Memo

To: Leon Reiter, Seismologist, NWTRB

From: William G. Melson, Senior Scientist, Smithsonian Institution, and consultant to the Board on volcanological issues

Subject: Responses to Questions resulting from the November 8, 2001, meeting at NWTRB Headquarters regarding igneous intrusion consequences.

Date: November 21, 2001

The five questions that you asked at the meeting provide an excellent framework to deal with the issues of consequences of igneous intrusion. I've slightly modified the questions hopefully without losing their intent:

1. ***How realistic are the so far written accounts of the consequences of igneous intrusion in the NRC-contractor manuscripts by Woods et al. papers (various drafts with differing emphasis and authorship order), and DOE modeling (AMRs) in response?***

The approaches so far in the NRC-funded manuscripts are conservative, to the point of being unrealistic. I also have concerns about how realistic the DOE numerical simulations are in regard to the severity of an intrusion into the repository, as explained below.

**2.** ***What are the strengths and weaknesses of the proposed scenarios*****?**

The main strength of the NRC-funded work by Woods et al. is to bring the potentially major consequences of an igneous intrusion that brings HLW to the surface or into the groundwater into serious consideration. For example, DOE has and will be examining many issues, documented in the various DOE-NRC exchange documents, as a result the NRC concerns.

I perceive the following weaknesses in the work so far done by Woods and his colleagues and by DOE in response to the ongoing DOE-NRC exchange. I may not have all the manuscripts from the NRC contractors and the latest DOE AMRs; I am referring to the earliest versions:

More precise attempts to understand and quantify a number of model pathways that potentially would disrupt waste packages and lead to transport of radionuclides to the surface or into the water table are needed.

The model is without probability spreads for the various parameters that will influence the intrusive scenario. For example, the interaction attendant on intersection of drift(s) by a dike is an extremely complex phenomenon with essentially no good analogs of which I know. The model needs to consider spreads of: magma volumes and intrusive rates; viscosity, density, and water and other volatile contents including acid residues in condensates from volcanic gases; dike propagation models; drift wall interactions; drift

layout; backfill and barrier effects; package interactions with magma, gases, and solidified magma; and so on.

Basaltic magmas like those of the Crater Flats Volcanic Field are not superheated, that is, above their liquidi, and yet this is not dealt with adequately in the analysis. I believe this is an important omission because extraction of heat by (1) contact with cooler objects (waste packages and drift walls), (2) by adiabatic expansion of dissolved gases, or (3) by contact with ground water results in solidification through crystallization and quenching to glass. These effects need to be taken more rigorously into account in the various numerical simulations. Magmas cannot simply melt their way through barriers without attendant solidification, which will tend to choke instead of open passageways to the surface.

This tendency to solidify can lead to coating of canisters and to sealing of a drift(s) possibly leading to surface eruption of the intrusive elsewhere away from the repository. How likely is this compared to the conservative scenarios put forth by Woods et al. and taken up by the initial DOE assessments? The possibility of clogging and drift sealing has not been addressed rigorously and yet is a real possibility.

Roughness effects from waste packages, drift walls, and engineered barriers are not taken into account adequately.

Rock mechanic factors involved in intrusive scenarios are outside the expertise of the NRC team and bear, for example, on the extent of drift roof collapse, and rock fracturing that leads to surface pathways (hydrofracturing) and need to be incorporated in future modeling. Local and regional stress fields as they bear on magma movement need to be more fully assessed, as they were at this meeting by Derek Ellsworth in regard to the stress field around drifts heated by the waste packages.

Magma, shock waves, and pyroclastic impacts on the canisters are also, I believe, sketchy at this point as best I can ascertain. I am not at all persuaded that the release resulting from such interactions will be as great as input into the various NRC contractors and DOE simulations would suggest. In general, I am concerned about the "faith" being put into the numerical simulations in general as they so far have been used. These simulations yield what appears to be a quantitative and realistic spread of consequences that are totally inconsistent with the complexity of the processes and completeness of the input values as well the number crunching procedures in the simulations.

Although we did not get to it at our Nov. 8 meeting, I am concerned also as to the adequacy of the ASHPLUME code. ASHPLUME calculates ash distribution in airfall to the ground as a function of column height, wind direction, eruption volume rate, and so on and is used to calculate radionuclide distributions by NRC contractors and DOE. The code was taken from earlier research not related to Yucca Mountain and then modified to take into account additional parameters thought to be important by NRC contractors.

ASHPLUME needs to be thoroughly reviewed by the likes of Steve Carey at Rhode Island and others who also have experience in eruption column particle distributions as a function of eruption volume rate, particle-size distributions, column height, wind speed and direction, and so on. ASHPLUME does this but so far, to the best of my knowledge, has not been adequately reviewed; if so I've seen no written references to such second opinions. ASHPLUME, given its critical importance in both the NRC and DOE simulations, ought to be carefully examined as to its adequacy. One immediate need for further consideration is the mechanisms in detail that will release material from

the canisters, a parameter not included in ASHPUME models. The points I raise above, as to rapid magma solidification and some sealing of material and possibly even of the conduits near the dike egress, also need to be taken into account in realistic models.

***3. How can they be expected to change with more research?***

All of the factors mentioned above can be dealt with in a more comprehensive way than so far done. It is unclear to me, however, whether or not the DOE responses to the NRC concerns will be sufficient to deal with the factors I have outlined above. DOE modeling so far, like the NRC-funded research, is erring, I believe, on the highly, indeed unrealistically so, conservative side, for example in the amount of release from canister disruption. They have to a large extent built upon the Wood et al. highly conservative model. For this reason, their calculated doses are, I believe, at the extreme high end of likely probability spreads in consequence analysis.

***4. Will the model become less or more severe with consideration of these concerns?***

I believe incorporation of the effects mentioned above will in general considerably lessen the calculated dose probabilities resulting from of an igneous intrusion into the repository. But, I believe each aspect of the modeling so far, including the shock-wave consequences so eloquently stated by Meghan Morrissey at our meeting, are inadequate modeled because of the reliability of the input parameters, the algorithms so far used, and, especially, lack of adequate external (not DOE nor NRC) review of the consequence modeling. I am left unclear still as to the actual impact of shock waves on the canisters. The mere phrase "shock wave", I believe, has raised and will raise a concern as much emotional as real.

***5. What can be done to increase certainty?***

Here are two options among many possibilities:

A. Await the evaluations underway by the DOE and NRC responses, to see how well they deal with concerns, as well as ongoing reviews of the Woods et al. models and DOE's AMRs.
B. Recommend that DOE convene an interdisciplinary panel along the lines of the PVHA approach to additionally and on a broader base derive models of igneous intrusive consequences.

Finally, the consequence analyses so far done may be taken to be limiting and critical factors in overall repository performance. If this turns out to be so, the modeling so far done needs to be subjected to a thorough external review with a broad-based team, including additional numerical simulations that include all variables and their ranges and a critical assessment of the algorithms that are used. But, how important is this work given the extremely low probability of dike intersection with the repository in the first place?