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U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

Testing Priorities at Yucca Mountain: Recommended Early Tests to Detect Potentially Unsuitable Conditions for a Nuclear Waste Repository

Volume II

Report of the Test Prioritization Task Force

March 1,1991

UNITED STATES DEPARTMENT OF ENERGY

Testing Priorities at Yucca Mountain: Recommended Early Tests To Detect Potentially Unsuitable Conditions for a Nuclear Waste Repository

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Volume II
Appendices

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Volume II
Table of Contents

Appendix A
Sources of Potential Concerns

Introduction

Appendix A is intended to exhibit the origin of the potential concerns (PCs) used in the present analysis of the TPT. PCs analyzed in the Importance and Testing Workshops with the experts (Integration Group Panels) were identified and defined by the TPT Core Team and discussed in the meetings. As a result of these discussions several changes occurred, and the final list of PCs that were analyzed is provided in Table 3-1.

Initially the Core Team correlated the Potentially Adverse Conditions (PACs) contained in 10 CFR Part 60 with the PACs and the Disqualifying Conditions contained 10 CFR Part 960. This correlation and the appropriate text of 10 CFR Part 960 and 10 CFR Part 60 are presented under each PC short title. Several PACs in 10 CFR Part 960 are not listed among the PACs of 10 CFR Part 60. A correlation matrix of the PCs with PACs and disqualifiers contained in 10 CFR Part 60 and Part 960 is presented in Table A-1. There are several wording differences between 10 CFR Part 60 and 10 CFR Part 960. The PCs were modified accordingly to reflect the intended concern of the regulations. In the subsequent text and in Table A-1, the numbers in italics represent the identifying numbers of the PCs in this analysis that address the concern of a given PAC.

Throughout the analysis, external comments received by the Project on the Site Characterization Plan (SCP) were considered by the Core Team and workshop participants in their assessments and analyses. These comments included submittals from the State of Nevada, Edison Electric Institute, Environmental Protection Agency, Department of the Interior, and various other agencies and groups. References to the major comment packages on the SCP are included in the bibliography found in Appendix B.

Potentially Adverse Conditions derived from 10 CFR Part 960 and 10 CFR Part 60 ***(including disqualifying conditions from 10 CFR Part 960)***

Introduction

The first number preceding each abbreviated title corresponds to the PC number found in Table 3-1 in Volume I. Many of the regulatory concerns, expressed below, were addressed by assessments of multiple PCs. Similarly, in some cases multiple regulatory concerns were addressed by a single PC. These have been recorded by listing multiple PC numbers, in parentheses at the head of each paragraph below. The statements of PACs and disqualifiers are preceeded by the section number and title from the regulations; "60" refers to 10 CFR Part 60 and "960" refers to 10 CFR Part 960. The text used to define each PC for assessment purposes can be found in Appendices C and D. Copies of the full text from the regulations, as listed below, were presented and available in all assessment workshops.

Each 10 CFR Part 60 PAC is prefaced by the statement "The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area."

Regulatory Concerns

(5, 2.1, 6, 8) Geohyd. Chg. affecting WI
960.4-2-1 Geohydrology. (c) Potentially Adverse Conditions.
(1) Expected changes in geohydrologic conditions--such as changes in the hydraulic gradient, the hydraulic conductivity, the effective porosity, and the ground-water flux through the host rock and the surrounding geohydrologic units--sufficient to significantly increase the transport of radionuclides to the accessible environment as compared with pre-waste-emplacement conditions.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(H8) Usable Water In CA
960.4-2-1 Geohydrology. (c) Potentially Adverse Conditions.
(2) The presence of ground-water sources, suitable for crop irrigation or human consumption without treatment, along ground-water flow paths from the host rock to the accessible environment.

(2.1, 2.2) Complex Geology

960.4-2-1 Geohydrology. (c) Potentially Adverse Conditions.

(3) The presence in the geologic setting of stratigraphic or structural features--such as dikes, sills, faults, shear zones, folds, dissolution effects, or brine pockets--if their presence could significantly contribute to the difficulty of characterizing or modeling the geohydrologic system.

(6) Expected GWWT < 1000y

960.4-2-1 Geohydrology. (d) Disqualifying Condition.

A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.

60.113 (a) (ii) (B) (2).

(2) Geologic Setting. The geologic repository shall be located so that pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

(3, 26) Reactive GW Chem (EBS)

960.4-2-2 Geochemistry. (c) Potentially Adverse Conditions.

(1) Ground-water conditions in the host rock that could affect the solubility or the chemical reactivity of the engineered-barrier system to the extent that the expected repository performance could be compromised.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.

(7) Ground-water conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

(20) Sorp/Rock Strength Reduction

960.4-2-2 Geochemistry. (c) Potentially Adverse Conditions.

(2) Geochemical processes or conditions that could reduce the sorption of radionuclides or degrade the rock strength.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.

(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.

(4) Oxidizing GW in Host Rock
960.4-2-2 Geochemistry. (c) Potentially Adverse Conditions.
(3) Pre-waste-emplacement ground-water conditions in the host rock that are chemically oxidizing.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(9) Ground-water conditions in the host rock that are not reducing.

(18) Rock Cond. Beyond R.A.T.
960.4-2-3 Rock characteristics. (c) Potentially Adverse Conditions.
(1) Rock conditions that could require engineering measures beyond reasonably available technology for the construction, operation, and closure of the repository, if such measures are necessary to ensure waste containment or isolation.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(21) Geomechanical properties that do not permit design of underground opening that will remain stable through permanent closure.

(22, 24, 21, 23) Therm/Rad Effects on WI
960.4-2-3 Rock characteristics. (c) Potentially Adverse Conditions.
(2) Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

(24, 22, 21, 23) Therm Effects on WI
960.4-2-3 Rock characteristics. (c) Potentially Adverse Conditions.
(3) A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

(9, 10) Water Table Rise
960.4-2-4 Climatic changes. (c) Potentially Adverse Conditions.
(1) Evidence that the water table could rise sufficiently over the next 10,000 years to saturate the underground facility in a previously unsaturated host rock.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(22) Potential for the water table to rise sufficiently so as to cause saturation of an underground facility located in the unsaturated zone.

(5) Climatic Effect on RN Transp.
960.4-2-4 Climatic changes. (c) Potentially Adverse Conditions.
(2) Evidence that climatic changes over the next 10,000 years could cause perturbations in the hydraulic gradient, the hydraulic conductivity, the effective porosity, or the ground-water flux through the host rock and the surrounding geohydrologic units, sufficient to significantly increase the transport of radionuclides to the accessible environment.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(25) Past Extreme Erosion
960.4-2-5 Erosion. (c) Potentially Adverse Conditions.
(1) A geologic setting that shows evidence of extreme erosion during the Quaternary Period.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(16) Evidence of extreme erosion during the Quaternary Period.

(25) Geomorphic Processes
960.4-2-5 Erosion. (c) Potentially Adverse Conditions.
(2) A geologic setting where the nature and rates of the geomorphic processes that have been operating during the Quaternary Period could, during the first 10,000 years after closure, adversely affect the ability of the geologic repository to isolate the waste.

(7) 200m Depth Infeasible
960.4-2-5 Erosion. (d) Disqualifying Condition.
The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.

*(*See Below) Dissolution Evidence*
960.4-2-6 Dissolution. (c) Potentially Adverse Condition.
Evidence of dissolution within the geologic setting--such as breccia pipes, dissolution cavities, significant volumetric reduction of the host rock or surrounding strata, or any structural collapse--such that a hydraulic interconnection leading to a loss of waste isolation could occur.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(10) Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets.

*(*See Below) Dissolution Likelihood*
960.4-2-6 Dissolution. (d) Disqualifying Condition.
The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation.

(13) Past Active Tectonism (Faulting, etc.; exclude igneous activity)
960.4-2-7 Tectonics. (c) Potentially Adverse Conditions.
(1) Evidence of active folding, faulting, uplift, subsidence, or other tectonic processes or igneous activity within the geologic setting during the Quaternary Period.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(16, 17) Past Active Igneous Activity
60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(15) Evidence of igneous activity since the start of the Quaternary Period.

*(**See Below) Historical Seismicity*
960.4-2-7 Tectonics. (c) Potentially Adverse Conditions.
(2) Historical earthquakes within the geologic setting of such magnitude and intensity that, if they recurred, could affect waste containment or isolation.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

*(**See Below) Potential for Increased Seismicity*
960.4-2-7 Tectonics. (c) Potentially Adverse Conditions.
(3) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or the magnitude of earthquakes within the geologic setting may increase.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude or earthquakes may increase.

*(**See Below) High Local Seismicity*

960.4-2-7 Tectonics. (c) Potentially Adverse Conditions.
(4) More frequent occurrences of earthquakes or earthquakes of higher magnitude than are representative of the region in which the geologic setting is located.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

(15) Tectonic-induced Lakes

960.4-2-7 Tectonics. (c) Potentially Adverse Conditions.
(5) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such magnitudes that they could create large-scale surface-water impoundments that could change the regional ground-water flow system.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional ground-water flow system and thereby adversely affect the performance of the geologic repository.

(11, 12) Tectonic Effects on reg. GW Flow

960.4-2-7 Tectonics. (c) Potentially Adverse Conditions.
(6) Potential for tectonic deformation--such as uplift, subsidence, folding, or faulting--that could adversely affect the regional ground-water flow system.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional ground-water flow system.

(13) Tectonic Effects on WI

960.4-2-7 Tectonics. (d) Disqualifying Condition.
A site shall be disqualified, if based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur.

(H4, H3) Extraction of Nat. Res.

960.4-2-8-1 Natural Resource. (c) Potentially Adverse Conditions.
(1) Indications that the site contains naturally occurring materials, whether or not actually identified in such form that (i) economic extraction is potentially feasible during the foreseeable future.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(17) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:
(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(H5) Evid. of Subsurface Mining

960.4-2-8-1 Natural Resource. (c) Potentially Adverse Conditions.
(2) Evidence of subsurface mining or extraction for resources within the site if it could affect waste containment or isolation.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(18) Evidence of subsurface mining for resources within the site.

(H5) Evidence of Drilling

960.4-2-8-1 Natural Resource. (c) Potentially Adverse Conditions
(3) Evidence of drilling within the site for any purpose other than repository-site evaluation to a depth sufficient to affect waste containment and isolation.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(19) Evidence of drilling for any purpose within the site.

(H1) H.I. Effect Gd. Water Flow

960.4-2-8-1 Natural Resource. (c) Potentially Adverse Conditions.
(5) Potential for foreseeable human activities--such as ground-water withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activities, or the construction of large-scale surface-water impoundments--that could adversely change portions of the ground-water flow system important to waste isolation.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(2) Potential for foreseeable human activity to adversely affect the ground-water flow system, such as ground-water withdrawal, extensive irrigation, surface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

(H4) Nat. Res. of >Gross or Net Value

960.4-2-8-1 Natural Resources. (c) Potentially Adverse Conditions.
(ii) such materials have a greater gross value, net value, or commercial potential than the average for other areas of similar size that are representative of and located in the geologic setting.

960.4-2-8-1 Natural Resource. (c) Potentially Adverse Conditions.
(4) Evidence of a significant concentration of any naturally occurring material that is not widely available from other sources.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(17) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that: (ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

(H5) Prev. Mining, etc. Create Path.

960.4-2-8-1 Natural Resource. (d) Disqualifying Conditions.
A site shall be disqualified if--
(1) Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or

(H6) Mining Outside the Controlled Area

960.4-2-8-1 Natural Resource. (d) Disqualifying Conditions.
(2) Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.

(H1) H.I. effects on Resp. Flooding

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(19) Rock & GW Complex Engr.

60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(20) Rock or ground-water conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(8) Perched Water
60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(23) Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

(1.1) Gas Flow Radionuclide
60.122 Siting Criteria. (c) Potentially Adverse Conditions.
(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment.

Notes
*The Regulatory concerns in 10 CFR Part 60 and 10 CFR Part 960 include Dissolution Evidence and Dissolution Likelihood. These two concerns were eliminated from further consideration because they were intended to address a salt site or other site where dissolution processes could have a major impact. The Site Characterization Plan addressed this issue. No testing programs were planned because of a lack of present dissolution processes at the Yucca Mountain Site and because dissolution effects and processes were judged to be of little importance in the future at the Yucca Mountain site. The group of experts at the Importance Workshops (See Appendix B) also concluded that no further analysis of the potential dissolution effects by the TPT was necessary.

**These postclosure potential concerns include a consideration of "Historical Seismicity," the "Potential for Increased Seismicity" in the future, and the potential occurrence of "High Local Seismicity" in the future. These three potential concerns were not formally addressed by the TPT. Through discussions with a limited number of experts in the fields of seismicity and performance assessment, the collective effects of these three potential concerns were not judged to have a significant effect on the waste isolation capabilities of the site.

Rationales behind these judgements included the expectation that seismicity and ground motion of a given magnitude could be adequately mitigated by engineering of the repository design and the waste package design, that the present information on historical seismicity and tectonics indicate that future seismicity is expected to remain the same or decrease, and that local seismicity in the Yucca Mountain area is less than surrounding areas in Nevada and is not expected to be significantly higher in the future. The TPT does acknowledge that these three potential concerns need to be more thoroughly evaluated and assessed in the future.

Table A-1. Correlation of 10 CFR 960, Potentially Adverse and Disqualifying Conditions with 10 CFR 60.122, Potentially Adverse Conditions

	10 CFR 60																								
10 CFR 960	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	ASSESSMENT CORRELATION
GEOHYDROLOGY																									
PAC 1		+	+	+	X																	+	+		(5.2.1.6.8)
PAC 2		+															X								(H8)
PAC 3				+						+					+								+		(2.1, 2.2)
DISQUAL																									6
GEOCHEMISTRY																									
PAC 1							X																		3.26
PAC 2								X																	20
PAC 3									X																4
ROCK CHAR																									
PAC 1																				X	X			+	18
PAC 2							+	+		+	+				+					+	+			+	(22.24.21.23)
PAC 3							+	+												+	+				(24.22.21.23)
CLIMATE CHANGE																									
PAC 1					+	+																+			(9.10)
PAC 2					+	X																			5
EROSION																									
PAC 1																X									(25)
PAC 2	+		+													+									(25)
DISQUAL																									(7)
DISSOLUTION																									
PAC 1										X															•
DISQUAL										+															•
TECTONICS																									
PAC 1											X				X										(13.16.17)
PAC 2												X													•
PAC 3													X												•
PAC 4														X											•
PAC 5			X																						(15)
PAC 6				X																					(11, 12)
DISQUAL											+	+	+		+										13
NAT RESOURCE																									
PAC 1																	X								(H4,H3)
PAC 2																		X							(H5)
PAC 3																			X						(H5)
PAC 4																		X							H4
PAC 5		X																							(H1)
DISQUAL 1																		+	+						(H5)
DISQUAL 2																	+	+	+						(H6)

+ = CORRELATES
X = STRONGLY CORRELATES
• SEE DISCUSSION IN APPENDIX A

Outline of the Potential Concerns Elicited at the February 8, 1990, meeting of the TPT and Yucca Mountain Project Staff

This is a list of concerns elicited during the February 8, 1990 meeting of the Surface Based Prioritization Core Team (i.e., now the TPT) and Yucca Mountain Project staff (SAIC, 1990, February 22; see Appendix B for a reference). *The list was generated without discussion of the importance of the concerns.* The Core Team has used this information in developing the assessment methodology and in evaluating the "importance" of the items as the methodology was applied. Following the February 8 meeting, the Core Team met to consider the unedited information (below), revise the list into PCs, and evaluate the list along with the other information assessed by the Core Team. The meeting summary letter (SAIC, 1990: February 22) was distributed and considered at all meetings of the TPT for the Phase I effort.

Those Project Staff in attendance at the meeting included:

Tim Barbour	USGS/SAIC	Steve Mattson	SAIC
G. E. Barr	SNL	John H. Peck	SAIC
Jeremy Boak	DOE/YMPO	Chris Rautman	SNL
Anne Cavazos	SAIC	Gary D. Roberson	DOE/YMPO
Robert Craig	USGS	Eric Ryder	SNL
Bruce Crowe	LANL	Gerald Shideler	USGS
Russ Dyer	DOE/YMP	Scott Sinnock	SNL/LV
Ken Eggert	LANL	Tim Sullivan	DOE/YMPO
Jerry Frazier	SAIC	Jerry Szymanski	DOE/YMP
W. Haslebacher	WESTON	Scott Van Camp	DOE/HQ
Dwight Hoxie	USGS	Arthur Watkins	SAIC
Bill Hughes	DOE/YMPO	Dale Wilder	LLNL
Paul Kaplan	SNL	Albert Williams	DOE/YMPO/QA
Pete Karnoski	SAIC, QA	Bill Wilson	USGS
August Matthusen	SAIC	Jean Younker	SAIC

The concerns elicited from the meeting participants include those outlined below. The PC numbers in parentheses have been added to correlate with the numbers in Table 3-1, Volume I. The summary of the February 8, 1990, meeting and the table below were distributed to the Importance and Testing Workshop participants. The experts were asked to consider these concerns when evaluating and assessing the potential concerns. Those items marked with an asterisk were not expressly considered in the assessment because they were inappropriate for this analysis or considered to be extremely unlikely to occur.

Concerns List

Geochemistry
(5,2.1,6,8,3,26,4,1.1)
- Difficulty of characterizing radionuclide transport
- Large geochemical variability of fluids making contact with waste package
- Radionuclide movement through fractures in the unsaturated zone and saturated zone
- How we will model fracture pathways to model transport
- Extreme variations in ground-water chemistry
- Uninhibited gaseous releases from canister

Rock Characteristics
(5,2.1,6,8,2.2,18,24,22,21,23)
- Is conductivity enhanced by tectonics
- Effective bulk strength of bedrock
- Areally distributed steplike displacement along fractures
- Canister rupture due to lithostatic loads being applied
- Thermal conductivity less than assumed in models
- Do fracture pathways exist between repository and accessible environment (water releases and gaseous)
- Do continuous fracture pathways exist between the surface and repository
- Thickness and distribution of lithophysal zones in Topopah Spring Member
- Distribution of high density fracture
    - Excavation/borehole stability zones
    - Fracture flow
- Thickness and distribution of zeolitic layer
    - Effectiveness of transport barrier

Climate Change
(5,2.1,2.2,6,8,9,10)
- Increased effective moisture in next 10,000 years and effects on hydrology
    - Increased infiltration
    - Increased flux
    - Water table rise
    - Saturated repository
- Origin and significance of hydrogenic deposits
    - Ascending waters
- Large degree of uncertainty regarding future climate and future hydrology
- Spring deposits

Human Interference/Natural Resources
(H3,H4,H5,H6,H1,H8)
- Assess resource potential early (includes minerals, hydrocarbons, geothermal)

Tectonics
(16,17,13,15,11,12,13,8 and see explanations above for those concerns on seismicity))

- Volcanic eruption
- Earthquake hazards
- Demonstration of resolution of volcanic disruption
- Recurrence of faulting
  - Disruption of repository
  - Surface facility disruption
  - Altering hydrologic regime
  - Public perception
- Geologic stability
- Reliance on geophysical data
- What is volume of water coming up faults
- Tectonic induced changes in conductivity exceeds >10E-4
- Large tectonically induced change in upward flux (time dependent changes in Rayleigh stability)
- Fault rupture of waste package
- Quaternary faulting at site (age, offset, recurrence interval)
- Presence of detachment faults
- Relevant earthquake sources
  - Use of 10,000 year cumulative-slip-earthquake concept, how we approach 10 CFR 50, Appendix A usage]
- Stress field at site (How it relates to future faulting mechanisms]
- Low velocity upper mantle anomaly indicated by teleseismic data [may indicate magma chamber)
- *Deep crustal outgassing

Other
(5,2.1,6,8,9,10)
- Saturated repository

(2.1,2.2)
- Reliance on multiple natural barriers

(2.1,2.20
- Prioritization of tasks based on current conceptual models

(H1,H4,13,11,12,15,16,17,13,9,10)
- Resolving effect of tectonic and geothermal processes on geohydrology at Yucca Mountain

(2.1,2.2)
- Have we identified all processes at site and mechanisms driving them?

(2.1,2.2)
- Have we identified appropriate boundary conditions and initial conditions?

Other (continued)
(2.1,2.2)
- Have we identified the domain with regard to coefficients being modeled?

(1.1)
- Define gas flow

(2.1,2.2)
- Complexity of system (including uncertainty)

(20,18,22,24,21,23,19)
- Engineering measures may not be adapted to natural environment
- *Bureaucracy

Erosion
(25)
- Impact of erosion on location of surface facilities and marker system

Geohydrology
(5,2.1,6,8,2.2,6,20,9,10,5,15,11,12,13)
- Transient recharge conditions
  - Shortening of travel times
  - Altering geochemical environment
  - Increased water in boreholes
- Steep gradient (examine potential of controlling faults; also understand consequences of gradients)
  - Change in water table configuration
  - Flooding repository or shorten flow path
  - Public Perception
- What are the controlling factors of conductivity
  - Alteration in conductivity may cause a change in the water table, flood repository, or shorten flow paths
- Large enhancement of contemporary conductivity structure (>10E2)
  - Subset of previous conditions
- Local upward flux boundaries along Solitario and Paintbrush faults (Upward flux=lateral flux)
  - Localized upwelling of water entering repository
- Extreme quantities of ground water entering waste package boreholes (>5 L/yr)
- Transient flow in throughgoing faults
- Gas phase and vapor phase transport effects on moisture balance
  - Release of Carbon-14
  - Ability to characterize unsaturated zone hydrology
  - GWTT
- Characterize hydrology of fractures in Calico Hills

Geohydrology (continued)

- Characterize presence and attributes of fracture networks in Calico Hills
  - Fractures--present or not
    - Fractures--open or not
    - Fractures-interconnected or not
      - Tests:
      - Core analysis
      - Pneumatic testing
      - VSP
      - Two angled holes with cross-hole pneumatic tracer testing
- Characterize hydrology of Calico Hills
  - Waste isolation
- Examine occurrence of perched water (how, when, and where)
  - Flooding of repository
  - Altering flow paths
- Test hypothesis that welded tuffs behave as porous media
  - Ability to characterize hydrology, GWTT and radionuclide transport
- Do circumstances exist that are conducive to the formation of wetting front instabilities?
  - Flow paths
  - GWTT
  - Transport
- Definition of recharge mode (e.g., fault infiltration--how important)
  - GWTT
  - Transport
  - Water chemistry
- Magnitude of flux in the unsaturated zone (both liquid and vapor) and temporal and spatial variability and what conditions control flow path
- Role of regional carbonate aquifer in hydrologic flow system
  - Ability to characterize hydrology
  - Public perception

In addition, the following was submitted by Bruce Crowe (LANL) as a handout at the February 8 meeting. The concerns listed here were discussed during the meeting and included in the above outline.

Site Concerns
Los Alamos Perspective
(biased by B. Crowe)

Three levels of Comments are provided:

1. Broad issues to the overall approach for evaluating a site for disposal of high-level radioactive waste.

2. Site Characterization issues that are judged to be of potential concern for the suitability of the Yucca Mountain site (in order of decreasing importance). These concerns include issues that could lead to disqualification of the site or could be used to criticize the site if they are not studied early in the site characterization program.

3. Suggested priorities and concerns with the Site Characterization Plan.

Broad Issues:

1. Complexity of the processes of radionuclide migration.

   The key issues for suitability of a repository is the ability of the repository and the repository system (waste package, rock system, and the geochemical and hydrologic setting) to isolate waste radionuclides from the accessible environment for the required containment period. Radionuclide transport associated with movement of moisture is the major process that can lead to release of radionuclides. A major concern with radionuclide transport is the ability of the scientific community to conduct laboratory experiments, modeling, and field experiments to demonstrate a sufficient understanding of the processes of radionuclide transport. These concerns include the geochemical complexity and the sorption mechanisms of waste radionuclides, particularly the actinides, the difficulty of modeling radionuclide migration in a dynamic flow system through fractured rock of the unsaturated and saturated zones, the difficulty of designing and conducting field experiments for studying radionuclide migration, and the need for validating radionuclide transport models through comparison with results from field experimentation.

2. Uncertainty in Geoscience (see discussion in USGS Circular 779, Bredehoft et al., 1978).

Many geologic processes cannot be described adequately from a mechanistic perspective. Predictions of future operation of geologic processes will often be based on evaluation of the geologic record to establish past rates of operation of processes. Predictions of future rates will have significant uncertainty.

3. Experimentation in the Unsaturated Zone.

The processes of water movement in the unsaturated zone are difficult to characterize. It is extremely difficult to design experiments in the unsaturated zone that do not disturb the in situ conditions. A major challenge for site studies is designing and conducting experiments in the unsaturated zone that will lead to sufficient understanding and demonstration of understanding of processes of water movement.

Site Qualification Issues
Yucca Mountain Site

(Ranked in order of judged importance to successful licensing of a repository site)

1. Over-reliance on the nominal case and calculated ground-water travel time for meeting licensing requirements (performance allocation).

The potential disqualifying events are unexpected events and we need to demonstrate that the site contains waste under those conditions. This should require use of natural barriers including the waste package, the geochemical barrier, <u>and</u> the hydrologic flow system. Failure to use a multiple natural barrier concept in performance assessment could result in exceeding release limits for some unexpected conditions.

2. Transient recharge conditions.

Transient increases in infiltration rates (natural and associated with future climate changes) could induce episodes of rapid fracture flow in the unsaturated zone and through the repository to the water table. This could lead to greatly shortened transport times to the water table.

3. Continuous fracture systems or hydrologic discontinuities in the zeolitized/vitric tuff interval.

The presence of undetected fracture systems of lithologic or structural features that could produce lateral flow in the zeolitic/vitric sequence beneath the repository and between the water table and bypass this hydrologic and geochemical barrier.

4. Steep hydrologic gradient.

   The origin of steep hydrologic gradient has not been adequately explained and data relating to its origin may not be obtained in a timely manner. Is a scenario possible of rapid breakdown of the steep gradient and associated down-gradient modification of the unsaturated zone? Our judgment is that this is not a disqualifying issue, but if priority is not given to obtaining data to understand this feature, it could be cited as a potentially disqualifying issue.

5. Difficulty of characterizing radionuclide transport (hydrologic and geochemical processes) in the unsaturated and saturated zones.

   Demonstration of an adequate understanding of radionuclide transport requires an integrated program of laboratory studies, model development and model validation through field experimentation for both the saturated zone and the unsaturated zone. Without an adequate and comprehensive program sufficient data may not be obtained to take credit for the beneficial aspects of radionuclide transport.

