UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, DC 20555 - 0001

November 13, 2006

MEMORANDUM TO: John T. Larkins, Executive Director
ACRS/ACNW

FROM: Michael Snodderly, Chief ***/RA/***
Technical Support Branch
ACRS/ACNW

SUBJECT: ATTENDANCE AT US NUCLEAR WASTE TECHNICAL REVIEW BOARD (US NWTRB) WORKSHOP ON LOCALIZED CORROSION OF ALLOY 22 IN YUCCA MOUNTAIN ENVIRONMENTS, AND WORKSHOP 3 OF THE PROBABILISTIC VOLCANIC HAZARD ANALYSIS UPDATE (PVHA-U) FOR YUCCA MOUNTAIN

William Hinze (ACNW member) attended both days of the PVHA-U meeting and Day 1 of the subject NWTRB workshop. Neil Coleman (ACNW Senior Staff Scientist) attended the NWTRB workshop and Day 2 of the PVHA-U meeting. The joint trip report for both meetings is attached. If you have any questions please contact Neil Coleman at 301-415-7656.

Attachment: As stated

cc w/att:
ACNW Members
ACNW Staff
L. Kokajko, HLWRS
S. Jones, NMSS
B. Sosa, EDO

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DATE	**11/8/2006**		**11/9/2006**		**11/13/2006**		**11/13/2006**	

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U. S. Nuclear Waste Technical Review Board (NWTRB)
Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments
September 25-26, 2006

The purpose of the NWTRB workshop was to present and discuss data, analyses, studies, and models of localized corrosion of Alloy 22 in aqueous environments that could exist in a repository at Yucca Mountain. Although the focus was on localized corrosion, general corrosion was also discussed. The workshop was co-chaired by NWTRB Chairman John Garrick and Board members Ron Latanision and David Duquette. Copies of presentation slides and a transcript will be made available online at the following website: http://www.nwtrb.gov/. The following outline shows the sessions and presentation topics from this workshop:

Monday, September 25

Session on Environments on Waste Package Surfaces

1. Evolution of environments in a repository in Yucca Mountain
2. Chemistry of water contacting engineered barriers
3. Effect of cyclic, sporadic, or episodic processes on evolution of environments in a repository in Yucca Mountain
4. EPRI-sponsored studies on evolution of environments in a repository at Yucca Mountain
5. Update of State of Nevada research on waste package environments in Yucca Mountain

Tuesday, September 26

Session on Localized Corrosion of Alloy 22 (I)

1. New alloy-22 data and their relevance to high-temperature localized corrosion
2. Update of State of Nevada research on corrosion of alloy 22
3. Corrosion in salt environments at elevated temperatures
4. Crevice corrosion initiation and propagation tests
5. Localized corrosion data and analyses from the Materials Performance Thrust of the Department of Energy's OCRWM [Office of Civilian Radioactive Waste Management] Science and Technology Program

Session on Localized Corrosion of Alloy 22 (II)

1. Corrosion models to support total system performance assessments
2. Developments in modeling localized corrosion of Alloy 22
3. Development and implementation of the localized corrosion model
4. Summary of NRC work and waste package corrosion risk insights

Prior to the NWTRB meeting, four potential questions were provided to participants as part of the workshop agenda:

a. Are data, understanding, and models sufficient to bound potential environments on waste packages in a repository in Yucca Mountain with reasonable confidence from a corrosion standpoint? (If so, what do they show; if not, what needs to be done?)

b. Are data, understanding, and models sufficient to assess with confidence whether localized corrosion of the (Alloy-22) outer surfaces of waste packages in a repository in Yucca Mountain is likely to occur? (If sufficient, how likely is corrosion; if not sufficient, what needs to be done?)
c. If localized corrosion of the outer surfaces of waste packages occurs, will it be deep and/or widespread? Explain basis for response.
d. What are the consequences of localized corrosion?

