VII-3.3 MODEL OUTPUT

The regional flow model was validated by comparing model outputs with the regional potentiometric surface, hydraulic head measurements in individual wells, hydraulic gradients, and spring discharges (D'Agnese et al. 1997, p. 94). D'Agnese et al. (1997, p. 104) conclude that a general comparison of the simulated hydraulic heads with the regional potentiometric surface map indicates that the regional model depicts major features of the head distribution very well. Although this conclusion was confirmed by a comparison of the estimated potentiometric surface in D'Agnese et al.'s (1997) Figure 27 with the simulated surfaces in their Figures 48 through 53, the simulated surfaces are considerably smoother and do not exhibit the variability of the estimated surface.

In areas of flatter hydraulic gradients, simulated heads were within 75 m of observed well levels everywhere in the model and generally within 50 m. Based on the standard error of the regression of simulated and observed heads, the effective model fit for most wells is 45 m (D'Agnese et al. 1997, p. 94). In areas of steep gradients, the differences between simulated and measured heads are as large as 300 m. D'Agnese et al. (1997, p. 94) consider this match to be good in view of the 2,000 m head drop across the system. D'Agnese et al. (1997, p. 104) consider good fits to have residuals of less than 20 m (one percent of the total head drop), moderate fits to have residuals of 20 m to 60 m, and poor fits to have residuals greater than 60 m. By this definition, the overall goodness-of-fit would be considered moderate. Matching spring flows was found to be difficult and the measured values were generally underestimated. The sum of all simulated spring flows is 51,700 m^3/day, whereas the sum of all observed spring flows is 120,000 m^3/day (D'Agnese et al. 1997, p. 94). This difference may be primarily due to the model's inability to allow for changes in storage.

D'Agnese et al. (1997, p. 104) note that an indication of nonrandom distribution of head residuals in the model subregions suggests that the model may be in error. However, across the entire model the residuals do generally vary randomly about zero (D'Agnese et al. 1997, Figure 56). The overall water budget for the model is good, with inflows balancing outflows within 2,000 m^3/day (D'Agnese et al. 1997, Table 17). In this water budget calculation, pumping is included among the regional discharges.

D'Agnese et al.'s (1997, p. 104) definitions of goodness-of-fit are appropriate and indicate that this model provides a moderately accurate simulation of the Death Valley regional flow system. Considering the large size of the region, the hydrogeologic complexity, and the relatively sparse data, achieving any better overall validation accuracy would have been surprising. The team found that the Death Valley regional flow model database was well researched, the model was appropriately constructed, and the resulting output provides a reasonable simulation of regional groundwater flow despite the possibility of model error indicated by the authors (D'Agnese et al. 1997, p. 112).

The residual uncertainty in the model simulations is well described by its authors (D'Agnese et al. 1997, pp. 95 to 112). Uncertainties in the model output are of potential concern because the simulated fluxes along the boundaries of the saturated zone site-scale model account for most of the flow through that model. Available measures of overall model uncertainty include comparisons of predicted and measured heads, and the water balance residual. As previously mentioned, the overall goodness-of-fit to measured heads is considered moderate, and the water budget residual of 2,000 m^3/day is about 0.5 percent of the total daily flow of about 406,000 m^3/day through the model domain (D'Agnese et al. 1997, Table 17).

In this AMR, the fluxes in the three regional model layers were combined to provide total flow across the boundary for vertical panels of various widths extending from the water table to a depth of 2,750 m below the water table. The uncertainties are incorporated into the saturated zone site-scale model by treating the fluxes as target values during model calibration (CRWMS M&O 2000, p. 47). Fixed head boundary conditions were derived around the perimeter of the site-scale model from regional water level and head data, where heads were varied laterally along the model perimeter but were held constant in the vertical direction and in time (CRWMS M&O 2000, p. 25). Other targets that affect fluxes were also considered during site-scale model calibration, including rock permeabilities and specific discharge estimates given by the Saturated Zone Expert Elicitation Panel (CRWMS M&O 2000, p. 42). A comparison of the resulting calibrated boundary fluxes of the site-scale model with those determined from the regional model shows that total fluxes reasonably match within 8 to 21 percent for the northern, eastern, and southern boundaries, but a difference on the order of 100 percent was found for the western boundary (CRWMS M&O 2000, Section 6.1.4). The western and southern boundaries were not used as calibration targets in the site-scale model (CRWMS M&O 2000, Table 14). The reasons for these differences are attributed primarily to the greater resolution of the site-scale model (CRWMS M&O 2000, p. 81). Use of the regional model flux data as target rather than absolute values in the site-scale model is appropriate considering the uncertainties inherent in those data.