6. Magmatic disruption of the repository with associated eruption of waste contaminated magma in the accessible environment.

   Present calculations indicate the worse case probability of repository disruption is about 10^{-7} yr^{-1}. The combined conditional probability of volcanic disruption and associated radiological releases that exceed the regulatory release limits should be less than and may be considerably less than 10^{-8} yr^{-1}. This should not be a disqualifying condition. A key question is whether these calculations can be determined with a reasonable degree of uncertainty based on an analysis of the past geologic record.

7. Resource potential of the Yucca Mountain region--including petroleum and mineral deposits.

   Yucca Mountain is located within a petroleum belt and directly south of the Claim Canyon caldera segment. Caldera margins are prime target for mineral exploration. Our judgment is that this is probably not a disqualifying issue. However, data must be obtained early in the site characterization program to adequately disprove these concerns.

8. Potential for faulting along existing faults or new faults.

The presence of many faults adjacent to the exploration block, some with evidence of multiple episodes of movement in the Quaternary, suggest a relatively high probability of recurrence of faulting. Our judgment is that it will be difficult to identify a scenario associated with faulting that could lead to unacceptable radiological releases. However, it is an issue that will be raised by outside reviewers. It can best be resolved by early assessments of the consequence of faulting events and establishment of conservative design criteria.

9. Geologic stability of the Yucca Mountain site.

The combined concerns raised by Quaternary faulting, presence of Quaternary volcanism, seismicity, and new geodetic data suggesting historic deformation may lead to perceptions that the site is unsuitable in the public and political perspective.

10. Tectonic setting of the site and reliance on geophysical data to discriminate tectonic models.

The tectonic setting of the site is complex. Multiple tectonic models may be feasible to explain structural features of the site area. Geophysical data will be required to supplement drilling data to attempt to constrain possible tectonic models. Interpretations of the geophysical data will be non-unique. Failure mode tectonic or volcanic models may be proposed that can be regarded as permissive with geophysical data. Examples: detachment faulting, models for the geometry of detachment systems, origin of Crater Flat, presence of magma bodies below the Yucca Mountain region, correlation between seismicity and surface faults.

Site Characterization Issues

1. Insufficient priority is given to developing an integrated laboratory, modeling and field approach to understanding radionuclide transport. Field experiments are extremely difficult to design, they may be expensive and they may be lengthy. Field validation of radionuclide models is viewed as an essential element of the program and the field experiments part of this work may not be given sufficient priority in the site characterization plans.

2. Testing in the ESF may not be of sufficient duration or may be too constrained (non-aggressive testing) to satisfy data needs for understanding radionuclide transport. We recommend construction of surface-based facilities (multiple adits) outside the disturbed zone (for freedom of experimentation) but in identical rock lithologies as the exploration block. These adits should be used for aggressive hydrologic and radionuclide migration experiments before construction of the exploratory shaft.

3. Deepening of Trench 14 may provide a relatively inexpensive and potentially definitive approach to resolving the origin of the vein deposits. This should be done early in the site characterization program.

4. Early scheduling of drill holes G-7, G-5, and G-6 are important for timely resolution of questions of resource potential in the Yucca Mountain area.

5. An expanded exploration program is needed to examine the nature and geometry of the vitric-zeolite transition in the exploration block. This may require more exploration within the central part of the exploratory block. Drifting in the Calico from the ESF may provide much of this needed information. This issue should be examined as part of the current plans to evaluate the exploration options of the Calico Hills interval.

6. There may be insufficient penetration of drill holes into the saturated zone to allow for adequate characterization of the transport pathways in the saturation zone. Additionally, there may not be sufficient data provided by the shallow drill holes to characterize the geometry of the transition from the volcanic sequence into the Paleozoic.

7. Increased priority should be given to examining the penetration depths of the ^{36}Cl bomb pulse in the exploration block. This is needed to evaluate the importance of fracture flow in the block. Original plans allow for testing of the depth of the bomb pulse in the ESF. Because the ESF will be delayed, this work should become a priority in the drilling exploration program.

8. The understanding of the release of ^{14}C in the unsaturated zone may be insufficient for site characterization.

Appendix B
Testing Prioritization Task (TPT) History

Brief Description of the Testing Prioritization Task (TPT) History

The Testing Prioritization Task (TPT) was issued guidance (DOE, Oct. 31. 1989), conceptualized, designed, and implemented during the late fall of 1989 through January of 1990. An implementation plan was written, reviewed, and approved; potential decision analyst consultant(s) reviewed and hired; quality assurance planned and implemented; and potential Core Team members identified and selected. The implementation plan (DOE,1990: DOE/YMP/90-4) was issued as a controlled document on January 1, 1990.

The Core Team met throughout the month of January to develop an analytic approach that would meet the project objectives and to prepare for the February 8, 1990 meeting (SAIC, Feb. 22, 1990; and Appendix A) to elicit concerns from Project technical staff.

The TPT objectives were:
1) Provide an early prioritization of the "testing" program based upon "tests" that need to address the important/likely Potentially Adverse Conditions contained in 10 CFR Part 60 and 10 CFR Part 960 and the Disqualifying Conditions contained in 10 CFR Part 960 that could be considered to have some significant probability of affecting management's and technical experts' consideration of the suitability or unsuitability of the Yucca Mountain site. A decision-aiding methodology was to be developed for this early prioritization.

2) Develop other decision-aiding methodologies that could be used to address site unsuitability analysis early during site characterization.

3) Develop a method and capability to re-assess the prioritization of testing at different points in time during site characterization.

An introduction to the task was also given in the February 8, 1990 open elicitation meeting. This meeting elicited concerns raised by Project technical staff concerning the suitability of the site. The concerns raised in the February 8 meeting were then considered by the Core Team in their further analyses of the prioritization of testing (See Appendix A for additional information). An integration meeting of the several related task forces was conducted in March, 1990 (DOE, March 20, 1990). These included the Alternatives to the Current License Application Strategy, Calico Hills Risk Benefit, Surface-Based Prioritization, and the Exploratory Shaft Alternatives Tasks.

Core Team meetings and meetings of the Core Team with expert panels were held in the next few months. These meetings are further described below and the meeting summaries are referenced in the *Special Bibliography of Correspondence and Other Items* contained in this appendix. Much of the time of the Core Team in the months of May, June, and July was spent preparing presentations that expressed ideas concerning the evaluation of a potential site suitability analysis, and ensuring that the efforts of the TPT met management directives. In August, the TPT was redirected toward developing a methodology that could be applied in an early timeframe, and yet, maintain the rigor of the original task in future efforts. The Core Team developed a phased approach to meet this need (SAIC, Oct. 1, 1990). The Phase I approach was developed as a "simple" spreadsheet model, whereas the Phase II approach plans to utilize a total-system-performance model that aggregates parameters at a lower level of analysis (i.e., such parameters are easier to assess by the experts and the analysis is more robust and more easily defendable). This report presents the results of Phase I. The present report on the Phase I efforts of the TPT will be submitted to the Yucca Mountain Project (YMP) for review on February 8, 1991. A management assessment meeting is scheduled for February 14, 1991. The results of the February 14, 1991, meeting and the YMP review will be incorporated into this report and the report forwarded to the DOE/OCRWM, RW-1 on March 1, 1991. Further details concerning the TPT's development and ensuing activities can be found in the documents that are listed in the *Special Bibliography of Correspondence and Other Items.*

Main Phase One Application Workshops, Dates of Workshops, and List of Attendees

Five assessment meetings were held for the Phase One effort of the TPT. These meetings are the main basis for the Core Team conclusions and recommendations. Careful selection of the experts was made by the Core Team, the DOE oversight managers, and the Participants managers. Experts were selected for their overall knowledge of the Yucca Mountain Project, their individual expertise of the scientific concerns, and their objectivity.

The Core Team made a significant effort to ensure that clear definitions of the parameters being elicited were established and that the assessments of uncertainty were unbiased and carefully considered. It is readily acknowledged by the Core Team that the definitions and assessments of uncertainty are extremely important in the evaluation of the PCs.

Importance Workshops

#1	Las Vegas, NV	October 17-18, 1990
#2	Menlo Park, CA	October 31-November 2, 1990

The experts who attended one or more of the above listed meetings are listed below. Each is a member of the Integration Group specified in the TPT Management Plan (DOE, Jan. 1990). Each expert was assigned a voter identification number. These identification numbers were maintained throughout this series of meetings. The purpose of these meetings was to assess the importance of each potential concern.

Voter Number, Experts name, and Organization

1	Julie Canepa	Los Alamos National Laboratory
2	Larry Rickertson	Roy F. Weston, Inc.
3	Dwight Hoxie	U.S. Geological Survey
4	Felton Bingham	Sandia National Laboratories
5	Scott Sinnock	Sandia National Laboratories
6	Lyn Ballou	Lawrence Livermore National Laboratory
7	Robert Raup	U.S. Geological Survey
8	Steven Mattson	Science Applications International Corp.
9	Jean Younker	Science Applications International Corp.

Testing Assessment Workshop

#1	Las Vegas, NV	November 28-29, 1990
#2	Menlo Park, CA	December 11-13, 1990
#3	Las Vegas, NV	January 17-18, 1991

The experts who attended one or more of the above listed meetings are listed below. Each expert is a member of the Integration Group, as specified by the TPT Management Plan (DOE, Jan. 1990). Each expert was assigned a voter identification number. These identification numbers were maintained throughout this series of meetings. The purpose of these meetings was to assess the accuracy of testing for selected potential concerns.

Voter Number, Experts name, and Organization

1	Lyn Ballou	Lawrence Livermore National Laboratory
2	Robert Raup	U.S. Geological Survey
3	Dwight Hoxie	U.S. Geological Survey
4	Joel Bergquist	U.S. Geological Survey
5	Richard Spengler	U.S. Geological Survey
6	Scott Sinnock	Sandia National Laboratories
7	Gary LeCain	U.S. Geological Survey
8	Julie Canepa	Los Alamos National Laboratory
9	Alan Flint	U.S. Geological Survey
10	Mike Chornack	U.S. Geological Survey
11	Barney Lewis	U.S. Geological Survey (Workshop #1 only)
12	Robert Craig	U.S. Geological Survey
13	Richard Luckey	U.S. Geological Survey
14	Steven Mattson	Science Applications International Corp.
15	August Matthusen	Science Applications International Corp.
16	Bruce Crowe	Los Alamos National Laboratory
17	Paul L. Cloke	Science Applications International Corp.

TPT Core Team Composition

The composition of the Core Team has varied in size and composition through time. The size of the Core Team has fluctuated because of the varied inputs needed at different times throughout the task. Several members of the Core Team were lost due to retirement, other commitments, etc. New Core Team members were selected by management for their ability to replace the expertise needed in the course of the TPT task. All of the Core Team members had a positive and beneficial impact on the TPT.

Present Core Team Members

Steven R. Mattson—SAIC, Senior Staff Geochemist/Geologist, Core Team Lead.
Bruce Judd—Decision Analyst, Decision Analysis Company, Core Team Decision Analysis member.
Scott Sinnock—Sandia National Laboratory, Performance Assessment Core Team member.
Dwight Hoxie—U. S. Geological Survey, Hydrologist, Core Team Site member.

Past Members of the Core Team

Tim Barbour—SAIC, Golden, Colorado, Core Team Site member until approximately April of 1990 when William Wilson replaced T. Barbour.
William Wilson—U. S. Geological Survey, Hydrologist, Core Team Site member (Served until approximately September of 1990, when Bill retired from the USGS and was replaced by Dwight Hoxie).

Occasional Members of the TPT Core Team
Martha Pendleton—SAIC, Geologist
August Matthusen—SAIC, Geologist
Robert Gamble—Roy F. Weston, Inc., Geologist

Other Workshops Which Will be Applicable to the Phase II Effort of the TPT and Any Future Suitability Analyses

These workshops were a part of the initial effort of the TPT. They were intended to serve as the assessments that would be needed for application of a total-system-performance model that would evaluate the prioritization of testing for the Yucca Mountain Project management (see Volume I for more description and the bibliography in this appendix for background documentation). Much of the information assessed in these meetings will be applicable to any further assessments of the TPT or applicable in any directed evaluations of site suitability. Each workshop listed below has the list of experts who were in attendance, the title of the workshop, and the dates upon which the meeting took place. Each expert is a member of the Integration Group. Several people at the workshops were attending as observers (e.g., observers are noted by an asterisk). The meeting summary for each workshop can be found in the bibliography contained in this appendix.

Performance Assessment Panel Workshop— April 9–20, 1990
(SAIC, May 14, 1990: Letter)

Rally Barnard	SNL
Tito Bonano	SNL
Russ Dyer	YMP/DOE
Paul Eslinger	PNL
Dwight Hoxie	USGS
Bruce Judd	Decision Analysis Co.
Paul Kaplan	SNL
Richard Lee	SAIC
Steve Mattson	SAIC
Bill O'Connell	LLNL
Larry Rickertsen	Weston
Ben Ross	Disposal Safety, Inc.
Scott Sinnock	SNL
Bill Wilson	USGS

Unsaturated Zone Site Panel Workshop- April 26, 1990
(SAIC, May 14, 1990: Letter)

Carol Boughton	USGS/NHP
Michael Chornack	USGS/NHP
Robert Craig	USGS/YMPB
Alan Flint	USGS/NHP
Bruce Judd	Decision Analysis Co.
Jack Kume	USGS/NHP
Edward Kwickles	USGS/NHP
Barney Lewis	USGS-NHP
Steve Mattson	SAIC
Charles Peters	USGS/NHP
Scott Sinnock	SNL/LV
Rob Trautz	USGS/NHP
Merrick Whitfield	USGS/NHP
Bill Wilson	USGS
Albert Yang	USGS/NHP

SZ Site Panel Workshop—May 4, 1990
(SAIC, May 14, 1990: Letter)

*Tim Barbour	SAIC
John Czarnecki	USGS WRD-NHP
Joe Downey	USGS WRD-NHP
Elisabeth Ervin	USGS WRD-NHP
Dan Gillies	USGS WRD-NHP
Ed Gutentag	USGS WRD-NHP
Bruce Judd	Decision Analysis Co.
Kenzi Karasaki	LBL
Richard Luckey	USGS WRD-NHP
Steve Mattson	SAIC
Gary Patterson	USGS WRD-NHP
*Gerald Shideler	USGS/GD
Scott Sinnock	SNL
Bill Steinkampz	USGS WRD-NHP
Bill Wilson	USGS

Geochemistry Panel Workshop—May 25, 1990
(SAIC, June 21, 1990: Letter)

Julie Canepa	LANL
Ken Eggert	LANL
Dave Hobart	LANL
Bruce Judd	Decision Analysis Co.
Schön Levy	LANL
Steve Mattson	SAIC
Arend Meijer	LANL
Ned Patera	LANL
Bruce Robinson	LANL
Robert Rundberg	LANL
Scott Sinnock	SNL
Ines R. Triay	LANL
Dave Vaniman	LANL
Bill Wilson	USGS

Waste Package Panel Workshop— June 6, 1990
(SAIC, June 21, 1990: Letter)

Lyn Ballou	LLNL
*Jim Blink	LLNL
*Anne Cavazos	SAIC
*Dwayne Chesnut	LLNL
Bill Glassley	LLNL
Bill Halsey	LLNL
Bruce Judd	Decision Analysis Co.
Annette MacIntyre	LLNL
Steve Mattson	SAIC
Bill O'Connell	LLNL
Ray Stout	LLNL
Rich Van Konynenburg	LLNL
Dale Wilder	LLNL
Bill Wilson	USGS

Gas Panel Workshop—June 22, 1990
(SAIC, August 9, 1990: Letter)

Bruce Judd	Decision Analysis Co.
Steve Mattson	SAIC
Scott Sinnock	SNL
Don Thorstenson	USGS (Reston)
Rich Van Konynenburg	LLNL
Ed Weeks	USGS

Special Bibliography of Correspondence and Other Items

The following bibliography is selective and is not a reflection of the full records package of the TPT. Most internal memos, scheduling letters, Quality Assurance documentation, viewgraph presentations, etc. have been omitted. Items found on this list were selected to reflect and exhibit, in detail, the course of events, the development of methodology used by the TPT, the application of the methodology by the TPT, scheduling of the TPT, and other influences on the methodology and application of the methodology utilized by the TPT for both Phase One and Phase Two of the Task. The list is chronological with respect to date of issue and not necessarily with date of occurrence.

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DOE, 1990, Review of Draft Implementation Plan for Surface-Based Prioritization Effort, Letter: Barrett, L. H. to Gertz, C., January 8, 1990.

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DOE, 1990, IMPLEMENTATION PLAN FOR THE SURFACE-BASED PRIORITIZATION TASK FORCE, Letter: Gertz, C. to Barrett, L., January 11, 1990, YMP:MBB-1524, 1 Enclosure.
Enclosure: Implementation Plan for the Surface-Based Prioritization Task Force.

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USGS, 1990, Prioritization of surface based testing, Memorandum: Czarnecki, J. B. to Wilson, W.E., February 5, 1990, USGS LRC 1.1.01, Water Resource Division

USGS, 1990, Prioritization of Surface-Based Testing at Yucca Mountain, Memorandum: Gilles, D.C. to Distribution, February 5, 1990, GS.90.A.001012., 1 enclosure.
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Enclosure: RPSBT Activities Summary

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Enclosure 1: Attendee List.

Enclosure 2: Agenda.

Enclosure 3: SBP Briefing.

Enclosure 4: SBP Reference List

Enclosure 5: ESA Briefing.

Enclosure 6: CHRB Briefing.

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Enclosure 2: Overheads from Presentation to Retardation Panel.

Enclosure 3: Information Elicited from Retardation Panel.

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Enclosure I: Enclosure list and brief description of enclosures. One page.

Enclosure II: Phase One approach, viewgraph package, presented to the Integration Group for the TPT. Twenty-six pages.

Enclosure III: Meeting and training attendance for the TPT meetings of October 17-18, 1990. Three pages.

Enclosure IV: Meeting summary and topics of discussion. Four pages.

Enclosure V: Assignments for the next TPT Meeting October 31-November 1-2, 1990. One page.

Enclosure VI: Geometric means for the assessment on gas flow of radionuclides (10 CFR Part 60.122-c-24). One page.

Enclosure VII: Geometric means for the assessment on sorption/rock strength reduction (10 CFR 960.4-2-2-c-2). One page.

Enclosure VIII: TPT Prioritization Worksheet (Assessments and notes from the October 17-18, 1990 meeting of the Core Team and Integration team). Three pages.

Enclosure IX: List of PAC's with assignment to individuals for the next TPT meeting. Initials of individual responsible (See Enclosure IV for reference). One page.

Enclosure X: Example ballot used in this TPT meeting.

SAIC, 1990, SCP activity relations to Potentially Adverse Conditions (postclosure), Letter: Barbour, T. to Sinnock, S., October 29, 1990, 1 enclosure.

Enclosure: ParaTrac: Correlation of Potentially Adverse Conditions with Site Characterization Activities.

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Enclosure 2: Agenda.

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Enclosure II: Phase One approach, additional viewgraph package to supplement the viewgraph package for the October 17-18, 1990 meeting, presented to the Integration Group for the TPT. Twenty one viewgraphs.

Enclosure III: Meeting and training attendance for the TPT meetings of October 31-November 1-2, 1990. Three pages.

Enclosure IV: Assumptions and Ground Rules for the meeting. Two Pages.

Enclosure V: Subjective Probability Assessment Sheet (100 to 1 in 10,000), four pages.

Enclosure VI: Initial Ranking of Potential Concerns: Ballot used to provide the initial ranking and the results of this initial ranking. This ranking was used only to determine which order the Potential Concerns would be assessed during the course of this meeting of the IG and CT. Four Pages.

Enclosure VII: Ballots used in this part of the Phase One Assessment and a summary text of the rationales provide by many of the Integration group members for each potential concern. Sixty-seven pages.

Enclosure VIII: Final results of individual ballots on each Potential Concern presented in table form. Thirty four pages.

Enclosure IX: Preliminary results of the IG and CT assessments for "Importance to Waste Isolation" (Test Accuracy and other components of Phase 1 have not yet been assessed, one page).

Enclosure X: References

DOE, 1990, RESPONSE DEVELOPMENT FOR THE NUCLEAR WASTE TECHNICAL REVIEW BOARD'S (NWTRB) SECOND REPORT TO CONGRESS AND INTEGRATION GROUP (IG) MEETING IN LAS VEGAS, NEVADA, ON JANUARY 29-31, 1991, Letter: Gertz, C. to Distribution, December 7, 1990, RSED:TWB-1027, 3 enclosures.

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Enclosure I: List of Enclosures.

Enclosure II: Attendance List.

Enclosure III: Overhead Presentation.

Enclosure IV: Meeting Summary.

Enclosure V: Sample Ballot.

Enclosure VI: Copies of Assessments.

Enclosure VII: Voting Plans.

Enclosure VIII: ParaTrac Data Sheet.

Enclosure IX: Individual Ballots.

SAIC, 1991, SUMMARY OF DECEMBER 11-13, 1990, MEETING OF THE CORE TEAM AND INTEGRATION GROUP FOR THE TESTING PRIORITIZATION TASK (TPT), Letter: Waddell, J. to Distribution, JDW:SRM:lcr:L91-6241, January 14, 1991, 6 enclosures.

Enclosure I: Enclosure List and References, 1 page.

Enclosure II: Meeting Attendance Lists, 3 pages.

Enclosure III: Assessment Variable List, 2 pages. This is the list of Potential Concerns that need to be addressed in term of "test package" accuracy. The assessment thresholds for these potential concerns are also included.

Enclosure IV: Sample ballot used in the test assessment process, 1 page.

Enclosure V: The meeting summary, 20 pages. Each Potential Concern is addressed separately with outlines of important facets of the discussion or assessment process noted. The list of tests, activities, or study plans considered are also listed.

Enclosure VI: Ballots, 224 pages. Each ballot from each individual with their assessed numbers are included. Not every voter is reflected on each Potential Concern because different Integration Group members were present on different days and because not all voters felt comfortable or qualified to vote on all Potential Concerns.

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Enclosure: Report Outline.

Mattson, S., 1991, Core Team Activities for the Testing Prioritization Task (TPT) November 7-8, 1990, SAIC Interoffice Memo: Mattson, S. to Younker, J., SRM:sjt:M91-004, January 9, 1991, 2 enclosures.
Enclosure 1: Notes from Core Team Meeting Nov. 7, 1990: Identification of Important Concerns and Plans for Assessing Testing Accuracy.

Enclosure 2: Assessment of Future Basaltic Volcanism.

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Enclosure I: Enclosure List and references, 1 page.

Enclosure II: Meeting Attendance Lists, 2 pages.

Enclosure III: The meeting summary, 15 pages. Each Potential Concern is addressed separately with outlines of important facets of the discussion or assessment process noted. The list of tests, activities, or study plans considered are also listed.

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Enclosure I: PARATRAC: Site Characterization Activity Summary.

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Enclosure I: Page 14 of Volume I.

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Appendix C
Importance Assessments

Introduction

This appendix presents the results of the assessments of the "importance" of each of the 32 potential concerns (PCs) listed in Table 3-1, which were considered during this Phase I analysis. As described in Volume I, Chapter 1 and Volume II, Appendix A, the PCs derive principally from the potentially adverse conditions cited in 10 CFR Parts 60 and 960. The "importance" of a PC is defined as the product of two factors: (1) the consequences for waste isolation in the presence of the PC and (2) the probability that the PC will be present or will occur at the site during the next 10,000 years. The consequences for waste isolation are stated quantitatively in terms of the total cumulative release of curies from the repository to the accessible environment over the next 10,000 years normalized to the radionuclide release limits established by the Environmental Protection Agency (EPA) in 40 CFR Part 191. The consequence for waste isolation of a particular PC is defined to be the incremental increased curies released to the accessible environment relative to the baseline cumulative release that would be expected to occur over 10,000 years in the absence of all PCs. In order to assess the probability of occurrence of a PC at the site, each PC was defined, to the extent feasible, in terms of a quantitative measure whose magnitude could be determined or inferred from tests performed at the site. Each PC measure was assigned a value, denoted the Assessment Threshold (AT), such that values of the measure greater than the AT would indicate that the PC was present.

The PC importance assessments were completed by the participants at two workshops convened for this purpose in Las Vegas, Nevada, on October 17-18, 1990, and in Palo Alto, California, on October 31 to November 2, 1990, respectively. (See Appendix B for the list of participants at these workshops and references to the meeting summaries.) The assessment process consisted of the following sequence of steps:

1. The workshop participants reviewed and discussed the definition, measure, and AT for the PC and, with the concurrence of the TPT Core Team, revised these as necessary to facilitate and improve the accuracy of the assessment.

2. A ballot was taken on which each participant provided an initial set of assessments for each of the items labelled A, B1, B2, C, and D on the ballot (see the sample ballot for PC #1: "Gas Flow Radionuclide").

3. The results of this initial ballot were displayed and discussed by the workshop participants. Information was exchanged among the participants and rationales for specific assessment values were given. This discussion was

important for optimizing consensus and convergence during the assessment process.

4. A final ballot was taken and the results were recorded to complete the assessment.

The individual assessments identified as items A, B1, B2, C, and D on the ballots were intended to provide the following information:

A The probability that the PC is present under existing site conditions or was present in the past, as specified in the definition of the PC.

B1 The probability that the PC will be present or will occur during the next 10,000 years, based on the definition of the PC and the specified value assigned to the AT.

B2 The probability that the PC, if present, will affect waste isolation at the site.

C The factor by which the total cumulative curies released to the accessible environment would be increased if the PC were present (expressed as a multiplier on the expected baseline release assessed in item D, below).

D Baseline total cumulative curies that would be expected to be released from the repository to the accessible environment in the absence of all <u>PCs</u> (expressed as a fraction of the EPA limits for allowable cumulative release).

An additional intermediate assessment, designated B1′ on the ballots, was made for PC #5: "Climate Effect on Radionuclide Transport." For this PC, B1 entailed the assessment of the *conditional* probability that the AT will be exceeded in the next 10,000 years, *given* that it had been exceeded during the Quaternary Period. Subsequently, B1′ assessed the *conditional* probability that the AT will be exceeded during the next 10,000 years given that it had not been exceeded in the past. Although item B1′ was assessed for only one PC, this assessment was allowed as an option for all of the PCs and, consequently, is included in the summary tables.

Item D, the expected baseline releases, was assessed only once at the outset. The result of this assessment was carried through on all of the ballots and is presented in the summary table for each PC. In assessing the baseline release, the workshop participants were instructed to assume (1) that ten percent of the total inventory of the waste canisters would fail during the first 10,000 years and (2) that radionuclide release to the accessible environment would occur solely by ground-water transport.

