U.S NUCLEAR REGULATORY COMMISSION
DIVISION OF WASTE MANAGEMENT

COMPILATION OF USGS COMMENTS

Nevada Nuclear Waste Storage Isolation
Subtask 1.6
Review of Site Characterization Plan

Prepared by

Water, Waste, and Land, Inc.

for

Nuclear Waste Consultants

TECHNICAL ASSISTANCE IN HYDROGEOLOGY
PROJECT B - ANALYSIS
RS-NMS-85-009

August, 1988

Water, Waste & Land, Inc.
CONSULTING ENGINEERS & SCIENTISTS

August 16, 1988

WWL #4001

Mr. Mark Logsdon
Nuclear Waste Consultants, Inc.
155 South Madison Street, Suite 302
Denver, Colorado 80209

Dear Mr. Logsdon:

In a letter dated May 17, 1988, Water, Waste and Land, Inc. (WWL) was requested to summarize and categorize the USGS comments on the Department of Energy's Consultation Draft Site Characterization Plan. The format of this report was requested to be consistent with that which will be used for the upcoming Subtask 1.4 Conceptual Model Report, but allowing for differences due to differing objectives of the two tasks. In addition, the NRC staff requested that the USGS comments be distilled down to be as brief as possible and the page number(s) of the original survey comment along with cross references to applicable sections of the CDSCP be included in each summary.

The report requested by the NRC is enclosed. This document was produced with Word Perfect and the Word Perfect file USGSREV.001 is included on the enclosed diskette. The report is also provided as an ASCII format file (USGSREV.ASC) on the diskette. Please forward this document and the diskette to the NRC as soon as you have completed your review. Feel free to contact us if you have questions or comments regarding this submittal.

Sincerely,

WATER, WASTE & LAND, INC.

Tom L. Sniff
Senior Engineer

TLS:dml
Enclosures

1.0 INTRODUCTION

The United States Geological Survey (USGS) provided a wide range of comments and observations regarding the Consultation Draft Site Characterization Plan (CDSCP) prepared by the Department of Energy (DOE). For the purpose of this report, the USGS comments were divided into the following five categories:

Technology Limitations
Conceptual Model Alternatives
Supplemental Testing
Testing Gaps
General Comments

Each of the above categories therefore serves as a major section of this report.

To further categorize the comments, each was assigned to the appropriate subsystem, component and element of the hydrogeologic system using the systematic descriptions provided in a letter from Jeff Pohle to Nuclear Waste Consultants dated May 17, 1988. A subsystem is defined as a major portion of the groundwater system. For the NNWSI project, there are three such subsystems:

(1) Site Unsaturated,
(2) Site Unsaturated, and
(3) Regional Saturated Subsystem.

A component is defined as a major portion of the system or subsystem. An example of a component would be the lateral boundaries of the Regional Saturated Subsystem. An element is a part of the component. The Topopah Springs unit is an element of the hydrogeologic units component of the unsaturated zone subsystem. A general outline of the Yucca Mountain groundwater system using these systematic descriptions is provided in Table 1.

Each USGS comment is divided into a Title, followed by the page number where the comment was found. Immediately beneath the title is the appropriate titles (subsystem, component, element) from the Hydrogeologic System Outline (Table 1). A brief summarization of the comment is provided next. Finally, the CDSCP cross references are listed.

TABLE 1
Yucca Mountain Hydrogeologic System

I. Site Unsaturated Zone
   A. Spatial Coordinates
   B. Hydrogeologic Units
      1. Alluvium and Colluvium
      2. Tiva Canyon
      3. Paintbrush Nonwelded Unit
      4. Topopah Springs Welded Unit
      5. Calico Hills Nonwelded Unit
      6. Prow Pass Unit
   C. Boundary Conditions
      1. Flux
      2. Recharge
      3. Discharge
      4. Potential
   D. Repository Induced Changes
   E. Flow and Transport
      1. Modeling
      2. Chemical and Isotopic Analysis

