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FROM: R. Wright, WMHT

March 1983

101.1

SITE ISSUE ANALYSES (SIAs) --
BACKGROUND INFORMATION FOR
PREPARATION OF BWIP DRAFT SITE
CHARACTERIZATION ANALYSIS

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Issue No. 1.1

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What is the nature of the present groundwater system?

3. Importance of the Issue to Repository Performance

A knowledge of the nature of the groundwater system is required for evaluation of the performance of any repository. This performance evaluation is critical to the licensing process.

4. Portions of 10 CFR That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

Specifically, 10 CFR 60 requires

- o evaluation of radionuclide release for comparison with the EPA standard (§60.112 - Performance Objective)

- o evaluation of undisturbed groundwater travel time (§60.113(a)(2) - Geologic Setting)

In addition an evaluation of a wide range of potentially favorable and unfavorable conditions is required by the rule (§60.112(b) and (c), respectively).

All of these determinations require a knowledge of the nature of the groundwater system.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

The groundwater flow system is currently not adequately understood. The directions and velocities of flow in the presently existing system cannot be assessed, and it is not presently possible to make any of the evaluations of repository performance which depend upon hydrogeology. These evaluations depend upon an understanding of the components of the groundwater system, which are discussed in the following site issue analyses:

- parameters (1.1.1)
- recharge and discharge locations (1.1.2)
- boundaries (1.1.3)
- structural heterogeneities (1.1.4)
- stratigraphy and lithology (1.1.5)
- hydrochemistry (1.1.6)

These components must also be organized into a conceptual model of the system, which is discussed in SIA 1.1.7. This model can then used for mathematical analysis, as discussed in SIA 1.1.8.

Uncertainties

The present uncertainty about the nature of the groundwater system derives from the uncertainties in the components, of which key items are:

- Parameters and heads are known only within very wide ranges, and some important parameters are not known at all.

- o Boundary conditions including recharge and discharge locations, have not been investigated in the field.

- o The hydrogeologic significance of known structural heterogeneities is unclear, and it is not known whether all significant heterogeneities have been identified.

- o The significance of stratigraphy and lithology within the flow system has not been demonstrated.

- o The hydrochemistry cannot by uniquely interpreted.

Because of these uncertainties, the conceptual model of the groundwater system is uncertain, and thus modeling remains highly speculative. These uncertainties are discovered in more detail in the appropriate sub-issue analyses.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Several key sets of information are needed to allow development of an acceptable understanding of the nature of the groundwater system. The major requirements are:

- o A reliable knowledge of the present groundwater heads must be obtained, both in three dimensions and over time. This information is needed to allow evaluation of existing flow directions, and to allow calibration of the steady-state hydraulic aspects of any predictive hydrogeologic model.

- o Information is required about the actual behavior of the system when it is subjected to a hydrogeologic stress. This information is needed to calibrate the dynamic hydraulic aspects of any predictive hydroreologic model.

- o More appropriate information is required on key hydraulic parameters, particularly horizontal and vertical hydraulic conductivity. Values of these parameters appropriate to repository scale do not exist, and are required for performance assessment.

- o A great deal more information is required about parameters which control fluid and solute transport in the system. Most importantly, the porosity, of the host rocks is presently almost unknown. This parameter directly controls fluid and solute particle velocities in the system, and is critical to performance evaluation. Retardation and dispersion behavior is also inadequately known at present. Finally, matrix diffusion behavior and parameters have not been evaluated, despite the possibility that this mechanism may have a major positive effect on repository performance.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide Information Needs of (6):

The planned approaches to evaluating the present groundwater system are essentially a continuation of the previous testing program. Primary emphasis will remain on temporary completions in single boreholes to obtain further information about heads, horizontal hydraulic conductivities, and hydrochemistry. In addition, several dual-borehole tests are planned within the Cold Creek Syncline and one cluster test is planned at a site immediately south of the RRL site. While a general description of the proposed testing program is presented in the SCR and supporting documents (BWIP 1982a, 1982b and 1982c), details are lacking. Additional tests will be conducted in portholes and possible room-scale environments within the exploratory shafts. Several tracer tests are planned to evaluate effective porosity and dispersivity, although locations and test details are not specified in the SCR. Boundary conditions will be evaluated using hydrogeologic test data and the results of regional models. Hydrochemical samples will be taken during the single borehole drill-and-test sequence and from selected zones in existing holes using double packer systems. The effects of geologic discontinuities and structures upon groundwater flow will be evaluated using results of hydrogeologic tests, hydraulic head measurements and hydrochemistry. DOE plans to perform numerical modeling at various scales to resolve all other questions about boundaries, flows, and to validate the conceptual hydrogeologic model.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The NRC staff finds that the proposed test plan will not provide adequate definition of the groundwater system.

This conclusion is drawn from the conclusions of the contributing site issue analyses (1.1.1 through 1.1.8) and is based primarily upon the following factors:

- Head distributions developed from temporary completions are too inaccurate to allow the flow system to be identified.

- Hydraulic conductivities developed from tests in single boreholes vary extremely widely. The values are inappropriate for use in performance evaluation because they do not allow development of sufficient confidence in the results.

- Models used for evaluation of the performance of the repository will not be able to be calibrated in the steady-state case because of the lack of accurate head data, or in the transient case because of the lack of sufficient area-scale perturbation tests. Without such calibrations modeling of performance is not reliable.

- Fluid and solute transport parameters will not be sufficiently improved by the proposed test program to allow needed predictive capability to be developed.

The NRC staff regards truly large-scale testing of this site as essential.

Such testing is entirely feasible at this site (Appendix E) and is considered to be the normal test approach for site evaluations (as distinct from reconnaissance) in layered material suites. A limited number of such tests would provide much of the data which the NRC staff has identified as lacking. The staff also considers that one such test should be conducted at the center of the repository location, to provide an hydraulic analogue of repository performance. This test would directly address many of the repository performance questions, and would very much reduce uncertainty about behavior of the groundwater system.

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Issue No. 1.1.1

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What is the three-dimensional distribution of hydrogeologic parameters (including vertical and horizontal hydraulic conductivity, hydraulic head, effective porosity, double porosity, dispersivity, and matrix diffusion)?

3. Importance of the Issue to Repository Performance

The three dimensional distribution of hydrogeologic parameters is necessary for formulating and calibrating groundwater models for performance evaluation.

4. Portions of 10 CFR 60 That Are Directly Connected To This Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With An Analysis of Uncertainties

Present State of Knowledge

Hydrogeologic parameters primarily have been measured from single-hole tests using packer technology. Numerous measurements of horizontal hydraulic conductivity and hydraulic gradient have been obtained in interflow zones. Some measurements of horizontal hydraulic conductivity in dense basalt zones have been taken. No measured values of vertical hydraulic conductivity exist. Two tracer tests have been conducted at one location to measure effective porosity and dispersivity. Matrix diffusion has not been measured. A high degree of variability exists in the measured parameters, making interpolation between measured values unfeasible at this time using normal interpolative methods.

Uncertainties

The accuracy and representativeness of measured data are uncertain because of potential problems associated with using packer technology for head measurement (Appendix G), drilling mud (Appendix I), the large variability of data (Appendix H) and the lack of large-scale tests for bulk parameters (Appendix E). Because of this uncertainty in the measured data, there is also a high degree of uncertainty associated with the use of normal interpolative methods to develop the three-dimensioned distribution of hydrogeologic parameters.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

Representative bulk values of hydraulic parameters measured at a scale appropriate for performance assessment are required. Accurate long-term measurements of hydraulic head are also necessary. An interpolative method to define the three-dimensioned distribution of parameters must be developed and validated.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

Additional testing of hydraulic parameters and measurement of hydraulic heads are planned in single boreholes using packer technology. Several dual-borehole tests and at least one multiple-hole test are also planned. Specific details of the planned tests are not given in the SCR. Tests for hydraulic parameters are planned from the exploratory shaft and underground test facility. The detailed methodology by which measured data will be used to develop the three-dimensioned distribution of hydrogeologic parameters is not presented in the SCR. The SCR indicates that an iterative process between data collection and modeling will be used to establish additional data needs.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The NRC staff finds that primary emphasis on single-hole tests using packer technology and the limited number of multiple-hole tests will not provide sufficient bulk hydrogeologic parameters for repository performance evaluation. The NRC staff considers that short-term monitoring of hydraulic head using packer technology to be inadequate and that long-term monitoring using conventional methods to be necessary. It is also important to consider matrix diffusion, since this could have a positive effect upon repository performance. Integration of measured data into a three dimensional distribution of parameter values is not currently feasible due to large variations in measured values and uncertainty in their representativeness. The iterative process described to establish additional data needs is considered very appropriate. However, it does not appear that the proposed plans contain enough large-scale testing to permit adequate development of the three-dimensional parameter distribution.

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Issue No. 1.1.1.1

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are measured hydrogeologic parameters of each unit tested?

3. Importance of the Issue to Repository Performance

Formulation of defensible groundwater models for performance evaluation, and development of a continuous three-dimensional distribution of parameters for use in those models requires a data base of representative hydrogeologic parameters obtained by in situ testing.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Values of horizontal hydraulic conductivity are primarily from single-hole tests in flow tops, with some values from dense basalt zones. One multiple-hole test in DC7/8 yielded a bulk value representative of a scale of at least 15 meters (50 feet). Present data are extremely variable, even within the same stratigraphic unit tested at different locations (see NRC-0960 Appendix H). Based on these test results, flow tops are significantly more permeable than dense basalt zones. No values of vertical hydraulic conductivity have been measured. Effective porosity is on the order of 10^{-4} based on only two tracer tests over a distance of approximately 15 meters (50 feet) in an interflow breccia in DC7/8. Dispersivity, based on the same DC7/8 tests, is 2-3 feet. No data on matrix diffusion coefficients are available. Hydraulic head has been measured within a number of test intervals using packer technology to obtain hydraulic isolation.

Uncertainties

Analysis of uncertainties considers only horizontal hydraulic conductivity effective porosity, dispersivity and hydraulic head. Measured horizontal hydraulic conductivity has a high degree of uncertainty because of short duration tests on single wells drilled using mud rotary techniques. Effective porosity and dispersivity have been measured at only one site, over a very limited lateral distance. Uncertainties in hydraulic head result from the lack of long-term time-coincident data, possible disturbances caused by drilling and testing, and measurement using packer technology. It is our belief that much of the variability and uncertainty has been introduced by the method and scale of testing.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

Bulk values of horizontal and vertical hydraulic conductivity need to be measured using appropriate tests (e.g., see Appendix E). A data base needs to be established for effective porosity, double porosity, dispersivity, and matrix diffusion coefficient. Measurements that represent stable long term hydraulic head are required. All parameters should be measured at the scales required for performance assesment.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

Additional measurements of hydraulic parameters and hydraulic heads are planned in selected intervals of the Saddle Mountain, Wanapum and Grande Ronde Basalts. The great majority of these tests are to be in single boreholes using packer technology. Several dual-borehole tests are planned within the Cold Creek

Syncline (e.g., DC-1/2, DC-4/5, DC-7/8), and one cluster test (multiple borehole) is planned immediately soth of the RRL site (DC-16, A, B, C).

One large-scale test is planned in the Cold Creek Valley, some 10 kilometer (6 miles) from the RRL. A general description of these plans is provided in the SCR and supporting documents BWIP 1982a, 1982b and 1982c. Vertical hydraulic conductivity will be determined in multiple-hole tests using the ratio method (Neuman and Witherspoon, 1972). Specific zones to be tested are not described in the SCR. The SCR indicates that permanent installations for monitoring hydraulic head are being considered, although further details are not provided. Tracer tests are planned to evaluate effective porosity and dispersivity. Plans for evaluating matrix diffusion and double porosity are not provided. Some hydraulic testing is planned in the exploratory shaft and underground test facility (SCR p. 17.2-26 to 28), however, no details are provided.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of of Success</u>:

<u>Likelihood of Success</u>

It is difficult to evaluate the previously described planned approaches because no details are presented in the SCR. However, the plans appear to place primary emphasis on single-hole tests using packer technology. The NRC staff feel the limited number of multiple borehole tests (DC-1/2, DC-4/5 and DC-7/8, and DC-16A, B and C) and the relatively small volume of the medium to be tested will not provide sufficient bulk hydrogeologic parameters for the performance evaluations required by Draft 10 CFR 60. It is also questionable whether the information gathered during the planned large scale test will be transferred to the site. DOE's plans are incomplete because plans to evaluate matrix diffusion and double porosity are not given. The current and proposed method of measuring hydraulic head using packer technology is considered inadequate. Permanent (or semi-permanent) piezometers are considered necessary to accurately evaluate hydraulic head (see Appendix G).

The tests planned for the test shaft and test facility are essential to the development of an understanding of the near-field hydrology, but do not in any way remove the necessity for obtaining bulk geohydrologic parameter for the far-field system.

In summary, the NRC staff finds believe that the proposed testing program will not yield the needed information on hydraulic parameters, aquifer/aquitard continuity and hydrogeologic effects of geologic discontinuities (See Appendices H and O).

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Issue No. 1.1.1.2

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What is the method of data integration which is used to develop the three-dimensional distribution of hydrogeologic parameters?

3. Importance of the Issue to Repository Performance

The development of a continuous three-dimensional distribution of parameters from a finite number of measured data points requires a defensible method of data integration and interpretation.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summarize Pertinent Topics and the Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Available data (i.e., measured values of horizontal hydraulic conductivity) indicate that normal methods of interpolation between measured data are not valid because of very large and apparently unpredicatable spatial variations. Existing performance models are based upon mean parameter values from single-hole tests which are considered representative of specific units. For example, the preliminary RHO performance model presented in Section 12.4.3 subdivides the analysis domain into basalt flows consisting of dense zones and flow tops. With two exceptions, the hydraulic properties of each of the two types of layers (dense, flowtop) are the same.

Uncertainties

Large uncertainties will exist in integrative methods because of large variation in measured values and lack of knowledge about their representativeness. It is not clear whether parameters spatially vary in a random manner or whether they vary in a definable manner.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

It must be demonstrated that measured hydrogeologic parameters are representative at a scale appropriate for performance assessment. Also, an integrative method to define the three-dimensional distribution of parameters must be developed and validated.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

Hydrogeologic testing plans are discussed in 1.1.1.1. The detailed methodology by which measured data will be used to develop the three-dimensional distribution of hydrogeologic parameters is not presented in the SCR. The SCR contains a brief description of the use of geostatistical interpolation (Kriging) to analyze available horizontal hydraulic conductivity data from the Umtanum flow and Mabton interbed (SCR pp. 12.4-17 to 20). However, details of the analysis are not provided. The SCR indicates that results from testing activities will be continuously input to modeling studies and that "additional data needs will be established by an iterative process between data collection and modeling confidence."

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

Interpolation of hydrogeologic parameters between points at which measured values exist is not feasable based upon existing data. If the variation currently reported (e.g., 4 to 6 orders of magnitude for horizontal hydraulic conductivity (BWIP, 1982, p. 33)) is characteristic of repository scale volumes of material, then the methodology being used is appropriate. However, the methodology it may be inadequate to achieve the required accuracy of performance evaluation. If parameter variation at a repository scale is much smaller than that observed in existing data, then an interpolative method could probably be developed and the required accuracy of performance evaluation may be achieved. It does not appear that the proposed program is sufficient in either case because of the limited number and locations of appropriate large-scale tests.

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Issue No. 1.1.2

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the groundwater recharge and discharge locations, mechanisms, and amounts for the Pasco Basin?

3. Importance of the Issue to Repository Performance:

Knowledge of groundwater recharge and discharge locations, mechanisms, and amounts is necessary input for formulating both conceptual and mathematical models of groundwater flow systems in the Pasco Basin and for calculating travel times.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties:

Present State of Knowledge

Groundwater recharge and discharge locations for deep aquifers are currently not identified due to complex distribution of hydraulic head data. Mechanisms and amount of groundwater recharge and discharge are not defineable at this time. Data are conflicting but suggest that groundwater discharge enters the Columbia River within the Pasco Basin. Doe assumes that groundwater recharge areas are usually basalt outcrops while discharge is into either an overlying aquifer or into a surface water body (SCR 5.1-12). Thus, the major recharge area for the Grande Ronde would be outside the Pasco Basin at locations where the Grande Ronde is at or near surface. DOE assumes that the groundwater in the basalts discharges to the Columbia River near Wallula Gap (SCR, p. 5.1-57, 61, and 64). Assessment of the importance and magnitude of recharge/discharge through basalt confining layers is not possible because vertical hydraulic conductivity has not been measured.

Uncertainties

Groundwater recharge and discharge locations, mechanisms and amount in the Pasco Basin are not defineable at this time due to the complexity and limited areal distribution of the available hydraulic head data, limited data on vertical and horizontal hydraulic conductivity, and lack of demonstrated hydraulic continuity (Appendices G and O). Regional hydrochemical data which might help identify recharge and discharge locations and mechanisms has not been collected.

Water balance studies have proven inconclusive due to inaccuracies inherent in obtaining the required data. In particular, high flow of the Columbia River makes it impractical to calculate potential discharge from deep basalts to the Columbia River based on measured river flows. That is, error in flow measurement of the Columbia River exceeds expected discharge from the basalt.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

A broader data base is required in a vertical and areal sense that also minimizes the effects well drilling and testing procedures have on measured heads. Hydraulic head data are required that represent long-term water level recovery at most test intervals in all wells. Because veriations will affect recharge/discharge mechanisms and amounts, vertical and horizontal hydraulic conductivity requires definition over broad areas in the vicinity of Reference Repository Location (RRL) in order to identify variations in this property. Testing is needed on a number of colonnade/entablature zones to measure bulk values.

Detailed, accurate head and hydrochemical data delineating recharge/discharge areas are needed.

The impact of vertical leakage through what are assumed by RHO to be low hydraulic conductivity, confining layers must be assessed.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

Evaluation of groundwater recharge/discharge primarily will involve continued field testing of hydraulic parameters and hydraulic heads within the Pasco Basin. In particular, vertical interaction between aquifers in the basalts as well as between basalt aquifers and unconfined aquifers will be evaluated using measurements of hydraulic head and vertical hydraulic conductivity. Hydrochemistry will also be used to evaluate vertical groundwater mixing. No additional regional recharge/discharge studies (i.e., outside the Pasco Basin) are discussed in the SCR. For purposes of modeling, emphasis will apparently be placed upon defining head and flux conditions at the boundaries of the Pasco Basin which constitutes the extent of the far-field model. Sensitivity studies will be conducted to evaluate the effects of different boundary conditions upon the groundwater flow paths and travel times.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

An evaluation of DOE's planned approaches is not feasible because no details are presented in the SCR. Details concerning dual- and multiple-borehole tests are not provided in the SCR, hence no evaluation can be made as to the likelihood of success in determining the previously described hydrogeologic parameters, especially vertical hydraulic conductivity. The concept of determining fixed point in time as well as time variant measurements of hydraulic heads is appropriate; however, details for obtaining time-variant measurements of hydraulic head are not presented. No evaluation can be made as to the probability of success in determining the variations in hydraulic head within the basalt intraflows and flow tops.

Staff believes that the importance of vertical leakage has not been sufficiently evaluated as a major recharge-discharge mechanism.

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Issue No. 1.1.3

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the boundary conditions of the flow systems significant to repository performance?

3. Importance of the Issue to Repository Performance

Knowledge of boundary conditions is necessary input for formulating both conceptual and mathematical models of existing groundwater flow systems for analysis of repository performance.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With An Analysis of Uncertainties

Present State of Knowledge

Boundary conditions of the Pasco Basin are basically unknown. External basin boundaries are no flux (flow) or constant flux and are controlled by geology and/or hydrology. Present knowledge only provides a general framework for the conceptualization of these boundaries. For example, past modeling efforts have based boundaries partially upon maps of the configuration of head distribution within the Mabton interbed (S.C.R., p. 12.4-7,15). Boundaries internal to the basin are also controlled by geology and/or hydrology. Examples include mapped and inferred structural and stratigraphic discontinuities (S.C.R., p. 3.7-29 and Appendix O of this document) and head pattern changes, such as flow toward Gable Mountain in the Mabton interbed (S.C.R., p. 5.1-54).

Uncertainties

The existence and character of postulated boundaries are not definitive. The distribution of vertical and horizontal gradient in the basalts on the Hanford Reservation as well as near the Pasco Basin boundaries is poorly defined. Boundaries are postulated on the basis of structural features, not on the basis of head measurements and large scale, state-of-the-art pump tests. Boundary conditions must either be evaluated accurately or moved out far enough away from the region of interest (i.e., the Pasco Basin) that they do not significantly affect the model results.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

Information about heads, permeabilities and mass fluxes at boundaries is required. It may be possible to obtain this information at least in part from calibration of Pasco-Basin-scale models. Model calibration is dependent upon knowledge of the three-dimensional distribution of hydrogeologic parameters (see SIA 1.1.1).

Boundary conditions associated with structural or stratigraphic discontinuities must be identified by long-term, high-stress hydrogeologic testing. Lateral continuity of hydrogeologic properties requires definition, especially in the vicinity of the RRL. Definition of hydrogeologic significance of the Umtanum Ridge-Gable Mountain structural features north of the RRL is particularly important.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

The SCR does not include a plan specifically directed toward boundary conditions.

Evaluation of boundary conditions will be based upon existing and future hydrogeologic data coupled with modeling studies. Since the planned hydrogeologic testing program concentrates on the RRL site and the Cold Creek Syncline, it is not apparent that data required for definition of boundaries will be obtained for the far-field modeling effort. Proposed tests for hydraulic parameters and heads in the areas of the far-field boundaries rely upon single-hole techniques.

Additional definition of the apparent hydrologic discontinuity west of the RRL will be achieved by the testing the McGee well and nearby boreholes (SCR, p. 12.3-42).

Planned hydrogeologic data collection in the R.R.L. and the Cold Creek Syncline (SCR, Chapter 13) will be input to improve modeling and thus understanding of modeled boundary conditions.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success:</u>

It is important to define hydrogeologic boundaries with field data. The current hydrogeologic test plans place major emphasis upon the RRL site and the Cold Creek Syncline. It is not clear that the existing plans will be sufficient to define boundary conditions to the extent that a high degree of confidence can be placed on the results of far-field models. As an example, the potentially important Umtanum Ridge-Gable Mountain structural feature will not be investigated using multiple-hole tests under present plans. The reliance upon single-hole tests and head measurements using packer technology will probably not provide sufficient data to estimate heads and flux rates at far-field boundaries.

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Issue No. 1.1.4

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: How and to what extent is groundwater flow affected by structural discontinuities?

3. Importance of the Issue to Repository Performance

Structural discontinuities can affect groundwater flow significantly. These structural discontinuities frequently are associated with hydrogeologic boundaries that are necessary inputs to the conceptual and mathematical models of groundwater flow systems for far field and Pasco Basin studies.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 & 60.124

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

The effect on groundwater flow of structural discontinuitiesis poorly understood. Little evidence exists indicating large scale structural discontinuties in the subsurface within the Cold Creek syncline area; however, geophysical and hydrological data indicate that numerous small-scale discontinuities may be present. Geologic and geophysical evidence are discussed in SIA No._____ and NR-0960, Appendix O.

Little is known about the effects of structural discontinuities due to the limited understanding of the groundwater flow systems and related areal hydraulic continuity (NR-0960, Appendix H). Some of the hydrogeologic information collected to date has revealed evidence of the effects of structural discontinuities on the flow systems. Analysis of hydrochemical data presented in the SCR suggests that groundwater mixing is taking place in the vicinity of the Untanum-Gable mountain structure. Data from wells immediately west of the RRL indicate an abrupt change in a hydraulic head which may indicate the effects of a structural discontuity. A northeast treading magnetic arousely shown on Figure 3-52 of the SCR, is in the vicinity of this hydraulic head difference.

Uncertainties

Structural discontinuities have been inferred primarily from surface geophysical methods and little effort has been made to confirm and/or define their existance, nature and extent limitations in geological and geophysical methods allow for the possibility of undected features (see NR-0960, Appendix O and SIA No._____). Considerable uncertainty regarding the nature of the groundwater flow systems exists, and the effect of structural discontinuities is highly dependent upon the conceptual groundwater model assumed. Discussion of the significance of conceptual groundwater models is presented in NR-0960, Appendix O.