The assessment summaries provided in this appendix report the results of the individual importance assessments for each PC. The assessment summaries are identified by the PC number and title and supply the following information:

- Definition of the PC measure
- Value assigned to the assessment threshold
- Statement of the relevant regulatory concerns from 10 CFR Parts 60 and 960 (see also Appendix A)
- Definitions of the assessment items A, B1, B1′ (if used), B2, C, and D
- Synopsis of the workshop discussion and voting rationales
- Table displaying the results of the final assessment ballot.

Column 1 of the table identifies each workshop participant by their assigned voter number; columns 2 through 7 list the individual assessments of the items A, B1, B′, B2, C, and D, respectively. Column 8 lists the resulting importance of the PC, which was calculated according to the formula

$$\text{Importance} = A \times B1 \times B2 \times (C-1) \times D$$

when $B1' = 0$. In the case of PC #5, "Climate Effects on Radionuclide Transport," for which $B1' \neq 0$, the factor A in the above formula was replaced by the factor A′ defined by the formula

$$A' = A \times B1 + B1' \times (1.0-B1)$$

and B1 subsequently was set equal to 1.0 for this PC. Both the arithmetic and geometric means were used as summary statistics for the entries in each column and are listed in the bottom two rows of the table.

In considering the PCs related to the effects of human intrusion, the workshop participants agreed to include PC #H2: Usable Water in the Controlled Area— ux with PC#H1: Human Intrusion Effects on Geohydrology; and PC #H7: Evidence of Previous Drilling included with PC #5: Evidence of Previous Mining.

Additional discussion of the PCs and their definitions and assessment thresholds is presented in Appendix D. In several cases, the PC definitions were modified during the Testing Assessment Workshops in order to facilitate the assessment of test accuracy. Where such modifications were necessary, care was taken by the Core Team to ensure consistency between the definitions used for the importance and test-accuracy assessments.

Probability & Consequence Assessment Ballot (Sample)

Name: ______________________________ Ballot *(circle one):* 1st Final

Condition: 1. Gas flow radionuclide (ref # 46).

Assessment Threshold: curies released by gas flow are greater than 2% of the EPA limits.

A. Probability that the curies released by gas flow are greater than 2% of the EPA limits = ______________

COMMENTS:

B1. Probability that the condition occurs during next 10,000 yrs., (given the way we have defined this condition and AT) = (= 1.0, by definition)

COMMENTS:

B2. Probability that the condition affects waste isolation (given the way we have defined this condition and AT) = (= 1.0, by definition)

COMMENTS:

C. Multiplier on performance, relative to the no-condition repository.
By how much does the fact that
the curies released by gas flow are > 2% of EPA limits
multiply the expected curies released,
relative to the repository where
the curies released by gas flow are < 2% of EPA limits
and no other conditions exist (i.e., all 33 other measures < their ATs).

$$C = \frac{\text{expected curies released, given that } \underline{\text{this}} \text{ AT is exceeded}}{\text{expected curies released, given that } \underline{\text{no}} \text{ AT is exceeded}} = \_\_\_\_\_\_\_\_\_\_$$

COMMENTS

D. As a basis for the above answer, what is your estimate of expected curies released, given that no condition exists, i.e., that all 34 measures are less than their respective ATs?
Expected curies released, given that no condition exists = ______________.

Vote unless you feel that you do not have a basis for judgment.

PC #1: Gas Flow Radionuclide

Measure: Expected curies released to the accessible environment from the repository by gaseous transport of radionuclides through the unsaturated zone

Assessment threshold (AT): Two percent of the EPA limits as set forth in 40 CFR 191 for total cumulative releases over 10,000 years

Regulatory Concern:

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (24)

Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment.

Importance Assessment Questions:

A Probability that the curies released by gas flow will exceed 2% of the EPA limits during the next 10,000 years.

B1 Probability that the adverse condition occurs during the next 10,000 years (which, in accordance with the definition of column A, is identically equal to 1 for this concern).

B1' Not used in this assessment.

B2 Probability that the condition will affect waste isolation, given the definition of this condition and the AT.

C Multiplier on site performance relative to that expected, given no gaseous radionuclide releases.

D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#1: Gas Flow

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B 1	B 1'	B 2	C	D		Product
1	0.7	1		1	2000	0.00001		1.4E-02
2	0.7	1		1	100000	0.000001		7.0E-02
3	0.5	1		1	200000	0.000001		1.0E-01
4	0.5	1		1	100000	0.000001		5.0E-02
5	0.5	1		1	10000000	1E-08		5.0E-02
6	0.9	1		1	10000	0.00001		9.0E-02
7	0.7	1		1	200000	0.00001		1.4E+00
8	0.5	1		1	20000	0.000001		1.0E-02
9	0.7	1		1	2000	0.00001		1.4E-02
Avg	6.3 e-1	1.0 e+0	0.0 e+0	1.0 e+0	1.2 e+6	4.9 e-6		2.0 e-1
GMn	6.2 e-1	1.0 e+0	0.0 e+0	1.0 e+0	5.281 e+4	1.7 e-6		5.5 e-2

Discussion

The AT was set equal to two percent of the EPA limits, which was the median value of expected gaseous radionuclide releases as assessed by the Exploratory Shaft Alternatives Task at a workshop conducted in Albuquerque, New Mexico, on October 11, 1990. Carbon-14 (as carbon dioxide) is considered to be the primary radionuclide that could be released to the accessible environment by gaseous transport through the unsaturated zone.

PC #2: Complex Geology—Aqueous

Measure:	Expected curies released to the accessible environment from the repository by aqueous transport of radionuclides
Assessment threshold (AT):	Ten percent of the EPA limits as promulgated in 40 CFR 191 for total cumulative releases over 10,000 years

Regulatory Concern:

960.4-2-1 Geohydrology, (c) Potentially Adverse Conditions, Item (3)

The presence in the geologic setting of stratigraphic or structural features--such as dikes, sills, faults, shear zones, folds, dissolution effects, or brine pockets--if their presence could significantly contribute to the difficulty of characterizing or modeling the geohydrologic system.

Importance Assessment Questions:

- A Probability that geologic complexity of the site will cause problems in modeling or in obtaining modeling parameters that lead to an underestimate of radionuclide releases by > 10% of the EPA limits.
- B1 Probability that the condition occurs during the next 10,000 years, given that it is currently present at the site.
- B1' Not used in this assessment.
- B2 Probability that the condition will affect waste isolation, given that it will occur at the site during the next 10,000 years.
- C Multiplier on site performance, relative to that expected if the condition does not occur.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#2: Complex Geology—Aqueous

Workshop: import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.5	1		1	100000	0.00001		5.0E-01
2	0.1	1		1	100000	0.000001		1.0E-02
3	0.01	1		1	1000000	0.000001		1.0E-02
4	0.05	1		1	500000	0.000001		2.5E-02
5	0.05	1		1	10000000	1E-08		5.0E-03
6	0.01	1		1	10000	0.00001		1.0E-03
7	0.01	1		1	10000	0.00001		1.0E-03
8	0.01	1		1	500000	0.000001		5.0E-03
9	0.01	1		1	10000	0.00001		1.0E-03
Avg	8.3 e-2	1.0 e+0	0.0 e+0	1.0 e+0	1.4 e+6	4.9 e-6		6.2 e-2
GMn	2.9 e-2	1.0 e+0	0.0 e+0	1.0 e+0	1.430 e+5	1.7 e-6		6.8 e-3

Discussion

The issue in this PC is not the inherent geologic complexity of the site per se. The concern is that the structural and stratigraphic complexity of the site will lead to such large modeling errors that model-based predictions of total cumulative radionuclide releases to the accessible environment by aqueous dissolution and transport processes will underestimate true releases by at least a factor of 0.1 times the current EPA limits. Errors of such magnitude could be produced only by appreciable failure to adequately characterize the site or to properly incorporate and account for known complexity within the predictive models.

Because the baseline aqueous releases in the absence of any adverse conditions are expected to be small (Column D), the propagation and accumulation of small modeling errors over simulation times of up to 10,000 years are not regarded as likely to produce a cumulative error sufficient to exceed the assessment threshold. Given complete specification of the geologic complexity of the site, the adequacy and accuracy with which models predict aqueous-phase radionuclide releases ultimately will require appropriate review and acceptance by the scientific community. This PC bears heavily on the issue of validating site-characterization and performance-assessment models and the related concern of achieving adequate scientific confidence in the site and its effects on the repository system.

PC #2: Complex Geology—Gaseous

Measure: Expected curies released to the accessible environment from the repository by gaseous transport of radionuclides

Assessment threshold (AT): Ten percent of the EPA limits as promulgated in 40 CFR 191 for total cumulative releases over 10,000 years

Regulatory Concern:

960.4-2-1 Geohydrology, (c) Potentially Adverse Conditions, Item (3)

The presence in the geologic setting of stratigraphic or structural features--such as dikes, sills, faults, shear zones, folds, dissolution effects, or brine pockets--if their presence could significantly contribute to the difficulty of characterizing or modeling the geohydrologic system.

Importance Assessment Questions:

- A Probability that geologic complexity of the site will cause problems in modeling or in obtaining modeling parameters that lead to an underestimate of releases by > 10% of the EPA limits.
- B1 Probability that the condition occurs during the next 10,000 years, given that it is currently present at the site.
- B1' Not used in this assessment.
- B2 Probability that the condition will affect waste isolation, given that it will occur at the site during the next 10,000 years.
- C Multiplier on site performance, relative to that expected if the condition does not occur.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#2: Complex Geology—Gaseous

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B 1	B 1'	B 2	C	D		Product
1	0.1	1		1	5	0.02		8.0E-03
2	0.5	1		1	10	0.1		4.5E-01
3	0.3	1		1	100	0.02		5.9E-01
4	0.4	1		1	1000	0.0005		2.0E-01
5	0.5	1		1	10	0.02		9.0E-02
6	0.5	1		1	1	0.1		0.0E+00
7	0.5	1		1	5	0.02		4.0E-02
8	0.1	1		1	5	0.01		4.0E-03
9	0.5	1		1	1.01	0.1		5.0E-04
Avg	3.8 e-1	1.0 e+0	0.0 e+0	1.0 e+0	1.3 e+2	4.3 e-2		1.5 e-1
GMn	3.2 e-1	1.0 e+0	0.0 e+0	1.0 e+0	4.337 e+0	2.1 e-2		2.3 e-2

Discussion

Because rapid transport of carbon-14 through the unsaturated zone will be difficult to model accurately, there is appreciable likelihood that existing site complexity could lead to an error in predicting carbon-14 releases by an amount equal to 0.1 times the EPA limits, given that expected carbon-14 releases under present site conditions will be two percent of the EPA limits as assessed in Column D by the workshop participants.

PC #3: Reactive Ground-Water Chemistry

Measure: Total dissolved solids (TDS) of ground water that could potentially contact the engineered barrier system

Assessment threshold (AT): TDS > 10,000 ppm

Regulatory Concern:

960.4-2-2 Geochemistry, (c) Potentially Adverse Conditions,Item(1)

Ground-water conditions in the host rock that could affect the solubility or the chemical reactivity of the engineered-barrier system to the extent that the expected repository performance could be compromised.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (7)

Ground-water conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

Importance Assessment Questions:

- A Probability that present ground water in the Topopah Spring unit has a mean TDS > 10,000 ppm.
- B1 Probability that the AT will be exceeded in the next 10,000 years, given that it is exceeded now.
- B1' Not used in this assessment.
- B2 Probability that exceeding the AT will affect waste isolation, given that the AT will be exceeded in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse condition are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#3: Reactive Ground-Water Chemistry

Workshop: Import. #2
Date: 10/31 90
Respondents: 9

#	A	B 1	B 1'	B 2	C	D		Product
1	0.001	1		0.5	10	0.00001		4.5E-08
2	0.001	1		0.01	10	0.000001		9.0E-11
3	0.0001	1		0.5	10	0.000001		4.5E-10
4	0.001	1		0.01	5	0.000001		4.0E-11
5	0.0001	1		1	100	1E-08		9.9E-11
6	0.001	1		0.5	100	0.00001		5.0E-07
7	0.0001	1		0.3	10	0.00001		2.7E-09
8	0.0001	1		0.5	100	0.000001		5.0E-09
9	0.001	1		0.5	10	0.00001		4.5E-08
Avg	6.0 e-4	1.0 e+0	0.0 e+0	4.2 e-1	3.9 e+1	4.9 e-6		6.6 e-8
GMn	3.6 e-4	1.0 e+0	0.0 e+0	2.1 e-1	1.929 e+1	1.7 e-6		2.3 e-9

Discussion

Total dissolved solids (TDS) was selected as a bulk measure of possible chemical reactivity of ground water in the Topopah Spring host rock. TDS values exceeding 10,000 ppm were regarded by the workshop participants as an indication of a major flaw in our conceptual model of the ground-water chemistry at the site. Such a flaw could lead to high uncertainty in predicting aqueous-phase radionuclide releases based on the nominal SCP waste-package design. The assessment threshold of 10,000 ppm is approximately 100 times greater than the TDS measured in water well J13. Ground-water chemical reactivity is of concern because of the potential for inducing waste-canister corrosion and breaching. Ground water with a high TDS would be of concern in this regard depending on the ionic strength of, for example, Cl and F anions.

PC #4: Oxidizing Ground Water in Host Rock

Measure: Eh of ground water in the host rock under present conditions

Assessment threshold (AT): 400 mV

Regulatory Concern:

960.4-2-2 Geochemistry, (c) Potentially Adverse Conditions, Item (3)
Pre-waste-emplacement ground-water conditions in the host rock that are chemically oxidizing.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (9)
Ground-water conditions in the host rock that are not reducing.

Importance Assessment Questions:

- A Probability that present ground water in the Topopah Spring unit has an Eh > 400 mV.
- B1 Probability that the AT will be exceeded in the next 10,000 years, given that it is exceeded under present conditions.
- B1' **Not used in this assessment.**
- B2 Probability that exceeding the AT will affect waste isolation, given that the AT will be exceeded in the next 10,000 years.
- C Multiplier on site performance, relative to that expected if the condition does not occur.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#4: Oxidizing Ground Water in Host Rock

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B 1	B 1'	B 2	C	D		Product
1	0.9	1		1	1.1	0.00001		9.0E-07
2	0.8	1		1	1.1	0.000001		8.0E-08
3	1	1		1	1.01	0.000001		1.0E-08
4	0.8	1		0.001	10	0.000001		7.2E-09
5	0.8	1		1	1000	1E-08		8.0E-06
6	0.9	1		0.9	10	0.00001		7.3E-05
7	0.8	1		0.01	1.1	0.00001		8.0E-09
8	0.85	0.95		0.1	100	0.000001		8.0E-06
9	0.9	1		0.1	10	0.00001		8.1E-06
Avg	8.6 e-1	9.9 e-1	0.0 e+0	5.7 e-1	1.3 e+2	4.9 e-6		1.1 e-5
GMn	8.6 e-1	9.9 e-1	0.0 e+0	1.6 e-1	3.078 e+0	1.7 e-6		4.9 e-7

Discussion

Eh (with no pH constraints) was selected by the workshop participants as being an appropriate bulk measure of the degree to which oxidizing conditions are present within the Topopah Spring host rock. Because pore-water within the unsaturated zone at the site is in contact with air, ground water within the host rock is expected to be oxidizing under existing site conditions. Consequently, the relatively high value of Eh = 400 mV was selected as the assessment threshold.

Because present waste-package design is based on the expectation of oxidizing ground-water conditions, the degree to which the water is oxidizing was considered to have relatively small impact on the waste-isolation capability of the site as measured by the multiplier on performance assessed in Column C. For example, some preliminary performance-assessment models have considered Eh values as high as 700 mV, corresponding to water fully saturated with oxygen. Because Eh is not directly measurable, but must be interpreted based on a chemical-equilibrium model, considerable uncertainty may be associated with determining Eh values much greater than 400 mV.

PC #5: Climate Effect on Radionuclide Transport

Measure: Flux of ground water through the repository level in response to climate change during the Quaternary

Assessment threshold (AT): 10 times present flux

Regulatory Concern:

960.4-2-4 Climatic changes, (c) Potentially Adverse Conditions, Item (2)

Evidence that climatic changes over the next 10,000 years could cause perturbations in the hydraulic gradient, the hydraulic conductivity, the effective porosity, or the ground-water flux through the host rock and the surrounding geohydrologic units, sufficient to significantly increase the transport of radionuclides to the accessible environment.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (6)

Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

Importance Assessment Questions:

- A Probability that the ground-water flux through the repository level in response to climate change during the Quaternary exceeded > 10 times present flux.
- B1 Probability that the AT will be exceeded in the next 10,000 years, given that it was exceeded in the Quaternary.
- B1' Probability that AT will be exceeded in the next 10,000 years.
- B2 Probability that exceeding the AT will affect waste isolation, given that the AT will be exceeded in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

Discussion

Because the current ground-water flux through the unsaturated zone at the site is considered to be small (i.e., in the range from 1 to 4 mm/yr), an increase of flux by a factor of ten still does not represent a large flux and could have occurred during periods of greater-than-present precipitation during the Quaternary. Based on results from a two-dimensional, regional ground-water flow model, Czarnecki (1984) estimates (conservatively) that doubling current precipitation would increase the net (saturated-zone) ground-water flux near the site by a factor in the range from 2 to 4. Because Czarnecki's estimate was conservative, it was suggested that doubling precipitation would be unlikely to produce as much as a tenfold increase in flux at the site. It was argued that the mechanisms controlling flux at the site would not have been sufficiently different during the Quaternary to produce a sustained tenfold increase in flux.

If the AT were exceeded during the Quaternary, then the likelihood of its being exceeded during the next 10,000 years could be approximated by the ratio of 10,000 years to the duration of the Quaternary, which yields a value of approximately 0.01. Other factors include the possibility that the site is becoming increasingly arid as a result of the rain-shadow effect of the Sierra Nevada. One also must assess how many of the past pluvials would have produced a tenfold increase in flux in order to extrapolate into the future.

If a tenfold increase in flux did not occur during the Quaternary, and "if the past is key to the future," it is unlikely to occur during the next 10,000 years. On the other hand, future flux at the site might be independent of both present and past and so lead to the higher probability values assessed in Column B1'.

The probability that a tenfold increase in flux will affect waste isolation depends on the magnitude of the present flux. If the present flux is very low, the probability is also low; whereas if the present flux is sufficiently high that a tenfold increase could lead to appreciably greater contact of water with the emplaced waste, this probability may be high. This consequence is reflected also in Column C. If a tenfold (or more) increase in flux were to contact the waste, there is likely to be a tenfold increase in the rate at which canisters fail. However, the unsaturated zone may remain a significant barrier to radionuclide conditions so that expected effects on performance may be small.

IMPORTANCE BALLOT — **Workshop: Import. #2**
#5: Climate Effects on Radionuclide Transport — **Date: 10/31/90**
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	1	0.01	0.001	0.1	1.2	0.00001		2.0E-09
2	0.001	0.1	0.0001	1	10	0.000001		1.8E-09
3	0.5	0.01	0.001	0.01	1.1	0.000001		5.5E-12
4	0.01	0.01	0.0001	0.9	100	0.000001		1.8E-08
5	0.5	0.1	0.0001	1	50	1E-08		2.5E-08
6	0.2	0.1	0.001	0.5	100	0.00001		1.0E-05
7	0.01	0.01	0.001	0.5	100	0.00001		5.4E-07
8	0.01	0.01	0.001	0.2	20	0.000001		4.1E-09
9	0.5	0.1	0.0001	0.7	100	0.00001		3.5E-05
Avg	3.0 e-1	5.0 e-2	6.0 e-4	5.5 e-1	5.4 e+1	4.9 e-6		5.1 e-6
GMn	6.6 e-2	2.8 e-2	3.6 e-4	3.2 e-1	1.462 e+1	1.7 e-6		2.7 e-8

PC #6: Expected Ground-Water Travel Time

Measure: Expected travel time for ground water (on fastest path of likely and significant radionuclide transport)

Assessment threshold (AT): 1,000 years

Regulatory Concern:

960.4-2-1 Geohydrology, (d) Disqualifying Condition

A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.

Importance Assessment Questions:

- A Probability that the expected ground-water travel time < 1,000 years.
- B1 Probability that the AT will be exceeded in the next 10,000 years, given that it is expected to be exceeded under present conditions.
- B1' Not used in this assessment.
- B2 Probability that exceeding the AT will affect waste isolation, given that the AT will be exceeded in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#6: Ground-Water Travel Time

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.1	0.9		0.01	10	0.00001		8.1E-08
2	0.0001	1		1	10000	0.000001		1.0E-06
3	0.01	1		1	1000	0.000001		1.0E-05
4	0.05	1		0.8	10000	0.000001		4.0E-04
5	0.0001	0.9		1	1000	1E-08		9.0E-10
6	0.0001	1		1	1000	0.00001		1.0E-06
7	0.001	1		1	1000	0.00001		1.0E-05
8	0.0001	0.95		1	1000	0.000001		9.5E-08
9	0.01	1		1	1000	0.00001		1.0E-04
Avg	1.9 e-2	9.7 e-1	0.0 e+0	8.7 e-1	2.9 e+3	4.9 e-6		5.8 e-5
GMn	1.5 e-3	9.7 e-1	0.0 e+0	5.8 e-1	9.887 e+2	1.7 e-6		1.4 e-6

Discussion

In order to address this PC, the workshop participants first considered DOE's intended meaning of the terms "expected" and "pathway" in 10 CFR Part 960. The term "expected" was interpreted to designate the expected value (i.e., the mean) of a GWTT probability distribution. The term "pathway" was envisioned to be effectively a stream tube having a cross-sectional area of about 10,000 m^2, corresponding approximately to the practical limiting size of an element in a finite-element ground-water flow model.

Values of GWTT much less than 1,000 years probably could occur only if continuous fracture pathways were present through all or most of the unsaturated zone and, in addition, there was rapid ground-water flow within the saturated zone. The GWTT through the saturated zone was assessed at a workshop held in Denver, Colorado, on May 4, 1990 (see Appendix B), and the workshop respondents estimated that there was a probability of 0.85 that the GWTT in the saturated zone alone would exceed 1,000 years.

One-dimensional, steady-state flow modeling by Paul Kaplan of Sandia National Laboratories (Felton Bingham, oral communication) yields a probability of 0.2 that the GWTT is less than 1,000 years if continuous fracture pathways are present in the Calico Hills nonwelded hydrogeologic unit. Considerable uncertainty is associated with these modeling results, however, and the model simplifications and approximations probably lead to unrealistically short travel times.

PC #7: 200m Depth Infeasible

Measure: Feasible repository-construction depth below the directly overlying ground surface

Assessment threshold (AT): 200 meters

Regulatory Concern:

960.4-2-5 Erosion, (d) Disqualifying Condition

The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.

Importance Assessment Questions:

- A Probability that the AT is exceeded, i.e., that present site conditions will not allow construction as described.
- B1 Probability that the AT will be exceeded in the next 10,000 years, given that it is assessed as exceeded now.
- B1' Not used in this assessment.
- B2 Probability that the AT being exceeded will affect waste isolation, given that the AT will be exceeded in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#7: 200m Depth Infeasible

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.01	1		0.001	1.01	0.00001		1.0E-12
2	0.0001	1		0.0001	1	0.000001		0.0E+00
3	0.0001	1		0.0001	1.01	0.000001		1.0E-16
4	0.005	1		0.0001	1.001	0.000001		5.0E-16
5	0.0001	1		0.001	1.1	1E-08		1.0E-16
6	0.005	1		0.0001	1.1	0.00001		5.0E-13
7	0.0001	1		0.0001	1.01	0.00001		1.0E-15
8	0.001	0.99		0.001	1.01	0.000001		9.9E-15
9	0.01	1		0.000001	1.01	0.00001		1.0E-15
Avg	3.5 e-3	1.0 e+0	0.0 e+0	3.9 e-4	1.0 e+0	4.9 e-6		1.7 e-13
GMn	8.6 e-4	1.0 e+0	0.0 e+0	1.3 e-4	1.010 e+0	1.7 e-6		1.8 e-15

Discussion

The intent of this potential concern is to determine whether physical conditions at the site would prevent the 200-meter repository depth criterion from being met. This concern was not intended to be a repository design issue. The depth from land surface to the repository will depend upon the location and areal extent of the repository. The area occupied by the repository will be determined by such considerations as maximum thermal-loading criteria (which will govern the spacing between waste packages) and the need to avoid placing waste in fault or rubble zones. All parts of the repository reference-design facility are more than 200 meters below land surface. It was pointed out that locating the repository at a depth shallower than 200 meters would *increase* the unsaturated-zone flow path for aqueous-phase radionuclide transport, but would *decrease* the flow path for gaseous-phase transport.

PC #8: Perched Water

Measure: Total area of perched water at or above the repository level

Assessment threshold (AT): Ten percent of the repository area

Regulatory Concern:

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (23)

Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

Importance Assessment Questions:

A Probability that the total area of perched water at or above repository level exceeds 10% of the repository area under present conditions.

B1 Probability that perched water will occur over 10% of the repository area at or above the repository level during the next 10,000 years, given that perched water presently occurs as described in A.

B1' Not used in this assessment.

B2 Probability that the prescribed occurrence of perched water will affect waste isolation, given that it occurs in the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Estimate of expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#8: Perched Water

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.01	0.5		0.1	10	0.00001		4.5E-08
2	0.01	0.9		0.01	2	0.000001		9.0E-11
3	0.001	0.5		0.9	5	0.000001		1.8E-09
4	0.1	1		0.5	2	0.000001		5.0E-08
5	0.1	0.2		1	2	1E-08		2.0E-10
6	0.1	0.5		0.1	1.1	0.00001		5.0E-09
7	0.05	0.7		0.01	10	0.00001		3.2E-08
8	0.01	0.9		0.1	20	0.000001		1.7E-08
9	0.1	1		0.1	10	0.00001		9.0E-07
Avg	5.3 e-2	6.9 e-1	0.0 e+0	3.1 e-1	6.9 e+0	4.9 e-6		1.2 e-7
GMn	2.6 e-2	6.2 e-1	0.0 e+0	1.2 e-1	3.606 e+0	1.7 e-6		8.2 e-9

Discussion

The occurrence of perched-water zones within the uppermost 30 meters below land surface were excluded because, although these are known to occur, they are short-term, transient phenomena that will have no direct impact on waste in the repository. The workshop participants concluded that one or more perched-water zones at or above the repository level with a total aggregate area of at least 10 percent of the total area of the repository would need to occur in order for perched water to be a serious concern. This criterion was developed and established as the assessment threshold by the workshop participants.

