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Distribution:
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To: Johnson

Comments--EA
U.S. Department of Energy
Attn: Comments-EA
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Sir:

The Department of the Interior has reviewed the draft environmental assessment for a nuclear waste repository at the Hanford Site, Benton and Franklin Counties, Washington. Our detailed comments are attached. We appreciate the opportunity to review this document.

Sincerely,

Bruce Blanchard, Director
Environmental Project Review

Enclosure

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General

The opportunity to comment on the draft Environmental Assessments (EAs), the nine candidate sites for the first repository for civilian high-level radioactive waste is appreciated. These large, complex reports represent a meaningful contribution in terms of effort and time. The effort of preparation was obviously large, and available time was short, which might very likely have contributed to some significant shortcomings of internal consistency in the reports. There apparently was little time or manpower devoted to the cross checking of values or descriptions within individual reports. Since the time available for review and comment was also short, research of the background reference documents was not possible. Thus our reviews are necessarily based on the knowledge and experience of individual reviewers, bureau experience and expertise, and the content of the draft Environmental Assessments. Also, our experience at each of the candidate sites is vastly uneven, and the review comments reflect this unavoidable variation.

Three related basic issues that became apparent during our review of the EAs are (1) the modeling of hydrologic systems, (2) the identification of failure modes and the most likely pathways of radionuclide release, and (3) conclusions reached in the EAs are not supported by the data base. In regard to modeling assumptions, reliability of data, and limitations of results of the modeling of hydrologic systems should be better described. Such descriptions might help explain apparently inconsistent ground-water travel times given in different sections of the salt-site EAs as is noted in the specific comments.

The failure modes addressed in the EAs are simplistic. We are particularly concerned that all available geotechnical information available for the various host rocks apparently has not been used to assess the mechanical and thermal responses of the geologic and hydrologic systems to the repository. This is particularly true with regard to the sites where the host rock lies below the water table. The possibility that a response of these systems to a repository might be the opening of vertical pathways for fluid circulation is dismissed either summarily or by means of a partial and theoretical analysis. Probable flow paths from the repository frequently are determined on the basis of inconclusive data on head gradients, on restrictive assumptions on the nature of water-bearing zones, and on flow directions through salt units determined by the unsupportable assumption of Darcian flow through a uniformly saturated and homogeneous porous medium. In general, the conclusions of the EAs as a body appear to go well beyond what the data base justifies. Confidence in the objectivity of the reports will be enhanced by conservation, and demonstrated by closer adherence to what the data base can support. Conclusions are supported with little data in many instances. For example, values for effective porosity and dispersion are necessary to calculate radionuclide transport. Field measurements of those parameters are rare, yet calculations are made as if sufficient data were in hand.

We recommend the EAs should contain a comprehensive discussion of the schedule for various activities related to characterization and nomination of a site. The reviewer must understand what activities will be undertaken concurrently; those activities that will be phased; how review of completed studies will be undertaken; a description of the

intermediate decision points in the characterization phase; and how sites being characterized will be evaluated during this process. We believe this important information is needed in the final EA to ensure that sites with presently unknown flaws could be eliminated from further study during the characterization phase. The discussions in Section 4, Expected Effects of Site Characterization Activities, should incorporate this information.

To address chapter 7 adequately requires not only solid, broad-scope technical experience but also an awareness of the needs, goals, and guidelines applied to The Civilian Radioactive Waste Management Program. Chapter 7 is being reviewed here as a unique element since the same text for this chapter appears in each EA. The results are presented separately and not in site-specific terms.

We have two concerns about the ranking system used: (1) the comparison uses different kinds of data, different qualities of data, and different distributions of data, assembled and evaluated by different teams for different kinds of sites; and (2) the ranking scheme which treats all issues of equal value does not seem to be fully defensible, because all concerns are not truly equal in isolating high level radioactive waste.

With regard to the first concern, it is unclear why sites, for which many geotechnical studies have been completed, have been compared to sites for which comparable studies do not exist. Generally, further investigation of a phenomenon, topic, region, etc., reveals increasing complexity over what had previously been described; also, even major new findings often accompany further studies. Therefore, in all likelihood, were the Richton, Deaf Smith, and Davis Canyon Sites as extensively studied as the Hanford and Yucca Mountain Sites, they might not appear as "favorable" in the analyses as the sparse data suggest. Accordingly, some ranking "penalty" probably should be assigned to these sites (Richton, Deaf Smith, and Davis Canyon) in both post and preclosure rankings prior to attempting a meaningful comparison with the Hanford and Yucca Mountain Sites. In addition, a) we wonder if the facts are accurate and complete as stated, b) whether the facts are correctly used and inferences based on them are correctly drawn, c) whether these facts and inferences are correct and fairly summarized and transferred from one chapter to another and into Chapter 7 in particular. We have noted many deficiencies during our review. Some of these deficiencies, such as unsupportable assumptions on ground-water flow provide key input for the rankings in Chapter 7. Accordingly, many of the rankings in Chapter 7 become questionable and may even be in error. Therefore we recommend Chapter 7 should discuss the effect of differences in the data bases among the sites in the comparable analysis. Such a discussion certainly is needed.

Furthermore, the EA's taken as a body are very uneven in treatment of available data. This is understandable to a degree, because each of the site EA's was prepared by a different team of experts describing sites that very considerably in physical characteristics. This unevenness introduces difficulties for the authors of Chapter 7 when using an "equal weight" decision process. There is a need to establish some common framework or operational procedure to obtain some comparability of facts for the sites. This may be approached by assignment of an "important factor" or a weighting to each of the elements of a site (such as elements of ground-water hydrology, tectonics, geochemistry).

Our second concern is that the comparative analysis in Chapter 7 does not adequately weight the favorable and potentially adverse conditions by their importance. Preclosure and postclosure factors are weighted virtually the same (49:51). Mistakes during construction and operation can, at least in principle, be corrected, but postclosure failures are unlikely to be remedied. Within each group of guidelines, the favorable and potentially adverse conditions are weighted equally. There is such a long list of different conditions that a condition of singular importance for one site receives no particular attention. The comparative analysis resolves into a vote-counting numbers game, as if each vote had the same importance, which is definitely not the case.

