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Sandia National Laboratories
Waste Isolation Pilot Plant

AP-139

Analysis Plan for Updating the Model for Regional Groundwater Flow in the Vicinity of the Waste Isolation Pilot Plant

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1 INTRODUCTION

1.1 Background

The Waste Isolation Pilot Plant (WIPP) is a deep geologic repository developed by the U.S. Department of Energy (DOE) for the disposal of transuranic (TRU) and mixed waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Parts 191 and 194.

Site-scale and regional hydrogeology are key aspects of siting, characterization, performance prediction, and performance monitoring for any nuclear waste repository. For WIPP, the hydrogeology of the Culebra Dolomite Member of the Rustler Formation is of particular interest when predicting repository performance for postulated disturbance scenarios involving intrusion by exploratory drilling. The Culebra is one of the most transmissive units above the repository, and thus is a possible pathway for offsite migration of radionuclides in the event of a drilling intrusion.

During preparation of the WIPP Compliance Certification Application [*DOE*, 1996], three-dimensional numerical simulations were used to enhance conceptual understanding of the hydrogeology of the Culebra in the context of the regional groundwater flow system and its response to varying climate conditions [*Corbet and Knupp*, 1996]. Groundwater flow over 6000 square kilometers of southeastern New Mexico and west Texas was simulated to evaluate the possible effects of future climate change on the performance of the WIPP. The domain of the regional groundwater flow model, along with its relationship to the WIPP site boundaries and regional topographic features are shown in Figure 1.

Steady-state simulations were performed to examine the sensitivity of simulation results to assumed values for hydraulic conductivity and recharge rate. Transient simulations, covering the time period from 14,000 years in the past to 10,000 years in the future, (ranging from semi-humid climates, in which the water table is a subdued replica of the land surface, to semiarid climates, in which the water table is at depth and is sloped along the regional gradients of the land surface) provided insight into how regional groundwater flow patterns respond to changes in climate.