NRC/CNWRA Presentations

An NRC staffer gave a talk titled "Summary of NRC Work and Waste Package Corrosion Risk Insights." He summarized staff views on topics such as the persistence of passive films on metal surfaces and the role of restricted openings that could be caused by corrosion in waste package surfaces. The proposed NRC performance assessment model assumes no localized corrosion due to salt deliquescence. The following summary of NRC/CNWRA [Center for Nuclear Waste Regulatory Analyses] work on waste package corrosion was presented:

> Brines formed from salt mixtures (Na-K-Cl-NO_3) at elevated temperatures will more likely result in general corrosion than localized (crevice) corrosion. CNWRA experiments indicate high general corrosion rates on the order of 1 μm/yr, which may lead to potential reductions in wall thickness of the Alloy 22 waste package. Mechanical interaction analyses may need to take this wall thickness reduction into account. Longer-term tests are ongoing to evaluate uncertainties in general corrosion rates and localized corrosion susceptibility.
>
> Brines that form by evaporation of seepage waters are mostly benign to Alloy 22, but some compositions could initiate localized corrosion of the waste package material. Contact of seepage water may be prevented by drip shields. The localized corrosion susceptibility decreases with decreasing temperature. If seepage water contacts waste packages at temperatures close to 100°C, localized corrosion should be considered in performance assessments.
>
> Soluble salts have significant concentrations of corrosion inhibitors (nitrate and sulfate, based on limited data on dust samples). Crevice corrosion of Alloy 22 shows a strong tendency of stifling and repassivation near the boiling point.

The NRC staffer presented the following risk insights with regard to corrosion:

> General corrosion appears to be a more significant process than localized corrosion. Uncertain effects from long-term chemical or structural changes in passive film stability warrant additional consideration. Crevice corrosion shows a strong tendency of stifling and repassivation in a simulated crevice corrosion environment of Alloy 22 near the boiling point. Crevice corrosion of the waste package could result in a small opening area, which limits the potential for radionuclide releases. Brines that form by evaporation of seepage waters are mostly benign to Alloy 22, but some compositions could initiate crevice corrosion of the waste package material.

As part of the NRC path forward, the staff seeks to understand and better constrain conditions and mechanisms of localized and general corrosion. To reduce data and model uncertainties, additional model support and data will be evaluated.

A CNWRA staffer gave a presentation with results of laboratory corrosion tests, showing corrosion rates as high as 10 microns/year. Such a rate, if correct, would theoretically lead to early penetration of waste packages.

Observations

Two repository environments were discussed during this meeting, and it was important to note which environments were being addressed by each speaker. The first environment represents the relatively dry thermal period during the first thousand years when temperatures would be maintained above the boiling point. Little or no seepage would occur during this time, but a dust layer on waste packages would be expected with small amounts of concentrated brines possibly forming within the dust layer. The second environment represents the post-thermal period when seepage could enter disposal drifts. The amount of seepage that could directly contact waste packages would depend on the condition of drift walls, which controls the effectiveness of the capillary barrier, and on the condition of drip shields during that period. The CNWRA corrosion tests that were described do not appear to represent conditions that could realistically arise in a repository because they intermix geochemical and thermal environments. For example, CNWRA tests on Alloy 22 corrosion were done using full immersion in dense brines that could be produced by salt deliquescence. Immersion causes a very large (virtually infinite) volume of hot ($\geq$150°C) acid to be placed in contact with the samples. This may not be realistic because the potential repository at Yucca Mountain is unsaturated. Enhanced dripping in tunnels would not be expected to occur until after 1000 years, when temperatures would be sub-boiling. Also, the CNWRA experiments do not consider the strong capillary and surface tension effect in dust layers where brines would preferentially remain in contact with dust particles of high surface area rather than metal surfaces.

Recommendation

The Committee may want to examine these matters as part of a future briefing on corrosion-related issues for Yucca Mountain.

Nye County (Nevada) Presentation

A Nye County representative gave a talk titled “Effect of cyclic, sporadic, or episodic processes on evolution of environments in a repository at Yucca Mountain.” Unlike previous modeling efforts, unsaturated zone modeling work applied by Nye County suggests that water vapor in the near field moves predominantly toward (rather than away from) repository drifts. The presenter also hypothesized that the repository would experience a cyclical corrosion environment because barometric pressure changes would cause moisture to flow into and out of repository drift walls. This cyclical corrosion would hypothetically cause alternating wet and dry conditions and changing ionic strength and composition of water in drifts.

