D1020 PDR-1 LPDR- WM-10 (2) WM-11 (2) WM-16 (2)

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

'87 JUN 26 A9:53

June 22, 1987
Contract No. NRC-02-85-008
Fin No. D-1020
Communication No. 134

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

RE: Topical report #2

Dear Jeff:

I have enclosed a copy of our draft outline for Topical Report #2 entitled "Evaluation of Methodologies to Quantify and Reduce Uncertainty During Site Characterization in Order to Demonstrate Compliance with 10CFR60.113(a)(2): Pre-Waste Emplacement Groundwater Travel Time."

The process of developing this outline within our shop required more time than I had anticipated. I was unable to send a copy to Nuclear Waste Consultants until June 19. They have not had an adequate length of time to review the outline. This outline is forwarded to you without their concurrence. We will review their comments as soon as we receive them.

Please call if you have any questions regarding this outline.

Sincerely,

Gerry

Gerry V. Winter

8771474б

WM Project: WM-10, 11, 16 WM Record File: D1020
PDR yes LPDR yes
(Return to WM, 623-SS)

GVW:sl

enclosure

WM-RES
WM Record File D1020

WM Project 10, 11, 16
Docket No.
PDR ✓
LPDR ✓ (B, N, S)

Distribution:
Pohle

(Return to WM, 623-SS)

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TOPICAL REPORT #2
EVALUATION OF METHODOLOGIES TO QUANTIFY AND REDUCE UNCERTAINTY DURING SITE CHARACTERIZATION IN ORDER TO DEMONSTRATE COMPLIANCE WITH 10CFR60.113(a)(2): PRE-WASTE EMPLACEMENT GROUNDWATER TRAVEL TIME

DRAFT

Introduction

The purpose of this topical report is to present methodologies for quantifying and reducing uncertainty associated with the basic hydrogeologic testing procedures that are expected to be implemented at the three high level waste sites under consideration. The subject testing methodologies must consider the two groundwater flow conditions that occur at the sites. Saturated groundwater flow occurs in the basalts at the Hanford site in Washington, and in the salt sequence at the Deaf Smith County site in Texas. At this time no evidence suggests that unsaturated flow occurs within the formations of interest at either of these sites. However salt formations have not been tested during the repository site selection program. Unsaturated groundwater flow occurs in the welded tuffs at the Yucca Mountain, Nevada site. Testing methodologies that can be used to characterize unsaturated flow and concomitant coefficients are more limited in number and variability than those available for characterizing saturated flow and concomitant coefficients. The basic premises proposed for quantifying and reducing uncertainty are applicable to testing technologies for both saturated and unsaturated flow.

Under ordinary circumstances a major technique for reducing uncertainty consists of the acquisition of additional data using multiple measurements and multiple tests at equal scales. The relationship between the amount of additional data acquired and the reduction of uncertainty is not linear in most cases. In some cases a large amount of additional data may be required in order to achieve a small reduction in uncertainty for some coefficients. Additional data also help prioritize the relative importance of the uncertainties outlined in Topical Report #1.

Examples cited in the following outline are not intended to be complete. It is not the intent of this outline to present all possible examples.

Professional judgment plays a major role throughout the processes of test design, data collection and data interpretation, and in the prediction of groundwater travel time. While this outline suggests that statistical and geostatistical methods should be used to help reduce and quantify uncertainty, professional judgment is required to create a valid data base, to implement the application of defensible statistical methods to that data base and to interpret their results.

It should be noted that each of the topics discussed herein requires the existence of a valid, reliable quality assurance program. Each discussion is presented on the assumption that a reliable QA program exists at each appropriate step in the data collection or analysis procedure. Valid, reliable QA programs are prerequisite to the minimization of uncertainty.

Three major divisions are used in the following outline. These divisions are: 1. Conceptual hydrogeologic model(s), 2. Collection and adjustment of field and laboratory data for factors such as salinity and temperature differences, 3. Derivation of coefficients, and 4. Quantification of conceptual hydrogeologic model(s).

Testing Methodologies and Methods to Quantify and Reduce Uncertainty

1. Conceptual hydrogeologic model(s)

   1.1. Summary of procedures: Conceptual models must be developed for various purposes such as hydrogeologic testing and predicting groundwater travel time. Apply an iterative procedure to this analysis.

   1.2. Reduction of uncertainty

      1.2.1. Use panels of experts to identify all valid conceptual models using the same data bases.

      1.2.2. Select conceptual models that are valid with respect to the data base that exists at the time of the evaluation. Eliminate all unreasonable conceptual models

      1.2.3. Test the selected conceptual models for internal consistency (i.e., is the value of hydraulic conductivity reasonable with respect to the value of effective porosity derived in the evaluation process)

      1.2.4. Rank the remaining conceptual models in the order of their probability of occurrence according to the professional judgment of the panel of experts.

