CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: DOE/NRC Technical Exchange on Unsaturated Zone Flow and Transport (20.01402.861)

DATE/PLACE: August 15–16, 2000,
Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA

AUTHORS: James Winterle

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PERSONS PRESENT:

CNWRA participants were J. Winterle, D. Hughson, R. Fedors, and L. McKague. The NRC was represented by C.W. Reamer, J. Anderson, N. Coleman, and B. Leslie.

BACKGROUND AND PURPOSE OF TRIP:

The purpose of this technical exchange was to identify needs for additional data or information necessary for resolution of subissues of the Key Technical Issue (KTI) on Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) that are related to unsaturated zone (UZ) flow and transport. Specifically, the subissues addressed at this exchange included: Climate Change, Hydrologic Effects of Climate Change, Present-Day Shallow Infiltration, Deep Percolation, and Matrix Diffusion (UZ portion only).

SUMMARY OF ACTIVITIES:

For each of the subissues identified above, a portion of the technical exchange was devoted to presentation of site data, conceptual models, and methodology by knowledgeable members of the DOE Yucca Mountain Project (YMP) staff and YMP contractor agencies (e.g., LBNL, U.S. Geological Survey, and Sandia National Laboratories). During and following the DOE presentations, NRC and CNWRA staff were afforded ample opportunities to ask detailed technical questions and discuss alternative conceptual models and data interpretations. These discussions were followed by NRC/CNWRA caucus sessions to evaluate what additional data or analyses might be required to close each subissue. At the end of each of the two meeting days, some time was allotted for questions by meeting observers—representatives from the State of Nevada, Nye County, and the Nuclear Waste Technical Review Board, for example.

The end result of the technical exchange is that the two subissues on Climate Change remain closed; the Shallow Infiltration subissue has been reopened; and the Deep Percolation subissue and UZ portion of the Matrix Diffusion subissue are closed, pending review of additional data and analyses.

A more in-depth description of the technical discussions and the agreements reached between NRC and DOE can be found in the attached meeting minutes (Attachment 1) and Summary of Resolution of the USFIC KTI (Attachment 2). Note that not all of the attachments referred to in the meeting minutes are provided (presentation slides, etc.); they can, however, be obtained from the author upon request.

PROBLEMS ENCOUNTERED:

A recurring question that was not fully addressed at this technical exchange can be summarized as follows. When assessing whether a particular feature or process of the natural system has been adequately characterized, relative to its importance to performance, what assumptions should be made regarding the performance of the engineered barrier system? For example, a Total System Performance Analysis sensitivity analysis was presented by DOE showing that a significant increase in the fraction of wetted waste packages has a minimal effect on repository performance over a 100,000 yr period. The conclusion from this analysis, however, was strongly influenced by the assumption that waste packages and drip shields perform as advertised. While it may be unrealistic to presume total failure of an engineered barrier, it is not possible to assess the degree of credit taken for natural system features and processes without somehow "underperforming" the engineered barriers. Many of the path to resolution agreements between NRC and DOE that followed this technical exchange were phrased to the effect that DOE should provide certain data or analyses, or "justify that [they] are not needed." Presumably, such justification would be a repository performance sensitivity analysis. This is likely to be a recurring path to issue resolution for other KTIs. Thus a decision needs to be made regarding what assumptions should be made regarding engineered barrier performance when assessing relative importance of natural system features and processes.

PENDING ACTIONS:

See meeting minutes (Attachment 1).

RECOMMENDATIONS:

This was the first technical exchange in a series focused on issue closure. To aid others in preparation for upcoming technical exchanges, a summary of lessons learned, prepared by J. Anderson of NRC, is also provided in Attachment 3.

SIGNATURES:

James Winterle
Geohydrology and Geochemistry

8/28/2000
Date

CONCURRENCE:

English C. Pearcy
Manager, Geohydrology and Geochemistry

8/28/2000
Date

Budhi Sagar
Technical Director

8/28/2000
Date

ATTACHMENT 1
Meeting Minutes

ATTACHMENT 1
Meeting Minutes

Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Unsaturated and Saturated Flow Under Isothermal Conditions

August 16-17, 2000
Berkeley, California

Introduction and Objectives

This Technical Exchange and Management meeting on Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review and the U.S. Department of Energy (DOE) site recommendation decision. Consistent with NRC regulations on prelicensing consultations and a 1992 agreement with DOE, staff-level resolution can be achieved during prelicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket the license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level during prelicensing is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. Pertinent additional information could raise new questions or comments regarding a previously resolved issue.

