DRAFT

INTEGRATED COMMENTS ON
CONSULTATION DRAFT SITE CHARACTERIZATION PLAN
YUCCA MOUNTAIN NEVADA

Prepared for

Nuclear Waste Consultants, Inc.
U.S. Nuclear Regulatory Commission

Prepared by

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1.0 INTRODUCTION

This report was prepared by Water, Waste and Land, Inc., (WWL) as directed in a letter dated June 21, 1988, from Jeff Pohle of the U.S. Nuclear Regulatory Commission (NRC) to Mark Logsdon of Nuclear Waste Consultants, Inc., (NWC). WWL serves as a subcontractor to NWC under Contract No. NRC-02-85-009 and is responsible for the Nevada Nuclear Waste Storage Investigations (NNWSI) portion of the project. The NNWSI project concerns evaluation of Yucca Mountain, Nevada, as a repository for high level radioactive waste materials. Both WWL and NWC were involved in review of the Consultation Draft Site Characterization Plan (CDSCP) for the Yucca Mountain site which was released by the U.S. Department of Energy (DOE) on January 11, 1988.

In his letter of June 21, 1988, Mr. Pohle requested that WWL formulate one integrated comment for each of the three main areas of investigation outlined in the CDSCP -- Regional Hydrogeology, Site Saturated Zone Hydrogeology, and Site Unsaturated Zone Hydrogeology. Based on Mr. Pohle's letter, each integrated comment was to be supported by the individual points developed during review of the CDSCP by the NRC staff. Additional points, based on the DOE/NRC Conceptual Model meeting and review of the CDSCP by the U.S. Geologic Survey (USGS), are also used to support the integrated comment for each major area. The overall focus of each integrated comment was based on the following criteria, as quoted from Mr. Pohle's letter:

- Are the studies/activities planned under each area of investigation adequate to address each process/assumption (including alternatives)?
- Are the studies/activities planned under each area of investigation adequate to provide a data base which is consistent with identified performance modeling strategies?

To develop each of the integrated comments, the point papers which were developed by the NRC and submitted to the DOE after review of the CDSCP were reviewed and categorized according to the three major areas of concern as identified previously. In addition, comments prepared by the USGS regarding the CDSCP were reviewed and incorporated as individual points under the integrated comment if they were not repetitions of points developed by the NRC or if they were not too general in nature. A short paragraph summarizing each point was then prepared and organized under the appropriate major area of concern. A cross-reference to the pertinent portion of the CDSCP is included at the end of each point summary.

This report is organized according to the major areas of concern, starting with the Site Unsaturated Zone which is the most specific (and presumably the most important). The second section relates to the Site Saturated Zone which appears to be of limited importance with respect to meeting regulatory requirements but may provide insight and support for unsaturated zone interpretations. The third section is dedicated to those points raised regarding the Regional Hydrologic System. Because this latter aspect of site characterization is primarily concerned with development of a reasonable framework for the local zones and development of reasonable and proper boundary conditions for models which may be used to evaluate the performance of the site, the NRC staff did not provide any formal comments and all of the 'points' listed in this report were presented by the USGS.

2.0 SITE UNSATURATED ZONE

A number of points regarding the DOE's CDSCP for the Yucca Mountain unsaturated zone have been compiled from NRC point papers and a USGS review of the CDSCP. The NRC addressed the problem of prototype testing, as well as other key issues on the characterization of unsaturated zone necessary to meet performance objectives. The USGS points questioned several testing programs such as infiltration tests, diffusion tests, and pump tests.

Prototype testing (Section 2.1) has been presented by the DOE in a number of studies for the analysis of hydrologic characterization of the unsaturated zone at Yucca Mountain. One conclusion that can be reached from the CDSCP review is that there may not be enough time to complete long-term monitoring of the unsaturated zone and prototype testing of the instrumentation. Description of all such prototype testing should be presented within the SCP. Alternative data collection techniques should be discussed should the prototype instrumentation prove unfeasible.

Conceptual Model comments (Section 2.2) concerns the CDSCP characterizing the site unsaturated zone adequately, including NRC's comment that there is a need to evaluate fracture flow to better understand ground water flow and travel times. The USGS points out that fracture flow could occur under areas of Yucca Mountain which receive large amounts of runoff. Also, several drifts or faults that penetrate Yucca Mountain will need to be evaluated to determine their effect on the long-term isolation capability of the geologic repository. Both the NRC and the USGS point out that a great deal of thought must be given to the coordination between interdisciplinary investigations in the transfer of technical data obtained. Examples of these points are given in Section 2.3.

In Section 2.4, questions were raised concerning the tests involved in determining hydrologic and transport properties. These questions included proposed infiltration and diffusion tests in the exploratory shaft. In addition, the use of nitrogen injection for testing purposes was identified as possibly being detrimental to geochemical samples. The USGS stressed that any programs that are specific to field collection of data from the sub-soil unsaturated zone be given a priority in terms of timing, manpower, and fiscal support.

Additional comments provided by the USGS and the NRC are listed in Section 2.5. Although these comments do not necessarily fit under a specific category, they are still valid comments which should be addressed. Finally, although it was not presented as a comment by either the NRC or the DOE, the programs in the CDSCP for determining the Representative Element Volume (REV) need further detail. The required size of an REV for fractured, unsaturated tuff may be difficult to deduce. This implies that it may be difficult to demonstrate that values estimated for hydrogeologic parameters are actually representative of the fractured, tuff units at Yucca Mountain.

The following points regarding the CDSCP were presented by the NRC and the USGS. Each point listed includes the respective agency which raised the point as well as the page number from the report in which the point was found. In addition, a cross reference to an appropriate section of the CDSCP is included for each comment.

2.1 - Prototype Testing Technology

o NRC Comment #6 - Site Unsaturated Hydrologic System (p. 18)

The CDSCP does not describe the prototype (research) testing program, which will develop the technology and ability to successfully conduct unsaturated zone percolation tests. Characterization of the site will depend heavily on the design and results of this prototype testing. A study activity describing the planned unsaturated zone percolation prototype testing program should be included in the SCP.

CDSCP Cross References - Study 8.3.1.2.2.3: Characterization of Percolation in the Unsaturated Zone - Surface Based Study.

CDSCP Cross References - Study 8.3.1.2.2.4: Characterization of Yucca Mountain Percolation in the Unsaturated Zone - Exploratory Shaft Facility Study

o NRC Comment #7 - Vertical Borehole Studies (p. 19)

Alternative data collection techniques have not been considered should the planned instrumentation for the site vertical borehole studies fail or prove unfeasible. There may not be enough time to complete long-term monitoring of the unsaturated zone and prototype testing of the instrumentation. Also, many of the instruments may fail or drift out of calibration during the long period of monitoring. Therefore, reliable instrumentation must be developed and used. Alternative methods of collecting data from the unsaturated zone should be explored.

CDSCP Cross References - Activity 8.3.1.2.2.3.2: Site Vertical Borehole Studies

o NRC Comment #102 - Exploratory Shaft Facility Studies (p. 143)

In several activity descriptions, it is proposed that air coring will be used to drill holes to be used for permeability testing. This raises questions about the reliability of the permeability values thus obtained. Prototype testing is recommended to alleviate doubts about permeability measurements in air drilled holes.

CDSCP Cross References - Section 8.4.2.5.1: Exploratory Shaft Facility Studies

o USGS Comment - Unsaturated Zone Data Acquisition (p. 113)

The acquisition of data from the deep unsaturated zone using surface-based techniques cannot be taken for granted. Presently available techniques are not yet capable of producing data from the deep unsaturated zone that can be used with complete confidence. The USGS urges that any programs (Investigations, Studies, or Activities) that are specific to field collection of data from the sub-soil unsaturated zone be given utmost priority in terms of timing, manpower, and fiscal support.