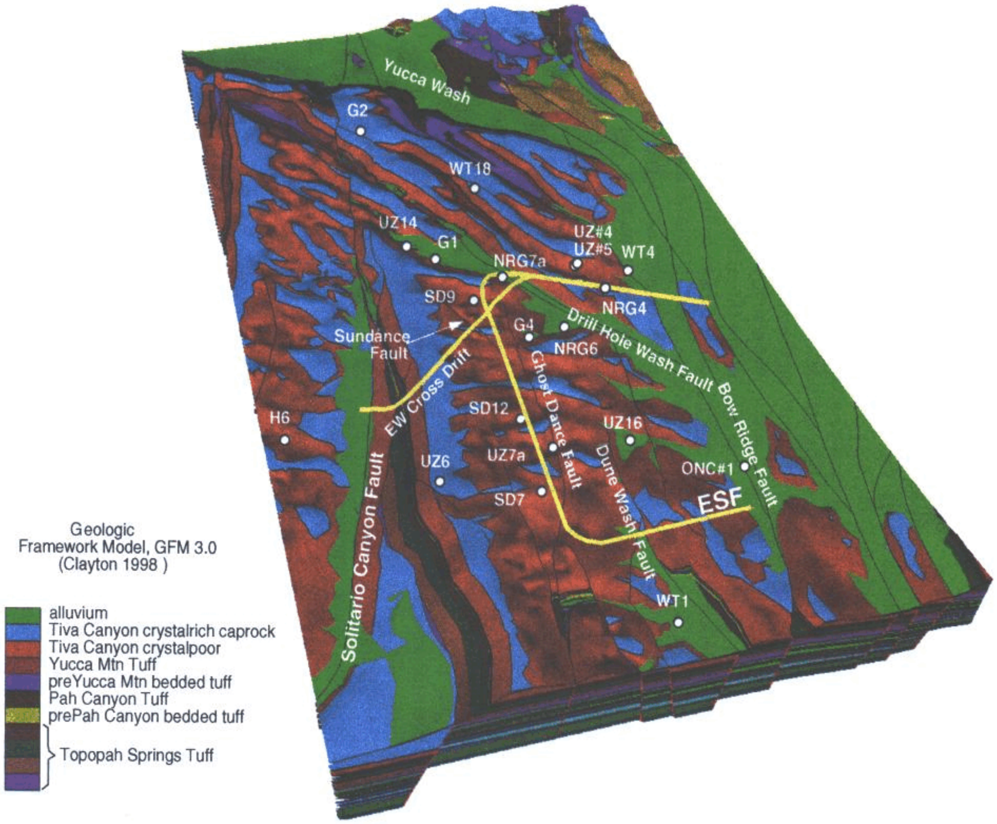

Figure 1. Locations of selected boreholes at Yucca Mountain with respect to the tunnels (after Figure 2 of Bodvarsson et al., 1999).

Observations

The barometric pressure changes and cyclical corrosion postulated by the Nye County presenter appear to insignificant in a repository at Yucca Mountain. Ahlers (1999) reported that the Paintbrush tuff nonwelded unit (PTn), which is located above the repository horizon, is an effective pneumatic barrier that attenuates the barometric signal at repository depths. Figure 1 shows selected borehole locations at Yucca Mountain. Figure 2 presents air pressure data collected in 1995 at the surface and at four depths down to the repository horizon. As shown in the upper two plots in Figure 2, the barometric wave is almost completely attenuated in the Topopah Spring tuff where the repository would be built. Ahlers et al. (1999) describe Figure 2 as a data set typical of Yucca Mountain.

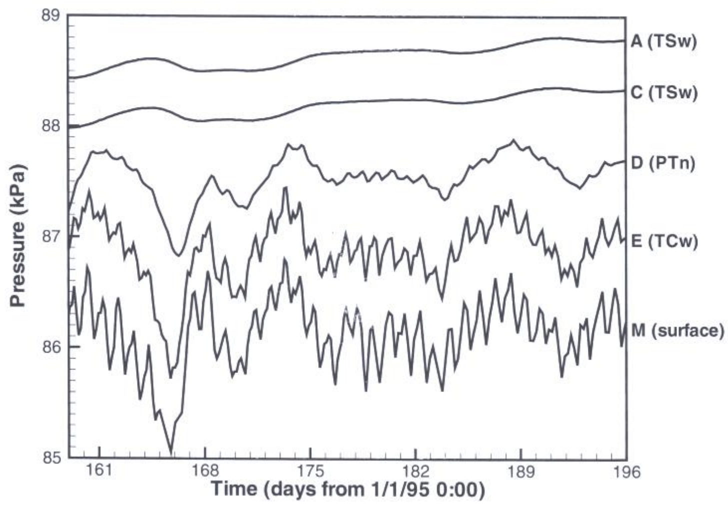

Figure 2. Ambient pneumatic pressure data from borehole NRG-7a. Instrument locations are located in the middle Topopah Spring (repository horizon) [A], upper Topopah Spring [C), Paintbrush Tuff nonwelded [D], and the Tiva Canyon caprock [E] (after Figure 1 of Ahlers et al. [1999]).