Issues are "closed" if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in the license application.

The objective of this meeting is to discuss and review the progress on resolving unsaturated zone issues under the USFIC KTI (see Attachment 1 for list of subissues). The quality assurance (QA) aspect of this KTI was determined to be outside the scope of the meeting and will be tracked in NRC's ongoing review of DOE's QA program.

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, the NRC staff agreed with DOE that subissue 1 and 2 are still closed. Subissue 3 is open. Subissues 4 and 6 (UZ portion) are closed-pending. Subissue 5, which relates to the saturated zone (SZ) and Subissue 6 (SZ portion) will be discussed in an upcoming KTI technical exchange and management meeting.

Specific NRC/DOE agreements made at the meeting are provided as Attachment 1. The DOE Action Plan for Net Infiltration Issues is included as Attachment 2. The DOE ongoing and planned testing synopsis (Testing and Modeling Activity Description) is provided as Attachment 3. The

agenda and the attendance list are provided as Attachments 4 and 5, respectively. Copies of the presenters' slides are provided as Attachment 6. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Technical Discussion of Climate Change and Hydrologic Effects of Climate Change

Climate Change Subissue

A summary of the current status of resolution was presented (see attachment on "Unsaturated Zone (UZ) Flow Under Isothermal Conditions" by Claudia Newbury). There are six acceptance criteria; five of which are considered closed both in the NRC USFIC Issue Resolution Status Report (IRSR) and by the DOE. The sixth acceptance criterion pertains to QA and was determined to be outside the scope of the meeting and will be tracked in NRC's ongoing review of DOE's QA program. DOE presented its current approach to climate change (see attachment on "Unsaturated Zone (UZ) Flow Under Isothermal Conditions: Climate Change and Hydrologic Effects" by Claudia Newbury). DOE's approach to future climate for the Site Recommendation (SR) is based on paleoclimate data. No expert elicitation will be used and no additional work is planned for a potential License Application (LA). They use three future climate states (i.e., modern, monsoon, and glacial transition) based on analog climate sites. The DOE SR approach is different than that used in their Viability Assessment (VA), but is acceptable. Questions by Center for Nuclear Waste Regulatory Analyses (CNWRA) and NRC staff focused on predictions of climate states and the infiltration used for periods beyond 10,000 years. A glacial transition is assumed after 2000 years from present. NRC staff concluded that they had no further questions and that the subissue remains closed.

Hydrologic Effects of Climate Change

A summary of the current status of resolution was presented (see attachment on "Unsaturated Zone (UZ) Flow Under Isothermal Conditions" by Claudia Newbury). There are five acceptance criteria; four of which are considered closed both in the NRC USFIC IRSR and by DOE. The fifth acceptance criterion pertains to QA and was determined to be outside the scope of the meeting and will be tracked in NRC's ongoing review of DOE's QA program. DOE presented its current approach to hydrologic effects on climate change (see attachment on "Unsaturated Zone (UZ) Flow Under Isothermal Conditions: Climate Change and Hydrologic Effects" by Claudia Newbury). DOE's SR approach assumes a rise in the water table of 120 meters [(documented in the Unsaturated Zone Process Model Report (PMR)]. No expert elicitation will be used and no additional work is planned for a potential LA. NRC staff indicated that information obtained from the Nye County wells suggests that DOE's approach is acceptable, but conservative. NRC staff concluded that they had no further questions and that the subissue remains closed.

2) Technical Discussion of Present-Day Shallow Infiltration

A summary of the current status of resolution was presented (see attachment on "Unsaturated Zone (UZ) Flow Under Isothermal Conditions" by Claudia Newbury). There are six acceptance criteria; five of which were previously considered closed by both NRC and DOE. The sixth acceptance criterion pertains to QA and was determined to be outside the scope of the meeting and will be

