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STATE OF NEVADA REVIEW OF PHASE I OF THE INTRAVAL PROJECT

by

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The Nevada Agency for Nuclear Projects/Nuclear Waste Project Office (NWPO) was created by the Nevada Legislature to oversee federal high-level nuclear waste activities in the State. Since 1985, it has dealt largely with the U.S. Department of Energy's siting of a high-level nuclear waste repository at Yucca Mountain in southern Nevada. As part of its oversight role, NWPO has contracted for studies ofvarious technical questions at Yucca Mountain Project.

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INTRODUCTION

The INTRAVAL Project which started in October, 1987, was designed to be an international cooperation project and is managed by the Swedish Nuclear Power Inspectorate. The project was to undertake the issue of what constitutes a validated model in terms of repository performance assessment. The US Nuclear Regulatory Commission (NRC) in 10CFR60.21 requires an explanation of measures used to support the models utilized in the assessment of performance which are included in the License Application. The NRC Nureg 0856, "Final Technical Position on Documentation of Computer Codes for High Level Waste Management" defines the term validation to be, "assurance that a model as embodied in a computer code is a correct representation of the process or system for which it is intended".

The notion of validating that a code accurately represents the operational physical processes at a given site has turned out to be a very difficult endeavor. Especially for sites such as Yucca Mountain where the flow regime is poorly known. There is currently no mathematical description of unsaturated flow in fractured - porous media which the majority of the scientific community can support with confidence. Further, all overall performance calculations performed to date by the U. S. DOE assume one dimensional porous flow which enters through the top of Yucca Mountain and makes it way to and through the repository. Not surprisingly these types of calculations lead to the conclusion that little or no release is possible via the groundwater pathway.

Quite naturally, the State of Nevada is concerned with these types of calculations, preferring to see something more realistic in terms of conceptual models, fracture pathways, and releases. This concern is carried into the INTRAVAL process because if the DOE is to validate a model of flow at Yucca Mountain within INTRAVAL, the model must be realistic.

STATE PARTICIPATION

The U.S. Nuclear Waste Policy Act of 1982 establishes the technical review role of States in the development and siting of a High-Level Nuclear Waste Repository. The State of Nevada believes that decisions made within INTRAVAL may directly effect evaluation activities with respect to Site Characterization or overall repository performance. Therefore, it was within this review role that the State of Nevada requested permission to observe the activities of INTRAVAL.

We believe that due to the amount of effort the DOE has put into INTRAVAL to date, that they will utilize the results of INTRAVAL as a validation of the flow field at Yucca Mountain. This is perfectly acceptable as long as the model is realistic. The endorsement of such a prestigious international group would be highly favorable in the licensing arena.

However, what should be noted with respect to the unsaturated zone test cases is that a truly international review has not been performed as with most other INTRAVAL test cases. Normally the validation of a test case involves a team of modelers made up from several countries. Each one of the team performs calculations and compares and contrasts results, thus constituting an international peer review. With the unsaturated zone test cases, the teams have been only American. This is because no other INTRAVAL participating countries plan to site a high level waste facility in unsaturated fractured-porous media. While the U. S. Nuclear Regulatory Commission has supported several universities in this process, the bulk of the peer review of certain test cases is funded almost entirely by the U.S. DOE. In one test case, "G Tunnel", no peer review was done because the data required for other team members to model the problem was never released until the end of Phase I and the results of that test case issued. Thus, not a true international review is accomplished as it would appear.

VALIDATION STRATEGIES

During Phase I of INTRAVAL, two validation strategies were proposed to the group which, if followed, would constitute a "validated" model. One was provided by the U.S. DOE and one by Sandia National Laboratories under funding by the U.S. NRC. The impetus for strategy development is mainly coming from the needs of the U.S. performance assessment program, although such a strategy should be a product of INTRAVAL, if one can be agreed upon. The two approaches, while similar in some aspects, represent different philosophies regarding what constitutes validation. It is clear that during the early phases of INTRAVAL no consensus exists as to what constitutes an acceptable validation. Obviously, it is different things to different people. Given the various roles and objectives of the participants, i.e. regulators, researchers, modelers, experimenters and repository developers, the definition of validation will be difficult to pin down and will naturally evolve with experience and time.

While currently INTRAVAL does not intend to develop or propose a generic validation strategy, we believe strategies should emphasize the following aspects of validation: 1) ensure controlling processes are adequately evaluated and simulated; 2) promote development of performance measures, and 3) promote open and multiple review processes.