2. Collection and adjustment of field and laboratory data

   2.1. Hydraulic head

      2.1.1. Summary of procedures: Head data must be collected for the various purposes for which it is required, including the determination of the direction of groundwater flow, the magnitude of the hydraulic gradient, and the calculation of hydrogeologic coefficients. Head data are collected by steel tape measurements (surveyors), M-scope measurements (electric tape), float actuated recorder measurements, and pressure transducer measurements. Data are corrected for variable fluid densities using analytical techniques or numerical mathematical models. Ranges of values for point source head measurements must be developed.

2.1.2. Quantification and reduction of uncertainty in head data

2.1.2.1. An appropriate QA plan must be implemented to ensure the validity of the head and pressure measurements (i.e., piezometer seals must be tested, transducers and other measuring devices calibrated). Uncertainty in head measurements is reduced by monitoring discrete intervals that are selected using professional judgment.

2.1.2.2. Use multiple methods to measure head or pressure. Compare the sets of data statistically.

2.1.2.3. Take repeated measurements of head or pressure in each piezometer using a single, calibrated measurement device. Calculate mean and variance; use variance as an index of uncertainty.

2.1.2.4. Compare point values of head on a temporal basis as part of the procedures required to establish baseline and pretest trends. Temporal head data are required for the derivation of certain hydrogeologic coefficients (i.e., transmissivity, storativity, and leakance).

2.1.2.5. Ascertain by professional judgment the validity of the analytical or numerical adjustments applied to density calculations.

2.1.2.6. Resulting maps of head distributions within or among identified hydrostratigraphic units or zones should be prepared and analyzed statistically for quantification of error.

2.1.2.7. Measure head in a sufficient number of piezometers to represent the three-dimensional distribution of head spatially. Geostatistical methods should be used to determine number of piezometers required to delineate the distribution of head.

2.1.2.8. Check results for compatability with conceptual model(s).

2.2. In situ moisture tension

2.2.1. Summary of procedures: Data are collected for various purposes including delineation of potential flow paths in the unsaturated zone and predicting travel times in the unsaturated zone. Data are collected using psychrometers (high moisture tensions) and tensiometers (low moisture tensions). Ranges of values are derived for each measuring point.

2.2.2. Quantification and reduction of uncertainty

2.2.2.1. Install and monitor sufficient number of psychrometers and/or tensiometers to obtain the true three-dimensional distribution of in situ moisture tensions. Professional judgment, along with geostatistical methods, must be relied upon to minimize uncertainty.

2.2.2.2. Install and monitor some paired installations of psychrometers or tensiometers; paired installations should be installed because of the difficulty in obtaining consistent and reliable data from these devices under the conditions anticipated at Yucca Mountain; the number of paired installations should be a fixed percentage of the total number of installations. Professional judgment is required to determine the value of the fixed percentage. Statistical analysis of paired data will quantify uncertainty.

2.2.2.3. Statistical procedures can be utilized to quantify the error in the resulting data base.

2.3. Steady or unsteady state flow in the unsaturated zone

2.3.1. Summary of procedures: Data are collected for several purposes but primarily to determine whether episodic pulses of infiltration will produce steady or unsteady state flow in the unsaturated zone. Data are collected using large scale infiltration tests with multiple installations of instrumentation at appropriate depths (based on professional judgment about fractured rock) at multiple locations within the expected areal bounds of a large scale infiltration test

2.3.2. Quantification and reduction of uncertainty

2.3.2.1. To the extent possible conduct a testing program that facilitates statistical analysis of flow in the unsaturated zone.

2.3.2.2. Conduct two large scale infiltration tests at adjacent test locations at each test site on Yucca Mountain using identical experimental test design emplacement procedures; tests must be conducted contemporaneously at same scale. Calculate mean and variance of results of pairs of data. Use variance to quantify uncertainty.

2.3.2.3. Conduct additional tests at adjacent locations at the same scale if results of first test indicate that additional tests are needed. Compare test results statistically to quantify uncertainty.

2.3.2.4. Conduct additional tests at different rates of application determined from the results of the first tests. Compare results statistically.

2.3.2.5. Error in the test results can be quantified by analyzing the test results statistically. Quantification of uncertainty must be accomplished with professional judgment if the resulting data base is inadequate for spatial statistical techniques.

2.4. Aquifer samples (core)

2.4.1. Summary of procedures: Cores are collected for various purposes including measurement of hydraulic conductivity, porosity, moisture content, moisture tension, and for evaluating or developing conceptual models.

2.4.2. Cores are collected under in situ conditions. However it should be noted that most cores experience property changes upon removal from their in situ stress environment.

2.4.3. Quantification and reduction of uncertainty

2.4.3.1. Sufficient cores of equal scale must be obtained to represent spatially the three-dimensional distribution of the coefficient(s) being measured and their compatability with the alternative conceptual models. Professional judgment is unavoidable. Statistical analyses should be used to quantify spatial uncertainty among and within hydrostratigraphic units or zones. Quantification of uncertainty must be accomplished with professional judgment if the resulting data base is inadequate for spatial statistical techniques.