CDSCP Cross References - Investigation 8.3.1.2.2: Studies to Provide a Description of the Unsaturated Zone Hydrologic System at the Site

o USGS Comment - General Comment: Open Borehole Sampling (p. 119)

The data from UZ-1 have taken a long time to obtain because the time to reach equilibrium or steady state at the down-hole sampling stations has been long. The data even now are not totally unequivocal. Preliminary studies have shown that flow in open boreholes responds to both barometric and thermal effects and may provide insight into potential or existing gas flow paths with Yucca Mountain. In addition, although not depth-specific, gas samples obtained during extended periods of exsurgence of open boreholes may be more contaminant free than samples extracted after substantial pumpout of stemmed and instrumented boreholes. Additional emphasis should be placed on open borehole studies and all existing or to be drilled boreholes should be dedicated to stemming and instrumentation.

CDSCP Cross References - Activity 8.3.1.2.2.3.2: Site Vertical Borehole Studies

- USGS Comment - Infiltration Tests in the Exploratory Shaft Facility (p. 171)

  It is not clear how the infiltration tests described in Activity 8.3.1.2.2.4.2 will meet its experimental objectives. Inflow and changes in saturation in the matrix can be monitored as a function of time, but flow in the fractures could bypass the monitoring holes totally undetected. In this case, effective hydraulic conductivity could not be determined because the area involved in flow is not known. Infiltration tests involving a sand bed is unlikely to provide sufficient suction control to allow tests to be run at less than almost complete saturation. Consideration should be given to using either a plaster crust of ceramic plate coupled to the infiltration block with diatomaceous earth.

  It seems necessary to isolate the block with vertical impermeable sheet walls and a suction plate underneath. Under these conditions, some idea of when steady-state or near-steady state conditions were obtained could be assessed by comparing inflow to outflow. Once steady state is approximately achieved, effective hydraulic conductivity as a function of saturation (and possibly pressure head) could be obtained. This test should be evaluated in a laboratory prototype before being conducted in the ES.

CDSCP Cross References - Activity 8.3.1.2.2.4.2: Infiltration tests in the Exploratory Shaft Facility.

2.2 - Conceptual Model

- NRC Comment #5 - Artificial Infiltration - (p. 17)

  It is questionable whether the results of ponding studies at Yucca Mountain can be applied to Fortymile Wash. The ponding studies will be used to characterize the range and spatial variability of infiltration rates, flow velocities, and flow pathways in approximately the upper 15 feet of both consolidated and unconsolidated surficial materials. The surface strata at Yucca Mountain and Fortymile Wash are quite different. The results of infiltration tests on the mountain surface probably will not be transferable to the alluvium of Fortymile Wash. A technical justification for the transfer should be shown.

CDSCP Cross References - Activity 8.3.1.2.2.1.3: Evaluation of Artificial Recharge

- NRC Comment #63 - Preliminary Performance Allocation for System Element 1.2.1.1 (p. 90)

  The last tentative goal on page 8.3.2.5-21 indicates that high confidence is needed that ES-1 shaft will terminate no less than 150 m above groundwater table. It does not appear that this goal is reached under the present ES-1 design. The SCP should provide a basis for the goal and assurance that the goal will be met with high degree of confidence.

CDSCP Cross References - Section 8.3.2.5: Issue Resolution Strategy for Issue 4.4: Are the technologies of repository construction, operation, closure, and decommissioning, adequately established for the resolution of the performance issues?

o USGS Comment - Recharge (p. 104)

The DOE implies on page 3-207 of the CDSCP that recharge is areally uniformly distributed. This implied assumption in turn appears to drive the repeated assertion that flow is predominantly in the matrix. However, recharge is almost undoubtedly focused beneath washes, unvegetated talus slopes overlying highly fractured bedrock, and in open exposed fractures. In areas of focused recharge, fracture flow might predominate. Substantial evidence already exists to support the concept of focused recharge with neutron logs obtained in washes indicating that deep percolation occurs following runoff events.

(From p. 150, USGS Comments on the CDSCP) The unsaturated zone hydrologic hypotheses presented by the DOE on page 8.3.1.2-42 (Table 8.3.1.2-2) of the CDSCP needs clarification. It is unlikely that net infiltration beneath the plant root zone of vegetated areas is the major source of recharge at Yucca Mountain. Instead, most of the recharge is along ephemeral stream channels, from beneath unvegetated talus slopes, and in exposed open fractures.

CDSCP Cross References - Activity 8.3.1.2.1.3.3: Fortymile Wash Groundwater Recharge

CDSCP Cross References - Investigation 8.3.1.2.2: Unsaturated Zone Description

CDSCP Cross References - Study 8.3.1.2.2.1: Characterization of Unsaturated-Zone Infiltration

CDSCP Cross References - Study 8.3.1.2.2.4: Characterization of Yucca Mountain Percolation in the Unsaturated Zone--Exploratory Shaft Facility Study

CDSCP Cross References - Study 8.3.1.2.2.6: Characterization of Flux Within the Paintbrush Nonwelded Unit in the Vicinity of the Ghost Dance Fault

o USGS Comment - Unsaturated Zone Processes Around Yucca Mountain, (p. 131)

The study of unsaturated zone processes in the broader general area of Yucca Mountain, instead of only at Yucca Mountain, need greater emphasis. For instance, more should be done in the Fortymile Wash area where much of the recharge to the ground water system is assumed to have occurred. Additional studies in the Amargosa Desert may be in order. It has been assumed that recharge to the Amargosa Desert area is mainly from surface runoff. This may not be the case; unsaturated zone studies may shed additional light on this problem.

CDSCP Cross References - Study 8.3.1.2.2.10: Unsaturated Zone System Analysis and Integration

2.3 - Interdisciplinary Management Coordination

o NRC Comment #24 - Surface Based Testing (p. 41)

The individual, the cumulative, and the synergistic effects of drilling the shallow and exploratory holes have not been considered in exploratory shaft construction and testing for the waste isolation integrity of the site. It is recommended that the SCP broaden its analysis of the potential impact of exploratory shaft construction and testing on the waste isolation capability of the site. An analysis of the effects of proposed boreholes, trenches and other characterization activities within the zone mechanically influenced by the exploratory shaft should also be included.

CDSCP Cross References - Section 8.4.1.1: Preparation for Surface Based Testing

CDSCP Cross References - Section 8.4.2.5.1: Exploratory Shaft Facility Studies

o NRC Comment #30 - Acquisition of Subsurface Information (p. 47)

The required integration of site-specific subsurface information with repository design is not considered in this section. The SCP should consider repository layout, location of emplacement holes and repository drifts in the drill site selection criteria and show that the systematic drilling program and the repository layout are integrated.

CDSCP Cross References - Study 8.3.1.4.3.1: Systematic Acquisition of Site Specific Subsurface Information

o NRC Comment #98 - Underground Test Facilities (p. 137)

A reasonable assurance that the shafts are adequately separated so that construction in ES-2 does not adversely affect the ability to obtain required data in ES-1 and adjacent test areas has not been provided. An analysis of potential hydrological interference should be conducted, including anticipated fluids in ES-2 as well as unanticipated releases. Potential adverse effects of the construction of ES-2 using the drill and blast method on the ability to obtain required data in ES-1 and adjacent test areas should be addressed and mitigated.

CDSCP Cross References - Section 8.4.2: Underground Test Facilities

2.4 - Hydrologic/Transport Properties

- NRC Comment #9 - Percolation Tests in the Unsaturated Zone (p. 21)

  The CDSCP does not contain a description of any hydrologic testing activities at the repository level within the drifts to the Ghost Dance fault, beneath Drill Hole Wash and to the Imbricate-Normal fault zone. Activities should be developed for geohydrologic testing in the drifts at the Ghost Dance fault, the Imbricate-Normal fault zone, and beneath Drill Hole Wash.

CDSCP Cross References - Study 8.3.1.2.2.4: Characterization of Yucca Mountain Percolation in the Unsaturated Zone - Exploratory Shaft Facility Study

- NRC Comment #10 - Percolation Tests in the Unsaturated Zone (p. 22)

  Hydrologic and geochemical tests planned for the exploratory shaft may have been compromised by past drilling activities associated with hole USW G-4. Drilling activities at USW G-4 may have changed the hydrologic characteristics of the rock where the exploratory shaft will be located. The possible effects of the drilling of USW G-4 on planned hydrologic and geochemical tests at the exploratory shaft site should be evaluated.