Hydrologic testing has consisted of single-point borehole tests in small diameter holes which has done little to define the overall hydrologic system and assess the effects of structural discontinuities on the systems. Single-point tests stress only the test horizon within close proximity of the well so results cannot be considered representative of the scale of structural discontinuities. Furthermore, the test hole locations have not been controlled by inferred structural discontinuity locations shown on Figure 3-52 of the SCR, and so few hydrologic data can be considered representative of structural discontinuities.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of the Construction Authorization Application

Further collection and interpretation of geologic and geophysical data are needed to accurately locate and identify structural discontinuities. The effects of known or inferred structural discontinuities on groundwater flow need to be defined together with locating any other discontinuities were not detected by geological or geophysical studies. A much better understanding of the overall groundwater flow systems is essential to this goal. Testing is required on a scale large enough to stress a significant area; sufficient observation wells to facilitate the location and characteristics of structural discontinuities are required. Such tests should be conducted on more than one interflow zone to verify the hydrogeologic continuity at the site.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

Additional borehole investigation and prediction from tectonic models are planned. Boreholes designated for future testing include some in the Cold Creek Valley west of the RRL and DC-18 near the Gable Mountain structure. The nature of data expected from boreholes is not specified in the SCR, but presumably additional stratigraphic information and single-hole hydrologic test data will be obtained. Further analysis of large-scale structures, primarily through field mapping, is planned in an effort to refine the mechanical model to predict the nature and occurance of structures. Numerical modeling of groundwater data will be done to define groundwater flow paths and predict effects of structural discontinuities.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

It is difficult to analyze the work plans because the SCR contains only general information on methods and location of further work. Drilling a few additional holes will provide additional stratigraphic information from which definition of some structural discontinuties may be possible. However, the location of proposed drilling sites does not appear to be determined by potential geophysical anomalies (SCR, Figure 3-52) so most of the inferred discontinuities will remain unconfirmed and others may remain undetect (see SIA No. __).

Knowledge of the groundwater flow systems and of the effects of structural discontinuties is very incomplete and proposed hydrologic testing will do little toward furthering understanding.

Other than the plans to test the Cold Creek Valley structure, no plans are presented to analyze the existance and significance of the inferred structure in the RRL area SCR, (Figure 3.52), therefore, these discontinuities will not be hydrogeologically characterized. Drilling and testing near Gable Mountain may increase the knowledge of ground water flow near this major structure but will do little toward defining the existence and effects of structures on a large scale because multiple-hole, state of the art, pump tests apparently have not been planned in this area.

Large scale pump tests should not only better define hydrologic parameters but should also be useful in locating hydrogeologic boundaries large-scale pump testing which have not been detected by geologic or geophysical studies. Without studies directed specifically at structural discontinuites, the likelihood of defining the effects of structural discontinuities on groundwater flow to achieve realistic estimates of groundwater travel time is very low.

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Issue No. 1.1.5

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: How and to what extent is groundwater flow affected by stratigraphic and lithologic discontinuities?

3. Importance of the Issue to Repository Performance

Stratigraphic and lithologic discontinuities can significantly affect groundwater flow. These stratigraphic and lithologic discontinuities are associated frequently with hydrogeologic boundaries that are necessary inputs to the conceptual and mathematical models of groundwater flow systems and to travel time calculations.

4. Portions of 10 CFR 60 That Are Directly Connected to the Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With An Analysis of Uncertainties

Present State of Knowledge

The Columbia River Basalt Group consists of numerous separate basalt flows varying in thickness and area extent. Distribution of individual basalt flows within stratigraphic units containing multiple flows, can be less continuous than the stratigraphic unit due to pinch out of individual flows. Independent of flow distribution, internal flow structures vary markedly. Intraflow structures include variations of flow top, entaplature, colonnade, vertical fans, vesicle zones, brecciation, and tiering. A relationship has been demonstrated between petrography and intra-flow structure such that flow top, colonnade and entableture can be identified. However, prediction of intraflow structure variation away from any sample location is unreliable. Some of the intraflow flow structures such as inverted fans could significantly increase fracture density and related vertical permeability. Fracture filling may moderate potential changes in vertical permeability. However, little is currently known about the extent, spacing and filling of fractures near the RRL (see Appendix O for further discussion).

Knowledge of the groundwater systems is so limited that the assessment of potential effects of stratigraphic and lithologic discontinuities is highly conceltural. Hyprologic testing to date has consisted of single-hold parker isolation tests which uield little data on bulk horizontal hydraulic conductivity and no data on medical hydraulic conductivity. In addition, 95 percent of the tests have been performed on the flow top with the remaining five percent in flow interiors.

Uncertainties

A high degree of uncertainty exists with regard to the effect of stratigraphic and lithologic discontinuities on groundwater flow. This uncertainity is due to the severely limited understanding of the groundwater flow system, the limited knowledge of the areal distribution of stratigraphic and lithologic discontinuities, and the inadequacy of the current testing program. The potential significance of stratigraphic and lithologic discontinuities on groundwater flow is highly dependent upon the degree of vertical interconnection assumed in the conceptual model which is used to describe the existing groundwater flow systems. Currently insufficient data exist to permit on accurate determination of the degree of vertical interconnection due to the effects of stratigraphic and lithologic discontinuities.

The SCR indicates that the location, nature, and distribution of stratigraphic and lithologic discontinuities cannot be predicted with any certainty. Thus, determining of effects through numerical modeling and related travel time callulations are very uncertain.

Hydrologic testing consists of single-well packer isolation testing which test primarily horizontal parameters from vertically limited zones and do not provide vertical hydraulic conductivity data. Furthermore, single-well tests have a limited radius of investigation and cannot adequately test the scale of stratigraphic discontinuities. Finally, certains intraflow structures (most significantly inverted fans) cannot be detected from fracture analysis in cores, petrographic analysis or borehold geophysical analysis. Therefore, these potentially significant features cannot be located or identified for testing.

6. <u>Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application</u>

Locations of lithologic or stratigraphic variation must be identified and state of the art testing of these locations conducted to determine the effect of these discontinuities on groundwater flow and related travel times. Testing is required on a scale large enough to stress a significant area to include the scale of anticipated discontinuity. Sufficient observation wells to facilitate the general location and characteristics of discontinuities are needed. Identification of the type of discontinuity is not needed. Tests should be conducted on more than one stratigraphic unit as well as individual flows to verify the overall hydrogeologic continuity at the site at various scales.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

Additional testing is planned in both existing boreholes and a few new boreholes. The nature of the data expected from these boreholes is not specified in the SCR, but presumably will consist of additional stratigraphic information and single hole dual hole and two clusters, hydrologic tests. DOE plans to evaluate the significance of inverted fan structure on hydrogeologic properties only if such structure is identified during exploratory shaft construction. No information on how this evaluation might be done is presented in the SCR. Numerical modeling will be used to describe groundwater flow in zones of stratigraphic and lithologic variation.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

Additional drilling and borehole hydrologic testing may provide additional localized data, but large geographic areas will remain for which little or no data exist concerning stratigraphic discontinuities or groundwater flow system parameters. Efforts to produce a numeric model will require the assumption of continuity among data locations. Therefore the data base should demonstrate continuity. Current limitations in identifying heterogeneities from borehole data suggest that additional borehole data will not provide significantly greater resolution of subsurface stratigraphic and lithologic heterogeneities. In addition, single-hole hydrolic testing will yield little data useful to determination of hydrologic effects of these heterogeneities. Without state of the art large scale hydrologic testing oriented specifically toward stratigraphic heterogeneities, the proposed program will be very incomplete and the probability of such a program adequately defining the groundwater flow system will be very low.

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Issue No. 1.1.6

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What is the hydrochemistry of the groundwater systems of the Pasco Basin?

3. Importance of the Issue to Repository Performance

Knowledge of hydrochemistry can be combined with other hydrogeologic data to better define both conceptual and mathematical models of existing ground water flow systems for farfield and Pasco basin studies. DOE hypothesizes that hydrochemical data can yield unambiguous information on the flow system at Hanford. Appropriate use of the hydrochemical data must made in analyzing flow paths, flow rates and ages of groundwater.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

The SCR reports hydrochemical data from only 4 boreholes which penetrate the Grande Ronde, and there has been no attempt to collect regularly spaced samples. While vertical hydrochemical profiles in some wells show apparent breaks in major ion, dissolved gas, and/or isotopic values, the profiles are not qualitatively among the four deep holes. Based on limited samples presented in the SCR and in the July 1982, hydrogeology workshop, NRC staff notes that hydrochemical data from wells DC-12, DC-14 and DC-15 are compatible with an hypothesis of mixing between the Wanapum and Grande Ronde or even between the Saddle Mountains and Grande Ronde, as suggested by DOE for DC-15 (SCR, p. 5.1-139). Carbon-14 analyses of inorganic carbon in the groundwater provide calculated apparent ages, but the apparent ages have not been corrected by state-of-the-art methods (Appendix F). Consequently, the NRC staff places no credence in the carbon-14 apparent ages reported in the SCR.

<u>Uncertainties</u>

The number of boreholes and the vertical spacing of data points within the boreholes is an inadequate data base for applying hydrochemical data to flow system analysis. DOE has presented no information in the SCR on methods and procedures of sampling and chemical analysis. Consequently, there is substantial uncertainty as to the validity and integrity of the analytical data. The potential for cross-unit mixing in open boreholes at BWIP has been raised by Witherspoon (1979), but the SCR does not address this uncertainty. The collection of water samples during the drill-and-test sequence described in the SCR (p. 5.1-14 - 5.1-15) is not a state-of-the-art sampling technique. Carbon-14 apparent ages have not been appropriately corrected for the effects of methane or other geochemical processes. DOE has presented no regional values of 50 or $8^{18}0$ and no systematic palcoclimatologic and palcohydrologic models with which their model of large scale recharge over geologically significant time spans can be tested. In the absence of such data and models, interpretations of stable isotope of oxygen and hydrogen are highly uncertain. DOE has made no attempt to geochemically characterize methods from the Paleozoic section underlying the tasking basalts. Thus, their assertion that the methane in the Saddle Mountains and Wanapum Basalts was produced in-situ, rather than being produced in the Palcozoic section and concentrated in structural or stratigraphic traps in the younger basalts, has a measure of uncertainty. No measurements for matrix-diffusion coefficients in Hanford basalts have been presented in the SCR, nor have any estimates been used in preliminary assessments of matrix diffusion effects.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of the Construction Authorization Application

For the hydrochemical and isotopic data to be applied appropriately, representative groundwater samples must be acquired from locations and depths that are relevant to hydrostratigraphic unit boundaries the regional hydrologic system, and the proposed repository location. The boreholes used for sampling must be drilled in a manner that does not detract from sample integrity and be instrumented in a manner that provides for repeated sampling over long time periods. The data which are collected must be studied using state-of-the-art geologic, geochemical and isotopic conceptual and analytical models which are consistent with the overall conceptual model of groundwater flow.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

RHO will continue to collect hydrochemical samples as part of the drill-and-test plan. Water samples will also be collected in the exploratory shaft and from newly drilled and existing boreholes. Additional stable and unstable isotopes will be evaluated for their potential for flow system characterization and age dating. Hydrochemical models are proposed for analysis of hydrochemical variations and evolution, although details of such models are not provided. A peer review of hydrochemical data is proposed to obtain a technical consensus on the nature of groundwater chemistry and its use in conceptual model development.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

It is unreasonable to expect to obtain quantitative data on hydrochemistry and environmental isotopes that can be used to conclusively describe the origin, flow paths and age of the groundwater at depth in the Pasco Basin. While hydrochemical and isotopic data can provide useful supportive information, primary evaluation of the flow system must be based on geologic information and on the results of large-scale hydraulic testing and accurate measurements of hydraulic head.

It is essential that hydrochemical evolution be considered when using hydrochemistry to indicate possible flow systems. This is particularly important in utilizing carbon-14 and oxygen-18. It is important that RHO provide details of the hydrochemical models proposed.

In the opinion of the staff, hydrochemistry should be used as supporting data in the evaluation of hydrostratigraphic units and groundwater flow systems, not as the primary data. RHO is placing much significance upon hydrochemical indications of distinct, separate flow systems and low vertical permeabilities. We believe the flow system should be evaluated using standard hydrogeological testing techniques (e.g., large-scale pump testing) and that hydrochemistry should be used to support the results of physical testing. Alternatively, it must be demonstrated that hydrochemistry can be used for quantitative evaluations of groundwater flow.

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Issue No. 1.1.7

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What is the conceptual groundwater model(s)?

3. Importance of the Issue to Repository Performance

Conceptual models of the hydrologic system guide development of numerical models used to predict groundwater flow and travel times and dicrate the location, type and extent of future testing.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge With Analysis of Uncertainties

Present State of Knowledge

The preliminary conceptual hydrogeologic model is a stratified sequence of permeable flow tops separated by nearly impermeable flow interiors resulting in a highly confined flow system(s). Flow is assumed to be essentially lateral and controlled by the attitude of basalt units. Recharge to and discharge from deep basalt units is assumed to occur only where these units are at or near the surface or where vertical discontinuities permit significant vertical movement. Significant vertical mixing is thought to occur only where vertically disruptive features exists.

Uncertainties

The major uncertainty is whether the proposed conceptual model is valid. The variability and uncertainty in existing hydrogeologic data permit the formulation of several alternate conceptual models including:

- Continuous layered, leaky confined system (relatively high vertical hydraulic conductivity a really)
- Large-scale homogenous system with discontinuous layers (anisotropic)
- Structurally controlled semi-isolated cells (bounded by low hydraulic conductivity structures or zones)
- Structurally controlled, conduit-dominated system (bounded by high hydraulic conductivity structures or zones)

Other uncertainties in the conceptual model result from uncertainties in hydraulic parameters, hydraulic heads and hydrogeologic boundaries (e.g. structural and stratigraphic discontinuities, recharge/discharge) as outlined in Issues 1.1.1 through 1.1.6.

6. Summary of the Additional Information Needed to Resolve the Issues By the Time of the Construction Authorization Application

Alternative conceptual models need to be considered that fit the existing data. Representative bulk values for hydraulic parameters and reliable long-term hydraulic heads must be determined. Hydrogeologic boundaries must be located and assessed. The conceptual models should be reassessed based upon this new data. It may be possible to reduce the number of alternative conceptual models alternatively, additional conceptual models may be required.

7. Summary of the Planned Appraoches to Testing, Tests, Test Methods and Investigations To Provide the Information Needs of (6)

The planned efforts to refine the existing conceptual model are based on the additional determination of hydraulic properties, hydraulic heads, and hydrochemistry from existing and new boreholes. These efforts are based primarily on single-borehole tests and multiple-borehole tests. Results from test activities will be input to mathematical models to identify additional data needed to refine the conceptual model.

8. Analysis of (7) As To Completeness, Practicability and Likelihood of Success

The NRC staff finds that the existing hydrogeologic data could support several conceptual hydrogeologic models and not just the preliminary hydrogeologic model proposed by the DOE. Others conceptual models are certainly possible given the large variation and uncertainties in existing data. However, the SCR does not consider alternative conceptual models, nor do the plans specify that such a consideration will be made in the future. The hydrogeologic test plans are not considered adequate to definitively evaluate all possible conceptual models. Representative bullk values of hydraulic parameters, long-tern hydraulic heads and evaluation of hydrogeologic boundaries are considered extremely important by the NRC staff, if a defiitive conceptual model is to be determined. The tests proposed by DOE are considered inadequate of obtained the required data (see Issues 1.1.1 to 1.1.6).

The groundwater flow system(s) in Hanford basalts would appear to be amendable to large-scale testing (Appendix E). Such testing would not only yield bulk hydraulic parameters and information on hydrogeologic boundaries, but also may verify the conceptual model(s) most appropriate to the Hanford basalts.

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Issue No. 1.1.7.1

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: How is the choice of units supported by geologic data (including core data)?

3. Importance of the Issue to Repository Performance

Accurate definition of hydrostratigraphic units is essential to definition and modeling of the groundwater flow system or systems within the area of the proposed repository. These hydrostratigraphic units must reflect the geologic framework which is present.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summarize Pertinent Topics and the Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Definition of hydrostratigraphic units is based primarily upon defined basalt strigraphy. Three major hydrostratigraphic units corresponding to the three major formulational units of the Yakima subgroup (Saddle Mountains, Wanapum and Grande Ronde basalt) have been used in modeling. In some situations a fourth unit, that of the saturated part of the suprabasalt sediments has also been recognized, but in the modeling effort it is included with the underlying basalt unit. Some attempts to define smaller hydrostratigraphic units have been made in two dimensional models. These smaller units correspond directly to individual basalt flows or groups of flows within major stratigraphic subdivisions. Nowhere to hydrostratigraphic unit boundaries cross pure stratigraphic boundaries. Thus, geologic data in the form of defined basalt stratigraphic units not only supports the defined hydrostratigraphic units, but are the primary control for their definition. Other forms of geologic data are of lesser importance. Some attempts have been made to characterize intraflow structure based on basalt petrography; however, no link has been established between intrflow structure and the definition of hydrostratigraphic units. Similarly no effort has been made to tie mapped surface structures or their subsurface projections to hydrostratigraphic units. Major surface structures which produce topographically prominent features are used as evidence of boundary conditions.

Uncertainties

Subsurface stratigraphic and related hydrologic data comes from isolated and often widely scattered locations. Although major unit subdivisions are generally well defined and traceable in the subsurface, individual basalt flows within these units are sometimes not. Effects of subsurface structures on hydrostratigraphic units are unclear. Relationship of individual basalt flows to groundwater flow and thus to hydrostratigraphic units and major stratigraphic divisions is not well known.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

Additional definition of stratigraphic units in the subsurface will assist in delineating structure and stratigraphy, but hydrologic information is needed to further define hydrostratigraphic units.

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Issue No. 1.1.7.2

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: How is the choice of units supported by geophysical data?

3. Importance of the Issue to Repository Performance

Accurate definition of hydrostratigraphic units is essential to definition and modeling of groundwater flow system or systems within the area of the proposed repository. Geophysical methods are important tools for obtaining hydrologic and geologic information necessary to the delineation of these hydrostratigraphic units.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summarize Pertinent Topics and the Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Several surface geophysical methods have been applied during geologic investigations. Gravity and aeromagnetic surveys have been used to define anomalies which can then be investigated by more direct means. Seismic reflection surveys were used in an attempt to define and trace individual basalt units in the subsurface. Seismic reflection techniques were generally ineffective in defining individual basalt units due to poor velocity contrasts. Electric and radiation borehole logs provided information on stratigraphic horizons and helped define subsurface stratigraphy. These logs also provided information on porosity, fracturing, and intraflow structure. Fluid logs provided information on fluid movement, temperature and water quality. Remnant magnetism provided another means of identifying basalt flows and defining surface and subsurface stratigraphy. This technique was particularly useful in the younger part of the stratigraphic section where polarities of individual flows alternate, unlike the lower part of the section where several flows may have the same polarity. Attempts have been made to use magnetic inclination to further subdivide stratigraphic units.

Uncertainties

Borehole geophysical data require interpolation between points. Similar geophysical responses may not be produced by the same stratigraphic or geologic feature. Surface methods require substantial amounts of manipulation and interpretive processing making the results subject to the problems inherent in interpretation. Hydrologic data obtained from boreholes are subject to distortion because of drilling procedures, interconnection of aquifers and contamination.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

With the possible exception of borehole methods and the improvement in seismic record processing, it is unlikely that additional geophysical data will help further define hydrostratigraphic units. Borehole geophysics is, however, one area that could be quite useful as good quality data can be collected from core and non-core holes alike. Fluid and porosity logs of many holes could yield valuable insight into the nature of hydrostratigraphic units.

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Issue No. 1.1.7.3

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: How is the choice of units supported by hydrogeologic data (including hydraulic head distribution)?

3. Importance of the Issue to Repository Performance

Accurate definition of hydrostratigraphic units is essential to definition and modeling of groundwater flow systems within the area of the proposed repository. The hydrostratigraphic units must reflect the hydrogeologic properties of the system.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summarize Pertinent Topics and the Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Most hydrologic data collected to date has been obtained via the downhole testing program. Transmissivity and hydraulic conductivity values have been obtained for deeper zones almost exclusively through packer isolation, swabbing and injection tests performed within an isolated borehole. To a lesser extent pump testing has been done in shallower holes, primarily within the Saddle Mountains basalt and overlying sediments. Head data have been obtained almost exclusively from borehole testing of relatively short duration. Head data show considerable variety within individual boreholes with little consistent pattern which would serve to delineate hydrostratigraphic units. Deep holes near the Columbia River exhibit increasing head with depth. Contouring of potentiometric data indicates groundwater flow away from the surrounding topographically prominent ridges down to the Columbia River near the south end of the Pasco Basin. Head relationships indicate leakage to and from deeper zones depending upon location with the flow system. The hydrogeologic data collected do not support an areal pattern of hydrostratigraphic units.

Uncertainties

Borehole testing is limited to points within the system, and hydrologic data collected at these points may not be representative of bulk values of the system. Hydrologic data do not directly support selection of hydrystratigraphic units. Differences between measured head values and piezometers in wells create uncertainty about true hydrostatic head values representative of true head conditions.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

Data obtained from borehole testing programs need to be verified, probably by large-scale pump tests. Results of such tests should be compared to results of borehole tests. Other methods of checking values may involve large scale in situ testing underground. Similarly, hydrostatic head test data should also be verified, particularly in light of the wide variation that is apparent in some of the zones tested. Verifiable head data can be collected with carefully installed piezometer systems with sufficient time allowed for equilibration. Reevaluation of hydrostratigraphic units and basic flow system conceptualization should be done based upon a more complete data base.

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Issue No. 1.1.7.4

1. Name of the Site: Hanford BWIP

2. Statement of the Issue To what degree do hydrochemical and temperature data supprt the choice of hydrostratigraphic units?

3. Importance of the Issue to Repository Performance

Accurate definition of hydrostratigraphic units is essential to definition and modeling of groundwater flow systems within the area of the proposed repository using the modeling approach by RHO. The hydrostratigraphic units must be consistent with hydrochemical and temperature data.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Major inorganic composition of water appears to vary stratigraphically and areally with geologic unit sampled. Within the Saddle Mountains and Wanapum basalts water is generally of a sodium bicarbonate type. Grand Ronde basalt is characterized by a sodium-chloride water chemistry near the river but not near the RRL (DC-12). In 3 to 5 wells sampled, sodium and potassium cation and chloride anion concentrations in water obtained from the Grande Ronde near the river are generally noticeably higher than in samples obtained from Wanapum or Saddle Mountains basalts. Methene concentrations in the Eanapum and Saddle Mountains inter flows are substantially higher than Methane concentrations in the Grande Ronde. Trace element and radioistope analyses are rare and show few distinct breakdowns. Carbon-14 data obtained from a few boreholes do show older water at depth but do not delineate clear zones of differing age.

Methane generation in interflow zones complicate the interpretation of the apparent 14C ages. Oxygen and deuterion isotope and tritium data have been used to help define flow systems within the Saddle Mountains basalt. Temperature data collected consist primarily of continuous fluid temperature logs collected during bore hole geophysical logging. In addition, static temperature measurements were made at isolate locations within the borehole. Static temperature measurements were made as a check on fluid temperature logs.

Hydrochemical data indicate complete hydrostratigraphy and/or the possibility of sampling or analytical error. RHO has presented no information on methods and procedures of sampling or analysis. Mixing problems have been discussed by Witherspoon (1979). The nature of groundwater flow system is not well understood, so hydrochemical data are ambiguous. Uncertainty exists in demonstrating thermal equilibration of wells before temperature logging. The Limitd amount of data available make conclusions concerning hydraulic continuity highly questionable.

