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Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

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Mr. Matthew Gordon
Division of Waste Management
Mail Stop 623-SS
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

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Docket No.
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LPDR ✓ (B)
Distribution:
Gordon
(Return to WM, 623-SS)

Dear Matt:

Two copies of our review of the Lu and Yeh article on inverse modeling are enclosed. Please call if you have any questions concerning our review.

Based upon our discussions with you, we are not preparing written reviews of the following documents:

- RHO-BW-SA-364-P,
- RHO-BW-SA-366P,
- RHO-BW-SR-84-1-40P,
- RHO-BW-SA-372P, and
- RHO-BW-SA-370P.

These documents have been read for informational purposes only.

Sincerely,

Roy E. Williams

Roy E. Williams

2372

WMGT DOCUMENT REVIEW SHEET

FILE #:

ROCKWELL HANFORD OPERATION #:

DOCUMENT: Basalt System Characterization: Inverse Technique, by Lu and Yeh (undocumented paper prepared by Lu without date of publication or indication of manner of distribution)

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: July 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

Introduction and Overview

The report under review describes the large-scale multiple-well stress tests planned for the deep basalts at the Hanford site. The large-scale tests will entail the consideration of complex boundary conditions in the analysis of the data derived from the tests. The report under review outlines the potential problems associated with analysis of the conventional analytical data which will be derived from the large-scale pumping test. The report under review describes in general terms the use of an inverse modeling technique for the prediction of hydrogeologic parameters; the results of preliminary computer modeling studies using the inverse technique for identifying the critical parameters in one and two layer applications are presented. The report under review describes the results of the preliminary studies as being "promising".

Conceptual Model

The conceptual model, employed in the report under review, encompasses the reference repository location which lies within the Cold Creek Syncline. A hydrogeologic barrier is assumed to exist to the northwest and southwest in this conceptual model. The finite difference grid of the computer model is extended to the east such that the eastern boundary will have a negligible effect in the area of interest during the simulation. This eastern extension was necessitated by the fact that the model

used includes an impermeable boundary that exists along the outermost nodes. The model consists of 32 rows and 34 columns of blocks varying from 183 feet to 1 mile. The test cases simulated a single flow top overlain by a dense basalt flow interior; a second case simulated two flow tops separated by a dense interior.

Parameter Estimation

The values of transmissivity were entered into the model based on a four value distribution. The distribution included in the report under review is supposed to approximate one of the flow tops in the Grande Ronde Basalt. Transmissivity values of T_1 = 10, T_2 = 0.5, T_3 = 0.1, and 0 ft^2/day were used as input. Storativity for the flow top was estimated at 8×10^{-6}. The initial steady state head was estimated to be 400 ft throughout the flow top. As noted, the input values for the model were assumed; the method of selection of these values is not presented in the report under review.

Simulation

The simulations were conducted using a modified version of the Trescott three-dimensional finite difference model. The Trescott model uses a block centered, finite difference grid which can incorporate a variable grid spacing. The strongly implicit procedure was used throughout the duration of the numerical technique. Three dimensions are simulated by use of a series of two-dimensional models; the two-dimensional models are joined by an interaquifer transfer coefficient. This interaquifer transfer coefficient (TCF) determines the flow between layers based on Darcy's law. "The governing equation for each layer is

$$d/dx\ (T\ dh/dx) + d/dy\ (T\ dh/dy) + (TCF)\ \Delta h_z = S\ dh/dt + Q$$

where T is transmissivity, S is storage coefficient, h_z is hydraulic head difference between two layers, and Q is the source function." The inverse technique version of the Trescott model is called Trescott-Invert. According to the report under review the modified version of the Trescott model will provide estimates of the parameters T, S, and TCF. The version of the Trescott model developed by Rockwell assigns estimated values of the parameters based on the regions of a flow system which have been predetermined to be essentially constant with respect to transmissivity. "The program estimates the value of the parameters by minimizing an objective function of the form:

$$\min_{\underline{\underline{\ }}} J = \sum_{i=1}^{N} (h_i - h_i^*)^2$$

where $\bar{\theta}$ is the parameter vector (T, TCF, S); N is the total number of observations," h_i is the model solutions which are commensurate with observations, and h_i^* represents the observations. The parameter $\bar{\theta}$ is limited by upper and lower bounds assigned based on prior geologic information.

The base case for testing the inverse model in the report under review is the head distribution generated using the Trescott model as a conventional groundwater flow model. Zones of equal transmissivity were assigned within the finite difference grid using the values of transmissivity noted previously (T_1, T_2, T_3, and 0 ft^2/day). The generated head values were determined at actual observation well locations for a simulated pump test at well RRL-2B. The pumping rate was 30 gpm for 30 days in the report under review. This simulated head distribution is used as the "true" hydraulic head distribution for the subsequent cases wherein the inverse model is tested in the report under review.