The occurrence of perched water at or above the repository could affect waste isolation as a result of increased water contacting the waste either by direct flooding of the repository or by increased ground-water flux through the repository. If a perched-water zone of aggregate area equal to or exceeding the assessment threshold were to occur, other hydrologic conditions at the site would be expected to occur that probably would contribute to increased likelihood for aqueous-phase radionuclide releases.

PC #9: Water-Table Rise—200 meters

Measure: The occurrence of water-table rise due to climate or tectonic changes during the Quaternary

Assessment threshold (AT): 200 meters

Regulatory Concern:

960.4-2-4 Climatic changes, (c) Potentially Adverse Conditions, Item (1)

Evidence that the water table could rise sufficiently over the next 10,000 years to saturate the underground facility in a previously unsaturated host rock.

Importance Assessment Questions:

- A Probability that past climatic or tectonic changes during the Quaternary caused a rise in the water table of at least 200 m above the present level.
- B1 Probability that a 200 m water table rise will occur during the next 10,000 years, given that there was a 200 m water-table rise during the Quaternary.
- B1' Not used in this assessment.
- B2 Probability that a 200 m water-table rise will affect waste isolation, given that a water-table rise will occur in the next 10,000 years.
- C Multiplier on performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all 32 PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#9: Water Table Rise—200m

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.0001	0.01		0.5	100	0.00001		5.0E-10
2	0.001	0.01		0.5	10000	0.000001		5.0E-08
3	0.0001	0.01		0.9	100	0.000001		8.9E-11
4	0.001	0.01		0.9	1000	0.000001		9.0E-09
5	0.0001	0.01		1	100	1E-08		9.9E-13
6	0.001	0.01		1	100	0.00001		9.9E-09
7	0.0001	0.01		1	1000	0.00001		1.0E-08
8	0.000001	0.01		0.7	100	0.000001		6.9E-13
9	0.0001	0.01		1	100	0.00001		9.9E-10
Avg	3.9 e-4	1.0 e-2	0.0 e+0	8.3 e-1	1.4 e+3	4.9 e-6		8.9 e-9
GMn	1.3 e-4	1.0 e-2	0.0 e+0	8.0 e-1	2.773 e+2	1.7 e-6		4.8 e-10

Discussion

The definition of this PC includes components of duration and extent. As a general guide, the workshop participants considered that, to be of concern, a water-table rise would have to involve at least 10 percent of the repository area and be sustained for at least 1,000 yrs.

The likelihood of a 200-meter water table rise relative to present conditions is small because (1) geochemical data from well J13 (located approximately 5 km east of the site) indicate that during the Quaternary the water table there was never more than 2-3 meters above its present level for any sustained interval, and (2) hydrologic and geochemical data analyzed by Winograd and Szabo (1986) indicate that the regional water table has declined by as much as 130 meters during the Quaternary. Probability values ranging from 10^{-4} to 10^{-6} were regarded by the workshop participants to be effectively zero. If the water table were to rise 200 meters during the next 10,000 years, the resultant saturated zone would still be a significant barrier to radionuclide transport; although there might be an increased likelihood for the occurrence of fracture pathways.

PC #10: Water-Table Rise—20 meters

Measure: The occurrence of water-table rise due to climate or tectonic changes during the Quaternary

Assessment threshold (AT): 20 meters above present level

Regulatory Concern:

<u>60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (22)</u>

Potential for the water table to rise sufficiently so as to cause saturation of an underground facility located in the unsaturated zone.

Importance Assessment Questions:

- A Probability that past climatic changes or tectonic changes during the Quaternary caused to a rise in the water table of at least 20 m above present level.
- B1 Probability that there will be a 20 m water-table rise in the next 10,000 years, <u>given</u> that there was a 20 m water-table rise in the Quaternary.
- B1' Not used in this assessment.
- B2 Probability that that 20 m water-table rise will affect waste isolation, <u>given</u> that it will occur in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, <u>given</u> that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#10 Water Table Rise—20m

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.5	0.5		0.01	1.1	0.00001		2.5E-09
2	0 001	0.01		1	1	0.000001		0.0E+00
3	0.1	0.01		0.001	1.1	0.000001		1.0E-13
4	0.2	0.01		0.001	1.001	0.000001		2.0E-15
5	0.2	0.1		0.1	1.1	1E-08		2.0E-12
6	0.01	0.01		0.01	1.1	0.00001		1.0E-12
7	0.1	0.01		0.001	1.1	0.00001		1.0E-12
8	0.0001	0.01		0.1	1.1	0.000001		1.0E-14
9	0.1	0.01		0.01	1	0.00001		0.0E+00
Avg	1.3 e-1	7.4 e-2	0.0 e+0	1.4 e-1	1.1 e+0	4.9 e-6		2.8 e-10
GMn	3.0 e-2	2.0 e-2	0.0 e+0	1.3 e-2	1.022 e+0	1.7 e-6		2.8 e-13

Discussion

This PC addresses the possible occurrence and consequence of water-table rise at the site due to future climatic or tectonic change. This assessment, for an AT equalling 20 m, was made to investigate the sensitivity of the assessment to the choice of AT (See PC #9: Water-Table Rise–200 Meters). Although a 20-m water-table rise was judged more likely to have occurred during the Quaternary than a 200-m water-table rise (Col. A), both were judged to have small likelihood (0.01-0.02) of occurrences during the next 10,000 years (Col. B1). The only effect of a 20-m water-table rise on potential radionuclide releases will be to shorten flowpath lengths within the unsaturated zone below the repository level.

PC #11: Tectonic Effects on Regional Ground-Water Flow
Unsaturated Zone (UZ)

Measure:	Increase in ground-water flux during the Quaternary due to tectonic events along flow paths for contaminated water
Assessment threshold (AT):	Ten times present flux

Regulatory Concern:

960.4-2-7 Tectonics, (c) Potentially Adverse Conditions, Item (6)

Potential for tectonic deformation--such as uplift, subsidence, folding, or faulting--that could adversely affect the regional ground-water flow system.

Importance Assessment Questions:

A Probability that there was a tenfold increase of flux in the UZ during the Quaternary along flow paths for contaminated water as a result of tectonic events.

B1 Probability that there will be a tenfold increase of flux in the UZ during the next 10,000 years, given that such a flux increase occurred during the Quaternary.

B1' Not used in this assessment.

B2 Probability that a tenfold increase of UZ flux will affect waste isolation, given that such a flux increase will occur in the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Expected curies released, given that no adverse condition are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#11: Tectonic Effects—UZ

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.001	0.01		0.1	1.1	0.00001		1.0E-12
2	0.001	0.01		1	10	0.000001		9.0E-11
3	0.001	0.0001		0.1	10	0.000001		9.0E-14
4	0.001	0.01		0.1	100	0.000001		9.9E-11
5	0.0001	0.1		1	50	1E-08		4.9E-12
6	0.0001	0.01		1	100	0.00001		9.9E-10
7	0.001	0.01		0.5	10	0.00001		4.5E-10
8	0.000001	0.00001		0.2	20	0.000001		3.8E-17
9	0.0001	0.00001		0.1	100	0.00001		9.9E-14
Avg	5.9 e-4	1.7 e-2	0.0 e+0	4.6 e-1	4.5 e+1	4.9 e-6		1.8 e-10
GMn	2.2 e-4	1.7 e-3	0.0 e+0	2.8 e-1	1.692 e+1	1.7 e-6		2.7 e-12

Discussion

The probability of tectonic events or processes affecting the flux of ground water percolating through the repository level was assessed to be small because the workshop participants were unable to envision how such an effect could be produced. However, if a tectonic-induced flux increase in the unsaturated zone were to have occurred in the Quaternary, the likelihood that it would occur during the next 10,000 years could be approximated by the ratio of 10,000 years to the duration of the Quaternary, which is approximately 0.01. If the ground-water flux within the site unsaturated zone were to increase tenfold during the next 10,000 years, the impact on waste isolation would be the same as that assessed in PC #5: Climate Effect on Radionuclide Transport. The potential for tectonic events or processes to raise the water table to the repository level, and thereby increase flux, is subsumed by PC #9 and PC #10.

PC #12: Tectonic Effects on Regional Ground-Water Flow Saturated Zone (SZ)

Measure:	Increase in ground-water flux in the SZ during the Quaternary due to tectonic events along flow paths for contaminated water
Assessment threshold (AT):	Ten times present flux

Regulatory Concern:

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (4)

Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional ground-water flow system.

Importance Assessment Questions:

- A Probability that there was a tenfold increase of flux in the SZ during the Quaternary along flow paths for contaminated water as a result of tectonic events.
- B1 Probability that there will be a tenfold increase in flux in the SZ during the next 10,000 years, given that such a flux increase occurred during the Quaternary.
- B1' Not used in this assessment.
- B2 Probability that a tenfold increase of SZ flux will affect waste isolation, given that such a flux increase will occur in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#12: Tectonic Effects—SZ

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.5	0.1		0.1	10	0.00001		4.5E-07
2	0.001	0.01		1	1.1	0.000001		1.0E-12
3	0.75	0.01		0.000001	1.1	0.000001		7.5E-16
4	0.01	0.01		0.001	1.1	0.000001		1.0E-14
5	0.05	0.1		0.1	1.1	1E-08		5.0E-13
6	0.01	0.01		0.1	10	0.00001		9.0E-10
7	0.01	0.01		0.1	10	0.00001		9.0E-10
8	0.0001	0.01		0.01	20	0.000001		1.9E-13
9	0.00001	0.000001		0.1	1	0.00001		0.0E+00
Avg	1.5 e-1	2.9 e-2	0.0 e+0	1.7 e-1	6.2 e+0	4.9 e-6		5.0 e-8
GMn	6.4 e-3	6.0 e-3	0.0 e+0	1.7 e-2	1.803 e+0	1.7 e-6		8.6 e-13

Discussion

The probability of occurrence was assessed to be low because (1) evidence indicates that the water table has been declining at a rate of 20-50 cm/1000 years throughout the region (Winograd and Szabo, 1986) and (2) the present effectively flat hydraulic gradient beneath the site suggests a region of high transmissivity with the consequence that tectonic effects are unlikely to induce significant flux increases. On the other hand, tectonic events could affect the hydraulic properties of fractures, which could lead to increased flow through fractures. If tectonic-induced flux increases occurred during the Quaternary, their likelihood of occurrence during the next 10,000 years could be approximated by the ratio of 10,000 years to the duration of the Quaternary, which is approximately 0.01. If short ground-water travel times occur in the saturated zone, then increasing the flux will not affect the baseline radionuclide releases significantly.

PC #13: Past Active Tectonism (Faulting)

Measure:	Total fault-induced offset in the controlled area during the Quaternary
Assessment threshold (AT):	10 cm/10,000 years (i.e., 10 m per million years or 18 m in 1.8 million years)

Regulatory Concern:

960.4-2-7 Tectonics, (c) Potentially Adverse Conditions, Item (1)

Evidence of active folding, faulting, uplift, subsidence, or other tectonic processes or igneous activity within the geologic setting during the Quaternary Period.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (11)

Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

Importance Assessment Questions:

A Probability that total fault offset in the controlled area during the Quaternary was equal to a rate of 10 cm/10,000 years (i.e., 10 m per million years or 18 m in 1.8 million years).

B1 Probability that there will be a continuation of faulting of that magnitude during the next 10,000 years, given that it occurred during the Quaternary.

B1' Not used in this assessment.

B2 Probability that faulting will affect waste isolation, given that it will occur in the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#13: Past Active Tectonism

Workshop:	Import. #2
Date:	10/31/90
Respondents:	9

#	A	B1	B1'	B2	C	D		Product
1	0.5	0.5		0.001	1.1	0.00001		2.5E-10
2	0.1	0.1		0.01	10	0.000001		9.0E-10
3	0.1	0.01		0.0001	1.01	0.000001		1.0E-15
4	0.2	0.1		0.0001	1.1	0.000001		2.0E-13
5	0.05	0.5		0.1	1.2	1E-08		5.0E-12
6	0.5	0.01		0.001	2	0.00001		5.0E-11
7	0.2	0.6		0.01	10	0.00001		1.1E-07
8	0.01	0.8		0.001	10	0.000001		7.2E-11
9	0.6	0.6		0.001	1	0.00001		0.0E+00
Avg	2.5 e-1	3.6 e-1	0.0 e+0	1.4 e-2	4.2 e+0	4.9 e-6		1.2 e-8
GMn	1.5 e-1	1.6 e-1	0.0 e+0	1.7 e-3	1.375 e+0	1.7 e-6		2.4 e-11

Discussion

The probability of occurrence is relatively high because known fault displacements of about 1 meter have occurred near the site during the Quaternary. Continued faulting at the site is likely to occur in the future at the same rate as it occurred in the past; although the rates of active faulting may actually be decreasing. There is small probability that future faulting could disrupt a waste container because faulting is most likely to occur on existing faults and waste containers would not be emplaced in known fault zones. However, faulting could lead to increased releases if the faulting were to alter ambient hydrologic conditions, for example, by opening fracture conduits and causing a perched-water body to drain through the repository.

PC #14: Tectonic Effects on Waste Isolation

Discussion

Upon consideration of this potential concern, the integration group agreed that it had been addressed under potential concerns #s 10, 11, 12, 13, and 15, and therefore this evaluation was eliminated.

PC #15: Tectonic-Induced Lakes

Measure:	The area of a lake that, during the Quaternary, would have intersected the controlled area (CA), as indicated by Quaternary lake deposits
Assessment threshold (AT):	100,000 square meters

Regulatory Concern:

960.4-2-7 Tectonics, (c) Potentially Adverse Conditions, Item (5)

Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such magnitudes that they could create large-scale surface-water impoundments that could change the regional ground-water flow system.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (3)

Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional ground-water flow system and thereby adversely affect the performance of the geologic repository.

Importance Assessment Questions:

A Probability that Quaternary lake deposits indicate the occurrence of a tectonic-induced lake of at least 100,000 square meters in area, whose perimeter would have intersected the CA.

B1 Probability that tectonically-induced lakes will occur during the next 10,000 years, given the presence of Quaternary lake deposits as described.

B1' Not used in this assessment.

B2 Probability that the tectonically induced lakes will affect waste isolation, given that such lakes will occur in the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#15: Tectonic Induced Lakes

Workshop: Import. #2
Date: 11/1/90

Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.01	0.0001		0.1	10	0.00001		9.0E-12
2	0.001	0.001		0.01	1.01	0.000001		1.0E-16
3	0.001	0.00001		0.01	1.01	0.000001		1.0E-18
4	0.01	0.0001		0.01	1.01	0.000001		1.0E-16
5	0.01	0.0001		0.1	100	1E-08		9.9E-14
6	0.01	0.001		0.1	1.01	0.00001		1.0E-13
7	0.01	0.00001		0.8	100	0.00001		7.9E-11
8	0.001	0.01		0.1	10	0.000001		9.0E-12
9	0.1	0.001		0.1	1.01	0.00001		1.0E-12
Avg	1.7 e-2	1.5 e-3	0.0 e+0	1.5 e-1	2.5 e+1	4.9 e-6		1.1 e-11
GMn	6.0 e-3	2.2 e-4	0.0 e+0	5.8 e-2	1.350 e+0	1.7 e-6		4.4 e-14

Discussion

The workshop participants concluded that the probability of occurrence in either past or future was very small. The topographic and climatologic setting of the region surrounding the controlled area is not conducive to the formation of lakes. If such an event were to occur, however, there would be some probability of increased releases.

PC #16: Past Igneous Activity—Site Effects

Measure: Evidence of Quaternary igneous activity in the region

Assessment threshold (AT): Not specified; evidence exists for such activity

Regulatory Concern:

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (15)

Evidence of igneous activity since the start of the Quaternary Period.

Importance Assessment Questions:

- A Probability that the AT is exceeded, i.e., that there is evidence of Quaternary igneous activity in the region.
- B1 Probability that there will be igneous activity in the repository block in the next 10,000 years, given that there is evidence for the occurrence of igneous activity during the Quaternary.
- B1' Not used in this assessment.
- B2 Probability that that igneous activity will affect waste isolation, given that igneous activity will occur during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#16: Past Igneous Activity—Site

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	1	0.00001		0.5	50	0.00001		2.5E-09
2	1	0.001		0.1	1000000	0.000001		1.0E-04
3	1	0.0001		0.01	1.1	0.000001		1.0E-13
4	0.9	0.0001		0.5	1000	0.000001		4.5E-08
5	1	0.00001		0.7	100	1E-08		6.9E-12
6	1	0.00001		0.1	100	0.00001		9.9E-10
7	1	0.0001		0.5	1000	0.00001		5.0E-07
8	0.99	0.00000001		0.02	1000	0.000001		2.0E-13
9	1	0.0001		0.8	10000	0.00001		8.0E-06
Avg	9.9 e-1	1.6 e-4	0.0 e+0	3.6 e-1	1.1 e+5	4.9 e-6		1.2 e-5
GMn	9.9 e-1	2.2 e-5	0.0 e+0	1.7 e-1	4.287 e+2	1.7 e-6		2.6 e-9

Discussion

Because of the presence of young (<700,000 years) basaltic volcanic centers in Crater Flat, the probability that volcanism occurred during the Quaternary is 1.0 unless there are gross errors in the determination of the ages of these centers. The probability that volcanism will occur at the site during the next 10,000 years was estimated in the Environmental Assessment (DOE, 1986) to be in the range of 4.7×10^{-4} to 3.3×10^{-6} with a mean value of 1.3×10^{-4}. Based on these data and subsequent work by Bruce Crowe (Los Alamos National Laboratory), the workshop participants estimated a (geometric) mean value of 2.2×10^{-5} for the probability that igneous activity will occur at the site during the next 10,000 years.

Igneous activity could disrupt the repository by the subsurface intrusion of a dike or sill, or by the extrusion of lava or ash through the repository to land surface. Only those igneous events that breach the surface, however, would have a high probability of affecting waste isolation. If such events were to occur during the next 10,000 years, it could lead to direct releases to the accessible environment by the entrainment of waste in extruded volcanic products and, therefore, to the high consequences indicated in Column C.

PC #17: Past Igneous Activity—Controlled-Area (CA) Effects

Measure: Evidence of igneous activity in the region during the Quaternary

Assessment threshold (AT): Not specified; evidence has been found

Regulatory Concern:

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (15)

Evidence of igneous activity in the region since the start of the Quaternary Period.

Importance Assessment Questions:

A Probability that the AT is exceeded, i.e., that there is evidence for the occurrence of igneous activity in the region during the Quaternary.

B1 Probability that there will be igneous activity in the CA in the next 10,000 years, given that there is evidence for the occurrence of activity during the Quaternary.

B1' Not used in this assessment.

B2 Probability that that igneous activity occurring in the CA will affect waste isolation, given that igneous activity will occur during the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#17: Past Igneous Activity—Controlled Area

Workshop: Import. #2
Date: 10/31/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	1	0.0001		0.01	1.1	0.00001		1.0E-12
2	1	0.001		0.001	1.01	0.000001		1.0E-14
3	1	0.0001		0.000001	1.01	0.000001		1.0E-18
4	0.9	0.001		0.01	5	0.000001		3.6E-11
5	1	0.0001		0.01	1.1	1E-08		1.0E-15
6	1	0.0001		0.01	2	0.00001		1.0E-11
7	1	0.001		0.001	10	0.00001		9.0E-11
8	0.99	0.00001		0.00001	10	0.000001		8.9E-16
9	1	0.001		0.00001	1	0.00001		0.0E+00
Avg	9.9 e-1	4.9 e-4	0.0 e+0	4.7 e-3	3.6 e+0	4.9 e-6		1.5 e-11
GMn	9.9 e-1	2.2 e-4	0.0 e+0	4.6 e-4	1.246 e+0	1.7 e-6		4.0 e-14

Discussion

This concern addresses the possible effects of igneous activity within the controlled area, which, however, does not involve direct intrusion of the repository. The probability that such igneous activity occurred in the region during the Quaternary is the same as that assessed in PC #16: Past Igneous Activity—Site Effects. The probability of the future occurrence of such activity is approximately equal to the product of the ratio of the controlled area to the area of the repository and the probability assessed in Column B1 for PC #16, and, therefore, is greater than that assessed for PC #16 by a factor of ten (approximately).

The probability of affecting waste isolation is small because only indirect effects are involved (e.g., possible disruption of the saturated-zone hydrologic system near the repository). The consequences are less than those for PC #16 by a factor (100 to 1,000) proportional to the distance of the event from the repository.

PC #18: Rock Conditions Beyond Reasonably Available Technology

Measure:	Evidence of rock conditions that could require engineering methods beyond reasonably available technology (as defined below)
Assessment threshold (AT):	Failure of 10 percent or more of the facility to remain open until scheduled closure

Regulatory Concern:

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (1)

Rock conditions that could require engineering measures beyond reasonably available technology for the construction, operation, and closure of the repository, if such measures are necessary to ensure waste containment or isolation.

Importance Assessment Questions:

- A Probability that rock conditions requiring engineering methods beyond reasonably available technology are present.
- B1 Probability that those rock conditions will be present during operation of the repository, given that these conditions are currently present.
- B1' Not used in this assessment.
- B2 Probability that failure of 10% or more of the facility to remain open until scheduled closure will affect waste isolation, given that those rock conditions will be present during the operation of the repository.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#18: Rock Conditions Beyond Reasonably Available Technology

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.001	1		0.01	1.1	0.00001		1.0E-11
2	0.0001	1		0.0001	10	0.000001		9.0E-14
3	0.0001	1		0.001	1.01	0.000001		1.0E-15
4	0.01	1		0.0001	10	0.000001		9.0E-12
5	0.001	1		0.01	1.1	1E-08		1.0E-14
6	0.0001	1		0.001	1.1	0.00001		1.0E-13
7	0.0001	1		0.001	1.1	0.00001		1.0E-13
8	0.00001	1		0.00001	1.01	0.000001		1.0E-18
9	0.000001	1		0.000001	1.01	0.00001		1.0E-19
Avg	1.4 e-3	1.0 e+0	0.0 e+0	2.6 e-3	3.0 e+0	4.9 e-6		2.1 e-12
GMn	1.3 e-4	1.0 e+0	0.0 e+0	2.8 e-4	1.126 e+0	1.7 e-6		7.6 e-15

Discussion

The occurrence of this condition implies the presence, for example, of zones of extensive rubble (bad rock) at the repository horizon that could cause the failure or collapse of excavated openings. The workshop participants concluded that excavation failures would be highly unlikely either to occur or to affect waste isolation significantly. If the conditions were present, however, they were judged to continue to be present during the next 10,000 years. The consequences for waste isolation were judged to be small in comparison to other PCs evaluated because only a small part of the total repository area would be likely to be involved, and this localized effect would be unlikely to enhance radionuclide transport through the unsaturated zone.

PC #19: Rock and Ground-Water Complex Engineering

Measure:	Rock or ground-water conditions requiring complex engineering measures to prevent radionuclide release and transport by ground water
Assessment threshold (AT):	Tenfold increase in ground-water flux through the repository level

Regulatory Concern:

60.122 Siting Criteria, (c) Potentially Adverse Conditions, The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area, Item (20)

> Rock or ground-water conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

Importance Assessment Questions:

- A Probability that the rock conditions described above in the citation of 10 CFR 60.122(c)(20) are present at the site.
- B1 Probability that those rock conditions will be present during the next 10,000 years causing a tenfold increase of ground-water flux at the repository level, given that these conditions are currently present at the site.
- B1' Not used in this assessment.
- B2 Probability that a tenfold increase of flux will affect waste isolation, given that such an increased flux occurs during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#19: Rock and Ground Water Complex Engineering

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.08	1		0.5	10	0.00001		3.6E-06
2	0.001	1		0.001	10	0.000001		9.0E-12
3	0.001	1		0.001	1.01	0.000001		1.0E-14
4	0.0001	1		0.01	1.01	0.000001		1.0E-14
5	0.01	1		0.5	2	1E-08		5.0E-11
6	0.01	0.9		0.001	1.01	0.00001		9.0E-13
7	0.001	1		0.1	10	0.00001		9.0E-09
8	0.0001	1		0.001	1.01	0.000001		1.0E-15
9	0.0001	1		0.2	10	0.00001		1.8E-09
Avg	1.1 e-2	9.9 e-1	0.0 e+0	1.5 e-1	5.1 e+0	4.9 e-6		4.0 e-7
GMn	1.3 e-3	9.9 e-1	0.0 e+0	1.5 e-2	1.343 e+0	1.7 e-6		1.1 e-11

Discussion

The concern is that bulkheads, shafts, ramps, boreholes and other underground openings will require complex engineering measures in order to seal these openings to prevent their becoming preferential pathways for ground-water flow. The occurrence of the condition implies localized increases of ground-water flux into or out of the repository due to possible failure of the seals.

The workshop participants considered the probability of such conditions occuring to be small, but if these conditions did occur, they would have small probability of affecting waste isolation because they would tend to be highly localized. Further, through-going openings (shafts, ramps, and boreholes) will be located sufficiently distant from the waste so that a localized flux increase would not cause increased water contact with the waste. In addition, these openings will be backfilled and the hydraulic conductivity of the backfill material will limit the flux of water that could move through these openings in the event the seals should fail.

PC #20: Sorption/Rock Strength Reduction

Measure: Rate of transition of metastable mineral phases

Assessment threshold (AT): Sufficient to cause significant mineral changes at the site during the next 10,000 years

Regulatory Concern:

960.4-2-2 Geochemistry, (c) Potentially Adverse Conditions, Item (2)

Geochemical processes or conditions that could reduce the sorption of radionuclides or degrade the rock strength.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (8)

Geochemical processes that would reduce sorption or radionuclides, result in degradation or the rock strength, or adversely affect the performance of the engineered barrier system.