tracked in NRC's ongoing review of DOE's QA program. Although DOE proposed that the subissue should remain closed, their estimates of shallow infiltration have been revised downward since TSPA-VA, thus prompting NRC to reexamine the status of resolution. In addition to discussing the acceptance criteria DOE indicated that NRC still had questions. DOE presented its current approach to estimating shallow infiltration for present and future climate conditions (see attachment on "Estimated Shallow Infiltration..." by Joe Hevesi). NRC staff expressed concern that DOE upper-bound estimates of shallow infiltration for present and future climates may not be high enough to encompass the uncertainty inherent in the many infiltration model parameters and assumptions. NRC staff indicated that one acceptable approach would be to perform Monte Carlo analyses, similar to that performed for the glacial transition climate in the Analysis of Infiltration Uncertainty AMR (ANL-NBS-HS-000027), and base upper-bound infiltration estimates for each climate state on, for example, the upper 90th percentile. DOE staff proposed that another acceptable approach would be to provide additional model validation through an analysis of site geochemical, isotopic, and borehole temperature data. At the end of the meeting, DOE provided an Action Plan for the open net infiltration issues (See Attachment 2). The NRC stated that the subissue remains open pending its review of a DOE plan and schedule that provides additional justification that the proposed infiltration values are appropriate. This plan is to be provided during October 2000. The NRC also stated that, if the DOE approach is acceptable, this subissue will be considered as closed- pending at the November 2000 saturated zone meeting.

3) Technical Discussion of Matrix Diffusion

A summary of the current status of resolution was presented (see attachment on "Unsaturated Zone (UZ) Flow Under Isothermal Conditions" by Claudia Newbury). Currently NRC considers the subissue open and DOE proposed that the subissue should be closed "pending." There are four acceptance criteria; one of which is considered closed both in the NRC USFIC IRSR and by DOE. One acceptance criterion relates to the saturated zone and is not applicable to this meeting. The third acceptance criterion requires that if credit is taken for matrix diffusion then the transport predictions must be consistent with site geochemical and isotopic data. The fourth acceptance criterion pertains to QA and was determined to be outside the scope of the meeting and will be tracked in NRC's ongoing review of DOE's QA program. In addition to discussing the acceptance criteria DOE indicated that NRC still had three questions regarding matrix diffusion. DOE presented evidence to support its current approach to matrix diffusion (see attachment on "Matrix Diffusion" by Clifford Ho). Data from the Alcove 1 seepage experiments were presented with the conclusion that observed breakthrough of the bromide tracer was difficult to explain without assuming a relatively high rate of matrix diffusion (i.e., effective matrix diffusion coefficient of $2 \times 10^{-9} m^2/s$). It should be noted that the bromide breakthrough data available for review in the supporting AMR (MDL-NBS-HS-000006) consisted of only two data points representing the only very early part of the tracer breakthrough curve. However, Hui Hai Liu presented recent data and model results covering a two-year time period that yielded a similar conclusion. Data and model results were also presented by DOE that showed the conceptual model of matrix diffusion in the UZ is not inconsistent with observations of chloride concentration in matrix pore waters in the ESF and ECRB. DOE also presented plans for additional testing specifically designed to validate the matrix diffusion conceptual model wherein tracers will be introduced into ECRB Alcove 8 and monitored 20 m below in ESF Niche 3. NRC staff concluded that this subissue could be considered "closed, pending" if the DOE could agree to (i) provide an analysis with the Site Recommendation showing TSPA model sensitivity to matrix diffusion in the UZ, (ii) provide for NRC comment a work plan for the Alcove

8/Niche 3 study, and (iii) document results of the Alcove 8/Niche 3 study pertaining to matrix diffusion in AMR or other DOE-approved document.

4) Technical Discussion of Deep Percolation - UZ Flow and Transport Beneath the Repository

A summary of the current status of resolution was given in two presentations (see attachments on "Discussion of Deep Percolation - Seepage Into Drifts" by Joe Wang and "Discussion of Deep Percolation - Unsaturated Zone Flow" by Bo Bodvarsson). Currently NRC considers the subissue open and DOE proposed that the subissue should be closed-pending. There are six acceptance criteria; one of which is considered closed both in the NRC USFIC IRSR and by DOE. The sixth acceptance criterion pertains to QA and was determined to be outside the scope of the meeting and will be tracked in NRC's ongoing review of DOE's QA program.