CDSCP Cross References - Study 8.3.1.2.2.4: Characterization of Yucca Mountain Percolation in the Unsaturated Zone - Exploratory Shaft Facility Study

- NRC Comment #11 - Percolation Tests in the Unsaturated Zone (p. 23)

  No laboratory or field tests to confirm the current concept of moisture characteristic relations for fracture/matrix flow in unsaturated fractured rocks, which form a major part of the Yucca Mountain hydrologic conceptual model, are scheduled to be conducted early in the site characterization program. The current concept of moisture characteristic relations for fracture/matrix flow in unsaturated fractured rock should be demonstrated early in the program either by laboratory or field tests on dry fractured rock similar to that at Yucca Mountain.

CDSCP Cross References - Study 8.3.1.2.2.4: Characterization of Yucca Mountain Percolation in the Unsaturated Zone - Exploratory Shaft Facility Study

- NRC Comment #12 - Diffusion Tests in the Exploratory Shaft Facility (p. 24)

  Diffusion tests in the exploratory shaft may be affected by capillary effects in the unsaturated zone. Nonsorbing tracers in aqueous solution will be introduced into the bottom of the borehole in the unsaturated zone which will produce movement of the solution away form the borehole under a capillary pressure gradient. The diffusion test should be designed to eliminate or take into account capillary pressure gradient effects.

CDSCP Cross References - Activity 8.3.1.2.2.5.1: Diffusion Tests in the Exploratory Shaft Facility

- NRC Comment #22 - Radionuclide Retardation (p. 35)

  The conceptual model of matrix-dominated groundwater flow in the unsaturated zone drives the radionuclide retardation testing program. As a result, the determination of some parameters that may be important to site characterization are not planned. The SCP should include plans to determine the effect of speciation, colloids, matrix diffusion, and any other conditions or processes which may significantly affect radionuclide retardation in fractures.

CDSCP Cross References - Investigation 8.3.1.3.6: Studies to Provide the Information Required on Radionuclide Retardation by Dispersive, Diffusive, and Advective Transport Processes Along Flow Paths to the Accessible Environment

- NRC Comment #60 - Information Need 1.11.7 (p. 87)

  Consequences of drift caving should be evaluated before treating it as an obviously acceptable design approach. Cavities above drifts could greatly reduce resistance to airflow, and link the repository to preferential air flow channels along a fault, hence facilitating upward flow of airborne radionuclides. Also, large open space above failed drifts could become preferential condensation locations for water vapor, thus enhancing water flow down faults. Therefore, remedial action prior to backfilling that minimizes the potential for drift cave-in should be considered.

CDSCP Cross References - Section 8.3.2.2.7: Information Need 1.11.7: Reference Post-Closure Repository Design

- NRC Comment #61 - Air Quality and Ventilation (p. 88)

  Systematic studies or calculations may be needed to determine the heat and moisture transfer from the rock to the ventilation air. Consideration should be given to adding studies of the heat transfer coefficients for moisture and heat from rock mass to ventilation air.

CDSCP Cross References - Section 8.3.2.3.1: Information Need 2.7.1: Determination that the Design Criteria in 10 CFR 60.131 through 60.133 and any Appropriate Additional Design Objectives Pertaining to Radiological Protection Have Been Met.

CDSCP Cross References - Section 8.3.2.3.1.2: Application of Results

- NRC Comment #64 - Overview of the Seal Program (p. 91)

  The CDSCP does not include details of the in situ testing of the proposed seal design concepts. This information is necessary to evaluate the effects of seal testing activities on the ability of the site to meet the performance objectives (10 CFR 60.112 and 10 CFR 60.113). The in situ tests for seal components should commence as early as practical during the site characterization program such that adequate preliminary information would become available at License Application submittal.

CDSCP Cross References - Section 8.3.3.1: Overview of the Seal Program

- NRC Comment #70 - Information Need 1.12.1 (p. 99)

  It is unclear whether a reasonably conservative design approach has been used to determine required backfill hydraulic conductivity. It is recommended that a sensitivity analysis be performed in which the broad range of possible hydraulic conductivities of the rock mass is considered. In situ tests should be planned and initiated to obtain the needed data as soon as practical.

CDSCP Cross References - Section 8.3.3.2.1: Information Need 1.12.1: Site, waste package, and underground facility information needed for design of seals and their placement methods

o NRC Comment #101 - Exploratory Drifts (p. 142)

Details of remedial measures are needed to evaluate potential adverse impacts of penetrating target structures (i.e., ghost Dance fault, Imbricate Normal Fault Zone and Drill Hole Wash) on long term isolation capability of the geologic repository. These structures could become air or water flowpaths. Potential remedial measures that may be needed to isolate and stabilize the target structures should be discussed in the SCP.

CDSCP Cross References - Section 8.4.2.4: Exploratory Drifts

o USGS Comment - Permeability Testing: Nitrogen Injection (p. 120)

Nitrogen will be injected in a number of tests during the site characterization program. However, there does not seem to be any evidence in the CDSCP that the potentially detrimental effects of nitrogen injection on hydrochemistry samples or for that matter on other injection tests, have been considered at all in project design. Packer injection testing is found as a proposed activity throughout many of the site unsaturated zone characterization studies. In some cases the proposed injection tests are slug tests: in others, they are cross-hole tests to be run to steady state. It appears that a considerable volume of nitrogen gas is proposed to be injected into Yucca Mountain.

There are no simple guidelines as to what volume of injected gas will be detrimental to geochemical samples. In fact, the answer will obviously vary depending on what natural gas, or isotope, is to be measured. The potential effects of the gas injection need to be considered in the project designs.

CDSCP Cross References - Investigation 8.3.1.2.2: Studies to Provide a Description of the Unsaturated zone Hydrologic System at the Site

- USGS Comment - Unsaturated Zone Flow: Lithophysal Cavities in the TSw Unit (p. 108)

  No experiments regarding unsaturated flow in tuffs with lithophysal cavities are described. However, the presence of lithophase may substantially affect the unsaturated flow properties. Experiments are desirable to at least verify the conceptual model of unsaturated flow through such units. In addition, such data are needed to simulate unsaturated flow through the lithophysal zones in the unsaturated flow and transport codes. As stated on page 8.4-27, the upper Demonstration Breakout Room is designed to collect data on the compressive strength and thermal properties of highly lithophysal zones. It would appear reasonable to test hydraulic properties in the upper Demonstration Breakout Room as this area is designed to collect data on the compressive strength and thermal properties of highly lithophysal zones.

CDSCP Cross References - Study 8.3.1.2.2.3: Characterization of Yucca Mountain Percolation in the Unsaturated Zone--Exploratory Shaft Facility Study

- USGS Comment - Gas Circulation in the Unsaturated Zone (p. 110)

  On page 3-195 and 3-213, mention is made of thermally or barometrically driven advective transport of water vapor. Computations using measured thermal gradients at Yucca Mountain indicate that, under present thermal gradients, such convective cells would not occur unless the permeability of the rock were greater than about 100,000 darcies. The observation of substantial topographically-affected gas circulation in open wells on the crest of Yucca Mountain and the presence of dipping beds and outcrops of different altitudes suggests that some topographically-affected gas flow may occur. This phenomena needs further investigation.

CDSCP Cross References - Study 8.3.1.2.2.7: Characterization of Gaseous-Phase Movement in the Unsaturated Zone

o USGS Comment - Flow and Transport: Distribution Coefficients (p. 115)

The nature and complexity of trying to relate laboratory and modeling studies of sorption and retardation during transport are thoroughly recognized in the CDSCP and receive substantial discussion. However, there is no mention in the CDSCP of how the surface area of the natural rock media will be determined. The values of Kd's presented in Tables 4-12a and 4-12b are expressed in units of ml/g based on the concentration units in which the radionuclides were measured: activity/volume of solution and activity/mass of rock. Surface area is implicit in the fact that known grain-size ranges of crushed tuff are used in the sorption experiments. The question of evaluating natural surface areas is not dealt with in the CDSCP. Matrix vs. fracture flow is discussed in several studies and activities in Chapter 4 and Subchapter 8.3.1.3, but none of these studies appear to specifically enable the estimation of natural surface areas needed for use in transport modeling.