U.S. Department Of Energy (DOE) Strategy

The DOE's objective in developing a validation strategy is to provide a systematic approach for establishing the evidence that a performance assessment model has been properly derived from defensible premises and provides a good representation of the system being modeled. There are 3 major components to this approach:

- Record of the derivation of the model (The assumptions on which it is based, its limitations and the evidence that supports the assumptions.)
- Experiments which support assumptions.
- Formal Technical Review.

The DOE emphasis is on careful documentation of what has been done. The responsibility for the documentation falls on the modeler. The decision that some model has been validated is made by a formal Technical Review Committee.

The state of Nevada has concerns with this approach in its present form. Basically, as with any quality assurance measure, crossing the "t's" and dotting the "i's" falls short of assuring the science is correct, or predictable. The assumptions and limitations can be listed and debated and some experiments may be conducted to provide evidence which supports some of them. The problem lies in the complexity of the processes involved, their scale, spatial distribution and their complex couplings. While the DOE has many experiments planned, it will simply not be possible to conduct experiments to demonstrate many of the required complexities to be valid.

Further, as stated on page 12 of the Strategy, "the schedule for the site characterization and performance confirmation activities is such that some of the additional supporting information identified in subactivity 2.2.4 will not be available before a formal technical review is initiated". The Strategy suggests time periods of review be optimized and that the reviewers know what additional information will be available in the future. This is also of concern. Many of the planned tests which have been discussed for the unsaturated zone may not be accomplished

(USGS/NRC/DOE Technical Exchange, Denver, September, 1990). Also, analog recharge studies will take a minimum of five consecutive years to complete (Study Plan 8.3.1.5.2.1 - Characterization of the Yucca Mountain Quaternary Regional Hydrology). These events and time periods cast doubt on how much data will be available for model comparisons. We would like to see the DOE take steps to ensure the scientific data are collected so that a minimum number of parameters or distributions are decided by expert opinion.

Another shortfall of this approach is the limited peer review. By this, we mean the limited numbers of select reviewers. Historically the broad spectrum of open review has not been undertaken by DOE. Typically such review panels are comprised of only DOE or DOE-supported personnel. The State, on the other hand, would encourage a more open review process; one which encourages the broadest participation possible and one which encourages affected party participation. Members of the review groups must be knowledgeable of the relevant disciplines by rock type and preferable within the regional setting.

SANDIA NATIONAL LABORATORY (SNLA) VALIDATION STRATEGY

The SNLA philosophy of validation is that validation constitutes "acceptable uncertainty". The focus is on assessing site safety - not merely on investigating scientifically interesting phenomenon. In this approach the computer codes become less important than the underlying model (conceptual or mathematical) used to describe the process of concern. This is because procedures are well established to verify the mathematical performance of computer codes.

The strategy consists of 10 basic steps as follows:

1) Define model purpose.

2) Conceptual model development.

3) Define performance measures and acceptance criteria.

4) Design validation experiment.

5) Measure "independent" parameters and uncertainty.

6) Simulate the experiment with uncertainty.

7) Perform the experiment.

8) Assess adequacy of the model structure.

9) Assess adequacy of the input data.

10) Repeat the experiment over the possible range of conditions expected at the repository only.

SNLA makes a distinction between process models and model geometries. This approach may make sense if one considers the questions of spatial variability, however, it has been pointed out that this separation may not be appropriate for some types of small scale data or pore scale processes.

Perhaps the most important insight provided by this work is the need to define appropriate performance measures. This is extremely critical since the choice of performance measure will dictate the validity of a model. In many cases, depending on the measures chosen, a model may be determined valid for some and invalid for others. SNLA points out this is where DOE will rely on expert opinion to sort out the "valid " results. The State foresees problems with this reliance on experts and urges INTRAVAL and other participants to focus considerable effort, early on in this process, to defining appropriate performance measures.

We agree with SNLA that site safety must be the driving force for prioritization of work resources and it soon becomes apparent that with respect to Yucca Mountain, natural processes will be controlling. Here unsaturated fracture flow and transport processes will rank very high in uncertainty. So basic research into these processes is required to reduce uncertainty to acceptable levels, i.e. to validate these processes.

According to SNLA, INTRAVAL to date has approached the problem of validation in a backwards fashion. SNLA believes that INTRAVAL has done their experiments first and are now looking for the purpose. The State is in agreement but is sympathetic to the INTRAVAL attempts. After all, one must start somewhere and hindsight is always 20/20.