We recognize that a system of weighting is not easily created and the weights assigned to different conditions will be questioned. It is unclear whether any effort was made to evaluate an approach, as follows. For each of the sites determine an "importance factor" for each of the elements or characteristics of the site that must be used in the comparative analysis. These provide an initial basis for weighting the favorable and potentially adverse conditions individually for each site. As these weighting factors are necessarily judgmental, we recommend that various combinations of weighting factors be applied to determine if a consistent sequence of site rankings can be obtained. The use of Monte Carlo methods should be considered in this evaluation. If such a weighted evaluation process has not been attempted, we recommend that it be tried to determine whether or not the rankings remain stable when individual criteria are weighted. Another approach which would have merit in confirming the rankings would be to impanel a Delphi group. Both of these processes would tend to create a more defensible objective analysis of the sites, ultimately recognizing that subjective judgment is required to reach any ranking, no matter what method is employed. Therefore, we question the grades assigned in the Tables in Chapter 7 of each EA. We believe the addition of a U grade for unresolved would have better identified grey areas and urge this be considered in the preparation of final EAs. The following detailed comments on Chapter 7 point out examples where incorrect comparisons of site characteristics might have been made.

For example it is unclear how the "P" and "NP" scheme of table 7-1 furnish a basis for comparison. The data source for the table should be identified. We question the summaries entered into table 7-1 and others like it. For example, the trustworthiness values for some of the geohydrologic parameters for any of the sites based on preliminary results of studies to date should be presented. It is also unclear whether the benefits of the saturated versus the unsaturated zones have been compared.

Examples of concerns include Page 7-10, paragraph 1—On geohydrology, specifically on travel time to accessible environment, comparison for different sites: Very different data abundance, type of data (model, drill stem test, well data, etc.); different sites may have used different models and perhaps different factors for the margin of "conservative" safety allowance (this factor is cited as 10 for Hanford and Yucca Mountain for specific parameters, but may not be for others. We question whether a single PROSPECTOR type model can be used for all sites. For Richton Dome, travel time is apparently based on a stable and stationary salt dome. Possible diapir movement is covered under "favorable condition no. 2" of the comparison chart. For Richton Dome this criterion rates a P, favorable, but nothing is said about diapir movement.

Favorable condition no. 3 (page 7-12) is rated NP for five sites, but the treatment is much too brief. Here, with the admitted uncertainties, lie possible problems; the nature of the uncertainties and the likelihood of their resolution by preshaft studies and later shaft-based studies should be projected.

If only one of the four subconditions for favorable condition no. 4 is rated positive, the entire condition no. 4 is rated positive. It is unclear whether the four subconditions are of equal weight. We believe the rankings may not be the same for different types of host rock and hydraulic conditions. We recommend the expected flux be a factor in assessing the sites not withstanding the footnote on page 7-15. The assessments should address these issue.

By summarizing and ranking subcategories, such as geohydrology, possible interaction among the major factors (such as hydrology vs. geochemistry) is not considered. This problem must be addressed in the final assessment.

Geochemistry—Favorable condition no. 1—Concerning redox conditions of the sites—again we are faced with disparate bases of data and different uncertainties. The presence of methane and pyrite, etc., may not be pervasive, for instance.

Favorable condition no. 2—Discussion for Hanford concerns reducing conditions but for the other sites the condition is for sorptive properties of the matrix material. Sorptive property of host rock at Hanford is low. We do not understand how these distinct properties can be equated. Once rated, the basis becomes obscured and the reader/user is apt to accept the ratings as on a basis of commonality.

Favorable condition no. 3—Again, the same problem of how to (1) evaluate the individual factors, (2) rate their role for each site, and (3) compare among the sites, remain significant.

Favorable condition no. 4—Limiting release to less than 0.001 percent per year—is rated P for all sites. The bases are different—for all but Hanford it is the absence of water at the waste package; for Hanford it is the presence of reducing condition; high pH, and reduced corrosion of metal overpack (page 7-20). These are different factors, with different reliability. We also recommend the assessments investigate the availability of geochemically compatible and feasible backfills for different kinds of media.

Rock Characteristics (postclosure)—This factor should be prefaced by a statement of the expected magnitude of the thermal pulse for proper evaluation. This important consideration has been omitted. Possible changes in the geologic framework and hydrologic system as a result of the heat load from the emplaced waste should be given intensive attention in future studies. Attendant uncertainties should be explicitly explained in the final assessments. In particular, possible changes in ground water circulation and flowpaths, fracture development, aperature changes of existing fractures, hydrothermal alteration of rock, and vertical and horizontal movement of the rock and land surface should be addressed.

Not just the geohydrology but other properties, specifically postclosure rock characteristics, vary directly as the result of differences between saturated and unsaturated zones. Yet other than in the section on Geohydrology, the differences for these two types of sites are not clearly spelled out (an exception is the recognition of sealing by ductility, page 7-25).

Potentially adverse condition no. 1—It is unclear how the possible stability problem at Hanford is not expected to affect the containment capability. The document states this on page 7-25 without citing the basis for the conclusion.

In the ranking summary section, the possible importance of "potentially adverse condition no. 2" is not given thorough treatment. The possible brine migration effect is allowed in the discussion under that heading, but without apparent justification other than the statement that "these phenomena are not expected to have significant effects at any of the sites," dismissed in the summary discussion. Further, the report states that the salt sites are rated higher because of lack of significant adverse properties. Both statements directly contradict the earlier, more specific discussions. This discrepancy must be investigated and supported.