CDSCP Cross References - Overview 8.3.1.3: Overview of the Geochemistry Program. Description of the Present and Expected Geochemical Characteristics Required by the Performance and Design Issues

CDSCP Cross References - Investigation 8.3.1.3.4: Studies to Provide the Information Required on Radionuclide Retardation by Sorption Processes Along flow Paths to the Accessible Environment

o USGS Comment - Diffusion Tests in the Exploratory Shaft Facility and the Unsaturated Tuff Block (p. 174)

It is unclear that these tests in the exploratory shaft facility will give values on diffusivity. This is true because the tracer-tagged water will migrate by capillarity and by gravity, carrying the tracer with it. Thus the predominant transport will be by convection rather than diffusion. Perhaps an alternate approach would be to place a solid soluble salt in the borehole and then determine the distribution of that dissolved salt in soil solution in the overcored material. Some interference to pure diffusion would arise in that vapor would condense on the salt, to be re-imbibed by capillarity into the rock. This effect would be much less than that due to capillarity on the injected water body, however. The design of the diffusion tests in the unsaturated tuff block seems to imply that diffusion, and only diffusion, will contribute to the movement of aqueous solutions of tracers. This assumption is too simplistic for this analysis.

CDSCP Cross References - Study 8.3.1.2.2.5: Diffusion Tests in the Exploratory Shaft Facility.

CDSCP Cross References - Activity 8.3.1.3.8.2.3: Diffusion in an Unsaturated Tuff Block

- USGS Comment - Environmental Tracers: Surface Water Studies (p. 123)

  There is very little, or no, emphasis in the various proposed meteorology and surface water studies and activities on collection of samples for chemical and isotopic analysis. Since precipitation and surface water are the two components of infiltration and recharge, it would seem that chemical and isotopic analysis of both are desirable, and that there should be more integration of effort between these various activities. As an example, studies proposed in the Climate section of the CDSCP (8.3.1.5) discuss collection of precipitation samples for deuterium and oxygen-18; the Fortymile Wash recharge study mentions chemical and isotopic analysis of precipitation, surface water, and groundwater samples.

CDSCP Cross References - Investigation 8.3.1.2.1: Studies to Provide a Description of the Regional Hydrologic System

CDSCP Cross References - Overview 8.3.1.12: Overview of the Meteorology Program Description of Meteorological Conditions required by the Performance and Design Issues

CDSCP Cross References - Activity 8.3.1.2.1.3.3: Fortymile Wash Recharge Study

- USGS Comment - Unsaturated Zone Characterization of Percolation (p. 168)

  On page 8.3.1.2-139 of the CDSCP (Study 8.3.1.2.2.3) it states that "aperture distributions and spacings estimated from fracture permeability distributions will permit computations of bulk conductivity as a function of matrix suction." It is unclear how these are to be used to develop k-curves. A given permeability value says nothing about aperture distributions and spacings, as densely spaced fine apertures or sparsely spaced coarse apertures give the same permeability. This method needs to be clarified.

CDSCP Cross References - Investigation 8.3.1.2.2: Studies to Provide a Description of the Unsaturated Zone Hydrologic System at the Site

CDSCP Cross References - Study 8.3.1.2.2.3: Characterization of percolation in the unsaturated zone--surface based study.

2.5 - Miscellaneous

o NRC Comment #8 - Vertical Borehole Studies (p. 20)

The CDSCP does not describe the logic used to locate vertical boreholes designed to test the unsaturated zone. Without this information it is difficult to determine if the holes have been correctly located to provide a representative description of the repository setting. Therefore, the SCP should include a description of how the boreholes have been located. In addition, the hydrologic drilling program should be integrated with the systematic drilling program for geologic and natural resource characterizations.

CDSCP Cross References - Activity 8.3.1.2.2.3.2: Site Vertical Borehole Studies

o NRC Comment #65 - Overview of the Seal Program (p. 93)

The CDSCP states that "The lack of aquifer above the waste emplacement horizon at the Yucca Mountain site, makes it unnecessary to install either permanent or temporary shaft or ramp seal components at the time of access construction." The SCP should either describe contingency plans for providing seals, if substantial water is encountered at the time of access or during the rest of ESF construction, or provide reasonable assurance, by analysis or by reference, that no operational seals will be necessary.

CDSCP Cross References - Section 8.3.3.1: Overview of the Seal Program

o NRC Comment #66 - Overview of the Seal Program (p. 94)

The CDSCP states that "The shaft liner can be removed to emplace seal components later." Removing a concrete liner cast in place against the rock is very likely to disturb the adjacent rock and could significantly affect the waste isolation capability of the site. It is recommended that the SCP evaluate the consequences of removing a shaft liner, specifically the risk of developing a zone of enhanced fracturing at a seal location, as a result of stress redistribution following liner removal.

CDSCP Cross References - Section 8.3.3.1: Overview of the Seal Program

o NRC Comment #67 - Seal Components (p. 95)

The CDSCP statement that "boreholes that are upgradient or long distances from the repository may not require sealing" appears to be driven largely by considerations of the vertical downward flow in the pre-repository rock environment, and does not represent a conservative sealing approach. It is recommended that the SCP incorporate a decision making strategy that includes adequate consideration of gaseous radionuclide migration and of thermally driven or disturbed water flow paths. Also, the SCP should provide detailed information on boreholes that are not planned to be sealed and the reasons for the decision.

CDSCP Cross References - Section 8.3.3.1: Overview of the Seal Program

CDSCP Cross References - Section 8.3.3.1.2: Seal Components

o NRC Comment #100 - Exploratory Drifts (p. 140)

The extent of site exploration described in the CDSCP indicates that the DOE plans to explore only a small portion of the underground repository block through underground testing and drifting. The SCP should show that the proposed underground exploration and testing together with surface-based site characterization, would sufficiently establish the geologic conditions and the ranges of important geomechanical, hydrologic and other needed parameters across the entire repository block. Alternatively, additional drifting to yield a more complete and representative characterization of the repository block should be proposed.

CDSCP Cross References - Section 8.4.2.4: Exploratory Drifts

o USGS Comment - Unsaturated Zone Ventilation (p. 106)

Only one design for ventilation of the waste-emplacement area is discussed. This design has air being drawn in at the Exploratory Shafts and exhausted at the Emplacement Area Exhaust Shaft. The forced ventilation will be opposite in direction to the natural ventilation. As an alternative hypothesis, natural ventilation could potentially dry the repository horizon. Consideration should be given to maximizing natural ventilation by drilling an exhaust shaft at the top of Yucca Mountain. Advantages of utilizing the natural ventilation scheme would be to perhaps substantially reduce the potential for leaching of waste by liquid water for the first 1,000 years of repository existence. It would also reduce the time and power needed for forced ventilation to cool the repository to workable temperatures during needed inspections in the caretaker period, and hence reduce the operating expenses. This approach appears to be called for on page 8.3.2.2-6. Disadvantages would include an increased hazard of gaseous radionuclide escape and greater construction expenses incurred by the deep ventilation shaft. The effects of both forced and natural ventilation on the repository heat and water budgets should be considered.

CDSCP Cross References - Study 8.3.1.2.2.7: Characterization of Gaseous-Phase Movement in the Unsaturated Zone

CDSCP Cross References - Activity 8.3.1.15.1.8.4: Air Quality and Ventilation Experiment

o USGS Comment - Unsaturated Zone Flow (p. 116)

The primary mechanism for flow in the unsaturated zone at Yucca Mountain is believed by the DOE to be in the matrix. However, flow can occur in the fractures of the unsaturated zone at Yucca Mountain. Can the Rainier Mesa be used as an analog for unsaturated-zone processes at Yucca Mountain? Pre-testing hydrochemical work has been done at Rainier Mesa, and fracture flow was indeed found to occur in the unsaturated zone. In Chapters 3, 4, 8.3.1.2, and 8.3.1.3 there exists the explicit statement that in the unsaturated zone water will move primarily by matrix flow, and in the saturated zone primarily by fracture flow. The possibility that fracture flow may occur in the unsaturated zone should be considered.