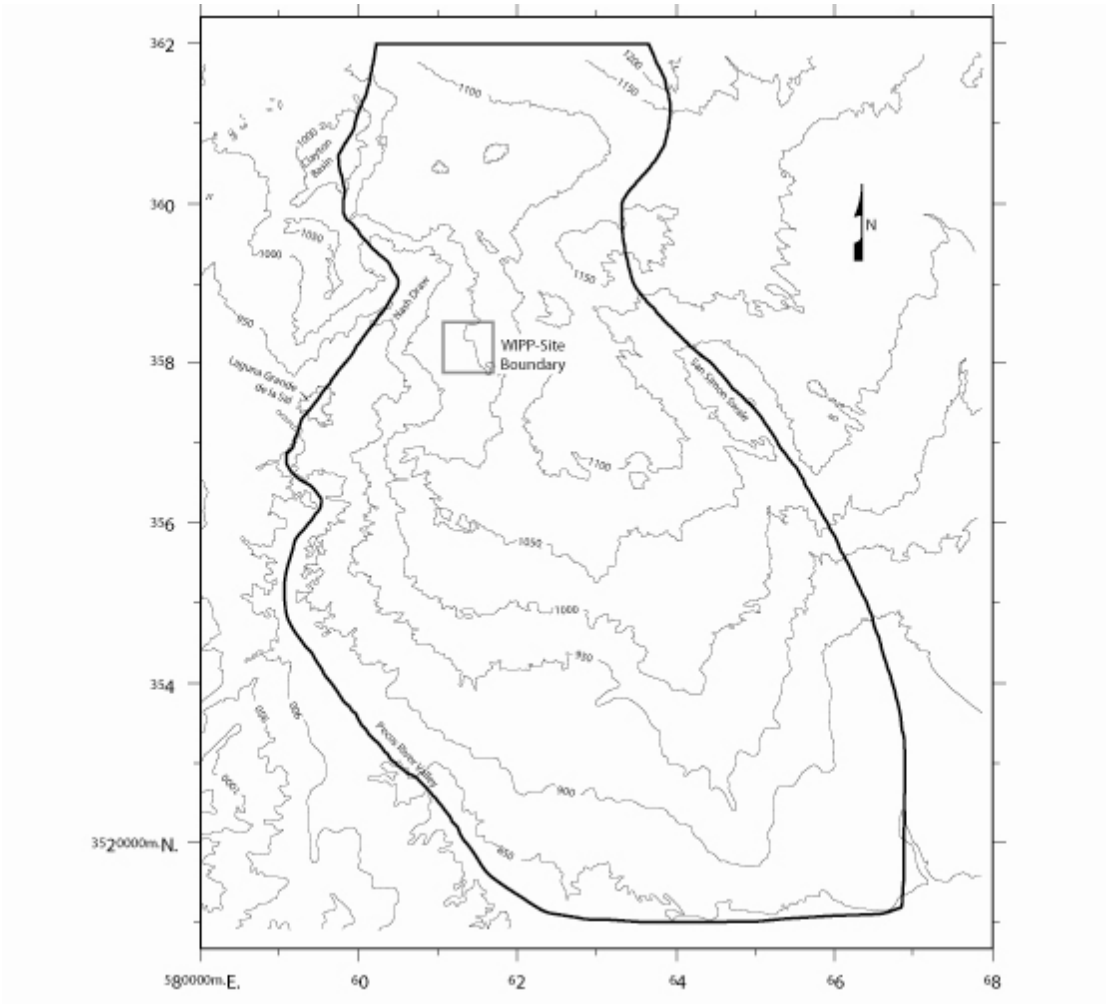

Figure 1. Regional groundwater model domain superimposed on topographic map. Contour interval is 50 m. Model boundary follows major hydrologic divides [*Corbet and Knupp*, 1996].

Because accurately predicting future climates is not possible, simulations incorporated future recharge rates that represented the full range of reasonably expected future hydrologic conditions. The most extreme effects of future wetter climates were represented by assuming recharge rates sufficient to raise the water table so that it was everywhere close to the land surface. Simulation results suggested that climate-induced changes in Culebra flow will be small and will mainly reflect future short-term wet periods such as have occurred over the past 8,000 years. Predicted maximum future flow rates in the Culebra were less than two times present-day rates. These results were used to infer input parameters for the two-dimensional performance-assessment calculations of Culebra flow and transport (specifically, the parameter GLOBAL:CLIMTIDX).

Recently, the EPA has requested that DOE reconstitute the capability to perform regional groundwater flow modeling in the vicinity of the WIPP site [*Cotsworth*, 2004]. This analysis

plan (AP) describes the approach, tasks, key personnel, and computational resources to be used in this compliance related analysis.

1.2 Objectives

This Analysis Plan directs the work to be performed by Sandia National Laboratories (SNL) to: 1) demonstrate reconstitution of the capability to perform numerical modeling of the regional groundwater flow system in the vicinity of the WIPP (i.e. software and supporting data); 2) review geological and hydrological information obtained since the original analysis; and 3) update the regional groundwater flow model as dictated by new data and interpretations.

2 APPROACH

In general, the approach to this analysis consists of the following steps:

1. Select simulation software.
2. Review the data used in the original analysis in order to confirm its adequacy.
3. Repeat selected calculations to demonstrate reproducibility.
4. Review geological and hydrogeological data and interpretations produced since the original analysis in order to identify any significant additions or changes.
5. Perform simulations to evaluate the impact of new data and/or interpretations.

2.1 Software

The simulation code used in the original analysis of Corbet and Knupp [1996] was SECOFL3D. At the time the referenced work was performed, SECOFL3D was not qualified for use under Nuclear Waste Management Procedure NP 19-1, *Software Requirements.* It had been exempted from the NP 19-1 requirement because the output of the SECOFL3D simulations were not a direct input to WIPP PA calculations [*Corbet*, 1996a]. Although not qualified to NP 19-1 criteria, the development and testing of SECOFL3D was extensively documented [*Corbet*, 1996b; 1997a; b].

