

**PHASE I REVIEW: DIFFUSION TESTS IN THE  
EXPLORATORY STUDIES FACILITY  
(STUDY PLAN 8.3.1.2.2.5, Revision 0)**

by

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**Introduction**

The stated purpose of the DOE "Study Plan 8.3.1.2.2.5, Revision 0, titled "Diffusion Tests in the Exploratory Studies Facility", is to investigate the ability of diffusion to reduce the rate of ground water radionuclide transport from the repository through the unsaturated zone to the underlying water table or to the surface. Data from this study will help to compute retardation due to the diffusion of radioactive waste species such as  $^{99}\text{Tc}$  and  $^{129}\text{I}$ . In conjunction with tuff sample laboratory measurements of diffusion (Study Plan 8.3.1.3.6.2), these data will also help to define the statistical basis for the diffusion parameters used in performance assessment modeling.

The diffusion tests will use in situ testing to determine the extent to which nonsorbing tracers diffuse into the water-filled pores of the Topopah Spring welded unit and the vitric and zeolitic zones of the Calico Hills nonwelded unit. In the Exploratory Study Facility plans, each diffusion test will be performed in an alcove (approximately 6 x 6 m) in the exploratory drifts of the Topopah Springs unit and the Calico Hills unit. From boreholes drilled in the alcoves, tracers will be introduced and permitted to diffuse into the rock. At the end of the test, emplacement locations will be over cored, and tracer concentrations will be measured.

One test interference effect not considered by this study plan is the potential for exploratory drifts to influence the results of diffusion testing by drying the rock. By referencing calculations in Sobolik, 1991, the

staff was able to reach a conclusion that there would probably be no measurable drying effects on this experiment. However, should this study be sensitive to moisture contents, the design of the experiment may need to be reconsidered as improved predictions of Exploratory Study Facility drying effects are completed, or changes occur to Exploratory Study Facility design and scheduling.

In conducting this review the NRC staff did not identify an "objection" level concern. However, in making this determination the staff did not consider test interference and repository performance impacts from the construction of exploratory tunnels in the Topopah Springs unit or the Calico Hills unit. It is anticipated that the DOE will consider these effects in it's on going evaluation of characterization activities and that the NRC staff will review against these potential concerns when the DOE has identified an exploratory facilities design and conducted an analysis of how the design meets relevant 10 CFR 60 regulations.

This study plan is a candidate for a detailed technical review based on criteria 1 and 3 from step 6 of part 4.2 of the Review Plan. This review has shown that the study plan is related to one or more key site related issues and references many prototype tests.

This Phase I review of the study plan was done with respect to  
(A) DOE/NRC agreement on the content of study plans;  
(B) identification of objections; (C) closure of NRC open Items; and  
(D) the need for a Detailed Review (See Review plan for NRC staff review of DOE study plans, revision I, 12/6/90).

Evaluation of Study Plans Relative to the Agreement and to the Responsible DOE Contractors QA Program (Objectives 1 and 5)

Criterion 1 The content of the study plan under review is reasonably consistent, as appropriate for the activities, tests and analyses described, with the Agreement (NRC-DOE meeting on the level of detail for site characterization plans (SCP) and study plans, May 7-8, 1986).

Staff Review

Attached is an itemized checklist (Attachment A) of the study plan content as compared to the agreement on content resulting from the NRC/DOE level of detail meeting. In general, the content of the study plan is reasonably consistent with the agreement. However, the details of the tests are contained in technical procedures which were not provided as part of the study plan. Further, many of these technical procedures have not as yet been written. Out of 13 technical procedures identified in the report, 11 of the procedures have yet to be developed. Specific dates are not included in this study plan, because it depends upon the Exploratory Studies Facility construction schedule, which has been revised from that originally stated in the Site Characterization Plan.

It should also be noted that for each type of test the study plan did not indicate the level of QA and provide the rationale for any tests that are not QA level one. Further the study plan did not reference the applicable specific QA requirements applied to the test or the levels of QA applied to each type of analysis. The reason for this is that a determination of the quality status for the activities of this study will be made separately, according to AP-6.17Q, "Determination of the Importance of Items and Activities", which implements NUREG-1318, "Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance Requirements ." The results of that determination will be contained in the Q-List, Quality Activities List and non-Selection Record, which will be controlled documents. Furthermore, QA grading packages for the activities of this study plan will be prepared separately, according to AP-5.28Q, "Quality Assurance Grading". The resultant Quality Assurance Grading Report will be issued as a controlled document.