II. Site Saturated Zone
   A. Spatial Coordinates
   B. Hydrogeologic Units
   C. Boundary Conditions
   D. Flow and Transport
      1. Modeling
      2. Chemical and Isotopic Analysis

III. Regional Saturated System
   A. Spatial Coordinates
   B. Hydrogeologic Units
   C. Boundary Conditions
   D. Flow and Transport
      1. Modeling
      2. Chemical and Isotopic Analysis

2.0 TECHNOLOGY LIMITATIONS

Technology limitations pertain to the USGS comments which call into question the DOE's ability to obtain data or perform experiments within a reasonable time period at the Yucca Mountain site.

Unsaturated Zone Data Acquisition - p.113
Site Unsaturated Zone
Boundary Conditions
Potential

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

Open Borehole Sampling - p.119
Site Unsaturated Zone
Boundary Conditions
Potential

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

Permeability Testing: Nitrogen Injection - p.120
Site Unsaturated Zone
Boundary Conditions

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

Regional System Evapotranspiration Studies - p.159
Regional Saturated System
Boundary Conditions

The USGS made the following points on the evapotranspiration studies proposed by the DOE in the CDSCP:

1. The description of the evapotranspiration studies is reasonably acceptable, but the methods and technical procedures section is completely unacceptable.
2. Use of a flux-versus-depth to water function is too simplistic to work.
3. Vertical gradients as measured in boreholes will be of limited utility in delineating areas of groundwater discharge by evapotranspiration.
4. 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:

Infiltration Tests in the Exploratory Shaft Facility - p.171
Site Unsaturated Zone
Boundary Conditions

The following comments pertain to Activity 8.3.1.2.2.4.2 - Infiltration tests in the exploratory shaft facility. The CDSCP states the objective of this activity is to determine the hydrologic conditions that control the occurrence of fracture and matrix flow.

1. It seems unlikely that a sand bed can 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 of Paris crust of a ceramic plate coupled to the infiltration block with diatomaceous earth.
2. It is not clear how the infiltration test 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.

3. 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.

3.0 CONCEPTUAL MODEL ALTERNATIVES

Conceptual model alternatives contains those USGS comments which suggest, either explicitly or implicitly, an alternative conceptual model for certain aspects of the Yucca Mountain Geohydrologic System.

Recharge - P.104
Site Unsaturated Zone
Boundary Conditions
Recharge

The DOE implies on page 3-207 of the CDSCP that recharge is aerial 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. Thus, although the average flux over the entire area might in fact be about 0.5 mm/year, 95% of the recharge might occur from 5% of the area and might average 1 cm or so a year in these areas. 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.

Although not explicitly stated, the conceptual model of focused recharge was used implicitly in locating access tubes in the neutron-hole network and in designing the Fortymile Wash studies. Nonetheless, the ramifications of such focused recharge seem inadequately addressed. The alternative hypothesis needs to be articulated in the general comments and in the following investigation and studies.

(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

Unsaturated Zone Saturation - p.107
Site Unsaturated Zone
Repository Induced Changes

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 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

Unsaturated Zone Flow: Lithophysal Cavities in the TSw Unit - p.108
Site Unsaturated Zone
Hydrogeologic Units
Topopah Springs Welded Unit

No experiments regarding unsaturated flow in tuffs with lithophysal cavities are described. However, the presence of lithophysae may substantially affect the unsaturated flow properties. Experiments are desirable to at least verify the conceptual model of unsaturated flow through such units.