The Death Valley regional flow model was the most recent saturated zone model of the Yucca Mountain region at the time the study in this AMR was performed. It incorporates updated geological and hydrogeological data, it benefits from the recent geological and hydrogeological conceptual models, and it provides a three-dimensional representation of the region. The earlier models substanially simplified the complex 3-dimensional heterogeneity of the natural flow systems. For example, Waddell (1982) used a 2-dimensional model to simulate the regional groundwater system for the Nevada Test Site. Shortcomings of that study included poorly represented structural controls on flow, an inability to consider vertical groundwater movement, and large uncertainties in transmissivity values (Waddell 1982, p. 65). Czarnecki and Waddell (1984) used a 2-dimensional model to evaluate sub-regional groundwater flow in the Amargosa Desert. This model had many of the same shortcomings of Waddell's earlier (1982) work, with particular difficulty in matching observed heads in areas of strongly vertical groundwater flow (Czarnecki and Waddell 1984, p. 30). Rice's (1984) model of the Nevada Test Site was again 2-dimensional and also had difficulties in areas of vertical groundwater flow (Rice 1984, p. 34). Sinton (1987) developed a quasi 3-dimensional model for the Nevada Test Site covering essentially the same area modeled by Waddell (1982). Sinton's model had two transmissive layers in which horizontal flow could occur, a lower layer consisting primarily of the deep carbonate aquifer and an upper layer consisting primarily of basin fill and volcanic rocks. Vertical flow was simulated as leakage between the layers. Studies conducted by Sinton showed that the model was particularly sensitive to small changes in recharge and discharge rates and recommended that these be further investigated in future studies (Sinton 1987, p. 81). Although the Death Valley regional groundwater flow model prepared by D'Agnese et al. (1997) still considerably simplifies the actual flow system, the extensively researched input database, the fully 3-dimensional modeling, and the use of three conductive layers represent substantial improvements over past modeling efforts. Upon review of the alternative models, the Death Valley regional flow model was found to be the most appropriate source of information for both distributed recharge and lateral flow boundary conditions for the saturated zone site-scale flow and transport model.

VII-3.4 SUMMARY OF EVALUATION RESULTS

The Death Valley regional flow model database was well researched, the model to be appropriately constructed, and the resulting output to provide a reasonable simulation of regional groundwater flow. Quantification of the recharge component of flow was reviewed in particular detail because of the reliance placed on those data in this AMR. Several approaches to estimating recharge from precipitation were evaluated by the regional model's authors before deciding on a modification of an empirical relationship developed by Maxey and Eakin (1950). Shortcomings of other, more recent techniques were identified, particularly for application to desert areas where small amounts of recharge are ignored. A modified Maxey-Eakin method was also used by the YMP in preparing the AMR, *Simulation of Net Infiltration for Modern and Potential Future Climates* (USGS 2000), and the method is widely used and accepted by the technical community.

The Maxey-Eakin method was modified in the regional model to make it more sensitive to the four critical potential recharge indicators within the region: altitude, slope-aspect, relative rock and soil permeability, and vegetation. Regional maps were prepared for each of these indicators and through a series of steps a final recharge database was produced. The accuracy and suitability of the database were evaluated by the model authors and found to be appropriate for regional modeling. It is noted, however, that even with the better defined potential recharge areas, the rates are still based on empirical estimates rather than actual measurements and reflect a significant uncertainty in the regional modeling.

Within the area of the saturated zone site-scale flow and transport model, the recharge fluxes from the regional model are consistent with similar magnitude fluxes independently estimated from the unsaturated zone site-scale flow model and with focused recharge from Fortymile Wash.

The regional model's input database was diligently compiled using appropriate methodologies that take into account the difficulties of handling large amounts of data for a large region as well as the relatively large uncertainties that are present in much of the developed information. Discharges from evapotranspiration, playa evaporation, spring flow, and pumping were well researched, particularly the evapotranspiration component which constituted the largest single source of discharge. As expected, recharge was dominated by infiltration of precipitation. The effort expended by the model authors to corroborate the various model inputs lent credibility to their results.

Use of the MODFLOWP code in constructing the model is appropriate. The MODFLOW code has become an industry standard and the advantages of the MODFLOWP adaptation in simplifying the calibration process and evaluating the model results are important. The restraint exercised by the model authors in not modifying the model without supporting hydrogeologic criteria and in maintaining the hydraulic parameter values within reasonable bounds is appropriate.