**Criterion 2** All study plan references have been provided when the study plan was issued.

#### **Staff Review**

All study plan references are readily obtainable by the U.S. NRC library.

**Criterion 3** Open items relative to the QA program of the DOE contractor responsible for the study plan that could call into question the quality of the study plan, have been resolved.

**Staff Review**

Based on a note from John Buckley, Quality Assurance Section, to Charlotte Abrams, Repository Licensing and Quality Assurance Project Directorate, dated 08/06/92, there are currently no open quality assurance items that would call into question the quality of the investigation to be conducted under this study plan.

**Identification of Objections (objectives 2 through 6)**

**Staff Review**

In conducting this review the NRC staff did not identify an "objection" level concern. However, in making this determination the staff did not consider test interference and repository performance impacts from the construction of exploratory tunnels in the Topopah Springs unit or the Calico Hills unit. It is anticipated that the DOE will consider these effects in it's on going evaluation of characterization activities and that the NRC staff will review against these potential concerns when the DOE has identified an exploratory facilities design and conducted an analysis of how the design meets relevant 10 CFR 60 regulations.

**Criterion 1** Potential adverse effects on repository performance:

**Staff Review**

The potential impacts on the site from the diffusion tests are of a local scale. Physical impacts include the construction of alcoves at three locations (Topopah Spring Member tuff and the vitric and zeolitic zones of the Calico Hills unit) in the Exploratory Studies Facility. Core holes drilled in the alcoves will be approximately 10 m deep and 0.3 m in diameter. No hydrologic impacts will result from the drilling because the drilling fluid will be air. Chemical impacts will be minimal because all of the tracers are planned to be removed in the core that is retrieved.

The core holes can be back filled at the conclusion of these tests to minimize residual impacts on the underground facilities. The NRC staff expects that proper sealing of boreholes will eventually be performed consistent with 10 CFR 60.134, which states "Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period of permanent closure". All work will be performed in a manner consistent with the guidelines given in the Site Characterization Plan, Section 8.4 (DOE, 1988).

**Criterion 2** Potential significant and irreversible/unmitigable effects on characterization that would physically preclude obtaining information necessary for licensing.

#### **Staff Review**

In the present Exploratory Studies Facility plans, each diffusion test is to be performed in specifically designed alcoves (approximately 6 x 6 m) in the Topopah Spring Member and the vitric and zeolitic zones of the Calico Hills unit. The arrangement and dimensions of the various openings are expected to change as additional design or operations analyses are completed. The final location and design of the diffusion tests need to take into account three types of Exploratory Studies Facility activities that have the potential to interfere with the diffusion tests: those generating heat, stress, or changes in water content. These types of interferences are discussed in detail in the Site Characterization Plan, Section 8.4.2.3 (DOE, 1988) and are summarized below.

Because fluid viscosity and density vary with temperature, diffusion rates are also a function of temperature. Consequently, the diffusion tests must be conducted in an isothermal environment, outside the zone of influence of temperature changes arising from the mined opening and of the various heater tests planned by Sandia National Laboratories and Lawrence Livermore National Laboratory. Boreholes will be capped to isolate them from temperature fluctuations in the mined openings. Thermal perturbations could arise if the diffusion tests were located within the zone of influence of any of the heater tests planned for the Exploratory Studies Facility. Relevant Sandia National

Laboratory experiments include the heater experiment in unit TSw1, canister-scale heater experiment, Yucca Mountain heated block, thermal stress measurements, and heated room experiment, described in Site Characterization Plan, Sections 8.3.1.15.1.6.1 through 8.3.1.15.1.6.5.

The engineered barrier system field test, or waste package test, planned by Lawrence Livermore National Laboratory, (Site Characterization Plan, Section 8.3.4.2.4.4) also will give rise to thermal perturbations in the surrounding rock. The zones of thermal influence of these tests range from a few meters up to a maximum of 28 m.