Importance Assessment Questions:

- A Probability that the rate of transition of metastable mineral phases at the site will be sufficient to cause significant mineral changes during the next 10,000 years.
- B1 Probability that the rate of transition as defined in "A" above continues throughout the next 10,000 years, given that these changes presently are occurring.
- B1' Not used in this assessment.
- B2 Probability that the rate of mineral-phase transition as defined above will affect waste isolation, given that the rate continues during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#20: Sorption / Rock Strength

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B 1	B1'	B 2	C	D		Product
1	0.0001	1		0.01	1.1	0.00001		1.0E-12
2	0.001	1		0.001	1.1	0.000001		1.0E-13
3	0.001	1		0.001	1.1	0.000001		1.0E-13
4	0.0001	1		0.001	1.2	0.000001		2.0E-14
5	0.001	1		0.001	1.1	1E-08		1.0E-15
6	0.0001	1		0.01	1.1	0.00001		1.0E-12
7	0.00001	1		0.001	1.01	0.00001		1.0E-15
8	0.000001	1		0.001	100	0.000001		9.9E-14
9	0.000001	1		0.000001	1.01	0.00001		1.0E-19
Avg	3.7 e-4	1.0 e+0	0.0 e+0	2.9 e-3	1.2 e+1	4.9 e-6		2.6 e-13
GMn	6.0 e-5	1.0 e+0	0.0 e+0	7.7 e-4	1.139 e+0	1.7 e-6		1.1 e-14

Discussion

The probability that these conditions occur was judged to be low because mineralogic changes generally are so slow that significant changes over a 10,000-year time scale are unlikely. If mineral changes were to occur during the next 10,000 years, their effects on waste isolation were judged to be highly uncertain but probably small. Changes could increase radionuclide retardation, for example, by the zeolitization of volcanic glass and the formation of zeolites and clays in fractures. The changes considered by this concern presume the absence of the repository. Repository-induced mineralogic change is addressed by PC #22: Thermal/Radioactive Effects on Waste Isolation—Altering Sorbing Zeolites. The possible effects on rock strength were not considered explicitly because these do not directly affect waste isolation, although they would be important for engineering design.

PC #21: Thermal/Radioactive Effects on Waste Isolation
Permeability Change

Measure:	Increased permeability of host rock within ten meters of each canister
Assessment threshold (AT):	Fivefold permeability increase

Regulatory Concern:

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (2)

Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (3)

A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

Importance Assessment Questions:

- A Probability that rock conditions are such that thermal/radioactive effects will cause a fivefold or more increase in permeability within a radius of 10 meters around each canister.
- B1 Probability that such an increase in permeability will actually occur, given that rock conditions are such that thermal/radioactive effects could cause such an increase.
- B1' Not used in this assessment.
- B2 Probability that such an increase in permeability will affect waste isolation, given that the permeability increase will occur in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#21: Thermal Radionuclide Effects—Permeability Change

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.2	0.8		0.5	1.1	0.00001		8.0E-08
2	0.001	1		0.01	1.01	0.000001		1.0E-13
3	0.001	1		0.001	1	0.000001		0.0E+00
4	0.1	0.5		0.01	1.01	0.000001		5.0E-12
5	0.01	1		0.01	1.1	1E-08		1.0E-13
6	0.1	0.9		0.01	1.1	0.00001		9.0E-10
7	0.1	0.9		0.1	1.1	0.00001		9.0E-09
8	0.01	0.8		0.0001	1.01	0.000001		8.0E-15
9	0.1	1		0.0001	1.01	0.00001		1.0E-12
Avg	6.9 e-2	8.8 e-1	0.0 e+0	7.1 e-2	1.0 e+0	4.9 e-6		1.0 e-8
GMn	2.3 e-2	8.6 e-1	0.0 e+0	5.6 e-3	1.028 e+0	1.7 e-6		5.2 e-12

Discussion

This concern addresses the occurrence and consequences of possible permeability increases in the host rock near the repository that may be caused by elevated temperatures produced by heat released from emplaced waste within the repository. Increased temperatures are expected to induce thermal stresses within the near-field host-rock environment that could affect the pore-size distribution within the rock matrix as well as fracture apertures. The magnitude of these possible changes and their effects on permeability is highly uncertain, and the workshop participants concluded that either permeability increases or decreases were plausible, depending on local rock and fracture properties. If permeability increases were to occur, their possible effects on waste isolation would conceivably include increased ground-water flow contacting the waste as well as increased potential radionuclide transport away from the repository. Because thermally-induced permeability changes are expected to be highly localized near the repository, the workshop participants generally agreed that their overall effect on waste isolation would be small.

PC #22: Thermal/Radioactive Effects on Waste Isolation Altering Sorbing Zeolites

Measure:	Rate of thermal- or radiation-induced transition of mineral phases
Assessment threshold (AT):	Sufficient to cause significant mineral changes at the site during the next 10,000 years

Regulatory Concern:

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (2)
Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (3)
A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

Importance Assessment Questions:

- A Probability that rock conditions are such that thermal/radioactive effects will cause a rate of transition of mineral phases sufficient to cause significant mineral changes during the next 10,000 years.
- B1 Probability that there actually will be such a rate of mineral-phase transition, given that rock conditions are such that thermal/radioactive effects will cause such a rate.
- B1' Not used in this assessment.
- B2 Probability that the induced rate of mineral phase transition will affect waste isolation, given that the induced rate will occur during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#22: Thermal Radionuclide Effects—Sorbing Zeolites

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.1	0.9		0.5	1.1	0.00001		4.5E-08
2	0.01	1		0.01	1.01	0.000001		1.0E-12
3	0.01	1		0.001	1.1	0.000001		1.0E-12
4	0.05	0.5		0.01	1.001	0.000001		2.5E-13
5	0.01	1		0.001	1.01	1E-08		1.0E-15
6	0.01	0.9		0.001	1.1	0.00001		9.0E-12
7	0.01	0.9		0.001	1.001	0.00001		9.0E-14
8	0.0001	0.1		0.1	10	0.000001		9.0E-12
9	0.01	1		0.0001	1.01	0.00001		1.0E-13
Avg	2.3 e-2	8.1 e-1	0.0 e+0	6.9 e-2	2.0 e+0	4.9 e-6		5.0 e-9
GMn	9.3 e-3	6.9 e-1	0.0 e+0	4.3 e-3	1.028 e+0	1.7 e-6		1.3 e-12

Discussion

Bish (1990) examined the transformation of zeolite phases at expected repository-induced temperatures (100° to 200°C) and concludes that sorbing properties may not be adversely affected. Concern was expressed, however, that extrapolating these conclusions over periods of 1,000 years or more is uncertain because the rate of change may be too slow to be observable in short duration laboratory experiments. The alteration of zeolites may not be accompanied by a loss of radionuclide retardation because the alteration products may retain high sorbing properties. Consequently, the probability of occurrence was judged to be small, and the impact on waste isolation was judged to be both low probability and of small consequence in comparison to other PCs evaluated.

PC #23: Thermal/Radioactive Effects on Waste Isolation
Resaturation Flux

Measure: Increase in ground-water flux due to resaturation

Assessment threshold (AT): Ten times the current flux during any 100-year period during the next 10,000 years

Regulatory Concern:

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (2)

Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (3)

A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

Importance Assessment Questions:

A Probability that rock conditions are such that resaturation will cause a tenfold increase of ground-water flux during any 100-year period during the next 10,000 years.

B1 Probability that such resaturation will occur, given that rock conditions are such that thermal/radioactive effects could cause the resaturation.

B1' Not used in this assessment.

B2 Probability that that resaturation will affect waste isolation, given that resaturation will occur during the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#23: Thermal Radionuclide Effects—Resaturation Flux

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.1	0.9		0.5	10	0.00001		4.1E-06
2	0.1	1		0.1	10	0.000001		9.0E-08
3	0.001	1		0.001	1.01	0.000001		1.0E-14
4	0.4	0.5		0.01	1.1	0.000001		2.0E-10
5	0.01	1		0.1	1.1	1E-08		1.0E-12
6	0.9	0.5		0.1	1.1	0.00001		4.5E-08
7	0.01	0.1		0.001	1.001	0.00001		1.0E-14
8	0.01	0.01		0.7	10	0.000001		6.3E-10
9	0.001	1		0.0001	1.01	0.00001		1.0E-14
Avg	1.7 e-1	6.7 e-1	0.0 e+0	1.7 e-1	4.0 e+0	4.9 e-6		4.7 e-7
GMn	2.5 e-2	3.9 e-1	0.0 e+0	1.9 e-2	1.161 e+0	1.7 e-6		5.0 e-11

Discussion

This concern considers the scenario in which the heat generated by the emplaced waste causes moisture to be driven away from the repository as steam, which subsequently condenses and returns in the form of liquid water when the repository environment eventually cools. Although the phenomenon is likely to occur, there is small probability that the resaturation flux under unsaturated-zone conditions in the host rock would exceed ten times the current flux because (1) water driven away from the repository would tend to disperse throughout a large volume of the unsaturated zone and would not be available as return flow to the repository and (2) the rate of resaturation would be slow and would tend to prevent localized concentration of flux. If the resaturation flux were to exceed the present ground-water flux throughout the repository by a factor of ten, the effects on waste isolation were judged generally to be small, but some workshop participants felt these effects could produce as much as a possible tenfold increase in baseline releases to the accessible environment.

PC #24: Thermal/Radioactive Effects on Waste Isolation Corrosive Steam Environment

Measure: Waste package environmental conditions

Assessment threshold (AT): Characteristics of corrosive steam

Regulatory Concern:

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (2)
Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

960.4-2-3 Rock characteristics, (c) Potentially Adverse Conditions, Item (3)
A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

Importance Assessment Questions:

- A Probability that near-field rock conditions are such that a corrosive steam environment will be produced around the waste package for at least 100 years.
- B1 Probability that such a corrosive steam environment will occur, given that rock conditions are such that a corrosive steam environment could occur around the waste package for at least 100 years.
- B1' Not used in this assessment.
- B2 Probability that corrosive steam environment will affect waste isolation, given that such an environment will occur in the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#24: Thermal Radionuclide Effects—Corrosive Steam

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.1	0.9		0.1	10	0.00001		8.1E-07
2	0.7	0.7		0.01	1.1	0.000001		4.9E-10
3	0.1	1		0.001	1.1	0.000001		1.0E-11
4	0.3	0.5		0.01	1.1	0.000001		1.5E-10
5	0.5	1		0.01	1.1	1E-08		5.0E-12
6	0.1	0.5		0.01	1.1	0.00001		5.0E-10
7	0.1	0.9		0.001	1.1	0.00001		9.0E-11
8	0.001	0.5		0.1	10	0.000001		4.5E-10
9	0.5	1		0.01	1.01	0.00001		5.0E-10
Avg	2.7 e-1	7.8 e-1	0.0 e+0	2.8 e-2	3.1 e+0	4.9 e-6		9.0 e-8
GMn	1.2 e-1	7.5 e-1	0.0 e+0	1.0 e-2	1.210 e+0	1.7 e-6		3.1 e-10

Discussion

Because waste package surface temperatures may be as much as 250°C, the waste package is likely to be exposed to a steam environment, which could affect the corrosion rates of the waste packages. Corrosion rates in steam environments were judged to be less than those in an aqueous (saturated) environment. Therefore, although the condition was judged likely to be present, its presence was judged to produce insignificant consequences with respect to waste isolation in comparison to other PCs evaluated.

PC #25: Geomorphic Processes—Past Extreme Erosion

Measure: Erosion or incision rates during the Quaternary

Assessment threshold (AT): Sufficient to affect waste isolation during the next 10,000 years

Regulatory Concern:

960.4-2-5 Erosion, (c) Potentially Adverse Conditions, Item (1)

A geologic setting that shows evidence of extreme erosion during the Quaternary Period.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (16)

Evidence of extreme erosion during the Quaternary Period.

960.4-2-5 Erosion, (c) Potentially Adverse Conditions, Item (2)

A geologic setting where the nature and rates of the geomorphic processes that have been operating during the Quaternary Period could, during the first 10,000 years after closure, adversely affect the ability of the geologic repository to isolate the waste.

Importance Assessment Questions:

- A Probability that such high erosion or incision rates occurred during the Quaternary.
- B1 Probability that those erosion or incision rates will occur during the next 10,000 years, given that they occurred during the Quaternary.
- B1' Not used in this assessment.
- B2 Probability that these erosion or incision rates will affect waste isolation, given that they occur during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#25: Geomorphic Processes—Past Extreme Erosion

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.001	0.2		0.1	2	0.00001		2.0E-10
2	0.0001	1		0.9	1000	0.000001		9.0E-08
3	0.000001	1		0.9	100	0.000001		8.9E-11
4	0.0001	0.5		0.1	100	0.000001		5.0E-10
5	0.0001	0.2		1	2	1E-08		2.0E-13
6	0.0001	1		0.1	1.01	0.00001		1.0E-12
7	0.0001	0.9		0.001	1.1	0.00001		9.0E-14
8	0.00001	1		0.01	10	0.000001		9.0E-13
9	0.00001	1		0.01	1.01	0.00001		1.0E-14
Avg	1.7 e-4	7.6 e-1	0.0 e+0	3.5 e-1	1.4 e+2	4.9 e-6		1.0 e-8
GMn	4.6 e-5	6.4 e-1	0.0 e+0	7.6 e-2	3.124 e+0	1.7 e-6		8.0 e-12

Discussion

The rate of erosion at Buckboard Mesa, a basaltic plateau located 14 miles north of the site in a region of higher precipitation, is estimated to be 1 centimeter per 10,000 years. The rate of incision of Forty-Mile Wash east of Alice Ridge is estimated to be 3 meters per 10,000 years. There is no evidence for significant scarp retreat at or near the site. Consequently, the probability of past or present extremely high erosion rates was judged by the workshop participants to be negligibly small.

If extreme erosion or incision rates were to have occurred in the past, however, they would be likely to continue during the next 10,000 years. Because extreme erosion or incision rates could affect waste isolation, for example, by exhuming the buried waste or by altering surface topography and drainage and relieving overburden stress sufficiently to cause increased ground-water flux in the unsaturated zone, some workshop participants regarded this concern to be a high-consequence, low-probability event.

PC #26: Reactive Ground-Water Chemistry—UO_2 Solubility

Measure: Solubility of UO_2 in ground water within the Topopah Spring unit

Assessment threshold (AT): 0.002 Molar

Regulatory Concern:

960.4-2-2 Geochemistry, (c) Potentially Adverse Conditions, Item (1)

Ground-water conditions in the host rock that could affect the solubility or the chemical reactivity of the engineered-barrier system to the extent that the expected repository performance could be compromised.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (7)

Ground water conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

Importance Assessment Questions:

- A Probability that present ground-water conditions are present within the Topopah Spring unit such that UO_2 solubility exceeds 0.002 molar.
- B1 Probability that the AT will be exceeded during the next 10,000 years, given that it is exceeded under present conditions.
- B1' Not used in this assessment.
- B2 Probability that exceeding the AT will affect waste isolation, given that the AT will be exceeded during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#26: Reactive Ground-Water Chemistry—UO_2 Solubility

Workshop: Import. #2
Date: 11/2/90
Respondents: 8

#	A	B1	B1'	B2	C	D		Product
1	0.05	1		0.8	1.1	0.00001		4.0E-08
2	0.0001	1		0.1	10	0.000001		9.0E-11
3	0.001	1		1	1.01	0.000001		1.0E-11
4	0.05	1		0.9	1.1	0.000001		4.5E-09
5	0.1	1		1	10	1E-08		9.0E-09
6	0.01	0.9		1	10	0.00001		8.1E-07
7	0.001	0.9		0.9	10	0.00001		7.3E-08
8	0.001	1		0.01	100	0.000001		9.9E-10
9								0.0E+00
Avg	2.7 e-2	9.8 e-1	0.0 e+0	7.1 e-1	1.8 e+1	4.3 e-6		1.0 e-7
GMn	4.7 e-3	9.7 e-1	0.0 e+0	4.0 e-1	2.685 e+0	1.3 e-6		4.1 e-9

Discussion

UO_2, occurring as both crystalline and amorphous uranium oxide, composes the matrix material within the spent-fuel waste. Consequently, the solubility of UO_2 was adopted as a surrogate measure of radionuclide solubility in ground water that may contact the waste.

UO_2 solubility under current unsaturated conditions in the host rock is highly uncertain; currently assumed values, however, are a factor of 10 less than the assessment threshold. The consequences of greater solubility of UO_2 on other radionuclide solubilities are also uncertain (e.g., congruent vs. noncongruent leaching). Increased solubility does not necessarily imply increased radionuclide releases, which also depend upon waste-package design and the chemistry of water in contact with the waste. If UO_2 solubility presently exceeds the assessment threshold, this condition probably will persist during the next 10,000 years.

PC #H1: Human Intrusion Effects on Geohydrology

Measure: Change in future ground-water flux as a result of human activity

Assessment threshold (AT): Sufficient change in flux to affect waste isolation

Regulatory Concern:

960.4-2-8-1 Natural Resource, (c) Potentially Adverse Conditions, Item (5)

Potential for foreseeable human activities--such as ground-water withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activities, or the construction of large-scale surface-water impoundments--that could adversely change portions of the ground-water flow system important to waste isolation.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (2)

Potential for foreseeable human activity to adversely affect the ground-water flow system, such as ground-water withdrawal, extensive irrigation, surface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (1)

Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

Importance Assessment Questions:

- A Probability that human activity will cause ground-water flux changes sufficient to affect waste isolation.
- B1 Identically equal to 1.0 by definition.
- B1' Not used in this assessment
- B2 Probability that human-induced flux changes will affect waste isolation, given that these changes will occur during the next 10,000 years.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#H1: Human Intrusion Effects on Geohydrology

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.001	1		1	10	0.00001		9.0E-08
2	0.01	1		1	10	0.000001		9.0E-08
3	0.000001	1		1	10	0.000001		9.0E-12
4	0.01	1		0.9	10	0.000001		8.1E-08
5	0.5	1		1	10	1E-08		4.5E-08
6	0.01	1		1	10	0.00001		9.0E-07
7	0.001	1		0.1	10	0.00001		9.0E-09
8	0.001	1		0.1	30	0.000001		2.9E-09
9	0.0001	1		0.7	10	0.00001		6.3E-09
Avg	5.9 e-2	1.0 e+0	0.0 e+0	7.6 e-1	1.2 e+1	4.9 e-6		1.4 e-7
GMn	1.5 e-3	1.0 e+0	0.0 e+0	5.7 e-1	1.125 e+1	1.7 e-6		1.5 e-8

Discussion

Human intrusion that would affect the post-closure geohydrologic system includes, for example, the introduction of drilling fluid into the site by future exploratory drilling, the use of the site for underground disposal of fluid waste independent of nuclear waste, or other future human activity that could introduce fluids that would affect the waste isolation capabilities of the site (e.g., by altering ground-water flux, cannister stability, etc.). Although such occurrences were judged to be unlikely, they would be events of relatively high consequence in comparison to the other PCs evaluated.

PC #H3: Usable Water in Controlled Area—Direct Intrusion

Measure: Rate of drilling in the repository block for the purposes of exploration for or exploitation of usable water or economic resources

Assessment threshold (AT): Three drillholes per square kilometer (ref., 40 CFR 191)

Regulatory Concern:

<u>960.4-2-1 (Human Intrusion) Geohydrology, (c) Potentially Adverse Conditions, Item (2)</u>

The presence of ground-water sources, suitable for crop irrigation or human consumption without treatment, along ground-water flow paths from the host rock to the accessible environment.

Importance Assessment Questions:

- A Probability that drilling will occur at a rate greater than three drillholes per square kilometer in the repository block, in search of usable water or economic resources.
- B1 Identically equal to 1.0 by definition.
- B1' Not used in this assessment.
- B2 Probability that such drilling will directly intersect waste and affect waste isolation.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, <u>given</u> that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT | **Workshop:** Import. #2
#H3: Direct Intrusion | **Date:** 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.01	1		0.02	1000	0.00001		2.0E-06
2	1	1		0.1	10000	0.000001		1.0E-03
3	0.001	1		0.01	10000	0.000001		1.0E-07
4	0.1	1		0.04	3000	0.000001		1.2E-05
5	0.5	1		0.001	100000000	1E-08		5.0E-04
6	0.01	1		0.02	10000	0.00001		2.0E-05
7	0.01	1		0.08	10000	0.00001		8.0E-05
8	0.001	1		0.02	1000000	0.000001		2.0E-05
9	0.1	1		0.05	10000	0.00001		5.0E-04
Avg	1.9 e-1	1.0 e+0	0.0 e+0	3.8 e-2	1.1 e+7	4.9 e-6		2.4 e-4
GMn	2.6 e-2	1.0 e+0	0.0 e+0	2.2 e-2	3.143 e+4	1.7 e-6		3.0 e-5

Discussion

This concern involves predicting possible human activity that would be likely during the next 10,000 years, and, in addition, would include the likelihood of a loss of institutional controls at the site. The concern must consider all ways that exploratory or production drilling into the repository block for water or natural resources (including oil and gas) could directly intrude emplaced waste and produce direct radionuclide releases to the accessible environment. The assessment threshold of 3 boreholes per square kilometer was adopted from an estimate in 40 CFR Part 191 of the expected density of future boreholes in non-sedimentary-rock terrains.

The consequences of direct intrusion, should it occur, could produce releases that exceed the baseline releases in Column D by a factor of 1,000 or more (see page 8.3.5.13-85 of the Site Characterization Plan). The extraction of a 6-centimeter diameter core from a waste package could cause a release of about 0.03 of the EPA limits. Direct penetration of a single waste package 1,000 years after emplacement could cause releases equivalent to 10 to 20 times the EPA limits (extremely conservative scenario endmember). Many considerations were weighed in this analysis, including the observation that it would be more likely for a current-technology drill bit to be deflected by, rather than penetrate, a waste canister.

PC #H4: Natural Resources

Measure: Presence of potentially economically recoverable natural resources

Assessment threshold (AT): Recoverable economically now or in next 10-30 years

Regulatory Concern:

960.4-2-8-1 Natural Resource, (c) Potentially Adverse Conditions, Item (1)

Indications that the site contains naturally occurring materials, whether or not actually identified in such form that (i) economic extraction is potentially feasible during the foreseeable future, or;

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (17)

The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:
(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future;

960.4-2-8-1 Natural Resource, (c) Potentially Adverse Conditions, Item (1)

(ii) such materials have a greater gross value, net value, or commercial potential than the average for other areas of similar size that are representative of, located in, the geologic setting.

960.4-2-8-1 Natural Resource, (c) Potentially Adverse Conditions, Item (4)

Evidence of a significant concentration of any naturally occurring material that is not widely available form other sources.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, Item (17)

The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that: (ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

Importance Assessment Questions:

- A Probability that the economic resources described above exist now.
- B1 Probability that those resources will exist in the next 10,000 years, and that they will be exploited in a way that results in a flux that is ten times the present flux over at least 10% of the repository area, given that they exist now.
- B1' Not used in this assessment.
- B2 Probability that the higher flux will affect waste isolation, given that the higher flux happens.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#H4: Natural Resources

Workshop: Import. #2
Date: 11/1/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.0001	0.1		1	10000	0.00001		1.0E-06
2	0.001	0.001		1	100	0.000001		9.9E-11
3	0.001	0.001		1	100	0.000001		9.9E-11
4	0.02	0.01		0.9	100	0.000001		1.8E-08
5	0.001	0.5		1	1E+09	1E-08		5.0E-03
6	0.01	0.01		0.5	1000	0.00001		5.0E-07
7	0.05	0.001		0.7	100	0.00001		3.5E-08
8	0.0001	0.001		0.1	100	0.000001		9.9E-13
9	0.01	0.001		0.7	10	0.00001		6.3E-10
Avg	1.0 e-2	6.9 e-2	0.0 e+0	7.7 e-1	1.1 e+8	4.9 e-6		5.6 e-4
GMn	2.2 e-3	5.6 e-3	0.0 e+0	6.5 e-1	9.837 e+2	1.7 e-6		1.3 e-8

Discussion

The "foreseeable future" in economic geology extends only about 10-30 years. Estimates of this activity during the next 10-30 years can be projected and the consequences for waste isolation over 10,000 years then considered. Much evidence exists for the occurrence of mineral resources, including hydrocarbons, in the State of Nevada. Given that the repository area is approximately 2.5 square miles, it is unlikely that potentially economic resources exist (see SCP, Chapter 1.7). However, if they are present, it must be further considered whether they woud be recoverable practically with current technology. With these considerations and a knowledge of hydrology, it was difficult to envision how the exploitation of natural resources could increase ground-water flux over ten percent of the repository area. If this condition should occur during the next 10,000 years, however, it would be expected to have a large impact on waste isolation in comparison to the other PCs evaluated.

PC #H5: Evidence of Previous Mining

Measure:	Ground-water flux through the repository
Assessment threshold (AT):	Tenfold increase in flux over 10% of the repository area

Regulatory Concern:

960.4-2-8-1 Natural Resource, (c) Potentially Adverse Conditions, Item (2)

Evidence of subsurface mining or extraction for resources within the site if it could affect waste containment or isolation.

60.122 Siting Criteria, (c) Potentially Adverse Conditions, The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area, Item (18)

Evidence of subsurface mining for resources within the site.

960.4-2-8-1 Natural Resource, (d) Disqualifying Conditions
A site shall be disqualified if–, Item (1)

Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment;

Importance Assessment Questions:

- A Probability that previous mining, exploration, etc., has occurred in the repository block or controlled area.
- B1 Probability that those pathways will remain open and cause a ground-water flux that is ten times the present flux over at least 10% of the repository area, given that previous mining, exploration, etc., has occurred.
- B1' Not used in this assessment.
- B2 Probability that the higher flux will affect waste isolation, given that the higher flux occurs.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#H5: Past Mining

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.01	0.001		1	10	0.00001		9.0E-10
2	0.001	0.0001		1	10	0.000001		9.0E-13
3	0.001	0.001		1	10	0.000001		9.0E-12
4	0.02	0.001		0.9	10	0.000001		1.6E-10
5	0.0001	0.0001		1	10	1E-08		9.0E-16
6	0.001	0.0001		0.5	10	0.00001		4.5E-12
7	0.001	0.0001		0.7	100	0.00001		6.9E-11
8	0.0001	0.00001		0.1	100	0.000001		9.9E-15
9	0.0001	0.000001		0.7	10	0.00001		6.3E-15
Avg	3.8 e-3	3.8 e-4	0.0 e+0	7.7 e-1	3.0 e+1	4.9 e-6		1.3 e-10
GMn	8.4 e-4	1.0 e-4	0.0 e+0	6.5 e-1	1.633 e+1	1.7 e-6		1.4 e-12

Discussion

Considerations for this PC were similar to those for PC #1 and PC #H4. The main variations were in the type of human activity that might lead to an increase in flux.

Measure: Ground-water flux through the repository

Assessment threshold (AT): Tenfold increase of flux over 10% of repository area

Regulatory Concern:

960.4-2-8-1 Natural Resource, (d) Disqualifying Conditions, Item (2)

Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.