CDSCP Cross References - Activity 8.3.1.2.1.3.3: Fortymile Wash groundwater Recharge

CDSCP Cross References - Investigation 8.3.1.2.2: Unsaturated Zone Description

CDSCP Cross References - Study 8.3.1.2.2.1: Characterization of unsaturated-Zone Infiltration

CDSCP Cross References -Study 8.3.1.2.2.4: Characterization of Yucca Mountain Percolation in the Unsaturated Zone--Exploratory Shaft Facility Study

CDSCP Cross References - Study 8.3.1.2.2.6: Characterization of Flux Within the Paintbrush Nonwelded Unit in the Vicinity of the Ghost Dance Fault

3.0 SITE SATURATED ZONE

Comments and questions generated by the NRC and the USGS during the review of the CDSCP are presented for the site saturated flow system. The focus of the NRC's comments concern satisfying the design criteria for characterization of flow paths and travel times, as well as integration of testing programs to efficiently address information needs. The USGS comments focus on information gaps in the conceptual model for site saturated flow as well as criticizing DOE assumptions concerning their site saturated aquifer system testing programs.

Comments made by the NRC concerning the Issue Resolution Strategies (Section 3.1) deal with the inadequacy on the part of DOE to meet regulatory requirements for determining ground water travel times from the disturbed zone to the accessible environment. The NRC believes that procedures for this determination using cumulative distribution functions do not represent true travel times and new procedures should be evaluated. Another comment regarding the ground water travel time issue calls for the DOE to demonstrate the manner in which performance parameters are correlated with testing strategies. The NRC also indicates a need to develop a management plan to allow rapid resolution of technical concerns regarding groundwater travel time. The need to identify whether or not a "significant source" of ground water exists outside the controlled area is also cited by the NRC.

In Section 3.2, Testing Programs Evaluation, the NRC noted that a lack of integration exists between the hydrology and geochemistry testing programs for characterizing sorption mechanisms in both the unsaturated and saturated zones at Yucca Mountain. With regard to planned tests, the USGS criticized the scale of the multiple well tests. The USGS stated that given the scale of the present tests, little understanding of the large-scale flow and transport

mechanisms needed to satisfy design criteria for transport to the accessible environment would result. Questions regarding tracer tests as well as radionuclide retardation calculations were raised by the NRC.

Additional points within Section 3.2 include NRC comments which stress the need for more comprehensive fracture flow studies as well as the evaluation of the influence created on flow directions and magnitudes by the faults that are present within eastern Yucca Mountain. Also, the USGS stated that a priority be put on a complete chemical and isotopic analyses of samples taken from both existing and proposed boreholes since they represent the only presently available access to the unsaturated-saturated zone boundary. They went on to suggest that chemical and isotopic analyses should be performed on all water samples collected (where feasible).

The following 'points' are presented by the USGS and the NRC concerning comments and questions on the DOE's CDSCP for the Yucca Mountain site saturated flow system. The comments include the page number of the respective CDSCP point papers, and a CDSCP cross reference location on which the questions are raised for easy reference.

3.1 - Issue Resolution Strategies

o NRC Comment #86 - Issue Resolution Strategy - (p. 118)

Procedures for calculating pathways and groundwater travel times presented in the strategy for Issue 1.6 (Regulatory Requirements for Groundwater Travel Time) may not be adequate for determining the groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment. The NRC staff presently has a concern that the use of cdf's (cumulative distribution function), as described in the CDSCP, will not fulfill the regulatory requirement.

CDSCP Cross References - Section 8.3.5.12: Issue Resolution Strategy for Issue 1.6: Will the site meet the performance objective for pre-waste-emplacement groundwater travel time as required by 40 CFR 60.113?

o NRC Comment #87 - Issue Resolution Strategy - (p. 120)

The performance parameters for Groundwater Travel Time listed in Tables 8.5.5.12-2 and 8.3.5.12-3 cannot be correlated with tests described in Sections 8.3.1 to 8.3.1.16. The NRC staff concludes that it is not possible to effectively evaluate the adequacy of the hydrogeology program of investigations, with respect to resolving Performance Issue 1.6, unless a connection between the issue resolution strategy and the testing program is provided.

CDSCP Cross References - Section 8.3.5.12: Issue Resolution Strategy for Issue 1.6: Will the site meet the performance objective for pre-waste-emplacement groundwater travel time as required by 40 CFR 60.113?

o NRC Comment #88 - Issue Resolution Strategy - (p. 121)

No plan incorporating technical or management activities is presented to track progress in providing and closing out information need 1.6.1 with respect to validating flow model concepts as was done for mathematical model validation in Section 8.3.4.12.2. As a consequence, the ability to resolve a potentially significant technical concern related directly to the performance issue on groundwater travel time is reduced. A plan should be included which incorporates parameters, activities, logic and schedules/milestones for formulating and establishing the credibility of conceptual flow models into the process of providing information need 1.6.1.

CDSCP Cross References - Section 8.3.5.12: Issue Resolution Strategy for Issue 1.6: Will the site meet the performance objective for pre-waste-emplacement groundwater travel time as required by 40 CFR 60.113?

o NRC Comment #96 - Issue Resolution Strategy - (p. 135)

The CDSCP does not identify the presence or absence of a "significant source" of groundwater outside of the controlled area as an information need to be incorporated into the logic (approach) to resolve Issue 1.2. The presence or absence of "significant sources" of groundwater into the resolution strategy should be included as an information need. A decision point should also be incorporated into the logic diagram with a related milestone/schedule to close out the question.

CDSCP Cross References - Section 8.3.5.14: Issue Resolution Strategy for Issue 1.2: Will the mined geologic disposal system meet the requirements for limiting individual doses in the accessible environment as required by 40 CFR 191.15?

3.2 - Testing Programs Evaluation

o NRC Comment #15 - Reactive Tracer Testing - (p. 27)

Geohydrology Activity 8.3.1.2.3.1.7 will provide information on fundamental sorption mechanisms. However, it is not clear how this activity will be integrated with the geochemistry program. The integration of the work described with work characterizing sorption in both the saturated and unsaturated zone described in the geochemistry program should be clarified. Additional methods of obtaining information on radionuclide sorption should be considered in the SCP. One approach would be to attempt to gain information on radionuclide mobility under similar tuff-groundwater situations from the many bomb test sites at the Nevada Test Site.

CDSCP Cross References - Activity 8.3.1.2.3.1.7: Testing of the C-Hole Site with Reactive Tracers

o USGS Comment - Multiple Well Tests (p. 180).

The DOE states on page 8.3.1.2-295 of the CDSCP that although single well tests are useful for determining aquifer properties on a local scale, multiple well test will be required to understand the nature and areal distribution of bulk aquifer properties. However, even the proposed multiwell tests are at a scale which is minute compared with the travel distance from the repository to the 'accessible environment'. Thus multiple well testing may shed little light on the large-scale flow and transport of which understanding is required to satisfy design criteria. In particular, measurement of local dispersion coefficients with tracer tests will likely give values unrelated to dispersion at the large scale of the design criteria.

CDSCP Cross References - Investigation 8.3.1.2.3: Studies to Provide a Description of the Saturated Zone Hydrologic System at the site.

o NRC Comment #14 - Conservative Tracer Testing - (p. 26)

One objective of the C-hole tests is to determine matrix diffusion. It is not apparent that matrix diffusion can be determined from these tests as designed. In order to determine matrix diffusion, at least two types of tracers are required, one that diffuses into the matrix and one that does not. To determine the effect of matrix diffusion on the migration of tracers, it is recommended that various size particles or colloids be included in the C-hole tests.