As stated earlier, the question of developing weighting factors cannot be overemphasized. The almost unmanageable list of different conditions (favorable, potentially adverse, etc.) almost dictates that any single item on the list runs the risk of being forgotten. Thus it appears to become a numbers game with vote counting, as if each vote has the same importance. However, this is manifestly not so. An adverse condition on brine migration in salt should have overwhelming importance if it is present; a corresponding overwhelming factor for basalt might be the postclosure hydrology. The present report completely overlooks these partly judgmental factors. As a result, we believe the rankings might be unrealistic.

Potentially adverse condition no. 1—We question whether the following factor is worth worrying about. If precipitation and runoff rise significantly in the next 100,000 years, could new perched aquifers be created in what is now the unsaturated zone? If so, and if the repository shaft passes through this new aquifer, that could be a cause for concern.

Erosion—Favorable condition no. 3 is readily the important one. As long as the waste is unlikely to be exposed, the primary function of the repository will be fulfilled, thus the other two are insignificant. They merely help to ensure that condition no. 3 is fulfilled in the absence of more direct data. The three conditions are not equal and should not be so listed or compared.

Favorable condition no. 1—Could be rated NP (as is the case for NTS), but if the site is one of depositional aggradation, then it should not pose a problem (may pose one in case of rapid deposition, if a particular horizon is thereby pushed down into the underlying water table; if this should be a topic of concern, it isn't discussed).

Favorable condition no. 2—Wording could, in combination with condition no. 1, be construed to mean that erosion at Hanford during the next 10,000 years could amount to 450 m.

Potentially adverse condition no. 1, page 7-35—This reference to deposition during the last glacial period implies changes in hydrologic conditions resulting from climate effect. Under the latter heading, the only reference (page 7-31) refers to "changes" without any specifics. Taking these two entries together, could imply there's more to the story, for instance infiltration of ground water and resultant changes in permeability, sorptive properties (due to different material in fractures), flux, etc.

Qualifying conditions—The reason for making the qualitative distinction between Hanford and the other sites is not obvious; this point accents the concern about the basis for comparison among the sites.

Dissolution—Potentially adverse conditions and favorable conditions—the presence of breccia pipes, etc., at the three salt sites being conceded, the important task should be to ascertain the age of these activities. Right now the responses given to the two issues above for the three salt sites are not consistent.

Tectonics (postclosure)—Potentially adverse condition no. 1. Diapirism was included in the listing, but no evaluation was given for the salt sites. This might affect the ranking.

Human Interference—No more than passing mention of artificial markers. Are there any site-specific factors affecting the use of artificial markers?

Potentially adverse condition no. 1—What are considered as resources today may not be what people will seek in 5,000 years. Think of oil or coal in the pre-Marco Polo western world, or rutile, or uranium, or bauxite (or, in the foreseeable future, anorthosite). Our present conception of resources is no reliable guide for future explorers. Also, we believe the proximity to a National Park is a significant factor that should be considered under this heading.

Postclosure Systems Guidelines, Pages 7-53 and 7-54—No mention is made of whether the same waste form is assumed for all the sites, or whether waste forms and waste packages are tailored to the sites. We believe one should assume that the decision made in 1984 on the once-through uranium cycle, without reprocessing, will be valid in 20 years. Assessment of the qualifications of sites for use sometime in the 21st century probably should include the option of disposal of reprocessing waste, both hot and cool. Therefore, the assessment is thus quite uncertain and the site comparison may be prejudiced. Page 7-54 states that the waste packages are expected to last "indefinitely." This assumes a dry repository. Possible brine migration or possible electrolytic reaction of waste with water has not been considered. In the EA report for Davis Canyon, the authors mention (pages 6-92 and 6-93) 25 and 8 liters of brine accumulation per emplacement for cooled high-level radioactive waste and for spent fuel rods, respectively, in 100 years, and conceded that "...the presence of brine is expected to cause some corrosion of the waste cannister." Surely, such factors could and should be given thorough consideration and not merely be counted as a vote.

Radiological Hazards, Favorable condition no. 1, population density should address transient populations. For example, this factor might affect the density for Davis Canyon.

Site Ownership and Control—The rankings seem highly artificial to us. Other than top-ranking Hanford, we cannot agree with the priorities. An Act of Congress is required to transfer lands controlled by this Department. We question the success of a process of eminent domain.

Meteorology—This discussion is an example of the comparison (admitted by the authors of the report) of different kinds of data or absence thereof. The sites cannot be ranked on this basis.

Cost—It is not clear whether the cost includes the construction of transportation facilities to the sites and special transportation vehicles. This cost category is not listed under either "construction" or "operation." Transportation costs may vary greatly among the sites.

Format

Topics are difficult to follow because data and interpretations commonly found grouped in a technical report by discipline are scattered throughout several chapters. This is especially notable for geologic and hydrologic matters. Summaries of individual disciplines should be presented thus facilitating a more complete understanding of what is known and what must still be discovered. Alternatively, a detailed index in the final EA could help alleviate the problem. One or the other is necessary for a meaningful exposition of what is known.

As a basis upon which to develop some perspective on the overall quality of presentation, one report, Swisher site, was scanned intentially for internal consistency. This exercise revealed literally hundreds of inconsistencies and contradictions. If this report is representative of the entire group, the Environmental Assessments need a greal deal of hard work before final release. Details of this scanning effort are not provided. But they could be made available upon request should they be considered of value later.

In the interest of utility and effectiveness of the document, the reader should not be required to turn each assessment more than 90° in order to read the material. Some tables are upside down requiring a turn through 180°. It is also possible to find an illustration oriented with words right side up only to find a table on the next page printed upside down. Illustrations and tables in this text should be identically oriented.

Specific Comments

Three major assumptions pervade the geotechnical portions of this document. Because we are not in agreement with these assumptions in the EA, many of the conclusions regarding whether specified qualifying and disqualifying conditions are (or are not) met must also be called into question. Two of these assumptions have been questioned before by geologic and hydrologic review panels and in a comprehensive review (Robertson, May 6, 1983) by the USGS.