Additional data jon hydrochemistry and environmental isotopes would be useful in providing a more complete description of the groundwater in the Pasco Basin. However, in the opinion of the staff, the hydrochemical data at Hanford cannot be used to define hydrostratigraphic units. Hydrochemistry should be used as supporting data in the evaluation of hydrostratigraphic units, not as primary data. Evaluation of and vertical lmixing if it is not considered within the framework of the physical groundwater system. Apparent hydrochemistry breaks can be the result of rock chemistry or dilution effects and do not always indicate hydraulically separate flow systems. Thus, although the NRC believes hydrochemistry can provide very useful information about the flow system, a primary emphasis in the planned hydrogeology program should be placed upon evaluation of the physical system (see Appendix F).

6. <u>Summary of the Additional Information Needed to REsolve the Issue By the Time of the Construction Authorization Application</u>

Additional information needed includes more and closer spacing of hydrochemical sampling and analyses within most boreholes and collection of analyses from a greater number of boreholes. RHO must demonstrate that samples taken from open boreholes are not subject to pre-sampling mixing or, if not possible to demonstrate RHO must instrument boreholes in a manner that should hydrochemical and isotopic data that have integrity. Additional testing for methane concentrations, from both the tertiory and the ________ sections, may provide insight into groundwater flow and should be attempted. Carbon-14 data must be corrected for the effects of methane, and other geochemical process should or no credence an be given to age dates. Data must be considered in terms of hydrochemical evolution involving all major rock-water interactions within the groundwater system and must be integrated into a reasonable conceptual model of groundwater flow before they can be used to support hydrostratigraphic units. Temperature data appear to provide little help in defining hydrostratigraphic units.

7. <u>Summary for the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

Continued collection hydrochemical data is planned by RHO. Data are to be collected from lnewly drilled as well as existing boreholes. Testing is planned for mass chemistry isotopes. The SCR states that the new data will be used to define the conceptual model of groundwater flow, but it gives no details on how this goal will be achieved.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

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Issue No. 1.1.7.5

1. Name of the Site: Hanford BWIP

2. Statement of the Issue

1.1.7.5 What is the relationship between the hydrostratigraphic units and the units tested for hydrogeologic parameters?

3. Importance of the Issue to Repository Performance

Accurate definition of hydrostratigraphic units is essential to definition and modeling of groundwater flow systems within the area of the proposed repository. For the modeling efforts to be reliable, the hydrostratigraphic units must be defined in terms of units which have been tested hydrologically.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summarize Pertinent Topics and the Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Units tested for hydrologic parameters are zones within one or more of the major geologic units. Units tested may consist of a group of basalt flows, a single basalt flow, part of an individual basalt flow, or the zone between basalt flows. In most cases, the zone tested makes up only a fraction of the hydrostratigraphic units as defined by RHO. In addition, the tested unit is not only limited vertically but is also limited horizontally, as the radius of test investigation is quite small. Thus, the location tested may more accurately be described as a point within the horizon or interval.

To our knowledge RHO has not defined specific HSU's nor have they defined criteria for the determination of HUS's. Numerical modeling studies conducted by RHO have indicated that prediction of flow paths is sensitive to the selection of units for modeling. However, final selection of units for the purpose of performance modeling has not been made. Since appropriate HSU's have not been determined, little can be said concerning the relationship between HSU's and units tested for hydrogeologic parameters.

Uncertainties

The principal uncertainty is whether or not hydrologic parameters obtained from testing zones or points within specific horizons are representative of total hydrostratigraphic unit parameters. The other uncertainty is whether or not values obtained from a particular point are valid representations for that point or whether testing techniques introduce bias.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

Values for hydrologic parameters obtained through packer isolation testing in small diameter boreholes should be verified by other techniques such as large scale pump testing. Elimination of uncertainty with regard to the applicability of values obtained in point testing to the hydrostratigraphic units is more difficult. However, large scale testing used to check single borehole test results would also provide (bulk parameter) values for the hydrostratigraphic unit or units in question. Verifiable head data is also required.

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Issue No. 1.1.7.6

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What is the relationship between the hydrostratigraphic units and the units used in groundwater modeling?

3. Importance of the Issue to Repository Performance

Accurate definition of hydrostratigraphic units is essential to modeling of the groundwater flow systems within the area of the proposed repository.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summarize Pertinent Topics and the Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

Hydrostratigraphic units have not been defined per se; thus subdivisions established for the purposes of modeling are taken as defined hydrostratigraphic units. Because of this assumption, there is little difference between modeled and defined hydrostratigraphic units. As far as hydrologic properties are concerned, however, each model unit is assigned a single average horizontal and vertical hydraulic conductivity value which results in anisotropy being distributed evenly throughout the total hydrostratigraphic unit. Within actual units however, distribution of hydrologic properties is most certainly not uniform.

Uncertainties

The principal uncertainty is whether or not values assigned to units for modeling purposes adequately reflect the true bulk values of those hydrologic parameters for the actual hydrostratigraphic units. For modeling purposes, assumptions are made as to the geometry of units that may not accurately reflect true geometric conditions. It is not clear what effect such differences will have on the validity of model results.

6. Summary of the Additional Information Needed to Close Out the Issue by the Time of the Construction Authorization Application

In order to assure that modeled hydrologic parameters reflect true conditions within the actual hydrostratigraphic unit, field test values on which these parameters are based must be further verified. Second, it would be necessary to obtain additional subsurface structural and stratigraphic information to check validity of modeled unit geometry. An increased density of bulk parameters would replace the model units.

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Issue No. 1.1.8

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the mathematical models used to predict groundwater flow?

3. Importance of the Issue to Repository Performance

A mathematical model to predict groundwater travel times and flow paths is essential to predictions of repository performance.

4. Portions of Draft 10 CFR 60 That Are Directly Conneced To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Present State of Knowledge With an Analysis of Uncertainties

Present State of Knowledge

DOE has obtained or formulated a number of numerical codes for near-field and far-field groundwater modeling. The level of sophistication of the numerical codes is high. The conceptual groundwater model used by DOE (see issue 1.1.7) consists of horizontal, laterally continuous basalt layers with permeable flow tops and interbeds and low permeability dense flow interiors. DOE's numerical models have been based only upon this conceptual model, including the most recent effort present in the SCR utilizing the code PORFLO (SCR, p. 12.4-28 to 50). This latest model utilizes simplified geology, constant parmeter values within layers and assumed boundary conditions. It is not clear from the SCR that existing models have been calibrated against measured head conditions.

Uncertainties

Major uncertainties are associated with all existing numerical groundwater flow models of the Pasco Basin and near-field. The most significant uncertainty is in the validity of the conceptual model (see SIA 1.1.7). Other uncertainties result from the highly variable nature of hydraulic parameters, unknown boundary conditions, the lack of appropriate hydraulic head data to use for model calibration, and the failure to include specific geologic conditions. Uncertainties associated with the mathematical bases of the numerical models are relatively low but not insignificant.

6. Summary of the Additional Information Needed Resolve the Issue By the Time of Construction Authorization Application

Alternative conceptual models which fit existing data need to be developed. Measurements of representative bulk hydraulic parameters and reliable long-term hydraulic heads are required. Hydrogeologic boundaries must be located and assessed. Based upon the additional information, conceptual models should be assessed and numerical models developed for all valid conceptual models. Calibration of numerical models based upon representative hydraulic heads is required. Additional calibration could be made against large-scale hydrogeolic tests.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations To Provide the Information Needs of (6)

The present conceptual groundwater flow model will be refined by additional determinations of hydraulic properties, hydraulic heads and hydrochemistry from existing and new boreholes. Existing numerical codes will be verified and bench marked. Selected models will be used to predict groundwater travel times and flow paths. Parametric and sensitivity studies will be conducted to identify key parameters, parameters distributions and model inputs. Stochastic models may be used to bound predictive uncertainty. Numerical groundwater models will also be used to guide additional needs for field investigations.

8. <u>Analysis of (7) As To Completeness, Practicability and Likelihood of Success</u>

The NRC staff finds that the propsed plans for mathematical modeling are not adequate to predict groundwater flow system behavior. Apparently the DOE will consider only the existing conceptual flow system model as a basis for mathematical models. Existing data indicate that other conceptual models may be possible (see issue 1.1.7), and therefore should be considered by mathematical modeling or conclusively disproven.

The NRC staff is concerned that the proposed field program is not adequate to provide representative hydraulic parameters, hydraulic heads and hydrogeologic boundary conditions as noted in issue 1.1.1 to 1.1.6. In particular, the lack of representative long-term hydraulic heads will not allow sufficient calibration of numerical models. Furthermore, DOE does not demonstrate how consideration will be given in numerical models to the interactions between the shallow unconfined aquifers and the deep besalt. This is considered to be important because of the significant water table changes which have occurred at the RRL site as a result of artifical recharge activities. No plans are presented for the calibration of numerical models against laege-scale tests, even though such calibration would add considerable validity to the numerical models.

DOE has taken the approach of testing components of the hydrogeologic system and then using numerical models to combine components and predict the hydraulic behavior of the system. One advantage of the Hanford site is its testability using large-scale hydrogeologic tests (Appendix E). Therefore, it is possible to directly observe the hydraulic behavior of the system, rather than rely totally upon <u>predicted</u> hydraulic behavior from numerical models.

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Issue No. 1.2

1. Name of the Site: Hanford BWIP

2. Statement of the Issue

1.2 What are the types, probabilities, and nature of natural changes that could affect groundwater flow?

3. Importance of the Issue to Repository Performance

Several natural changes could occur in the site environment that could potentially affect groundwater flow at or near the Reference Repository Location. These changes could include catastrophic Columbia River flooding, glaciation, precipitation, evapotranspiration, and tectonic or structural stresses. These changes could affect the rate and location of recharge and discharge to the basalt units and the rate and direction of ground water movement.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Present State of Knowledge

Investigations have been made of the probable extent of catastrophic Columbia River flooding based on both natural and breeched-dam flooding. The nature and extent of previous glaciation has been studied, as have the current rates of precipitation and evaporanspiration. Conceptual regional tectonic models exist currently.

Uncertainties

A level of uncertainty exists when attempting to extrapolate type, probability and nature of future events. However, greatest uncertainty lies with DOE's plans to resolve this issue. Plans included with the SCR are not fully detailed and, at times, appear to lack full sunthesis of available approaches to issue resolution.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of the Construction Authorization Application

An estimate of the probabilities of occurrence of catastropic natural events is necessary. In addition, a more refined estimate of the duration of a glacially induced flood is necessary. Flood levels and durations of floods from additional dam failure scenarios may be required. More detail is presented in the following subissues.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to PRovide the Information Needs of (6)

As noted in (3.), plans included with the SCR are not fully detailed. As indicated in the SCR, the ultimate use of the data resulting from investigations into the types, probabilities and nature of natural changes that could affect groundwater flow is as input to a groundwater simulation model. Complete plans for synthesis of this data or actual values to be input are not fully included in the SCR.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

There is reason to assume that adequate plans can be formulated and proper estimates obtained in order to satisfactorily resolve this issue. The rigor required to formulate these data estimates will largely depend on the sensistivity of the groundwater flow system to these events and the ability of DOE to develop a realistic conceptual and numerical groundwater flow model. In order to adequately analyze this issue and DOE's progress to date, two assumptions were required. First, that an adequate conceptual and numerical flow model can and will be developed and second, that the groundwater flow system has the potential to be sensistive to changes in natural events.

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Issue No. 1.2.1

1. Name of the Site: Hanford BWIP

2. Statement of the Issue

1.2.1 What are the types, probabilities, and nature of catastrophic Columbia River flooding changes that could affect groundwater flow?

3. Importance of the Issue to Repository Performance

Estimates of the probability and extent of catastrophic Columbia River flooding is necessary before the effects of such events on groundwater flow (flow paths, discharges, velocities, travel time) can be predicted and thus related to repository performance.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State Knowledge

Flood frequency analyses and flood inundation maps have been prepared for various flood events. These events include the 100-year and PMF (probable maximum flood) as well as for a 50% breach failure of Grand Coolee Dam. River blockage and flooding resulting from landslides along the Columbia River has also been investigated. Of those scenarios investigated, maximum flooding near the Hanford site would occur as a result of a 50% breach of Grand Coulee Dam. However, this event does not result in overland flooding at the RRL.

Uncertainties

As noted in the SCR (page 7.2-6), no determinations have yet been made with respect to dam failure breaches greater than 50% at Grand Coulee Dam or to failures of dams upstream of Grande Coolee Dam and associated resonant failures of dams downstream. Therefore, it is uncertain that such a scenario (50% breach) would or would not represent an upper bound catastrophic flooding event to be used as input in assessing impacts on the groundwater flow system. DOE has concluded (SCR, page 13.3-65) that catastrophic flooding (failure of ice dams), associated with renewal of continental glaciation, represents the most significant potential impact. Without an estimate of flood levels or duration of a flood resulting from total breach of Grand Coulee or possible multiple dam failures it is uncertain which event represents a reasonable upper bound.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of the Construction Authorization Application

An estimate of flood levels and duration of a flood resulting from total breach of Grand Coulee Dam or possible multiple dam failures may be required to support DOE's conclusion that an ice dam failure subsequent to a renewal of continental glaciation represents the most significant (upper bound) catastrophic flood event.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

DOE does not have specific plans to either numerically simulate additional dam failure scenarios or to provide an estimate of flood levels and durations of such scenarios.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

The importance of this issue relates to a parallel albeit different, issue. That is the assessment of the effects of catastrophic flood events on the groundwater flow system. As indicated in the SCR, DOE plans to assess the potential for vertical movement of groundwater, resulting from flood waters, within the Pasco Basin using numerical models. Assuming that adequate regional groundwater models are developed, the effects of catastrophic flooding on the groundwater flow system. and thus repository performance can be successfully assessed. However, if the groundwater flow system is found to be sensitive to large scale surface flooding a more complex analysis of transient surface water hydraulics of additional dam failure scenarios may be required to assure that an adequate upper bound of catastrophic flood events is assessed.

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Issue No. 1.2.2

1. Name of the Site: Hanford BWIP

2. Statement of the Issue

1.2.2 What are the types, probabilities, and nature of glaciation changes that could affect groundwater flow?

3. Importance of the Issue to Repository Performance

Knowledge of the types, probabilities, and nature of glaciation changes is necessary before the effects of such changes on groundwater flow (flow paths, discharges, velocities, travel time) can be predicted and then related to repository performance.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge with an Analysis of Uncertainties

The nature of previous glaciation has been studied fairly extensively. Probabilities can be estimated based on the geological record.

As stated in the SCR (p. 8.3-8), glacial lakes formed where river drainages were blocked by ice, and sudden release of glacier-dammed lakes caused catastrophic floods of unprecedented magnitude. Anywhere from 7 to 40 glacial floods have been hypothesized to have occurred in the Pasco Basin. One additional hypothesis is that multiple flood surges occurred rather than separate floods. The two largest floods occurred approximately 18,000-20,000 and 13,000 years ago, and resulted in floodwaters to elevations 366 and 274 meters above mean sea level, respectively, in the Pasco Basin. There is no evidence that an ice sheet has ever reached as far south as the Hanford site. DOE has concluded that the type and nature of glaciation change that could possibly effect groundwater flow is catastrophic flooding, presumably resulting from an ice dam failure (SCR, p 13.3-65). The precise duration of such a flood is not known but DOE has assumed that each flood probably consisted of short-lived crests and that floodwaters within the basin subsided over a period of weeks.

Because evidence of Pleistocene glacial flooding exists in the geologic record of the Pasco Basin, the probability of such flooding and even flood elevation levels can be estimated to an acceptable level of uncertainty. The greatest uncertainty will be with the duration of the flood event. The duration of a flood event will depend on the flooding hypothesis chosen. As an example, multiple flood surges could conceiveably result in longer term standing water than separate flood events. The level of uncertainty is not known.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of the Construction Authorization Application

The probability of glacial flooding, flood elevation levels and duration of flood events require more complete definition.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigaitons to Provide the Information Needs of (6)

The SCR indicates that the potential for vertical movement of groundwater resulting from standing floodwaters within the Pasco Basin will be assessed using numerical simulation and that the sensistivity of regional groundwater flow models to adjustment of recharge parameters will be evaluated (SCR, p. 13.3-79). There are no specific statements regarding either intent or planned approaches to calculate the probability of glacial flooding, flood elevation levels and duration of flood events of which the latter two are required as input to any numerical groundwater simulation model.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

Although no specific plans are available to assess as to completeness, practicality and likelihood of success, information included in the SCR indicate that a data base exists from which the probability of glacial flooding and flood elevations could be predicted. Prediction of flood event durations is likely to be more difficult. The overall importance and eventual resolution of this issue greatly depends on the sensitivity of the deeper groundwater flow systems to surficial flooding of both recharge-discharge and other areas.

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Issue No. 1.2.3

1. Name of the Site: Hanford BWIP

2. Statement of the Issue

1.2.3 What are the types, probabilities, and nature of precipitation/evapotranspiration changes that could effect groundwater flow?

3. Importance of the Issue to Repository Performance

Knowledge of the probabilities and nature of potential future changes in precipitation/evapotranspiration is necessary before the effects of such changes on groundwater flow (flow paths, discharges, velicites, travel time) can be predicted and then related to repository performance.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge with an Analysis of Uncertainties

Present State of Knowledge

As indicated in the SCR (p. 8.3-1), a coherent hemispherical or continental picture of Quaternary paleoclimate is available from evidence from a variety of disciplines. In the SCR DOE has concluded that regional paleoclimatic work for the Pacific Northwest is in the early stage of initial reconnaissance studies and Quaternary paleoclimatic studies of the area are spares. Because of this and considering the nature of geologic formations and geologic history of the Hanford Site, DOE has also concluded that it is unlikely that much quantitiative information can be developed from onsite investigations. Reliance is to be placed on palynological work in the Forest Boundary Zones on the periphery of the Columbia Plateau to develop paleoclimatic information required for the project.

Uncertainties

Historical temperature data from the area (period of record 1912-1970, being updated for the last decade) has been extrapolated to provide estimates of minimum and maximum temperature and rates of change for future time periods. Similar projections for historical precipitation data resulted in the conclusion that the mean annual precipitation since about 13,000 years ago is probably within a factor of 2 of the present mean annual precipitation of about 16 centimeters (SCR, page 8.3-5). Historical evapotranspiration (Et) data are not available for the Hanford Site. However, estimates of Et have been made using available climatological data and standard empirical relationships. No future predictions of Et are discussed in the SCR.

The probability of climatic changes occurring is high in the long term, but the magnitude and type of change is difficult to accurately predict.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of the Construction Authorization Application

The probability and nature of potential changes in the precipitation-evapotranspiration rates require definition. The probable changes that could occur in the precipitation/evapotranspiration rates require investigation, both upstream along the groundwater gradient and in the vicinity of the RRL.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

Although information in the SCR indicates that reliance is to be placed on palynological work done on the periphery of the Columbia Plateau to develop paleoclimatic information required for the project, neither the palynological data nor specific plans for its integration into the project data base are presented. Additional information in the SCR indicate that paleoclimate information on regional precipitation is insufficient for future predictions.

All future predictions for temperature and precipitation are based on historical records only (1912-1970). Plans for extrapolating empirical Et information are not presented.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

Because the SCR indicates that paleoclimatic information will be used to construct scenarios to assess repository performance [groundwater flow system] while at the same time indicating that paleoclimatic information is insufficient to make projections, the likelihood of success is in question. It appears likely that a more rigorous synthesis of paleoclimatic and historical data will be necessary.

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Issue No. 1.3

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the types, probabilities, and nature of human-induced changes (excepting repository-induced changes) that could affect groundwater flow?

3. Importance of the Issue to Repository Performance:

Several human-induced changes could occur in or near the RRL that could have an impact on the groundwater flow systems. Future groundwater use in the area would probably be restricted in the vicinity of the RRL, but potential onsite users of the reservation could have an impact on groundwater flow systems. Drilling activities could interconnect hydrostratigraphic units and potentially alter groundwater flow systems. Changes in existing offsite groundwater withdrawal rates could alter groundwater flow systems. Waste water disposal and irrigation return flow also could change groundwater flow system. Dam construction on the Columbia River could change existing recharge/ discharge relationships between the river and the basalts.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue:

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties:

Present State of Knowledge

Existing groundwater users in the area have been surveyed, and water resource economics in the Pasco Basin have been analyzed with an emphasis on surface water resources (SCR 7.3-2). Plans for further Columbia River dam projects are dependent on a number of variables including engineering, economic, and environmental considerations. DOE has performed scenario analysis of repository penetration by a borehole. DOE has also assessed the economic likelihood of various groundwater withdrawal/recharge scenarios.

Uncertainties

The future use of the groundwater resources in the area is dependent on future demand and availability of alternate supplies, both of which have inherent uncertainities. Waste water disposal and irrigation return flow also could change groundwater flow systems. The existing groundwater flow systems have to be understood before changes in the systems can be predicted.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

The existing groundwater flow systems have to be defined and understood before changes in the systems can be predicted. This requires a better understanding of the hydrogeologic parameters, boundary conditions and recharge/discharge areas, mechanisms and rates. Predictions of future changes in the use or uses of groundwater require refined estimates of growth, demand, and cost of water resources in the Pasco Basin. Information needed to assess changes of withdrawal or recharge patterns includes economic assessment and understanding of water resource availability. Information is required on the location of potential dams and proposed stages upstream and downstream of the proposed dams.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

The SCR describes plans for evaluating human-induced changes to the groundwater system resulting from groundwater withdrawal/recharge, occupancy and modification of the Columbia River floodplain, and boreholes. These changes will be evaluated using numerical models of groundwater flow.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success:</u>

RHO plans to address all relevant man-made changes and, assuming that appropriate models are developed, the planned investigations appear conceptually adequate. Development of appropriate models will require a better knowledge of the existing groundwater flow system. Because it appears that continued groundwater development for agriculture will occur, it is important to consider all aspects of this activity. The installation of permanent head monitoring devices is required to adequately assess the impact of groundwater withdrawal. Staff notes that if uncertainties in the present groundwater flow systems remain unresolved, efforts to predict changes will be fruitless.

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Issue No. 1.3.1

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: How does the value of water resources in the Pasco Basin compare with the value in other surrounding areas of similar size, and what is the potential for future use?

3. Importance of the Issue to Repository Performance:

Groundwater is the likely medium of transport should stored radioactive waste leave the repository site. It is essential to know what factors would significantly alter the existing ground water flow systems. Of the possible factors affecting change in the flow system, human-induced ones are significant because of the potential for major changes.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties:

Present State of Knowledge

Information has been developed concerning the water resource economics within the Pasco Basin, with an emphasis on surface water resources (SIA 7.3-2). In a very general sense, it is probably accurate to conclude that the value of the water resources in the Pasco Basin is similar to that of the resource in nearby areas. Most surrounding areas enjoy a similar availability of the resources and have basically the same uses and costs. Thus, it is unlikely that there would be a great difference in resource value between the basin and other surrounding areas. It is important to note that the value of the groundwater in storage at great depths is probably low because of the major costs of deep well development. Assessment of future use depends upon projections of population growth, resource uses, cost, and changes in resource quality or availability. If, for example, cost, use and growth conditions remain similar to those present today, it is unlikely that future groundwater use will rise dramatically. If, however, future demand for the resource increases sharply, a change in the availability of surface water resources in the future could cause a drastic increase in groundwater use.

Uncertainties

The uncertainties inherent in projecting future use of the resources are those involved in (1) adequately determining the alternative supplies available and (2) accurately predicting future demand.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

In order to adequately define future use of the water resources, it would be necessary to refine estimates on future growth, demand, and costs of water resources in the Pasco Basin. It would be also necessary to refine methods for estimating current resource availability. Accurate socio-economic models for future water use are needed.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

No formal numerical analysis of the consequences of various conjunction surface/groundwater use scenarios has been performed. Plans in the SCR include the formal description of a credible scenario near the RRL and the performance of a consequence analysis using numerical models. No additional studies of the economics of water resources in the Pasco Basin are planned.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

Existing projections of water resource development and economics should be updated as necessary. Credible scenarios of water resource development should be developed. It is not clear if more than one scenario will be considered by RHO, although consideration of various scenarios will probably be required. The economics of water resource development should be considered for each scenario. Although development of predictive models based on future water resource values is possible, the likelihood of success of such an effort is difficult to assess because of the many uncertainties involved.

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Issue No. 1.3.2

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the types, probabilities, and nature of water resource development (drilling) changes that would affect groundwater flow?