If DOE chooses a ventilated repository design, then barometric cycles would occur in the repository, but cooler conditions would prevail underground. DOE currently plans to seal access ramps boreholes, and ventilation shafts, which would restore pneumatic conditions to approximately the pre-construction state (before a tunnel boring machine penetrated the PTn unit). Figure 3 shows that the effectiveness of the PTn pneumatic barrier correlates well with the thickness of this nonwelded tuff unit. The pneumatic barrier was only reduced within some boreholes that intersected fault zones (e.g., UZ#4 and UZ#5). Faults by themselves would have little pneumatic influence on a repository because the restricted and transient air movement through faults would be insignificant compared with the very large air volume in waste emplacement drifts.

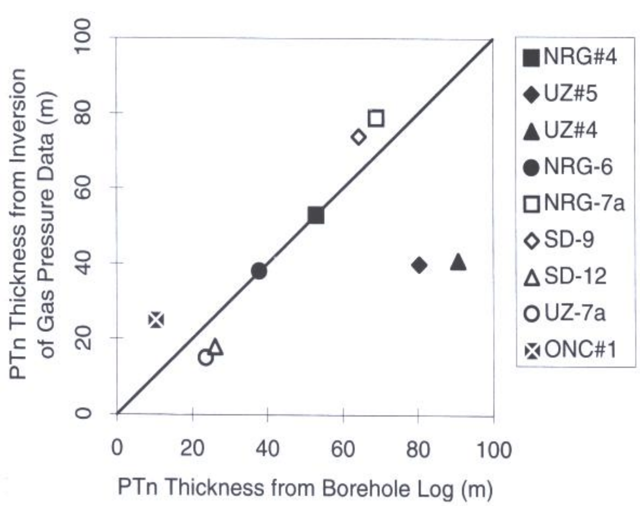

Figure 3. Correlation between the measured thicknesses of the Paintbrush Tuff nonwelded unit and the thicknesses estimated by inversion of pneumatic data (from Fig. 7 of Ahlers et al., 1999).

Additional Presentations

A DOE representative gave a talk titled "Development and Implementation of the Localized Corrosion Model." In the DOE model, localized corrosion is simulated to occur when the long-term corrosion potential is greater than or equal to the crevice repassivation potential. The model applies to temperature conditions less than 105°C, which is considered the maximum possible seepage temperature. The entire waste package surface is simulated to be subject to crevice corrosion. General corrosion is modeled to always occur. DOE has estimated the corrosion potential using tests of greater than 300 days duration. Over 55 test conditions are available, including: temperatures from 25°C to 155°C, pH from 1 to 13, NO_3 ranging from 0 to 18 molal, Cl from 0 to 36 molal, and NO_3/Cl ratios of 0 to 100. In the DOE model, once localized corrosion begins a linear corrosion rate is applied until waste package penetration occurs. Stifling of localized corrosion is not incorporated. The localized corrosion rate is applied using a log uniform distribution that varies from 12.7 microns/yr (0^{th} percentile) to 127 microns/yr (50^{th} percentile) to 1270 microns/yr (100^{th} percentile). These rates are based on testing in highly aggressive solutions.

DOE has screened out localized corrosion of waste packages due to dust deliquescence on the basis of low consequence. DOE considers that deliquescent brines will not initiate localized corrosion under repository-relevant conditions because the potential brine volume is so small and much of the brine would be held in surface dust due to capillarity and therefore have minimal contact with waste package surfaces. The limited brine volumes would limit the amount of Cl that would be available for reaction with metal, and corrosion products that may be formed could armor the metal surface and limit the progress of crevice corrosion.

Presenters representing the State of Nevada showed laboratory results that suggest spherical perforation pitting (SPP) could perforate C-22 containers in times as short as ten years or less, assuming that an environment of concentrated mixed HCl-HNO_3 can be accumulated. SPP reportedly occurs over a broad range of compositions of the mixed acid HCl-HNO_3 where the concentrations exceed several molar. SPP may occur over a range of temperatures, including room temperature. The presenters criticized the effectiveness of a capillary barrier at the drift/wall rock interface, and found no evidence that the NO_3 anion can function as a corrosion inhibitor.