Experiments regarding unsaturated flow in tuffs with lithophysal cavities are desirable to at least verify the conceptual model of 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

Gas Circulation in the Unsaturated Zone - p.110
Site Unsaturated Zone
Boundary Conditions
Flux

On page 3-195 and 3-213, mention is made of thermally or barometrically driven advective transport of water vapor. However, under present thermal gradients, convective cells would not occur unless the permeability of the rock were greater than about 100,000 darcies. 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

Flow and Transport: Distribution Coefficients - p.115
Site Unsaturated and Saturated Zone
Flow and Transport

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 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

Unsaturated Zone Flow - p.116
Site Unsaturated Zone
Flow and Transport

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

Regional Flow: Underflow from Pahranagat Valley - p.133
Regional Saturated System

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

Saturated Zone: Conceptual Model Hypothesis - p.151
Regional Saturated System
Flow and Transport

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

4.0 SUPPLEMENTAL TESTING

Comments contained in the Supplemental Testing section are data acquisition programs which the USGS believes are important to further characterize the site or reduce uncertainty in the conceptual model.

Sampling of WT Wells - p.118

Site Saturated Zone
Flow and Transport

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

Geochemical Reaction Modeling - p.121

Regional Saturated System
Flow and Transport

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

Hydrochemistry Tests in the Exploratory Shaft Facility - p.168
Site Unsaturated Zone
Flow and Transport
Chemical and Isotopic Analysis

It is stated in the description of this activity the "the carbon dioxide gas will be collected in molecular sieve in stainless steel cylinders and analyzed for carbon-14 and carbon-13 to carbon-12 ratio. The following information needs to be determined:

1. Carbon-13 ratios can be determined directly from gas samples of 500 cc or more. Why not use this technique for carbon-13 rather than adding the uncertainty of transferring the carbon dioxide on to and off of molecular sieve?
2. Vacuum distillation for deuterium and oxygen-18 will require great care to ensure quantitative extraction and thus no fractionation.
3. Analysis of noble gas isotopes might also add interesting information to this study.

CDSCP Cross References - Activity 8.3.1.2.2.4.8: Hydrochemistry Tests in the Exploratory Shaft Facility.

Unsaturated Zone Percolation - Exploratory Shaft Facility Study - p.170
Site Unsaturated Zone
Flow and Transport
Chemical and Isotopic Analysis

For the radial flow studies, a bolting and overcoring method will be used to obtain samples containing fractures that are approximately parallel to the mined surface. These samples are collected by first drilling a pilot hole perpendicular to the fracture: the fracture is then secured by a rock bolt, which holds the fracture together during core extraction, minimizing damage to the fracture plane (page 8.3.1.2-182 CDSCP).

If any of the open fractures contain calcite-silica deposits, a great deal of thought should be given to designing chemical, isotopic, petrologic studies of such vein-filling materials. Study of such veins could provide one of the few direct lines of evidence as to the nature of gas-water-rock interactions in an active natural fracture system.

CDSCP Cross References - Activity 8.3.1.2.2.4.1: Intact-fracture test in the Exploratory Shaft Facility.

Bulk Permeability Test in the Exploratory Shaft Facility - p.172
Site Unsaturated Zone
Hydrogeologic Units

On page 8.3.1.2-213 of the CDSCP it states that "these holes will be cross-hole tested with nitrogen to delineate the magnitude of the Klinkenberg effect and determine the air permeability-capillary pressure relationships." The following points need clarification:

1. It is not clear how the Klinkenberg effect can be evaluated. The effect should be small in the fractures, but quite significant in the matrix. The medium definitely should behave as one of double porosity, and possibly the matrix Klinkenberg effect could be evaluated by changes in the Warren and Root parameter with injection pressure as determined in successive tests. Alternatively, since the Klinkenberg effect is proportional to the square root of the mass of the gas molecule involved, nitrogen and helium could be used in successive tests, with differences in the Warren and Root parameter attributed to the Klinkenberg effect. If this is the plan, it should be so stated.
2. It is not clear how air permeability will be related to capillary pressure. This should be clarified.

CDSCP Cross References - Activity 8.3.1.2.2.4.3: Bulk Permeability Test in the Exploratory Shaft Facility.