Seepage Into Drifts

The DOE presented the ongoing and planned testing and modeling activities to evaluate seepage into drifts (Slide #2). In addition to discussing the acceptance criteria DOE indicated that NRC still had a number of questions in this area. The DOE then discussed the ongoing passive monitoring and active seepage characterizations. Questions by CNWRA and NRC staff focused on the east-west drift and the need for the drift to equilibrate to pre-ventilation conditions. The NRC staff indicated one reason to continue the passive monitoring, including a drip cloth, is that this approach would allow for an evaluation of the alternate conceptual model of film flow leading to dripping under low flux conditions. The next point addressed was the need to demonstrate for all niche and alcove hydraulic tests that ventilation has not biased the test results. Details on niche studies which attempt to overcome ventilation effects were discussed. The relative importance of micro-fractures on matrix porosity interpretations and concepts of flow was presented by M. Morganstern (Consultant to Nye County). The importance of measuring effects of ventilation in all testing, as is now being conducted in some tests, was mentioned by NRC staff. The use of natural analogs to support short term predictions of long-term seepage estimates was addressed. Finally, results from recent testing in the lower lithophysal unit indicate that the unit has stronger capillarity and higher permeability than middle nonlithophysal tuff. Detailed fracture surveys, where the cutoff for mapping features was 10 cm, support the measured permeability. As a result of measured hydrologic characteristics the predicted seepage threshold for the lithophysal unit is higher than in other units. The next point of discussion was evaluation of the steady-state deep percolation assumption. Information on seepage calibration models matching a sequence of pulses was offered as one line of evidence that the effects are already considered. The importance of the Paintbrush Tuff non-welded unit in damping transient effects was also offered as a line of evidence why transient effects do not need to be considered. NRC staff pointed out the importance of potential high angle fault features that intersect the unit as a way to bypass the dampening effect. In addition, preliminary results by CNWRA staff applying the approach used in the Technical Basis Document for the Viability Assessment indicated that transient effects may not be completely dampened. The next point discussed was the analysis of alternate scenarios of waste-package or drip shield wetting over the performance period. DOE indicated that alternative scenarios are being performed for the TSPA-SR. The final point of discussion was that the effect of drift collapse on seepage rates should account for the scale of asperities in drift geometry caused by rockfall. Information was provided that the effects of both rockfall and drift collapse are being evaluated. CNWRA staff stressed that the scale of those studies is not sufficiently small to address the technical concern. Scales

comparable to the inverse van Genuchten alpha parameter are appropriate, so that seepage would not be under-predicted for small scale asperities. During the summary of this topic the importance of the discrepancy between the observation of secondary mineralization in lithophysal cavities at fluxes below the seepage threshold was discussed. The CNWRA staff suggested that this was evidence for the alternate conceptual model of film flow under low flux conditions and this line of evidence of alternate approach needs to be reconciled.

Unsaturated Zone Flow

The importance of the calibrated properties model to derive parameter sensitivities and uncertainties used in modeling unsaturated flow fields was presented. The chloride and temperature calibrations were described as important constraints on infiltration rates. Perched water calibrations were addressed. The water potential data from the cross-drift was presented. Discussion of the information focused on how different conceptual models of flow (dual permeability and the active-fracture) might lead to different interpretations for matrix saturations. Additional information on the effective damping of episodic transient pulses of surface infiltration was presented and the importance of varying properties sets was discussed. The CNWRA reservations on transient events, presented in the previous discussion on the seepage, were re-iterated. Flow patterns and lateral diversion in the Calico Hills non-welded unit was the next point of discussion. The average quantity of water laterally diverted in DOE models which would then flow down faults and bypass sorptive units was presented. The average value was 50 percent for glacial transition conditions and a lower percent under current climate conditions. CNWRA staff indicated that information only on averages for the whole model was insufficient to assess the current approach. The fraction of diversion under the repository and ranges of diversion in different portions of the model was necessary for the CNWRA assessment. The amount of credit for retardation of radionuclide transport was stated to be highest for the lowest Topopah Spring unit, less for the vitric non-welded portion of the Calico Hills, and still less for the zeolitic Calico Hills unit. CNWRA staff indicated that the information on the geochemistry of perched water, and the pore water adjacent to the perched zones, was not addressed in the presentation and may not be in an analysis and model report (AMR). NRC staff stated that this information is needed to complete their assessment of DOE's approach for flow beneath the repository. The NRC staff stated that the subissue is closed-pending if the DOE would agree to the items listed in Attachment 1.

5) Update on Features, Events and Processes (FEPs).

The DOE stated that it was revising the FEPs AMR and would have it completed by December 2000. Following the FEPs AMR revision, the DOE stated that it would revise the FEPs database. The DOE also stated that it was developing a FEPs cross-walk between the UZ FEPs and the USFIC KTI.