SECOFL3D was subsequently renamed MWT3D (Moving Water Table in 3 Dimensions). MWT3D Version 2.40 was qualified under NP 19-1 and transitioned to the WIPP PA software baseline [*Corbet*, 1999]. However, not all of the features used in the regional groundwater flow analysis were qualified. The MWT3D code was later retired, but has recently been returned to the WIPP PA software baseline as MWT3D Version 2.50 [*WIPP PA*, 2007a; b; c; 2008a; b; c; d]. Returning the code to the software baseline involved testing all features relevant to the regional groundwater flow analysis, and porting the code from the WIPP PA VMS Cluster (ccr.sandia.gov) to the WIPP PA Linux Cluster (alice.sandia.gov). MWT3D Version 2.50 will be the main code to be used in the work described in this analysis plan.

MWT3D performs steady-state or transient simulations of saturated flow in porous media subject to free surface and seepage face boundary conditions on the upper surface of the computational domain. An important functionality of this code is to allow the position of the

water table (upper surface of the computational domain) to move in response to an applied vertical flux (net recharge or infiltration). The governing groundwater flow equation is discretized as centered differences on a finite-volume staggered mesh. The formulation is fully implicit. In order to maintain a fully saturated domain, the computation mesh deforms such that its upper surface is at the moving water table.

2.2 Data Review

The regional groundwater flow model requires, as input, a representation of structure and layering of the rock units as well as a representation of the hydraulic properties of the rocks. This information, combined, is referred to as the hydrostratigraphy. An extensive data collection, reduction, and analysis effort was required to define the hydrostratigraphy input for the regional groundwater model, although Corbet [1996a] indicated that the data were not qualified at the time of the analysis. Regardless of the preceding statement regarding data qualification, a significant documentation effort was made and an extensive set of records exists. The process of representing the hydrostratigraphy of the WIPP region in the groundwater flow model is recorded in three record packages.

The first record package, *Stratigraphic Data Used for the 3-D Rustler Formation Hydrologic Model* [*Corbet*, 1996c], describes the compilation of a list of elevations of the tops of selected stratigraphic units in the Rustler and Salado Formations in the vicinity of the WIPP site and within the state of New Mexico. This information is used to construct contour maps that show the elevation and shapes of the upper surfaces of these stratigraphic units. These maps are referred to as structure contour maps or structure maps. The structure maps, in turn, are used to determine the thickness of model cells in the three-dimensional model of groundwater flow in the rock units above the Salado Formation. A second record package, *Contour Maps Used for the 3-D Rustler Formation Hydrologic Model* [*Corbet*, 1996d], describes the process used to construct the structure contour maps. This second package also describes how additional stratigraphic data from Texas were compiled to supplement the New Mexico information. A third record package, *Stratigraphic Gridding and Zone Identification for the 3-D Rustler Formation Hydrologic Model* [*Corbet*, 1996e], describes how the structure maps were used to determine the dimensions of the model cells and assign hydraulic properties to each cell.
In order to address concerns about data qualification, the existing data set and the procedures used to develop simulation inputs will be reviewed. Data identified as lacking sufficient support will be re-validated with quantitative and/or qualitative acceptance criteria and documented per the Analysis Report requirements of Appendix B of Nuclear Waste Management Procedure , NP 9-1 *Analyses*.

2.3 Demonstrate Reproducibility

The analysis reported by Corbet and Knupp [1996] included 54 steady-state and 17 transient simulations. The main objective of the steady-state simulations was to examine the sensitivity of model results to values of selected model parameters in order to enhance the conceptual understanding of the hydrologic system. The transient simulations provided insight into how the hydrologic system responds as the potential recharge changes with time.

In order to demonstrate reproducibility, selected steady-state and transient simulations will be re-run using MWT3D Version 2.50 and compared to the results obtained by Corbet and Knupp.