3. Importance of the Issue to Repository Performance

Groundwater is the likely medium of transport should stored radioactive waste leave the repository site. It is essential to know what factors would significantly alter the existing groundwater flow systems. Of the possible factors affecting change in the flow system, water resource development is significant because of the potential for major changes.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

One change related to groundwater resource development that could affect the flow system is vertical interchange within the system through open or poorly sealed boreholes. In these instances, boreholes open to specific zones of differing hydrostatic head would provide open conduits for exchange. Such exchange could create accelerated vertical leakage conditions and markedly affect groundwater flow by short-circuiting natural flow paths. Considerable disruption of the flow system could occur in a situation where numerous wells exist through which vertical interchange is taking place. DOE has performed a scenario analysis of repository penetration by a borehole.

Uncertainties

It is difficult to ascertain the precise nature, magnitude and effect of vertical interchange because the nature of groundwater flow in basalts is not well understood.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Information needed to adequately assess the effect of vertical interchange among aquifers or aquifer systems through wells includes accurate values for hydraulic conductivity for zones of influx and efflux, hydraulic head differences between these zones, and amount of water that is being transferred. In addition, a basic understanding of the existing groundwater flow systems is necessary in order to determine the effect of such interchange (see SIA 1.1 and subissues, above). Accurate data on existing wells in the area of interest through which such interchange might be taking place are also needed. This information should include depth of casing, screen and/or perforations, and type of seal, if any.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

Currently, drilling on the Hanford Reservation is strictly controlled by the U.S. Department of Energy. Thus, the possibility of future uncontrolled drilling is remote unless control of the site is lost. Data have been collected on existing well locations and construction. DOE has performed a scenario analysis of repository penetration by a borehole, and the consequences of boreholes on repository performance will be numerically modeled. No modeling of open borehole effects on general flow systems is intended.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>:

Success of the evaluation hinges on the accuracy of the groundwater flow system model, and on accurate well location and construction data. An accurate model cannot be constructed without obtaining data on hydraulic continuity, vertical hydraulic conductivity, horizontal hydraulic conductivity, hydrogeologic boundary conditions, and hydraulic head data unaffected by possible man-induced transient effects. With these accurate data, numerical modeling is feasible; without them, little model success is likely.

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Issue No. 1.3.3

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the types, probabilities, and nature of groundwater withdrawals and recharge changes that could affect groundwater flow?

3. Importance of the Issue to Repository Performance

Groundwater is the likely medium of transport should stored radioactive waste leave the repository site. It is essential to know what factors could significantly alter the existing groundwater flow systems. Of the possible factors affecting change in the flow systems, large-scale withdrawal or recharge is significant because of the potential for major changes.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

Although little specific information on the effect of groundwater resource development in the vicinity of the Hanford site exists, some conclusions can be drawn from the nature of groundwater flow in general and the effects of groundwater withdrawal in other areas. Withdrawal of groundwater creates an "artificial" discharge situation within the groundwater flow system. Some groundwater is diverted from its normal flow path into a path which takes it to this discharge point. Conversely, liquid waste disposal, irrigation return flow, and surface water impoundments can create "artificial" recharge situations. If the amount of discharge or recharge is substantial and the location is close to a particular point of interest, groundwater flow at that point can be affected. Substantial but areally distributed discharge or recharge from or to a single hydrostratigraphic unit can produce an overall change in the hydraulic head on the unit and increase or decrease leakage from units above and/or below.

Uncertainties

Uncertainties inherent in determining types, probabilities, and nature of groundwater withdrawals or recharge changes is highly dependent on the future use of the water resources as described in SIA 1.3. Uncertainties are also dependent on the availability and nature of the groundwater resource, which has not been adequately defined in the basalts in the Pasco Basin.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Information needed to assess adequately the changes of withdrawal and/or recharge patterns in the Pasco Basin includes assessment of the economic likelihood of withdrawal/recharge scenarios and an accurate understanding of resource availability. Resource availability is dependent on accurate definition of hydrogeologic parameters controlling groundwater flow systems.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

DOE has assessed the economic likelihood of various groundwater withdrawal/recharge scenarios. Future work will include description of a credible scenario and analysis of the consequences using numerical models. The scenario will probably include maximum groundwater withdrawal for irrigation. Further details are not provided in the SCR.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>:

The plans in the SCR state that one credible scenario for groundwater development will be developed. Although the intent is to treat a maximum credible groundwater withdrawal, other scenarios are possible and should be considered (e.g., different locations, various well depths). Consequence modeling will require a better understanding of the groundwater flow system than currently exists. The installation of permanent head monitoring devices will be required to address current effects of groundwater withdrawal within and outside the Pasco Basin.

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Issue No. 1.3.4

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the types, probabilities, and nature of changes from dam construction on the Columbia River that could affect groundwater flow?

3. Importance of the Issue to Repository Performance

Groundwater is the likely medium of transport should stored radioactive waste leave the repository site. It is essential to know what factors could significantly alter the existing groundwater flow systems. Of the possible factors creating a change in the flow systems, future dams on the Columbia River could be important if there is significant hydraulic connection with the deep aquifer systems.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

Dam construction on the Columbia River would raise the river level and the water level of the associated unconfined aquifer (hydrostratigraphic unit), at least in the immediate vicinity of the river. Dam construction and subsequent reservior filling potentially could change the river from a line sink to a line source. Harty (1979) analyzed the effects of the proposed Ben Franklin dam on the shallow groundwater system. Changes in groundwater flow which could occur in the basalts of the Pasco Basin are largely unknown and are highly de½emdemt on the location of a dam.

Uncertainties

The basic uncertainty is due to the lack of knowledge of the groundwater flow systems. If the flow systems were well known, then prediction of changes by processes such as dam construction would be definable. Uncertainty is introduced in all aspects of the analysis based on the correct knowledge of groundwater flow systems.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Additional Information Needed

Basic information needed to assess the changes induced by dam construction revolves about obtaining an accurate understanding of the existing groundwater flow systems. Information needs include the location of potential dams, proposed stages upstream and downstream of the dam, and the basic hydrogeologic data required to define horizontal and vertical groundwater flow.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

RHO plans to assess changes to the deep groundwater system caused by dam construction by incorporating the results of a study by Harty (1979) into groundwater flow models of the deep basalts.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

Assuming that appropriate groundwater models are developed, the proposed plans are adequate. The development of appropriate models will require a better understanding of the existing flow system, including accurate information on hydraulic continuity, vertical and horizontal hydraulic conductivity, hydrogeologic boundaries, and hydraulic heads which are unaffected by transient conditions.

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Issue No. 1.4

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the expected effects over time on groundwater flow paths, velocities, dispersivities, discharges, and travel times resulting from repository-induced changes (including underground facility construction, dewatering and long-term stability, borehole/shaft seal failure, thermomechanical, thermal buoyancy, and thermal alteration of fracture filling minerals)?

3. Importance of the Issue to Repository Performance

Knowledge of the range and character of repository induced changes on groundwater flow paths, velocities, dispersivities, discharges and travel times is important in assessing repository suitability and design.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

A groundwater sink will be created during the construction and operation of an underground repository, because seepage and shaft inflow will have to be pumped out. The repository will continue to act as a sink even after the repository is allowed to flood, because a significant cone of depression will have developed around the repository during its active life. This will alter existing groundwater flow paths, velocities, discharges, and travel times until the system returns to pre-repository conditions. Thermal effects could decrease effective porosities and hydraulic conductivities in the vicinity of the repository while decreasing the viscosity of the groundwater. The viscosity decrease would increase the rate of groundwater movement. Thermal buoyancy effects will produce an additional component related to potential and hence hydraulic gradient that will affect groundwater movement. Failure of the borehole/shaft seal could provide a direct flow path from the repository at depth to shallower strata, thus to other flow units.

Uncertainties

The documentation of repository-induced changes is speculative, since no case histories exist from which real data can be obtained.

Models have not been adequately validated. A major gap in achieving validation is the lack of bulk parameter values, the lack of verifiable head measurements, and the lack of any induced, large-scale disturbances (e.g., pump tests) which can be used to calibrate the model.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Additional Information Needed

Additional data are required to make individual assessments of repository-induced changes. The existing groundwater flow systems require better definition before induced changes can be predicted. Specifically, hydraulic head distributions and both vertical and horizontal hydraulic conductivities require better definition both within groundwater flow units and between groundwater flow units.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

Assessment of post-closure repository performance will be made using numerical models on three scales: canister-and-room scale modeling utilizing rock stress/strain, heat transport, fracture-flow and radionuclide transport data; repository-scale modeling (near-field) utilizing heat transport, groundwater flow and radionuclide transport data; far-field-scale modeling utilizing groundwater flow and radionuclide transport data. Both deterministic and probabilistic models will be used. Testing from the exploratory shaft and underground test facility will be conducted to provide data for these models.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The numerical codes proposed for modeling the repository-induced effects upon groundwater flow have not been fully validated but will probably be adequate. However, it is questionable whether the proposed hydrogeologic investigations will provide representative data pertaining to bulk hydraulic parameters and hydraulic heads, particularly for use in the near-field and far-field models. The proposed multiple-well test in DC-16 A, B, C may provide bulk hydraulic parameter measurements for the near-field model, as will appropriate testing in the exploratory shaft and underground test facility. However, representative heads and bulk parameters for use in the far-field model will probably be lacking unless additional large-scale tests are performed and permanent piezometric installations provided.

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Issue No. 1.5

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the expected effects over time on groundwater flow paths, velocities, dispersivities, discharges, and travel times resulting from human-induced changes, excepting repository-induced changes (including water resource exploration, groundwater withdrawals and recharges, dam construction on the Columbia River, and human-induced structure and tectonic changes)?

3. Importance of the Issue to Repository Performance

Knowledge of the range and character of human-induced effects on groundwater flow paths, velocities, dispersivities, discharges and travel times is important in assessing repository suitability and design.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Present State of Knowledge

Human-induced changes in the groundwater flow systems in the area surrounding the repository should be minimal if control can be exercised over all activities at the site. Groundwater withdrawals, recharge and resource exploration should be minimal to non-existent on site. The influence of potential Columbia River dam construction on the groundwater flow system is unknown due to the number of questions that exist pertaining to the vertical and horizontal hydraulic head distributions at the site. The influence of potential hydrogeologic boundaries is unknown, and vertical hydraulic conductivity has yet to be quantified. Human-induced tectonic and structural changes should be minimal to non-existent if control can be exercised over the site. Off-site control would be less stringent, and therefore irrigation pumpage could affect groundwater levels and the rate and direction of groundwater movement on site.

Uncertainties

Uncertainties as to human-induced changes should be minimal except in regards to the effects of off-site changes and possible Columbia River dams. This uncertainty is due to inadequate data on the distribution of hydraulic head that may be influenced by transients (NR-0960, Appendix G), horizontal hydraulic conductivity data that may be adversely influenced by drilling mud (Appendix I), the lack of vertical hydraulic conductivity data, and the question of lateral hydrogeologic continuity (NR-0960, Appendices H and O) and boundary conditions. A number of potential human-induced changes are dependent on socio-economic factors, which are not currently quantified.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Additional Information Needed

Additional data are required to make individual assessments of human-induced effects. The existing groundwater flow systems require better definition before the induced effects can be predicted. Specifically, hydraulic head distributions, vertical and horizontal hydraulic conductivity, and hydraulical continuity require better definition areally. Predictive socio-economic models must be developed and validated.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

DOE plans to analyze the altered properties and conditions associated with non-induced phenomena and determine the probability of the occurrence of the event. The hydrogeologic tests will provide the data used to formulate a conceptual and numerical groundwater model. The effects of human-induced changes upon the groundwater systems will be evaluated using primarily mathematical groundwater models.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>:

The hydrogeologic tests proposed by DOE are not presented in sufficient detail to warrant an evaluation of the likelihood of success of these tests. Determination of hydrogeologic parameters under the constraints of NR-0960, Appendices E, F, G, H, I and O are mandatory for the appropriate conceptualization of groundwater flow systems and numerical simulation. Numerical simulation provides a basis for evaluating various human-induced changes on the groundwater flow system, but this approach is not detailed in the SCR.

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Issue No. 1.6

1. Name of the Site: Hanford BWIP

2. Statement of the Issue: What are the expected effects over time on groundwater flow paths, velocities, dispersivities, discharges, and travel times resulting from natural changes (including catastrophic Columbia River flooding, glaciation, precipitation/evapotransporation, structure and tectonic stress).

3. Importance of the Issue to Repository Performance:

Knowledge of the range and character of naturally induced effects on groundwater flow paths, velocities, dispersivities, discharges and travel times is important in assessing repository suitability and design.

4. Portions of Draft 10 CFR 60 That Are Directly Connected To The Issue:

60.21, 60.111, 60.112, 60.122, 60.123 and 60.124

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties:

Present State of Knowledge

Catastrophic Columbia River flooding could have negligible effect or a significant impact on groundwater flow, but insufficient data exists to define even current relationships between the river and the basalts. Specifically, vertical hydraulic head distribution and vertical hydraulic conductivity need better definition. The potential effects of glaciation are unknown, although

DOE has concluded that catastrophic flooding associated with the renewal of continental glaciation is the most significant potential impact (SCR, p. 3.4-3, 8.3-5-8). Alteration of the existing precipitation/evapotranspiration patterns could affect the location of recharge and discharge areas and the direction and rate of movement of groundwater flow. Such impacts are also highly dependent on a clear understanding of the existing groundwater flow systems. The effects on the groundwater system due to site specific structural and tectonic stress changes are not known.

Uncertainties

The uncertainties associated with predicting naturally induced effects on the groundwater systems arise from the difficulty of trying to predict the nature and extent of natural phenomena while the existing groundwater systems are inadequately defined. The existing groundwater systems cannot be defined without demonstrated hydraulic continuity (NR-0960, Appendices O, H, and F), bulk values for vertical and horizontal hydraulic conductivity that are unaffected by drilling mud (NR-0960, Appendices I and E), hydraulic head data unaffected by possible transient conditions (NR-0960, Appendix I), and accurate locations and descriptions of hydrogeologic boundary conditions.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

The existing groundwater flow systems require better definition before naturally induced effects can be predicted. Specifically, hydraulic head distributions and vertical and horizontal hydraulic conductivity, and hydraulic continuity require better definition area. The probability and nature of various individual and combinations of various natural changes must be determined so that their impact on groundwater flow systems can be simulated with a mathematical groundwater model.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

DOE plans to analyze the altered properties and conditions associated with naturally-induced phenomena and determine the probability of occurrence of the event. Hydrogeologic tests are planned with the intent of providing the necessary hydrogeologic data for refining DOE's conceptual and mathematical groundwater models. The effects of natural changes upon the groundwater systems will be evaluated using primarily mathematical groundwater models.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The hydrogeologic tests proposed by DOE are not presented in sufficient detail to warrant an evaluation of the likelihood of success of these tests. Determination of hydrogeologic parameters are mandatory for the appropriate conceptualization of groundwater flow systems and numerical simulation. A model cannot be properly validated without detailed data for bulk values of vertical and horizontal hydraulic conductivity, hydraulic continuity, hydrogeologic boundary conditions, and static hydraulic heads. These parameters must be determined under the constraints established in NR-0906, Appendices E, F, G, H, I, and O.

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Issue No. 2.1

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What are the possible mechanisms by which water will penetrate the packing material around containers?

3. Importance of the Issue to Repository Performance

Penetration of the packing material around the container by groundwater may result in contact of the waste container with the groundwater. In turn, contact of the waste container with groundwater may lead to corrosion, thus compromising the integrity of the container and of the waste form within. Movement of water through the waste package provides a potential release pathway for radionuclides to the near field.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113 Performance of particular barriers after permanent closure.

(a) General provisions.

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste package will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total annual release at 1,000 years following permanent closure.

Design Requirements for the Waste Package

§ 60.135 Requirements for the waste package and its components.

(a) Waste package design requirements for high-level waste.

(1) Packages for HLW shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Penetration of the packing material by water may occur as a result of an increase in hydraulic conductivity caused by one or more of the following chemical degradation mechanisms (BNL-NUREG-31770, 1982):

- loss of hydrothermal stability.
- aging.
- selective dissolution on leaching of the packing material matrix.
- radiation effects, including radiolysis.

The hydrothermal stability of the packing material is the principal source of uncertainty.

Water may also penetrate the packing material by means of the following mechanical failure mechanisms (BNL-NUREG-31756, 1982):

- fracturing
- embrittlement
- liquefaction
- hydrologic erosion
- poor initial filling and/or mixing of clay and basalt.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

Further investigation is needed of the changes in the hydraulic conductivity of candidate packing materials resulting from the chemical degradation mechanisms listed in (5), above, in the 100° to 300°C temperature regime at pressures of 300 bars with the dissolved solids concentrations, the Eh, and the pH of the simulated groundwater at their expected values under repository conditions. Also, the mechancal failure mechanisms listed in (5), above, need further study under expected repository conditions. (For example, it is not clear if such mechanical failure mechanisms occur under expected repository conditions.) Because irreversible microstructural changes may occur in the packing material as a result of exposure to repository conditions, the effects of the history of the material as well as the effects of the conditions at the time of testing should be addressed. (For example, how does prior exposure of the material to 300°C at 300 bars for some specified time period affect the hydraulic conductivity later at 100°C at 300 bars?)

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6):

The present issue is addressed by the following Work Element in the SCR:

> W.1.15.B: Define the characteristics of the packing materials required to retard the flow of groundwater to the container. Identify packing materials with these characteristics.

Measurements of the hydraulic conductivities, swelling pressures, and mechanical strengths of various unspecified basalt/bentonite mixtures are planned. These properties will be measured as a function of temperature and density. The dependence of these properties on moisture content and grain size must also be determined. These data will be used to verify the licensability of the reference waste package packing material mixture of 25% bentonite/75% basalt by volume. Other potential mixtures (for example, crushed basalt and sand) will also be investigated.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The conditions under which the measurements described in (7), above, will be performed are not well defined in the discussion of Work Element W.1.15.B in the SCR. Pressure is not explicitly mentioned as an important variable, nor is any mention made of the use of simulated basalt groundwater at the appropriate pH and Eh as the permeating fluid. Temperature of up to 300°C at pressures of 300 bars (maximum lithostatic pressure) in the presence of simulated groundwater are discussed in connection with other Work Elements, for example, W.1.16.B. Measurements of the wetting of an initially dry packing material are not explicitly noted in the SCR, and measurement of the hydraulic conductivity as a function of the hydraulic gradient are not discussed. It is possible to conduct measurements of the penetration of packing materials by water under repository conditions in autoclave systems, so that the investigations required to provide the information needs are likely to be successful.

References:

1. BNL-NUREG-31756, "Testing for Mechanical Failure of Bentonite in a Discrete Backfill for Basalt and Salt Repositories, Draft Report," B. Siskind, Brookhaven National Laboratory, August 1982.

2. BNL-NUREG-31770, "Chemical Failure Modes of Bentonite and Zeolites in Discrete Backfill for Nuclear Waste Repositories, Draft Report," D. Eastwood, Brookhaven National Laboratory, August 1982.

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Issue No. 2.1.1

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What are the possible mechanisms by which water will penetrate packing materials around containers?

3. Importance of the Issue to Repository Performance:

Many function shave been assigned to the packing material in various waste package designs. A recent conceptual design by Westinghouse (AESD-TME-3113, Appendix A, reported in BNL-NUREG-31756, Section 1.1) considers only one of the proposed packing material functions to be important for meeting the 10 CFR 60 objectives, namely, control of the groundwater flow to the waste form and, after saturation, out of the waste package. Contact of the waste container with groundwater may affect the integrity of the container and of the waste form within. The flow of groundwater through the waste package provides the major credible anticipated process or event by which radionuclides could be released to the accessible environment.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

§ 60.135 Requirements for the waste package and its components.

(a) Waste package design requirements for high-level waste

(1) Packages for HLW shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility on the geologic setting.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties:

Considerable data have been generated on the chemical degradation and mechanical failure modes affecting the transport of water through candidate packing materials (BNL-NUREG-31770, BNL-NUREG-31839), but much of the testing has been done under conditions not representative of expected repository conditions (NUREG/CR-2755; BNL-NUREG-31756). Possible chemical failure modes for packing materials have been identified as: loss of hydrothermal stability, aging, decrease in sorptive capacity by chemical reaction or poisioning, selective dissolution or leaching of the packing material matrix, and radiation effects including radiolysis. The hydrothermal stabilities are the principal cause of concern, depending not only on temperature, but also on groundwater composition, extent of water saturation, rates of reaction,e xchangeable cations, and pressure. Mechanical failure modes identified are fracturing, embrittlement, hydrologic erosion, and liquifaction.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

It is recommended that the loss of hydrothermal stability of candidate packing materials at higher temperatures (e.g., >100°C, for bentonite) be investigated further. Other chemical failure modes also need more research to quantify their effects (BNL-NUREG-31770). Measurements of the self-sealing properties of the packing materials at temperatures expected in the repository and for longer time periods would be useful as would direct measurements of the rate of flow of the permeating fluid through the packing material, also under conditions simulating the repository environment. In particular, it is urged that realistic values of the hydraulic gradients be used in such studies. Incipient failure may be detectable by obtaining information on any changes in the molecular and crystal structure of the packing material under anticipated repository conditions.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

References:

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BWIP DSCA/SIA 2.1.1.1/COOK

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Issue No. 2.1.1.1

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue:

To what extent over time will groundwater flow, temperature, or other effects change the ability of packing materials to control flow through those materials? What chemical and physical changes are possible? What are the chemical and physical properties?

3. Importance of the Issue to Repository Performance

Many functions have been assigned to the packing material in various waste package designs. A recent conceptual design by Westinghouse (AESD-TME-3113, Appendix A, reported in BNL-NUREG-31756, Section 1.1) considers only one of the proposed packing material functions to be important for meeting the 10 CFR 60 objectives, namely, control of the groundwater flow to the waste form and, after saturation, out of the waste package. Contact of the waste container with groundwater may affect the integrity of the container and of the waste form within. The flow of groundwater through the waste package provides the major credible anticipated process or event by which radionuclides could be released to the accessible environment.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.135 Requirements for the waste package and its components

(a) Waste package design requirements for high-level waste

(1) Packages for HLW shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the

emplacement environment do not compromise the function of the waste packages or the performance of the underground facility on the geologic setting.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Degradation of the ability of the packing material to retard the flow of water may result from a variety of chemical and physical failure modes (See 2.1.1). Although such failure modes have been characterized to varying degrees (BNL-NUREG-31770; BNL-NUREG-31839), much of this information is not relevant to repository conditions (NUREG/CR-2755, Section 2.2.1).

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

The ability of packing material to retain its hydraulic properties during the required time period may be greatly affected by the thermal environment. The packing material will experience a temperature cycle from an initial repository ambient temperature (60 to 70°C) to as high as 250-300°C and then a slow return to ambient. Thus, it is important that the temperature dependence of the chemical and physical properties on which the packing material attributes are based be known over these temperature ranges. The thermal history of the material as well as the temeprature at the time of testing is also significant. Stability of the packing material can also be affected by groundwater composition, Eh and pH. (NUREG/CR-2755, Section 2.2.1.) In order to define the testing conditions relevant to the near-field repository environment, the design of the waste package as well as the characteristics of the undisturbed geologic environment must be specified. The crucial quantity which needs to be measured is the rate of flow of water through the packing material as a function of the near-field environmental parameters and of the previous history of the test sample.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

References:

1. AESD-TME-3113, "Engineered Waste Package Conceptual Design; Defense High-Level Waste (Form 1), Commercial High-Level Wsate (Form 1), and Spent Fuel (Form 2); Disposal in Basalt - Draft Report," U. S. Department of Energy, Office of Nuclear Waste Isolation, September, 1981.

2. BNL-NUREG-31756, "Testing for Mechanical Failure of Bentonite in a Discrete Backfill for Basalt and Salt Repositories - Draft Report," Brookhaven National Laboratory for the U. S. Nuclear Regulatory Commission, August, 1982.