A DOE representative from Sandia National Laboratories gave a talk titled "Evolution of Waste Package Environments in a Repository at Yucca Mountain. This included a discussion of sources of dust in the tunnels. Dust generated by tunnel operations has <1% soluble salts and mainly consists of insoluble material derived from silica or feldspars. Atmospheric dust introduced from the outdoors has approximately 10% soluble salts. This dust source would be eliminated if a repository were eventually to be sealed. Deliquescent brines could form in dust on waste packages during the early thermal period. The amount of brine that can form depends on the amount of dust present. An upper bound for dust deposited was estimated at 26 mg/cm^2, and the upper bound for the brine volume is 1.8 micro L/cm^2. The presenter noted that rock dust may add mass to the dust but would not be a significant source of soluble salts.

Dense deliquescent brines would be expected in dust on waste packages only during the early thermal phase at high temperatures, and then only in small amounts. Approximately 100 pore water samples have been analyzed. NO_3/Cl ratios were >0.5 in more than half of samples. At higher temperatures the NO_3/Cl ratios would rise, which would be chemically favorable for reducing corrosion. The presenter noted that some pore water compositions may have been altered by the breakdown of plastic wrap that was used to preserve moisture conditions in some geologic cores. The natural pore water compositions appear to be more favorable than those affected by breakdown of plastic and subsequent bacterial action.

An EPRI representative discussed the potential for localized corrosion of Alloy 22 in multi-salt deliquescent brines. He noted that acid degassing would lead to loss of HCl and HNO_3 from deliquescent brines that may form. Volatile gaseous species would reportedly be removed from the surface by diffusion and advection and would also be consumed by reaction with the overwhelming mass of minerals in the drift walls. Preferential degassing of HCl over HNO_3 would help to reduce corrosivity during acid degassing. The presenter reported there is strong experimental evidence in support of corrosion stifling (termination). He discussed the evolution of conditions for three water chemistry assemblages, and in each case assumed that no acid degassing would occur. Even so, no localized corrosion would result. The presenter concluded there is no evidence to suggest that high temperature deliquescent brines will impact the safety of a Yucca Mountain repository.

Cited References

Ahlers, C. F., S. Finsterle, and G. S. Bodvarsson (1999). Characterization and prediction of subsurface pneumatic response at Yucca Mountain, Nevada. *J. Contam. Hydrology*, 38, 47-68.

Bodvarsson, G. S., W. Boyle, R. Patterson, and D. Williams (1999). Overview of scientific investigations at Yucca Mountain - the potential repository for high-level nuclear waste. *J. Contam. Hydrology*, 38, 3-24.

Probabilistic Volcanic Hazard Analysis Update (PVHA-U)
Yucca Mountain Project
Workshop 3 - Preliminary Assessments
September 26-27, 2006

The goals of PVHA-U Workshop 3 were as follows:

Provide an update on the data and information that have been compiled in the PVHA-U database.

Summarize the expert elicitation process being followed, including the first round of interviews held in July and August, 2006.

Provide a forum for the expert panel to present and discuss their preliminary assessments of the technical issues.

Provide an opportunity for the panel to review, understand, and challenge the assessments made by their colleagues on the panel.

Focus discussions on the uncertainties in models and parameters, such that the experts will be repared for the second round of elicitation interviews in November and December 2006.

To outline the scope and schedule of future elements of the PVHA-U.

Workshop 3 consisted of a series of topical sessions in which 2 or 3 panelists summarized their preliminary assessments. The topical sessions are outlined below:

Summary of Preliminary Assessments - Event Definition
Dike Geometries
Eruptive Conduits and Sills
Scenarios of Event Characteristics
Types of Future Eruptions

Summary of Preliminary Assessments - Spatial Models
Spatial Zones
Events within Regions of Interest
Geologic Datasets Relevant for Estimating Spatial Uncertainty

Summary of Preliminary Assessments - Temporal Models
Recurrence Models: Poissonian and Episodic

Observations
A number of key points were discussed by the panelists, related to factors that influence locations of volcanism, changes in volcanism over time, style of volcanism, hypothetical associations between volcanic fields, and the time period to use to project future volcanism.

A panelist provided additional commentary regarding the use of lithostatic pressure data to compare with areas where past volcanism has occurred. Topography alone defines the shortest path to the surface. At Yucca Mountain itself intrusions may have been inhibited over the last 10-12 Myr by higher rock pressure compared to the basin area to the west (Crater Flat). Using lithostatic pressure data provides information about possible influences on magma flow paths in the upper crust. The panelist observed that, in dying volcanic systems like the Crater Flat region, the driving energy of the magma systems is low enough that lithostatic pressure variations may be sufficient to help guide magma flow paths. Eruptions from such systems would be favored to occur in basins rather than in adjacent topographically high areas like Yucca Mountain. There are exceptions, but most of the basaltic eruptions near Yucca Mountain occurred in the basins. More energetic magma systems of greater volume (e.g., Reveille Range-Lunar Crater) would be less sensitive to lateral lithostatic pressure variations and might therefore show less tendency to concentrate eruptions in topographic lows.