2.4 Evaluate New Data and/or Interpretations

Geological and hydrogeological data/interpretations produced since the original analysis will be reviewed to identify any significant additions or changes. Of particular interest will be data/interpretations that impact:

- topography and model boundary positions
- model boundary conditions
- computational mesh resolution
- stratigraphy and/or hydrostratigraphy

In particular, data from all new wells drilled and tested on behalf of WIPP since 1996 will be incorporated in the revised model, as well as data from many of the recently drilled oil and gas wells around the WIPP site. Data from recently completed geologic studies (e.g., [*Powers*, 2006; 2007]) will also be incorporated, as appropriate. These studies addressed possible areas of recharge to the west and south of the WIPP site and modifications to the Rustler Formation halite margins, respectively.

The work of *Corbet and Knupp* [1996] included a limited mesh refinement study using a steady-state problem, but it was unknown whether the asymptotic regime had been reached. Consequently, truncation error due to insufficient grid resolution cannot be said to have been eliminated from the uncertainties present in those simulations. Therefore, a more thorough mesh refinement study will be included in the planned work. This study will look at refining the mesh uniformly and/or refining the mesh in the region near WIPP where there is more data.

2.5 Evaluate Impact of New Data/Interpretations

In order to evaluate the impact of new data and/or interpretations, the model will be revised to incorporate the new information, selected steady-state and transient simulations from Corbet and Knupp [1996] will be re-run, and the old and new results will be compared. If appropriate, additional simulations unrelated to the previous analyses may be performed.

3 TASKS

The tasks, principal responsible personnel, and schedule are summarized below in Table 1. An analysis report describing the work completed in Tasks 1-4 will be produced approximately one month after all analysis tasks have been completed.

Table 1. Analysis Tasks[a].

Task	Description	Principal Responsible Personnel	Approximate Completion Date
1	Review Historical Data and Develop Acceptance Criteria	Kanney Powers	July 31, 2008
2	Verify Reproducibility	Kanney	August 31, 2008
3	Review New Data/Interpretations	Kanney Powers	September 30, 2008
4	Model and Evaluate Impact of New Data/Interpretations	Kanney	December 31, 2008

a. Schedule may vary due to availability of computing resources and qualified stratigraphic data.

4 SOFTWARE AND HARDWARE

The main code to be used for this analysis is MWT3D Version 2.50. MWT3D calculations will be performed on the WIPP PA Linux Cluster (see Table 2). Additionally, commercial off-the-shelf (COTS) software, such as Access®, ArcGIS®, Excel®, Grapher®, Kaleidagraph®, MATHEMATICA®, MATHCAD®, or MATLAB®, running on MS Windows XP®-based PC workstations may be utilized. The use of any COTS application will be verified per Nuclear Waste Management Procedure NP 9-1, Appendix C as appropriate.

Table 2. WIPP PA Linux Cluster (alice.sandia.gov)

Operating System	Red Hat Enterprise Linux Release 4
Processors	26 (1 dual processor server node and 12 dual processor compute nodes)
Server Node	2U rackmount server system with dual Intel Pentium 4 (Xeon), 2.8Ghz processors
Compute Nodes	1U rackmount workstation system with dual Intel Pentium 4 (Xeon), 3.0 Ghz processors

5 SPECIAL CONSIDERATIONS

None.

6 APPLICABLE PROCEDURES

All applicable WIPP QA procedures will be followed when conducting these analyses.

- Training of personnel will be conducted in accordance with the requirements of Nuclear Waste Management Procedure NP 2-1, *Qualification and Training*.
- Analyses will be conducted and documented in accordance with the requirements of Nuclear Waste Management Procedure NP 9-1, *Analyses*.
- All software used will meet the requirements laid out in Nuclear Waste Management Procedure NP 19-1, *Software Requirements* and NP 9-1, as applicable.

- The analyses will be reviewed following Nuclear Waste Management Procedure NP 6-1, *Document Review Process*.
- All required records will be submitted to the WIPP Records Center in accordance with Nuclear Waste Management Procedure NP 17-1, *Records*.

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