3. BNL-NUREG-31770, "Chemical Failure Modes of Bentonite and Zeolites in Discrete Backfill for Nuclear Waste Repositories - Draft Report," Brookhaven National Laboratory for the U. S. Nuclear Regulatory Commission, August, 1982.

4. BNL-NUREG-31839, "Data Requirements for Mechanical Failure of Bentonite in a Discrete Backfill for Basalt and Salt Repositories - Draft Report," Brookhaven National Laobratory for the U. S. Nuclear Regulatory Commission, August, 1982.

5. NUREG/CR-2755, "Discrete Backfill Testing Required to Demonstrate Compliance with 1000-Year Radionuclide Containment - Final Report," Brookhaven National Laboratory for the U. S. Nuclear Regulatory Commission, May, 1982.

Document Name:
BWIP DSCA/SIA 2.2/CHANG

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Issue No. 2.2

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington.

2. Statement of the Issue: To what extent over time will groundwater flow, temperature, or other effects change the ability of packing materials to control flow through those materials? What chemical and physical changes are possible? What are the chemical and physical properties?

3. Importance of the Issue to Repository Performance: Changes in the chemical and physical properties of the packing material may affect the ability of these materials to control the flow of groundwater and radionuclides through the waste package. Contact of the waste container with groundwater may compromise the integrity of the container and of the waste form within movement of water through the waste package provides a potential release pathway for radionuclides.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue:

§ 60.113 Performance of particular barriers after permanent closure.

(a) General provisions.

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (a) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (b) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste package will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total annual release at 1,000 years following permanent closure.

DESIGN REQUIREMENTS FOR THE WASTE PACKAGE

§ 60.135 Requirements for the waste package and its components.

(a) Waste package design requirements for high-level waste.

(1) Packages for HLW shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Reduction of the ability of the packing material to retard the flow of water and radionuclides may result from a variety of chemical and physical changes:

- loss of hydrothermal stability
- aging
- decrease in sorptive capacity by chemical reaction or poisoning
- selective dissolution or leaching of the packing material matrix
- radiation effects, including radiolysis
- fracturing
- embrittlement
- liquifaction
- hydrologic erosion.

Although such degradation mechanisms have been characterized to varying degrees, much of this information has been obtained under conditions not typical of those expected in the BWIP repository (see NUREG/CR-2755, BNL-NUREG-31756, and BNL-NUREG-31770, 1982).

Several chemical and physical properties of the packing material which are of primary importance in the ability of the packing material to control flow are affected by the above changes. These properties are the hydraulic conductivity, swelling pressure, plasticity (on extrudability), density, diffusion coefficient, sorptive capacity, and ion exchange capacity.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

Because the packing material will experience a temperature cycle from an initial repository ambient temperature (60 to 70°C) to as high as 250-300°C and then a slow return to ambient while the pressure increases to 300 bars, the temperature dependence of the chemical and physical properties on which the packing material attributes are based must be known over a temperature range of 60 to 300°C at 300 bars of pressure. The effects of groundwater composition, Eh and pH on the chemical and physical properties of the packing material must also be known. (NUREG/CR-2755, 1982, Section 2.2.1). Very similar information needs have been identified in the SCR (Section 15.3).

- Thermal stability of potential packing materials (primarily basalt/bentonite mixtures) in the temperature range 150° to 300°C at 300 bars for up to 6 months.

- Mineralogical and chemical characterizations of alteration phases for basalt and packing materials under expected repository conditions (150° to 300°C, 300 bars, simulated groundwater chemistry, expected Eh and pH).

- Effects of radiation on the above measurements.

- Rates of the above processes.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

Approaches to the present issue are implicitly addressed by the following work elements in the SCR:

- W.1.16.B Define the characteristics of the packing material required to reduce the rate of radionuclide release from the waste package. Identify packing materials with these characteristics.

Hydrothermal experiments are being conducted under site-specific conditions in the range of 150 to 300°C to determine the thermal stability limits of packing materials. The effects of dehydration on the structural stability of hydrated candidate packing materials (for example, smectite clays, zeolites) are being investigated. On the basis of data being generated currently, packing material mixtures will be chosen and flow-through experiments completed under repository conditions to measure radionuclide transport through a saturated packing material. These data will then give an indication of whether radionuclide transport rates [and the flow of groundwater] can be controlled satisfactorily by the packing materials.

- W.1.12.A Determine the extent to which the interaction between the container materials, waste form, packing material, and host rock in a saturated environment results in retardation of radionuclides.

Hydrothermal-interaction studies of barrier materials are to be carried out with controlled experimental parameters over the relevant range of repository conditions. Temperatures should range between 100° and 300°C, with a total pressure of 300 bars (full lithostatic pressure). Periodic sampling of the groundwater solutions under test conditions is necessary to determine the rate of approach to steady-state solution composition. Hydrothermal hot-cell testing of engineering-scale waste packaged will be scoped to measure critical interactions in a radiation field.

- W.1.3.A Determine the effect of the waste package radiation environment on the near-field geochemistry, waste package, and barrier material performance.

Two methods are planned for investigating the effect of radiation on stability and degradation modes of barrier materials:

(1) Imposition of a radiation field on standard container and packing material testing apparatus.

(2) Inclusion of barrier materials with radioactive waste forms inside hydrothermal autoclaves of a hot-cell facility.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The planned approach described in (7), above, is relatively complete. Details of the proposed studies are not given in the SCR, but such studies are well within the state of the art with respect to feasibility. Measurements combining the features of all three work elements should also be carried out, that is, a flow-through experiment under expected repository conditions including interaction between the waste package components under hydrothermal conditions in a radiation field. Such a study would, in effect, be a waste package simulation. The studies outlined in (7), above, from the SCR, as well as the waste package simulation just mentioned, should be carried out for extended periods of time, at least the six months noted in (6) above and longer, if possible. (There are some minor problems with the Work Elements. For example, no external pressure is mentioned in W.1.16.B. Also, the lower limit of the temperature range is given as 150°C in W.1.16.B and 100°C in W.1.12.A. Probably, a better, more comprehensive lower limit would be 60°C as noted in (6), above, based on ambient repository conditions.)

References:

1. BNL-NUREG-31756, "Testing for Mechanical Failure of Bentonite in a Discrete Backfill for Basalt and Salt Repositories, Draft Report," B. Siskind, Brookhaven National Laboratory, August 1982.

2. BNL-NUREG-31770, "Chemical Failure Modes of Bentonite and Zeolites in Discrete Backfill for Nuclear Waste Repositories, Draft Report," D. Eastwood, Brookhaven National Laboratory, August 1982.

3. NUREG/CR-2755, "Discrete Backfill Testing Required to Demonstrate Compliance with 1000-year Radionuclide Containment," A. Bida and D. Eastwood, Brookhaven National Laboratory, May 1982.

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Issue No. 2.3

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What are the hydrothermal conditions with time at the surfaces of the waste form and container and within packing materials which influence property changes and radionuclide release?

3. Importance of the Issue to Repository Performance

The stability of a waste package component on exposure to liquid water at temperatures between about 50° and 400°C and at high enough pressures to keep the water in a liquid state is termed hydrothermal stability (BNL-NUREG-31770, 1982, p. 50). Hydrothermal stability is a primary consideration in any analysis of waste package performance because of the possibility of groundwater intrusion in the presence of radioactve decay heat under an external hydrostatic and/or lithostatic pressure. Loss of integrity of the waste package may result if any of its components have poor hydrothermal stability characteristics.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113

(a) General provisions.

(1) Engineered barrier system.

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geological setting over long times.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste package will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total annual release at 1,000 years following permanent closure.

§ 60.135 Requirements for the waste package and its components.

(a) Waste package design requirements for high-level waste.

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength,

mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

The near-field temperature conditions for the undisturbed basaltic host rocks are relatively well defined, a range of 60° to 70°C having been given as a "reasonable estimate" for the Umtanum flow in the Grounde Ronde formation. Estimates have also been made for the maximum temperature (300°C) and pressure (100 bars and 300 bars for the hydrostatic and lithostatic pressures, respectively, at a depth of 1000 m). The temperature will decrease as the radionuclides in the waste decay, leveling off to the original temperature of the flow after about 1000 years. The pressure at the time of emplacement is close to atmospheric, but after repository closure the pressure is expected to increase over a unspecfied time period to some value between the hydrostatic and lithostatic pressures. See NUREG/CR-2780 (1982) and the references cited therein, in particular RHO-BWI-ST-7 (1980) and NWTS-16 (1981), for further details.

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

Better definition of the near-field temperature and pressure characteristics as a function of time is needed and can be obtained only from an analysis of specific waste package designs within a well-characterized near-field repository environment. The thermal loading of the waste form and the thermal conductivity characteristics of the waste package components and of the host rock must be used to calculate the near-field temperature as a function of time. The swelling characteristics of the packing material upon exposure to water must be used to deduce the rate of approach to pressure equilibrium.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Approaches to the present issue are implicitly addressed by the following work elements in the SCR:

W.1.2A. Determine conditions that affect design of waste packages, including thermal loading, mechanical loading, and chemical environment during...emplacement...and after repository decommissioning.

Thermal hydraulic models of the waste package, repository, and host rock will be used to estimate the time for migration of groundwater around and into the waste package. The results will depend on the specific repository and waste package designs selected, so the evaluations will be updated for the conceptual, preliminary, and final design phases.

W.1.12A. Determine the extent to which the interaction between the container materials, water form, packing material, and host rock in a saturated environment results in retardation of radionuclides.

Hydrothermal-interaction studies of barrier materials are to be carried out with controlled experimental parameters over the relevant range of repository conditions. Temperatures should range between 100° and 300°C at a pressure of 300 bars (lithostatic pressure). Hydrothermal hot-cell testing of engineering-scale waste packages will be scoped to mesure critical interactions [identified in the hydrothermal interaction studies of barrier materials] between the several components of a waste package which incorporates a radioactive waste form. Test data will be reconciled with model predictions.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success

The two approaches outlined in (7), above, should together lead to a better definition of the hydrothermal conditins in the vicinity of the waste package. The two planned approaches are not described in detail in the SCR and could not be at the present stage of waste package design. The period of time over which the hydrothermal studies would be carried out is not given in the SCR. Feedback between the thermal hydraulic modeling and the hydrothermal-interaction studies will be necessary as part of the development of both the hydraulic modeling and the hydrothermal-interaction studies. The modeling and the hydrothermal-interaction studies are both feasible.

References:

1. BNL-NUREG-31770, "Chemical Failure Modes of Bentonite and zeolites in Discrete Backfill for Nuclear Waste Repositories - Draft Report," D. Eastwood, Brookhaven National Laboratory, August 1982.

2. NURC/CR-2759, "Discrete Backfill Testing Required to Demonstrate Compliance with 1000-year Radionuclide Containment," G. Bida and D. Eastwood, Brookhaven National Laboratory, August 1982.

3. NUREG/CR-2780, "Near-Field Repository Conditions in Basalt and Salt" and B. Siskind and D. Hgieh, Brookhaven National Laboratory, May 1982.

4. NWTS-16, "Draft Interim Reference Repository Conditions for Nuclear Waste Repository in Basalt," Reference Repository conditions Interface Working Group, National Waste Terminal Storage Program, ONWI, DOE, September 1981.

5. RHO-BWI-ST-7, "Engineered Barrier Development for a Nuclear Waste Repository in Basalt: An Integration of Current Knowledge," M. J. Smith and others, Rockwell Hanford Operations, May 1980.

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Issue No. 2.4

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What are the possible mechanical failure modes for the container?

3. Importance of the Issue to Repository Performance

The container is generally considered to be the most important engineered barrier with respect to containing radionuclides. Because of this a container which remains unbreached by mechanical failure modes for extended periods will allow in-situ radionuclide decay, and delay the onset of waste-form leaching. Thus, a container will be of significant importance with respect to defining the radionuclide source term.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113 Performance of particular barriers after permanent closure

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission produce decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

A recent report by Soo and Brewster (BNL-NUREG-31774, 1982) shows that the mechanical failure of a HLW container is primarily dependent on the specific design, the temperature history and the mode of loading. Containers constructed of thick, ductile, high-strength alloys will be more resistant to mechanical failure; lower temperatures will increase the strength and also reduce the possibility of failure. (It should be noted that corrosion-enhanced mechanical failure such as stress corrosion cracking, is considered elsewhere.) With respect to the effect of stress state on the failure for a container, four (4) different loading conditions are of importance (a) failure from lithostatic/hydrostatic stresses , (b) failure from seismic activity, (c) failure from waste form swelling or internal gas pressurization and (d) failure from residual stresses.

In a sealed basalt repository a summary report by Siskind and Hsieh (BNL-NUREG-51548, Part 1, 1982) states that at a depth of 1100 m the hydrostatic and lithostatic stresses in basalt would be 11 and 33 MPa, respectively. Recent work shows that the horizontal component of the stress from the rock overburden could be as high as 66 MPa (Doe, ONWI-9(4), 1980). However, in the case of BWIP, bentonite packing material would exert an additional stress on the container when it swells through saturation with groundwater. This swelling pressure would be additive to the hydrostatic stress and the total effective hydrostatic stress on the container could be as high as 21 MPa. At a temperature of 300°C, there could be deformation of the low carbon steel container, especially in the void region adjacent to the waste glass surface. This could lead to creep or ductile failure of the container.

Seismic events in which hard rock masses could deform along linear faults were considered to be a source of high stress by Pusch (KBS Report, KBS-TR-22, 1977). His analysis showed that certain materials used in KBS container designs would not withstand shear stresses which could breach the container. He believed, however, that high strength materials could withstand mechanical failure provided packing materials were placed around the container.

Waste glass may suffer from irradiation induced swelling which will deform the type 304L stainless steel mold into which the glass is cast. However, a maximum volume increase of 1 percent is anticipated after 1000 years and this would be expected to cause deformation in the mold rather than the surrounding low carbon steel container in the BWIP design.

Residual stresses in the low carbon steel container are probably concentrated in welded regions. Although they may induce local deformation at 300°C due to stress relief effects, they do not appear to present a problem in the absence of an aggressive environment. Since the BWIP waste package is non-shielded, hydrogen will be generated by gamma radiolysis and this could lead to container failure.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

In order to successfully specify a mechanically-adequate container design the following additional data requirements will be required:

(a) A conservative estimate of anticipated stress levels in the container system over the 1000 year containment period.

(b) A specification of the maximum compressive stresses (vertical and horizontal) and likely shear modes acting on the container system over the 1000 year containment period.

(c) Accurate estimates of the container temperature as a function of time.

(d) A detailed description of waste package materials, geometries, and dimensions to determine stress-strain behavior under likely loading conditions.

(e) Comprehensive information of creep and other mechanical properties for low carbon steel base and welded material for temperatures between 80-300°C. Effects of hydrogen level on deformation behavior also need to be determined.

(f) Multicomponent stress analysis to determine how the waste form and packing material modify the loading and deformation of the container.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>:

The contents of Work Element No. W.1.2.A purport to address the evaluation of mechanical loads on the container but, as discussed in NRC Issue No. 2.6 the actual plan for this effect does not seem to devote enough effort to this problem. There is little description of the types of mechanical failure which could occur after repository closure, with the exception of stress-corrosion cracking and hydrogen embrittlement described in Work Element W.1.6.A. It is felt that some consideration should be given to specifying likely mechanical failure modes for breaching the container since the distribution and size of failed zones will determine the rates of release of radionuclides from the waste form.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of of Success</u>:

At present the definition of mechanical failure modes for the container are not adequately addressed in the SCR Work Element. It is recommended that this be carried out as a priority since the types of failure will influence radionuclide release rates. If the waste package design and repository conditions are well defined it is likely that the controlling failure mode can be identified, and verified by experiment and structural analysis.

References:

1. BNL-NUREG-31774, "Mechanical Failure Mode Data Requirements for TiCode-12 High Level Wave Container System (Draft Report), August 1982.

2. NUREG/CR-2780, "Near Field Repository Conditions in Basalt and Salt," Brookhaven National Laboratory Report, 1982.

3. ONWI-9(4), "Stripa In-Situ Stress Measurements," 1980.

4. KBS-TR-22, "The Influence of Rock Movement on the Stress/Strain Situation in Tunnels on Bore Holes with Radioactive Canisters Embedded in a Bentonite/Quartz Buffer Mass," 1977.

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Issue No. 2.5

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What are the chemical and physical property changes in container materials and what are the resultant properties.

3. Importance of the Issue to Repository Performance

The container will be the principal component that restricts water from reaching the waste form. Since its chemical and physical properties will be altered by corrosion and mechanical failure, its impact on the rate of radionuclide release needs to be quantified.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§60.113 Performance of particular barriers after permanent closure

(1) Engineered Barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

The consequences of container corrosion and mechanical failure processes need to be evaluated insofar as they affect the behavior of adjacent waste package components. Several important factors concern their effect on the release of radionuclides from the waste form, and packing material performance. In the one case, the rate at which repository water flows around the waste form depends on the corrosion/mechanical failure mode operating. For example, catastrophic cracking from hydrogen embrittlement would be expected to give water unlimited access to the waste form, whereas failure by a small number of corrosion pits may restrict the release of radionuclides. A scenario for the corrosion/mechanical penetration of the container will, therefore, be needed. With respect to corrosion of low carbon steel, voluminous oxide formation will inhibit heat transfer and may elevate the waste form temperature and enhance the leach rate. Together, the corrosion products and released radionuclides could form alteration products with the surrounding packing material and alter their sorptive behavior.

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

The following data will be needed to characterize the interaction behavior of the container with adjacent barriers:

(a) A postulated container failure scenario which will permit an estimate to be made of the rate at which repository water passes through a perforated container to the waste form. This will enable the effect of water residence time on leachability to be determined.

(b) Estimates of the thickness and thermal conductivity of oxide films on the container. This will permit temperature profiles through the waste package to be determined as a function of time.

(c) An evaluation of the change in packing material performance as a result of interactions with corrosion products from the waste form and container.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Several Work Elements in the SCR (W.1.6.A, W.1.7.A, W.1.12.A, W.1.19.B) generally cover the performance of waste package components after repository closure. However, none address in any detail the specific issues listed in section (6) above. It is possible that as the BWIP effort progresses, these specific issues will require analysis and be factored into the ongoing research and development programs. To fully characterize these the physical and chemical nature of changes in the container characteristics, however, an extensive effort is required since the changes will be severe as the residence time of the waste package in the repository becomes large. Thus, a satisfactory means of estimating these long term changes from short term experiments needs to be developed.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success

As specified in (7), above, the BWIP program does not directly address the long term physical and chemical changes in package components due to interaction effects. Because of the complexity of the problem, definitive data may not be obtainable but it may be possible to make conservative estimates of the changes which can then be factored into waste package design. In doing so, the ability of the engineered system to meet NRC performance criteria can be addressed.

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Issue No. 2.6

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What are the mechanical loads on the container vs. time? How do the packing materials alter the loading?

3. Importance of the Issue to Repository Performance

The basic importance of mechanical failure issues for BWIP containers is described in NRC Issue No. 2.4 and focuses on the container's role in radionuclide containment and source term quantification. The current Issue on the definition of the load vs. time relationship is of importance since it is needed to qualify the mechanical design of the container system, to estimate the degree of container breaching so that water flow rates around the waste form can be examined for leach rate analysis, and to estimate the time when the waste form will be contacted by water.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

§ 60.113 Performance of particular barriers after permanent closure

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission produce decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

At this time the BWIP waste package design is tentative as are estimates of the anticipated temperature changes with time. Effective lithostatic/hydrostatic stresses also appear to be largely unknown. The recent work at Stripa (KBS-TR-22, 1977) shows that horizontal stresses in granite may be twice as large as those estimated from the rock overburden so that any mechanism failure of the container would more likely occur from this stress condition. Shear failure may also be a possibility due to rock movement along fault planes. At this time, therefore, significant uncertainties exist with respect to the identification of the stressing mode on the container, the magnitudes of the stresses, the effects on a deformable packing material in redistributing stresses, and the rate of deformation. Until these factors are quantified the mechanical failure time for a container cannot be determined.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

In order to successfully specify a mechanically-adequate container design the following additional data requirements will be required:

(a) A conservative estimate of anticipated stress levels on the container system over the approximately 1000 year containment period.

(b) A specification of the maximum compressive stresses (vertical and horizontal) and likely shear modes acting on the container system over the approximately 1000 year containment period.

(c) Accurate estimates of the container temperature as a function of time.

(d) A detailed description of waste package materials, geometries, and dimensions to determine stress-strain behavior under likely loading conditions.

(e) Comprehensive information of creep and other mechanical properties for low carbon steel base and welded material for temperatures between 80-300°C. Effects of hydrogen level on deformation behavior also need to be determined.

(f) Multicomponent stress analysis to determine how the waste form and packing material modify the loading and deformation of the container.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

The general outline in SCR Work Element No. W.1.2.A covers the recommended work scope in their Site Issue Analysis. It covers the proposed determination of temperature, loading and environmental histories for the waste package. However, the plan for Work Element W.1.2.A. on page 15.3-13 seems to focus only on chemical/hydraulic effects with little consideration for evaluating the loading to be expected on a waste package as a function of time. Much more emphasis needs to be placed on the latter since mechanical failure modes may be extremely important with regard to demonstrating compliance with NRC performance objectives.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

Based on the discussion in (7) above extra emphasis will be needed on characterizing the waste package loading history for the anticipated BWIP repository design. Apart from this the overall BWIP test plan, which correlates environment and thermal conditions with loading history, apears to be appropriate. A reevaluation of the test program should be carried out by NRC as full details of the loading are specified.

References:

1. KBS-TR-22, "The Influence of Rock Movement on the Stress/Strain Situation in Tunnels or Bore Holes with Radioactive Canisters Embedded in a Bentonite/Quartz Buffer Mass," 1977.

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Issue No. 2.7

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What are the possible corrosion failure modes for the container?

3. Importance of the Issue to Repository Performance

The container is generally considered to be the most important engineered barrier with respect to containing radionuclides. Because of this a container which remains unbreached by corrosion failure modes for extended periods will allow in situ radionuclide decay, and delay the onset of waste-form leaching. Thus, a container will be significant importance with respect to defining the radionuclide source term.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(a) General provision.
(1) Engineered barrier system.

(i) The engineered barrier system shall be design so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long time.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Voluminous data exist on the corrosion of low carbon steel in a wide range of aqueous solutions. Uniform corrosion, pitting, crevice corrosion, stress corrosion cracking and hydrogen embrittlement are known to occur.

Although uniform corrosion rates in "clean" water are unlikely to cause failure of the BWIP container, based on available data on the range of uniform corrosion rates, pitting may present a problem since the rate of penetration may be higher by a factor of 4 to 11 (Southwell, Romanoff). Thus pits may penetrate the BWIP container during the containment period.

Crevice corrosion may readily occur in low carbon steel due to the formation of an oxygen concentration cell consisting of a small oxygen starved anode and a large cathode with a higher surrounding oxygen level. In the crevice region (the anode) the lack of oxygen allows the hydrogen ion concentration to rise and attract ions such as Cl^- to migrate to the crevice to maintain electroneutrality. As HCl builds up, the metal in the crevice region is rapidly attacked. A similar mechanism applies to pitting.

Carbon steel can suffer failure by stress corrosion cracking (SCC) under caustic environments and mechanical tensile stresses. Current theory uses a variety of mechanisms to describe all the characteristics and mode of SCC. These can be segregated into roughly three categories: having cracks which are associated with either

(a) pre-existing active paths

(b) strain generated active paths

or (c) specific ansorption at subcritical stress sites.

Pre-existing active paths in an alloy are formed by microsegregation and precipitation within a metal, usually at grain boundaries. Local galvanic cells are established weakening the metal against mechanical failure.

Microsegregation can be minimized by proper melting practice and careful consideration of casting technique. Precipitation can be minimized by keeping alloy content low and removing sulfur (Parkins).

Strain generated active paths usually initiate at slip steps occuring at the surface of the metal. SCC proceeds intergranularly. Specific absorption paths require absorption of gases (particularly H_2) in small cracks on the surface of the metal (Parkins).