CDSCP Cross References - Activity 8.3.1.2.3.1.5: Testing of the C-Hole Sites with Conservative Tracers

o NRC Comment #19 - Radionuclide Retardation - (p. 31)

The integration of the program emphasizing the measurement of distribution coefficients, expressed in terms of Kd, as a function of water composition, radionuclide composition, and rock type with work described under geohydrology Activity 8.3.1.2.3.1.7 is not clear. The integration of this work is important to gaining an overall understanding of sorption and should be clarified. In the SCP additional methods of obtaining information on radionuclide sorption should be considered. One possible approach would be to attempt to gain information on radionuclide mobility under similar tuff-groundwater situations from the many bomb test sites at the Nevada Test Site.

CDSCP Cross References - Investigation 8.3.1.3.4: Studies to Provide the Information Required on Radionuclide Retardation by Sorption Processes along Flow Paths to the Accessible Environment

CDSCP Cross References - Investigation 8.3.1.3.7: Studies to Provide the Information Required on Radionuclide Retardation by all Processes along the Flow Paths to the Accessible Environment

o USGS Comment - Well Test Tracers (p. 182)

Well tests planned for Activities 8.3.1.2.3.1.5 and 8.3.1.2.3.1.6 involve use of conservative tracers in pumping tests. Would it be feasible or desirable to use labeled water (HTO or deuterium and oxygen-18) as a tracer? An advantage would be monitoring of water molecules directly, without concern for sorption, etc., of solute tracers.

CDSCP Cross References - Activity 8.3.1.2.3.1.5: Testing of the C-hole Sites With Conservative Tracers

CDSCP Cross References - Activity 8.3.1.2.3.1.6: Well Testing With Conservative Tracers Throughout the Site

o NRC Comment #13 - Site Saturated-Zone Groundwater Flow System - (p. 25)

Activities presented for the study - Characterization of the Site Saturated Zone Groundwater Flow System - do not appear to be adequate for characterizing saturated zone hydrologic boundary conditions, flow directions and magnitudes. The study to characterize the saturated zone should contain activities for addressing the influence of faults within and east of the repository block on flow directions and magnitudes. In addition, the study should be integrated with the geophysical program and the systematic drilling program for geologic characterization.

CDSCP Cross References - Activity 8.3.1.2.3.1: Characterization of the Site Saturated-Zone Groundwater Flow System

o NRC Comment #29 - Characterization of Site Structural Features - (p. 45)

The CDSCP's approach to characterizing the complex three-dimensional nature of fracture systems in the repository block relies too heavily on fractal analysis of outcrop exposures. Also, the CDSCP limits the objectives of fracture network studies to providing fracture parameters and analyses to supporting hydrologic modeling. Such a narrow approach and limited objective to characterization may not lead to adequate descriptions of the fracture networks. The SCP should integrate fracture studies proposed by various methods: fractal analysis, shaft/drift mapping, geologic mapping, systematic drilling and core analysis, hydrologic tracer testing and geophysical surveying including borehole geophysics.

CDSCP Cross References - Activity 8.3.1.4.2.2.2: Surface Fracture Network Studies

CDSCP Cross References - Activity 8.3.1.4.2.2.4: Geologic Mapping of the Exploratory Shaft and Units

o USGS Comment - Sampling of Water Table Wells (p. 118)

Activities 8.3.1.2.1.3.2 and 8.3.1.2.3.2.1 propose drilling additional water table (WT) holes and sampling existing WT boreholes. Chemical and isotopic analyses are proposed for new holes after geophysical logging. These wells (both existing and new) should be sampled for complete chemical and isotopic analyses. This is an item that should be given extremely high priority, since they provide the only presently available access to the unsaturated-saturated zone boundary. In addition, the holes should be packed off a short distance above the water table and pumped for gas sample collection. The gas samples should be analyzed for composition and for C-13, C-14, deuterium, and O-18. The information gained would appear to be critical to establishing boundary conditions for both unsaturated and saturated zone hydrochemical modeling.

CDSCP Cross References - Activity 8.3.1.2.1.3.2: Regional Potentiometric Level Studies

CDSCP Cross References - Activity 8.3.1.2.3.2.1: Assessment of Site Hydrochemical data Availability and Needs

- USGS Comment - Fortymile Wash Recharge Study (p. 119)

  Chemistry/isotopes are not mentioned among the six parameters of activity 8.3.1.2.1.3.3, although p. 89 states that "all samples" will be subject to chemical and isotope analyses. It is not clear to which samples "all samples" refer - saturated, unsaturated, or both. Chemical isotope analyses should be conducted to whatever extent is practical on all water samples collected. In addition, it is recommended that a nest of gas sampling piezometers be installed in the Fortymile Wash for composition and isotropic analyses of unsaturated-zone gases, such as the CO_2 content and its carbon-13 and carbon-14 signature. These data would appear to be important, or even critical, to establishing the extent and timing of the presumed recharge from Fortymile Wash to the regional system.

CDSCP Cross References - Activity 8.3.1.2.1.3.3: Fortymile Wash Recharge Study

4.0 REGIONAL FLOW SYSTEM

The points presented in this section come entirely from the USGS comments regarding the CDSCP. There were no point papers from the NRC which specifically addressed the regional flow system.

Several of the comments raised by the USGS were related to DOE plans for modeling the regional flow systems. These comments are summarized in Section 4.1. Generally, the USGS is concerned about the effects of using models to evaluate flow paths and travel times in that models often result in averaged conditions which probably do not reflect actual conditions. In addition, they express concern regarding the use of two-dimensional simulation models to evaluate flow systems in which vertical gradients as well as substantial lateral heterogeneity are important. The USGS also cites the need to describe how uncertainty in model input parameters will effect simulation results.

Areas of uncertainty due to the lack of data include vertical flow through a multi-layer system, anisotropy, homogeneity of aquifer properties on a regional scale, boundary conditions, and areas of unknown data within the regional system. Such uncertainties are believed by the USGS to inhibit the DOE's attempt to satisfy the design criteria for flow paths and travel times at the Yucca Mountain Site. These comments are presented under Section 4.2, Hydrogeologic Properties.

Section 4.3 of this report presents USGS recommendations for alternative techniques and hypotheses involving testing programs and hydrogeologic interpretations. A different model is proposed for modeling geochemical reactions in addition to the recommendation for dissolved oxygen sampling to help define the regional flow direction. The USGS also felt that the DOE's

practice of characterizing the tuff aquifer system as a single aquifer system was incorrect and that alternative hypotheses should be evaluated.

Section 4.4 summarizes comments regarding the lack of coordination among the various Investigations, Studies, and Activities to share information and data to effectively characterize the regional system. An example is in the area of modeling where redundancy exists in many of the proposed chemical, hydrologic, hydrochemical, and solute transport models proposed throughout the CDSCP. It is recommended that the DOE evaluate how the inter-discipline fields can coordinate efforts to provide an efficient means to data acquisition so that redundancy of effort can be avoided.

The following 'points' were presented by the USGS concerning characterization of the regional flow system in the vicinity of Yucca Mountain. Each comment includes the page number of the USGS review of the CDSCP as well as a cross-reference to pertinent CDSCP sections.

4.1 Modeling/Simulation

- USGS Comment - Simulation of Regional Groundwater Flow (p. 149)

  Specific questions were raised by the USGS concerning the present and planned simulations of regional groundwater flow. The uncertainties listed are questioned as to their affect on the calculation or estimation on the regional hydraulic properties, such as transmissivities, flow rates and directions, and travel times. These uncertainties are listed below:

  - Regional estimate of recharge
  - Regional estimate of underflow from areas outside the model boundaries
  - Estimate of potentiometric head
  - Estimate of groundwater discharge
  - Estimate of the type of rocks through which groundwater flows beneath a given location
  - Uncertainty in averaging hydraulic properties over a given area and depth

CDSCP Cross References - 8.3.1.2: Overview of the Geohydrology Program
Description of the Present and Expected Geohydrologic Characteristics required by the Performance and Design Issues

- USGS Comment - Overview of the Geohydrology Program (p. 178)

  The DOE states on page 8.3.1.2-40 that "Hydrologic modeling produces the velocity field essential for defining flow paths and computing groundwater travel time. Such modeling requires sufficiently detailed knowledge of the hydrologic framework and the three-dimensional distribution of potential values and conductivity properties." A velocity field defined in this way only gives some mean picture of actual flow paths and values. Water seeks to flow in the path where it loses least energy. Thus, a single preferred large scale flow path from the repository to the accessible environment may be made up of a series of connected and non-connected fractures and permeable zones with internal velocities orders of magnitude greater than a local modeled average of the area. Therefore, hydrologic modeling probably does not define velocities and flow paths accurately enough to satisfy the design criteria.