The first case studied by the authors of the report under review did not divide the area into zones of suspected equivalent transmissivities. They found that the inverse modeling produced a "reasonable" value of transmissivity relative to the initial base case T_1 value. (The transmissivity values listed as T_2 are assumed to be T_1 values under Case 1 in Table 1.) However, significant error appeared at several locations. This error in head prediction relative to the base case head values was greatest at wells DC-22 and RRL-6. Small errors in head were apparent at other wells except for DC-19 where the error was negligible. Case 2 evaluated the inverse technique with the grid divided into three subregions. The subregions were the same as used to generate the "true hydraulic heads." The found that the inverse technique recovered the "true T's." Case 3 evaluated the effect of inducing a measurement error which was simulated by a Gaussian noise of standard deviation equal to 0.7 ft. The authors of the report under review found that the least square error increased drastically. They found also that T_1 and T_3 were almost completely recovered while T_2 exhibited a significant error. Case 4 evaluated the efficacy of the inverse model when applied to a two layer system. A TCF value was incorporated to account for the hydraulic properties of the basalt dense interior between the two layers. The inverse model produced values for the TCF, T_1, T_2, and T_3. They also applied a Gaussian noise of standard deviation equal to 0.3. Parameters T_1, T_3, and TCF were recovered almost completely after increasing the duration of pumping. T_2 attained only 80% of the true value.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM

This document is important to the Waste Management Program in

that it indicates the probable use of inverse modeling techniques for evaluation of the large-scale test data from the BWIP site. The inverse technique is one of two major types of data analysis techniques which will be used on the test data. The authors of the report under review point out that there are a number of inherent assumptions which will be violated at the site which are required for a complete analysis by analytical means. Problems or deficiencies apparent in this brief paper should be discussed by the NRC. These problems and deficiencies if not highlighted at this time will undoubtedly be incorporated into later inverse modeling techniques of the large-scale test data.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT

General Technical Discussion

The inverse technique described in the document under review is dependent upon the manner in which the manipulator of the model assigns zones of equivalent transmissivity to the finite difference grid. A numerical value of transmissivity is not assigned to these zones at this stage; only an upper and lower bound on transmissivity are assigned. The inverse technique determines values of transmissivity for these zones. This process of assigning zones of equivalent transmissivity appears to be subjective. A basis for this process is not discussed. The process of assigning zones of equivalent transmissivity introduces an additional unknown into the inverse technique. The inverse technique is not applied to different zoning patterns; the sensitivity of the inverse technique to the assignment of zoning patterns is unknown.

The effects of varying the finite difference grid spacing are not addressed. The effects may or may not be significant but the report does not address the subject of grid spacing. It is possible that the inverse technique is sensitive to the selection of grid spacing. For example, a finer grid may be required to inverse model a flow top with a low transmissivity.

The inverse technique described in the report under review compares heads based on simulated data for the block centered finite difference grid. The value of using hydraulic head values adjusted to represent true water levels in the wells should be considered. Adjusted head values may improve the sensitivity and accuracy of the inverse technique.

One concern noted during our review of the subject document is the apparent lack of consideration of storativity in the confining unit. The discussion on pages 3 and 4 of the document under review indicates that the transfer coefficient (TCF) does not account for the storativity of the confining unit. The

document under review assumes that the storativity of the confining unit is infinitesimally small. The inverse technique is simplified and data input minimized by using the TCF function. The use of the TCF function eliminates an extra layer(s) of nodes which would be required to represent a confining unit with a finite storativity. The approach used in the document under review is appropriate for long term test considerations; the ultimate question is whether or not the large scale tests will be of sufficient duration to warrant this simplification.

As it stands, the subject document indicates that vertical leakage will be evaluated for one confining unit only. The TCF function probably will be appropriate for late time data analysis from the pump test. Early time head data during a pumping test may be significantly affected by the storativity of the confining units. The rapidity with which the pressure pulse will be transmitted through the confining unit(s) is also a function of the storativity of the confining units.

We believe that the general conceptual model and basic approach outlined in this paper are appropriate. We wish to emphasize that it is easy to fall into the trap of relying on inverse modeling to an extent which is not warranted. The analytical techniques should be applied whenever and wherever possible. The combination of analytical and inverse modeling techniques is certainly appropriate for the evaluation of any and all data developed from large-scale testing. The weakness of the inverse technique when applied to a multilayered aquifer system is that it is necessary to determine the value of several independent variables with what amounts to one finite difference equation.

REFERENCES

Trescott, P.C. reprint July 1976. Documentation of Finite-Difference Model for Simulation of Three-Dimensional Ground-Water Flow: U.S. Geological Survey, Open-file report 75-438.