The role of hydrogen in SCC is not explicitly defined, although it is clear that H_2 will encourage SCC (Logan and Yolken). In some cases if metal is in a strained condition, hydrogen will reduce the metal's yield strength to the point where it can fail mechanically (Bhat). Since large hydrogen overpressures may exist in a basalt repository (based on calculations of equilibrium of iron oxides in basalt with groundwater - SCR page 11.4.16), hydrogen assisted failure of carbon steel is a possibility. In addition, groundwater radiolysis may also produce sufficient hydrogen to initiate failure of the container.

The rate of hydrogen diffusion into a metal and the depth of attack (decarburization and fissuring) varies with metal heat treatment, H_2 pressure, atmospheric moisture content and temperature (Bhat, Gutziet, Logan). There exists an incubation period for attack, although it is shortened considerably by water vapor. Water vapor also increases the depth of hydrogen attack. However, Gutziet and Thygenson report attack depths which logarithmically approach only a few millimeters.

Solution chemistry and mechanical strength also play a dominate role in the modes of SCC. In aqueous chloride environments, for example, SCC is dependent on the yield strength of the alloy. Probability of failure increases for steels with strengths greater than 689 MN/m^2 (100,000 psi), while steels less strong appear uniformly resistant. Cracking rate increases with temperature and Cl^- concentration, but the critical stress factor (K_{ISCI}) does not.

In addition to the above mentioned issues on the corrosion of the carbon steel container during the repository post-closure period, there exists a potential for serious container corrosion during the repository operations period when groundwater is likely to contact the hot container prior to the loading of the bentonite/basalt packing. Water contacting the 300°C container will boil and leave a residue of chlorides, carbonates, and sulfates, etc., which could be deleterious, especially since it may be in contact for decades under oxic conditions. Conceivably, pitting and SCC could occur on the container surface, most likely in highly stressed regions adjacent to the container support structures.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Applicaton

The following basic data will be needed to fully quantify the corrosion behavior of a low carbon steel container in BWIP:

(a) A specification of the temperature-time history and load-time of the container during the pre- and post-closure periods.

(b) A specification of the Eh, pH in the vicinity of the container as a function of time during the pre- and post-closure periods.

(c) A determination of the water chemistry between the container and packing material.

(d) Long term data on the uniform, pitting, and crevice corrosion rates for base and welded material during the pre- and post-closure periods.

(e) Examination of the stress on the container and its effects on stress corrosion and hydrogen embrittlement.

(f) Determination of gamma radiolysis effects in terms of oxygen and hydrogen pickup, and how these factors influence uniform and local corrosion. See also Issue 2.10.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

The SCR addresses the need to fully characterize corrosion failure modes in low carbon steel in order to determine whether the container can meet NRC radionuclide containment requirements. In the test program given in Work Element W.1.6.A (Table 15-2) the basic research will be centered on testing a range of candidate metals to determine which are the most corrosion resistant. Advance tests will then be conducted on two to three high priority metals to be tested in the presence of packing material for a range of anticipated repository conditions, including radiation. Uniform corrosion, pitting, stress-corrosion cracking, intergranular corrosion, crevice corrosion, and hydrogen embrittlement are all to be addressed.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>

The test program as briefly outlined in Table 15-2 is logical and complete with the possible exception that the corrosion during repository operation is not addressed. The program should be adequate if the tests take into detailed consideration the localized conditions which will be present between the container and packing material. Also, alteration number be focused on the effects of local inhomogeneities and precipitation which are known to significiantly affect corrosion. Characterization of welds is also mandatory.

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2. Romanoff, M., Underground Corrosion, NBS Circular 579, April 1957.

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4. Logan, H. L. and H. T. Yolken, "The Role of Hydrogen in the Stress Corrosion of Low Carbon Steels." 2nd International Congress on Metallic Corrosion, March 11-15, 1963, p. 109-115.

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ISSUE NO. 2.8

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What is the effect of packing materials on the corrosion mechanisms for the container?

3. Importance of the Issue to Repository Performance

The container's ability to restrict water ingress to the waste form surface depends on its resistance to corrosion failure. Any adverse interaction with packing materials is likely to accelerate uniform and localized corrosion and lead to a reduction in containment time.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§60.113 Performance of particular barriers after permanent closure.

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission produce decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Most research carried out to date on metallic corrosion of container materials involves the exposure of metal samples in prototypic groundwater, i.e., single component testing. The presence of packing material adjacent to the container may adversely affect the rate of corrosion by providing a geometry equivalent to that for crevice corrosion in which local water chemistries may be dramatically altered. In the small volume of water between the container and packing material it is probable that rapid changes in groundwater pH values will occur, possibly leading to accelerated uniform corrosion and pitting and also hydrogen absorption. Complex corrosion product/packing material interactions may occur which again may lead to a poorly defined local repository water chemistry. Radiolysis effects would also be magnified in the restricted volumes of water.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Comprehensive data are needed to characterize container/packing material interactions in order to:

(a) Determine Eh, pH conditions at the container surface and correlate these with long term local and uniform corrosion rates.

(b) Determine chemical changes in the groundwater as a result of corrosion and radiolysis products and correlate these with local and uniform corrosion rates.

(c) Determine of chemical changes in the groundwater as a result of its passage through packing materials and correlate these with local and uniform corrosion rates.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

The test programs described in Table 15-2 of the SCR, viz. Screening and advanced tests on container components with and without packing material being present (Work Element W-1.6.A), directly address the need to determine the possible deleterious effects of packing materials on corrosion failure rates. Eh and pH correlations are a part of this test effort as well as radiation effects.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

The general outline of the interaction tests specified in Table 15-2 appear satisfactory but the completeness and likely needs of the program will depend on the specific types of tests carried out, and the means by which extrapolation of test data to long term behavior prediction is developed.

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Issue No. 2.9

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: How do Eh, pH, and pO_2 change with time in the vicinity of the container and in the packing?

3. Importance of the Issue to Repository Performance

Eh, pH, and dissolved oxygen content of the repository water will largely determine the container life and the radionuclide release rate of the waste package. The corrosion rate of the mild steel container is expected to depend greatly on dissolved oxygen content (RHO-BWI-ST-15, 1982). The stability of the packaging material under hydrothermal conditions may depend upon the pH because the solubilities of component phases are affected by strongly alkaline or acid solutions (BNL-NUREG-31770, 1982). The values of these parameters will change with time following repository closure as the repository temperature changes and as transport processes and controlling chemical reactions proceed. These values are needed in order to simulate tests of waste package behavior in the changing repository environment in the laboratory.

4. Positions of 10 CFR 60 that are Directly Connected to the Issue

§60.113 Performance of particular barrier after permanent closure

(a) General provisions

(1) Engineered barrier system

(i) The engineered barrier system shall designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partical or complete filling with groundwater of all available void spaces in the underground facility occurs. (ii) In satisfying preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that: (A) Containment of HLW within the HLW waste package will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be aproved or specified by the Commission. (b) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be presented at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components.

(a) High-level-waste package design in general.

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Anticipated Eh, pH, and dissolved oxygen contents are presently predicted from studies on basalt-seawater systems, direct laboratory measurements on synthetic groundwater contacted with crushed basalt, measurements on samples of basaltic groundwater and observed stable mineral assemblages (RHO-BWI-ST-7, 1980; PNL-4382, 1982). These data imply that the repository Eh and pH will be controlled by the geochemical properties of the basalt. Strongly reducing anoxic conditions (Eh $\sim$-0.5 eV) are predicted to prevail over most of the repository lifetime. Oxygen introduced during repository emplacement operations is expected to be scavenged following repository closure. pH will initially drop to a minimum value of $\sim$ 6.0 and then rise to $\sim$ 9.6 as the temperature drops (RHO-BWI-ST-7, 1980). Uncertainties associated with Eh and pH predictions include the following: (1) the Eh of repository groundwater is difficult to measure under field conditions (PNL-4382-and NUREG/CR-2780).

Present Eh data from field samples are largely inferred from thermodynamic considerations or observed chemical speciation in redox couples. The application of oxygen buffers such as the QFM (quartz-fayalite-magnetite) buffer to the relatively low temperatures expected after the repository thermal period involves some uncertainty. The application of the Eh calculated from redox couples to specific corrosion reactions involving the canister or to estimation of radionuclide solubilities relies on the untested assumption that chemical equilibrium exists between a large number of aqueous species and solid phases. (2) The present data base on O_2 scavenging kinetics in basalt-water systems is limited. Detailed information is not available on surface area and/or surface alteration effects which may limit uptake rates. Initially, it was estimated that several hundred years might be required to achieve equilibrium redox conditions following repository closure (RHO-BWI-ST-7). Recently, these estimates have been substantially reduced to several hundred hours, according to information presented in the SCR (p. 15.3-19). (3) It is not yet clear how well "bulk" Eh and pH determinations carried out at high water to rock ratios reflect local conditions at the interface between packing and a (possibly corroding) container. (4) Recent experiments to investigate the geochemical reactions between groundwater and packing components were largely carried out under accelerated conditions in a static environment. Additional information is needed to relate accelerated hydrothermal test results to anticipated reactions and reaction rates in the repository environment.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

The reaction kinetics of oxygen scavenging should be determined and confirmed under actual field conditions over a range of temperature and groundwater flow. Rate limitations imposed by surface area and/or surface alteration of the basalt should be clearly defined. Analytical techniques used to predict "steady state" Eh conditions should be confirmed. The application of the quartz-fayalite-magnetite and hematite-magnetite buffers to low temperature systems should be justified more completely on kinetic or experimental bases. Additional experimental calibrations of the quartz-pyroxene-magnetite and the magnetite-pyrite-sulfate buffers over the temperature range expected in the waste package are needed. Oxygen fugacities should be calculated from actual mineral compositions observed at the repository horizons. The degree of correspondence between "bulk" solution properties and those local properties very near the packing-container interface should be established. This should include consideration of solution radiolysis effects (see Issue No. 2.10). It should be confirmed that the dominant reactions in accelerated hydrothermal tests will also be rate controlling in the repository environment over a range of flow rates and temperatures.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

The BWIP program includes plans to model the Eh and pH of groundwater that will prevail in candidate repository horizons before the engineered facility is constructed and during the period of geologic control after repository closure. In Work Element W.1.5.A the nature of the geochemical interactions between basalt and groundwater which control the Eh and pH will be determined. The kinetics and temperature dependence of the dominant mechanisms will be studied. The geochemical model which is formulated in this work element will be validated against field measurements obtained in W.2.10.C. In the latter work element, the Eh of groundwater in candidate repository horizons will be measured in-situ by potentiometric methods, and by dissolved redox couples and indicator dyes.

The Eh and pH of possible solutions in the waste package during the thermal period will be estimated from studies carried out in Work Elements W.1.12.A, W.1.3.A and W.1.2.A. In the first work element, the chemistry of solutions produced by hydrothermal reactions between basaltic groundwater, waste form, host rock, the canister and packing materials will be studied. The rate of influx of water into the waste package will be estimated in Work Element W.1.2.A. The effect of both external and internal radiation fields on the oxidation potential of the groundwater will be inferred from radiolysis and corrosion studies to be carried out in W.1.3.A. In Work Element W.3.2.A, thermodynamic and kinetic arguments will be formulated to justify the extrapolation of the results of short-term hydrothermal laboratory parameters to predictions of long-term repository performance.

In Work Element W.1.14.B, BWIP staff members will determine the type of chemically-tailored packing that will be required to poise the Eh and pH of the waste package environment at levels which will insure the strong retardation of radionuclides. Methods to measure in-situ Eh and pH during laboratory hydrothermal experiments will be developed. These techniques will be used to obtain measurements of oxygen consumption rates in experimental systems as functions of temperature, pressure, surface area and water: rock ratio.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success

The BWIP program contains plans to measure the Eh of groundwaters in contact with the waste package by a number of different techniques. There is no assurance that redox equilibria will exist between all aqueous species; the BWIP approach does not place undue reliance on any single redox couple. The projects listed in (7) are directed toward obtaining a portion of the information needed to resolve Issue 2.9. The planned approaches for these projects, however, are not described and referenced in the Site Characterization Report in sufficient detail to allow a meaningful critique. For example, on p. 15.3-3 of the SCR, Work Element W.1.5.A is concerned with in-situ drill hole data and preliminary experimental data (including some time-dependent pH data) from autoclave tests; there are, however, no references to the planned approaches to investigations of time-dependent compositional data. Mention is made (on p. 15.3-19) of indirect Eh measurements by oxygen depletion which indicate Eh control within several hundred hours by basalt at 200°C, but no source of more detailed information is given. It is difficult to assess if BWIP plans to obtain reliable in-situ potentiometric measurements of Eh of groundwaters of candidate repository horizons will be successful. These plans are dependent upon the successful development of new equipment. Current techniques produce results that are very hard to interpret; in addition, currently available instruments allow Eh determination in shallow holes or in surface waters but not at great depths.

The degree of correspondence between Eh and pH of bulk solutions and those occurring at the interface between packing and container is not addressed in the BWIP plans. The differences between "bulk" and local equilibria in heterogeneous systems will be important in both experimental and natural systems.

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3. PNL-4382, "Overview of Hydrothermal Testing of Waste Package Barrier Materials at the Basalt Waste Isolation Project," M. J. Apted, Chapter 6.2 in Workshop on the Leaching Mechanisms of Nuclear Waste Forms - Summary Report, J. E. Mendel, Ed., August 1982.

4. RHO-BWI-ST-7, "Engineered Barrier Development for a Nuclear Waste Repository in Basalt: An Integration of Current Knowledge," M. J. Smith, Rockwell Hanford Operations, May 1980.

5. NUREG/CR-2780, Part 1, BNL-NUREG-51548, "Near-Field Repository Conditions in Basalt and Salt," B. Siskind and D. Hsieh, Brookhaven National Laboratory, May 1982.

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Issue No. 2.10

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What is the radiolytic generation of hydrogen, oxygen and other species due to gamma radiation in the vicinity of the container.

3. Importance of the Issue to Repository Performance

The chemical durability of the barrier components which retard the progress of water to the waste forms depends sensitively upon the Eh, pH and oxygen content of the water to which these components are exposed. These properties in turn may be affected by gamma radiolysis processes in the groundwater. For example, corrosion rates of the mild steel container could be increased if radiolytic oxidants are generated in sufficient quantity. This issue is directly related to issue No. 2.9 which generally addresses the evolution of Eh, pH and PO_2 in the vicinity of the container and packaging.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.113 Performance of particular barrier after permanent closure

(a) General provisions

(1) Engineered barriersystems

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, asssuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

A substantial amount of information exists on radiolysis effects in pure water. Radiolysis data on rock salt brines is presently available and additional data are being generated. Radiation corrosion data are also available for various reactor applications and are being generated for container/brine systems.

These data have been recently reviewed (Glass, 1981) from the viewpoint of corrosion effects on HLW containers. However, a bounding analysis for conditions relevant to a basalt repository has not been carried out.

Uncertainties in the yields of radiolysis products in basaltic groundwaters under BWIP conditions largely reflect the lack of direct experimental data. As a first approximation one might consider basaltic groundwater as similar to deionized water. However, scavenging or recombination processes peculiar to the particular chemical makeup (including possible corrosion products, etc.) of the system under study might significantly affect this correspondence. It has been postulated (Smith, 1980) that under the strongly reducing conditions anticipated under steady state conditions in the backfill, water radiolysis would be suppressed by recombination process involving dissolved hydrogen. Calculations (Bunns and Moore, 1976) for water radiolysis in a reactor environment indicate that the concentration of radiolytically produced oxidants such as OH and O_2 may be substantially reduced by dissolved hydrogen pressures of ~ 0.01 MPa. On the other hand, when scavengers are present, water radiolysis can proceed far beyond this point. Irradiated brines, for example, may yield H_2 pressures greater than 0.6 MPa. The major uncertainties, then in the radiolysis product yields and levels in the vicinity of the container are associated with (1) the rates at which radiolytic process compete with the geochemical buffering process (2) uptake and loss mechanisms for dissolved hydrogen (3) the effects of possible scavengers and (4) the rate at which oxidizing species are consumed in corrosion.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Information to bound the formation rates (G-values) and steady-state concentration of O_2, H_2 and H_2O_2 will be required. Other radiolysis products which might alter Eh or pH should be identified and their effects bounded. This information should consider the influence of radiation dose rates, temperature and local conditions at the container packing interface. In particulat, the following information should be obtained.

- The effect of dissolved hydrogen concentration on steady state concentration of radiocysis products,

- The rate at which dissolved hydrogen concentrations will change near the container/packing interface due to geochemical radiation and transport processes.

- Indentification of any scavenging mechanisms, including corrosion which would complete with recombination processes for depletion of radiolytic oxidants.

- The possible effects of local inhomogenieties (i.e., cells or crevices, etc.) at the container-backfill interface.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

For an unbreached container, only the corrosion tests under gamma irradiation described in work element W.1.3.A appear to be immediately relevant. Backfill is to be exposed to extermal gamma irradiation in work elements W.1.3.A. It is not clear if the conditions of the backfill experiment will be applicable for assessing radiolysis effects at the container/backfill interface. These experiments appear to be of the scoping type. In the corrosion experiments, hydrothermal tests are to be carried out to determine if radiation affects corrosion rates. If an effect is observed, further measurements will be carried out. Detailed experimental conditions are, however, not stipulated.

Hydrothermal testing expeiments using radioactive waste forms as a radiation source are also described in work element W.1.3.A. In principle, these should display radiation effects within the entire waste package, in the presence of interacting components. It may be difficult, in such a complex system, to extract data on particular radiation effects (i.e., supression of radiolysis by dissolved hydrogen) from these experiments. The extent of interaction between these experiments, and the backfill and corrosion these under extermal irradiation, was not described.

8. Analysis of (7) As To Completeness, Practicality and The Likelihood of of Success

The experiments described in the planned approach do not, in general, appear capable of generating detailed information on the anticipated concentrations of radiolytic species. This is admittedly judgemental, since the plans are not set forth in detail. However, no specific mention is made for directly identifying radiolytic species or determining the kinetic aspects of the radiolysis mechanism (dose rate effects, G-values and steady state concentrations, etc.) Rather the approach is to determine now (if at all) radiation affects a particular process (e.g. corrosion) under a particular set of conditions (e.g. hydrothermal contact with basaltic groundwater at low pH). Subsequent plans will depend on the results of these scoping experiments.

In the absence of a mechanistic study on radiolysis effects themselves, a major concern with the present approach is how well the planned experiments reflect worst case or bounding conditions. This topic is not discussed in the test plans; indeed, some mechanistic consideration might be necessary to define such conditions. For example, if a locally reducing environment and/or a high hydrogen fugacity is postulated to be important in suppressing radiolysis effects, then scoping tests should reflect the manner and extent to which such conditions may be established in the repository environment. Tests where the geochemical reactions are accelerated or the hydrogen artificially contained may mask the significance of radiolysis effects.

References

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Issue No. 2.11

1. <u>Name of the Site</u>: BWIP - Hanford, Washington

2. <u>Statement of the Issue</u>: What is the dependence of the oxygen removal rate from packing material upon temperature, pressure, radiolysis, packing materials physical characteristics, groundwater flow rates, composition, and time?

3. <u>Importance of the Issue to Repository Performance</u>

Eh is a key factor in the performance of the packing, container, and waste form. The rate of change of Eh values within the waste package following repository closure is said to be dominated by oxygen scavenging in the packing material following resaturation. The rate at which this oxygen scavenging occurs is broadly relevant to all issues concerning the geochemical environment of the packing, container, and waste form (see issues 2.9, 2.10 and 2.18). The ability of the packing material to provide a low Eh environment must be known over a range of external variables, both to establish anticipated behavior and to determine operating limits for waste package performance.

4. <u>Portions of 10 CFR 60 That Are Directly Connected To The Issue</u>

§ 60.113 Performance of particular barriers after permanent closure

(a) General provision.
(1) <u>Engineered barrier system</u>.

(i) The engineered barrier system shall be design so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractuinal releases to the geologic setting over ling time. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be desinged, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in lthe underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components.

(a) <u>High-level-Waste package design in general</u>.

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Oxygen uptake in the packing is expected to result largely from oxidation reactions involving iron-bearing minerals in the crushed basalt component. Evidence for strongly reducing conditions in basaltic groundwaters has been discussed in conjunction with issue 2.9. Equilibrium Eh properties have been described in terms of the oxidation of Fe_2SiO_4 to Fe_3O_4 + SiO_2 (RHO-BWI-ST-7, 1980). According to recent information, species such as $FeSiO_3$ may also participate in the oxygen scavenging mechanisms in an apparently amorphous reaction zone.

Thermodynamic data are available for the Fe_2SiO_4 - Fe_3O_4 - SiO_2 system. Uncertainties in using these data to predict equilibrium Eh conditions in the repository have been referred to in Issue 2.10. Further uncertainties exist regarding the rate at which oxygen removal will occur following repository closure. These uncertainties fall into two classes.

First, it remains to be established that the particular reactions proposed will be rate-limiting in removing oxygen from the packing under repository conditions. Other reactions may occur in the backfill, such as alteration of the bentonite component (Wood, M. I., 1982) under hydrothermal conditions or corrosion at the container-packing interface. The relative importance of these reactions in determining local oxygen depletion rates (including synergistic interactions with the crushed basalt) should be determined.

Second, the available kinetic data on oxygen scavenging by crushed basalt are quite limited. Before laboratory data obtained under accelerated test conditions can be used to project oxygen scavenging rates in the packing under repository conditions, two types of information are required:

1. Information on the fundamental rate constants which describe the oxygen scavenging reaction(s), in the vapor and liquid phases. This should describe the effects of external variables such as temperature, pH, and pressure.

2. Information on the effect of "process parameters," such as water-to-rock ratio, surface-to-volume ratio, repository flow rate and radiolysis effects (see Issue No. 2.10) on the extent to which the scavenging reactions operate. In particular, it should be established how oxygen scavenging rates will be affected as reaction products accumulate on material surfaces.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

The basic licensing data required are concerned with establishing which components of the packing material, including any alteration products, control oxygen levels in the packing material/water system barriers. Current thermodynamic data indicate which reactions are important in depleting the oxygen level but the rates are not known. Because of this it is not currently possible to accurately estimate the rate at which the repository reverts to an equilibrium condition after closure. Of particular importance is the effect of gamma radiolysis on oxygen generation rates. Information will be required to determine if radiolytic oxygen is present in sufficient amounts to prevent the repository from quickly reaching an anoxic state after closure.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

BWIP Waste Elements W.1.2.A, W.1.3.A and W.1.5.A basically address local environmental conditions in the waste package components, including the bentonite/basalt packing. Water composition and Eh/pH conditions will be measured for pristine basalt coditions using drill hole techniques and hydrothermal conditions will be simulated with autoclave system. Local changes caused by gamma irradiation will be included in Work Element W.1.3.A. Since the rate of oxygen removal from packing material may be a slow process, very long term autoclave tests are likely to be required for prototypic conditions of temperatures, irradiations, and water flow rates. A series of tests under accelerating test conditions will be needed to supplement the data produced for realistic repository conditions.

8. Analysis of (7) As To Completeness, Practicality and The Likelihood of of Success

The three Work Elements described in (7) above are broad in scope and can encompass potential licensing data needs. However, the BWIP programs should be monitored by NRC to ensure that the required level of detail is appropriate.

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Issue No. 2.12

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: How do microbes affect conditions controlling corrosion modes? What effect do microbes have on the conditions affecting transport?

3. Importance of the Issue to Repository Performance

Corrosion of the container is expected to be a critical consideration in determining how water will penetrate the waste package. It has been recognized for some time (Shrier, 1976) that the corrosion rates of metals, and in particular iron, can be enhanced by microbial activity under certain conditions. Microbial activity may also affect pH and redox environments. If these effects were to occur under repository conditions radionuclide transport properties in the packing material could be modified. This would affect the manner in which radionuclides are released from the waste package.

Microbial activity in a deep geologic repository has not been extensively studied. Under anticipated repository conditions, one might anticipate that microbial effects would be relatively limited. A bounding analysis, however, is necessary to establish the extent and significance of microbial effects on conditions within the waste package.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113 Performance of particular barriers after permanent closure.

(a) General provisions.

(1) Engineered barrier system.