CDSCP Cross References - 8.3.1.2: Overview of the Geohydrology Program
Description of the Present and Expected Geohydrologic Characteristics required by the Performance and Design Issues

o USGS Comment - Calculation of Flow Paths, Fluxes, and Velocities (p. 184)

The DOE states on page 8.3.1.2-343 of the CDSCP that a sensitivity analyses and simulations of flow and transport in hypothetical flow systems will be conducted on the applicability of techniques, used for the local hydrologic-well tests to the regional scale. Hypothetical systems will be similar conceptually but will be simplified for ease of data input. Within these analyses, homogeneity will be assumed for the regional scale, however, no measurements will be available to prove homogeneity. Moreover, even if the assumption of homogeneity were correct, the single realization of the multitude of possible parameters fields that exists at Yucca Mountain may exhibit peculiar flow paths not similar to the mean behavior predicted statistically. Further, it is not possible to assign objective probabilities to the likelihood of this occurrence.

CDSCP Cross References - Activity 8.3.1.2.3.3.3: Calculation of Flow Paths, Fluxes, and Velocities within the Saturated Zone to the Accessible Environment

o USGS Comment - Regional Hydrologic System Synthesis and Modeling (p. 161)

The USGS had several questions relating to Study no. 8.3.1.2.1.4, Regional hydrologic synthesis and modeling, in particular, activities two through four. Subregional and regional modeling is not specific and can mean the act of doing many things. The models can be analytical, electric analog, conceptual, sand tank, etc. These activities need further definition. In addition, the four activities that comprise this study contain only one short paragraph involving geochemistry.

The following comments and questions pertain to proposed areal modeling:

1. An explanation needs to be given for using the two-dimensional groundwater flow model developed by Czarnecki and Waddell (1984) and why it is not being revised to three dimensions to account for leakage between the lower carbonate aquifers and the overlying volcanics and basin-fill deposits.

2. Hydrochemical studies suggest that water chemistry varies depending on the major rock types (volcanics and carbonate) and the water in the carbonate rocks "evolve" downgradient because of leakage of a different "type" of ground water from the overlying volcanic rocks and perhaps from basin-fill deposits. How can this hypothesis be evaluated with a two-dimensional groundwater flow model?

The following comments and questions pertain to proposed cross-sectional modeling:

1. Can the simulations be done with anisotropy in the vertical and horizontal directions to assess the effect it may have on groundwater flow?

2. Will the two dimensional model include the underlying carbonate rock aquifer? The statement implying that the current potentiometric data suggest the vertical component is minor conflicts with data that there is an upward head gradient between the carbonate rocks and the overlying volcanics.

3. Will a new computer code be developed to simulate flow in a vertical section as implied in the first paragraph on page 8.3.1.2-103? If so, why?

CDSCP Cross References - Study 8.3.1.2.1.4: Regional Hydrologic System Synthesis and Modeling

CDSCP Cross References - Study 8.3.1.2.1.4.2: Subregional Two-Dimensional Areal Hydrologic Modeling

CDSCP Cross References - Activity 8.3.1.2.1.4.3: Subregional Two-Dimensional Cross-Sectional Hydrologic Modeling

4.2 Hydrologic Properties

o USGS Comment - Interrelationships of Geohydrology Investigation (p. 179)

In summarizing the studies for the saturated zone, the DOE state on page 8.3.1.2-59 "Adequate statistical characterization of the geometry of hydrostratigraphic units and their hydraulic conductivity, storativity, dispersivity, and porosity requires that a sufficient number and distribution of boreholes be drilled to determine these properties." Statistical or deterministic characterization of these properties is valid only for the scale and at the locations at which measurements are made. Unless Yucca Mountain has an unusually homogeneous aquifer system (which is not the case, as stated in the plans), the small-scale measurements planned will likely miss key features in the aquifer that control specific higher velocity flow paths.

CDSCP Cross References - 8.3.1.2: Overview of the Geohydrology Program
Description of the Present and Expected Geohydrologic Characteristics Required by the Performance and Design Issues

o USGS Comment - General Comments on Chapter 3 (p. 133)

It should be stated that the hydraulic properties of the hydrogeologic units are unknown over large areas of the study area. In areas of no information, hydraulic properties may also vary greatly and may affect the concept of groundwater flow. The USGS disagrees with the interpretation of potentiometric surface contours drawn on figure 3-9. The contours have no control (wells) for an area of 80 by 100 kilometers yet potentiometric contours have been approximated through the area whereas in areas of control, some contours have been omitted. What basis is used to draw the contours in the area of no control? The contours in areas of no control should be omitted from the figure.

o USGS Comment - Studies to Provide a Description of the Regional System (p. 152)

The USGS has specific questions concerning the description of the regional flow system. The questions are:

1. On what basis is the boundary of the groundwater flow system drawn in Figure 8.3.1.2-5?

2. Is additional information needed regarding the lack of heads over vast areas of the regional study area, the cause(s) of the steep head gradients to the north, or whether groundwater flow from areas to the north may enter the regional study area?

3. The regional hydrogeologic data used to delineate elongate groundwater subbasin was not presented in Chapter 3, and the basis for the boundaries is unclear. The boundaries seem more related to a simulation model than to hydrogeologic data.

4. Regional groundwater modeling has only included horizontal heterogeneities where known. It has not addressed vertical heterogeneities nor heterogeneities in areas of no information. (page 154, USGS Comments).

5. The discussion does not mention how the uncertainty of the lateral model boundaries will be assessed (p.156, USGS Comments).

6. It is unclear how sensitivity analyses will be performed on fault zones (p.156, USGS Comments).

7. No mention is given to the lack of data over large areas and how the lack of data is going to be incorporated into the analyses or in defining uncertainties in the model results (p.157, USGS Comments).

8. Is the regional flow system the same as the regional study area in Activity 8.3.1.2.1.3.2 (p.157, USGS Comments)?

9. Can heads in an anisotropic aquifer system be used to adequately define flow directions (p.157, USGS Comments)?

CDSCP Cross References - Investigation 8.3.1.2.1: Studies to Provide a Description of the Regional Hydrologic System

CDSCP Cross References - Study 8.3.1.2.1.3: Characterization of the Regional Groundwater Flow System

o USGS Comment - Underflow from Pahranagat Valley (p. 132)

Groundwater flow from Pahranagat Valley into the hydrogeologic study area was estimated by Winograd and Friedman (1972) on the basis of deuterium values of groundwater discharging from springs at Ash Meadows. However, we have no direct evidence of underflow. Unless more direct evidence is provided, we should continue to assume underflow from Pahranagat Valley is possible but uncertain, and we should plan our studies to address this uncertainty.

CDSCP Cross References - Investigation 8.3.1.2.1: Studies to Provide a Description of the Regional Hydrologic System

- o USGS Comment - Studies to Provide a Description of the Regional System (p. 155)

  Activity 8.3.1.2.1.1.1, Precipitation and Meteorological Monitoring is part of the study "Characterization of the meteorology for regional hydrology" (8.3.1.2.1.1). As such, this activity should include sampling for precipitation chemistry and isotopes. Activity 8.3.1.2.1.2.1 (Surface-water Runoff Monitoring) as proposed, contains no provision for geochemical or isotopic sampling. These parameters should be included in this activity.

  The activity states on page 8.3.1.2-71 of the CDSCP that both regional and site specific precipitation data will be correlated with paleoclimatic data. What paleoclimatic data and what kind of correlations to what purpose?