Diffusion Tests in the Exploratory Shaft Facility - p.174
Site Unsaturated Zone
Flow and Transport

The objective of these tests are to determine in situ the extent to which nonsorbing tracers diffuse into the water-filled pores of the tuffs that the exploratory shaft will penetrate. The following points need clarification:

1. It is unclear that these tests 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.
2. The design of this activity seems to imply that diffusion, and only diffusion, will contribute to the movement of aqueous solutions of tracers.

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

Site Saturated Zone - Well Test Tracers - p.182
Site Saturated System
Flow and Transport

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

5.0 TESTING GAPS

Comments contained in the Testing Gap section are data acquisition programs which the USGS believes are completely lacking in the CDSCP and are required to further characterize the site or reduce uncertainty in the conceptual model.

Fortymile Wash Recharge Study - p.119
Site Saturated Zone

Nothing shown on the map of the potentiometric surface in the vicinity of Yucca Mountain supports the hypothesis that Fortymile wash is a major recharge source. That hypothesis has been developed mainly using geochemical data, yet no mention is made of using geochemistry to support or refute the hypothesis. 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/isotopic analyses should be conducted to whatever extent is practical on all water samples collected. Gas sampling piezometers should be installed in the Wash for composition and isotopic analyses of unsaturated zone gases. The most important analysis from these piezometers are probably CO2 content and its carbon-13 and carbon-14 signature. Chemical/isotopic analyses should be conducted to whatever extent is practical on all water samples collected in the Fortymile Wash Recharge Study.

CDSCP Cross References - Activity 8.3.1.2.1.3.3: Fortymile Wash Recharge Study

Environmental Tracers: Surface Water Studies - p.123
Site Unsaturated Zone
Boundary Conditions
Recharge

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

Conceptual Model of Regional Flow System - p.124
Regional and Site Saturated System

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

Unsaturated Zone Processes Around Yucca Mountain, p.133
Hydrogeologic System

The study of unsaturated zone processes in the broader general area of Yucca Mountain, instead of only at Yucca Mountain, need greater emphasis.

1. 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.
2. Groundwater conditions south of Yucca Mountain are not adequately known. A better knowledge of the flow down gradient from the repository site is needed.

One or more series of wells along a groundwater flow path can be used to study groundwater movement and the geochemical evolution of groundwater from beneath Yucca Mountain to groundwater discharge areas. This information will be invaluable in describing and understanding the discharge part of the flow system.

CDSCP Cross References - Study 8.3.1.2.2.10: Unsaturated Zone System Analysis and Integration
CDSCP Cross References - Investigation 8.3.1.2.3: Studies to Provide a Description of the Saturated Zone Hydrologic System at the Site

Unsaturated Zone Characterization of Percolation - p.168
Site Unsaturated Zone
Boundary Conditions

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 aperture 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.

Unsaturated Zone System Analysis and Integration - p.176
Site Unsaturated Zone
Flow and Transport
Chemical and Isotopic Analysis

These comments pertain to Activity 8.3.1.2.2.10.2:

1. Carbon dioxide containing C-14 is not a reliable tracer of unsaturated water flow because it moves by gaseous diffusion much more rapidly than does the water.
2. Carbon dioxide partitioning between soil gas, water, and the solid phase is highly complicated, and has not been identified as an aspect of the model.

CDSCP Cross References - Study 8.3.1.2.2.10: Unsaturated-Zone System analysis and Integration
CDSCP Cross References - Activity 8.3.1.2.2.10.2: Numerical Simulation of the Concepts.

Interrelationships of Geohydrology Investigations - p.179
Regional and Site Saturated System
Hydrogeologic Units

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

6.0 GENERAL COMMENTS

USGS comments in this section are as the title suggests, of a general nature. Many of these comments relate to the overall approach to a testing program or a data acquisition study.

General Comment: Dissolved oxygen in groundwater - p.117
Site and Regional Saturated Zones
Flow and Transport
Chemical and Isotopic Analysis

The analysis and interpretation of dissolved oxygen in groundwater, on both a regional and sit-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. 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.

