FINAL REPORT

MERIT PANEL REVIEW OF THE C-TANK FARM CLOSURE PERFORMANCE ASSESSMENT

by

David Kosson, Ph.D., Panel Coordinator
Consortium for Risk Evaluation with Stakeholder Participation (CRESP)
Professor and Chair of Civil and Environmental Engineering
Vanderbilt University
Nashville, TN

Helen Grogan, Ph.D.,
Cascade Scientific
Bend, OR

Kathryn Higley, Ph.D., CHP, Associate Professor
Department of Nuclear Engineering and Radiation Health Physics
Oregon State University,
Corvallis, OR

Randy Maddalena, Ph.D.
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
Berkeley, CA.

Chris Whipple, Ph.D., Principal
ENVIRON International Corp.
Emeryville, CA.

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EXECUTIVE SUMMARY

A merit panel was convened by CH2M-Hill Hanford Group Inc. (CH2M-Hill), with concurrence of the U.S. Department of Energy (DOE) and the State of Washington Department of Ecology, to review the *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE, 2003; Preliminary Performance Assessment). Waste Management Area C consists of the waste storage tanks (C-Tank Farm), associated waste transfer and processing equipment, and vadose zone contamination from past waste leaks or releases in the vicinity of the storage tanks. The goals of the Preliminary Performance Assessment are to evaluate risks to human health through potential exposure pathways to contaminants remaining in Waste Management Area C after closure and to provide insights into approaches for maintaining those risks below acceptable levels essentially in perpetuity. The Preliminary Performance Assessment does not include evaluation of risks (i) to worker, the public or ecology resulting from the activities necessary to achieve the closure configuration (e.g., removing recovered waste, placing overlying barriers to infiltration and intrusion at the site), (ii) from treatment and disposal of recovered waste, (iii) to ecology after closure. In addition, the Preliminary Performance Assessment does not adequately put closure of Waste Management Area C in context with contamination and risks from neighboring contaminated areas and existing groundwater contamination in close vicinity.

The evaluation and balancing of these additional risks and other factors are a necessary part of overall risk management and decision making, but beyond the scope of the Preliminary Performance Assessment.

The specific objectives of this Merit Panel review are

1. to review the Preliminary Performance Assessment, evaluating (i) if all processes were appropriately considered that may result in future human health impacts from the tank farm after closure, and (ii) if the Preliminary Performance Assessment is an effective risk communication vehicle; and,

2. to provide recommendations for future performance assessments.

These objectives were achieved by review of the Preliminary Performance Assessment, numerous additional related documents, input solicited from the U.S. Department of Energy, Washington State Department of Ecology, tribal nations, the Hanford Advisory Board, U.S. Environmental Protection Agency, and the public. Technical clarifications also were provided in response to Panel questions by CH2M-Hill throughout the review.

The Merit Panel recognizes that the Preliminary Performance Assessment was prepared early in the closure process, in part to help guide the closure process. The Preliminary Performance Assessment obviously reflects an enormous effort on the part of CH2M-Hill and others. They are to be commended for their willingness to solicit review and input at this early stage in the process when both information and processes are in a state of flux. The Panel is sensitive to the potentially confusing and sometimes conflicting regulatory environment in which this assessment must be conducted. None the less, the Panel thinks that certain aspects of the Preliminary Performance Assessment can be revised in order to more directly meet its stated goals.

As a result of the preliminary nature of the Preliminary Performance Assessment, there are many uncertainties about the contaminant inventory and characteristics within Waste Management Area C and the final closure configuration. These uncertainties will be reduced as the closure process progresses. There are uncertainties about contaminant transport and the closure system performance that can be reduced, although not eliminated, through additional field and laboratory measurements. However, there are substantial uncertainties about the closure system performance, contaminant transport and human health risks that are not reducible. The greatest irreducible uncertainty is that associated with future human activities that may potentially disrupt the closure system, alter groundwater flow or direction, or lead to human contact with contaminated vadose zone materials or groundwater. Additional uncertainty that is irreducible beyond a limited extent, is knowledge of heterogeneous properties and processes that occur at various spatial scales in the subsurface and future climate conditions. It is in the context of the uncertainties described above that the Preliminary Performance Assessment uses engineering models based on conceptual models that contain assumptions and simplifications to evaluate long-term health risk as a consequence of potential human exposure. Model sensitivity analysis and parameter sensitivity is the tool that usually is used to evaluate the relative importance and implications of these uncertainties.

Below is a list of the Merit Panel's primary concerns and recommendations regarding the Preliminary Performance Assessment as a result of this review: The Panel thinks, that because of the nature of many of the recommendations, it is not possible to discern in advance whether the impact of implementing the recommendations will result in overall increased or decreased estimates of risk. The Panel does think that implementation of these recommendations will provide improved clarity and credibility to the risk evaluation process and subsequent decisions based on the analysis.

1. The Preliminary Performance Assessment is not written in a manner that clearly and effectively communicates the objectives and results of the evaluation to a general audience or to a technical audience. The assessment's objectives, methodology, assumptions, results and uncertainties should be described within the main body of the report; and, detailed information necessary for auditing and replication (when necessary for verification or subsequent updating as new information becomes available) should be placed in appendices. The current Preliminary Performance Assessment lacks such organization, contains inconsistent levels of detail, does not contain sufficient information or clarity for a knowledgeable technical reviewer to replicate calculations or to audit the results, and needs technical editing to improve the clarity of the important messages being communicated. The relationship of the Preliminary Performance Assessment to other risk evaluations, closure design criteria and decision processes also should be clearly stated in the document.

2. The Preliminary Performance Assessment should be evaluated for consistency with potential future closure requirements under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Although the closure process is being carried out under the Resource Conservation and Recovery Act (RCRA), DOE and Ecology requirements, Waste Management Area C is also part of the Central Plateau Area of the Hanford Site, which will likely require closure under CERCLA in the future. It is not clear that the current Preliminary Performance Assessment fully considers potential requirements under CERCLA. For example, it appears that CERCLA closure would require a maximum dose rate of 15 mrem/yr, while current planning under DOE orders is based on 25 mrem/yr for the C-Farm closure (*PPA*, p. 1-16). However, the Hanford-wide all-pathway dose limit is 100 mrem/yr (*PPA*, Table 1-2) which is significantly above the CERCLA closure limit.

3. The criteria and rationale for selecting specific models (e.g., for contaminant release, transport through the vadose zone, and transport through groundwater) should be clearly defined. Model uncertainty (e.g., physics, chemistry and biology), parameter uncertainty, and underlying assumptions should be clearly stated. Uncertainty propagation should be achievable throughout the risk evaluation process. Previous use, in and of itself, is insufficient justification for model selection. Evaluation of model sensitivity and parameter uncertainty should be presented.

4. The Preliminary Performance Assessment should evaluate additional physical failure modes and their implications for contaminant release and exposure. These evaluations should recognize that (i) engineered materials are unlikely to deteriorate in such a manner that they resemble the sands and fill material surrounding the tanks, (ii) deterioration is likely to be progressive, not instantaneous at some time in the future, and (iii) surface barriers (i.e., caps) are unlikely to retain their integrity with respect to hydraulic properties for 500 years. For example, if the tanks are filled with granular materials that have appreciable hydraulic conductivity and porosity, and the tank shell remains intact, a bathtub effect may result that places significant hydraulic head over the waste residuals in the tank, potentially enhancing their release. Alternatively, if a low permeability and porosity grout is used to fill the tank, then release from the residuals remaining in the tank may be reduced. However, in this case, infiltration may be diverted away from the tank's footprint indefinitely, creating an umbrella effect, and enhancing release and transport of contaminants remaining in the vadose zone after closure because of the increase in water flux through areas around the tanks.

5. The assessment of contaminant release from residual waste in the closed tanks, ancillary material and contamination currently in the vadose zone should be based on models that reflect controlling release mechanisms determined through future characterizations efforts. The Preliminary Performance Assessment illustrates the significance of either relatively fast or slow release of the contaminant inventory remaining after closure, but lacks sufficient characterization data to determine the controlling mechanisms or rates and does not adequately reflect the most likely

controlling release mechanisms. Contaminant release will most likely be controlled by one or more of the following mechanisms: (i) dissolution of sparingly soluble phases, (ii) diffusion through grout and tank shell concrete matrices with slow rates of moisture exchange at the external boundary, resulting in boundary conditions different than assumed in the current analysis (e.g., a non-zero boundary condition would result), or (iii) slow desorption phenomena. These processes also typically will not scale linearly with contaminant inventory.

6. Evaluation of contaminant transport to and with the groundwater should include more thorough discussion of model uncertainties and sensitivity analysis. The direction and travel times to the Columbia River for contaminants released from Waste Management Area C depend strongly on when contaminants reach the groundwater underlying the site and other site-wide activities that impact groundwater flow. For example, current travel times to the Columbia River are estimated at approximately 50 years because of site-wide activities, while travel times under conditions that existed before site activities are estimated at approximately 1000 years. Additional evaluation and explanation of the potential for fast flow paths is needed, especially given the history of modeling at the Hanford site where preliminary models unintentionally excluded important processes and consequently overestimated contaminant travel times. Results should present the location and magnitude of peak groundwater concentrations as a function of time, in addition to the concentration as a function of time at the Waste Management Area C and Central Plateau boundaries.

7. Exposure assessment should include additional sensitivity analysis and present the contributions of individual pathways to dose and risk for each scenario examined. Recommendations presented above that affect contaminant release and transport will have both positive and negative impacts on exposure. Recognizing that exposure assessment scenarios are hypothetical constructs of future human behavior, and human behavior is highly variable, the specific scenarios should be viewed as example cases of individual exposure, but sufficient information should be provided for reviewers to construct alternative exposure scenarios, that may include or exclude specific pathways. This approach should apply to exposures that occur through groundwater use (direct and indirect) and intruder scenarios.

8. The Preliminary Performance Assessment should estimate the quantity of contaminated material remaining in the subsurface, which if exposed by an inadvertent intruder would cause unacceptable risk. This quantity should be presented as a function of time after closure. The risk from component pathways also should be presented. The most significant risks identified in the analysis appear to be associated with the inadvertent intruder scenario, particularly if intrusion occurs soon after closure. DOE guidance is cited to support the assumption that no intrusion occurs for 500 years, but no supporting technical basis for this assumption is provided. Currently, the Preliminary Performance Assessment focuses on a well drilling scenario to result in direct and indirect exposure to contaminated materials remaining below surface barriers after closure. It would be very helpful to discuss whether the surface barrier could be

detected by an inadvertent intruder and whether it could prevent well drilling, particularly during the period after closure when the greatest hazard remains (e.g., during the first 100 years after closure). If the closure barrier is designed to dissuade drilling, then the likelihood of this scenario occurring is diminished. However, given the uncertainty of future human activities, the potential for some aggressive action to expose and disperse contaminated material remaining below the closure barrier is possible.

9. Ecological risk has been explicitly excluded from the Preliminary Performance Assessment, but it is the view of the Panel that preliminary work should be started in this area, including, at a minimum, an examination of potential radiological impacts to biota using the current guidance of the Department of Energy.

10. The Preliminary Performance Assessment should include estimates of the upper, lower and central tendency of contaminant release, peak contaminant concentrations in groundwater at important geographic boundaries, and human health risk from individual pathways. Use and presentation of only "conservative" assumptions that include safety factors at multiple levels, distorts understanding of risk by only providing an estimate of maximum risk. Understanding the range of risk presented by different scenarios and exposure pathways provides a clearer understanding of uncertainties in the evaluation.

11. In the Panel's view, there are elements that whether from lack of documentation or their absence caused the total analysis not to provide an upper bounding estimate of risk. These aspects include:

    - the assumption that the vadose zone is homogeneous and uniform within defined stratigraphic layers, with no fast-flow pathways,
    - the failure to consider episodic precipitation events (including multiyear periods of high precipitation) that could result in higher-than-estimated recharge rates (Section 6.4 of the Preliminary Performance Assessment indicates that the vadose zone flow and transport model considered transient recharge rates. How this was considered is not clear.),
    - the assumption that the surface barrier will remain intact and can result in recharge rates one-seventh of those of the natural system for 500 years,
    - the failure to consider an inadvertent intruder's borehole as a fast pathway for waste to move to ground water,
    - the failure to consider tank failure modes such as "bathtubbing" that could result in release of contaminants in a pulse, tank integrity over periods greater than 50 years would divert infiltration (i.e., "umbrella effect"), increasing the rate of transport of contaminants already in the vadose zone to groundwater, or that tank failures before 50 years would lead to transport of residual wastes while recharge is high.

- the use of ground water concentrations averaged over the fence line as exposure concentrations for the groundwater pathway and as input to the streamtube groundwater model.

For these reasons, the Panel does not agree that the current analysis is necessarily conservative.

Many of these comments reflect limitations of the models and data that are apparently known to the Preliminary Performance Assessment team. Section 7 of the Preliminary Performance Assessment, and Table 7-6 in particular, identify and evaluate the relative importance of modal and data limitations. The table also describes the Preliminary Performance Assessment team's estimates of the feasibility of improvements to the analysis as it goes forward. This is a constructive and useful component of the preliminary analysis. However, the technical basis for these suggested improvements is difficult to identify in the main text of the report.

The Merit Panel also recommends that insights gained through the Preliminary Performance Assessment be used to consider how the closure and future performance assessments could be improved. For example, the following actions at Waste Management Area C should be evaluated as a result of the Preliminary Performance Assessment:

1. Installation of a temporary barrier to minimize infiltration at Waste Management Area C as soon as possible. Infiltration is the primary mechanism that results in transport of contaminants in the vadose zone to groundwater. The amount of infiltration that will occur over the 45 years projected until closure is completed exceeds the amount of infiltration estimated for the subsequent 500 years. Early application of measures to minimize infiltration may greatly reduce or delay the release of contaminants to groundwater. This early action also should be evaluated for other waste management areas.

2. The use of Waste Management Area C as a controlled experiment to gain insights to improve closure of other tank farms. The current plans and commitments will require closure of all the tanks without allowing for monitoring and feedback from experience. Waste Management Area C can serve as a prototype closure, and with appropriate characterization and monitoring during and after closure, serve to substantially reduce uncertainty and thereby improve the assessments for this and other waste management areas with similar characteristics. This will require completing physical closure of Waste Management Area C before closure of the tank farms and with enough time to gain monitoring data that can aid in the decisions for the other cases.

INTRODUCTION

An independent review panel (the Panel) has been assembled by CH2M-Hill Hanford Group to provide early independent technical input into the risk evaluation process to be used for closure of high level waste tank farms at the Hanford site. This input is achieved through review of the initial (revision 0) *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE, 2003; Preliminary Performance Assessment) with additional background and detailed supporting information provided by related documents. The Preliminary Performance Assessment for Waste Management Area C was selected as the focus for this review because it is the first performance assessment associated with high level waste tank farm closure at the Hanford Site, and therefore, it is anticipated to serve as a template for future performance assessments that will influence the closure process for multiple tank farms. This document provides the results of the Preliminary Performance Assessment review by the Panel and related recommendations. The Panel was selected by CH2M-Hill Hanford Group with agreement on membership by the Washington State Department of Ecology.

The specific objectives of this review are to

1. review the Preliminary Performance Assessment, evaluating (i) if all processes were appropriately considered that may result in future human health impacts from the tank farm after closure, and (ii) if the Preliminary Performance Assessment is an effective risk communication vehicle; and,

2. provide recommendations for future performance assessments and tank farm closure activities.