Assumption I

The assumption that the dense interiors of the basalt flows (hereafter, flow interiors) are of very low permeability may be incorrect despite supportive results obtained from hydraulic tests of most boreholes. Given the presence of cooling, flow emplacement, and tectonic fractures within the flow interiors (see figure 3-36 and accompanying discussion on pages 3-82 through 3-93), we believe such dense brittle rock-subjected to ongoing north-south compression throughout the Quaternary—will contain interconnected fracture porosity and permeability. Certainly, older fracture surfaces will also be altered, or filled with clay minerals, and some of these are undoubtedly sealed as stated in the EA; but, since tectonic compression has continued throughout the Quaternary (see pages 3-53 and 6-129), new fractures (not yet sealed by clay mineral alteration products) must continually form, and some of these are bound to be interconnected. The EA acknowledges the presence of fracture zones of high permeability in the flow interiors (page 3-86), but we do not believe that sufficient evidence is currently available to reach the stated conclusion that they will be few in number.

It is well-known that vertical boreholes cannot provide a representative test of high angle (i.e. near vertical) fractures, and thus such tests will greatly underestimate the fracture transmissivity of flow interiors. Indeed, one of a dozen or so cited tests of the flow interiors yielded an extremely high hydraulic conductivity of 10^{-4} meters per second (m/sec) (pages 3-85 and 3-86); this very permeable fracture (shear zone) is, however considered by the EA to be (page 3-86) "...a localized feature (as symbolically shown as feature E in figure 3-36) because at other borehole sites tested, this same stratigraphic zone possesses a much lower hydraulic conductivity typical of other basalt flow interiors studied."

Evidence for significant vertical hydraulic continuity between basalt flows of the region was presented in the USGS comprehensive review (Robertson, 1983) but not cited in the EA.

The correctness of the EA's assumption regarding the fracture transmissivity of the flow interiors is crucial not only to the question of what constitutes the accessible environment (see item II below), but also to the question of minability, which is discussed under item III.

Assumption II

The assumption that the accessible environment is 10 km, or so, down the hydraulic gradient is also in question. This assumption may not be valid under either pre- or post-repository conditions. Consider the following:

1. Natural upward head gradients apparently exist beneath the repository (pages 3-89 and 6-72; also table 6-5 on page 6-73). Further, strong geochemical evidence for such upward flow beneath the repository area is given in Robertson (1983).

2. New joints will form as a result of stress relief caused by shaft and repository construction (page 6-106). The EA acknowledges that these new fractures constitute avenues of ground-water flow and discusses at length the need for grout curtains to prevent such flow (see page 6-106 and figure 6-4 on page 6-105) around the periphery of the shaft.

3. Additional fracturing will also be induced after repository closure by stresses created during the thermal period (page 6-107); upward directed heads are also likely to be augmented during this period.

4. The grout curtains designed to reduce vertical flow in the new fractures adjacent to the shaft will, of course, be subjected to the ongoing horizontal tectonic stress for centuries to millenia after closure of the repository.

5. Basalt flows in the upper half of the basalt sequence (specifically, the Saddle Mountains and Wanapum Basalts) are currently utilized as aquifers (page 6-205) elsewhere in the Pasco Basin, and might well serve as aquifers above or adjacent to the repository in the future.

From the above five considerations (which are based on information given in the EA) and the vertical permeability concerns expressed above, we can only conclude that the accessible environment may well lie 2 km down the hydraulic gradient (that is at the boundary of the controlled area).

Assumption III

Mining a repository (page 6-184) in highly fractured rock overlain and underlain by aquifers containing water pressures of 1,400 pounds per square inch (psi) (page 6-201) probably will not be a routine task. The EA concludes (page 6-204 and 6-209) there are no known case histories of excavation in basalt to comparable depths, and acknowledges (page 6-184) that during construction a major inflow of water under high pressure is possible and constitutes "a potentially hazardous condition." Yet, the EA implies that all problems can be handled with established engineering practices.

The reasoning ignores the following:

1. Testing of rock permeability in small diameter holes driven ahead of working faces (in order to identify water-bearing fractures) may not yield information on the potential for massive rock bursts which could occur in the drafts due to 1,400 psi acting on highly fractured or brecciated portions of the basalt flows.

2. Similarly, short-term hydraulic tests in small diameter holes may not yield representative data pertinent to the potential for piping out of clay minerals lining fractures. Yet, such piping might occur over periods of days in the underground workings, with an attendant one or more order of magnitude increase in the discharge from selected fractures.

3. The tunneling literature cited in support of minability may be misleading. First, water inflow to most tunnels can gravity drain; it need not be lifted 3,000 ft to the surface. Second, most tunnels are not constructed thousands of feet below major aquifers. While high pressure and flows are frequently encountered in tunnels driven through fault zones beneath mountains, the volume of water in storage in these zones is generally small and therefore the flow rapidly decreases with time. Should permeable fracture zones be found in the repository (and not be groutable due to high discharge) there will not be a diminishing of flow; a flooding out of the drifts and shaft is a real possibility, despite the availability of several high-yield pumping stations.

4. There are documented cases of mines which have been flooded out after encountering fault zones; see, for example USGS Professional Paper 406 for documentation of such flooding in fractured carbonate rocks within the zone of saturation. The authors of the EA must examine the literature on mine flooding, and its causes, rather than tunneling case histories.

We agree that individually the potential mining issues have been encountered at other locations and have been successfully solved. However, the combination of rock stress, potential large volume of water inflow at high pressure, and high working temperatures in a potentially methane rich atmosphere is a unique problem, and the assumption that previous experiences will make solution of the problems simple is probably overly optimistic.

Reservations concerning the permeability of the flow interiors (item I) and minability (item III) have been expressed over the past 4-6 years by experienced earth scientists. And, the issue regarding proximity of the accessible environment (item II) is certainly implicit in the earlier critiques.

We are aware that concerted scientific effort is currently underway to address many of the unknowns which we have raised in connection with our EA review; however, the credibility of the document is considerably diminished without a full discussion of the uncertainties and unknowns.