Importance Assessment Questions:

- A Probability that future mining outside the CA will cause a tenfold increase of ground-water flux through 10% of the repository area.
- B1 (Is 1.0 by definition).
- B1' Not used in this assessment.
- B2 Probability that the higher flux will affect waste isolation, given that the higher flux happens.
- C Multiplier on site performance, relative to that expected in the absence of adverse conditions.
- D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#H6: Future Mining

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.001	1		0.1	10	0.00001		9.0E-09
2	0.000001	1		1	10	0.000001		9.0E-12
3	0.000001	1		1	10	0.000001		9.0E-12
4	0.0001	1		0.9	100	0.000001		8.9E-09
5	0.00001	1		1	10	1E-08		9.0E-13
6	0.00001	1		0.5	10	0.00001		4.5E-10
7	0.0001	1		0.7	100	0.00001		6.9E-08
8	0.000001	1		0.1	100	0.000001		9.9E-12
9	0.000001	1		0.7	10	0.00001		6.3E-11
Avg	1.4 e-4	1.0 e+0	0.0 e+0	6.7 e-1	4.0 e+1	4.9 e-6		9.8 e-9
GMn	1.0 e-5	1.0 e+0	0.0 e+0	5.1 e-1	2.102 e+1	1.7 e-6		1.7 e-10

Discussion

Discussions held were similar to those for PC #s H4, H1, and H5.

PC #H8: Usable Water in Controlled Area—Saturated Zone (SZ)

Measure: Ground-water flux in the SZ

Assessment threshold (AT): Tenfold increase in flux along contaminated pathways to the accessible environment

Regulatory Concern:

960.4-2-8-1 Natural Resource, (d) Disqualifying Conditions, Item (2)

Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.

Importance Assessment Questions:

A Probability that usable water is present within the controlled area.

B1 Probability that usable water would be exploited to cause a tenfold increase in ground-water flux in the SZ, given that the usable water exists.

B1' Not used in this assessment.

B2 Probability that the increased flux will affects waste isolation, given that the increased flux, as described, will occur for a significant period in the next 10,000 years.

C Multiplier on site performance, relative to that expected in the absence of adverse conditions.

D Expected curies released, given that no adverse conditions are present, i.e., that all PC measures are less than their respective ATs.

IMPORTANCE BALLOT
#H8: Usable Water in Controlled Area—SZ

Workshop: Import. #2
Date: 11/2/90
Respondents: 9

#	A	B1	B1'	B2	C	D		Product
1	0.9	0.5		0.01	1.2	0.00001		9.0E-09
2	1	0.01		1	1.1	0.000001		1.0E-09
3	0.9	0.1		0.9	1.01	0.000001		8.1E-10
4	1	0.05		0.9	1.01	0.000001		4.5E-10
5	1	0.9		0.1	2	1E-08		9.0E-10
6	0.9	0.1		0.1	1.1	0.00001		9.0E-09
7	0.9	0.01		0.1	1.1	0.00001		9.0E-10
8	0.95	0.01		0.0001	10	0.000001		8.6E-12
9	1	0.01		0.5	10	0.00001		4.5E-07
Avg	9.5 e-1	1.9 e-1	0.0 e+0	4.0 e-1	3.2 e+0	4.9 e-6		5.2 e-8
GMn	9.5 e-1	5.1 e-2	0.0 e+0	9.0 e-2	1.227 e+0	1.7 e-6		1.7 e-9

Discussion

Because of the presence of usable water in the region (e.g., well J-13, which is located about 5 km east of the site), there is a high probability that usable water is present in the saturated zone beneath the controlled area. Also, because the region is arid, there is a high probability that ground-water resources there will be exploited. Increasing flux is not a likely concern for this PC (see the discussion under PC #s H4 and H3 where this is evaluated). The concern for this PC is that the withdrawal of water near the controlled area could produce a cone of depression that would cause a local increase of the hydraulic gradient and, consequently, of the ground-water flux in the saturated zone. It was viewed, however, that increasing the ground-water flux within the saturated zone was unlikely to produce radionuclide releases that would significantly exceed the assessed baseline releases.

Appendix D
Testing Assessments

Introduction

This appendix presents the results of workshops that were conducted to assess the accuracy with which tests performed at the site can be expected to detect the presence of potential concerns (PCs) considered in this Phase One analysis. (References to specific workshops can be found in the "Special Bibliography of Correspondence and Other Items" of Appendix B.) The intent of the workshops was to identify and prioritize those tests at the activity level within the Site Characterization Plan (SCP) that could be undertaken at an early stage of the site-characterization program to support an early evaluation of site suitability. For this purpose, as described in Volume I, Chapter 3, a restricted set of 10 PCs was selected for assessing test accuracy. These PCs were judged to be the most important with respect to their likelihood of occurrence and consequences for waste isolation. The methods used to quantify test accuracy are detailed in Chapter 3 of this report and will not be elaborated further in this appendix.

The same workshop format and process were used to perform the test-accuracy assessments as were used to perform the importance assessments, as described in the Introduction of Appendix C. The workshop participants first reviewed the definition of the PC, its measure, and the assessment threshold (AT). In a few cases, the participants determined that insufficient information was provided by the importance assessments to address testing and test accuracy adequately, and, for these cases, additional assessments were required. For example, in considering PC #5: "Climate Effect on Radionuclide Transport," it was first necessary to assess prior probability distributions on both the present and the expected future ground-water flux through the repository level at the site. In all cases where such additional assessments were performed, the assessment results are shown on the test-accuracy assessment summaries included in this appendix.

Following review of the PC and performing such preliminary assessments as required, the participants identified the tests (specifically, studies and activities as described in Chapter 8 of the SCP) whose results could indicate the presence of the PC under consideration. In most cases, the assessed accuracy of testing referred to a suite, or package, of tests rather than to a single test. Tests were also grouped into different levels of testing depending on the availability of data (e.g., use existing data only, use existing data plus data from a few new boreholes drilled at the site, use the preceding data plus data from testing within the Exploratory Shaft Facility). Test accuracy was assessed in either of two ways: (1) as a set of discrete probabilities (e.g., designated P1, P2, and P3 on the test-accuracy assessment summaries) that the test will detect the PC or (2) in terms of an 80-percent confidence interval expressed in terms of a specified interval or a multiplicative F factor, as described in Chapter 3. The assessment process consisted of each participant preparing an initial ballot for each package of tests and level of testing identified for the PC under consideration. The results of the initial ballot were discussed, and a final ballot was taken to complete the assessment.

The test-accuracy assessments were conducted at two workshops in Las Vegas, Nevada, on November 28-29, 1990, and January 17-18, 1991, and at one workshop in Palo Alto, California, on December 11-13, 1990. (See Appendix B for the list of participants at these workshops.) The results of these assessments are reported on the test-assessment summaries provided in this appendix.

Test Assessment and Accuracy Ballot #___

Potential Concern:____

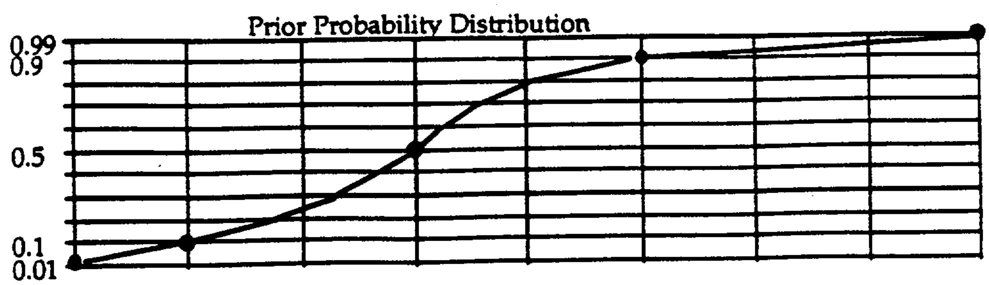
Name:____________________ **Number:**________ **Date:**____________

Assessment variable:____

____

Units:____

Cumulative probability*
*(Prob. that assessment variable is less than or equal to x)



______ Very low ______ Low ______ Median ______ High ______ Very high

Test Accuracy Assessment:

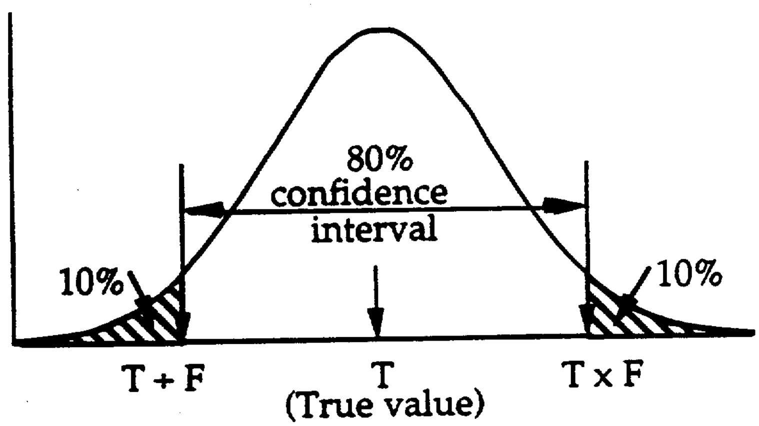
True Value: ______ Low ______ Median ______ High

Accuracy assessment: *(choose one method)*

"F" Factor: ----- ----- -----

80% error bar: ----- ----- -----

Probability density



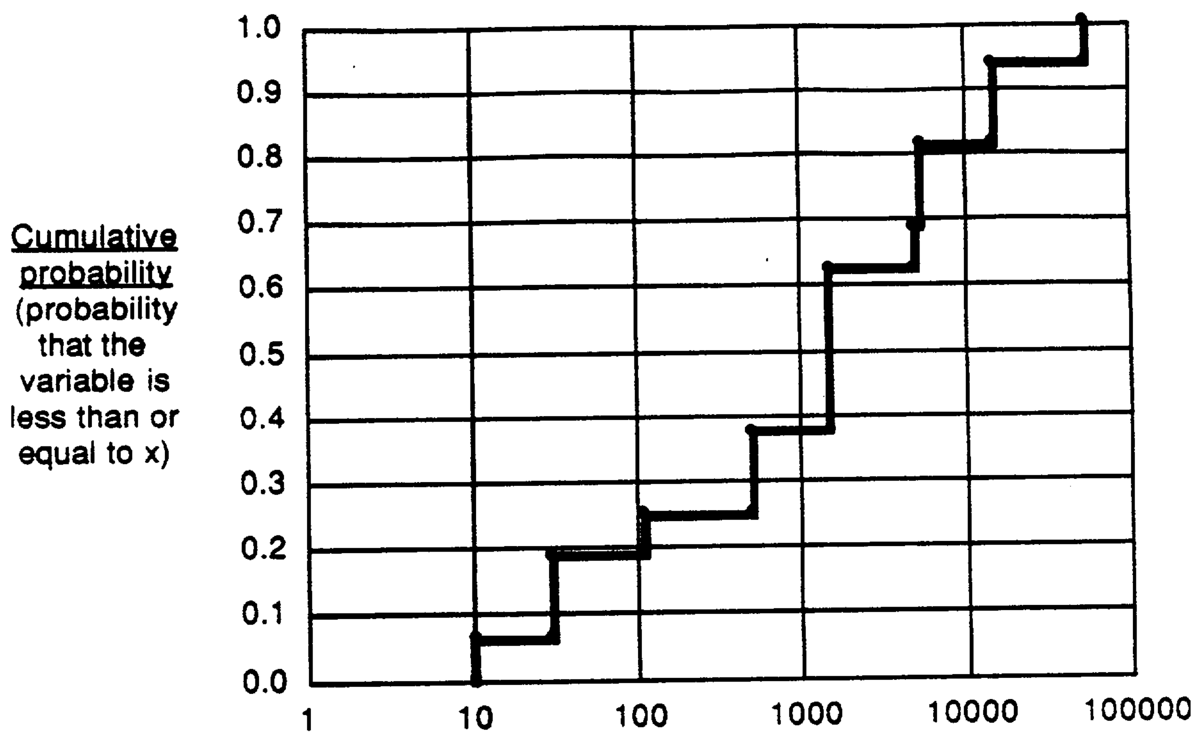
Reported value from testing

PC #1: Gas Flow Radionuclide

Measure: Gaseous carbon-14 travel time (inert gas flow time TIMES carbon-14 retardation factor)

Assessment threshold (AT): 10,000 years

Prior Probabilty Distribution
#1: Gas Flow Radionuclide



Variable: Expected travel time for carbon 14 along path of significant transport
Units: Years Date Assessed: 11/1/90

Tests for Gas Flow Time

Testing for bulk air permeability was used as a proxy for all tests related to gas-flow time, and the accuracy associated with testing for gas flow time was assumed to be the same as that for the permeability tests.

SCP Activity #	Title
8.3.1.2.2.3.2	Site vertical boreholes (air permeability testing)
8.3.1.2.2.4.4	Radial boreholes test in the exploratory shaft facility
8.3.1.2.2.4.5	Excavation effects test in the exploratory shaft facility

TEST ACCURACY BALLOT — Workshop: Test. #1
#1: Gas Flow Radionuclide—Inert Gas Flow Time — Date: 11/28/90
Bulk air permeability tests are a proxy for flow time tests — Responses: 1
F Factors for given true values — **Low and high test results**

#	1E-18	1E-12	1E-08		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1										
2										
3										
4										
5										
6										
7	5	3	3		2E-19	5E-18	3.3E-13	3E-12	3.3E-09	3E-08
8										
9										
10										
11										
12										
13										
14										
15										
Avg	5	3	3		2E-19	5E-18	3.3E-13	3E-12	3.3E-09	3E-08
GMn	5.0 e+0	3.0 e+0	3.0 e+0		2.0 e-19	5.0 e-18	3.3 e-13	3.0 e-12	3.3 e-9	3.0 e-8
				F	5.0	5.0	3.0	3.0	3.0	3.0
				Average F	5.0		3.0		3.0	

Tests for Carbon-14 Retardation

SCP Activity #	Title
8.3.1.3.8.1	Radionuclide retardation
8.3.1.2.2.7.1	Gaseous phase chemical investigations

TEST ACCURACY BALLOT — **Workshop:** Test. #1

#1: Gas Flow Radionuclide—Retardation — **Date:** 11/28/90

Responses: 4

F Factors for given true values — **Low and high test results**

#	1	50	500		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1		5	5		1	50	10	250	100	2500
2										
3										
4										
5										
6					1	90	10	250	50	2000
7										
8		3	3		1	3	16.6667	150	166.667	1500
9										
10										
11										
12										
13										
14		3	2		1	10	16.6667	150	250	1000
15										
Avg	#DIV/0!	3.66667	3.33333		1	38.25	13.3333	200	141.667	1750
GMn	#NUM!	3.6 e+0	3.1 e+0		1.0 e+0	1.9 e+1	1.3 e+1	1.9 e+2	1.2 e+2	1.7 e+3
				F	1.0	19.2	3.9	3.9	4.2	3.3
				Average F	10.1		3.9		3.7	

Discussion

1. Gas Flow Time

Expected gas-flow times from the repository horizon to land surface through the unsaturated zone at the site were assessed at the Gas-Flow Workshop held for these purposes by the TPT in Denver, Colorado, on June 22, 1990. (See Appendix B.) Gas flow time, effective diffusion coefficient, retardation, rapid-release fraction, and source term were discussed. The results of this workshop indicated that gas-flow times are expected to be short. We used the following discrete approximation for gas flow time: a probability of 0.1 that gas-flow time equals 10 years, a probability of 0.5 that gas-flow time equals 30 years, and a probability of 0.9 that gas flow time equals 110 years. This is considered preliminary, and further detailed assessment is warranted during Phase II.

In order to produce longer gas-flow times, a pervasive low-permeability bottleneck for gas flow would have to be present. Such a bottleneck is unlikely in highly fractured welded tuffs but may be caused by unfractured nonwelded tuffs, altered tuffs, and in welded tuffs in which the degree of welding increases without concurrent increase in fracturing. In addition to bottlenecks, highly brecciated zones, such as the Ghost Dance fault, may constitute rapid gas-flow pathways. With respect to this PC, "pore space" is interpreted to include both fracture and rock-matrix pore space. As a first approximation, gas-flow time is inversely proportional to permeability; consequently, intrinsic bulk (matrix plus fracture) permeability was selected as the appropriate test parameter for gas-flow time. Because the water table beneath the site is known to respond to barometric effects, there is apparent rapid pressure-wave transmission through the unsaturated zone. Results of air-permeability testing indicate that the intrinsic bulk permeability of the fractured, partially welded tuff at Apache Leap, Arizona, ranges from 1E-14 to 1E-16 m^2.

2. *C-14 Retardation*

Three possible models for C-14 retardation within the unsaturated zone were identified at the TPT Gas-Flow Assessment Workshop held in Denver, Colorado, on June 22, 1990. (See Appendix B.) The first model assumes no retardation of C-14 and, therefore, assigns a value equal to 1.0 to the C-14 retardation factor. A second model considers only C-14 exchange between aqueous and gas phases within the matrix/fracture pore space with a corresponding C-14 retardation factor in the range between 10 and 100. The third model includes possible C-14 exchange with solid-phase carbonates (e.g., calcite) that may be present within the unsaturated zone, which could lead to retardation factors ranging from 100 to 900. Presently available data on conditions within the unsaturated zone at the site are insufficient to permit selection of an appropriate model. To assess the test-accuracy for C-14 retardation, the Core Team regarded the C-14 retardation factor to be a discrete random variable with possible expected values equal to 1, 50, and 500 with probabilities of occurrence equal to 0.25, 0.5, and 0.25, respectively, corresponding to the three possible models. The retardation-factor value of 50 was given higher weight because it represents a conservative value intermediate between the two extremes of no C-14 retardation and high C-14 retardation. The problem of the degree of C-14 retardation, if any, will be reconsidered during the Phase Two analysis. Although testing and site data may permit identification of an appropriate C-14 retardation model for the site, the actual value for the C-14 retardation factor (unless evidence indicates there to be negligible retardation) is likely to remain highly uncertain. Laboratory experiments, for example, in crushed tuff columns, may not be representative of actual field conditions and processes at the site. Mineralogical studies indicate that calcite is present in fractures above the potential repository horizon but not in the rock matrix. However, rapid advective C-14 movement in the fractures coupled with slow C-14 exchange rates between gas and solid phases may lead to little gas-solid retardation within the fractured tuff units. Kinetic effects will also control the rates of liquid-gas C-14 exchange and, therefore, the contribution of this mechanism to C-14 retardation in both fractures and rock-matrix pores. There may be a tendency to err on the side of conservatism and to assume no retardation when, in fact, components of either or both the liquid-gas, and solid-gas retardation models may be operating under site conditions.

PC #2: Complex Geology—Aqueous

Measure: Expected curies released by aqueous flow

Assessment threshold (AT): Ten percent of the EPA standard

Tests for Complex Geology: Level 1—Borehole studies (2-6 boreholes)

SCP Activity #	Title
8.3.1.2.2.3.2	Site vertical boreholes - 1 to 3 feature based boreholes
8.3.1.2.2.3.3	Solitario Canyon horizontal borehole study - 1 horizontal borehole
8.3.1.2.3.1.1	Solitario Canyon fault study - 2 boreholes
8.3.1.2.3.1.2	Site potentiometric-level evaluation - Those portions that target the steep gradient investigations - 2 boreholes
8.3.1.4.2.2.3	Bore hole evaluations of faults and fractures
8.3.1.4.3.1.1	Systematic drilling program - 1 to 3 exclusive of the features
8.3.1.2.2.3.1	Matrix hydrologic properties testing
8.3.1.4.2.1.3	Borehole geophysical surveys
8.3.1.4.2.1.1	Surface and subsurface stratigraphic studies of the host rock and surrounding units - Focusing on study of bedded tuff, this allows determination of the extent of such hydrologic properties such as moisture content
8.3.1.4.2.2.1	Geologic mapping of zonal features in the Paintbrush Tuff (We question whether there are sufficient drill rigs to complete this level of testing)

TEST ACCURACY BALLOT
#2.1: Complex Geology—Aqueous (Level 1-Boreholes)

Workshop: Testing #3
Date: 1/17/91
Respondents: 10

#	P 1	P 2	P 3
1	0.05	0.6	0.2
2			
3	0.01	0.6	0.4
4			
5	0.1	0.6	0.1
6	0.005	0.8	0.2
7	0.1	0.7	0.1
8			
9	0.05	0.9	0.1
10	0.03	0.75	0.1
11			
12	0.05	0.6	0.15
13	0.05	0.5	0.1
14			
15	0.05	0.6	0.15
Avg	0.0495	0.665	0.16
GMn	3.7 e-2	6.6 e-1	1.4 e-1

P1: Probability that condition* exists

P2: Probability of finding the condition, given that it exists

P3: Probability of finding the condition, given that it does not exist

*Conditions with significant consequence for waste isolation: Underestimate releases by 10% of the EPA standard

Tests for Complex Geology: Level 2
(Level 1 borehole studies (2-6) plus additional boreholes drilled at the time of the ESF)

SCP Activity #	Title
8.3.1.2.2.4.10	Hydrologic properties of major faults encountered in main test level of the exploratory shaft facility
8.3.1.2.2.4.7	Perched water in ESF - If the ESF encounters perched water, then we do this test
8.3.1.2.3.4.6	Calico Hills test in the exploratory shaft facility
8.3.1.4.2.2.4	Geological mapping of the exploratory shaft and drifts - Of particular interest are faults, fractures and stratigraphic discontinuities within the geologic mapping
8.3.1.2.2.3.1	Matrix hydrologic properties testing - This is a particular study in the ESF

TEST ACCURACY BALLOT
#2.1A: Complex Geology—Aqueous
(Level 2-Boreholes + ESF)

Workshop: Testing #3
Date: 1/17/91
Respondents: 10

#	P 1	P 2	P 3
1	0.05	0.9	0.05
2			
3	0.01	0.8	0.1
4			
5	0.1	0.8	0.05
6	0.005	0.95	0.05
7	0.1	0.85	0.05
8			
9	0.05	0.95	0.05
10	0.03	0.95	0.05
11			
12	0.05	0.95	0.05
13	0.05	0.6	0.04
14			
15	0.05	0.9	0.05
Avg	0.0495	0.865	0.054
GMn	3.7 e-2	8.6 e-1	5.2 e-2

P1: Probability that condition* exists

P2: Probability of finding the condition, given that it exists

P3: Probability of finding the condition, given that it does not exist

*Conditions with significant consequence for waste isolation: Underestimate releases by 10% of the EPA standard

Discussion

The Testing Workshop assessment panel had considerable difficulty in defining this PC in terms of an appropriate quantitative measure and in relating the PC directly to specific tests at the site that would contribute to an early evaluation of site suitability. Consequently, the assessment panel considered this concern twice: first at the Testing Workshop held in Palo Alto, California, on December 13, 1990, and then again at the Testing Workshop held in Las Vegas, Nevada, on January 17, 1991. (See Appendix B.) The Core Team recognized that identifying an appropriate set of tests and assessing their accuracy with respect to this PC could prove to be difficult. Consequently, the Core Team proposed an alternative interpretation in terms of the spatial distribution, in particular, the concentration and localization of ground-water flux that would not be predicted by the performance-assessment models and, therefore, could lead to an underestimate of aqueous-phase radionuclide releases equal to or exceeding 0.1 times the EPA standard for cumulative releases. After considerable discussion the workshop participants concluded that the proposed surrogate interpretation of the PC was not a meaningful statement of the actual concern addressed by the PC. Consequently, the participants agreed to the following definition of the PC: "Stratigraphic or structural features that could cause releases to be underestimated by 10% of the EPA standard." The types of features that may be involved were identified to be the following:

- Blind faults with net displacements of at least 2 m occurring at depth at the site with no surface expression

- Broken (faulted or fractured) zones associated with the major faults in the area

- Interconnected fracture systems

- Stratigraphically controlled spatial distribution (heterogeneity) of hydrologic properties

Some panel members expressed the concern that expressing the quantitative measure of the PC in terms of repository performance placed undue importance on complexity as it relates to performance-assessment modeling rather than on its consequences relative to our ability to characterize a highly complex site. Panel members also raised the question whether the spatial distribution of hydrologic properties constituted a "feature" in the sense of 10 CFR 960, although the group and Core Team consensus was that stratigraphically controlled spatial variability was, indeed, a "feature."

This PC was reassessed at the Testing Workshop held on January 17, 1991, out of concern that the participants had not achieved common understanding and agreement at the preceding workshop. Furthermore, the aggregate of tests identified at the previous workshop consisted virtually of the entire site characterization program and did not identify a restricted set of tests that might be important for an early evaluation of site suitability. The participants considered that the PC addressed two issues: (1) Basic geologic and hydrologic properties and features and (2) predictive performance-assessment modeling. Because models, in order to be tractable, generally must simplify the systems they are intended to represent, the issue addressed by the PC is the presence of such geologic complexity that the simplified models would lead to predicted releases that would underestimate true releases by at least 10% of the EPA standard. We know that we can characterize the site to a finer level of detail than we can model it (for example, we cannot realistically hope to model the detailed water-saturation profile that we might actually observe in a borehole). Consequently, we must be concerned with those aspects of site-complexity that would significantly reduce our confidence in the model results not with the modeling effort in itself. There are two issues: (1) the presence of features at the site that would be difficult to detect but, if not accounted for in the models, could lead to significant underestimates of releases, and (2) features that may be present and detected at the site but that could not be readily allowed for in the models.

Because the TPT effort is to identify and prioritize tests that relate to an early evaluation of site suitability, this testing assessment should focus on those tests pertaining to specific features at the site that are known and could contribute to site complexity. If these features are present and are hydrologically complex, and, thus, important for flow and transport modeling, they will be associated with what should be a detectable anomaly in the flow system (e.g., a region of abnormally high saturation near a fault transecting the unsaturated zone). The testing should be directed towards identifying such features and detecting any associated hydrologic anomalies that might be present. Examples of such features currently known to be present at the site include (1) the Solitario Canyon and Ghost Dance faults, (2) the nonwelded Paintbrush Tuff units above the Topopah Spring unit, (3) stratigraphic discontinuities and fracture distribution within the Calico Hills unit, and (4) the steep hydraulic gradient in the saturated zone north of the site. These are features where we might expect to detect anomalies under present conditions. If we do not detect the occurrence of anomalies associated with these features, then it may not be important to look elsewhere for them; however, if we detect the presence of anomalies with these features, we will need to examine other locations and features that also might produce or be associated with anomalies. Focussing on testing related to the specific site features identified above, the workshop participants assessed the following probabilities:

P_1 = probability that the features, as described above, are present at the site.

P_2 = probability that a test or aggregate set of tests at the site will detect these features at the site given that the features are present (true positive).

P_3 = probability that the tests will indicate these features to be present when, in fact, they are not present at the site (false positive).