While the SNLA approach has shortcomings, it does put higher emphasis on processes which are important to safety. The strategy should be exercised over a range of performance measures and subjected to intense review by the scientific community. In this fashion the approach can be better defined.

COMMENTS ON TEST CASES

Test cases 10, 11, and 12 deal with unsaturated flow processes. Our current understanding of these processes stems from basic soil physics research which typically is conducted to depths of a few meters. In the U.S. high-level waste disposal program, we are concerned with these processes at depths of up to 750 meters. Unfortunately, there is a dearth of relevant data at these depths and the U.S. DOE program has produced and published almost no hydraulic data over the past 10 years on the unsaturated zone for the Yucca Mountain region. This adds to the difficulties in validation, i.e. a data set must first exist on which to validate conceptual processes.

The U.S. NRC, on the other hand, through their research efforts at Apache Leap and Las Cruces Trench is responsible for producing most of the unsaturated zone data available to date in the U.S. program. These data sets are made available to INTRAVAL participants. While these data are of tremendous value, they cannot compensate for the lack of data at Yucca Mountain in the DOE validation process. We remain convinced that validation is, of necessity, a site specific problem.

These unsaturated zone experiments have all had to be performed more than once, with the exception of the USGS G-Tunnel Experiment. (This experiment should have been repeated, however, the U.S. DOE decided to close G-Tunnel in order to save program dollars.) These experiments were redone, each time with a better understanding of data requirements and likely glitches. While nothing is wrong with this approach (repeatability is in fact preferable), it points out that high quality results are generally not obtained on the first run of an experiment. This is especially true of prototype testing needed to characterize unsaturated fracture flow and transport processes. Basically, we have come a long way, but we have even further to go before we can make the statement that unsaturated flow process models have been validated.

TEST CASE 10 - LAS CRUCES TRENCH

This test case is geared more to near-surface processes commonly associated with low-level waste disposal. A number of researchers are modeling the experiments performed at this site using a variety of mathematical techniques which technically range from very simple to extremely complex.

This experiment is worthwhile and has provided a number of valuable insights. First, complexities due to different radionuclide or chemical retardation values is apparent and underscores the need to develop meaningful performance measures.

Secondly, many of the simple methods have given generally comparable results to the more complex methods, though none of the modeling can be said to be perfectly representative for all performance measures. One must now ask when these results are adequate for licensing a facility. While it is of scientific interest to exactly match lateral spreading and exact concentrations with depth, the accuracy requirements depend on the problem and the timeframe of interest. These trench experiments are extremely well instrumented at very small spacings. The luxury of this much instrumentation will likely not be possible at a proposed U.S. low-level disposal site. This is because of cost and time factors related to the siting programs initiated under the U.S. Low-Level Nuclear Waste Policy Act.

TEST CASE 11 - APACHE LEAP TUFF

Test case 11 is composed of several individual experiments which are being carried out at the University of Arizona under U.S. NRC funding. These experiments cover differing scales, including laboratory, block and field scale work. Opportunities exist to examine effects of scaling. Continuation of this work, as well as additional field work, is proposed and recommended for Phase II of INTRAVAL.

1) Laboratory Tuff Core Heating Experiment - The purpose of this experiment is to evaluate the magnitude and distribution of fluids and solutes along a partially saturated tuff core. The experiment utilizes a heat source to induce flow and transport processes in a closed system.

This experiment has done a lot to further our understanding of migration of solutes under thermal conditions expected in the nearfield of a HLW repository. However, since the cores used were mostly unfractured (perhaps some microfractures were present) and the system itself is closed. The experiment should continue to be duplicated to assess effects of fracturing. A Phase II heater experiment has been proposed for the field scale. This experiment should help to clarify these fracture effects under open conditions. Validation work has proceeded well and the experiment's replicability has been established.

2) Block Scale Fractured Rock Experiment - The objective of this experiment is to characterize fluid flow and solute transport in variably saturated fractured tuff rocks. To investigate this behavior, a series of experiments has been designed to characterize the hydraulic properties of the matrix and fractures under a range of matrix suctions. The principal question is whether or not the convection-dispersion equation (Richard's equation) is valid for unsaturated tuff.

The University of Arizona is continually improving upon the experimental conditions and has overcome some early problems. This experiment will be carried forward under Phase II. It is recommended that during Phase II this experiment try to answer questions such as under what conditions does flow actually occur in the fracture.