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (b) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional release to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release of any radionuclide from the engineered barrier system follows the containment period shall not exceed one part in 100,000 per year of the inventory of the radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components.

(a) <u>High-level-waste package design in general</u>.

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Microbial effects on corrosion have been studied for some time in connection with behavior of pipes, and other objects, buried in soils. Corrosion may be enhanced either through this action of microbial metabolic products, such as sulfuric acid or sulfides, cathodic deploarization associated with anaerobic growth, or local changes in solution chemistry which establish electrochemical cells (Shrier, 1976). It has been estimated that bacterial activity may account for as much as 50% of the failures of structures buried in soils. Perhaps the most important effects in this respect are associated with the actions of bacteria on sulfur-containing compounds. Under aerobic conditions, <u>Thiobacillus thio-oxidans</u> may produce sulfuric acid by direct oxidation of sulfur; Ferrobacillus (or Thiobacillus) <u>ferro-oxidans</u> may oxidize the ferrous ions in FeS_2 producing acidic waters. It is noteworthly that the thiobacillus attacks the iron directly (Alexander, 1977). Other sulfate reducing species such as Desulfurvibra Resulfuricans may produce corrosions of iron under anaerobic conditions both by generating the corrosive species H_2S, and possibly by a mechanism involving cathodic depolarization. Acid species produced will decrease the local pH; Eh values will also be affected by microbial redox behavior. Anaerobic microbes, for example may reduce the Eh value of a soil from 0.4 to - 0.1 V within one month after flooding (Spencer, et al., 1963).

In the present context, the major uncertainty in assessing microbial effects lies in estimating the effect of repository conditions on microbial activity. The waste package represents a hostile environment for microbes - temperatures in excess of 100°C coupled with a relatively intense ionizing radiation field would appear to provide an initially sterile atomsphere, although this must be established. It seems most plausible that microbial activity in the waste package could begin if microbes are transported to its vicinity toward the end of the thermal period (several hundred years after closure). It remains to be established if this is a viable scenario, and how well the available nutrients (in particular carbon) would support an anaerobic microbe population. Microbial activity has proved troublesome in gold and coal mining operations. On the other hand, Belgian workers (Dresselaers, 1982) examining long term (60-90 years) corrosion of cast iron structures in underground coal mines were unable to find any evidence of Thiobacillus, ferro-oxidans, or Desulfurvibro Desulfuricans. Possibly, some preventative measures were taken. In any event, it is difficult to generalize about microbial activity, and site-specific evaluations are needed.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

Owing to the uncertainty regarding deleterious bacterial action on container corrosion, assessments will be required to scope the problem. The most important data required would be a determination of the likelihood that corrosion causing bacteria can survive at container temperatures up to 250-300°C in the presence of intense gamma irradiation. If they are destroyed by this environment, then bacterial migration to the container followed by bacterial corrosion can only occur at some time after the temperature and radioation levels have decayed to low levels. In this case the possible transport of bacteria by groundwater flow should be studied.

Champion (1964) briefly outlines procedures which have been used to evaluate bacteria-induced corrosion. These involve techniques in which selected organisms have been maintained in culture media under anaerobic conditions. Simular studies could be used to first establish colonies of bacteria under prototypic groundwater compositions and then subject them to anticipated hydrothermal and gamma irradiation coditions. If the bacteria are destroyed then further studies on container corrosion will be unnecessary unless new populations of bacteria can be transported to the waste package after the thermal period. If the bacteria survive then their impact on corrosion could be estimated using laboratory corrosion cells similar to those described by Uhlig (1951) or later derivatives.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Bacterial corrosion of the container system is not specifically addressed in the SCR.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

This section is not applicable in the absence of a well-defined bacterial corrosion study by BWIP.

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ISSUE NO. 2.13

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What is the solubility of radionuclides vs. time in the vicinity of the waste form and packing materials? How are the radionuclides released from the waste form?

3. Importance of the Issue to Repository Performance:

Radionuclides released into a volume of water adjacent to the waste form will be partitioned among aqueous species, radiocolloids and pseudocolloids. The concentrations of each of the components at any time is related to the physicochemical environment and degradation modes of the waste form. The mass flux of radionuclides from the waste package to the near field environment can be no larger than the product of the radionuclide concentration (including aqueous species and other forms) times the volumetric flux of water through the waste package. The relationship of radionuclide solubilities and waste form degradation modes to time dependent parameters such as temperature, redox potential and pH must be known before the release rate of radionuclides from the waste package can be predicted.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

§ 60.113 Performance of particular barriers after permanent closure

(a) General provisions

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground faiclity occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system followng the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components.

(a) High-level-waste package design in general

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility of the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties:

The solubilities of radionuclides and the durability of waste forms over a wide range of physico-chemical conditions must be understood in order to predict radionuclide release rates during the regulatory period. As discussed in Issues No. 2.3 and 2.9 during the containment period, the immediate surroundings of the waste form may change from a high temperature, acidic, oxidizing environment to a cooler, alkaline, reducing one. The properties of a glass waste form may change due to devitrification and radiation damage (Issue No. 2.14).

At present it is not possible to predict the solubilities of radionuclides at elevated temperatures (200-300°C) with any confidence. Most of the available radionuclide stability complexation constants have been obtained at temperatures below 50°C (Apps, J.A.). Experimental determinations of solubilities of waste form components at higher temperatures have shown that it is difficult to assign solubilities to waste elements at the present time (Fullam, H. T.). It may not be possible to determine the temperature dependence of radionuclide solubilities without a large number of solubility measurements at several temperatures (Apps, J. A.). Based on theoretical calculations and a limited amount of experimental data, it has been suggested that some of actinides and rare earths in the waste form may exhibit a negative temperature coefficient of solubility (Ogard, A.; Lemire, R.).

Waste elements which can have several oxidation states may exhibit Eh-dependent solubilities. Experimental studies at low temperatures (25°C) suggest that the solubilities of uranium, neptunium, technetium and selenium under oxidizing conditions are several orders of magnitude higher than they are under reducing conditions (Wood, B. J.). In simple glass-water systems, other multivalent elements such as plutonium and americium have solubilities which are insensitive over the Eh range relevant to waste repositories in basalt (Wood, B. J.). The solubilities of monovalent waste elements may be independent of Eh; however, if the element forms complexes with ligands whose concentration are Eh-dependent (e.g., SO_4^{2}/HS^-), then the solubility may depend on the redox potential.

The solubilities of elements which form aqueous hydroxyl complexes or solid oxides and hydroxides (e.g., $Sb(OH)_3^\circ$, $Sn(OH)_4^\circ$, $U(OH)_5^-$, $UO_2(OH)_2$, $Pu(OH)_4(am)$, $Am(OH)_2^+$ may exhibit a complicated dependence upon solution pH (Apps, J. A.).

The leaching behavior of glass is also dependent upon a large number of environmental parameters. These include temperature, Eh, pH, radiation damage (Northrup, C.), thermal history of the glass and solution (Clark, D. E.; Fullam, H. T.), solution composition (Stone, I.), and the surface area to volume ratio of the glass-water system. All of these parameters will vary during the regulatory period. The deposition of a surface film of insoluble oxides and hydroxides or the formation of a leached layer on the waste form will reduce the leach rate (Lanza, F.). Leachability generally increases at higher temperatures and can be related to the Arrhenius equation (Westsik, 1981). The actual temperature relationship, however is, element specific and depends upon the solution chemistry and occurrence of secondary hydrothermal reactions (Westsik, 1980; Stone, J.). Spent fuel leaching is less dependent on temperature and may show a negative temperatue dependence (McVay, G. L.).

In an open system, where waste elements are flushed from the waste package by rapidly flowing groundwater, the leach rate and fluid velocity will determine the radionuclide release rate. Under stagnant conditions, where the products of leaching accumulate in the leachant, radionuclide solubilities and diffusion rates will control the release rate.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>:

As increased understanding of radionuclide complexation must be obtained for the most toxic elements at high temperatures. Formation constants and free energy data should be obtained for radionuclide complexes at elevated temperatures under the range of redox potentials and radiation fields relevant to the rpository. Both the aqueous species and solid phases that control the solubility of the waste elements under these conditions should be identified.

A basic understanding of the mechanisms of waste-water interactions should be obtained from simple systems. Leaching studies should be carried out under repository conditions wih "aged," devitrified glass as well as fresh glass. Tracer and fully-loaded waste forms should be leached in solutions whose compositions approximate those expected within the waste package. The concentrations of the radionuclides, and not just the major glass components in the reaction solutions, should be measured in these experiments. The stability of leached layers which form during glass dissolution should be evaluated.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>:

Work Element W.1.4.A involves the determination of solubilities kinetic behavior and speciation of key radionuclides which might be released from the waste package. Aqueous species and solid phases which control the steady-state concentrations of radionuclides will be identified under the temperature and redox ranges expected for the repository. Hydrothermal tests with non-radioactive analog waste forms as well as hot-cell autoclave tests are planned (Work Elements W.1.3.A, W.3.7.). The importance of the formation of colloids or mobile complexes of waste elements will be investigated under environmental (radiation, temperature, pressure, redox, ligand concentrations) conditions relevant to the BWIP repository

(Work Element W.1.10.A.). The extrapolation of data from short-term experiments to long-term prediction will be done only after the appropriate thermodynamic and kinetic arguments can be formulated. Tests will be accelerated by increasing the flow rate in flow-through hydrothermal autoclaves. The range of flow rates over which steady-state results are applicable to long-term performance assessment will be determined (W.3.2.A.). The potential of waste package solutions to reach and maintain radionuclide supersaturation for long periods of time will be examined in detail (Waste Element W.1.4.A.).

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

The research objectives described in the Work Elements discussed above are fairly complete. The actual steps that will be undertaken to achieve these goals are not described in enough detail to allow a critique. Several important topics are mentioned as being important, but no systematic approaches to address these problems are described. These include: (1) investigations of the limitations of the reliance on solubility constraints to characterize radionuclide transport (i.e., persistence of supersaturation), (2) determination of the relevant time scales for processes occurring in accelerated laboratory tests and the repository (i.e., expected lifetimes of metastable phases in the laboratory compared to those in the repository), and (3) the ability to introduce radionuclides at the start of solubility experiments in chemical forms that are relevant to the repository system (i.e., as the products of waste form dissolution; cf. Appendix R, section 2.4.3.2).

The dependence of the solubility determinations and leach rate studies upon the SA/V ratio (surface area/solution volume) of the glass-water system was not addressed in the plans. It may be impossible to characterize the solution phase under the high SA/V ratios that would probably prevail in the repository. The effect of radiation on the leaching properties of aged, partially devitrified waste glass was not discussed in the plans.

BWIP researchers place considerable reliance upon solubility as a barrier to radionuclide release. Although the final equilibrium solubilities in the glass-water-nuclide system are independent of reaction paths, the radionuclide release during the time period through which phase changes take place may be significant. The actual reaction paths of the system and their dependences on changes in the environmental parameters should be investigated unless it can be shown that this effect is not important.

The potential formation of pseudocolloids by adsorption of radionuclides onto ferrosilicate colloids (McVay, G.) or degradation of a radionuclide enriched gel layer on the surface of the waste form (Avogadro, A.; Trocellier, P.; Malow, G.) was not addressed in the project plans. Such colloids may transport a non-trivial fraction of the waste in accident scenarios in which the packing material and canister are breached and the waste form comes into contact with a large flux of water (cf. Appendix R, section 2.2.4).

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Issue No. 2.14

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What properties of the waste form change with time and alter the ability of the waste form to contribute to the overall performance of the repository system or impact on the performance of other barrier materials and properties of the site?

3. Importance of the Issue to Repository Performance

The solidified waste form is the source term for release of radionuclides to the rest of the repository system and subsequently to the biosphere.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(a) General provisions.

(1) Engineered barrier system.

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional release to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in the uncertainties in assessing repository performance are large, special emphasis is placed upon the ability to contain to wastes by waste packages within an engineered barrier system. This is known as the containment period. The engineered barrier system includes the waste packages and the underground facility. A waste package is composed of the waste form and any containers, shielding, packing, and absorbent materials immediately surrounding an individual waste container. The underground facility means the underground structure, including openings and backfill materials, but excluding, shafts, boreholes, and their seals.

Following the containment period special emphasis is placed upon the ability to achieve isolation of the wastes by virtue of the characteristics of the geologic repository. The engineered barrier system works to control the release of radioactive material to the geologic setting and the geologic setting works to control the release of radioactive material to the accessible environment. Isolation means the act of inhibiting the transport of radioactive material to the accessible environment in amounts and concentrations within limits.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Properties of the waste form will impact on the underground facility, particularly the groundwater. Vitrified radioactive waste and spent fuel will cause both thermal and radiation induced changes in the groundwater. Since the packing material performance, the corrosion behavior of the container(s) and the leaching of the waste form itself are all dependent on the water pH, Eh, and chemical composition, the changes in these properties induced by the presence of the waste should be addressed. (It should be noted that by simply increasing the temperature of the medium, leaching can be increased orders of magnitude and corrosion rates will also be enhanced.) The effects of the water environment will alter the time of containment and the rate of radionuclide release.

In addition, the waste form may undergo changes with time that affect the rate at which radionuclides are released. Devitrification (Hench, 1982) phase separation as well as changes in the glass induced by fission product decay may alter the leach properties of the glass. Recently it has been suggested that the phase separation resulting from isothermal devitrification of the glass may result in as much as a factor of 140 increase in the leach rates of glass (Hench, 1982). Decay of the fission products will produce compositional changes in the glass, the magnitude of which will depend on waste composition.

There is also evidence that surface film formation on SRP glass results in a more durable waste form (Wicks, 1982). The film which is rich in Fe and Mn appears to be protective. In contrast, the presence of iron in the leaching medium (McVay, 1982) has been shown to increase the leach rate of glass. While these results are not directly comparable, the question of surface film formation and the effect of the environment and other package components on the durability of film is an issue that should be addressed if film formation is claimed to enhance the performance of the glass. For spent fuel the effects of aging on its performance have not been determined, nor have the effects of cladding failure and corrosion product buildup.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>

The long term performance of the repository system is affected by the thermal and radiolytic changes in the groundwater caused by the presence of the waste. In addition, the performance of man made barriers and the rate of release of radionuclides from the waste form is affected by the environment. The following information is necessary to resolve these issues:

a. Combined thermal and radiolytic effects on groundwater.

b. The relative magnitude of changes in glass properties, e.g., degree or amount of devitrification/separation to be expected under conditions of a thermal gradient and changing composition.

c. The effect of compositional changes, phase separation and devitrification on film formation as well as the effect of the environment (water composition, Eh, pH, temperature) on film formation.

d. The effects of aging in spent fuel.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

The text of the BWIP SCR (Chapter 11) specifically states that the present data base is inadequate for determining the performance of the waste form (either borosilicate glass or spent fuel) in basalt repository conditions. The problems of devitrification, phase separation, and compositional changes in glass as well as phase change and compositional variability in spent fuel are noted. The potential interaction of the waste form with other barrier materials as a function of temperature radiation and groundwater chemistry (including Eh and pH) are also discussed.

A program is planned to determine the performance of package materials under basalt conditions (W1.1A). The work scoped in this work element has complementary test activities to consider the aspects of radiation and barrier material interactions (W1.6A, 1.12A, and W3.7A). These tests appear to be planned for hydrothermal conditions only.

8. Analysis of (7) As To Completeness, Practicality and The Likelihood of Success

The description given in the work plans is inadequate to insure that the program is complete and likely to succeed in addressing 6(a)-(d). For example, the materials testing plan (W1.1A) appears to be designed to evaluate the performance of the waste form under hydrothermal conditions alone. This assumes that mechanisms of leaching will not change with time and would also infer the potential problems of long term changes in the waste form (phase separation, compositional changes, etc.) are not to be addressed. If containment fails when hydrothermal conditions no longer apply and long term changes in the waste form have occurred, the leach rates or dissolution characteristics determined under hydrothermal conditions may have no similarity to the behavior at later times.

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Issue No. 2.15

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What is the effect of water resident time on release of radionuclides from the waste form?

3. Importance of the Issue to Repository Performance

In modeling rates of release of the various components of solid nuclear waste forms exposed to chemical degradation in aqueous media, a distinction exists between the processes which control the overall degradation rates and transport of material away from the waste form under conditions of short residence times on one hand and of (high flow) long residence times (low flow) on the other. At high rates (or high dilutions) the degradation rates are largely affected by the leaching kinetics of the solid in water, where the composition of the water reflects the conditions prevailing in the environment of the waste package rather than interaction with the waste form. At low flow rates the loss rates depend in part upon the thermodynamic solubility and upon the rate at which the water in contact with the solid (which has been considerably modified as a result of dissolution of species from the waste form) is replaced with fresh, unreacted water. Under repository conditions, water exchange rates are likely to be low in a large number of cases, and therefore solubilities consitutes a key factor in determining the long-term durability of the material.

As mentioned above, water subjected to prolonged interaction with the material becomes substantially altered. This alteration of the composition affects the reactivity of the medium with respect to the dissolution of a particular species from the waste form in the following ways: (1) pH changes, e.g., increase in pH due to dissolution of alkaline components from the solid, cause large effects on solubility limits as well as on leach retes; (2) increasing concentration levels on species of interest may result in approaching saturation in the case of nearly insoluble species; (3) increasing concentrations of other degradation products can affect subsequent dissolution of the species of interest due to secondary interactions; (4) increasing solute concentrations in the aqueous phase can give rise to phenomona such as re-adsorption, ion-exchange and other modifications of the solid-liquid interface which affect further material transport processes across the surface; (5) pH changes as discussed in (1) above may influence formation of complex ions, for example, carbonate oxilate, sulfonate and ferro-silicate complexes, and colloidal particles which in turn pick up radionuclides and effect their mobilization (Macedo, Avogadro). All of these processes affect transport of radionuclides in the engineered barrier system and hence rates at which they will be released from the system.

For an engineered system design which does not include barriers which impede radionuclide transport or provide sorptive properties, the release rate from the waste form would determine the engineered system performance. For engineered systems with multiple barriers controlling release, the waste form release rates will greatly affect the reliability of the overall system performance.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113 Performance of particular barriers after permanent closure

§ 60.135(a) Requirements for the waste package and its components; waste package design requirements for high level waste

5. Summary of the Present State of Knowledge With Analysis of Uncertainties

General correlations of release rates of radionuclides from borosilicate glass and spent fuel exist for many different conditions. Releases are controlled by diffusion mechanisms for young glass and by dissolution of the glass over the long term. Typical values for dissolution rates range from 10^{-4}g/cm^2-day to 10^{-7}g/cm^2-day depending on water resident times and resulting solution chemistry (BNL-NUREG-51494).

Knowledge of the solution (pH and dominant soluble and colloidal species) chemistry in the multicomponent system, including aged glass, canister corrosion products and packing material where water resident times is a variable, represents a major uncertainty in resolution of this issue.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>

Multicomponent testing of materials utilized in the waste package with conditions controlled, i.e., gamma radiation, temperature and heat flux, must be accomplished to verify anticipatal ranges of the key chemical parameters, Eh and pH, are properly identified complexes and colloidual particles which occur in the multicomponent system must also be accomplished.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>

<u>References</u>:

1. Macedo, P. B., et al.; "Aluminosilicate Saturates As a Solubility Control In Leaching of Nuclear Waste-Form Materials" PNL-4382, Workshop on the Leaching Mechanisms of Nuclear Waste Forms, May 1982.

2. Avogadro, C. N., et al.; "Underground Migration of Long-Lived Radionuclides Leached From A Borosilicate Glass Matrix"; IAEA-SM-257/73, International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides From the Nuclear Fuel Cycle; July 1981.

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Issue No. 2.16

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What are the ranges of residence times of a unit volume of water in contact with a unit area waste form and when do the residence times occur? For spent fuel, how do hulls change the effective residence time?

3. Importance of the Issue to Repository Performance:

In modeling rates of release of the various components of solid nuclear waste forms exposed to chemical degradation in aqueous media, a distinction exists between the processess which control the overall degradation rates and transport of material away from the waste form under conditions of short repository water residence times (high flow) on one hand and of long residence times (low flow) on the other.

At high rates (or high dilutions) the degradation rates are largely affected by the leaching kinetics of the solid in water, where the composition of the water reflects the conditions prevailing in the environment of the waste package rather than interaction with the waste form. At low flow rates the loss rates depend in part upon the solubility of degradation products and upon the rate at which the water in contact with the solid (which has been considerably modified as a result of dissolution of species from the waste form) is replaced whith fresh, unreacted water. Under repository conditions, water exchange rates are likely to be low in a large number of cases, and therefore solubilities constitute a key factor in determining the long-term durability of the material.

As mentioned above, water subjected to prolonged interaction with the material becomes substantially altered. This alteration of the composition affects the reactivity of the medium with respect to the dissolution of a particular species from the waste form in the following ways:

(i) pH changes, e.g., increases in pH due to dissolution of alkaline components from the solid, cause large effects on solubility limits as well as on leach rates;

(ii) increasing concentration levels of species of interest may result in approaching saturation in the case of nearly insoluble species;

(ii) increasing concentrations of other degradation products can affect subsequent dissolution of the species of interest due to secondary interactions;

(iv) increasing solute concentrations in the aqueous phase can give rise to phenomena such as re-adsorption, ion-exchange and other modifications of the solid-liquid interface which affect further material transport processes across the surface

(v) pH changes as discussed in (i) above may influence formation, of complex ions, for examples, carbonate, and ferrosilicate complexes, and colloidal particles. Both complex ions and colloidal particles may in turn pickup radionuclides and effect their mobilization (Macedo, Avogadro).

All of these processes affect transport of radionuclides in the engineered barrier system and, hence rates at which they will be released from the system.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(a) General provision.

(1) Engineered barrier system.

(i) The engineered barrier system shall be design so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be desinged, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from lthe engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components

(a) <u>High-Level Waste package design in general</u>

(1) Packages for HLW shall be designed so lthat the in situ chemical, physical, and nuclear properties of the waste package and its interactions with lthe emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength,

mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

The residence times of water at the waste form are dependent upon the design of the engineered system and the thermal-hydraulic boundary conditions (in particular the hydraulic grandient around the waste package) through time affecting flow in the system. Differential pressures in the engineered system and near field, including those created by temperature will act to drive water from one part of the system to another and to effect mixing within the system. Analytical models are generally available to evaluate systems whose hydraulic characteristics are dominated by diffusion mechanisms or by convection. Uncertainties in material properties, particularly hydraulic conductivity, and the diversity of convective flow paths, for example, cracks in packing materials, holes or fissures in containers and cracks within waste forms, throughout the life of the engineered system, are the major uncertainties in applying hydraulic models. Estimates of residence times for water in engineered barrier system has been based on bounding calculations using hydraulic conductivities for typical packing materials measured in field tests as well as laboratory test (Bolmgren).

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Applicatoin:

Verification of the long term hydraulic conductivity of packing materials, for example, bentonite clay/crushed basalt aggregates, in changing repository conditions is of prime importance. Chemical alterations and changes in mechanical characteristics of the packing are key parameters which will effect hydraulic conductivity (Howard, Bolmgren).

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

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ISSUE NO. 2.17

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: How do the packing (spent fuel hulls if applicable), canister, and container materials and/or their alteration products interact with waste form to cause its alteration and/or effect release of radionuclides?

3. Importance of the Issue to Repository Performance:

Interaction of packing, canister and container materials and/or their alteration products and waste form can affect the mechanisms by which waste form release radionuclides and adversely reduce the overall containment capability of the repository. The time period and the rate at which this interaction take place must be known to evaluate the interaction's overall effect over the long term.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

§ 60.113 Performance of particular barriers after permanent closure

(a) General provisions

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall be exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the uderground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components

(a) High-Level Waste Packing Design in General

(1) Packages for HLW shall be designed so that the in-situ chemical, physical and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste

packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. <u>Summary of the Present State of Knowledge with Analysis of Uncertainties</u>:

Little is known about synergistic effects of waste form leaching and corrosion of its containers. Sorption of metal ions onto glass surfaces are known to reduce the rate of aqueous corrosion of glass including berryllium and zinc (Hudson), calcium (Oka), aluminum (Iler, Dilmore) and lanthanides (Buckwalter and McVay). A recent study on different candidate container materials has provided the following observation (Buckwalter and Pederson): (a) glass leaching in lead container was reduced by more than two orders of magnitude from that measured in teflon, while leaching in aluminum containers was reduced by nearly one order and (b) relatively minor effects on glass leaching were measured in copper, tin, and titanium containers.