These probabilities were assessed for each of two levels of testing defined as follows:

Level 1: Data collected from 2-6 new boreholes to be drilled specifically to investigate the features

Level 2: Level 1 data plus additional data to be collected from boreholes drilled concurrently with construction of the Exploratory Shaft Facility.

In order for a feature or combination of features to have a significant impact on waste isolation, they would have to cause a net volume discharge of water through the repository of at least 100 m^3/yr. Testing for anomalous conditions will be subject to uncertainties because of a lack of clear-cut criteria to distinguish anomalous conditions from, for example, "normal" spatial heterogeneity. However, if an anomaly is present of significant consequence for waste isolation, the testing program probably will detect it. There is a fairly large probability for occurrence of a false positive because of misinterpretation of test results and a bias towards conservatism.

Discussion

Test accuracy with respect to this concern was not assessed because (1) this concern was considered to be adequately addressed implicitly by the test accuracy associated with PC #1: Gas Flow Radionuclide, (2) complex geology may affect the waste-package environment and, thus, gaseous releases from the waste package but this consequence was not considered by the assessment panel, and (3) geologic and hydrologic complexity are more likely to enhance gas-phase radionuclide retardation such the current simplified gas-phase transport modeling studies probably *overestimate* rather than *underestimate* gas-phase releases.

PC #3: Reactive Ground-Water Chemistry

Measure: Total dissolved solids (TDS) of ground water that could potentially contact the engineered barrier system

Assessment threshold (AT): 10,000 ppm

PRIOR PROBABILITY DISTRIBUTION BALLOT Workshop: Testing #2
#3 Reactive Ground-Water Chemistry Date: 12/11/90
Respondents: 7

#	1%	10%	50%	90%	99%
1	50	100	300	1000	5000
2	60	100	200	800	2000
3	50	100	200	1000	2000
4					
5	50	100	200	500	2500
6	50	200	500	1000	3000
7					
8	90	120	1000	3000	5000
9					
10					
11					
12					
13					
14	50	100	350	1000	3500
15					
Avg	57.142857	117.142857	392.85714	1185.7143	3285.714286
GMn	5.6 e+1	1.1 e+2	3.3 e+2	1.0 e+3	3.1 e+3

Tests

SCP Activity #	Title
8.3.1.2.2.4.8	Hydrochemistry tests in the exploratory shaft (ESF)
8.3.1.2.2.7.2	Aqueous phase chemical investigations (vertical-boreholes)
8.3.1.2.2.4.7	Perched water (ESF, vertical boreholes)
8.3.4.2.4.1.3	Composition of vadose water from waste package environment (ESF)
8.3.4.2.4.4.2	Repository horizon rock-water interaction (ESF)

TEST ACCURACY BALLOT
#3: Reactive Ground-Water Chemistry

Workshop: Test. #2
Date: 12/11/90
Responses: 6

F Factors for given true values					Low and high test results					
#	100	350	1000		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1					75	200	250	500	800	1500
2										
3		3			90	300	116.667	1050	250	1500
4										
5					50	200	100	600	800	1200
6					50	200	200	500	850	1150
7										
8					90	350	300	1000	900	2000
9										
10										
11										
12										
13										
14	2	2	2		50	200	175	700	500	2000
15										
Avg	2	2.5	2		67.5	241.667	190.278	725	683.333	1558.333
GMn	2.0 e+0	2.4 e+0	2.0 e+0		6.5 e+1	2.3 e+2	1.8 e+2	6.9 e+2	6.3 e+2	1.5 e+3
				F	1.5	2.3	2.0	2.0	1.6	1.5
				Average F	1.9		2.0		1.6	

Discussion

This PC addresses the chemical reactivity of potentially corrosive water that could come in contact with the engineered components of the repository system, including the waste package. Of primary concern is the present-day chemical composition of water within the unsaturated Topopah Spring host rock. Total dissolved solids (TDS), expressed in parts per million (ppm), was selected as the quantitative measure of potential chemical reactivity of the water. Water from water-supply well J-13, which taps the Topopah Spring unit in the unsaturated zone, has a TDS of about 200 ppm. The composition of J-13 water is generally regarded to be typical of expected ground-water chemistry within the Topopah Spring in the unsaturated zone at the site. This conclusion is supported by the results of sorption experiments in which no significant change in water chemistry was observed as a result of passing J-13 well water through crushed tuff columns. Water from borehole UE-25P#1, which was drilled into the Paleozoic carbonate aquifer that underlies the Tertiary volcanics at the site, has a TDS content of about 1,000 ppm. The laboratory analysis techniques used to determine water chemistry and TDS are well established and highly accurate.

The principal source of error/uncertainty in determining the water chemistry in the unsaturated Topopah Spring is associated with (1) sampling methods and (2) spatial variability (heterogeneity). The extraction of pore water from unsaturated tuffs can be accomplished by squeezing core samples taken from the rock in a hydraulic press and by centrifuge methods. For nonwelded tuffs, squeezing is regarded to be the preferred method; although there remains some concern that the squeezing process may alter the ambient pore-water chemistry and could lead to erroneously high measured TDS values. Prototype studies by Yang (1990), however, indicate that water-chemistry changes induced by squeezing are small. Concern was expressed that these pore-water extraction methods may be difficult to apply to the densely welded tuffs, such as the Topopah Spring host rock, which are characterized generally by low porosities, permeabilities, and net pore-water contents. Consequently, present-day pore-water chemistry in the immediate repository environment may need to be inferred or interpolated based on samples obtained from overlying and underlying nonwelded tuff units. Some uncertainty may result because of possible large spatial water-chemistry variability and the failure of nonwelded-tuff water chemistry to be representative of host-rock conditions. Of major importance will be to determine the water chemistry (and TDS) of any perched water encountered within the deep (depth greater than 30 m) unsaturated zone. These data would be good indicators of the hydrochemical processes operating within the unsaturated zone.

Test-accuracy assessments tend to be skewed towards higher TDS values to account for possible effects due to the rock-squeezing pore-water extraction method. Testing is unlikely to produce a false negative, that is, of reporting a TDS < 10,000 ppm when the true water chemistry has TDS > 10,000 ppm. However, if the host-rock pore-water chemistry is inferred or interpolated from other (e.g., nonwelded) tuff units for which the TDS > 10,000 ppm, there is the possibility of generating a false positive in the host rock, that is, of concluding that the TDS > 10,000 ppm in the host rock when, in fact, the actual TDS <10,000 ppm.

Based on current data and expectations, the assessment panel concluded that there probably is little value to be gained by performing the water-chemistry tests early for resolving the issue of possible ground-water reactivity in the unsaturated zone. Water-chemistry and isotopic analyses, however, are extremely important for providing data on site hydrochemical processes in the unsaturated zone and for inferring ground-water flowpaths and travel times from field determinations of tritium, carbon-14, and chlorine-36 abundances.

PC #4: Oxidizing Ground Water in Host Rock

Measure: Eh of ground water in the host rock under present conditions

Assessment threshold (AT): 400 mV

PRIOR PROBABILITY DISTRIBUTION BALLOT
#4 Oxidizing Ground Water in Host Rock

Workshop: Testing #2
Date: 12/11/90
Respondents: 5

#	1%	10%	50%	90%	99%
1	50	100	400	600	800
2	50	100	400	600	750
3					
4					
5					
6	50	100	500	600	750
7					
8	100	400	500	700	770
9					
10					
11					
12					
13					
14	100	150	350	700	900
15					
Avg	70	170	430	640	794
GMn	6.6 e+1	1.4 e+2	4.3 e+2	6.4 e+2	7.9 e+2

Tests

SCP Activity #	Title
8.3.1.3.1- G	GW chemistry modeling
8.3.1.3.2.1.3	Fracture mineralogy study
8.3.1.3.2.1.1	Host rock mineralogy
8.3.1.3.2.2	Alteration history
8.3.1.2.2.7.2	Aqueous phase chemical investigation (same as reactive GW chemistry)
8.3.1.4.2.2.1	Subsurface stratigraphic study
8.3.1.4.2.2.3	Borehole evaluation of faults and fractures (vertical borehole)
8.3.1.4.2.1.5	Magnetic properties

TEST ACCURACY BALLOT
#4: Oxidizing Ground Water in Host Rock

Workshop: Test. #2
Date: 12/11/90
Responses: 3

F Factors for given true values / Low and high test results

#	200	400	600		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1					100	300	300	500	500	700
2										
3										
4										
5										
6										
7										
8					100	300	300	500	500	700
9										
10										
11										
12										
13										
14	1.5	1.5	1.5		133.333	300	266.667	600	400	900
15										
Avg	1.5	1.5	1.5		111.111	300	288.889	533.333	466.667	766.6667
GMn	1.5 e+0	1.5 e+0	1.5 e+0		1.1 e+2	3.0 e+2	2.9 e+2	5.3 e+2	4.6 e+2	7.6 e+2
				F	1.8	1.5	1.4	1.3	1.3	1.3
				Average F	1.7		1.4		1.3	

Discussion

Because hematite is stable up to an Eh value of 1.2, the presence of hematite would buffer the system and maintain oxidizing conditions. The expected range of Eh-pH conditions at the site can be inferred from Figures 9-2, 9-5, and 10-1 presented in Knauskopf (1979).

Measure: Future flux through the repository level due to climate change

Assessment threshold (AT): 10 mm/y

PRIOR PROBABILITY DISTRIBUTION BALLOT
#5 Climate Effect on Radionuclide Transport—
Current Flux

Workshop: Testing #1
Date: 11/28/90
Respondents: 6.6

#	1%	10%	50%	90%	99%
1	0	0.01	0.1	5	15
2		0.01	0.1	10	
3	0	0.01	0.1	1	10
4					
5					
6	-0.1	0	0.1	1	10
7	0	0.5	2	6	20
8					
9	0	0.1	1	10	12.5
10	0	0.1	0.5	10	13
11	0	0	0.2	1	10
12					
13	0	0.0001	0.01	4	15
14					
15					
Avg	-0.0125	0.08112222	0.4566667	5.3333333	13.1875
GMn	#NUM!	1.7 e-2	1.8 e-1	3.7 e+0	1.3 e+1

PRIOR PROBABILITY DISTRIBUTION BALLOT
#5: Climate Effect on Radionuclide Transport— Future Flux

Workshop: Testing #1
Date: 11/28/90
Respondents: 6.8

#	1%	10%	50%	90%	99%
1	0	0.1	1	10	20
2	0	0.01	0.2	10	20
3	0.01	0.1	1	10	20
4					
5					
6	-0.1	0.5	2	5	20
7					
8					
9	0	0.1	2	10	15
10	0	0.01	1	10	20
11	0	0.1	2	10	15
12					
13	0.01	1	10	30	90
14					
15					
Avg	-0.01	0.24	2.4	11.875	27.5
GMn	1.0 e-2	9.2 e-2	1.4 e+0	1.1 e+1	2.2 e+1

Tests

Package 1

SCP Activity #	Title
8.3.1.2.2.1	Infiltration studies
8.3.1.2.2.3	Characterization of matrix properties
8.3.1.4.2.2.2	Surface fracture network studies
8.3.1.4.2.2.3	Borehole evaluations of faults and fractures

Package 2 (these are primarily "confirmatory" and were not included in the assessment)

SCP Activity #	Title
8.3.1.2.1.1	Regional meteorology (current climate)
8.3.1.5.1 -	Past climate
8.3.1.5.1.6	Future climate modeling
8.3.1.2.2.2	Water movement test
8.3.1.2.2.7	Unsaturated zone hydrochemistry

TEST ACCURACY BALLOT
#5: Climate Effect on Radionuclide Transport

Workshop: Test. #1
Date: 11/28/90
Responses: 8

F Factors for given true values — Low and high test results

#	0.1	1	10		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1					0.0001	0.5	0.5	5	8	15
2										
3	10	5	2		0.01	1	0.2	5	5	20
4										
5										
6	100	10	3		0.001	10	0.1	10	3.33333	30
7	10	5	2		0.01	1	0.2	5	5	20
8										
9					0.1	5	0.1	5	2	12.5
10					0.01	1	0.1	5	7	12
11					0.0001	1	0.1	5	5	15
12										
13	30	15	5		0.00333	3	0.06667	15	2	50
14										
15										
Avg	37.5	8.75	3		0.01682	2.8125	0.17083	6.875	4.66667	21.8125
GMn	2.3 e+1	7.8 e+0	2.8 e+0		2.8 e-3	1.7 e+0	1.4 e-1	6.3 e+0	4.2 e+0	1.9 e+1
				F	36.3	17.2	7.2	6.3	2.4	1.9
				Average F	26.7		6.7		2.2	

Discussion

Because of expected spatial variability over the repository area, estimates of present-day ground-water flux within the unsaturated zone at the repository level are highly uncertain. An important study would be to determine the sensitivity of net infiltration and deep unsaturated-zone percolation to the effects of climate change. Future climatic change may not be important, however, because of long response times (hundreds to thousands of years) that may be characteristic of the hydrologic system. That is, the present flux distribution may be the result of climatic events occurring over the past thousand years or more. The data from the surface-based infiltration studies and from as few as 2 or 3 new deep unsaturated-zone boreholes would provide 90 percent of the information needed to address this PC . Detailed fracture data within the unsaturated zone probably are not needed.

Current flux was defined by the assessment panel to be the mean, present-day flux of ground water at the repository horizon, averaged over the repository area. The values of flux depend on the saturated hydraulic conductivity of the rock matrix; flux values greatly exceeding the conductivity values would produce saturated rock-matrix conditions and could not be sustained and maintain an unsaturated-zone environment. Early estimates of current flux (e.g., as given in the Environmental Assessment (DOE, 1986)) ranged from 1 to 8 mm/yr. A current flux equal to 8 mm/yr would correspond, for example, to an average annual precipitation of 200 mm/yr of which 4% would enter the unsaturated zone as net infiltration. There is evidence from the infiltration studies at the site that a net loss of water from the unsaturated zone has occurred during the past 5 years. One cannot completely rule out the possibility that the current net flux may be directed *upwards* as a result, for example, of capillary-wicking effects.

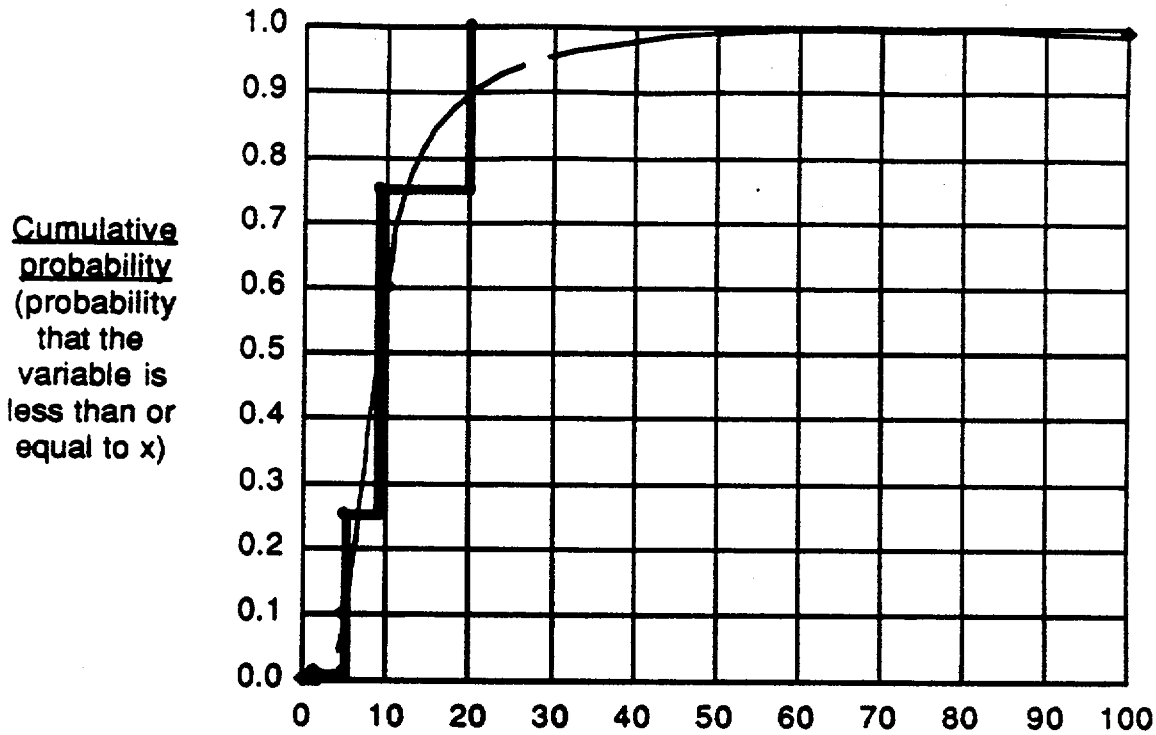
Future maximum sustained flux was defined by the assessment panel to be the maximum ground-water flux at the repository horizon, averaged over the repository area, that could be sustained for more than 10 years as a result of climate change during the next 10,000 years. Although climatic cycles drier than present conditions could occur in the future, the maximum flux here refers to that produced by a significantly wetter cycle. This concern refers specifically to the site and does not consider the regional saturated-zone ground-water flow system and recharge to this system. Although the unsaturated-zone system response time may be long, fast-flow pathways (e.g., fractures and faults) may be activated during wet climatic cycles and these could move ground-water rapidly to the repository horizon with subsequent lateral redistributions over part or all of the repository area. The most likely scenario for increased climatic-induced flux would be increased winter precipitation at the site.

Test-accuracy assessment were based on the availability during the next 1 to 3 years of data from the ongoing infiltration studies and from 2 or 3 new unsaturated-zone boreholes.

Measure: Expected travel time for ground water (on fastest path of likely and significant radionuclide transport)

Assessment threshold (AT): 1,000 years

Prior Probabilty Distribution
#6: Expected Groundwater Travel Time



Variable: Expected travel time for groundwater
Units: 1,000 Years
Date Assessed: 10/31/90

Tests

Direct measurements of ground-water age

SCP Activity #	Title
8.3.1.2.2.2.1	Chlorine 36
8.3.1.2.2.7.2	Aqueous Phase Chemical Investigation
8.3.1.2.2.4.8	Hydrochemistry in ESF
8.3.1.2.3.2.2	Hydrochemical characterization of water in upper part of saturated zone

Fracture pathways in UZ (ESF)

SCP Activity #	Title
8.3.1.2.2.4.10	Hydrologic properties of major faults encountered in main test level of the exploratory shaft facility
8.3.1.2.2.3.1	Matrix hydrologic properties testing
8.3.1.2.2.3.2	Site vertical bore hole study
8.3.1.4.3.1.1	Systematic drilling program
8.3.1.2.3.4.6	Calico Hills test in the exploratory shaft facility
8.3.1.4.2.2.2	Surface fracture network studies
8.3.1.4.2.2.3	Borehole evaluations of faults and fractures
8.3.1.4.2.2.4	Geological mapping of the exploratory shaft and drifts
8.3.1.2.3.1.1 thru 6	Testing of the C-hole sites with conservative tracers
8.3.1.2.2.4.1	Intact fracture test in the exploratory shaft
8.3.1.2.2.4.2	Infiltration (percolation) test in the exploratory shaft
8.3.5.12.2.2.2	Fracture flow phenomena

Hydrologic properties and conditions (including flux) of UZ

SCP Activity #	Title
8.3.1.2.2.3.1	Matrix hydrologic properties (above)
8.3.1.2.2.1.2	Evaluation of natural infiltration
8.3.1.2.2.1.1	Characterization of hydrologic properties of surficial materials
8.3.1.2.2.3.2	Site vertical bore holes
8.3.1.2.2.1.3	Evaluation of artificial infiltration

Hydrologic properties and conditions (including flux) of SZ

SCP Activity #	Title
8.3.1.2.3.1.1	Solitario Canyon fault study
8.3.1.2.3.1.2	Site potentiometric-level evaluation
8.3.1.2.3.1.3	Analysis of hydraulic tests
8.3.1.2.3.1.4	Multiple well tests
8.3.1.2.3.1.5	C-well tracers
8.3.1.2.3.1.6	Site tracers
8.3.1.2.1.3.2	Regional potentiometric level distribution

Levels of testing:

Level 1. No drilling and using only existing core samples.
Level 2. New drilling and coring plus Level 1
Level 3. Exploratory Shaft Facility (ESF) plus Level 2

Workshop: Test. #2

TEST ACCURACY BALLOT
#6: Expected Ground-Water Travel Time <1000 yrs.
Level 1 (no drilling)

Date: 12/12/90
Responses: 11

F Factors for given true values — Low and high test results

#	500	5000	20000		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1										
2					50	10000	100	10000	500	50000
3					50	10000	50	100000	1000	100000
4										
5	2	10	5		250	1000	500	50000	4000	100000
6					50	50000	50	100000	1000	200000
7					10	5000	1000	30000	5000	100000
8	3	8	2		166.667	1500	625	40000	10000	40000
9					100	1000	100	20000	5000	50000
10	5	2	3		100	2500	2500	10000	6666.67	60000
11										
12	5	10	10		100	2500	500	50000	2000	200000
13					50	50000	500	100000	1000	200000
14										
15					100	1000	1000	10000	5000	50000
Avg	3.75	7.5	5		93.3333	12227.3	629.545	47272.7	3742.42	104545.5
GMn	3.5 e+0	6.3 e+0	4.2 e+0		7.2 e+1	4.4 e+3	3.3 e+2	3.4 e+4	2.6 e+3	8.8 e+4
				F	7.0	8.8	15.2	6.7	7.8	4.4
				Average F	7.9		11.0		6.1	

TEST ACCURACY BALLOT | **Workshop:** Test. #2
#6A: Expected Ground-Water Travel Time <1000 years | **Date:** 12/12/90
Level 2 (new drilling) | **Responses:** 11

F Factors for given true values | **Low and high test results**

#	500	5000	20000		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1										
2					100	5000	500	10000	1000	50000
3	3	3	3		166.667	1500	1666.67	15000	6666.67	60000
4										
5	2	5	3		250	1000	1000	25000	6666.67	60000
6					50	10000	100	50000	2000	200000
7					100	3000	2000	20000	10000	50000
8	2	5	2		250	1000	1000	25000	10000	40000
9					400	600	3000	7000	15000	25000
10	2	2	3		250	1000	2500	10000	6666.67	60000
11										
12	2	5	5		250	1000	1000	25000	4000	100000
13					100	2500	1000	20000	2000	100000
14										
15					200	900	1500	9000	7500	40000
Avg	2.2	4	3.2		192.424	2500	1387.88	19636.4	6500	71363.64
GMn	2.2 e+0	3.8 e+0	3.1 e+0		1.7 e+2	1.7 e+3	1.1 e+3	1.7 e+4	5.0 e+3	6.1 e+4
				F	3.0	3.4	4.7	3.4	4.0	3.0
			Average	**F**	3.2		4.0		3.5	

TEST ACCURACY BALLOT — Workshop: Test. #2

#6B: Expected Ground-Water Travel Time <1000 years — Date: 12/12/90

Level 3 (ESF +#2) — Responses: 11

F Factors for given true values — Low and high test results

#	500	5000	20000		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1										
2					200	5000	1000	10000	5000	50000
3	2	2	2		250	1000	2500	10000	10000	40000
4										
5	1	2	1		500	500	2500	10000	20000	20000
6	10	5	5		50	5000	1000	25000	4000	100000
7					200	2000	2000	10000	10000	40000
8	1.5	2	2		333.333	750	2500	10000	10000	40000
9					400	600	4000	7000	15000	25000
10					250	1000	1000	10000	10000	50000
11										
12	2	2	2		250	1000	2500	10000	10000	40000
13					100	2000	1000	20000	10000	50000
14										
15					250	800	2000	8000	9000	35000
Avg	3.3	2.6	2.4		253.03	1786.36	2000	11818.2	10272.7	44545.45
GMn	2.3 e+0	2.4 e+0	2.1 e+0		2.2 e+2	1.3 e+3	1.8 e+3	1.1 e+4	9.5 e+3	4.1 e+4
				F	2.3	2.6	2.8	2.2	2.1	2.1
				Average F	2.4		2.5		2.1	

Discussion

Because the hydraulic conductivity of the unsaturated tuff units at the site are low, the occurrence of fast paths for ground-water flow imply the channelation of flow into zones of high matrix saturation or into fracture or fault zones. Under equilibrium conditions, flow in fractures and faults will lead to fast pathways only if there is a sharp transition from slow matrix flow and rapid fracture flow, otherwise the distinction between matrix and fractures is inconsequential. Rapid flow of ground water may occur in fractures and faults within the unsaturated zone, but these occurrences would tend to be localized, transient phenomena and would be unlikely to be capable of transporting "significant" quantities of radionuclides, where "significant" is interpreted to mean an appreciable fraction of the EPA standard for releases to the accessible environment. In order to lead to significant releases, a fast pathway would need to be (1) continuous from the repository horizon through the underlying unsaturated and saturated zones to the accessible environment and (2) capable of being sustained under present (i.e., pre-waste-emplacement) site conditions. If the ground-water travel time, as defined, is, in fact, 500 years, such fast pathways must be present and evidence for them (e.g., the presence of tritium, carbon-14, and chlorine-36 isotopes within the unsaturated and saturated zones) probably would be indicated by presently available data. Ground-water travel times greater than about 20,000 years are difficult to assess and all times greater than 20,000 years were considered to be equivalently long by the participants.

The test-accuracy assessments considered the availability of results from three levels of testing defined as follows:

Level 1: Presently available site data only; no drilling of additional boreholes. Presently available data were presumed to include both qualified and unqualified site data (e.g., core samples).

Level 2: Level 1 data plus the drilling of new boreholes. Drilling only a few boreholes may fail to detect localized fast pathways; consequently the workshop participants assumed the completion of the entire surface-based drilling program for this assessment. If fast pathways are present but are not detected by the surface-based program, these pathways probably would not be pathways for "significant" radionuclide transport.

Level 3: Data from Levels 1 and 2 plus the Exploratory Shaft Facility (ESF). Data from the ESF will be largely confirmatory with respect to this concern. Drifting, however, will provide better data on lateral spatial variability at the drift horizons.