The scope of this review is limited by the scope of the Preliminary Performance Assessment and other factors. The scope of the Preliminary Performance Assessment is confined to impacts from sources of contaminants originating within the footprint of Waste Management Area C (all tanks, ancillary equipment, other disposal activities within the closure area footprint, past spills, tank leakage, current contamination within the vadose zone, and associated groundwater plumes). The Preliminary Performance Assessment focuses on potential human health risks after closure, based on assumptions about the closure configuration, institutional control, land use and specific activities that result in human exposures to contaminants. The Preliminary Performance Assessment does not include

1. Human health risks as a consequence of activities required to achieve the designated closure end-state (e.g., worker risks, risks from disposal of waste processing products, risks from emissions during processes, processing facility closure, waste transportation risk);

2. Ecological risks resulting from the closure end-state or activities necessary to achieve the end-state; or,

3. Integration of risks from Waste Management Area C closure with restoration activity or end-state residual risks from other wastes or contaminated areas within the Hanford site.

These risks are not addressed in the Preliminary Performance Assessment and are therefore beyond the scope of this review. However, the Panel feels strongly that evaluation and integration of these risks are important components of risk management decisions and that a closure done without integrating these risks would be contrary to good risk management practice.

This review was achieved through review of the Preliminary Performance Assessment and supporting documents, and input provided by the Department of Energy- Office of River Protection, State of Washington Department of Ecology, tribal comments and public comments primarily received during a public session held on January 14, 2004 in Richland, WA. Clarifications were received during the review period from CH2M-Hill Hanford Group in response to questions from the Panel. The Panel held several conference calls (each typically lasting several hours) and exchanged comments via e-mail after the initial review session to discuss comments and recommendations.

The Panel did not carry out detailed review of model implementation (e.g., code verification, parameter verification, etc.), input data quality assurance, error checking or technical editing. The Panel also was constrained by the limited time available to complete this review.

The intended audiences for this review are (i) technical personnel responsible for implementing revisions to the current Preliminary Performance Assessment and future related performance assessments, and (ii) DOE, regulators, site contractors, tribal nations and other stakeholders who rely on the Preliminary Performance Assessment as part of risk management decisions.

This report reflects a consensus view of the Panel.

BACKGROUND ON WASTE MANAGEMENT AREA C AND CLOSURE REQUIREMENTS

Waste Management Area C is an approximately 220 x 160 m area that includes the C-Tank Farm along with associated transfer lines and ancillary equipment. The C-Tank Farm includes 12 primary tanks and four secondary tanks, all located below the ground surface. Primary tanks are 23 m in diameter, 4.9 m deep and each have a capacity of 2 million liters. Secondary tanks are 6.1 m in diameter, 5.2 m deep and each have a capacity of 208,000 liters. During more than 50 years of site operations, the tanks received wastes from a wide range of nuclear materials processing activities. Leaks have occurred from waste transfer activities (spills to the ground surface and from buried transfer lines) and from within the tanks.

Waste Management Area C is located within the 200-East Area of the Central Plateau at the Hanford site, and is one of seven waste management areas within the Central Plateau. Each waste management area includes one or more tank farms, transfer lines, ancillary equipment, and some include past near surface waste disposal locations. Within these seven waste management areas, there are 177 large underground storage tanks grouped into 18 tank farms. In addition, there are many nuclear materials processing areas within the Central Plateau. Thus, there are many contributors to current and potential future contaminants in the vadose zone and groundwater underlying the Central Plateau.

Closure of Waste Management Area C is governed under a complex set of regulatory requirements originating primarily from the State of Washington, US EPA under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Cleanup and Liability Act (CERCLA), and DOE orders. Additional requirements, including schedule considerations, are established under the Hanford Federal Facility Agreement and Consent Order (FFACO). All of these regulations must be considered as part of the closure process. Washington State Department of Ecology is the lead regulatory agency for Waste Management Area C based on its authority under RCRA. However, final closure of the Central Plateau (to occur after closure of the individual waste management areas) currently is governed under CERCLA, for which US EPA is the lead regulatory agency. This situation creates the possibility that adequate closure under RCRA may not be considered adequate under CERCLA unless criteria originating from both sets of regulations are considered. For example, closure under CERCLA may require a maximum dose rate of 15 mrem/yr while the current closure under DOE orders is based on a maximum allowable dose rate of 25 mrem/yr to someone living on or near the site in the future. In general terms, the goal of closure of each waste management area is to create an end-state (final physical configuration) that is protective of human health and the environment for the time periods over which the remaining hazards will persist and consistent with planned or anticipated land uses.

The general approach to the Waste Management Area C being pursued is to (i) remove waste materials contained in the primary and secondary tanks to the greatest extent practical, (ii) fill the emptied tanks with material to prevent future tank collapse (to avoid surface subsidence) and minimize water contact with any remaining waste, and (iii) install a surface barrier (cap) to minimize infiltration through, and potentially prevent inadvertent intrusion into, contaminants remaining in the vadose zone or subsurface structures. DOE orders require the development of a performance assessment as part of the closure process to evaluate the efficacy of the proposed closure end-state. The Preliminary Performance Assessment was prepared to meet applicable DOE orders and either fulfill or serve as the foundation for fulfilling the Washington State Department of Ecology requirements for a risk assessment as part of the closure process. According to the Preliminary Performance Assessment (PPA, p. 1-1):

> This preliminary performance assessment examines the long-term environmental and human health effects of the planned closure of the Waste Management Area C (WMA C), which is generally coincident with the 241-C tank farm area (C farm), to support the issuance of the *Tier 1 Closure Plan for Waste Management Area C, Hanford, Washington* (DOE-ORP-2003-17) and Waste Incidental to Repossessing petition as required by the Department of Energy's (DOE's) order on *Radioactive Waste Management* (DOE O 435.1). This document is prepared early in

> the life of the project, before any waste retrieval to support closure has been performed. Therefore the emphasis of this document is to present methods, procedures, existing data, and analysis approaches.

However, the Panel believes that the purpose of the Preliminary Performance Assessment should include an evaluation of the efficacy of the proposed approach, identify knowledge gaps, and clarify specific end-state design criteria. The Preliminary Performance Assessment may also suggest alternative approaches to achieve the desired protection of human health and the environment.

REVIEW COMMENTS AND RECOMMENDATIONS

RISK COMMUNICATION AND PROCESS TRANSPARENCY

The Panel thinks that consideration of risk communication and process transparency is of paramount importance to providing well understood and credible risk evaluations. These considerations should be reflected in definition of the goals and limitations for the Preliminary Performance Assessment. They also should be reflected in the Preliminary Performance Assessment organization and content.

Definition of the Preliminary Performance Assessment Goals and Limitations

The Preliminary Performance Assessment lacks an adequate description of the specific goals, objectives, bounding constraints and limitations of the process for the Preliminary Performance Assessment (Section 1.1 Purpose is insufficient). The Panel thinks that a specific statement should be included clarifying

- The relationship of the Preliminary Performance Assessment to other risk evaluations being carried out as part of the closure decision process
- The relationship of the Preliminary Performance Assessment to specific decisions that will rely on the outcome of the Preliminary Performance Assessment (e.g., regulatory, remedy timetable, monitoring requirements, etc.)
- The relationship of the Preliminary Performance Assessment to specific design criteria

In addition, it should be recognized that all models are simplifications used to represent the true system, containing uncertainties in future events (e.g., site use), system conceptualization (e.g., model uncertainty and system scenarios) and implementation (e.g., parameter estimates), but the Preliminary Performance Assessment is intended to provide the best approximation and analysis of uncertainties based on available knowledge. Some uncertainties may be reduced through information reasonably expected to be obtained in the future, while some uncertainties are irreducible. However, decisions must be made in this context to protect human health and the environment, now and long into the future. Section 7 of the Preliminary Performance Assessment discusses specific improvements that could be made to the assessment, including a subjective evaluation of the availability of the information needed for the improvement and the overall significance of the uncertainty reduction that would result. However, the descriptions of the analysis in the main body of the report make it difficult to evaluate the basis for these possible improvements.

In light of the uncertainties inherent in the Preliminary Performance Assessment, and the ability of assessments containing "conservative" approaches to provide a misrepresentation of risk by intending to only provide an estimate of maximum risk, the Panel recommends that future Preliminary Performance Assessments provide upper, lower and central tendencies to process components and risk estimates. When this is not possible, results should be presented that clarify the range of impacts from important uncertainties on process components and risk estimates. This should result in a better informed risk management process.

<u>Report Organization and Content</u>

The Panel thinks that for effective risk communication and technical credibility amongst the range of audiences that will evaluate the Preliminary Performance Assessment, the Preliminary Performance Assessment should be organized to meet the following objectives:

1. For a general public audience, summarize the justification for the preparation of a performance assessment. Include the specific objectives for the assessment, use of the results, underlying system configuration (closure) assumptions, analysis approach (including limitations and uncertainties), key findings, comparison with relevant criteria, relationship to previous results, and implications for subsequent activities. Some of this information appears in a well-organized discussion at the front of Section 6. It would be helpful to also include this information in the Executive Summary.

2. For a technical (regulatory and stakeholder review) audience, provide the same information as for a general audience. Give a clear progression from required criteria for human health and environmental protection, through key assumptions and uncertainties about each important component of the performance assessment (e.g., post-closure configuration, time line for key events, infiltration, source term, vadose zone contaminant transport, groundwater transport, exposure pathways, risk evaluations), detailed results including uncertainties in comparison to relevant criteria, and implications for future activities (including closure system criteria and further analysis). Throughout, focus should be on central issues, underlying risk drivers and uncertainty drivers.

3. For assessment documentation, detailed technical review and verification, provide for each component of the performance assessment (i) the alternatives considered (e.g., alternative physical system configurations, models, model assumptions), (ii) the rationale for selecting the specific alternatives used in the Preliminary Performance Assessment, (iii) technical details and citations sufficient for a

qualified technical team to replicate, verify or audit the completion of the Preliminary Performance Assessment. This includes version control and archiving of specific data and models used to derive the Preliminary Performance Assessment results, including lineage to original sources.

The above objectives suggest an organization that includes (i) an executive summary prepared for a general public audience (objective 1), (ii) the main report body prepared for regulatory and technical stakeholder review (objective 2), and (iii) separate appendices for each component of the Preliminary Performance Assessment that meet the requirements for detailed documentation, technical review and verification (objective 3). The Preliminary Performance Assessment does not meet the above objectives for the following reasons:

Within the Executive Summary

- too much technical jargon is used and insufficient explanation is provided to be comprehended by a general audience,
- key assumptions and underlying uncertainties in the assessment are not summarized,
- uncertainties in the assessment results are not presented, and,
- implications and recommendations for future activities are not provided.

Within the main body of the report

- technical information is provided in a widely varying range of detail, often including information extraneous to assessment focus, omitting important information, and failing to integrate information into meaningful summaries. For example
    - Extensive detail (ca. 26 pages) is provided on the site geology, but the importance and reduction of this information to the physical conceptual configuration used in the contaminant transport modeling is not clearly described.
    - Peak groundwater contaminant concentrations are only provided for the base case (Tables 4-7 to 4-10 and integrated (Fig 4-12) for a single case. No sensitivity to the scenario assumptions is reported.
    - An integrated nomenclature table (including units) is not provided and specific parameters are undefined (e.g., Equation 3-12). The report also switches between metric and British units.
    - The analysis of contaminant inventory is provided in excessive detail (Sections 2.3.4 and 3.2.3), has confusing discussion about which contaminants are of primary importance (p. 3-2), and then

proceeds to provide information on every constituent possible (Tables 3-2, 3-5).

- Rationalization of specific model or parameter selection is, in some cases, presented in extensive detail, distracting from the primary focus. In other cases, insufficient detail is provided to understand the basis for the model or parameter.

- With the exception of Sections 6 and 7, technical editing is needed throughout the report to provide improved precision and clarity in presentation

    - Terminology and basis for calculations is not uniform and often used without sufficient definition and precision, assuming an audience indoctrinated in site-specific jargon

    - Information is provided inconsistently or in unnecessarily confusing paragraphs

    - Citations are inconsistent and frequently incomplete. Citations should include indication of the specific section or page number within large reports. All cited documents should be available on the web site

    - Paragraphs or sentences are repeated in multiple places

    - Maps often fail to indicate the location of Waste Management Area C (the primary concern of this report), the boundary of the Central Plateau and other major physical features (e.g., Grand Coulee Dam)

<u>Within the appendixes</u>

- Insufficient detail is provided to replicate, verify or audit the analysis

- Primary results are presented in the appendices or other documents (e.g., for exposure assessment)

- Underlying equations, boundary conditions, and assumptions should be provided. Intermediate results and example calculations should be provided to guide the detailed reviewer

- Lineage of all parameters and models should be clearly defined, including citation to primary sources and version control of data and models.

OVERARCHING MODEL CONSIDERATIONS

The suite of models that make up the Preliminary Performance Assessment consists of a number of individual models with widely disparate levels of complexity. Because site-specific data for the Waste Management Area C is generally lacking, the parameterization and/or calibration of these models is often based on output from other models. This leads to a complex system of models and assumptions in the Preliminary Performance Assessment that is extremely difficult, if not impossible, to validate. Nevertheless, the Panel thinks that when models are used to support decisions with far reaching economic, human health and environmental implications, it is critical that these models be subjected to sufficient testing so that the acceptability of the models for the given task can be judged (Beck, Ravetz et al. 1997). Some of the models used in the Preliminary Performance Assessment have been subjected to earlier evaluation and verification efforts (Lenhard, Oostrom et al. 1995), or calibrated against generally accepted models such as the Hanford Site-wide Groundwater Model. However, the Preliminary Performance Assessment does not provide clear and sufficient detail for judging the adequacy of the models in the context of the Waste Management Area C closure. Evaluation of both the individual models and the overall suite of models in the context of the Waste Management Area C closure should be undertaken and presented as part of the Preliminary Performance Assessment. This effort should include system-wide mass balance checking along with comparisons of the model output with known solutions and field observation. Given the complexity and predictive nature of the Preliminary Performance Assessment modeling, both the evaluation of the models and communication of the results will depend heavily on more detailed uncertainty and sensitivity analysis than is currently included in the assessment. This analysis should include results of upper and lower bounds and central tendencies for parameter estimates and ranges for scenarios of important process components (e.g., contaminant inventory, source release, groundwater concentrations), pathway contributions to risk and overall risk for specific scenarios. This, coupled with other recommendations, should result in improved risk communication and risk management. Improved uncertainty/sensitivity analysis in the Preliminary Performance Assessment would also help guide the process of updating the assessment by identifying key data gaps and uncertainties.

Selection and parameterization of models

Although the general selection criteria for the models and code used in the Preliminary Performance Assessment are presented (*PPA* page 3-38), the final justification for selection of any given model seems to be based more on historical use across the Hanford reservation than on requirements specific to Waste Management Area C. As noted on page 1-21 of the report, the Preliminary Performance Assessment is "built on the successes of earlier performance assessments (Mann 1995, 1998, 2001) and tank farm-related analyses (Knepp 2002a and 2002b, RPP-10098, Wood et al. 2003, Connelly et al. 2003)." Although the Panel agrees that it is important to build on past experience in modeling, each new assessment should include enough information to justify the selection of both the individual models and the overall suite of models used in the assessment. Without clear documentation of the strengths and limitations of each selected model in the context of the current application, one would need to review a significant amount of model history, judge whether the model in question was appropriate for the past application, and then determine how relevant that application is to the current Waste Management Area C application. This places an unreasonable burden on readers, obfuscates the rationale for specific decisions and reduces confidence in the results.