Page 7, section 3, paragraph 2 - The statement that approximately 50 flows total 16,000 ft in thickness is incorrect. Only 10,000 ft have been drilled. A better statement would be "At least 50 flows occur in the upper half of the total basalt pile, which may be as thick as 16,000 ft." Moreover, at least 76 flows are known in the Pasco Basin (see pages 3-10 and 3-12).

Page 2-1, paragraph 3, line 6 - The viscosity was not low, as shown by calculations based on chemical composition. Lava spread widely and rapidly because of high eruption rate, not low viscosity (see Shaw and Swanson, 1970), Eruption and flow rates of flood basalts; Second Columbia River Basalt Symposium, Proceedings, page 217-299).

Same paragraph, lines 11-15 - The data were originally in metric form. They were then coverted into English units, and then back into metric. This leads to incorrect original estimates. The correct original values are 10-30 km^3 maximum volume, a few centimeters to more than 90 m range in thickness, with most between 20 and 35 m.

Page 2-5, paragraph 1 - Should mention that the entablature has more glass and smaller crystals than does the colonnade.

Page 2-8, line 1 - Younger age is not so well known. Say "between about 17 and 15 million years ago."

Page 2-8, paragraph 3, line 3 - Similar comment. Say "between about 15 and 13.5 million years."

Page 2-8, paragraph 3, line 5 - Dikes have been found for all members of the Wanapum and are shown on the maps open-filed by Swanson and others (1979a, 1981). A map not included in the reference list is the published color version of Swanson and others (1977). It has the same authorship and title as the 1977 map, has been updated, and is published as Misc. Geol. Invest. Map I-1139, 1980. This map shows dikes for all four members of the Wanapum Basalt.

Page 2-12, paragraph 3 - Blue Mountains are much more complicated than portrayed here. Numerous faults crosscut the uplift, and many local folds and warps occur on the flanks of the uplift.

Page 2-12, section 2.1.1.3, paragraph 1, last two lines - The statement is misleading about a few events. The earthquake swarm at Milton Freewater (along border) in 1936 was significant.

Page 2-15, section 2.1.2, paragraph 1, line 2 - What is meant by "low average rate of strain?"

Page 2-18, section 2.1.2, paragraph 1, line 11 - This statement could be misinterpreted. An average rate of 0.01 mm/yr is indeed slight, but if after 10,000 years the fault moves 100 mm, this is significant. The stick-slip versus creep situation should be explored.

Figure 2-17 - Location of Basalt Explorer not shown on map.

Figure 2-27 - It is unclear what is plotted, depth or elevation. To agree with the trough of the syncline, the plot must show elevation. State what is plotted in the text. Also note minor inconsistency in conversion between meters and feet for the 100 ft contour east of the trough with that elsewhere.

> This figure also raises another question. Was the same flow or flow contact encountered in each hole? If not, the contours do not necessarily reflect the dip of the basalt, as claimed in the text (page 2-51), but only the inclination of the basalt-sediment contact.

Figure 3-7 - Not the figure referred to on page 3-10, paragraph 1, last line.

Page 3-10, last paragraph - Change age as indicated in the comment on page 2-8.

Page 3-24, line 3 - The basis of the statement should be given.

Page 3-28, paragraph 4, line 1 - Change age as indicated in the comment on page 2-8.

Page 3-28, paragraph, 4, line 2-3 - Vents for Frenchman Springs occur only slightly east of Wallula Gap, hardly the "east side" of the plateau. Change text to read "linear vents on the east half of the Columbia Plateau."

Page 3-33, paragraph 5, line 3-4 - The reversed polarity is for a dike, not a flow, that is interpreted by Choiniere and Swanson to be perhaps the youngest, not the oldest, unit of Roza age.

Page 3-33, paragraph 5, line 5-7 - The inclinations from the boreholes could indicate tectonic tilting of the section. All inclinations (from Choiniere and Swanson, Van Alstine and Gillett, and Packer and Petty) fall within the range found by Rietman (1966), except for the dike of Choiniere and Swanson.

Pages 3-39 and 3-40 - The text should explain how the Ringold and Ellensburg are distinguished.

Page 3-43, paragraph 3 - The final EA should mention fanglomerate, since some is shown in figure 3-20 as part of the Ringold. It is unclear whether this is the fanglomerate referred to as the Plio-Pleistocene unit. The stratigraphic subdivisions and terminology should be consistent throughout the EA.

Page 3-45, paragraph 1, line 6 - The final EA should reference Richard Waitt's papers together with that of Baker. It is important to reference Waitt, for the possibility of frequent multiple floods bears on the integrity of the reference repository location (RRL).

Page 3-45, paragraph 4, line 6-8 - Many north and northwest trending faults crosscut folds. These are part of a regional right-lateral strike-slip fault system. These faults could provide vertical communication between basalt flows, and their presence should be acknowledged early.

Page 3-48, paragraph 1, line 4 - "the fault" should be described in the text. It is not mentioned previously. It should be shown on figure 3-23 in the final EA.

Page 3-49, paragraph 3, line 10-11 - These "small, monoclinal flexures" could be very significant, as they could be formed by faults such as those mentioned in comment on page 3-45. Their amplitudes, trends, and extents should be described.

Page 3-51, paragraph 3, line 7-9 - It is unclear if this is the fault suggested by Kienle and by Bond and others, (see first paragraph on this page). If not, the text should identify the fault.

Page 3-51, paragraph 4, line 6 - No "easterly trending segment of the Pasco syncline" is shown in figure 3-23.

Page 3-52, paragraph 1 - Should mention that this "alignment" is part of the regional Olympic Wallowa Lineament defined by Raisz.

Page 3-53, paragraph 2, line 6 - This is the first mention of northwest and northeast trending faults. They should be mentioned earlier, in a separate paragraph, pointing out their existence and their probable strike slip nature. See also the comment on page 3-45, paragraph 4.