Dissolved oxygen should provide a valuable adjunct to carbon-14 in defining directions of flow in areas of low hydraulic gradient. 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

Environmental Tracers: Radioactive Isotopes as Estimators of Age - p.122
Hydrogeologic System

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. 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.

A greater detail is required on the use of various isotopes for age calculations. The age of a substance, or phase, containing an isotope can be calculated only if all of the possible sources and sinks that can add or remove the isotope from the phase in question are known, as well as the rates of

transfer of the isotope 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

Overview of the CDSCP - p.124
Hydrogeologic System

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. Some study areas in the CDSCP might best be served by incorporation of the studies into cross discipline Investigations, Studies, or Activities. An example would be in the area of modeling. There appears to be a substantial redundance in many of the proposed chemical, hydrologic, hydrochemical, solute transport, etc., conceptual and numerical models proposed throughout the CDSCP.

A specific field-related example might be an integrated study of the various calcite-silica deposits, both regional and site-specific. An understanding of these deposits is important to tectonics, paleohydrology, paleoclimate, gas and water transport, caliche formation, and radionuclide sorption and transport, among others. Substantially more understanding might be gained in a shorter period of time by devoting a team effort to a focused study of these deposits, rather than having their study be ancillary to a dozen or more Activities with quite disparate aims.

Overview: General Comments on Chapter 3 and Chapter 8 - p.130
Hydrogeologic System

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. In other instances, projects refer to data collected by another activity, but the data being collected by that activity are not the same as that referred to. 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

General Comments on Chapter 3 - p.133
Regional Saturated System

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.

Referring to Figure 3-8 on page 3-59 of the CDSCP, Are some areas of the upper clastic aquitard actually the lower clastic aquitard? Is the lower carbonate aquifer present beneath areas outlined as the upper clastic aquitard? If so, how was this handled in the analysis?

The first time that boundaries of the study area have been discussed is on page 3.70. Such a discussion should be included when discussing Figures 3-8 and 3-9 (CDSCP pages 3-59 and 3-63) or it should at least precede these figures.

On what basis was the direction of groundwater movement determined as stated on page 3-74, last paragraph of the CDSCP? The data points shown on page 3-75, Figure 3-10 of the CDSCP should be identified as well or spring. The data points outside the study area should be shown on Figure 3-9.

Regional Flow: Simulation of Regional Groundwater Flow - p.149
Regional Saturated System

Specific questions which were raised about the present and planned simulations of regional groundwater flow are:

1. What is the uncertainty in the estimate of recharge and how does this uncertainty affect the calibration of transmissivity and estimates of groundwater flow?
2. What is the uncertainty in the estimate of underflow from areas outside of the model boundaries? To what extent may these uncertainties affect the calculation of transmissivity and estimates of groundwater flow?
3. What is the uncertainty in the estimate of the potentiometric head? To what extent does this uncertainty

affect the calculation of transmissivity and the estimates of groundwater flow?

2. What is the uncertainty in the estimates of groundwater discharge? To what extent may these uncertainties affect the calculation of transmissivity and estimates of groundwater flow?
5. What is the uncertainty in the types of rocks through which groundwater flows beneath a given location? To what extent may these uncertainties affect the simulation of groundwater flow beneath the proposed repository?
6. What is the uncertainty in averaging hydraulic properties over a given area and depth and how might this uncertainty affect the estimated flow velocities and travel times?

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

Studies to Provide a Description of the Regional System - p.152
Regional Saturated System
Boundary Conditions

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

Studies to Provide a Description of the Regional System - p.155
Regional Saturated System
Boundary Conditions

Activity 8.2.1.2.1.1.1, 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.

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?

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.

Regional Hydrologic System Synthesis and Modeling - p.161
Regional Saturated System
Boundary Conditions
Flow and Transport

1. The Activities of Study 8.3.1.2.1.4 are not clear, 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.
2. The four activities that comprise this study contain only one short paragraph involving geochemistry.