Judging the adequacy of the individual models in the Preliminary Performance Assessment is made even more difficult because of a lack of access to details about model formulations, parameterization and applications that are actually pertinent to Waste Management Area C. The Panel recognizes the need to reference previous work and appendixes when the referenced work provides important details and a clear basis for the current application. However, in some cases a significant amount of detail is provided in the Preliminary Performance Assessment for data, assumptions and calculations that do not appear to be used in the assessment. In other cases, the relationship between the information provided in the Preliminary Performance Assessment and the actual calculations is either ambiguous or altogether absent. A specific example is the calculation used to "translate" the STOMP model predictions to fence line averages. There are several different methods described for this "translation" in the Preliminary Performance Assessment (Section 3.5.1.1, Section 4.2.3, and Section 4.5), the *Initial Numerical Simulation Document* (Section 3.7) the *Model Data Package (MDP)* (Section 2), and the *S-SX Field Investigation Report*, which is referenced by both the Preliminary Performance Assessment and the *MDP*. However, the actual "translation" simply distributes the predicted mass from each source uniformly across the entire width of the fence line and depth of the aquifer. The superfluous and sometimes erroneous details presented in the Preliminary Performance Assessment and supporting documentation not only make interpretation of the results difficult but also jeopardize the overall credibility of the assessment. A clear and systematic presentation of the overall modeling approach and the individual models is needed.

Despite the lack of clarity in the description of models used in the assessment, the Panel's understanding is that several models and algorithms were selected or developed for use in the Preliminary Performance Assessment. In general, these include various source modules, a 2-D subsurface model, a steady-state groundwater transport model, a 1-D gaseous diffusion model and various exposure modules. The models have widely differing levels of sophistication ranging from simple hand calculations to highly resolved numerical simulation. In some cases a single model was used (e.g., diffusion to surface) while for other cases it appears that at least some of the models were run sequentially with output from one model used as input to the next. The actual model or set of models used for any given run varies depending on the radionuclide, release scenario and exposure scenario being investigated. The Panel is concerned that the range of model complexities and the sequential nature of the modeling approach in the Preliminary Performance Assessment can lead to errors that are difficult to identify. Of particular concern are unit errors and spatial/temporal scaling errors that might occur during the data transfer process from one model to the next. Mass balance errors and inconsistencies can also be an issue when more than one model is applied to a single source (e.g., both diffusion and subsurface modeling applied to past leaks). Although a general quality assurance plan is provided (or at least referenced) in Appendix D, a clear discussion of how these data transfer, scaling and mass balance issues have been addressed is needed.

The Panel thinks that the Preliminary Performance Assessment would benefit from a more fully integrated, mass conserving modeling approach -- even one that provides less resolution in some compartments. Relatively simple mass balance modeling approaches that link a source through multimedia environmental fate to exposure by multiple pathways has been useful for a wide range of modeling applications. Such an approach can provide additional insight into the overall performance of the closure process. The Panel notes that results from the highly resolved subsurface modeling under the tank farm are already greatly simplified by calculating a fence line average that effectively removes all spatial detail. A more fully integrated mass conserving modeling system could provide a testing ground for identifying plausible model outcomes, evaluating potentially important exposure pathways, exploring model sensitivities, and characterizing both model and parameter uncertainties. This type of analysis would not preclude the use of more detailed modeling. Rather, results from a fully coupled model can enhance the more detailed modeling by providing insight into the behavior of the system and by helping to identify areas where more detailed modeling is necessary. Such an approach is also expected to improve the interpretation and communication of results and help focus discussion/debate about model predictions on the most important factors in the assessment.

Section 2 of the Preliminary Performance Assessment leaves little doubt that there is sufficient information for general site characterization across the Hanford Reservation. However, it is not always clear to the reader how this information is processed or reduced to parameter values for the Preliminary Performance Assessment modeling. Despite the large amount of site-wide data, the Panel recognizes that data specific to the C-Farm is not readily available. As a result, actual values used in the assessment are apparently estimated through empirical or statistical relationships or based on best engineering judgment. This is particularly the case for the subsurface characterization where only a couple of boreholes provide general information on soil characteristics and currently none of the wells in Waste Management Area C actually penetrate the aquifer. The properties of the subsurface underlying the tank farm is inferred from laboratory-scale measurements based on wells and boreholes from other locations on the Hanford site (RPP-13310, Rev. 0). The Panel stresses that inferences, approximations and simplifications are a fundamental part of modeling and if the process is completed in a transparent and traceable manner it should not detract from the credibility of the model outcome. Unfortunately, the relationship between the data presented in Section 2 of the Preliminary Performance Assessment and the model inputs is not sufficiently traceable. The report would benefit by drawing a clear linkage between the raw data, modeling input values and the actual models used in the Waste Management Area C assessment.

The model parameterization process described in the Preliminary Performance Assessment would also benefit from the results of a parametric sensitivity analysis that identifies the key inputs to the assessment at an early stage of the project. The Panel recognizes that previous investigations at the Hanford Reservation provide insight about which factors and processes might be influential but an evaluation of model sensitivity in the context of the Waste Management Area C application is still required. Widely accepted methods are available for performing parametric sensitivity analyses (Saltelli, Chan et al. 2000). Understanding what inputs are important can also help focus the data collection process and improve the report's ability to develop and justify the actual inputs used in the assessment. Parameterization of the model(s), particularly those inputs that are found to be critical to the assessment, should include an estimate of both the expected value and the level of uncertainty associated with the estimate. Methods are readily available for characterizing uncertainty in model inputs (Morgan and Henrion 1990; Cullen and Frey 1999) and there certainly appears to be an abundance of relevant data.

Model verification and validation

Section 6.3 of the Preliminary Performance Assessment concludes that the performance of the Waste Management Area C closure has been completely addressed, and logically interpreted, that the results are representative and sufficiently rigorous (*PPA* page 6-4). There seems to be some effort in the Preliminary Performance Assessment to verify the code used in the models by comparison to simpler models such as hand calculation, and at least some of the numerical code has undergone previous evaluations (Lenhard, Oostrom et al. 1995). However, several key components of the model verification and validation process are either lacking or reported in insufficient detail for the reader to understand the basis of this conclusion. The Panel thinks that there are at least three additional evaluation efforts that would provide useful information to help characterize the adequacy of the Preliminary Performance Assessment modeling. These include (i) comparison of output from the selected models with known solutions or alternative models, (ii) comparisons with relevant monitoring data, and (iii) an assessment of internal consistency within the modeling suite through a more comprehensive mass balance.

Comparison with known solutions

The report refers to a number of exercises that compare the models used in the Preliminary Performance Assessment with other models. However, the report is not always clear whether these were formal comparison exercises designed to test the models or calibrations. In general, quantitative results from the model comparisons seem to be lacking. For example, the report states that "Previous work shows good agreement between the stream-tube calculations and the results of the Hanford Site-wide Groundwater Model." (*PPA*, page 4-2) but no quantitative results are provided. It appears that the stream-tube model was calibrated to fit the site-wide model so good agreement is expected. However, it would still be useful to report the difference between the predictions from the calibrated model and the more complicated model. In some cases, simple models were apparently used to "show that the complicated models provide appropriate results." (*PPA*, page 6-4). Again, quantitative results are not readily available to allow the reader to understand either the scope of the comparison or the level of agreement or disagreement between the models.

The Panel agrees that using manual calculations to verify spreadsheet calculations (*PPA*, page 3-68) is a useful quality assurance exercise but there are other opportunities available for testing that go beyond code verification to evaluate whether the assumptions and conceptual models are adequate and compatible. For example, it appears that the vadose zone model (e.g., STOMP) used in the Preliminary Performance Assessment includes gas-phase diffusion through the soil. Although gas-phase diffusion was not used to assess the groundwater pathway, the calculated diffusion in STOMP might provide a useful comparison for the simple diffusion model (hand calculation) used in the assessment. The comparison could quantitatively evaluate how much the boundary conditions are expected to "exaggerate the diffusion flux at the surface" (*PPA*, page 4-40). The comparison also could evaluate whether key assumptions in the conceptual model are appropriate, for example, given the time-frame of the analysis, is it appropriate to ignore accumulation of less volatile constituents at the surface?

Comparison with field observations

Earlier efforts to verify and validate the STOMP model are referenced in the Preliminary Performance Assessment documentation (Lenhard, Oostrom et al. 1995). Predictions from the STOMP model were compared to results from a packed soil column and the authors of the earlier publication conclude that the STOMP model may accurately forecast subsurface fate in the field if the site is adequately characterized and the model correctly parameterized. This conclusion highlights the importance of using site specific data whenever possible to evaluate models that are used in specific applications. The Panel understands that the predictive nature of the Preliminary Performance Assessment and the time-frame under consideration make it impossible to find data that is comprehensive and completely relevant to the study, but a significant amount of monitoring and site characterization data does exist at the Hanford Reservation and this data should be used for testing the relatively short-term predictive capabilities of the models. For example, measured moisture regimens in subsurface soils, gamma logging data, groundwater monitoring data and measured performance of the Hanford cap might all provide specific areas for evaluating the models used in the assessment. The Panel understands that model evaluation exercises that rely on comparison with field data are expected to be closely linked to efforts that lead to updating of the model. However, opportunities to test the Preliminary Performance Assessment models against field observations should be considered whenever possible and used as a way to enhance the credibility of the overall modeling process.

Mass balance checking

The Panel recognizes that mass balance has been assessed for at least one of the individual models in the Preliminary Performance Assessment. For example, mass balance was reported for the STOMP model (Zhang, Freedman, et al. 2003, Section 4.8) and the results are certainly within acceptable limits. However, it is unclear whether this answers the right question when concerned about the overall system of models used in the assessment. Mass balance is a fundamental test of an overall modeling exercise and every effort should be made to evaluate gains and losses for both the individual models and the suite of models making up the overall system.

Judgment or consensus about the adequacy of the models used in the Preliminary Performance Assessment will also be influenced by results from uncertainty and sensitivity analyses. These topics are discussed in the following sections.

Uncertainty and sensitivity analysis

The Preliminary Performance Assessment acknowledges that significant uncertainties exist in the Waste Management Area C modeling and the report presents a reasonably complete description of these uncertainties in Sections 4.9, 5.5 and 6.4. The general conclusion seems to be that the primary sources of uncertainty in the assessment are from the "inventory of tank residuals and the exposure scenario chosen." (*PPA*, page 7-5) and "…human decisions or actions …" (*PPA*, page 3-68). Although these are most certainly important uncertainties, the evidence presented in the report does not demonstrate that other uncertainties are not significant.

Many of the conclusions about uncertainty (and sensitivity) in the report seem to be based on – or supported by – experience gained through other assessments at the Hanford Reservation rather than Preliminary Performance Assessment modeling effort. The Panel agrees that previous experience is valuable and should be carried forward into the current and future assessments. However, it is important that the final modeling approach include a more rigorous treatment of uncertainty, particularly if the approach developed for the Waste Management Area C closure is meant to provide a model or guide for other waste management area closure assessments. In addition to supporting a general statement of confidence in the modeling outcome, the approach should also be able to identify key uncertainties in the possible scenarios, conceptual models, numerical models and parameters used in the assessment.

Model uncertainty (system physics, chemistry, biology)

A systematic analysis of uncertainty in the conceptual and numerical models is lacking. Several of the individual models used in the assessment have apparently been used extensively at the Hanford Reservation. Experience with a given model is advantageous because it often reduces the number of mistakes made by users during an application. However, the panel cautions that familiarity with a model does not necessarily mean that the model is adequate for the given modeling task. Being overly optimistic about ones understanding of the system can make it difficult to be objective during the model development and application process. Oreskes and Belitz (Oreskes and Belitz 2001) identify two key factors explaining why modeling done by "seasoned professionals" can over-estimate the benefits of a particular project. These are 1) inadequate incorporation of negative impacts of unknown or unlikely effects and 2) an optimistic bias with respect to implicit conditionals. Both of these factors are potentially relevant to the Waste Management Area C assessment and should be considered throughout the modeling process.

Uncertainty about the rate and direction of flow in the aquifer and the apparent assumption that flow remains constant for the duration of the analysis is an example of a situation where unlikely scenarios may be both significant and difficult to identify. Although much appears to be known about the aquifer at the Hanford Reservation, it is not entirely clear what will happen under Waste Management Area C as the flow changes from its current state to a more natural state. It is also not clear whether other currently unknown conditions might arise that have a significant impact on the groundwater (e.g., infiltration at other locations or unusual periods of precipitation). A directional change in the groundwater flow pattern might significantly reduce the apparent dilution rate. It is not clear that the current set of simulated conditions provides a bounding estimate for groundwater dilution that recognizes the possibility of very slow groundwater flow under the site. Another example of a potentially important event is related to the well driller scenario but where the well is drilled through the tank bottom short circuiting the vadose zone providing a fast flow path to the aquifer. The extent of this short circuit is unknowable but could be significant particularly if there is a buildup of water in the tank prior to drilling.

The potential for unanticipated events or combinations of events and the fact that our understanding of environmental processes is incomplete – even at the Hanford site – suggest a need for a more flexible and transparent modeling framework within the Preliminary Performance Assessment that will allow a large number of screening analyses to be done. These runs can be used to better identify potential combinations of processes and factors that result in elevated risk and as such require more detailed modeling or additional remedial action. In contrast, the modeling approach in the Preliminary Performance Assessment uses a predefined set of “sensitivity runs” to explore uncertainties about current and future environmental conditions. The Panel is concerned that the need to pre-define conditions for the sensitivity runs and the level of effort required for each run may limit the ability to explore different combinations of factors and processes in the assessment.

A more flexible modeling framework also might be necessary if organic chemicals are found to be present in the tank waste or vadose zone. Dismissal of the potential importance of organic chemicals in the waste, both as constituents of concern and modifiers of transport properties of other constituents, without more detailed analysis may be premature. An earlier report (Wiemers, Miller et al. 1998) provides an approach for selection of chemicals of concern for tank farm assessment, but this approach has not yet been applied in the Preliminary Performance Assessment. This suggests that the list of potential constituents of concern, including organic constituents, may need to be revisited as measurements are collected from the tanks so that the decision to exclude certain chemicals and chemical classes can be verified following a formal process, such as that laid out in Wiemers, Miller et al. (1998). If these chemicals can not be dismissed then the modeling approach used for the radionuclides may need to be revised in a way that incorporates fate and transport properties of organic chemicals.

Parametric uncertainty

It appears that the source or chemical release rate, the transfer rate through the vadose zone and dilution in the groundwater are the main parametric contributors to uncertainty in the fence line groundwater concentrations. Other factors such as location, magnitude and nature of the chemical inventory in the soil or tanks seem to be important for pathways not controlled by the groundwater. Each of these factors or processes is dependant on a number of other uncertain and/or variable parameters including chemical, environmental and human inputs to the assessment. For some of the parameters there appears to be sufficient data from the area or elsewhere on the Hanford site to estimate likely values. For other parameters the values are based on best judgment. All of the inputs to the current Preliminary Performance Assessment modeling are deterministic. The Panel thinks that uncertainty in the model parameters should be more fully characterized, particularly for those parameters to which the model predictions are highly sensitive.