Ground motion or changes in the stress state of the rock, for example, from drilling, mining, or blasting activities, could vibrate the diffusion volume to the extent that fracturing could occur during the experiment, thus affecting diffusion paths and rates. As a general rule of thumb, the stress-altered region resulting from blasting activities is estimated to extend about two drift diameters from the drift walls.

Finally, water added during tests or used in drilling or mining activities could move via fractures to the diffusion volume and thereby influence tracer transport rates and paths. Bromide used as a tag for the Exploratory Studies Facility drilling operations could conceivably interfere with the diffusion tests. However, water used in drilling is estimated to penetrate, in general, less than 10 m (33 ft) into the formation (Site Characterization Plan, Section 8.4.2.3.6.2). Tests in which water is to be added include the percolation tests, the radial borehole test, and the hydrologic properties of faults (Site Characterization Plan, Sections 8.3.1.2.2.4.2, 8.3.1.2.2.4.4, and 8.3.1.2.2.4.10). The locations of the diffusion test alcoves will be selected to minimize the potential for such interferences.

Testing and observations planned in the Exploratory Studies Facility during construction, such as the radial borehole test and excavation effects test, will provide data to confirm or better define these estimates. These potential interferences will be minimized by locating the diffusion test alcoves outside the zones of influences of other test activities, and by drilling the injection

boreholes to a depth (about 10 m, or 30 ft) sufficient to be outside the zone of stress relief induced by mining the experimental drift.

Another consideration is interference between the short-term (3-month) and long-term (12-month) diffusion tests. The boreholes for each pair of tests will be spaced sufficiently far apart to eliminate the possibility of interference.

One effect not considered by the study plan is the potential of exploratory drifts to influence the results of the diffusion tests by drying the rock. To maintain breathable air in the exploratory drifts, large amounts of air will be circulated from the land surface through the drifts. This will cause drying of the rock, with the fastest drying occurring in rock matrix in direct contact with the drift or near fractures with air flowing through them. It is not clear from the study plan how sensitive this test design would be to changes in rock water content, but Sobolik, 1991, contains some calculations of the extent of drying from drifts in the Topopah Springs unit and the Calico Hills unit over the active 100 year life of the repository (the period when the drifts are open to air circulation).

Diffusion tests are planned to be completed by 4.5 years from the start of Exploratory Study Facility construction (Study Plan, Figure 6). In the report by Sobolik, 1991, drying effects were calculated using fracture and matrix properties for a drift in the Topopah Springs unit and a drift in the Calico Hills unit. The results are displayed in Figure 45 and 47 (pages C-35 and C-37) of the report. For the time period of interest calculated drying effects appear to be about the same for both units. At the end of one year some drying was predicted at a distance of 5 meters from the drift and at the end of two years drying had progressed to a distance of 6 meters. At the end of ten years drying had progressed to a distance of 10 meters with a 10% reduction in saturation at a distance 5 meters and a 5% reduction at 7 meters. Since, the experiments in this study plan will take place at a distance 10 meters distant from a drift and will be completed 4.5 years from the start of Exploratory Study Facility construction, there would probably be no measurable drying effects on this experiment. However, should this study be sensitive to moisture contents, the design of the experiment may need to be

reconsidered as improved predictions of Exploratory Study Facility drying effects are completed, or changes occur to Exploratory Study Facility design and scheduling.

**Criterion 3** Potential significant disruption to characterization schedules or sequencing of studies that would substantially reduce the ability of DOE to obtain information necessary for licensing.

**Staff Review**

This study neither constrains or is constrained by the schedule or sequencing of other studies.

**Criterion 4** Inadequacies in the QA program which must be resolved before work begins.

**Staff Review**

Based on a note from John Buckley, Quality Assurance Section, to Charlotte Abrams, Repository Licensing and Quality Assurance Project Directorate, dated 08/06/92, there are currently no deficiencies that would call into question the quality of the investigation to be conducted under this study plan.

**Closure of NRC Open Items (Objectives 8 and 11)**

**Staff Review**

Not applicable - In its transmittal letter DOE did not propose to close any open items with this study.

**Need for Detailed Technical Review**

A study plan is a candidate for a detailed technical review if it meets any of the following 5 criteria from step 6 of part 4.2 of the Review Plan.