Based on the standard error of the regression of simulated and observed heads, the effective residual between actual and simulated heads was 45 m for most wells. A good fit would have residuals of less than 20 m (one percent of the total head drop), a moderate fit would have residuals of 20 m to 60 m, and a poor fit would have residuals greater than 60 m. By these definitions, the overall goodness-of-fit of the regional model would be considered moderate. As a result, a degree of uncertainty must be associated with the model outputs.

Uncertainties in the simulated fluxes along the lateral boundaries of the saturated zone site-scale model are potentially significant because these fluxes constitute the greatest sources of flow in the site-scale model and they are not independently corroborated. The use of nested models to estimate those fluxes provides an appropriate approach to reducing these uncertainties. The uncertainties were recognized in calibrating the site-scale model by using the regional model fluxes along with other data sources in a generalized manner as calibration targets rather than as fixed model inputs. Actual boundary conditions in the site-scale model were defined by fixed heads, which are better known than the boundary fluxes. This approach made the fluxes largely a function of the calibrated model permeabilities. A comparison of the resulting calibrated regional and site-scale model boundary fluxes shows reasonable matching of total fluxes but greater differences, some on the order of 100 percent, for individual boundary segments. These observations indicate that the use of the regional model flux data in the site-scale model is appropriately generalized considering the uncertainties inherent in those data.

VII-4. EVALUATION CONCLUSIONS

The conclusions of the Data Qualification Team's review of the regional model are presented below in terms of the evaluation criteria presented in the controlling plan (BSC 2001b, Addendum N).

1. Are the methods used to develop the Death Valley regional groundwater model reasonable and generally accepted by the technical community?

The methods used to develop the database, the choice of models, the methods of calibration, and the analysis of the results are all reasonable and generally accepted by the technical community. The use of GSIS to store, manipulate, and analyze the data, although relatively new, is also accepted by the technical community and represents a welcome addition that will ease the burden of dealing with large data sets.

2. Are the methods used in this AMR to develop boundary conditions from the regional modeling results reasonable and generally accepted by the technical community?

The method used to obtain distributed recharge data was to take them directly from the regional model input files and the method of nested models was used to obtain lateral flux boundary conditions. The recharge data were developed using the well-established and accepted Maxey-Eakin method and use of the regional model as a source for those data provides consistency among the YMP saturated zone flow models. The nested model approach for reducing the uncertainty in lateral flow boundary conditions for smaller models is also well-established and accepted by the technical community. Use of the regional model to determine the lateral flows is reasonable and provides additional consistency among the YMP saturated zone models. .

3. Are there more appropriate sources of information for developing the boundary conditions required in this AMR?

Other sources of similar information for distributed groundwater recharge and lateral fluxes were older and less well developed than the Death Valley regional flow model. The regional model was developed in part to support the site-scale modeling. It provides a reasonable and comprehensive simulation of regional flow, and is the most appropriate source of information for developing hydrologic boundary conditions for the site-scale model.

4. Are the boundary condition data and their associated uncertainties acceptable for their intended use?

Uncertainties in the lateral boundary condition data have been appropriately addressed by making them target values for site-scale model calibration. The calibration has been successfully completed using this approach, indicating that the boundary condition data have been successfully used and are therefore acceptable for their intended use. In addition, much of the source data for the regional model are YMP-accepted data, the regional model has been validated and residual uncertainties have been identified, and the modeling effort was adequately reviewed and documented.

VII-5. RECOMMENDATIONS

The Death Valley regional flow model database was well researched, the model was appropriately constructed, and the resulting output provides a reasonable simulation of regional groundwater flow. This model is the most recent and best saturated zone flow model of the Yucca Mountain region. It incorporates updated geological and hydrogeological data, it benefits from recent geological and hydrogeological conceptual models, and it provides a three-dimensional representation of the region. Upon review of the alternatives, the Death Valley regional flow model was found to be an appropriate source of information for both recharge and lateral flux boundary conditions for the saturated zone site-scale flow and transport model.

Based on the foregoing evaluation, the Death Valley regional flow model was found to provide a qualified source of data for establishing recharge and lateral flux boundary conditions for the saturated zone site-scale flow and transport model. In accordance with AP-3.10Q, this finding qualifies these data only for their intended uses in this AMR. The source DTN GS960808312144.003 will remain unqualified for other uses.