The subsurface geology and geochemistry under the tank farm is apparently based on numerous boreholes but it seems that many of these were drilled in a way that provided less than ideal information and most were some distance from Waste Management Area C. There is a detailed discussion of the geochemistry in Sections 2.2.10 and 3.4.3.3. However, it remains unclear what information was actually used in the assessment to parameterize the models. Despite the apparent lack of site-specific data, the vadose zone model is parameterized on a very fine grid (~1 meter square grid). The soil properties for these grids appear to be estimated using a statistical model and the report gives the general impression that there is a high degree of certainty in the estimated model parameters. Thus, it appears that information from a single bore hole somewhere on the plateau, and bench-top measurements of physical soil properties was extrapolated to parameterize the ~20,000 node grids used in the vadose model. The panel is concerned that when models are used to parameterize other models in the assessment, particularly at the level of detail used in the vadose model, it can potentially inflate uncertainty in a way that cannot be easily tracked. It may be that the soil properties are not influential to the model outcome but that should be demonstrated more clearly.

The Preliminary Performance Assessment uses a range of equilibrium soil-water partition (K_d) values between 0 and 1 to account for chemical property uncertainty and to assess sensitivity in the modeling approach. The Panel agrees that using different Kd values in the analysis provides a good first approximation of the importance of chemical mobility in the vadose zone. However, putting the focus on the single partitioning parameter (K_d) may discount the potential importance of other chemical properties and the many transport parameters (moisture retention, particle-size distribution, saturated and unsaturated hydraulic conductivity, bulk density, all the van Genuchten parameters) that are primarily based on small-scale laboratory studies or work performed at different locations in the Hanford 200 area (Khaleel, Connelly et al. 2003). Again, lacking a sensitivity analysis, it will be difficult to determine which uncertain parameters are influencing the outcome and how.

Calibration is certainly an acceptable part of modeling but the calibration should be based on data or a generally accepted model. It appears that a uniform mixing depth of grout was arbitrarily set to 32.5 inches to “keep the release duration to a reasonable value” (*PPA*, page 4-5). The Panel is not comfortable with selecting arbitrary input values that make a model produce results that are in agreement with prior expectations. If the closure plan is expected to leave ~ 1 inch of waste in bottom of tank covered with grout then the model should work within the bounds of the expected conditions. If the model does not work under those conditions then the conceptual model may not be appropriate. For example, alternative conceptualization of the grouted waste as either sandwiched between a grout layer and the tank wall, or intentionally mixed with a larger quantity of grout may be more appropriate. This conceptualization would facilitate both diffusion of constituents upwards into grout and through tank walls or different characteristic layers with either semi-infinite or non-zero boundary conditions, and more realistically capture likely physical processes.

Excluding outliers in measured data is also an acceptable practice under certain conditions, but excluding information simply because it cannot be explained given our current understanding of the system is not appropriate. For example, it appears that an arrow showing results from a borescope measurement of groundwater direction was removed from Figures 2-13 and 2-14 in Jones, Wood, et al. (2003, page 2-46 and 2-47) before the Figure was used as Figure 3-6 (*PPA*, page 3-51) in the Preliminary Performance Assessment. If the colloidal borescope measurements are not reliable for the conditions of the particular well in question then that should be stated prior to removing the data point. However, if the same issues of reliability apply to all the flows measured in this way, then presenting the three congruent arrows in Fig. 3-6 of the Preliminary Performance Assessment and deleting the one arrow that does not agree implies more confidence in the flow regime than is justified.

The Panel thinks that parametric uncertainty should be more formally characterized even if the deterministic approach is used. Characterizing uncertainty in the input parameters provides some basis for statements about the degree of conservatism. If a more detailed treatment of uncertainty is used then estimates of parametric uncertainty will also be required, particularly for the most influential inputs. Given the amount of data available for the Hanford Reservation, readily available methods (Morgan and Henrion 1990; Cullen and Frey 1999) should allow for constructing distributions for the inputs to the Preliminary Performance Assessment modeling to be constructed. Further, to facilitate review of the report, selected values and/or the distributions should be summarized in a single location within the report.

Sensitivity analysis

The Preliminary Performance Assessment lacks a detailed sensitivity analysis for most of the inputs to the modeling process. The “sensitivity runs” that are currently included in the analysis are designed to explore the variation in the modeling output caused by a relatively small set of parameters. The sensitivity cases are focused primarily on release rate from residual waste, volume of retrieval leaks and soil sorption coefficients. Other potential sensitivities are “inferred” from previous work (*PPA*, page 3-68 (first paragraph)). Limiting the analysis to a small set of sensitivity cases does not provide a clear picture of primary sources of variation in the modeling outcome, i.e., which inputs contribute most to variance in model predictions and why. The use of sensitivity runs also makes it difficult to identify important interactions among parameters.

The Panel recognizes that the overall modeling structure within the Preliminary Performance Assessment, which links models of widely differing levels of complexity, makes it difficult to perform a standard parametric sensitivity analysis. However, a wide range of methods are available for performing sensitivity analyses for any number of modeling applications (Saltelli, Chan et al. 2000). Methods are even available for use with complex models like the STOMP. A useful example is the GENII model used for biosphere calculations that was modified at Sandia National Laboratory into GENII-S (S is for stochastic) to allow propagation of uncertainties (Leigh, Thompson et al. 1993).

Exploring contribution to variance is not difficult once methods are in place to propagate uncertainty through a model.

Many of the recommendations in this and other section of the Panel's review, including issues related to both model application and risk communication, depend on a clear understanding of how the model(s) respond to changes in parameters and assumptions. The Panel thinks that the Preliminary Performance Assessment would benefit significantly from a detailed parametric sensitivity analysis that goes beyond the use of predefined sensitivity runs. Results from the sensitivity analysis could lead to a more transparent and traceable process for screening less important scenarios out of the assessment (e.g., biotic pathways and catastrophic events (*PPA*, page 4-43)) or for screening reactive chemicals and short-lived radionuclide out of the assessment so that more emphasis can be placed on the most important scenarios.

Propagation of uncertainty

As indicated earlier in this review, there is little effort in the Preliminary Performance Assessment to characterize parameter uncertainty and model uncertainty and propagation of uncertainty through the analysis is incomplete. Although the analysis considers temporal and spatial variation in some of the exposure pathways, the current Preliminary Performance Assessment modeling is essentially a deterministic analysis. The Panel thinks that the modeling would greatly benefit from a formal effort to propagate uncertainty through the modeling process using an uncertainty analysis that builds on results from the parametric sensitivity analysis. Results from the Preliminary Performance Assessment modeling should not only present the expected outcome but a statement about the level of confidence in the prediction. At a minimum, the expected outcome should be presented along with estimates of an upper and lower bound to give an indication of the potential variance in the model output.

Despite the significant amount of knowledge that has been gained about the Hanford Reservation over the past half century, it is important that the modeling approach applied to the Waste Management Area C closure not be presented as overly optimistic. The statement that "volumes and waste types of the major past leaks are fairly well known" (*PPA*, page 4-30) implies high confidence in leak volumes, but contradicts the earlier statement that "the volumes of waste lost to the WMA C vadose zone in various events are highly uncertain or unknown" (*PPA*, page 2-87). The Preliminary Performance Assessment refutes the original estimated leak volume for tank C-105 then specifies an apparently arbitrary value of 1000 gallons. This implies a high level of confidence that may not be warranted. The basis for this number is difficult to follow, and given that these past leaks are considered in this Preliminary Performance Assessment to be the risk drivers, the values may contribute significantly to uncertainty in the outcome. It might be better to say that reasonable bounding estimates for inventory (nature and extent of contamination) can be determined with uncertainty. The Panel thinks that a formal uncertainty analysis combined with data matching where feasible might provide an opportunity to increase confidence in some of the important assumption used in the model.

Given the lack of a formal uncertainty analysis, the Panel considers it inappropriate to assert that "it is very likely that there is less than 1 chance in 10 that performance 4-39 objectives in Table would not be met and that there is less than 1 chance in 1,000 that values would exceed 10 times the performance objectives." (*PPA*, page 4-16). Rather, the Panel recommends that a formal sensitivity and uncertainty analysis be developed and included in the modeling application. The final approach used in the assessment to propagate uncertainty should recognize that model uncertainties will likely increase significantly as the predictions move from the relatively near-term to the distant future. Uncertainty in the predictions will shift from parameters and processes to overarching model uncertainties and scenario uncertainties based on unknown and/or unknowable interactions between humans and the environment (Casman, Morgan et al. 1999). Thus, it is important to maintain a flexible modeling approach that is capable of providing appropriate levels of detail in both the predictions and the statement of uncertainty about those predictions.

Model evolution and incorporation of new knowledge

One of the primary selection criteria for the models used in the Preliminary Performance Assessment appears to be the need for enough flexibility to adapt to the "evolving features of the disposal system." (*PPA*, page 1-21). Both the regulatory requirements of the Preliminary Performance Assessment and the science and data supporting it are expected to change with time, so it is important to have a systematic and traceable process for incorporating new knowledge into the modeling and to link new knowledge to specific actions. Although the report clearly identifies future data needs (*PPA*, page 7-6) and recognizes that knowledge about the system will evolve, it lacks a clear plan for how this new knowledge will be incorporated into the modeling process and how updated modeling will impact site actions. The available information about what constitutes new knowledge and when and how to gather and report new knowledge seems to be more administrative guidance than a plan that takes advantage of, and builds on, the existing modeling and database. In addition, without adequate transparency, traceability and version controls of current models, then each update of the performance assessment becomes essentially a new modeling effort.

The existing models provide an opportunity to systematically identify data that will reduce uncertainty in the Preliminary Performance Assessment through an iterative process where models identify data needs that, when filled, lead to improved models that can be used to identify further data needs. Such an effort could support plans for further work as presented in Section 7.5 of the Preliminary Performance Assessment. Without such an approach, there is a potential to focus on collection of data that will not significantly improve the modeling. For example, it was indicated that new measurements of groundwater flows will be collected but given the changes to the aquifer as mounding continues to subside, it is unclear how that additional information will help improve the credibility of the predictions in the long term. If the modeling indicates that the rate and direction of groundwater flow is important but only during the time of contaminant breakthrough from the vadose zone to the aquifer, then better understanding of current conditions may not significantly reduce uncertainty in the analysis.

Methods are available for systematically characterizing and reducing uncertainty using Bayes Monte Carlo (Sohn, Small et al. 2000). Such a method might require some re-working of the overall modeling approach because the Bayes Monte Carlo requires that the model be amenable to a Monte Carlo Analysis. The linear/sequential modeling approach currently used in the Preliminary Performance Assessment is not easily amenable to this type of an analysis although other complex modeling systems have been modified to run stochastic simulation (Leigh, Thompson et al. 1993). Nevertheless, the Panel thinks that the Preliminary Performance Assessment modeling would benefit from a more traceable and proactive approach for explicitly incorporating new knowledge and experience into the assessment process.

CLOSURE-STATE PHYSICAL CONFIGURATION AND PERFORMANCE

Assumed Physical Configuration

The closure technology for the tank farm is discussed in Section 2.4 of the Preliminary Performance Assessment. Additional information is provided in the *Single-Shell Tank System Closure Plan*, RPP-13774, Rev. 2[1].

From a physical perspective, the closure system has two components. The first is how the tanks will be configured after the wastes have been retrieved, and the second is the surface barrier that will be constructed over an entire tank farm once all of the tanks have been emptied of waste and filled to prevent collapse. Each system is briefly described.

Concerning the tanks themselves, the Preliminary Performance Assessment indicates that after the wastes have been retrieved, the tanks would be filled to prevent subsidence. Section 2.4.5.1 of the Preliminary Performance Assessment indicates that "... gravel and grout dome fill are the preferred recommended technology. Other fill materials (like sand) are similar to gravel fill." However, gravel (high porosity, storage and hydraulic conductivity) and grout (low porosity, storage and hydraulic conductivity) have very different moisture transport characteristics that will affect system performance.

Following retrieval of the waste and stabilization of the tanks, the plan is to construct a surface barrier to cover the tank farm. This barrier is intended to maximize evapotranspiration, minimize infiltration, provide protection against erosion, and prevent burrowing animals and plant roots from coming into contact with the waste. No assumptions are explicitly stated about the intended ability of the barrier to prevent human intrusion, even though inadvertent human intrusion is considered an important potential exposure pathway. The surface barrier is assumed to perform effectively for 500 years, with a resultant infiltration rate during that period of 0.5 mm/year. After 500

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[1] available at http://www.hanford.gov/orp/content.cfm?sn=161&parent=142&pageid=244 *(no authors or publication date)*

years, the infiltration rate is assumed to increase to the long-term rate of 3.5 mm/year (see Table 3-16 of the PPA). No details of the design of the surface barrier are provided, other than that it is 5 m thick, that it will extend 100 feet past the edge of the tanks, and that its slope will be up to 3%. The basis for the estimated infiltration performance, as described in Section 4 of the *Modeling Data Package for an Initial Assessment of Closure for C Tank Farm* (RPP-13310, Rev. 0), are data from the Field Lysimeter Test Facility and the Prototype Hanford Barrier.

Preliminary Performance Assessment failure and release scenarios

Section 3.4.5 of the Preliminary Performance Assessment describes how the closure barriers are analyzed

> "With the exception of the surface barrier, facility structures are basically ignored in this analysis. The effect of the surface barrier is accounted for by changing the infiltration rate (see Section 3.4.6). The presence of other facility structures (e.g., the tank structures) disappear after 50 years. Thus, during the near term, the tanks act like umbrellas diverting moisture flow. In later years, the tanks do not divert the moisture away from the residual waste."

This approach means that prior releases, releases from spills during retrieval, and releases from ancillary equipment are all transported through the vadose zone with an assumed recharge rate of 100 mm/year until the year 2050. Until 2050, none of the residual waste in the tanks is released because it is protected from infiltration by the tank. At 2050, the surface barrier is estimated to reduce the annual recharge to 0.5 mm, and the waste tanks are assumed to disappear. The Preliminary Performance Assessment indicates that the effects of wind erosion and earthquakes were evaluated; a private communication from Fred Mann indicates that these scenarios were screened out of the assessment due to their lack of contribution to releases and the results not included in the report.

<u>Comments on Closure As It Affects Performance</u>

Under the timing described above, the tanks fail at exactly the same time the cover is installed. This may be very conservative, and the actual plan is to have the covers is place before 2050. However, if the Preliminary Performance Assessment is taken at face value, recognition that the times for tank failure and cover installation are uncertain would suggest the potential for tank failures before the cover is in place. This would allow residual wastes to be exposed to infiltrating water during the time when recharge is high. Conversely, complete failure of the structures is unlikely to occur within 50 years, and the failure state (depending on closure configuration) may result in continuance of the umbrella effect for a very long time period, potentially increasing release and transport rates of contaminants in the vadose zone outside of the structures.

On page 4-34, the Preliminary Performance Assessment reports that the S/SX/ FIR shows that installation of an infiltration cover in 2010 over past leaks could reduce their ground water concentrations and impacts by about a factor of 2. The role such a barrier might play in reducing concentrations from leaks during retrieval, or potentially preventing such leaks from occurring, is not discussed. But given the sensitivity of vadose zone transport to the recharge rate, such an interim barrier could be quite beneficial.