Page 3-53, paragraph 3, line 1 - Deformation does not equate with vertical strain. Suggest rewording as follows: "Deformation along zones of tectonic weakness (folds and faults) in the central Columbia Plateau was established by at least middle Miocene."

Figure 3-24 - The magnitude 2.2 earthquake mentioned on page 3-54 (paragraph 3, last line) along the southern boundary of the RRL is not shown in figure 3-24.

Page 3-79, paragraph 4, line 3 - The Cold Creek "barrier" has not been previously mentioned. Reference figure 3-1 here and describe the nature of the barrier in the text.

Page 3-79, paragraph 4 - Indicates flow patterns conform to bedrock dip. This oversimplifies and disregards 3-dimensional aspects of flow.

Page 3-79, paragraph 6 - Available data would indicate both horizontal and vertical movement in the flow interiors and flow tops, not just horizontal flow in the latter and vertical in the former, as is indicated in this paragraph.

Page 3-81, paragraph 1 - Available data would seem to suggest that ground-water discharge from the main part of the reservation is into the Columbia River within the boundary of the Hanford Reservation, not south of the reservation as indicated. Given the extent of available data, it is very premature to give a value for a lateral hydraulic gradient in the basalts. It is quite reasonable to assume the gradient is variable, not a constant.

Page 3-86, paragraph 1 - If the test discussed in this paragraph involved the use of mud during drilling, then it is possible that permeability could be higher than values determined during testing by some unknown amount. The uncertainty in reported values of only 2 to 3 times is potentially very optimistic. Because no drilling fluid loss was actually measured during the work by Spane and Thomas, 1983, transference of the results of this test to any other testing results is not justified. This is particularly true for the interflows and interbeds.

Page 3-86, last paragraph - The consideration of the fracture zone as a localized feature is unreasonable. Many fracture zones occur in the basalt, and in most cases they are continuous into either a fault zone, crush zone, or flow-top or basal breccia. Such a zone, if encountered in a hole, should a priori be considered as communicating with a larger structure, either tectonic or stratigraphic in nature.

Page 3-88, paragraphs 4 and 5 - The validity of values for hydraulic conductivities discussed in the fourth and fifth paragraphs of this page have been questioned by the USGS and others because drilling fluid was present to some unknown degree during testing. Results shown to the USGS indicate that the value determined for permeability of a given flow top varied by several orders of magnitude depending on the analysis used. These facts should be mentioned in the EA.

Page 3-89, paragraph 2 - The validity of hydraulic heads measured during the drill and test program have been severely questioned by the USGS and others because of the potential effects of drilling and the short recovery time allowed to establish heads. This should also be mentioned in the EA. One would not necessarily expect a constant gradient across the Cold Creek Syncline. The use of head data alone to determine the amount of water movement as is done in this paragraph is inappropriate. Accepting the head data at face value would seem to indicate that vertical gradients are approximately equal to or one order of magnitude higher than horizontal gradients.

Page 3-93, paragraph 2 - The concept of the hydrologic system as being one with predominantly horizontal flow in the interflow zones and vertical flow only in the flow interiors cannot be totally accepted based on available data. One must consider that the flow is 3-dimensional everywhere. It is highly possible that horizontal and vertical permeabilities of the flow interior are nearly the same.

Page 3-101, table 3-8 - Of the 24 species of animals listed on this table 22 are burrowing or denning. Of concern is the loss of 46 acres of terrestial resource with the resulting loss and disruption of wildlife habitat. The spoil site will contain some 1,324,000 cu ft of basalt drilling fines. We recommend that these spoils be cupped with the stripped surface overburden and be allowed to return to native vegetation.

Page 3-103 - The bald eagle (Haliaeetus leucocephalus) and peregrine falcon (Falco peregrinus) were identified in the draft EA as occurring within the area boundaries. We remind the Department of Energy (DOE) of their responsibilities under Section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended and encourage them to review their actions and to consult with the U.S. Fish and Wildlife Service if the project may affect listed species.

The ferruginous hawk (Buteo regalis), Swainson's hawk (Buteo swainsoni), long-billed curlew (Numenius americanus), Columbia milk-vetch (Astragalus columbianus), and persistent sepal yellowcress (Rorippa calycina var. columbiae) were identified in the EA as occurring on the Hanford Reservation. These species are currently under review as "candidate" for inclusion to the list of threatened or endangered species. As candidates, these species do not have any legal protection under the ESA. However, the cooperation and assistance of all Federal agencies to protect and even enhance populations of candidate species may preclude the need for their future listing. We would encourage DOE to do their utmost to insure that these species are protected from any adverse impact resulting from this proposal.

Page 4-8, last paragraph - The statement that "Existing regional wells outside the Hanford Site that are suitable for monitoring also have been identified and integrated into the existing U.S. Geological Survey regional groundwater monitoring network" is misleading. It is true that these wells have been identified by the USGS, but they have only been measured once. No plans presently exist to remeasure water levels in these wells. In addition, the regional ground-water monitoring network refers to mass water-level measurements being made by the USGS for the Columbia Plateau Regional Aquifer System Analysis Project, and those measurements end this year.

Page 5-40, Surface-water impacts - The statement that there are "...no perennial surface streams in the vicinity of the reference repository location" is only correct if one disregards the Columbia River. If one accepts the Columbia as a perennial stream, then one cannot automatically reach the conclusion that "...effects on the surface-water hydrology are expected to be minimal" unless one has already reached the conclusion that radioactive waste cannot reach the Columbia River in cncentrations high enough to degrade the river.

Page 5-40, Ground-water impacts - The conclusion that "...significant alteration of the hydrologic setting is not expected since the shaft would be cased and grouted" may be true for the long term, but not necessarily for the short term which could be measured in years. Direction and/or rate of ground-water flow could conceivably be altered for short timeframes because of shaft construction activities.