**In summary: this study plan is a candidate for a detailed technical review because it meets criteria 1 and 3. Each criterion is discussed below:**

**Criterion 1 The study plan may be related to one or more key site related issues.**

#### **Staff Review**

**This study plan is related to one or more key site related issues. Relationships to the issues are briefly discussed below.**

**Performance Issue 1.1 asks, "will the mined geologic disposal system meet the system performance objective for limiting radionuclide releases to the accessible environment as required by 10 CFR 60.112 and 40 CFR 191.13?" (Site Characterization Plan, Section 8.3.5.13; NRC, 1983; EPA, 1985). This issue requires that the geologic setting, engineered-barrier system, shafts, boreholes, and seals be designed so as to limit the cumulative release of radionuclides for 10,000 years following permanent closure of the repository. Site Characterization Plan, Table 8.3.1.2-1 (page 10 of 38) indicates that this study plan is responsible for providing diffusivity coefficients in support of this performance issue. Diffusion measurements from this study will be used to satisfy the requirements for the following information needs:**

**Information Need 1.1.1, "site information needed to calculate releases to the accessible environment" (Site Characterization Plan, Section 8.3.5.13.1).**

**Information Need 1.1.3, "Calculational Models for Predicting Releases to the Accessible Environment Attending Realizations of the Potentially Significant Release-scenario Classes" (Site Characterization Plan, Section 8.3.5.13.3). Parameters needed to satisfy this information need include, calculational models of transport of dissolved species in the unsaturated zone, including models developed in Investigation 8.3.1.3.7, "Radionuclide Retardation by all Processes Along Flow Paths to the Accessible**

**Environment". The diffusion study will contribute to the supporting data base for Investigation 8.3.1.3.7.**

**Performance Issue 1.2 asks, "will the mined geologic disposal system meet the requirements for limiting individual doses in the accessible environment as required by 40 CFR 191.15?" The results of this study will be used to satisfy the requirements for the site-specific Information Need 1.2.1, "Determination of Doses to the Public in the Accessible Environment Through Liquid Pathways." Parameters needed to satisfy this information need are the same as those required for Information Need 1.1.4 (Site Characterization Plan, Section 8.3.5.1.3.4) and include calculational models of transport of dissolved species in the unsaturated zone, including models developed in Investigation 8.3.1.3.7, "Radionuclide Retardation by all Processes Along Flow Paths to the Accessible Environment". The diffusion study will contribute to the supporting data base for Investigation 8.3.1.3.7.**

**Criterion 2 The study plan pertains to some NRC open items.**

**Staff Review**

**No NRC open items were identified by this review.**

**Criterion 3 The study plan describes unique, state-of-the-art tests or analysis methods that do not have a supportive scientific history of providing data usable in licensing.**

**Staff Review**

**Many of the tests in this study plan were partially developed and tested in prototype tests conducted at Apache Leap in Arizona and in G-Tunnel at the Nevada Test Site. However, additional prototype testing is needed to ensure that the diffusion tests will gather the information required.**

**Criterion 4** The study plan describes a study critical to the evaluation of site performance that cannot be repeated for a number of years due to its disruption of the natural baseline.

**Staff Review**

While it is not clear whether or not this study is critical to site performance; the natural baseline conditions will be disturbed in the immediate vicinity of the test. Only a small area should be disturbed, since at the end of the test the entire test area will be removed by overcoring with an approximately 30 cm diameter drill hole. Therefore, the test can be readily conducted in other areas nearby and Criterion 4 should not be a problem.

**Criterion 5** The study has some other critical relationship to potential licensing concerns.

**Staff Review**

The staff has not identified any licensing concerns in regard to this study plan other than those listed above.

**REFERENCES**

DOE (U.S. Department of Energy), December 1988. "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," 9 vols., DOE/RW-0199, Office of Civilian Radioactive Waste Management, Washington, D.C. Mary Ford

Sobolik, S.R., Fewell, M.E., and Eaton, R.R., 1991, Movement of Shaft and Drift Construction Water in Yucca Mountain, Nevada - An Extended Study, Sandia National Laboratories, SAND91-0791.