The surface cover

The estimated performance of the surface cover as an infiltration barrier is based on actual experimental evidence with the Prototype Hanford Barrier, which was constructed in 1994. However, the assumption that the infiltration will be limited to 0.5 mm/year for 500 years is not supported by any design details or analysis in the Preliminary Performance Assessment. The Panel thinks that the possibility that infiltration through the barrier will revert to the rates typical of the natural system sooner than 500 years should be evaluated.

These performance claims are consistent with the requirement that RCRA covers have a design life of 500 years. But simply using a performance requirement in a performance assessment does not address the issue of how the cover would actually perform. Absent design details and an analysis of foreseeable failure mechanisms, it is not clear whether or how the 500 year lifetime would be achieved.

Most of the experience with RCRA covers is with multilayer clay caps. The Panel understands that a clay cap will not be constructed to limit infiltration. Use of evapotranspiration covers for RCRA closures is a relatively new design, and failures have occurred (Hauser et al. 2001, Clarke et al., 2004). The Prototype Hanford Barrier includes an asphalt layer (Wittreich et al, 2003) and limits infiltration by selecting vegetation to maximize evapotranspiration. However, Wittreich et al report:

> "Optimal design of a candidate barrier requires close attention to the choice of plant species and may require some maintenance to ensure that the right mix of plant species remain active. Continued monitoring should provide valuable information on the plant dynamics and the time for recovery of native shrubs, such as sagebrush, after the increased stress caused by prolonged exposure to elevated precipitation."

The 500-year design life of the surface cover exceeds the period during which one can credit active institutional controls for maintaining the system. For this reason, it is difficult to understand how one can have confidence that evapotranspiration that differs from the natural system can persist for 500 years. In addition, over a period of 500 years, it may not be valid to assume that characteristics of the natural vegetation and the associated evapotranspiration characteristics will be constant. Adequate evidence supporting the prediction that infiltration would be limited to 0.5 mm/year is lacking.

The details of the surface cover, and how it may differ from the Prototype Hanford Barrier, are not provided in the Preliminary Performance Assessment. Insufficient information concerning the barrier design was provided for the Panel to understand its construction or durability. While the surface barrier is designed to prevent burrowing animals or plant roots from reaching the waste, the details of how this would be achieved are not provided.

In the Wittreich et al (2003) report on the Prototype Hanford Barrier, a key operating feature of the cover is noted:

> "An analysis of seasonal variations in precipitation, especially in winter amounts, is of particular importance in evaluating cover performance and the design of future covers to be used at the Hanford Site. It is important because vegetated capillary barriers are commonly designed to store all of the expected winter precipitation until it can be recycled by plants in the spring and summer months. The prototype Hanford barrier is designed with a 2-m silt-loam layer capable of storing approximately 600 mm of water, which is more than three times the long-term average precipitation (160 mm yr^{-1}) for the Site. This capacity has never been exceeded, not even during the treatability test when the prototype was irrigated. However, future designs must consider the winter storage requirements in their optimization of the thickness of the fine soil layer."

In the Preliminary Performance Assessment, no discussion of the storage capacity of the surface cover design is provided, and, although a detailed discussion of the climate and meteorology are provided in Section 2.2.5 of the Preliminary Performance Assessment, it was not clear if the weather data had been analyzed in a way that will allow selection of a design capacity. The analysis is somewhat more complicated than simply examining the extreme precipitation distribution; the capacity of the surface cover could be limited by a stretch of several wet winters in a row in combination with relatively cool summers. Regarding the analyses of seismic and wind erosions effects, it would have been helpful to have included those screening analyses in the report.

Tank closure

Specific details of how the tanks will be closed are not provided in the Preliminary Performance Assessment. A clear description of the assumed physical configuration of Waste Management Area C after closure, potential failure modes and failure states, and monitoring and maintenance of the closure configuration is lacking. The description within the Preliminary Performance Assessment should include definition of the assumed baseline performance criteria for the closure, and alternatives that are to be examined as part of the Preliminary Performance Assessment. For example, assumptions of net infiltration and presence or absence of an intrusion barrier are omitted from Section 2.4. The assumed impact and relationships to neighboring site facilities and waste management areas should also be delineated.

The closure configuration of the tanks, including the type of fill material added to the tanks, could affect how residual wastes in the tanks are released at future times. For example, if the tanks are filled with granular materials (e.g., gravel) that have appreciable hydraulic conductivity and porosity and the tank shell remains intact, a bathtub effect may result that places significant hydraulic head over the waste residuals in the tank, potentially enhancing their release. The assumption that the tank disappears as a barrier after 50 years may not be conservative in all cases. For example, it is possible that the top of the tank could fail before the bottom such that the tank would fill with water. If that were to occur, then, when the bottom failed, there might be sufficient water to allow for rapid transport through the vadose zone.

Alternatively, if a low permeability and porosity grout is used to fill the tank, then release from the residuals remaining in the tank may be reduced. However, in this case, infiltration may be diverted away from the tank's footprint indefinitely, creating an umbrella effect, and enhancing release of contaminants remaining in the vadose zone after closure because of the increase water flux through areas around the tanks.

From the information provided, it is difficult to tell how sensitive results are for the various exposure scenarios. Given the long vadose zone travel times for a recharge rate for 0.5 mm/year, exposures from ground water may be relatively insensitive to the release model selected. It would be helpful to include a graphical presentation of the release rates for the various models, along with graphical results for the arrival time of key radionuclides at the water table for each release scenario.

Analysis of the driller scenario

Absent presentation of a specific design, it is not possible to know whether the surface cover would provide any protection against inadvertent intrusion by a well driller. The requirements cited in the Preliminary Performance Assessment indicate that for the first 100 years after closure, active institutional controls will be relied upon to prevent inadvertent intrusion, construction of houses, agriculture, or other activities that could lead to releases or exposures to the residual wastes. The requirements also indicate that the inadvertent intruder analysis is to be evaluated at 500 years after closure. The tanks themselves include reinforced concrete tops and bottoms, but the assumption is that the tanks will not serve as any sort of barrier after 50 years. Between 100 years after closure, when active institutional controls may begin to fail and 500 years after closure, when the intrusion dose is evaluated, the protection against intrusion relies on unspecified passive barriers and markers. Between markers and barriers, the more significant barrier to intrusion is the design of the surface barrier.

In the Preliminary Performance Assessment, Figure 5-1 provides the calculated doses to a driller versus time, for the period from years 2000 to 2500. Given that the requirements were interpreted to simply require a calculation at 500 years, the Merit Panel is pleased that this additional information was provided. The details of Figure 5-1 demonstrate that while the most significant doses occur in the first 100 years, doses at and after 100 years can be above the 15 mrem/year dose rate limit for CERCLA closures.

The ability of the barrier to prevent a drill from penetrating the surface and tank is not discussed, nor is the likelihood that the barrier would at least alert the driller to unusual conditions, and possibly prevent intrusion into the waste residuals. Given that no credit is taken for protection from either the surface barrier or the closed tanks for the driller scenario, this is understandable. But it would be useful to consider how various designs for the barrier system, including both the surface cover and the filled tanks, might perform under this scenario. As currently written, the driller would not notice any of the intrusion features of the surface barrier, and then drills through the reinforced concrete tank top, 16 feet of grout and gravel, and the reinforced concrete tank bottom. However, other DOE sites (e.g., Savannah River Site) have explicitly considered prevention of human intrusion (e.g., by a driller) in the proposed design for closure, and consequently do not consider the inadvertent driller as a credible exposure scenario.

It appears that the borehole through the tanks in this scenario is not treated as a fast flow pathway for other scenarios such as the fence line resident or farmer. If the inadvertent intruder were to drill through the tank while it is in a bathtub-like condition, then a large quantity of water could drain into ground water almost instantly.

TEMPORAL ASSUMPTIONS

The performance assessment calculations are initiated on January 1, 2000 and continue for 10,000 years, with several key transition points considered. A base case infiltration rate or recharge of 100 mm/y is assumed for the present time and prior to closure of the Waste Management Area C. This infiltration rate reflects conditions historically at the site during ongoing operations. The closure barrier, an enhanced RCRA Subtitle C barrier, is assumed to be in place by 2050, and it is assumed to remain intact for its entire design life of 500 years. During this 500 year time period, infiltration is limited to 0.5 mm/y. In 2550, the barrier is assumed to degrade and infiltration increases from 0.5 to 3.5 mm/y. This infiltration rate is stated to be representative of the environment prior to the existence of Hanford in the early 1940s and is assumed to be what it would revert to in the future.

Institutional control is assumed to last for at least 100 years following closure of the Waste Management Area C, (p. 2-98) and a 500-year compliance time is used for an inadvertent intruder (the period during which an inadvertent intruder would be prevented from the site) (p. 1-10 and 1-18). According to supporting documentation for the PPA (Mann et al. 2003), the 500-year compliance time is based on DOE/HQ guidance (DOE G 435.1-1), and 10 CRF 61 Subpart C and D assuming that passive barriers and markers would be present and effective. This follows the precedent of other Hanford Site performance assessments (e.g. Kincaid 1995, Wood 1995a, 1996) (p. 1-18). However, although following precedent, actual performance in this regard (i.e., 500 years) is highly uncertain. In addition, the future land use for the 200 Areas, including Waste Management Area C is assumed to be protected such that artificial recharge, e.g., irrigated farming, could not occur (p. 3-67). These performance objectives are stated to be based on the requirements of 40 CFR 191 (p. 1-10). However, at the DOE WIPP facility where 40 CFR 191 is applied, human intrusion is assumed to occur 100 years following closure. In that case, it is accepted that the presence of markers and barriers reduce the probability/ frequency of intrusion, but do not delay the onset of when intrusion is possible, and not for more than several hundred years.[2]

The exposure scenarios for the performance assessment analysis appear to be somewhat inconsistent with the defined performance objectives, in that the inadvertent intruder is assumed to have access to the site after 100 years (*PPA*, page 3-57). Based on this, it is

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[2] Unlike the Hanford tanks, WIPP has no protective surface cover.

difficult to understand why compliance for the inadvertent intruder need only be demonstrated after 500 years and not 100 years.

The performance assessment calculations give the impression that the assumed time periods for institutional control, integrity of the passive barrier, and future land use are well established and accepted, but they actually are subject to significant uncertainty. Similarly, there are repeated statements about DOE's intentions to control the closed sites for as long as the waste may be dangerous. However, the processes for achieving institutional control at the site and the methods to ensure they are implemented successfully do not exist at the current time (NRC 2000). Some of these uncertainties are evident in Section 2.2.4.3 of the Preliminary Performance Assessment, which discusses future land use at the Hanford site and notes that "DOE's land use planning extends for only 50 years instead of the 100 years forecast by the Hanford Future Site Uses Working Group (HFSUWG 1992a)." (*PPA*, page 2-9). The report also goes on to state that "no formal land use planning is expected to be accurate over the hundreds to hundreds of thousands of years covered in this analysis." (*PPA*, page 2-10).

Key assumptions that define transition points in the performance of the system and that deserve closer attention include:

1. Time when institutional controls cease or fail

2. Time when the intrusion barrier fails

3. Loss of integrity of infiltration barrier

4. Impact of human behavior on infiltration (e.g., elevated infiltration rates)

5. The chemical and physical impact of structures (e.g. tanks, backfill)

6. Integrity, progressive failure and ultimate state of the failed structures (e.g., hydraulic conductivity at failure).

Before conducting sensitivity analyses related to these items, interactions and correlations between key parameters need to be considered to ensure that logical, consistent cases are evaluated. For example, as long as institutional control remains effective, it is reasonable to assume human intrusion is precluded. It is also reasonable to assume that a subsurface intrusion barrier designed to prevent inadvertent intrusion (e.g., well drilling) would be effective for more than 100 years. In the Preliminary Performance Assessment, loss of institutional controls is assumed to occur after 100 years, but inadvertent intrusion is first assumed to occur 500 years after closure. No information is provided on the barrier specification to prevent intrusion occurring after 100 years and before 500 years. The sensitivity of the results to assuming institutional controls fail after 50, 100 and 200 years, and that inadvertent intrusion near surface could then take place, should be examined. Similarly, the sensitivity of the results to the time at which the subsurface intrusion barrier (if one is present) loses integrity, the infiltration barrier loses integrity, tank structures lose integrity, and the impact of different infiltration rates in the future times require closer examination.

For many cases it is unlikely that an engineered structure will fail in such a manner as to revert to the state that existed before the structure was emplaced. For example, it is unlikely that tank and barrier structures would fail in such a manner that would result in hydraulic properties similar to surrounding sands and fill material. Thus, sensitivity to the time frame and ultimate states of failed structures should be considered.

RESIDUAL WASTE INVENTORY DISTRIBUTION AND COMPOSITION

The Preliminary Performance Assessment asserts that only a limited number of contaminants of concern (COCs) are considered because of its preliminary nature, and that a formal screening process, based on risk will be performed in subsequent assessments. This is a reasonable approach to take; however, the report is inconsistent and confusing in identifying the COCs. The text in Section 3.2.1 is difficult to follow. For example, on page 3-2 the Preliminary Performance Assessment states that carbon-14, selenium-79 and cyanide are identified by Callison (2002), and are consistent with previous assessments and groundwater monitoring of the unconfined aquifer. The Preliminary Performance Assessment then proceeds to dismiss these materials stating that the Hanford site-wide groundwater monitoring indicates they may not be important. The next paragraph then goes on to state that carbon-14 will be included. Later in the report results are presented for europium isotopes that are not even mentioned in Section 3.2.1. The criteria used to identify the relevant contaminants of concern need to be clearly and logically articulated. Also, the Panel suggests that an organic species should be considered in the preliminary assessment given the presence of organic contaminants in the wastes.

The Preliminary Performance Assessment provides extensive information about the historical operations at Waste Management Area C and the methods used to develop and update the Best Basis Inventory for the underground waste tanks. The Best Basis Inventory values are updated on a quarterly basis to reflect new data and waste transfer information. All of the tanks in Waste Management Area C have been sampled, which provides some confidence in the inventory estimates. However, in some tanks, the analysis was performed for only a limited suite of analytes and tank contents can be stratified or heterogeneous. The Hanford Defined Waste (HDW) computer model is used to estimate many, but not all, of the remaining contaminants. The HDW model is being updated (*PPA*, page 2-80) and the expected revisions to the inventory estimates for two key radionuclides, technetium-99 and iodine-129 are described. The Preliminary Performance Assessment draws attention to the fact that the Best Basis Inventory does not provide inventory estimates for all constituents, one of which is pertechnetate. The amount of free technetium-99 which is used to infer the amount of pertechnetate in samples taken from nine of the Waste Management Area C tanks is presented in Table 2-12 and discussed in the text. This discussion is separate from that for technetium-99 on the previous page. It is not clear to the reader how the two pieces of information are combined, what conclusions or assumptions are made in the assessment, and how conservative or otherwise these are considered to be.

Three basic tank waste retrieval methods are expected to be used: modified sluicing, mobile retrieval system, and vacuum-based retrieval. Modified sluicing is planned for waste retrieval from the larger 100-series tanks that are not identified as having leaked, whereas the mobile retrieval system is planned for those tanks that are assumed to have leaked. The vacuum-based retrieval is planned for the smaller 200-series tanks, miscellaneous underground storage tanks, and waste receiving facilities. In all cases, the Preliminary Performance Assessment considers the technologies to be capable of retrieving waste to both 90% and 99% retrieval.