2.4.3.2. Multiple samples of selected core from the same unit should be used in the test procedures selected for quantifying specific coefficients. QA procedures should include retesting selected core.

2.4.3.3. Results can be analyzed statistically in order to quantify error.

2.5. Laboratory measurement of hydraulic properties of cores.

2.5.1. Summary of procedures: Data are collected for various reasons including the measurement of effective hydraulic conductivity, porosity, moisture tension, moisture content, and other hydraulic properties. Measurements are made on cores. Measurements are corrected for variable fluid properties (density and surface tension).

2.5.2. Quantification and reduction of uncertainty. Uncertainty can be minimized by applying the aforementioned QA program to cores and by performing duplicate tests where possible. If professional judgment results in a sufficient number of measurements error should be quantified by statistical analysis of results.

2.6. Hydrochemistry and isotopic characteristics.

2.6.1. Summary of procedures: Data are collected for various purposes including delineation of groundwater flow systems and age dating. Appropriate sampling methodologies should be used for data collected at both in situ conditions and at the ground surface. Data are compared for differences between in situ and ground surface conditions and various chemical and isotopic conditions.

2.6.2. Quantification and reduction of uncertainty. Multiple samples can be collected from same piezometers. Mean and variance can be calculated and used to quantify uncertainty. Run multiple samples through laboratory test procedures. Compare results statistically. Statistical analyses of data among different piezometers in different units can be conducted to compare units. Geostatistical methods can be used to quantify uncertainty within or among units or zones on a spatial basis. Professional judgment should be used to formulate statistical analyses and to evaluate results for compatability with conceptual model(s).

3. Derivation of coefficients.

3.1. Transmissivity.

3.1.1. Summary of procedures: Use conceptual models to develop appropriate test designs. Attempt multiple analytical solutions; select most defensible by professional judgment. Attempt inverse modeling methodologies. Develop ranges of values of coefficients.

3.1.2. Quantification and reduction of uncertainty.

3.1.2.1. Conduct sufficient number of tests, at equivalent scales, to represent spatially the distribution of transmissivity. Have same data sets reviewed by panels of experts. Apply geostatistical analysis to quantify error and uncertainty.

3.1.2.2. Conduct additional tests (possibly at different scales) if expert panel judgment and geostatistical procedure indicates uncertainty is unacceptably large; decision to conduct these tests is based on evaluation of first tests. Repeat expert panel analysis and geostatistical quantification procedure.

3.2. Hydraulic conductivity.

3.2.1. Summary of procedures: Hydraulic conductivity is calculated from transmissivity by quantifying the thickness of the strata contributing to flow. Develop conceptual models and run multiple trace ejector tests to quantify the effective producing thickness of the test interval for which transmissivity has been quantified. Interpret and evaluate data that quantify effective thickness of producing zone(s) and transmissivity. Have data sets reviewed by panels of experts. Develop range(s) of values.

3.2.2. Quantification and reduction of uncertainty.

3.2.2.1. If possible, run multiple trace ejector tests to quantify the producing thickness.

3.2.2.2. Conduct trace ejector test at multiple discharge (pumping) rates from well.

3.2.2.3. Professional judgment must be relied upon to quantify uncertainty. Geostatistical analysis may or may not be feasible for quantification of uncertainty.

3.2.2.4. Use panel of experts to evaluate results with conceptual model.

3.3. Effective porosity and dispersivity (tracer tests).

3.3.1. Summary of procedures: Apply conceptual models and appropriate multiple test design features among tests. Attempt multiple analytical or numerical techniques for analysis of tracer test data. Develop range(s) of values of effective porosity and dispersivity.

3.3.2. Quantification and reduction of uncertainty.

3.3.2.1. Conduct the same test using different stresses (induced gradients). Compare results.

3.3.2.2. Have same data set reviewed by panels of experts. Statistical analysis may or may not be applicable. Sample size should be as large as possible.

3.3.3.3. Compare results to conceptual

model(s).

3.4. Hydrogeologic boundaries.

3.4.1. Summary of procedures: Apply conceptual models and appropriate test designs. Large scale tests using multiple observation wells are required for detecting and locating hydrogeologic boundaries. Attempt multiple analytical and numerical techniques where possible. Develop alternative interpretations of the nature and location of boundaries.

3.4.2. Quantification and reduction of uncertainty.

3.4.2.1. Conduct tests at multiple locations for boundary analysis.

3.4.2.2. Have same data set reviewed by several panels of experts. Statistical analysis is not appropriate.

3.4.2.3. Compare results to conceptual model(s).

4. Quantification of conceptual hydrogeologic model(s).

4.1. Introduction: The conceptual model(s) must be transformed into a mathematical format that allows calculation of ground water travel time. The data input into the conceptual model must consider the results of the panels of experts and the statistical nature of the information compiled from testing.