Measure: Total area of perched water at or above the repository level

Assessment threshold (AT): Ten percent

PRIOR PROBABILITY DISTRIBUTION BALLOT
#8 - Perched Water
(Numbers entered are percent: ".1%" = .001

Workshop: Testing #2
Date: 12/13/90
Respondents: 11

#	1%	10%	50%	90%	99%
1	0.01	0.1	1	10	20
2	0.0001	1	5	30	70
3	0.000001	0.00001	0.1	1	10
4					
5	0.01	1	5	10	15
6					
7	0.000001	1	3	5	20
8	1	2	5	10	15
9	0.000001	0.1	0.2	1.5	3
10	0.000001	0.01	1	5	10
11					
12	0.001	0.05	1	3	5
13	0.000001	0.001	5	10	60
14					
15	0.001	0.01	0.5	1	5
Avg	0.0929186	0.47918273	2.4363636	7.8636364	21.18181818
GMn	1.0 e-4	4.3 e-2	1.3 e+0	4.8 e+0	1.4 e+1

Tests

SCP Activity #	Title
8.3.1.2.2.4.10	Hydrologic properties of major faults encountered in main test level of the exploratory shaft facility
8.3.1.2.2.3.1	Matrix hydrologic properties testing
8.3.1.2.2.4.7	Perched water in ESF
8.3.1.2.2.3.2	Site vertical bore hole study
8.3.1.4.3.1.1	Systematic drilling program
8.3.1.2.3.4.6	Calico Hills test in the exploratory shaft facility
8.3.1.4.2.2.3	Bore hole evaluations of faults and fractures
8.3.1.4.2.2.4	Geological mapping of the exploratory shaft and drifts
8.3.1.2.2.1.2	Evaluation of natural infiltration

TEST ACCURACY BALLOT
#8: Perched Water—Level 1 (New Drilling)

Workshop: Test. #2
Date: 12/13/90
Responses: 11

F Factors for given true values — Low and high test results

#	0.05	1	5		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1					1E-06	0.5	1E-06	2	1	10
2					1E-06	3	0.01	10	0.1	20
3	20	5	4		0.0025	1	0.2	5	1.25	20
4										
5					0.005	1	0.2	5	1	20
6										
7					1E-06	1	1E-06	2	1E-06	10
8	100	10	2		0.0005	5	0.1	10	2.5	10
9					1E-06	1	0.5	5	1	10
10					0.001	0.5	0.5	2	2	10
11										
12	10	5	4		0.005	0.5	0.2	5	1.25	20
13					1E-06	2	1E-06	2	0.0001	5
14										
15					0.0001	1	0.1	5	1	20
Avg	43.3333	6.66667	3.33333		0.00128	1.5	0.16455	4.81818	1.0091	14.09091
GMn	2.7 e+1	6.3 e+0	3.2 e+0		4.8 e-5	1.1 e+0	5.7 e-3	4.1 e+0	1.2 e-1	1.3 e+1
				F	1041.4	22.6	175.9	4.1	41.5	2.6
				Average F	532.0		90.0		22.0	

TEST ACCURACY BALLOT
#8A: Perched Water—Level 2 (Level 1 + ESF)

Workshop: Test. #2
Date: 12/13/90
Responses: 11

F Factors for given true values — Low and high test results

#	0.05	1	5		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1					1E-06	0.5	1E-06	2	1	8
2					1E-06	2	0.01	8	0.1	15
3	20	4	2		0.0025	1	0.25	4	2.5	10
4										
5					0.005	1	0.2	3	1	10
6										
7					1E-06	0.5	1E-06	1.5	2	7
8	50	5	3		0.001	2.5	0.2	5	1.66667	15
9					1E-06	0.5	0.5	3	2	9
10					0.001	1	1	2	2	10
11										
12	8	3	3		0.00625	0.4	0.33333	3	1.66667	15
13					0.00001	1	0.0001	2	1	7
14										
15					0.01	0.1	0.5	2	2.5	10
Avg	26	4	2.66667		0.00234	0.95455	0.27213	3.22727	1.58485	10.54545
GMn	2.0 e+1	3.9 e+0	2.6 e+0		9.8 e-5	7.2 e-1	1.2 e-2	2.9 e+0	1.3 e+0	1.0 e+1
				F	511.3	14.3	82.5	2.9	3.9	2.0
				Average F	262.8		42.7		3.0	

Discussion

Perched water is defined to be water occurring within the unsaturated zone that is under positive hydraulic pressure and, therefore, could flow into a borehole or other openings. Perched water within the unsaturated zone is inherently unstable and would occur as a transient or episodic phenomenon. The presence of fractures as well as east-dipping strata at the site will tend to promote drainage of perched-water zones. Perched water could develop in localized zones, for example, as a result of increased precipitation and net infiltration coupled with the presence of permeability contrasts across stratigraphic contacts or at the boundaries of fault zones. No naturally occurring perched-water zones have been encountered thus far in drilling at the site; however, most of the drilling to date involved water mixtures as drilling fluid and the occurrence of perched water may not have been detected. However, a considerable volume of water-based drilling fluid has been introduced into the site from previous drilling and could be present in perched zones. For example, an apparent perched-water zone was encountered during the dry-drilling of borehole USW UZ-1 at the site but the zone was apparently caused by the migration of drilling fluid used during the drilling of nearby borehole USW G-1.

Flooding of the repository by perched water is unlikely because the highly fractured Topopah Spring host rock probably could not sustain a perched-water zone of significant areal extent. For the purposes of this assessment, to be a perched-water zone, positive pressure must be sustained for a period of at least several years or must occur intermittently at the same location. Perched-water zones at the site are most likely to occur in the units above the repository, for example, the bedded and nonwelded units of the Paintbrush Tuff located between the Topopah Spring and Tiva Canyon welded units. Limited available core data indicate that saturations presently may approach 0.9 within these units, which could lead to the formation of perched water. Water has been observed to enter drifts within the G-Tunnel Facility, which is excavated in unsaturated fractured tuff beneath Rainier Mesa at the Nevada Test Site. Most of the water is flowing through fractures and, although the source of the water is not known, its presence suggests the possible occurrence of overlying perched-water zones.

The assessment of test accuracy considered two levels of testing as follows:

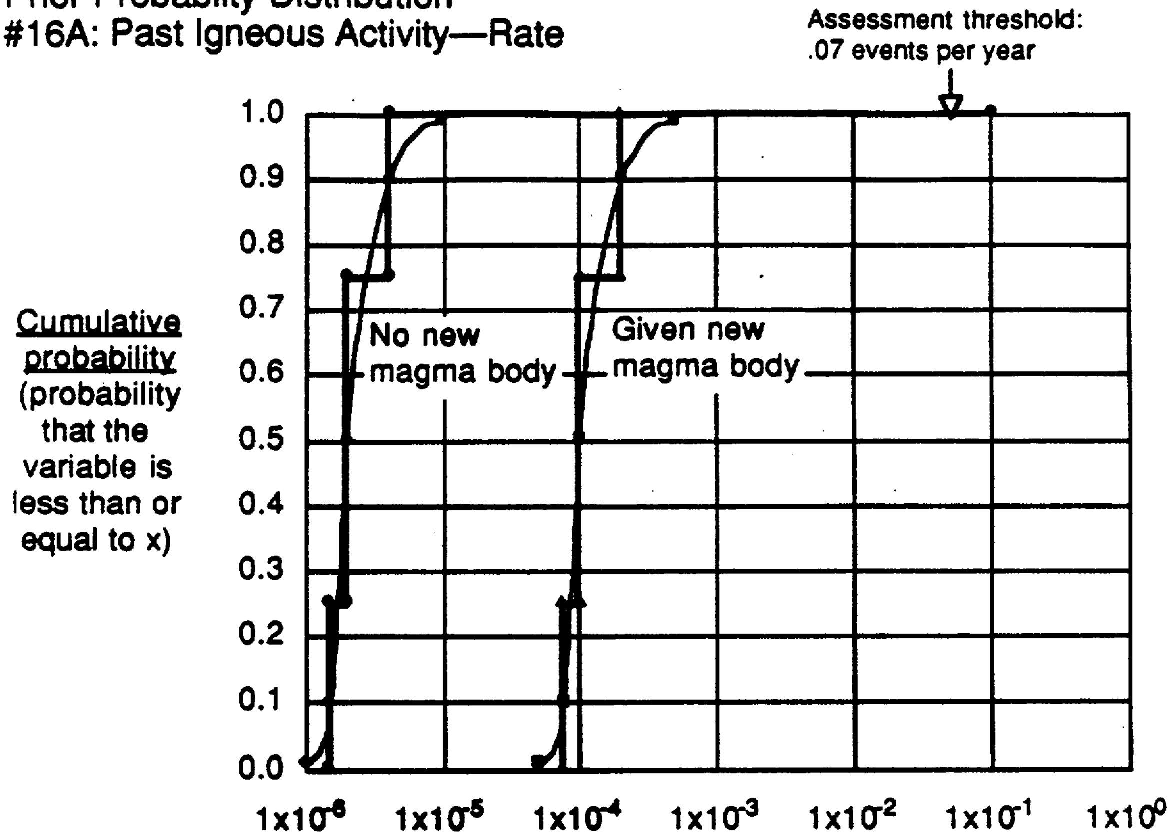
Level 1: Completion of the planned surface-based drilling program. Because perched-water zones are likely to be localized, a sufficient area of the site will need to be sampled to detect the likely occurrence of perched water. The degree of in-situ rock-matrix saturation (specifically, saturations exceeding 0.9) will be the most important test parameter other than the actual observation of water entering a borehole.

Level 2: Data from Level 1 testing plus the Exploratory Shaft Facility (ESF). Drifts within the Topopah Spring host rock are unlikely to encounter perched water. Ramp access to the ESF will have a greater likelihood of encountering perched water, if present, then shaft access. More important would be to drift in the upper nonwelded units, for example, across the Ghost Dance fault, where there is the greatest likelihood for the presence of perched water.

PC #16: Past Igneous Activity—Site Effects

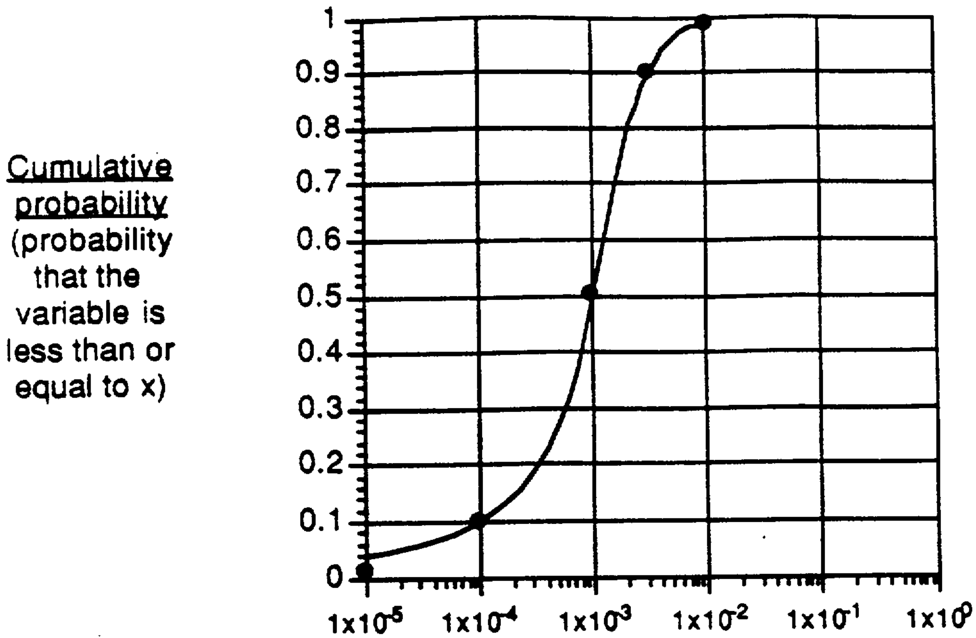
Measure:	Annual rate of volcanic events in the Yucca Mt. region
Assessment threshold (AT):	Testing assessment: 0.067 events in the region per year

Prior Probabilty Distribution
#16A: Past Igneous Activity—Rate



Variable: Annual rate of volcanic events in Yucca Mt. region
Units: Events in region per year **Date Assessed:** 1/18/91

Prior Probabilty Distribution
#16B: Past Igneous Activity—Disruption Parameter



Variable: Disruption parameter—the likelihood that an event in the region intersects the repository

Units: Unitless

Date Assessed: 1/18/91

Tests

Package 1—Rate of formation of volcanic events

SCP Activity #	Title
8.3.1.8.5.1.1	Volcanism drill holes - This activity uses aeromagnetic and ground-based magnetic and gravity geophysical methods
8.3.1.17.4.7.2	Detailed gravity survey
8.3.1.17.4.7.3	Detailed aeromagnetic survey
8.3.1.17.4.7.4	Detailed ground magnetic survey
8.3.1.8.5.1.2	Geochronology studies
8.3.1.8.5.1.3	Field geologic studies - Using aeromagnetic data to constrain buried flows
8.3.1.8.5.1.5	Evolutionary cycles of basaltic fields
8.3.1.8.1.1.2	Structural control - We are using tectonic studies to develop alternative models of the structural controls of volcanic sites
8.3.1.17.4.12.2	Evaluate tectonic models

TEST ACCURACY BALLOT

#16: Past Igneous Activity at the Site—Volcanism

Rate of volcanic events at the site

Workshop: Test. #3

Date: 1/18/91

Responses: 1.6

F Factors for given true values — Low and high test results

#	1	2E-09	100		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1										
2										
3										
4										
5		3					6.7E-10	6E-09		
6							5E-10	5E-08		
7										
8										
9										
10										
11										
12										
13										
14							1E-10	5E-08		
16							2E-11	5E-08		
Avg	#DIV/0!	3	#DIV/0!		#DIV/0!	#DIV/0!	3.2E-10	3.9E-08	#DIV/0!	#DIV/0!
GMn	#NUM!	3.0 e+0	#NUM!		#NUM!	#NUM!	1.6 e-10	2.9 e-8	#NUM!	#NUM!
				F	#NUM!	#NUM!	12.4	14.7	#NUM!	#NUM!
				Average F	#NUM!		13.6		#NUM!	

Package 2—New magma body

SCP Activity #	Title
8.3.1.8.1.1.3	Presence of magma body
8.3.1.17.4.12.2	Evaluate tectonic models
8.3.1.17.4.3.1	Deep geophysical surveys, e.g., seismic reflection and teleseismic work
8.3.1.8.5.2.3	Regional heat flow and at Yucca Mountain
8.3.1.17.4.1.2	Current seismicity
8.3.1.17.4.10	Geodetic leveling (this is at the study level)

TEST ACCURACY BALLOT

#16A: Past Igneous Activity at the Site—Volcanism
New Magma Body

Workshop: Testing #3
Date: 1/18/91
Respondents: 4

#	P 1	P 2	P 3
1			
2			
3			
4			
5	0.00005	0.6	0.40099
6	0.0005	0.7	0.2042771
7			
8			
9			
10			
11			
12			
13			
14	0.000005	0.5	0.300019
16	0.00003	0.7	0.300594
Avg	0.0001463	0.625	0.3014701
GMn	4.4 e-5	6.2 e-1	2.9 e-1

P1: Probability that new magma body exists

P2: Probability of finding the new magma body, given that it exists

P3: Probability of finding the new magma body, given that it does not exist

Pa: Probability that any magma body exists

Pb: Probability magma body is new (process has changed from the process that influenced the geologic record

Pc: Probability of finding a "new" magma body, given that an "old" magma body exists

Pd: Probability of finding a new magma body, given that no magma body exists

#	Pa	Pb	P1	P2	Pc	Pd	P3
5	0.005	0.01	0.00005	0.6	0.6	0.4	0.4009
6	0.01	0.05	0.0005	0.7	0.65	0.2	0.20427714
14	0.0001	0.05	0.000005	0.5	0.5	0.3	0.300019
16	0.003	0.01	0.00003	0.7	0.5	0.3	0.30059402
Avg	0.004525	0.03			0.5625	0.3	
GMn	2.0 e-3	2.2 e-2			5.6 e-1	2.9 e-1	

$P1 = Pa \times Pb$

$$P3 = \frac{Pa(1-Pb)Pc + (1-Pa)Pd}{(1-P1)}$$

Discussion

Test accuracy for this PC considers the evaluation of two measures: (1) the rate of formation of new volcanic centers within the Yucca Mountain region and (2) the disruption parameter, which is the conditional probability that an igneous event will intersect the repository, given that an event occurs within the region. The prior probability on the rate of igneous activity within the region was assessed based on the geologic record, which indicates that 11 basaltic events occurred during the past 3.7×10^6 yrs within the region (7 of these during the Quaternary) to yield a mean rate of occurrence in the range from 1.9×10^{-6} to 3.9×10^{-6} events/yr. Upper limits on the rate of occurrence are provided, for example, by Lunar Crater, Nevada, where the geologic record indicates a mean rate of occurrence of 5.6×10^{-5} events/yr during the Quaternary (past 1.8×10^6 yrs) and by Kilauea, Hawaii, with a current observed mean rate of 2×10^{-2} events/yr.

Geophysical (teleseismic) data indicate the occurrence south of the side of a low-velocity zone, which could be interpreted as evidence for the presence of a deeply buried magma chamber. Because silicic volcanism is not known to have occurred during the past 11 million years, the magma chamber, if present, probably is basaltic. With respect to its origin, the magma body, if present, could either represent a continuation of past igneous activity that would not affect the future rate of igneous activity or be a newly formed (during the Quaternary) body, in which case its consequences for future igneous activity is unknown. Based on the observation that Lunar Crater, Nevada, has been 100 times more active than the Yucca Mountain region and that there is a lag time for a volcanic center to reach peak activity (Crowe and Perry, 1989), the assessment panel assumed that, given a newly formed magma body, the rate of igneous activity would increase by a factor of 50 relative to the present rate. The panel also assessed the probability of occurrence of a new magma body and the test accuracy defined as the probability that the geophysical test methods will correctly or falsely indicate that a magma body is present.

If the location of volcanic centers is randomly distributed within the region, then the disruption parameter can be approximated by the ratio of the site area to that of the region, defined to be a circle or ellipse enclosing the site and known basaltic centers, and yields a value of 10^{-4}. A regression-fit structural-control model, on the other hand, yields values in the range between 10^{-3} and 10^{-6}. These values provided the basis for developing a cumulative probability distribution for the disruption parameter. Further details of the discussion centering on this PC can be found in the Meeting Summary (SAIC,1991, January 22).

PC #26: Reactive Ground-Water Chemistry—UO_2 Solubility

Measure: Solubility of UO_2 in ground water within the Topopah Spring Unit

Assessment threshold (AT): 0.002 Molar

PRIOR PROBABILITY DISTRIBUTION BALLOT
#26 Reactive Ground-Water Chemistry—UO_2 Solubility

Workshop: Testing #2
Date: 12/11/90
Respondents: 3

#	1%	10%	50%	90%	99%
1					
2					
3					
4					
5					
6	1E-08	0.000001	0.00001	0.0001	0.01
7					
8	1E-08	0.0000001	0.000001	0.00001	0.0001
9					
10					
11					
12					
13					
14	1E-08	0.0000001	0.00001	0.0001	0.001
15					
Avg	1E-08	0.0000004	0.000007	0.00007	0.0037
GMn	1.0 e-8	2.2 e-7	4.6 e-6	4.6 e-5	1.0 e-3

Tests

SCP Activity #	Title
8.3.5.10	Solubility of waste form
8.3.1.3.5.1	Solubility of radionuclides
8.3.5.10.2.1.1	Dissolution and leaching of spent fuel
8.3.5.10.2.1.2	Oxidation of spent fuel

(Note: these tests depend on results of water chemistry tests and results from waste package degradation tests and modeling.)

TEST ACCURACY BALLOT
#26: Reactive Ground-Water Chemistry—UO_2 Solubility

Workshop:	Test. #3
Date:	1/18/91
Responses:	3

F Factors for given true values — Low and high test results

#	1E-07	1E-05	0.001		Low-.1	Low-.9	Med.-.1	Med.-.9	High-.1	High-.9
1										
2										
3										
4										
5										
6										
7										
8					1E-07	0.00001	5E-06	0.001	0.0001	0.005
9										
10										
11										
12										
13										
14					1E-08	0.00001	5E-06	0.0001	0.0005	0.05
17					5E-08	0.0001	5E-06	0.001	0.00005	0.01
Avg	#DIV/0!	#DIV/0!	#DIV/0!		5.3E-08	0.00004	5E-06	0.0007	0.00022	0.021667
GMn	#NUM!	#NUM!	#NUM!		3.7 e-8	2.2 e-5	5.0 e-6	4.6 e-4	1.4 e-4	1.4 e-2
				F	2.7	215.4	2.0	46.4	7.4	13.6
				Average F	109.1		24.2		10.5	

Discussion

The assessment variable was redefined to be "solubility of UO_2 (including amorphous and crystalline uranium oxide) in the waste under repository conditions." Small solubility values are difficult to measure and will be subject to large uncertainty. Conservatism will tend to bias conclusions from experimental data towards high-solubility values. Realized UO_2 solubilities will depend on conditions (e.g., ground-water chemistry, ph, and Eh) within the repository environment and on the waste-package design and construction (Puigdomenech and Bruno, 1988; Puigdomenech , Casas, and Bruno, 1990; Wilson and Bruton, 1989; Wilson, 1990).

PC #H4: Natural Resources

Measure: Presence of potentially economically recoverable natural resources

Assessment threshold (AT): Recoverable economically now or in next 10-30 years

Tests

SCP Activity #	Title
8.3.1.9.2.1.1	Geochemical investigation
8.3.1.9.2.1.2	Geological / geophysical investigation
8.3.1.9.2.1.3	Geothermal investigation
8.3.1.9.2.1.4	Hydrocarbon investigation
8.3.1.9.2.1.5	Assessment activity (e.g., evaluation of process models)

Site data from other studies:

SCP Activity #	Title
8.3.1.4.2.1.1	3D modeling and stratigraphic studies (data comes from 8.3.1.4.2.1.1)
8.3.1.17.4.7	Subsurface geometry of Quaternary faults.

TEST ACCURACY BALLOT
#H4: Natural Resources

Workshop: Testing #2
Date: 12/11/90
Respondents: 8

#	P 1	P 2	P 3
1	0.01	0.6	0.1
2	0.02	0.7	0.005
3	0.001	0.3	0.001
4	0.001	0.66	0.005
5	0.03	0.4	0.005
6	0.01	0.5	0.01
7			
8			
9			
10			
11			
12			
13			
14	0.00001	0.75	0.05
15	0.001	0.75	0.01
Avg	0.0091263	0.5825	0.02325
GMn	2.2 e-3	5.6 e-1	9.4 e-3

P1: Probability that condition exists

P2: Probability of finding the condition, given that it exists

P3: Probability of finding the condition, given that it does not exist

Discussion

The potential for the presence of mineral and hydrocarbon resources at the site is described in Chapter 1, Section 1.7, of the Site Characterization Plan. The workshop participants considered the following natural resources with respect to their potential as economically recoverable resources at or near the site within the foreseeable future, specifically, the next 10-30 years: Geothermal energy, hydrocarbons, precious metals, and industrial commodities. The site is located in an area, designated the Eureka Low, characterized by low geothermal heat flux (less than 1.5 heat flux units (HFU)) relative to the surrounding Southern Great Basin (approximately 2 HFU). The Geothermal temperature gradient at the site is about 30° c/km. No coal seams or oil seeps are known to occur in the area, although Paleozoic sedimentary rocks are present at depth beneath the Tertiary volcanic rocks at the site. A new study by the Nevada Bureau of Mines and Geology (Castor, et al., 1989) indicated a low to very low potential for the occurrence of mineral, precious-metal, industrial-commodity, and energy resources for the purposes of withdrawal near the site.

Geophysical data indicate the presence of a regional east-west trending gravity and magnetic anomaly across the northern end of Yucca Mountain which could be indicative of a deep-seated intrusive body or, alternatively, of the metamorphesed Eleana Formation. Mineralization could be associated with an intrusive body, if present. Mineralization also could be associated with deep-seated detachment faults, if present beneath the site and if these faults are channels for mineralizing fluids. In today's marketplace, geophysical anomalies alone are rarely sufficient to promote further exploration; however, the presence of a sizeable or lone and very promising geochemical anomaly could lead to further exploration.

For the purposes of evaluating the tests related to this PC, the workshop participants agreed to interpret the PC in terms of the tests "finding" indicators of a potentially economic natural resource, sufficient to justify a "detailed" exploration program (e.g., systematic drilling of exploratory boreholes spaced on 500 to 1000-foot centers at the site) by a "prudent" exploration company. Consequently, the following three test-accuracy probabilities were assessed:

P1 Probability that economically viable mineral or hydrocarbon resources are present at or near the site.

P2 Probability that the site-characterization testing program will detect these resources given that they are present (true positive).

P3 Probability that the testing program will indicate the presence of these resources when they, in fact, are not present (false positive).

Because the planned "deep" boreholes are to be located outside of the proposed repository perimeter and will not penetrate the Tertiary/Paleozoic boundary, the testing program is not likely to detect deep-seated economic resources, which, however, would occur at depths that, at present, would preclude recovery. The probability of finding economic mineral resources is high if they are present, but given that they are present, difficulty would be encountered in gaining sufficient information to evaluate their economic viability. Consequently, it is unlikely that evidence found would justify an extensive exploration program under today's economic conditions or those economic conditions likely to occur during the next 10-30 years.

It was concluded that a systematic exploratory drilling program would not be likely given (1) what we presently know about the site, and (2) that we are basing our probabilities on present economic conditions or those economic conditions expected during the next 10-30 years. A few drill holes are much more likely relative to a systematic drilling program. The assessment here was used for the Phase I approach, but it is acknowledged that a slightly different approach should be taken in Phase II, given the discussion above.

PC #H1: Human Intrusion Effects on Geohydrology

Measure:	Change in future flux due to human activity
Assessment threshold (AT):	Sufficient to affect waste isolation

Discussion

After discussing possible approaches to "testing" for this PC, the workshop participants concluded that this PC is not amenable for resolution by the gathering of site technical data. Rather, this PC involves socio-economic issues that can be evaluated using currently available data. Consequently, this PC was not assessed for test accuracy.

PC #H3: Usable Water in Controlled Area—Direct Intrusion

Measure:	Rate of drilling in the repository block in exploration for or extraction of usable water or economic resources
Assessment threshold (AT):	Three drill holes per square kilometer

Discussion

Because this PC involves exploration for and extraction of, a natural resource, in this case usable water, it was incorporated into PC #4: Natural Resources with respect to assessing test accuracy.

PC #H8: Usable Water in Controlled Area—Saturated Zone

Measure:	Expected curies released by gas flow
Assessment threshold (AT):	Two percent of the EPA standard

Discussion

A test accuracy essessment was not performed for this PC for the reasons cited in the discussion of PC #H1: Human Intrusion Effects on Geohydrology.