It is inevitable that the residual waste inventory is uncertain because it is not known how much waste will be retrieved. The Preliminary Performance Assessment adopts a pragmatic approach towards estimating the residual waste inventory based on the projected retrieval techniques. Clearly, as waste is retrieved from a tank, the tank residuals should be sampled and analyzed so that the residual waste inventory can be updated. Completion of waste retrieval from several tanks will provide a firmer basis for estimates of residual waste quantities.

The volume and inventory associated with potential retrieval leaks is very difficult to determine. Tanks C-106 and C-107 are the only tanks in Waste Management Area C scheduled for wet retrieval, therefore it is reasonable that the assessment develops potential retrieval leak inventories for only these two tanks. In each case, two leak volumes are considered, a base case value of 8000 gal and an alternative case of 20,000 gal. It is difficult to assess how realistic these are, however, the methodology used to determine the inventories for each assumed leak volume appears conservative.

Fewer tanks are determined to have leaked than estimated in earlier assessments. In fact, tank C-105 is the only tank for which a leak inventory estimate is made. Much of the discussion from p. 2-87 onwards refutes earlier claims regarding leaks in the C-Tank Farm. However the groundwater monitoring observations are not satisfactorily reconciled with these assertions. For example, sharp peaks of nitrate and Tc-99 have been detected in groundwater monitoring wells, indicating near sources, and cyanide that is presumed to come from the C-Tank Farm has been detected in the aquifer (*PPA*, page 2-93).

The largest sources of leaks are attributed to three separate transfer line leaks, which are referred to as unplanned releases. The inventory estimate for the four past leaks combined is the largest source term for the system (*PPA*, Table 3-7). The report acknowledges that the inventory estimates for most of the events that resulted in waste lost to the Waste Management Area C vadose zone are highly uncertain or unknown (*PPA*, page 2-87). However, a contradictory statement that “volumes and waste types of the major past leaks are fairly well known” is made later in the report (*PPA*, page 4-30) implying high confidence in leak volumes. Overall, there is a sense that the source term for past leaks could be underestimated and is therefore not conservative (see earlier discussion in Propagation of Uncertainty). It is also difficult to determine from the information provided in the report what volume these leaks really represent given that the stated volumes are confined to a two-dimensional modeling space, and the sensitivity of the assumed leak geometry and spatial orientation on the resulting groundwater concentrations is not provided.

INFILTRATION

A recharge estimate of 3.5 mm/y is selected to represent the predevelopment conditions at the site (before 1945) which are characterized as a shrub-steppe ground cover. It is also assumed that recharge rates will return to these predevelopment conditions in the future once the closure barrier has degraded. In the Preliminary Performance Assessment, return to predevelopment conditions is assumed to occur in 2550, 500 years after closure of the site. However, the rationale for selecting this value is not clearly described in Section 3.4.6 of the report despite assurances that this would be the case earlier in Section 2.2.9.4. Furthermore, this value is lower than the long-term average infiltration rate of 7 ± 3 mm/y recently presented in Mayer et al. (2003) to represent the past 1,000 to 10,000 years at the site. The basis for selecting the lower value needs to be justified, if it is considered more appropriate. The sensitivity of the results to assuming a higher long-term average infiltration rate of 7mm/y also merits consideration.

A base case infiltration estimate of 100 mm/y is used to describe conditions at the site up until closure in 2050. This appears reasonable based on the data presented for the time period of operations.

Following closure of the site, minimal infiltration of 0.5 mm/y is assumed for 500 years (2050 – 2550). The barrier is assumed to function perfectly throughout its entire design lifetime. This appears to be an overly optimistic assumption given that the closure design is not identified at this time, and that no similar systems exist to verify the reasonableness of such an assumption for such a time period. For this reason the sensitivity of the results to assuming shorter barrier lifetimes would be appropriate to determine how important this parameter is for the system performance.

When reviewing the infiltration estimates it is striking how much greater the base case estimate (100 mm/y) is as compared to the infiltration rate of 3.5 mm/y, which reflects the natural environment in the absence of human activity. The largest infiltration rates at the site have been a direct consequence of human activity. It seems unreasonable to assume there could be no human activities resulting in similarly large infiltration rates hundreds or thousands of years into the future. The Hanford Site has impacted the demographics of the region significantly as compared to preconstruction times. Also Section 2.2.6 of the Preliminary Performance Assessment notes that the Hanford Site "has all the components that favor successful irrigated farming."(*PPA*, page 2-15). Therefore, although it is difficult from the current perspective to imagine what human activities might take place in the future that would result in similarly high infiltration rates, it is recommended that the sensitivity of the results to high infiltration rates at a range of time periods be explored. For example, at 100 years, immediately following the loss of institutional control, at 200 years, and at 500 years.

It is striking that the cumulative infiltration to the Waste Management Area C from now until closure is 4500 mm (45 years), in contrast to 250 mm over the 500 years of assumed cap integrity and 350 mm over the subsequent 100 years after cap failure. This suggests that immediate minimization of infiltration, even through temporary means, may have significant benefit.

One aspect of infiltration that the Preliminary Performance Assessment mentions, but does not appear to evaluate, is the significance of enhanced infiltration on a localized scale to provide faster transport of contaminants to the water table. Processes that could result in such an effect include rapid melting of a snow pack, and funneling or umbrella effects due to the shedding of water off the tank domes. Although the influence of the tank domes has been considered in the relatively near term prior to degradation of the tanks, and the flow of water around the tanks does seem to significantly influence both the rate and dispersion of contaminants from past leaks, elevated infiltration over the longer-term is not adequately addressed. The Panel recommends that the potential significance and uncertainty of such effects in the assumed low recharge environment be evaluated through sensitivity analysis.

SOURCE TERM RELEASE MODELING

Three different release models are used for releases of radionuclides and chemicals from tank residuals, an advection-dominated release model, a diffusion-dominated model assuming a semi-infinite source and zero concentration boundary, and a congruent dissolution model. In addition, five cases are applied (see *PPA*, Table 4-6) for uniform fractional release rates. Of these cases, the fastest release case examined is for a 10% release per year, with all waste having been released after 10 years. The other four cases involve slower rates – fractional releases of 10^{-3} to 10^{-6} per year during the first 500 years, followed by a hundred-fold increase in the release rate at 500 years. With respect to the congruent dissolution model, solubility refers to the dissolution rate of the residual waste cake left in the tank, not to solubility limits for specific radionuclides (*PPA* Section 3.3.3). It appears that for all release scenarios but the 10% fractional release rate scenario, credit is taken for delay in releases due to the 50 year period of assumed tank integrity. It was not clear whether the statement “other facility structures (e.g., the tank structures) disappear after 50 years” applies to the grout. However, this does highlight the need for long-term structural integrity as a design consideration for grout.

For each of the source term models, the analysis is based on a unit inventory, assuming that release as a function of time, subsequent processes and doses scale directly in proportion to total inventory. This allows the use of modeling based on unit inventory factors.

While the source release models used in the Preliminary Performance Assessment illustrate the different consequences of slow and fast release from residual contamination on groundwater concentrations, there is insufficient characterization data to select the most appropriate release models. Furthermore, the most likely mechanisms that will control release are not included. In addition, alterative release models are not considered for contaminants already in the vadose zone from past leaks. The most likely release controlling mechanisms are (i) solubility of the contaminants or the related controlling phases in the local pore water, (ii) aqueous-solid adsorption and ion-exchange, or (iii) diffusion through a finite source with a non-zero external boundary condition or semi-infinite media. Importantly, solubility controlled release and diffusion controlled release under these conditions will not scale linearly with contaminant inventory. Actual release controlling phenomenon may be different for different constituents and vary as a function of local pore water conditions. Results for the source term also should be consistent with assumptions about the mechanism and efficacy of the tank cleanout process (e.g., highly soluble constituents would be solubilized and removed during cleanout).

Release will be controlled by the solubility of the contaminants in the local pore water if the contaminants are present as precipitated solid phases, where the local pore water solution is saturated with respect to the contaminant of interest. This is in contrast to the congruent dissolution model, where release is controlled by the solubility of the primary solid phase matrix (e.g., sodium nitrate). However, very soluble solids such as sodium nitrate are likely to be removed during waste recovery operations, making application of the congruent dissolution model questionable.

Release will be controlled by the aqueous-solid adsorption or ion-exchange processes if concentrations of contaminants are lower than the threshold necessary to saturate solid phase adsorption or ion exchange sites. These processes may not be linear with respect contaminant concentration, although assuming linearity is a reasonable first approximation.

Release will be controlled by diffusion from a finite source with a non-zero boundary conditions for situations when there is relatively little water flux through the contaminated area. Local equilibrium will likely predominate at the pore-scale with diffusion occurring through the aqueous phase present in the pore space. The diffusivity will be a function of local conditions and will change over time, with changing pore solution conditions. A finite source model is appropriate because of the combination of relatively limited amount of contaminants, small spatial distances to the boundary, and long time frames evaluated. For waste remaining in closed tanks, the extent of mixing with grout used to close tanks and diffusion through the tank wall also should be considered. The appropriate external boundary condition is either diffusion into a finite external solution volume (finite bath) or diffusion away from the boundary based on diffusivity through the unsaturated surrounding soil. The amount of water flux around the material and the water saturation of the surrounding soil will determine which boundary condition is appropriate. Diffusivity through the unsaturated soil can be estimated using the Millington-Quirk relationship, however, this relationship does not account for aqueous phase discontinuity at low soil moisture contents, which may result in over-prediction of diffusion rates at these conditions. An alternative approach to account for low soil moisture conditions is presented by Schaefer, et al. (1995).

For the waste and grout, which are both initially alkaline materials, adsorption of carbon dioxide from the adjacent soil gas will carbonate the matrix, resulting in decreased pH and changes in release rates (Sanchez et al. 2002).

Characterization data obtained from contaminated vadose zone core samples, samples of waste remaining in tanks after retrieval, and grouted waste can provide sufficient information to distinguish between the mechanisms controlling release and develop reasonable parameter estimates. The approach proposed by Kosson et al. (2002), and recently recommended by Washington Department of Ecology for evaluation of fill material (Washington State Department of Ecology, 2003), is recommended to obtain necessary characterization data. This should be augmented with determination of pore water composition. These results will provide sufficient information for more robust modeling, including inferred geochemical speciation and diffusion controlled release rates (Garrabrants et al, 2003; van der Sloot et al. 2003).

Using models based on the controlling mechanisms as described above, may result in changes (most likely decreases) in the overall release rates by up to several orders of magnitude and more realistically capture changes in release rates in response to changes in overall system conditions. Release controlled by contaminant solubility or desorption should provide the upper bound to release predicted by diffusion. Alternative models should be considered for waste remaining in tanks, ancillary equipment, and past releases to the vadose zone.

An additional situation that the existing release scenarios do not address is the case where some portion of the tank wastes are released instantaneously when a tank wall or bottom fails and water from infiltration accumulated in the tank is rapidly released. The appropriateness of this scenario depends on the material used to fill the tank and improved understanding of tank failure modes.

VADOSE ZONE TRANSPORT

The unsaturated zone transport model is a conventional model for transport through homogeneous material, using standard K_d values to account for retardation along the flow path. Fast flow paths are not included in the model. The flow velocity is strongly dependant on soil moisture, which, in turn depends on the infiltration rate.

The impact of episodic and spatially non-uniform recharge is not clear in the Preliminary Performance Assessment. While rare floods were considered, e.g., failure of the Grand Coulee Dam, it was not evident in the Preliminary Performance Assessment that extremes of weather that would produce significant variations in recharge were evaluated. In addition to consideration of the distribution of extreme precipitation events, e.g., the 1,000-year rainfall or snowfall, it would be particularly useful to know what the historical record shows with respect to patterns of above-average precipitation periods of several years to several decades. The assumption that the infiltration each year is the average infiltration is not conservative; it will produce longer estimates of travel times than would a model that reflected variability in recharge rates.

In addition to evaluating how the variability in precipitation with time might affect recharge, it would be useful to consider how appropriate it is to assume a spatially uniform recharge rate. There may be processes, e.g., surface runoff, that create local wet spots that could saturate the surface barrier. It is a feature of the vadose zone model that wetter areas will flow faster than dryer areas. If this is also the case for the surface barrier, then breakthrough flow could occur at locally low or wet spots. This was not discussed in the Preliminary Performance Assessment.

Given that past operations, including tank leaks, have produced many ground water plumes across the site, discussion is needed to explain why it is plausible that the travel time for leaks of residual tank wastes, including non-retarding radionuclides such as technetium and iodine, could be over a thousand years. This is particularly important, given the history of past modeling at the site indicating that fast travel was impossible (e.g., cesium-137 modeling versus measurements). It is also important to explain the basis for excluding fast flow paths in this model.

Despite the repeated characterization of the Preliminary Performance Assessment as conservative, it is difficult to find conservatisms in the vadose zone transport analysis. The vadose zone is modeled as having spatially uniform properties. Recharge is uniformly low (and temporally uniform) during the period when residual tank wastes are available to be transported. While it is certainly conservative to assume K_d is zero for the mobile radionuclides and chemicals, other chemical conditions that could affect release and transport, e.g., high pH due to the use of grout, presence of chelating agents, fast pathways, are not considered. The impact of such conditions should be noted.

It appears that vadose zone flow rates are slow enough that diffusion and capillary flow within vadose zone in response to pore solution concentration and moisture gradients may be a significant transport mechanism over the time scales being evaluated. This also creates the potential for wastes to migrate upwards in response to drying conditions. The significance of these factors should be evaluated.

GROUNDWATER TRANSPORT

The groundwater transport modeling is described in Section 3.4.3.4 of the Preliminary Performance Assessment (*PPA*, page 3-46), Section 3.8 of the Initial Simulation Document (Zhang, Freedman et al. 2003) and Section 5.0 of the Modeling Data Package (Khaleel, Connelly et al. 2003). The vadose zone model (STOMP) was used in all cases to transport contaminant from each source to the Waste Management Area C fence line. Breakthrough curves were converted to “fence line averages” then combined to create a series of annual pulse inputs to the groundwater transport modeling, although it is not clear whether this pulse input was summed over the year or simply the peak value. Groundwater transport was modeled using an analytical steady-state streamtube model that included longitudinal, horizontal and vertical dispersion. The model calculates concentration at a specified location as a function of the dispersion properties, pore water velocity and time. The pore water velocity was apparently calibrated using results from an existing site-wide groundwater model (VAM3D). The report also indicates that the travel times were estimated from the site-wide model and these are listed in Table 3.9 (Zhang, Freedman et al. 2003), but it is not clear what the travel times were used for in the calculations.

A Hanford site-wide groundwater model that forms the basis for the streamtube modeling is presented in the report in a way that implies general acceptance of the site-wide model. However, there are likely large uncertainties in the predictions from the site-wide model and these uncertainties will carry through to the streamtube model. The Panel notes that the Hanford site-wide modeling effort is continually undergoing revisions to reduce and/or better characterize uncertainties (Cole, Bergeron et al. 2001). The Preliminary Performance Assessment should consider these uncertainties, particularly where they influence the estimates of travel distance, dispersivities and pore velocity that are used in the streamtube modeling.