Page 6-43, section 6.2.1.7.11, paragraph 2 - The purpose of the geohydrologic work at Hanford is to collect the necessary data to evaluate this disqualifying condition. Very little data are available at this time and based on this information it should be stated that this evidence does not support a finding that the site is disqualified. Level one should be the finding. A level two rating for this condition is not warranted.

Page 6-43, last paragraph - The conclusion stated here assumed that radionuclides will not migrate offsite at concentration levels high enough to affect the nearby ground-water supply or the Columbia River. This assumption cannot be supported or rejected on available data.

Page 6-44, paragraph 1 - The statement that ground-water current existing at the depth of the proposed repository is not suitable for human consumption or crop irrigation is not totally accurate. It is used for irrigation without treatment in other areas of the Columbia Plateau.

Page 6-63, last sentence, paragraph 1 - A determination of median preemplacement ground-water travel times is not possible with the limitations of present data. The first three sentences of the last paragraph under section 6.4.1.1.3 describe the existing situation accurately and should be kept in mind when considering the presence of favorable conditions.

Page 6-68, paragraph 3, sentences 2 and 3 - These two sentences are very misleading. They indicate that preliminary values of spatial permeability are available for flow tops, interior, and interbeds when in fact very little is known about horizontal permeability and water levels, and vertical permeability and effective porosity have not been measured for any of the units. No reasonable ground-water flow model is known to have been developed.

Page 6-69, second to last paragraph - Earlier concepts of the hydraulic head distribution for the reference repository indicated that head declined in the vertical direction from the Wanapum to the upper Grande Ronde and then increased. The results from the nested piezometers at DC 19, 20, and 22 indicate that flow is upward from the deep basalts to the uppermost Wanapum. Therefore, earlier concepts are, in fact, not being supported.

Also, by combining head data from the drill and test program with that for DC 19, 20, and 22 for each major flow top, no straightforward pattern of flow emerges.

Page 6-70, first paragraph following requirements for Favorable Conditions - Available data indicate an upward and predominantly vertical hydraulic gradient within the Reference Repository Location rather than a downward or predominantly horizontal gradient as stated or implied. Because of this, the site is unfavorable with regard to item (ii).

Page 6-70, paragraph 3, first sentence - As mentioned previously, flow in the basalts is 3-dimensional, not essentially 2-dimensional as stated.

Page 6-71 - Published reports of the USGS that describe ground-water models of selected areas in the Columbia Plateau give values for vertical permeability of basalt interiors ranging between 3.5×10^{-2} ft/day to 1.7 ft/day. These values are far higher than those described in this section, suggesting that (1) point values for horizontal permeability measured at Hanford are far too low, (2) there is great variability in vertical permeability values, (3) the concept that the ratio of horizontal to vertical permeability is about 2 to 1 is in error, (4) vertical movement across flow interiors is controlled by phenomena not yet tested at Hanford, or (5) some interaction of all the four items above is possible. Statements that the vertical permeabilities of the flow interior are very low should be reevaluated given the available data for the Columbia River basalts as a whole.

Page 6-71, last paragraph - Presentation of the permeability values in this paragraph has been made without the necessary qualifying remarks. This entire set of data has been severely questioned in the USGS review of the Site Characterization Report (SCR) and during the followup visit to Hanford in June 1983.

Page 6-72, first paragraph - Existing head data suggest that the vertical gradient is upward from the Umtanum to the Priest Rapids and downward from the Mabton to the Priest Rapids. Thus, ground-water movement in the basalts at the reference repository location is predominantly upward over most of the basalt and for several hundred feet above the suggested repository depth. Once again, the predominant hydraulic gradient is actually in the vertical direction (10^{-3}) not in the horizontal (10^{-4}).

Page 6-72, paragraph 2 - The picture of ground-water movement presented in the first part of this paragraph appears to be contradicted in the last part. In fact, the only head data that indicate the direction of vertical movement in the basalts are those for the piezometers at DC-19, 20, and 22. No other unquestioned data exist at this time. The pattern of flow most supported by the available data is one of downward near the anticlines (including the deep basalts) and upward flow near the river. Since the direction of water movement in the middle zone and deep basalts is upward at the Reference Repository it appears that upward flow actually begins west of the repository location. The hydraulic head data gathered during the drill-and-test period of data collection presented a very confusing picture with regard to the vertical and horizontal movement of water.

Page 6-76, section 6.3.1.1.8, paragraph 1 - The conclusions in this paragraph are not necessarily well founded. Initiation of deep (Grande Ronde) ground-water pumpage in the upper Cold Creek or Dry Creek Synclines could potentially alter existing hydraulic gradients significantly and thus flow direction and flow rates. At the present time, there is nothing to preclude the construction of irrigation wells to this depth. Other human activities such as damming the Columbia River or conversely, removing dams, could alter ground-water movement.

Page 6-77, top of page - Inclusion of travel time through the flow interior at the reference repository would conceivably increase the total travel time to the accessible environment, but the total time could still be less than presently predicted given the lack of data for such predictions.

Page 6-77, paragraph 1 - As stated previously, the present and possible activities of man in and surrounding the Hanford area can potentially alter hydraulic gradients in the Reference Repository Location in the foreseeable future. Conclusions given in this paragraph are not appropriate.

Page 6-77 - Regarding the statement that "...deep basalt ground-waters existing along likely ground-water flow paths from the host rock to the accessible environment contain natural chemical constituents that would require removal or treatment before these waters would be suitable for human consumption and crop irrigation"—it is true that sodium and salinity concentrations are high, but waters with similar concentrations are being used successfully for crop irrigation in other areas of the plateau. Normal well construction techniques result in considerable mixing of the Grande Ronde waters, thus reducing potential problems further.

Page 6-79, section 6.3.1.1.11 - Available data are insufficient to conclude much of anything with regard to ground-water travel time or direction. Most of the data used for existing predictions have been strongly questioned by the USGS in the past. The

distribution of effective porosity and vertical permeability is totally unknown. No tests have been made for vertical hydraulic conductivity. The two tests for measuring effective porosity were of questionable validity. Essentially all the data for horizontal permeability were determined by testing and drill hole data, all of which have been previously questioned. The 3-dimensional flow field is not yet established in the Reference Repository Location or the rest of the Hanford Reservation.