3) Apache Leap Field Imbibition/Redistribution Experiment - The purpose of this experiment is to evaluate the magnitude and distribution of fluid flow in unsaturated fractured tuff. This experiment, conducted at the Apache Leap field site, consisted of flooding a borehole with water and monitoring water movement away from the borehole. It was expected that during the injection phase, flow would be dominated by fracture properties and during the redistribution phase, dominated by matrix properties. The experiment was to be modeled using equivalent porous media continuum models instead of the discrete fracture approach. This approach

assumes that an anisotropic tensor can be used to represent the fractured nature of the rock.

Unfortunately, this experiment had some difficulties due to the large distance between the monitoring wells and the flooded borehole. In the repeat experiment proposed for Phase II, the monitoring holes will be placed 1 meter rather than 5 meters from the flooded hole. It will also be of interest to observe if any fractures are encountered which provide direct borehole communication.

4) Field Heating Experiment - The purpose of this experiment is to evaluate the magnitude and distribution of induced fluid flow around a heat source in unsaturated fractured tuff. Since this experiment is in its planning stage, it is promising from the validation aspect. It will provide an opportunity to utilize our knowledge of validation gained in the first Phase of INTRAVAL.

TEST CASE 12 - USGS G-TUNNEL EXPERIMENT

This USGS experiment was initially designed to examine effects of wet versus dry drilling techniques on the surrounding fractured tuff rock mass. For what it was designed to do, it was informative. As a validation experiment it leaves much to be desired. It is our opinion that as a validation experiment, it was ambitious and never well posed. This is because it was not initially designed to be a validation experiment but was backfit. Frequent changes in processes professed to validated, occurred throughout the experiment. Additionally, drilling errors lead to unanticipated layout changes and experimental conditions. (Boreholes were intersected and a dry-drilled hole was flooded.)

Since this experiment cannot be replicated due to G-Tunnel closure, it will not proceed into Phase II of INTRAVAL. Therefore, not much discussion is provided herein; except to say that the State of Nevada cannot consider Test Cast 12 as a validation of unsaturated flow and transport occurring at Yucca Mountain.

CONCLUSIONS

The first Phase of INTRAVAL has made some progress toward defining what validation means but has not yet reached a consensus within the group on an exact definition. Many participants, through the analysis of test cases, are beginning to understand what validation is not (i.e., calibration) though what it is, is more elusive.

INTRAVAL did not start out with a firm game plan to develop a definition or methodology to prove that a given computer application is valid. This planning is now beginning to develop and should continue in the Phase II efforts. Therefore, at this time, the State of Nevada does not consider any of the test case work on unsaturated fractured tuff to be shown "valid", or in any way representative of flow at the Yucca Mountain Site. Several valuable lessons can be learned by the experiences to date, which should be recognized and incorporated into the HLW siting programs.

- First, process model validation must take a priority over simple documentation of code assumptions and inputs. Uncertainties of modeling unsaturated fracture flow at great depths will be dominant in the program and, therefore, basic research into our understanding of the processes must occur prior to validation. Further, without a meaningful amount of hydraulic data to analyze, little progress can be made with respect to validating Yucca Mountain flow system models.

- Second, the time frames required to conduct meaningful prototype experiments and analyze resultant data has been shown to be large. Repeatability is crucial. The timeframes required for these analyses must be longer than is currently planned in the U.S. program.

- Third, within the INTRAVAL program, the State of Nevada would like to see INTRAVAL unsaturated zone Test Cases devote more time to fracture properties when validation of flow in unsaturated fractured media is attempted. In this regard, the Apache Leap Block experiments should be repeated. Examination of matrix equilibrium assumptions which allow fracture flow only after matrix saturation should be undertaken.

- Additionally, INTRAVAL work has shown that flexibility in design and conduct of experiments is required. QA measures serving to effectively restrict this flexibility should be revised so as not to inhibit experimental flexibility.

- Lastly, due to the importance of developing meaningful performance measures, it is recommended that INTRAVAL focus considerable effort on this issue. A peer review of the total range of performance measures should be undertaken. Also, a sensitivity analyses should be performed to identify factors which contribute to uncertainty. This analysis should include such things as our ability to quantify the physical processes operational at proposed sites. If after these steps reliance on expert opinion is still required, experts must come from the broader scientific community and must not have been selected because of loyalty to one involved party.

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