The NRC staff stated that two specific FEPs may need to be added to the list of FEPs considered by DOE. Linda Lehman's (consultant to State of Nevada) discussion of the potential for lateral flow in the Topopah Spring tuff resulting from infiltration along the eastern side of the Solitario Canyon Fault is one FEP that should be considered. The other FEP that DOE needs to consider concerns the potential for film flow occurring under low flux rates (see item number 2 under subissue 4 in Attachment 1).

C. William Reamer
Deputy Director
Division of Waste Management

Nuclear Regulatory Commission

Dennis R. Williams
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Office of Licensing &
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Attachment 1

ATTACHMENT 2

Summary of Resolution of the USFIC KTI

Summary of the Resolution of the Key Technical Issue on Unsaturated and Saturated Flow Under Isothermal Conditions

Subissue #	Subissue Title	Status	NRC/DOE Agreements
1	Climate Change	Closed	None
2	Hydrologic Effects of Climate Change	Closed	None
3	Present-Day Shallow Infiltration	Open	See attached DOE Action Plan for Net Infiltration Issues (Attachment 2)
4	Deep Percolation	Closed-Pending	1) The on-going and planned testing (see Attachment 3) are a reasonable approach for a licensing application with the following comments: a. For Alcove 8, Niche 3, consider a mass balance of water. b. Monitor evaporation during all testing. c. Provide testing plans and consider NRC comments, if any. 2) Include the effect of the low-flow regime processes (e.g., film flow) in DOE's seepage fraction and seepage flow, or justify that it is not needed. 3) When conducting seepage studies, consider smaller scale tunnel irregularities in drift collapse or justify that it is not needed. 4) Provide final documentation for the effectiveness of the PTn to dampen episodic flow, including reconciling the differences in chloride-36 studies. 5) Provide the analysis of geochemical data used for support of the flow field below the repository.

Attachment 2

5	Saturated Zone Ambient Flow Conditions and Dilution Processes	Open - See Note 1	TBD - See Note 1
6	Matrix Diffusion (UZ) Matrix Diffusion (SZ) See Note 1	Closed-Pending Open - See Note 1	1) The DOE will provide the final sensitivity analysis on matrix diffusion in the TSPA-SR, Rev. 0. Due Date: December 2000 2) The DOE will provide the final detailed testing plan for Alcove 8. The testing plan will be provided by August 28, 2000. The NRC staff will provide comments if any no later than two weeks after receiving the testing plan. 3) The DOE will complete the Alcove 8 testing, taking into consideration the NRC staff comments if any, and document the results in a DOE-approved AMR, due date: May 2001. TBD - See Note 1

Note 1 - Saturate Zone Ambient Flow Conditions and Dilution Processes (Subissues 5 & 6) were not addressed at this meeting and will be addressed in a future meeting.

ATTACHMENT 3

Summary of Lessons Learned from USFIC Technical Exchange

Lessons Learned From
USFIC Technical Exchange

The following are some general comments on the lessons learned from the USFIC technical exchange meeting for your consideration. The comments are not in order of significance and are not meant as things that must be done.

1) Time at the end of the meeting needs to be set aside for completing the meeting summary, and for review by both the NRC and DOE managers who will sign the meeting summary. It should take approximately two hours if topics have already been summarized for the previous days topics.

2) Having someone dedicated to taking detailed notes and preparing a summary of each session proved beneficial to getting the meeting summary completed efficiently. During the USFIC meeting both the staff and Center did this for certain topics.

3) The NRC and Center took about 45 minutes to an hour caucusing after each subissue discussion to determine what information was necessary for DOE to agree to that would allow us to go to closed-pending. This should be factored into meeting agendas.

4) Giving DOE the areas we had concerns with ahead of time helped focus the DOE presentation. Try to be as specific as possible.

5) If in the pre-conference phone calls DOE states that they will convince us at the meeting, they probably will stick to the same approach we had concerns about prior to the meeting. It may be beneficial to ask if they will present new information (why can't they discuss it during the pre-conference calls) or information already provided. The latter may lead to a problem in resolving the issue at the meeting.

6) As early as possible, obtain a list of DOE staff and contractors who will be attending the meeting. This may help the staff in assuring that people most knowledgeable about the issues will be there to discuss them.

7) Provide handouts to headquarters staff who will be on the bridge line (if possible).

8) Prior to the meeting, determine logistical needs for the preparation of the meeting summary (laptops - should probably have a backup; access to a printer; access to a copier).

Attachment 3