The most important input to the groundwater modeling appears to be the instantaneous source of solute mass at the fence line. It appears that the approach used in the Preliminary Performance Assessment modeling is to uniformly distribute the predicted mass or flux at the tank centerline across the entire fence line and depth of the aquifer. However, the description of how this was actually done in the Preliminary Performance Assessment is inconsistent and virtually incomprehensible. The Panel notes that the averaging process seems to dilute the centerline concentrations by a factor of 233 and it is completely unclear whether this dilution is appropriate for either the groundwater modeling input or for estimating exposure concentrations at the fence line. The Preliminary Performance Assessment does not provide adequate justification for the approach.

The fence line averaged input to the groundwater model is further diluted by dispersion both longitudinally and horizontally as the solute mass moves through time and space. There is also vertical dispersion, which seems counterintuitive given that the source is homogeneously mixed to the full depth of the aquifer. The hydrodynamic dispersivities are critical inputs to the streamtube model but the report is unclear about how values for these dispersivities were selected. Further, the Panel is concerned that dispersing the solute mass across the depth and width of the aquifer at the fence and then including lateral and vertical dispersion in the groundwater transport may not be an appropriate use of the model. Ahsanuzzaman et. al. (2003) indicates that there are limiting source dimensions for the type of instantaneous point source model used in the Preliminary Performance Assessment. These limiting dimensions do not seem to be considered in the current groundwater modeling. Justification for spreading the source over the length of the fence line, depth of the aquifer and distance of groundwater flow in a year, then further diluting the breakthrough curve with three-dimensional dispersion needs to be justified in the assessment.

No geochemical factors are considered in the analysis of groundwater transport other than a statement that Kd values greater than zero would reduce peak concentrations at the compliance points (*PPA*, 4-21). The streamtube model is essentially a lumped parameter model where all physical and chemical process or factors that influence the transport of contaminants in the groundwater are combined into the dispersivity and pore water velocity terms. Although the sensitivity of the Preliminary Performance Assessment modeling to saturated hydraulic conductivity was evaluated in at least one of the cases (Zhang, Freedman et al. 2003, page 4.3), it appears that this was only applied to the aquifer under the WMA and not to the assessment at the other compliance points.

Not including chemical factors that influence the level of retardation in the aquifer is probably a reasonable and conservative approach for the Exclusion Boundary and River compliance points. However, it is not clear how conservative this assumption is across the different exposure scenarios. For the groundwater pathway one would expect the mobile scenario to result in the maximum peak concentration because pollutants would travel as a plug with very little "chromatography" in the soil column and along the aquifer. However, for the scenarios that spread waste directly on the land surface by either inadvertent intrusion or contaminated groundwater irrigation, the less mobile pollutants may accumulate to a greater extent in the surface soil and in biota resulting in greater exposures. It is not clear whether the vadose and groundwater models adequately address the potential for accumulation of contaminants at the surface.

Overall, the Panel agrees that the simpler streamtube modeling approach is appropriate for the level of detail required in the assessment. However, the current documentation does not provide adequate information to replicate the results and it remains unclear whether important uncertainties have been addressed or if the model was applied correctly.

The Panel notes that negative travel times reported in Table 4-6 (*PPA*, page 4-22) do not make physical sense or the appropriate frame of reference was not clearly presented.

EXPOSURE ASSESSMENT

The exposure assessment as contained within the Preliminary Performance Assessment and its supporting "Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Preliminary Performance Assessments (HNF-SD-WM-TI-707 Revision 3)" appears to have been done in a manner generally consistent with previous assessments at the site. That being said, there is an unevenness in the presentation that contributes to difficulty in reading and interpreting the results. The plethora of regulations which may (or not) apply to this site undoubtedly hamper the authors' attempts at clarity. There also appears to be undue focus on conforming to the constraints of the RCRA closure activity, rather than trying to assess how a specific design would actually perform.

While the Preliminary Performance Assessment's exposure assessment is consistent with previous efforts at the site, greater effort needs to be made to ensure the latest science is reflected in the approach, per the recommendations of EPA (1997), particularly if this is being treated as a RCRA closure action. One example, discussed in detail below, is in the selection of soil ingestion parameters. Another issue which needs to be considered in greater detail is the generation of scenario-based unit dose conversion factors. The utility of generating such factors is obvious – it allows for repeated modification of the source term with only limited impact on the need to rerun the exposure assessment models. However at the heart of such factors is the assumption of linearity. In other words, the dose conversion factors scale linearly with changes in nuclide concentrations or inventory. The validity of this assumption needs to be examined in detail and results documented. This issue is also discussed below, as it applies to assumptions surrounding the driller scenario.

The heart of the exposure assessment is the presumption that the still-to-be designed barrier surrounding the waste functions as intended for a period of 500 years. While the surface barrier prevents intrusion by burrowing animals and plant roots for 500 years and limits infiltration to 0.5 mm/yr, it does not prevent driller intrusion. This apparent inconsistency in definition of the in performance of the system is of concern to the Panel.

The Panel also thinks the assertion in the Preliminary Performance Assessment that the approach used in the base case is "conservative" is not supportable, particularly considering that no final cover design or tank fill criteria have been selected. Section 3.5.1.2 of the Preliminary Performance Assessment notes that the base case scenario:

> "provides the "best" information on how the system may evolve given the information available. The base analysis case is not necessarily representative of the way the system will behave. As more information concerning the waste form, the disposal facility design, and disposal site location is gathered, the definition of the base analysis case is expected to evolve. The approach used in the base analysis case is conservative but reasonable."

The Panel thinks that a <u>reference</u> case should take no credit for cover, waste form, or structures following closure. A more reasonable approach would be to examine "preferred closure option(s)" to compare to the reference case to assess which factors are most important to exposure of both humans and biota.

<u>Scenario vs pathway and risk driver</u>

The work of Rittman (2003) provides scenario-based unit dose or risk conversion factors. The Preliminary Performance Assessment utilizes these factors by multiplying them with calculated release values to estimate total dose or risk for each scenario. While this appears to be an efficient approach to handling potential revisions in source terms, the Preliminary Performance Assessment does not address the underlying issue. How appropriate is the presumption of linear scaling of these risk and dose conversion factors?

For example, as part of the well-driller scenario, fixed dimensions of piping and a presumption as to of the length of the contaminated zone are utilized. Buried within this calculation is an assumption as to how the waste is spread onto the surface of the soil while the driller is working. Not examined in this process is the significance of the geometry of the retrieved waste to total dose rate. A "point source" of retrieved waste could potentially contribute a 100-fold greater dose rate than a plane or volume source. We cannot know what shape the material will fall into as someone drills and spreads it out on the ground, but it seems that it would be useful to understand how important (or not) this is in determining dose to the hypothetical intruder. Especially if this is one of the limiting scenarios.

In Rittman's work, a great deal of discussion centers on the optimum garden size for the suburban farmer and commercial farmer following the intrusion scenario. According to the text this is done in order to maximize dose from external sources relative to other routes. The Panel thinks it would be instructive to include some sort of "sensitivity" analysis to support the statement that the smaller garden size represents the maximal dose hazard. A further discussion of the "waste corrosion factor" which is referred to only on page 9 (Volume 0 par 3) and is used to estimate the unavailable portion of the waste is also warranted.

The Panel thinks that the display of doses and scenarios in the Preliminary Performance Assessment does not effectively communicate the various contributors to dose. It would be more appropriate to show (at least for the limiting cases) significant components (e.g., food, inhalation, external exposure, ingestion). This is a fairly typical method of displaying exposure assessments.

As stated earlier, the Panel does not agree that the exposure scenarios examined in the Preliminary Performance Assessment are necessarily conservative. For example, in Section 5.5.3 Waste Form Factor, page 5-15 of the Preliminary Performance Assessment it states that the amount of material contributing to internal dose is dependent on particle size. It assumes that the tanks will be filled with grout and that only some fraction of the grout material will be fine enough to contribute to internal dose once the material reaches the surface. The implication of this section is that one measure of conservatism in the dose assessment is the integrity of the waste form. However, elsewhere in the Preliminary Performance Assessment the waste is not presumed to be grouted and the long-term physical integrity of the grout is not considered. In the Numerical Simulation document (Zhang, Freedman et al. 2003, page 2.1) only the diffusion dominated release scenario cases (cases 11 and 13) used grout filled tanks or equipment. All the others were just backfill (page 2.1 of simulation document). Also, past and retrieval releases from the site will not be in grouted form. Finally, the time-frame for grout integrity has not been fully examined within the Preliminary Performance Assessment.

Appropriate exposure threshold criteria

The Panel thinks that the overlapping regulatory authorities make the presentation of threshold criteria somewhat problematic and results in a confusing display of results. However, the Panel also thinks that the selection of a 500-year compliance time for the inadvertent intruder may be inappropriate, considering both 40 CFR 191 and current DOE guidance. Part 191 specifically notes that performance assessments shall not consider any contributions from active institutional controls for more than 100 years after disposal.

The Panel also recognizes that the inadvertent intruder is a routine and accepted means of evaluating release directly from the waste form. However the Panel thinks that consideration should be given to other approaches to achieve the same end, which may not have as much uncertainty surrounding the assumptions. For example, on page 9 of 128 in Rittman's exposure assessment module (the well drilling scenario) it is noted that "the diameter of the well could range from 4 inches up to 12 inches. The larger the diameter, the more waste will be brought to the surface. Prior Hanford performance assessments assumed that the well diameter is 12 inches (30 cm). This value certainly establishes an upper bound on the volume exhumed by a well-drilling operation. A well diameter of 8 inches (20.3 cm) will be assumed in this report when example calculations are presented. Well diameter is not part of the dose, risk, or hazard index unit factors."

It seems inconsistent that an 8 inch diameter well was chosen over the 12– as the exhumed material is the key point in the dose discussion.

The Panel thinks that the soil ingestion factors used in the driller scenario appear to be less than conservative. In other human health risk assessments, EPA has used an "enhanced" soil ingestion rate of 330 mg/day to evaluate reasonable maximum exposure (RME) to utility workers. This estimate represents the 95th percentile value for adults reported by Stanek et al. (1997). Admittedly, the authors of that study noted that the estimate was "substantially uncertain." In other instances EPA has used a different enhanced soil ingestion rate of 200 mg/day to estimate reasonable maximum exposure soil ingestion exposures to farmers which represented the 90th percentile value reported by Stanek et al. (1997).

Although the Preliminary Performance Assessment indicates (p.44) that "the current EPA regulation governing drinking water, 40 CFR 141, is used to protect groundwater," the uranium MCL of 30 μg/L from 40 CFR 141.66(e) is not cited.

ECOLOGICAL ASSESSMENT

Substantive ecological assessments are not contained in the Preliminary Performance Assessment. The Panel thinks that this cursory examination of potential impacts is contrary to the philosophy of both EPA and DOE where it is strongly recommended that such assessments be made at least qualitatively early in the process. Examples of radionuclide preliminary remediation goals protective of ecological receptors can be calculated based on draft DOE standard of 0.1 rad/day for terrestrial animals and 1.0 rad/day for aquatic receptors[3]. For chemicals, preliminary remediation goals for soils potentially can be defined by risk-based ARARs in the Washington State Model Toxics Control Act (MTCA). Remediation goals for chemical contaminants in water, protective of groundwater, are based on maximum contamination levels (MCLs) and MTCA Method B levels.

The rationale for omission of an ecological assessment, as explained within the Preliminary Performance Assessment, is also inconsistent. The Executive Summary states that the Preliminary Performance Assessment "examines the long-term environmental and human health effects of the planned closure of the Waste Management

[3] the regulatory basis for much of this effort can be found at: *http://homer.ornl.gov/oepa/guidance/getbysubject.cfm*

Area C". Yet the performance objectives specified in Section 1.6 do not contain environmental standards, only human-based ones.

Text within the Preliminary Performance Assessment (section 4.14, page 4-43) dismisses the potential for biotic impacts. It states that biotic pathways are not credible over the time of compliance (1,000 years). However the figures presented in Appendix A of Zhang et al. (2003) indicate that a number of the cases (4, 5, 9, 11 & 13) resulted in migration of sometimes significant amounts of material to the surface where they would presumably be more available to bioturbation. Conversely, if the barrier fails, but the tanks remain intact, they could conceivably provide a reservoir of surface moisture, which also may prove attractive to biota.

RISK INTEGRATION

Overview

The Preliminary Performance Assessment for the closure of the Waste Management Area C is complicated by several factors. One is that the four release sources addressed in the Preliminary Performance Assessment – past leaks, leaks during retrieval, leaks from ancillary equipment, and releases of residual waste – occurred or will occur at different times and most likely under different hydrologic conditions. As a result, the timing and locations of exposures that would result from these releases vary. For example, the time to peak exposure from releases of residual tank wastes may occur hundreds or thousands of years after the peak time for past leaks. Obviously, if this is the case, different individuals are at risk from each source, and it would be incorrect to simply add the doses or risks for each release case.

A second factor is that the modeling is done on the basis of releases from an individual tank, but releases from several tanks with the Waste Management Area C may accumulate as ground water passed under the tank farm. It is therefore necessary to combine the collective effect on ground water for the scenarios in which ground water is the source of human exposure. This issue extends beyond the Waste Management Area C; Waste Management Area C is only one of many tank farms to be closed, and the releases to ground water from various tank farms and other sources can intersect. The integration of releases from Waste Management Area C with releases from other areas is not addressed in the Preliminary Performance Assessment. The Panel thinks that this integration must be achieved for informed final risk management decisions.

The Preliminary Performance Assessment addresses these points, but, with the exception of the doses resulting from inadvertent intrusion, the presentation of when, where, and how exposures from each waste source will occur are difficult to follow. This section includes suggestion regarding how the results could be more effectively integrated and presented.

Need to use multiple descriptions and measures to report results

Figures 5-1 and 5-2 effectively present the results of the analysis of doses to the driller. These curves illustrate that the only doses of significance from the tank residuals are the

30-year half-life radionuclides, Cs-137 and Sr-90. Table 6-2 provides similar results for the rural farmer inadvertent intruder scenario. Similar curves should be provided separately for all four sources, with identification of which radionuclides are the main dose contributors, although the Panel recognizes that for some of the scenarios only a limited number of chemicals are included in the analysis. In addition, for the scenarios where there are multiple exposure pathways (e.g., food, drinking water, soil ingestion, etc.), a graphical illustration of how much dose contribution comes from each pathway would be informative. Collectively, such a family of graphs would indicate the dose rates (a) for each scenario, (b) as they are distributed over time, (c) from which release source, (d) from which radionuclides or chemicals, and (e) through which exposure pathways.

Once the components of the analysis have been presented, the superposition of results can be presented. This superposition includes the compilation of exposures from multiple tanks, tank farms, and release sources. Clear graphical presentations of these results would help identify plausible and significant scenarios (i.e., which sources are potentially significant, and which are not.)

The amount of residual waste left in the tanks during retrieval is clearly an issue of importance to local citizens and to the regulators. Clear sensitivity analyses - especially concerning the residual amounts and the various release models for the residuals - are important for the performance assessment to be useful to interested parties. Such information should be provided from multiple perspectives. For example, a curve indicating how the dose rate versus time changes for different release models would be useful. It is noted that for the residual wastes, model forms are used that result in dose estimates that scale with the amount of residual wastes. But the comments in this review have identified situations where this assumed linearity between source activity and dose is not valid. Sensitivity analysis that considers such cases is important. How significant the differences in dose rate are for a range of tank residuals, when the four release sources are included, should be evaluated.