Page 6-82, paragraph 1 - The work of the interagency hydrologic working group has only one objective and that is to resolve hydrologic differences that exist in the conceptualization and definition of the ground-water flow system of the Pasco Basin. The group is not directly involved in generating any information for site characterization, including ground-water travel times. The document should reflect this.

Page 6-85, section 6.3.1.1.12 - Based on previous comments, the major conclusions are believed to be too positive and in some areas inaccurate.

Page 6-86 - The statement that an extensive data base exists on which to base major conclusions given on pages 6-85 and 6-86 seems very inappropriate. In fact, little is known about the spatial values that are needed to characterize the site with regard to ground-water flow rate and direction. The general lack of data is actually identified later in the same paragraph in the last half of page 6-86 in which specific uncertainties are listed.

Page 6-129, paragraph 3, lines 9-11 - Deformation by definition "occurs" in synclines, because a syncline is a product of deformation. Is "faulting" rather than "deformation" what is meant here?

Page 6-131, paragraph 2, lines 1-2 - It is assumed that this is the Melton-Freewater earthquake sequence. It has not been located well, but best locations place it west of the ill-defined Blue Mountains front. It was associated with the Hite fault.

Page 6-132, paragraph 1 - Again the "front" of the Blue Mountains is emphasized, and one of two possible nodal planes is accepted so as to implicate the Hite fault. This is all subjective and should be modified to reflect uncertainty regarding location and association with the Hite fault, and, for that matter, with the "Blue Mountains front." An equally (or more likely) possibility is that the earthquake was generated along a northwest trending right-lateral fault beneath the Walla Walla basin.

Page 6-132, paragraph 3, line 2 - "Since the Miocene" means in the last 5 million years (after the Miocene). Is that what is intended? Or does the author mean to include all time since about 15 million years ago?

Page 6-132, paragraph 3, lines 9-11 - $14/5 \times 10^6 = .00028$ percent; $100/5 \times 10^6 = .002$ percent. We believe this is a very short period of time indeed for judging expected future seismic patterns.

Page 6-136, paragraph 2, lines 10-14 What is the evidence for recurrence rates between 10,000 and 100,000 years? Such evidence has not been given earlier in the report, and it is not obvious that any evidence exists. Also, in line 12 by "large, moderate earthquakes" should be defined.

Page 6-136, paragraph 3, lines 4-6 - Deformation has occurred in the synclinal trough; otherwise there would be no syncline. Also, the structural analysis referred to dealt only with faults associated with folds, and not with crosscutting faults of later vintage, such

as the N to NNW trending right-lateral faults so common on the western plateau. Such faults cut both anticlines and synclines and are seemingly unrelated to any fold process. This is the kind of fault that is most likely to occur in the reference repository location, and its presence cannot be predicted.

Pages 6-135 and 6-136, section 6.3.1.7.10 - The entire section is vague because the reader doesn't know what is meant by "small," "moderate," and "large" earthquakes. The terms require definition.

Page 6-265 - The assumption that the principal groundwater flow path is through a basalt flow top directly overlying the repository is very restrictive and might not be realistic. The Hanford Environmental Assessment should contain some analysis of other possible pathways, such as are described in chapter 3, at least for the sake of comparison.

Page 6-266, paragraph 1 - The statement that "...there are enough preliminary transmissivity data from the deep basalt beneath the Hanford site to develop some statistics and infer a governing lognormal probability distribution" is not warranted. In fact, there are only three test holes drilled under conditions that would allow one to accept the values determined for permeability from those holes as representative of point measurements. These test holes are DC-19, 20, and 22. All the other information is suspect because of possible mud invasion. This means that there are only three values of permeability for any horizon, hardly enough to develop some statistics and infer a reasonable governing probability distribution. Since a probability distribution can only be inferred, and since values for hydraulic head and effective porosity are not even as well known, the rest of the discussion on pages 6-266, 6-267, and 6-268 regarding travel time is without much scientific foundation.

Page 7-6, Table 7-1 - Assignment of a grade P (present) Hanford for Favorable Condition (1) 10,000 year travel time is questionable.

Page 7-7, Table 7-1 - Assignment of grade P (present) for Favorable Condition (ii) downward or horizontal gradient is wrong. Strong evidence exists for upward-directed hydraulic gradients at this site.

Page 7-8, Table 7-1 - Assignment of grade NP (not present) for Potentially Adverse Condition 2 ground-water sources is misleading; it should be grade P. When mixed with shallower ground waters, the repository depth waters would be potable.

Page 7-9, Table 7-1 - Assignment of grade 1(a) for Disqualifying Conditions - 1,000 year travel time is questionable.

Page 7-20, Favorable condition no. 3 - Specifically cites Hanford basalt contains glass. If devitrified, it would form smectite and thus enhance absorption. However, this process would probably also lead to microcracks and could increase the hydraulic transmissivity.

Page 7-24, Table 7-3 - Assignment of grade NP (not present) for PAC (Potentially Adverse Condition) (1) Rock conditions-averaging measures is disputed.

Page 7-41, Table 7-7 - Assignment of grade P (present) for the FC (future tectonic processes, 1 out of 10,000) is highly questionable.

Page 7-47, Table 7-8 Assignment of grade 1(a) for Disqualifying Condition is highly questionable. Groundwater is also a mineral resources that can be tapped in or outside the controlled area. An assignment of grade 2(a) is in order.

Page 7-101, Table 7-17 - Assignment of grade NP (not present) for PAC's 2 and 3 is highly questionable.

Page 7-102, Table 7-17 - Assignment of grade 1(a) for the DC is questionable.

Page 7-108, Table 7-18 Assignment of grade NP (not present) for the PAC is questionable.

Page 7-109, Table 7-18 - Assignment of grade 1(a) for the DC is questionable.