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MEMORANDUM FOR: Myron Fliegel, Section Leader
Hydrology Section, WMGT
Division of Waste Management

FROM: Matthew Gordon
Hydrology Section, WMGT
Division of Waste Management

SUBJECT: VERIFICATION AND BENCHMARKING REPORT FOR MAGNUM-2D

As you requested, I have reviewed the subject report . The review is attached.

Original Signed By

Matthew Gordon
Hydrology Section, WMGT
Division of Waste Management

Enclosure:
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WMGT DOCUMENT REVIEW

Document Name: "Verification and Benchmarking of MAGNUM-2D: A Finite Element Computer Code for Flow and Heat Transfer in Fractured Porous Media," L. Eyler and M. Budden, Battelle Pacific Northwest Laboratories, Report No. PNL-5237, March, 1985

Reviewed by: Matthew Gordon, Hydrology Section, WMGT with input from Dan Goode, Hydrology Section, WMGT

File Nos: 3109.2, WM-8301

Date Review Completed: 5/14/85

Significance of Information to NRC Program:

BWIP intends to use the MAGNUM-2D code as one of a suite of codes used for modeling HLW repository performance at the Hanford site. This report generally follows the guidelines offered in Section D(2) of NRC's Final Technical Position on Documentation of Computer Codes for High-Level Waste (HLW) Management (Silling, 1983).

Brief Summary of Document:

In this document the capabilities of the MAGNUM-2D code are tested by comparisons with analytical solutions (termed "verification") and with results from other codes (termed "benchmarking"). The MAGNUM-2D code is a finite element code designed for modeling coupled or uncoupled heat transfer and fluid flow in porous and porous/fractured media. The Basalt Waste Isolation Project (BWIP) intends to use this code in modeling HLW repository performance at the Hanford site. The document identifies its objective as "provid[ing] a documented basis upon which conclusions can be drawn as to acceptability of MAGNUM-2D for simulation analysis of proposed waste canister emplacement in basalt rock formations "(p.3.5). Ten test problems are examined which involve uncoupled heat transfer and fluid flow, for which MAGNUM-2D is shown to perform acceptably. The authors note in the summary (p. v) that "additional testing needs to be conducted to specifically address fully coupled (buoyancy driven) flow and heat transfer for both transient and steady cases."

Comments:

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"Verification" is usually possible only for the simplest of problems. "Benchmarking," on the other hand, can be used to assess code performance on more complex problems, but can not be conclusive; for example, it may be that both of the compared codes are incorrect in terms of simulating real physical processes, even if their results are identical. Thus, verification and benchmarking are generally most useful to the investigator for identifying bugs in programs, inadequacies or inconsistencies in the user's manual, or misrepresentations of code capabilities in code documentation. The utility to NRC of verification and benchmarking by the licensee is that it provides some additional assurance that the code operates acceptably in a variety of situations. However, since each problem that the code will be used to solve will be different, this assurance can never be complete for any new given case.

My review of this document was approached by identifying the following questions:

1) Do the problems chosen adequately test the code capabilities?

2) Are the problems, code input, and results presented, in content and format, such that the code performance can be properly gauged?

3) Have the results been adequately interpreted in the document?

4) Are there any misstatements or other miscellaneous problems that have been identified during the review?

5) Is the document consistent with NRC's guidance (Silling, 1983)?

Missing from this list of questions is "Is the code appropriate for use by BWIP, i.e., shall NRC be willing to accept with little question future MAGNUM-2D results presented by BWIP?" Unfortunately, this question can be answered only when a code is clearly inadequate, which is not the case here. The best that can be said is that, for this particular set of problems, the code has been shown to perform acceptably.

The remainder of this review focuses on the interrelated questions identified above.

The problem statements, problem results, the q/a and q/c procedures, and the code assumptions are presented very clearly, with appropriate references to other documents. The User's Guide for MAGNUM-2D has apparently not been obtained by NRC, since it is not in my files nor the DCC files. This somewhat limits the scope of my review. The input files are not provided in the document, contrary to NRC's guidance (Silling, 1983), but are apparently kept

on file by the authors. However, the location of these files, or who to contact to obtain copies, is not indicated in this document.

The problems described in this document are either heat transport or fluid flow problems. No coupled heat transport/fluid flow problems were examined. It is stated on p. v that "a suitable tool for use as a comparison basis was unavailable at the outset of this work." However, several coupled flow/heat transport codes are in fact available for use as benchmarking tools, e.g. PORFLO, SWIFT, and TEMPEST (used in the report for heat transport only). In fact, a PORFLO verification and benchmarking report published in November 1984 contained two coupled flow/heat transport benchmarking problems. It is also interesting to note that several problems which are examined in the PORFLO report, which the MAGNUM-2D code should be capable of solving, are not examined in the MAGNUM-2D report: Problem noS. HT-2, heat transfer in uncoupled unidirectional flow; HT-3, repository scale transient heat conduction; and FF-3; repository-scale coupled flow and heat transfer. Likewise, the MAGNUM-2D report contains problems not examined in the PORFLO report that could have been solved by PORFLO: HT-1.1, transient multiregion conduction heat transfer in one-dimensional cylindrical geometry; and FF-4, steady flow in a porous media [sic].

It is noted on p. 2.2 that cross-terms in the hydraulic conductivity tensor are neglected by MAGNUM-2D. It is not clear that this assumption would be valid for simulating media which are discretely fractured in directions at angles to the hydrualic gradient.

All of the problems involving fluid flow used "no flow" or "constant head" boundary conditions. Problems posed in this way are tightly constrained in terms of solving for heads within the model domain. Since the user's manual was not available to this reviewer at the time of this review, it is not clear whether the code is capable of "fixed-flux" boundaries. For the type of problem examined in the MAGNUM-2D report (i.e., fixed head/no flow boundaries), the velocity output is more telling than the head output. For problems FF-6 and FF-8, the velocities calculated by MAGNUM 2-D were different from the velocities calculated by FTRANS by as much as 40% at certain points, even though calculated heads were identical to four significant digits. For the two problems noted, however, it is not known which code is correct, since there is no exact solution which is analytically tractable.

For problem FF-7, the code is compared to an unreferenced analytical solution. The assumptions and derivation of this analytical solution should have been provided to ensure that they correspond to the assumption of the numerical model.

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Problem FF-4 is difficult to follow. The dotted lines in figure 4.7.3 are not explained on the figure or in the text.

One benefit derived from the set of simulations described in the document is the correction of an apparent error in the calculation of darcy velocities for the line elements used in treatments of fracture flow. It is not clear whether this improvement is now a permanent part of the MAGNUM-2D code which will be used by BWIP.

In general, the code appears to have performed acceptably for the ten sample problems examined. It would be helpful to have the input available in the document (perhaps as a mocrofiche enclosure) to make the results readily reproducible and verifiable to future users of the code.

Action Taken: None

Action Required: None

Referred to (for info): Seth Coplan