CDSCP Cross References - Investigation 8.3.1.2.1: Studies to Provide a Description of the Regional Hydrologic System

CDSCP Cross References - Study 8.3.1.2.1.1: Characterization of the Meteorology for the Regional Hydrology

4.3 - Alternative Techniques and Hypotheses

o USGS Comment - Dissolved Oxygen in Groundwater (p. 117)

The analysis and interpretation of dissolved oxygen in groundwater, on both a regional and site-specific geographic scale, deserves far more attention than it is presently receiving. Although plagued by vagaries of sample collection and analysis, dissolved oxygen has one extremely important feature--in the absence of advection or diffusion, the concentration of dissolved oxygen can only decrease downgradient. Dissolved oxygen should provide a valuable adjunct to carbon-14 in defining directions of flow in areas of low hydraulic gradient. The presence, at the observed concentrations (Table 4-6, CDSCP) of Fe and Mn with dissolved oxygen is thermodynamically inconsistent, and if representative of in-situ conditions, of considerable importance to nuclide transport. The coexistence of high concentrations of Fe and Mn in oxygenated waters needs further investigation, perhaps by downhole sampling devices.

Another question involves the corrosion experiments such as those depicted in Table 7-10. Observed rates are very slow, attributable to formation of surface oxidized films. What about the stability of these films in the absence of dissolved oxygen in liquid water or the lack of oxygen gas in air-stream mixtures?

CDSCP Cross References - Activity 8.3.1.2.1.3.5: Regional Hydrochemical Tests and Analyses

CDSCP Cross References - Study 8.3.1.2.3.2: Characterization of the Site Saturated Zone Hydrochemistry

CDSCP Cross References - Investigation 8.3.1.3.1: Studies to Provide Information on Water Chemistry Within the Potential Emplacement Horizon and Along Potential Flow Paths

- USGS Comment - Geochemical Reaction Modeling (p. 121)

  For many of the potential applications throughout the CDSCP, geochemical reaction path calculations using EQ 3/6 or equivalent codes are the method of choice. However, in modeling efforts aimed at identifying reactions occurring in natural groundwater systems, given the existence of a geochemical data set for that system, an alternative modeling approach exists that should also be pursued. This alternative technique is an inverse modeling approach based on chemical mass balance calculations and is perhaps best discussed in Plummer, 1984. The USGS-WRD has found this approach to be a considerable value in its Regional Aquifer Systems Analysis Program. This alternative technique referenced by the USGS should be investigated.

CDSCP Cross References - 8.3.1.3 Overview of the Geochemistry Program
Description of the Present and Expected Geochemical Characteristics Required by the Performance and Design Issues

- USGS Comment - Conceptual Model Hypothesis (p. 151)

  The DOE hypothesis on page 8.3.1.2-51 (Table 8.3.1.2-2) of the CDSCP states that the tuff groundwater flow system behaves as a single, thick aquifer, with negligible vertical variations in hydraulic aquifer properties and seepage velocity. Is this a reasonable hypothesis, based on 50-m higher water levels in the Lithic Ridge tuff at well H-1 than in overlying units? And aren't the nonwelded units that separate each major ash-flow unit likely to be much less permeable than the highly fractured densely-welded units? An alternative hypothesis might be in order here for additional consideration.

CDSCP Cross References - 8.3.1.2 Overview of the Geohydrology Program: Description of the Present and Expected Geohydrologic Characteristics Required by the Performance and Design Issues

- USGS Comment - Regional System Evapotranspiration Studies (p. 159)

  The USGS states that the evapotranspiration studies proposed by the DOE in the CDSCP are reasonably described but the methods and technical procedures are completely unacceptable. For instance, use of a flux-versus-depth to water function is too simplistic to work. In addition, vertical gradients measured in boreholes will be of limited utility in delineating areas of groundwater discharge by evapotranspiration. As described, this activity is unlikely to produce useful data. Even under the best of circumstances, with a sound understanding of the problem and a substantial staff, the chance of success would be limited.

CDSCP Cross References - Investigation 8.3.1.2.1: Studies to Provide a Description of the Regional Hydrologic System

CDSCP Cross References - Activity 8.3.1.2.1.3.4: Evapotranspiration Studies

o USGS Comment - Regional Flow System (p. 124)

Two alternate hypotheses of reaction and flow in the region south of Yucca Mountain along Fortymile Wash cannot be distinguished on the basis of presently available data. The USGS recommends that a few additional holes be drilled in this area, of sufficient depth that vertical head relationships can be established, and that water chemistry can be sampled as a function of depth. One or more of these wells might be drilled in conjunction with wells planned for the Fortymile Wash recharge study (Activity 8.2.1.2.1.3.3)

CDSCP Cross References - Investigation 8.3.1.2.3: Studies to Provide a Description of the Saturated Zone Hydrologic System at the Site

CDSCP Cross References - Activity 8.3.1.2.1.3.3: Fortymile Wash Recharge Study

o USGS Comment - Environmental Tracers (p. 122)

The use of various radioactive isotopes as estimators of age occurs throughout the CDSCP. The degree of understanding associated with these discussions of age unfortunately varies considerably, and complete misunderstanding occurs often. A greater detail is required on the use of various isotopes for age calculations. The age of a substance or phase containing a radioactive isotope can be calculated only if all of the possible sources and sinks that can add or remove isotopes from the phase in question are known, as well as the rates of transfer of isotopes between phases. This sort of complexity is often unrecognized in the CDSCP.

CDSCP Cross References - 8.3.1.2 Overview of the Geohydrology Program
Description of the Present and Expected Geohydrologic Characteristics Required by the Performance and Design Issues

4.4 - Inter-Discipline Management Coordination

o USGS Comment - Overview of the CDSCP (p. 124)

There are some study areas or subjects in the CDSCP that occur many times over in a variety of chapters, and often within several activities and studies in a given chapter or subchapter. An example would be in the area of modeling, where there appears to be a substantial redundancy in many of the proposed chemical, hydrologic, hydrochemical, solute transport, etc., conceptual and numerical models proposed throughout the CDSCP. A specific field related example of an integrated study of the various calcite-silica deposits, both regionally and site specific. Substantially more understanding might be gained in a shorter period of time by devoting a team effort to a focused study of the deposits, rather than having their study be ancillary to a dozen or more 'Activities' with disparate aims. Therefore, some study areas in the CDSCP will be best served by incorporation of these studies into a cross discipline Investigation, Studies, or Activities.

o USGS Comment - Overview: General Comments on Chapter 3 and Chapter 8 (p. 130)

The structure and organization of the background material provided in Chapter 3 indicates a lack of coordination in the preparation of the chapter. Different sections have been prepared by different people and little effort has been made to remove the contradictions and redundancies. The general tone of the discussion of the unsaturated zone is inadequate. A decision seems to have been made early on that only flow in the rock matrix is important, and that no flow occurs in the fractures. This conclusion is not warranted at this time. The background discussion needs to reflect this uncertainty.

In Chapter 8, individual project plans and activities each appear to be collecting all their own data even when other activities are collecting the same data. There does not seem to be any effort to coordinate these kinds of activities. Many projects and activities that are clearly multi-disciplinary in character make little or no effort to include or even acknowledge the related and relevant supporting disciplines.

Throughout the CDSCP, there is an excessive reliance on the application of simulation models. Insufficient attention is given to the availability and quality of data needed for modeling applications. Optimistic references are made to combining numerous models to yield some form of site super-model, i.e., combining the groundwater flow model with a transport model and thermal mechanical model. Promised application of simulation modeling without proper acknowledgement of the limitations can be a substitute for rational thought and proper planning.

Major groundwater studies conducted in southern Nevada during the past several years by the USGS District Staff in Carson City have led to the development of new concepts of regional groundwater flow in that part of the state. These new concepts may help resolve problems and uncertainties in understanding regional groundwater flow that cannot be resolved with older concepts.

CDSCP Cross References - Chapter 3: Hydrology

CDSCP Cross References - Chapter 8: Site Characterization Program