Note that Section 4.9.4 states that "the impacts from residual waste are much smaller than from past leaks or potential retrieval leaks, which will occur before the barrier is installed." This statement should be accompanied by a description of how and when the impacts from each set of releases occur.

Risks from the perspective of the total system

For scenarios involving exposures to residual waste releases by a ground water pathway, doses are mainly due to Tc-99 and I-129. Under the current plan for tank farm closure and waste treatment, the wastes retrieved from the tanks will be split into a high-level stream to produce vitrified logs to be sent to a HLW repository such as Yucca Mountain for disposal. The remaining wastes will be vitrified and disposed of in the 200 Area. The current plan is that Tc-99 and I-129 would remain in the stream to be disposed of in the 200 Area.

Given that the current plan is that all the Tc-99 and I-129 in the tanks will be disposed of by shallow-land burial in the 200 Area, it would be useful to provide analysis and information on the relative performance of the two disposal systems for these two radionuclides. In particular, it would be useful to understand whether one disposal system offers significantly better waste isolation than the other for Tc-99 and I-129. Such an analysis should also provide insights into the benefits associated with achieving the targeted goals for waste retrieval from the tanks and closure requirements.

Further clarity is also needed in which limits will be exceeded, when and where. On page 6-5 of the Preliminary Performance Assessment, there is the following statement in the discussion of uncertainty about recharge rates: "…. While the use of a lower value (e.g., 1.95 in./yr [50 mm/yr]) will lead to a lower near term peak concentration, **the predicted fence line concentrations will still violate MCL and EDE limits**." (Emphasis added). This statement is out of character with the rest of the document that consistently implies a wide safety margin.

Impacts from restoration activities (e.g., source of cap materials)

Throughout the Preliminary Performance Assessment the presumption is made that a suitable barrier will be constructed over the tank farm and each tank will be stabilized. Yet no estimate is made of the volume or availability of material that will be required to satisfactorily close these sites. The Panel believes that it is inappropriate to presume complete functionality of a barrier system when the source material has not been identified. Because of the potentially large volume of material required, there may be associated impacts from this activity as well.

Need to address results that conflict with past analyses and perceptions

During the roughly 20 years in which plans to deal with the tank wastes have been explored, a variety of options have been proposed and analyzed. As data and other information, for example, from the Vadose Zone/Ground Water Integration Project have accumulated, the understanding of the waste and the site has evolved, as has the perception of how well various closure approaches would work. Where the current analysis and understanding conflicts with prior results, it is important to explain the basis for the new results. In order to minimize the credibility problems associated with the reaction "that's not what you told us two years ago," significant changes in the technical understanding, analysis and results should be identified and discussed.

One example was noted in the discussion of the vadose zone analysis: it was the need to reconcile the current analyses that indicate very long travel times through the vadose zone with past leaks that have already reached ground water. Another is the 1996 Tank Farm EIS (DOE/EIS-0189), which indicated that unacceptable consequences would result if 1% of tank wastes remained in the tanks as residuals[4]. The current analysis does not indicate that this is the case, provided that the inadvertent driller scenario can be avoided at early times. Further, the Preliminary Performance Assessment asserts that previous assumptions about the importance of tank residual waste and retrieval methods may be incomplete or faulty (*PPA*, page 6-4), and although the results from the current assessment might indicate this, the reason for the difference is not provided.

[4] This observation is based on a comment received during the Panel's public input session.

Yet another such issue concerns the estimated volume of past tank leaks, relative to the estimates of potential leaks during retrieval. The Panel found it difficult to understand how past leaks were estimated to be of the order of 1000 gallons, while leaks during retrieval are modeled with 8,000 and 20,000 gallon release scenarios.

ADDITIONAL OBSERVATIONS

Immediate Reduction of Infiltration

Installation of a temporary barrier as soon as possible to minimize infiltration at Waste Management Area C should be evaluated. Infiltration is the primary mechanism that results in transport of contaminants in the vadose zone to groundwater. The amount of infiltration that will occur over the 45 years projected until closure is completed exceeds the amount of infiltration estimated for the subsequent 500 years. Early application of measures to minimize infiltration may greatly reduce or delay the release of contaminants to groundwater. Evaluations completed for other Hanford waste management areas suggest that early reduction in infiltration may reduce groundwater contaminant concentrations by a factor of 2. However, the uncertainties described earlier in this review with respect to source term release and vadose zone transport suggest that benefits may be substantially greater. This early action also should be evaluated for other waste management areas.

Rapid Closure of Waste Management Area C as an Experimental System

Substantial reductions in the major uncertainties in the Preliminary Performance Assessment will only be achieved through closure experience. These uncertainties include final physical configuration, remaining contaminant inventory and form in the tanks after waste retrieval, leakage during retrieval, source term release mechanisms, etc. Therefore, the Panel believes that is would be extremely advantageous to complete physical closure of Waste Management Area C to serve as a prototype closure system with information gained serving to improve closure decisions for the other tank farms. The current plans and commitments will require closure of all the tanks with only limited allowance for monitoring and feedback from experience. This appears to be in-part because of the absence of focus on complete closure of a single waste management area early in the overall Office of River Protection closure process. Closure of Waste Management Area C should be accomplished with appropriate characterization and monitoring during and after closure, necessary to substantially reduce uncertainty and thereby improve the assessments for this and other waste management areas with similar characteristics.

CONCLUSIONS AND SUMMARY OF MAJOR RECOMMENDATIONS

The Merit Panel recognizes that the Preliminary Performance Assessment was prepared early in the closure process, in part to help guide the closure process. The Preliminary Performance Assessment obviously reflects an enormous effort on the part of CH2M-Hill and others. They are to be commended for their willingness to solicit review and input at this early stage in the process when both information and processes are in a state of flux. The Panel is sensitive to the potentially confusing and sometimes conflicting regulatory environment in which this assessment must be conducted. None the less, the Panel thinks that certain aspects of the Preliminary Performance Assessment can be revised in order to more directly meet its stated goals.

As a result of the preliminary nature of the Preliminary Performance Assessment, there are many uncertainties about the contaminant inventory and characteristics within Waste Management Area C and the final closure configuration. These uncertainties will be reduced as the closure process progresses. There are uncertainties about contaminant transport and the closure system performance that can be reduced, although not eliminated, through additional field and laboratory measurements. However, there are substantial uncertainties about the closure system performance, contaminant transport and human health risks that are <u>not</u> reducible. The greatest irreducible uncertainty is that associated with future human activities that may potentially disrupt the closure system, alter groundwater flow or direction, or lead to human contact with contaminated vadose zone materials or groundwater. Additional uncertainty that is irreducible beyond a limited extent, is knowledge of heterogeneous properties and processes that occur at various spatial scales in the subsurface and future climate conditions. It is in the context of the uncertainties described above that the Preliminary Performance Assessment uses engineering models based on conceptual models that contain assumptions and simplifications to evaluate long-term health risk as a consequence of potential human exposure. Model sensitivity analysis and parameter sensitivity is the tool that usually is used to evaluate the relative importance and implications of these uncertainties.

Below is a list of the Merit Panel's primary concerns and recommendations regarding the Preliminary Performance Assessment as a result of this review: The Panel thinks, that because of the nature of many of the recommendations, it is not possible to discern in advance whether the impact of implementing the recommendations will result in overall increased or decreased estimates of risk. The Panel does think that implementation of these recommendations will provide improved clarity and credibility to the risk evaluation process and subsequent decisions based on the analysis.

1. The Preliminary Performance Assessment is not written in a manner that clearly and effectively communicates the objectives and results of the evaluation to a general audience or to a technical audience. The assessment's objectives, methodology, assumptions, results and uncertainties should be described within the main body of the report; and, detailed information necessary for auditing and replication (when necessary for verification or subsequent updating as new information becomes available) in associated appendices. The relationship of the Preliminary Performance Assessment to other risk evaluations, closure design criteria and decision processes also should be clearly stated in the document.

2. The Preliminary Performance Assessment should be evaluated for consistency with potential future closure requirements under CERCLA. Although the closure process is being carried out under RCRA, DOE and Ecology requirements, Waste

Management Area C is also part of the Central Plateau Area of the Hanford Site, which will likely require closure under CERCLA in the future. It is not clear that the current Preliminary Performance Assessment fully considers potential requirements under CERCLA. For example, it appears that CERCLA closure would require a maximum dose rate of 15 mrem/yr, while current planning under DOE orders is based on 25 mrem/yr for the C-Farm closure (PPA, p. 1-16). However, the Hanford-wide all-pathway dose limit is 100 mrem/yr (PPA, Table 1-2) which is significantly above the CERCLA closure limit.

3. The criteria and rationale for selecting specific models (e.g., for contaminant release, transport through the vadose zone, and transport through groundwater) should be clearly defined. Model uncertainty (e.g., physics, chemistry and biology), parameter uncertainty, and underlying assumptions should be clearly stated. Uncertainty propagation should be achievable throughout the risk evaluation process. Previous use, in and of itself, is insufficient justification for model selection. Evaluation of model sensitivity and parameter uncertainty should be presented.

4. The Preliminary Performance Assessment should evaluate additional physical failure modes and their implications for contaminant release and exposure. These evaluations should recognize that (i) engineered materials are unlikely to deteriorate in such a manner that they resemble the sands and fill material surrounding the tanks, (ii) deterioration is likely to be progressive, not instantaneous at some time in the future, and (iii) surface barriers (i.e., caps) are unlikely to retain their integrity with respect to hydraulic properties for 500 years.

5. The assessment of contaminant release from residual waste in the closed tanks, ancillary material and contamination currently in the vadose zone should be based on models that reflect controlling release mechanisms determined through future characterizations efforts. Contaminant release will most likely be controlled by one or more of the following mechanisms: (i) dissolution of sparingly soluble phases, (ii) diffusion through grout and tank shell concrete matrices with slow rates of moisture exchange at the external boundary, resulting in boundary conditions different than assumed in the current analysis, or (iii) slow desorption phenomena. These processes also typically will not scale linearly with contaminant inventory.

6. Evaluation of contaminant transport to and with the groundwater should include more thorough discussion of model uncertainties and sensitivity analysis. The direction and travel times to the Columbia River for contaminants released from Waste Management Area C depend strongly on when contaminants reach the groundwater underlying the site and other site-wide activities that impact groundwater flow. For example, current travel times to the Columbia River are estimated at approximately 50 years because of site-wide activities, while travel times under conditions that existed before site activities are estimated at approximately 1000 years. Additional evaluation and explanation of the potential for fast flow paths is needed, especially given the history of modeling at the

Hanford site where preliminary models unintentionally excluded important processes and consequently overestimated contaminant travel times. Results should present the location and magnitude of peak groundwater concentrations as a function of time, in addition to the concentration as a function of time at the Waste Management Area C and Central Plateau boundaries.

7. Exposure assessment should include additional sensitivity analysis and present the contributions of individual pathways to dose and risk for each scenario examined. Recommendations presented above that effect contaminant release and transport will have both positive and negative impacts on exposure. Recognizing that exposure assessment scenarios are hypothetical constructs of future human behavior, and human behavior is highly variable, the specific scenarios should be viewed as example cases of individual exposure, but sufficient information should be provided for reviewers to construct alternative exposure scenarios, that may include or exclude specific pathways. This approach should apply to exposures that occur through groundwater use (direct and indirect) and intruder scenarios.

8. The Preliminary Performance Assessment should estimate the quantity of contaminated material remaining in the subsurface, which if exposed by an inadvertent intruder would cause unacceptable risk. This quantity should be presented as a function of time after closure. The risk from component pathways also should be presented. The most significant risks identified in the analysis appear to be associated with the inadvertent intruder scenario, particularly if intrusion occurs soon after closure. DOE guidance is cited to support the assumption that no intrusion occurs for 500 years, but no supporting technical basis for this assumption is provided. Currently, the Preliminary Performance Assessment focuses on a well drilling scenario to result in direct and indirect exposure to contaminated materials remaining below surface barriers after closure. It would be very helpful to discuss whether the surface barrier could be detected by an inadvertent intruder and whether it could prevent well drilling, particularly during the period after closure when the greatest hazard remains (e.g., during and immediately following the first 100 years after closure). If the closure barrier is designed to dissuade drilling, then the likelihood of this scenario occurring is diminished. However, given the uncertainty of future human activities, the potential for some aggressive action to expose and disperse contaminated material remaining below the closure barrier is possible.

9. Ecological risk has been explicitly excluded from the Preliminary Performance Assessment, but it is the view of the Panel that preliminary work should be started in this area, including, at a minimum, an examination of potential radiological impacts to biota using the current guidance of the Department of Energy.

10. The Preliminary Performance Assessment should include estimates of the upper, lower and central tendency of contaminant release, peak contaminant concentrations in groundwater at important geographic boundaries, and human health risk from individual pathways. Use and presentation of only "conservative" assumptions, including of safety factors at multiple levels, distorts

understanding of risk by only providing an estimate of maximum risk. Understanding the range of risk presented by different exposure pathways provides a clearer understanding of uncertainties in the evaluation.

11. In the Panel's view, there are elements that whether from lack of documentation or their absence caused the total analysis not to provide an upper bounding estimate of risk. These aspects include:

    - the assumption that the vadose zone is homogeneous and uniform within defined stratigraphic layers, with no fast-flow pathways,
    - the failure to consider episodic precipitation events (including multiyear periods of high precipitation) that could result in higher-than-estimated recharge rates,
    - the assumption that the surface barrier will remain intact and can result in recharge rates one-seventh of those of the natural system for 500 years,
    - the failure to consider an inadvertent intruder's borehole as a fast pathway for waste to move to ground water,
    - the failure to consider tank failure modes such as "bathtubbing" that could result in release of contaminants in a pulse, tank integrity over periods greater than 50 years would divert infiltration (i.e., "umbrella effect"), increasing the rate of transport of contaminants already in the vadose zone to groundwater, or that tank failures before 50 years would lead to transport of residual wastes while recharge is high.
    - the use of ground water concentrations averaged over the fence line as exposure concentrations for the groundwater pathway and as input to the streamtube modeling

For these reasons, the Panel does not agree that the current analysis is necessarily conservative.

The Panel also recommends that insights gained through the Preliminary Performance Assessment be used to consider how the closure and future performance assessments could be improved. For example, the following actions at Waste Management Area C should be evaluated as a result of the Preliminary Performance Assessment:

1. Installation of a temporary barrier to minimize infiltration at Waste Management Area C as soon as possible. Infiltration is the primary mechanism that results in transport of contaminants in the vadose zone to groundwater. The amount of infiltration that will occur over the 45 years projected until closure is completed exceeds the amount of infiltration estimated for the subsequent 500 years. Early application of measures to minimize infiltration may greatly reduce or delay the release of contaminants to groundwater. This early action also should be evaluated for other waste management areas.

2. The use of Waste Management Area C as an experiment to gain insights to improve closure of other tank farms. The current plans and commitments will require closure of all the tanks without allowing for monitoring and feedback from experience. Waste Management Area C can serve as a prototype closure, and with appropriate characterization and monitoring during and after closure, serve to substantially reduce uncertainty and thereby improve the assessments for this and other waste management areas with similar characteristics. This will require completing physical closure of Waste Management Area C before closure of the tank farms and with enough time to gain monitoring data that can aid in the decisions for the other cases.

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