A consultant for the State of Nevada recommended that the volcanism of the Reveille Range be more closely examined as a volcanic field that may be intimately linked to the Crater Flat field. One panelist commented that the 10-12 million year old Solitario Canyon Fault (SCF) dike belongs to the now dead caldera phase of Timber Mountain. Another participant noted that the petrology of that dike most resembles the basalts in Jackass Flats, where volcanism ceased in Miocene time. The orientation (strike) of dikes in the Yucca Mountain region is now seen as perhaps being more variable than was assumed in the earlier PVHA study (Geomatrix Consultants, 1996). There still appears to be a close association of dikes with pre-existing faults. Dike swarms may have been possible during periods of greater magma volume production, especially in Miocene time.

Weighting factors are now being developed for lithostatic pressure variations in the region and also for the cumulative regional extension map of Fridrich et al. (1999). The cumulative extension map integrates the extension over the last 12 million years in Crater Flat. Strain rates have greatly diminished since the Miocene. There is compelling evidence that volcanism has waned in concert with this great reduction in crustal strain. It was previously known that volumes of volcanism significantly declined after Miocene time. Figure 1, developed by F. Perry of Los Alamos National Laboratory, shows that volumes of Pliocene to Quaternary volcanism have also greatly declined, indicating that magmatic systems near Yucca Mountain are dying.

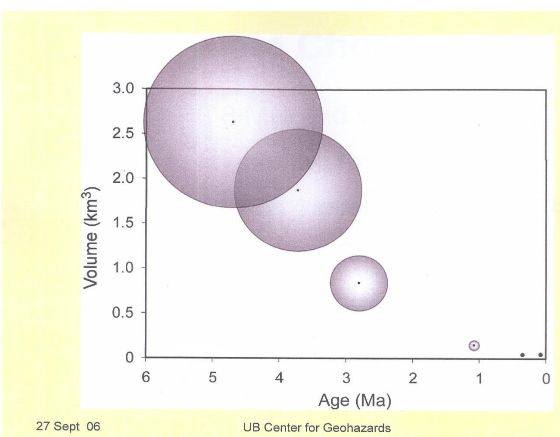

Figure 1. Age vs. volume for Plio-Pleistocene volcanic episodes. Figure includes buried Pliocene basalts in the northern Amargosa Desert. The diameter of the circles is proportional to volume. The dot at far lower right represents Lathrop Wells. The dot to its left represents Sleeping Butte. The small circle at 1.1 Myr represents the Quaternary cones of Crater Flat.

Based on the panelist discussions, some significant changes are being considered since the 1996 study. There is now greater emphasis by most panelists on the nature of Pleistocene activity (vs. earlier activity), dikes under consideration are shorter in length, the possibility of sills is being discussed, and there may be greater flexibility in possible dike orientations. Event (eruption) cycles are being discussed, and fewer hidden events are being considered based on the results of drilling anomalies. There remains considerable challenge in applying spatial and temporal models in a region where volcanism is so infrequent and has greatly declined. Phreatic eruptions (maar volcanos) seem to be no more likely in the future because at most the water table is expected to change by 20 to 30 m as a result of climate change.

The preliminary schedule of future PVHA-U activities is summarized below:

Elicitation interviews - round 2	NOV - DEC 2006
Preliminary hazard calculations and sensitivity analyses	JAN - MAR 2007
Workshop 4 feedback	APR 2007
Experts finalize their assessments	MAY 2007
Experts finalize elicitation summaries	JUN 2007
Final hazard calculations - aggregation of assessments	JUN 2007 - JAN 2008
Report preparation and finalization	NOV 2007 - JUN 2008

Cited references:

Fridrich, C., J. Whitney, M. Hudson, and B. Crowe (1999), Space-time patterns of L. Cenozoic extension, vertical axis rotation, and volcanism in the Crater Flat Basin, SW Nevada, in Cenozoic Basins of the Death Valley Region, GSA Spec. Pap. 333, pp. 197–212.

Geomatrix Consultants (1996), Probabilistic volcanic hazard analysis for Yucca Mountain, NV, Rep. BA0000000-1717-2200-00082, Rev. 0, San Francisco, Calif.