The following comments and questions pertain to Study 8.3.1.2.1.4.2.

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 Activity 8.3.1.2.1.4.3.

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

Studies to Provide a Description of the Site Unsaturated Zone - p.165
Site Unsaturated Zone
Flow and Transport
Chemical and Isotopic Analysis

The following comment pertains to the section "Technical Rationale for the investigation" on page 8.3.1.2-115 of the CDSCP:

1. It is not clear how environmental tracers give effective porosity in absence of flux data from other sources. This needs further definition.
2. Any isotope strongly subject to diphasic transport, such as carbon dioxide containing C-14, cannot be used to determine liquid travel times in arid or semiarid environments because gaseous diffusion is generally a much more rapid transport mechanism.

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

Unsaturated Zone Percolation - Surface Based Study - p.168
Unsaturated Zone

On page 8.3.1.2-147 of the CDSCP, it states that "Fluid permeability tests to be compared will include air permeability, Klinkenberg air permeability at different overburden pressures, specific water permeability, and oil permeability." It is not clear why oil permeability is being determined. How can these data be used?

This comment pertains to the discussion on nitrogen pressure injection testing on page 8.3.1.2-159 of the CDSCP (p.169, USGS Comments). In addition to affecting the moisture content near the borehole walls, nitrogen injection will impact the soil-gas and soil-water chemistry by stripping carbon dioxide and the environmental gas tracers, as well as altering the D and O-18 distribution. These gas chemistry data are needed to evaluate the potential

for gaseous radionuclide migration and may help determine vadose water travel time. Consideration should hence be given to performing withdrawal (pumping) tests instead. If this proves impractical, consideration should be given to pumping out several times the volume of nitrogen injected following the injection test.

On page 8.3.1.2-159 it states that "following the monitoring phase, the gas sampling access tubes will be used to inject water into each of the isolated, downhole instrument stations." The following comment pertains to this experiment. It seems unlikely that sufficient water could be injected into the gas sampling tubes to do more than test the backfill. Careful consideration should be given as to whether these experiments can be worthwhile.

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
CDSCP Cross References - Activity 8.3.1.2.2.3.2: Site Vertical Borehole Studies

Overview of the Geohydrology Program - p.178
Regional Saturated System
Flow and Transport Modeling

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. We would therefore disagree that hydrologic modeling defines 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

Site Saturated Zone - Multiple Well Tests - p.180
Site Saturated System
Hydrogeologic Units

The DOE states on page 8.3.1.2-295 of the CDSCP "In general, multiple well tests will be needed to evaluate complex heterogeneous flow models. While useful for investigating many aspects of saturated zone hydrology beneath Yucca Mountain, results of single well tests have limited use in understanding the nature and areal distribution of bulk aquifer properties."

It is suggested that multiple well tests will improve single well test understanding of fracture permeability and connectivity. While this may be relatively true, it points out that the plan drafters realize that the scale of the test is related to the property measured. A single-well test samples only a small aquifer volume; a multiple well test samples a larger volume and gives information on a larger scale. However, even the proposed multiwell tests are at a scale which is minute compared with the travel distance from 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

Calculation of Flow Paths, Fluxes, and Velocities - p.184
Site Saturated System

On page 8.3.1.2-343 of the CDSCP, the DOE state "Applicability of techniques proved successful at the scale hydrologic-well tests to large scale problems will be evaluated by conducting sensitivity analyses and simulations of flow and transport in hypothetical flow systems. The hypothetical systems will be similar conceptually and will retain many of the important hydrologic characteristics of Yucca Mountain but will be simplified for ease of data input."

Two approaches are suggested in the plans for dealing with the scale problem. Both approaches assume statistical homogeneity of parameters at the large scale. such large-scale homogeneity indeed must be assumed a priori; 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 parameter 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.