Chemisorption of metals on glass was reasoned to be the cause of this reduction in glass leach rate (Buckwalter and Pederson). Ferrous base metals have not been included in the study.

Effects of iron on waste glass leaching was subsequently studied (McVay and Buckwalter). It was reported that the presence of ductile iron in deionized water, tuff, and basalt groundwaters containing PNL 76-68 borosilicate glass cause changes in the leaching characteristics of the glass. Formation of iron silicate precipitates effectively removed many elements from solution. As a result, the basalt and tuff groundwater behaved similar to deionized water. The precipitates also retarded saturation effects. Iron/glass interactions resulted in iron enhancing glass leaching and glass enhancing iron corrosion.

Clay-water has been found to leach glasses up to five time faster than distilled water (Van Iseghem). Although leach rates are found in general in the afore-mentioned studies to saturate after relatively short time periods, transport of the products of leaching/corrosion can sustain leach/corrosion rates close to that by deionized water.

The SCR has specifically stated (in Section 11.2.2.2) the following: (a) that current data are insufficient to show that the waste form can, by itself, meet the proposed NRC (1981) release rate criterion and (b) it is not presently possible to assign partial reponsibility for meeting this criterion to each of the parts of the system.

Present understanding of this issue has been limited to defining broad range design criteria for waste package designs. Site specific information is needed to understand interaction of waste package components to refine these design criteria. (SCR sections 11.1.4, 11.3.2.2 and 11.3.2.3)

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>:

Short of in-situ experiments, leaching experiments must account for synergistic effects between the packing, canister, backfill waste form and/or their alteration product in conditions simulating those in the repository enviornment. To account for long time periods, altered groundwater as well as simulated aged waste forms must be used to reduce the uncertainties of adverse interactions.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>:

General information needs of this issue are discussed in issues W.1.A and W.3.A of the SCR.

<u>Issue W.1.A</u> Does the very near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance?

Issue W.3.A How can very near-field waste/barrier/rock materials interaction data, as measured experimentally, be extrapolated over time to reasonably assure that overall waste package and repository performance meets regulatory criteria?

Approaches to provide these information are explicitely addressed by the following work elements:

- Work Element W.3.1.A Define appropriate statistical techniques so that laboratory and field materials interaction data can be extrapolated over time to provide a reasonable assurance of the long-term performance of the engineered system.

The SCR indicates that performance evaluation tests on barrier materials could be achieved by evaluating laboratory physicochemical parameters to values that acclerate the expected degradation mechanisms. However, these tests are still in the planning stage since no multi-component interaction experiments and analysis have been reported in the SCR.

Quantification of these interactions using simulated waste and using actual waste are discussed in activities 21 and 26 respectively.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

Section 11.3.2.3 of the SCR discusses a general test program for Waste-Barrier-Rock interaction. Quantitative interaction data of multicomponent tests must be collected in the laboratory, extrapolated over time and progressively verified by in situ data as the latter become available.

The SCR discusses in situ experiments but does not give enough details to indicate how extensive such data will be used to ascertain reliability of performance prediction.

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Issue No. 2.18

1. Name of the Site: Basalt Waste Isolation Project (BWIP), Hanford, Washington

2. Statement of the Issue: How do the Eh, pH, and PO_2 change with time in the vicinity of the surface of the waste form?

3. Importance of the Issue to Repository Performance

The manner in which the waste form releases radionuclides (General Issue 4) and the manner in which radionuclides are released from the waste package (General Issue 5) will depend upon pH and redox conditions near the waste form. The dissolution or leaching behavior of the waste form will be sensitive to local pH and Eh conditions (see Issue No. 2.13). If, in fact, radionuclide transport within the waste package is controlled by solubility limitations, the evolution of Eh and pH within the waste package will be of particular importance since solubilities may depend strongly on redox conditions and pH. As pointed out under Issue No. 2.9, these parameters will change with time following repository closure as the repository temperature changes, and as transport processes and controlling chemical reactions proceed. The evolution of eH, pH, and PO_2 within the waste package must be known in order to determine if laboratory tests over a range of quasi-steady conditions can accurately reflect waste package behavior in the changing repository environment.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113 Performance of particular barrier after permanent closure

(a) General provisions
(1) Engineered barrier systems
(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially

complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Information on the anticipated Eh, pH, and disioned oxygen content within the waste package has been discussed in connection with Issue No. 2.9. To the extent that local conditions near the surface of the waste form are controlled by the crushed basalt backfill (Wood, 1982; RNO-BWI-ST-IS-1982) strongly anoxic conditions (Eh ~ -0.5 V) are expected to prevail for most of the repository lifetime. pH values are expected to range from 9 to 6, again assuming that dissociation of silicic acid in the basalt is the rate-controlling process.

Several uncertainties in the determining of the anticipated evolution of Eh and pH within the waste package have been described under Issue No. 2.9. These include (1) a lack of kinetic data to determine the rate at which geochemical reactions in the basalt would change the pH and Eh following repository closure and (2) confirmation that local pH and Eh conditions at the waste form surface will in fact be continued by reactions associated with basalt.

Uncertainties involving the kinetic data on basalt-related reactions have been referred to under Issues No. 2.9 and 2.11. Uncertainties in establishing the dominant mechanisms controlling Eh and pH at the waste form interface have to do with the waste form/groundwater interaction and with radiolysis effects. It has been recognized for some time (NUREG/CR-2333 BNL-NUREG-51458; PNL 4382a) that local chemical conditions may be modified by dissolution of the waste form. A familiar example is the increase in pH when alkaline components are removed from simulated waste glass in leaching experiments. This, however, may be offset by the presence of components such as phosphates, which buffer the leachate. [It is also worth noting that under certain conditions solubilities may be a strong function of pH.] Work is underway (PNL 4382b) in which the reaction between waste glass and basaltic groundwater is being studied under hydrothermal conditions in a static environment. Some data are available (RHO-BW-SA-194 P) on the effect of hydrothermal reactions on the evolution of pH within the systems supercalcine + basalt + water and supercalcine + water. These experiments indicate that the pH values may be affected (substantially lowered) by the presence of fine particles in the coarsely powdered samples. Consequently, it is not yet clear how well experiments on powdered samples reflect conditions near the surface of actual waste forms, which may be more nearly monolithic and in close proximately to container surfaces. Recently, it has been reported (McVay, 1982) that the leaching kinetics of waste glass may be significantly influenced, if not dominated, by the presence of ductile iron in the system.

The effects of irradiation on pH and redox potential continues have been discussed in conjunction with Issue No. 2.10 and 2.26. Briefly, radiolysis may affect both pH and redox behavior (Strickert and Rai, 1982; Nash, et al. 1982), and leaching kinetics for waste glasses (NUREG/CR-2333 Section 5.2.1.2). In general, ionizing radiation tends to increase leaching rates. Depending upon experimental conditions the increase may be substantial on rather modest. Some, but not all, of this affect can apparently be attributed to a pH decrease due to the formation of nitric acid by the radiolysis oxidation of N_2 in the presence of water. Presumably, this effect could also operate in the repository, utilizing atmospheric nitrogen introduced during the repository operating period.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

The significance of waste form - groundwater reactions in determining local pH and Eh conditions should be established for waste forms of interest. In order to provide a basis for extrapolating laboratory results to repository behavior, the degree of acceleration in laboratory experiments should be established. In particular, the kinetics of rate limiting reactions should be determined over a range of temperature and flow conditions. Reaction data obtained with crushed basalt mixtures should be compared to results using monolithic components to establish the significance of size and geometrical effects. These experiments should specifically include conditions simulating those at the waste form-containers interface. Finally, data will be required to establish the importance of radiolysis effects on Eh and redox behavior at repository temperatures and radiation dose rates. This data should produce bounding estimates on factors such as local HNO_3 formation rates and concentrations in repository groundwater contacted with waste form/container materials (see Issues No.2-10 and 2-26).

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

The BWIP Work Elements W.1.2.A and W.1.5.A broadly cover the information needs specified in (5) above. Part of W.1.2.A will involve a study of the chemical environment and the Eh/pH conditions around waste package components after emplacement and closure. In W.1.5.A the problem of defining how the basalt controls water composition and Eh/pH will be addressed. In situ data from drill holes and from autoclave tests will be obtained. Radiation testing will be performed in Work Element W.1.3.A to determine the effects on package component behavior.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

The BWIP Work Element described in (7) are broadly applicable and have the potential to generate necessary licensing data on waste package performance. However, monitoring the progress of the work will be required to ensure that the level of detail in the experimental program is adequate.

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Issue No. 2.19

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What is the production rate of particles and colloids (by or near the waste form) which can hold or transport radionuclides or affect waste form degradation?

3. Importance of the Issue to Repository Performance

Production of particles or colloids which can hold and transport radionuclides or effect waste form performance rank as one of the priority issues in understanding major mechanisms of radionuclide releases from the repository. The production of particles and colloids is not understood well enough to be calculated from basic principles. Nevertheless, it may be a major means of radionuclide release through groundwater transport. If it occurs extensively it can negate results predicted from models assuming solubility limitations.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(a) General provisions.

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional release to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Very little information is known about chemically specific colloidal and particulate formation that may occur near the waste form. These will strongly depend upon the materials used in the waste package and other properties of the repository water. What is known, for instance, of iron oxide and hydroxide colloids, indicates that both leaching of the waste form and sorption and migration of radionuclides are changed in the presence of Fe colloids and particulates.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>

By the time of construction authorization, DOE should have the following information:

(a) materials and design of the waste package

(b) groundwater composition and properties and how they are changed by interaction with the waste package

(c) engineering tests identifying formation and properties of colloids and particulates under expected conditions

(d) analysis and rationale for containment and controlled release mechanisms in the presence of colloids and particulates.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

Work element W1.10A addresses the problem adequately from the point of view of recognizing what variables are important in colloid and particulate formation. The document also states correctly that almost nothing is known.

8. <u>Analysis of (7) As To Completeness, Practicality and The Likelihood of of Success</u>

The plans describing the work to be done are so general as to preclude any quantitative estimate as to their effectiveness. A much more detailed description of the actual work to be done is required in order to estimate the likelihood of success.

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Issue No. 2.20

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: For spent fuel what are the failure mechanisms for hulls and what is their failure rate?

3. Importance of the Issue to Repository Performance

The presence of cladding hulls around fuel pellets will significantly alter the ability of repository water to contact fuel and leach out radionuclides. In order to satisfactorily quantify the source term the type and rate of hull failure will need to be evaluated.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(1) Engineered barrier system

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission produce decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional release to the geologic setting over long times.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Spent fuel waste packages will be subjected to both aqueous corrosion and to lithostatic and hydrostatic stresses which could cause failure of the container and the cladding hulls.

Zircaloy-2 hulls are designed to be resistant to corrosion failure in reactor coolants but these are dissimilar to environments anticipated in a repository. In the latter, filler materials may be interspersed between the fuel elements to act as neutron absorbers and a heat transfer medium. These fillers could cause aggressive local corrosion such as crevice attack which would be enhanced by low pH and radiolysis effects. Little is known about the local water conditions around cladding hulls and the types of corrosion to be expected over long periods of time.

Cladding hulls will also be highly embrittled during reactor operation. Ductilities as low as ten percent in elongation have been measured in spent fuel cladding (Lowry, 1978). Large lithostatic/hydrostatic loads may cause mechanical failure of the container and the cladding, and lead to enhanced radionuclide release.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

To specify the types of corrosion and mechanical failure of hulls the following basic data will be needed:

(a) A detailed specification of the spent fuel package design including materials in the package, temperature history, and local water conditions. Experiments will be required to characterize the corrosion failure processes so that long term estimates of hull failure rates are obtained.

(b) An examination of the magnitude and type of loading that will be exerted on the hulls, and an analysis of the extent and rate of mechanical failure.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

Section 11.1.2.1 of the SCR addresses the aqueous corrosion ressiance of cladding hulls around spent fuel pellets but there does not appear to be a plan by BWIP to credit the cladding with any containment or radionuclide controlled release capability. In fact, data given in Table 11-17 show that for tests at 250°C, under anoxic basalt water corrosion, a corrosion allowance to meet the 1000 year comtainments criterion would require a Zircaloy-2 thickness of between 0.69-3.3 in. This is much larger than the cladding thickness. Therefore, cladding hulls alone will have relatively little containment capability. However, based on the BWIP Work Element No. W.1.6.A. in Table 15-2 it seems that the presence of cladding material will be used in the materials interaction tests to evaluate container integrity under prototypic basalt condition. At this time full details of the characteristics of these tests and paramenters to be measured are not specified.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success:

As stated in (7) above the role of cladding hulls in contributing to radionuclide containment has not been directly addressed by BWIP. However, its influence on the behavior of surrounding barrier materials may be studied in planned interaction tests. The design of these tests, when available, will determine whether a complete design data based is likely to be obtained.

References:

1. NUREG/CR-0981, "Evaluation of Strength and Ductility of Irradiated Zircaloy - Task 5," Lowry, A., 1978.

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ISSUE NO. 2.21

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: What are the transport and retardation processes and how do they affect the flux of radionuclides with time in packing materials?

3. Importance of the Issue to Repository Performance:

The waste package must be designed to contain all radionuclides during the period when thermal effects, related to decay of short-lived nuclides, are most severe. The role of the packing in retarding the movement of radionuclides from the waste form, through the waste package, to the near-field environment is an important element of the waste package design. An understanding of the potential transport and retardation processes is necessary for predictions of the flux of contaminant from the waste package.

4. Portions of 10 CRF 60 That Are Directly Connected To The Issue

§ 60.113 Performance of particulat barriers after permanent closure.

(a) General provisions.
(1) Engineered barrier system.

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) contaiment of HLW will be substantially complete during the period whren radiation and theremal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractuioal release to the geologic setting over long time. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated process and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release of any radionuclide from the engineered barrier system follows the containment period shall not exceed one part in 100,000 per year of the inventory of the radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this required does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release limit shall be taken to be one part in 1000,000 per year of the inventory of radioactive waste, originally emplaced in thel underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Crtieria for the waste package and its components.

(a) <u>High-level-waste package design in general</u>.

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching fire

and explosion hazards, thermal loads, and synergistic interactions. Agency with respect to both anticipated processes and events and unanticipated processes and events.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties:

The potential mechanisms for radionuclide migration through the packing material are: (1) transport of aqueous species and colloids through pores and channels in the packing material (2) Fickian diffusion and (3) thermodiffusion (Soret effect). Migration can be retarded by processes such as reversible sorption, chemical substitution in secondary phases, precipitation and ultrafiltration. Convective fluid flow through the packing material is described in Issue No. 2.3. Radionuclide solubility and the production of colloids are discussed in Issues No. 2.13 and 2.19, respectively. The uptake of radionuclides in basalt alteration products is discussed in Issue No. 2.22. In this issue diffusion and sorption in the packing material will be addressed.

Fickian diffusion of radionuclides in bentonite and bentonite-quartz mixtures has been studied in several investigations. When the hydraulic gradient across the packing material is very low, diffussion is the dominant transport mechanism. Isotopes of strontium, radium, thorium, neptunium, plutonium and americium could be retained for more than 1000 years or until they decay to relatively harmless levels in a 1 meter thickness of 100% compacted bentonite or bentonite/quartz mixture (Smith, M. J.; Neretnieks, I.). Attempts to measure diffusion coefficients of radionuclides in candidate packing materials have met with limited success (Apps. J. A., Torstenfelt, B.). Many of the measured values appear to be compromised by irreversible sorption or precipitation. Based on a review of data collected before 1982, Apps (1982) suggested that a range of bulk sediment diffusion coefficients of 1×10^{-6} to 5×10^{-6} cm^2/sec was reasonable for modeling purposes.

Thermodiffusion (Soret effect) is a process whereby chemical species migrate down a thermal gradient. Large diffusive fluxes of sodium, magnesium and chloride have been observed in heat transfer and thermal gradient experiments involving pelagic clays, simulated waste glass and sea water (Thornton, C.).

Thermodiffusion of radionuclides across the packing may be important in mined geologic repositories. The importance of the effect must be evaluated on an element-specific basis for various times during the repository history (cf. Appendix R).

Sorption of radionuclides by packing material components (bentonite, basalt) will retard the migration of contaminants. Data have been obtained at several redox potentials and temperatures (Salter, P. F.; Westsik, J. H.; Smith, M. J.). In general, radionuclides which occur predominantly as anionic (I^-, TcO_4^-, SeO_3^{2-}), or neutral ($NpO_2HCO_3^0$, $UO_2CO_3^0$) species will be poorly sorbed by crushed basalt in the packing. Cationic species (SR^+, Cs^+) or easily hydrolyzable (Am, Pu) species are strongly sorbed at room temperature. The sorption behavior of Np, I, and Tc on basalt was found to be independent of temperature over the range of 23°C to 300°C. The sorption behavior of several elements (Cs, Sr, Ra) at high temperature is hard to assess because they may precipitate or be incorporated into hydrothermal secondary alteration products (cf. Issue No. 2.22). The temperature dependence of the sorption behavior of selenium, plutonium and americium is complex and poorly understood. The sorption ratio (Rd) of uranium in basalt systems increases with temperature over the range of 23°C to 300°C.

Isotopes of cesium and americium are strongly sorbed (Rd $>$ 1000 ml/gm) on smectite (bentonite). Uranium, radium and neptunium are weakly (Rd $\leqq$ 10) sorbed, whereas iodine, technetium and selenium are very weakly sorbed (Rd = 0-10 ml/gm). The reported behavior of plutonium varied from strong to moderate sorption on smectite (Salter, P. F.; Smith, M. J.). In general, the sorption behavior of radionuclides in basalt-bentonite-water systems also depends on solution composition.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Calculations of radionuclide retention times and release rates for the thermal period of the repsitory lifetime are often based on data which were collected under experimental conditions which are not representative of the expected physico-chemical environment of the waste package. Reliable extrapolations to actual repository conditions cannot be made without a firm theoretical understanding of the chemical processes responsible for the effects observed in the laboratory. Values of diffusion coefficients, radioelement retardation factors and the interstitial fluid velocity are important to prediction of radionuclide transport rates in the packing. Radionuclide distribution coefficients (Rd or Kd), the hydraulic conductivity of the packing material and molecular diffusion coefficients are used to calculate these parameters.

It is important to obtain accurate values of these constants under realistic conditions. To obtain this information, accurate estimates of the time required to resaturate the packing material should be obtained. Experimental determinations of radionuclide distribution coefficients should be made under realistic redox conditions and temperatures with radionuclide concentrations and species expected from degradation for the waste form. An evaluation of the potential importance of the Soret effect for radionuclide release from the waste package should be made. The fraction of radionuclides that may be transported as colloids or pseudocolloids should be assessed in the presence of waste form, canister and packing material.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

In Work Element W.1.16.B, BWIP researchers will study the thermal stability of the packing and the sorption and precipitation of radionuclides in this material. Hydrothermal rocking autoclave experiments will be conducted using radionuclide concentrations, redox conditions, temperatures, groundwaters and backfill (packing) materials appropriate for the BWIP site. Flow-through experiments at 65°-150°C using synthetic basaltic groundwater will be conducted to determine radionuclide transport rates through the packing. Hydrothermal interaction studies at higher temperatures (100°C to 300°C) and in radiation fields will also be carried out (W.1.12.A., W.1.3.A).

In Work Element W.2.4.A, BWIP staff members will determine sorption isotherms, kinetic behavior and the reversibility of sorption reactions for key radionuclides. These studies will be carried out under physico-chemical conditions expected in the near-field and far-field of the repository. The effect of complexing ligands on sorption behavior will be studied. Dynamic (flow-through) sorption experiments will be carried out to test the validity of batch sorption results and to assess the importance of particulate transport. The basic understanding of interactions between radionuclides and geologic materials gained in these studies will provide insights into the potential behavior of radionuclides within the waste package. Data concerning the solubility and speciation of radionuclides under expected repository conditions will be obtained in Work Element W.1.4.A.

Measurements of the hydraulic conductivities, swelling pressures and mechanical strengths of various basalt/benetonite mixtures as a function of temperature and density are planned in Work Element W.1.15.B.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of of Success</u>:

The commitment of the BWIP staff to make accurate determinations of radionuclide distribution coefficients (sorption ratios) and hydraulic conductivities of candidate backfill mixtures is clearly stated in the SCR. Other important objectives such as measurement of radionuclide release rates from experimental waste package systems and assessment of the importance of particulate transport are also described. The methods which will be used to achieve these goals, however, are not described in sufficient detail. Experimental procedures to obtain some of these data have been described in earlier BWIP publications; however, as described in Appendix R of the SCA, many of these measurements failed to produce interpretable results. Descriptions of the planned modifications to these earlier experiments are required by NRC personnel before the BWIP plans can be evaluated.

Several information needs described in (6) are not addressed sufficiently in the BWIP plans. These are: (1) determination of molecular diffusion coefficients of radionuclides at temperatures, pressures and with solution compositions expected in the waste package; (2) evaluation of the potential importance of thermo-diffusion (Soret effect) through the packing material; (3) measurement of Soret coefficients of radionuclides if it appears that this effect is important; and (4) estimation of rehydration rates of bentonite/basalt packing materials. The importance of the above information is described in Appendix R.

References:

1. Apps, J. A. and others, "Status of Geochemical Problems Relating to the Burial of High-Level Radioactive Waste, 1981," Draft Report, August, 1982, prepared for NRC by Lawrence Berkeley Laboratory, August, 1982.

2. Barney, G. S., Rockwell Hanford Operations, "The Kinetics and Reversibility of Radionuclide Sorption Reactions," RHO-SA-80, 1979.

3. Neretnieks, I., "Transport Mechanisms and Rates of Transport of Radionuclides in the Geosphere as Related to the Swedish KBS Concept," in _Underground Disposal of Radioactive Wastes_ Vol. II, (Vienna, I.A.E.A., 1980) IAEA-SM-243/108, pp. 315-339.

4. Salter, P. F., Ames, L. L. and J. E. McGarrah, Rockwell Hanford Operations, "The Sorption Behavior of Selected Radionuclides on Columbia River Basalts," Informal Report, RHO-BWI-LD-48, August, 1981.

5. Smith, M. J. and others, Rockwell Hanford Operations, "Engineered Barrier Development for a Nuclear Waste Repository Located in Basalt," RHO-BWI-ST-7, May, 1980, pp. 258-272.

6. Thornton, C. C., Seyfried, W. C. and L. H. Brush, "Waste Glass - Seabed Sediment Interaction: Observations of the Soret Effect," in _Workshop on the Leaching Mechanisms of Nuclear Waste Forms, May 19-21, 1982, Summary Report_, PNL-4382, August, 1982, pp. 227-238.

7. Torstenfelt, B. and others, "Diffusion Measurements in Compacted Bentonite," in _The Scientific Basis for Nuclear Waste Management_ Vol. 6, pp. 295-302.

8. Westsik, J. H. and others, "Permeability, Swelling and Radionuclide Retardation Properties of Candidate Backfill Materials," in _The Scientific Basis for Nuclear Waste Management_ Vol. 4, S. V. Topp, Ed. (North-Holland, New York, 1982), pp. 329-336.

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Issue No. 2.22

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: How do the species which incorporate radionuclides change with time in the waste package?

3. Importance of the Issue to Repository Performance:

When it is emplaced, the waste package will contain a reactive assemblage of phases (e.g., glass + metal + basalt + bentonite). Such a system will tend to convert to a more stable assemblage under the hydrothermal conditions that will prevail after repository closure. Given sufficient time, stable secondary phases will be produced; however, kinetic factors could favor the persistence of metastable intermediate phases for the entire regulatory period. The chemical and physical characteristics of these reaction products will differ from those of the original waste package. In order to predict the ability of the waste package to contain the radionuclides during the regulatory period, the properties and abundances of these metastable phases must be known.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

§ 60.111 Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

§ 60.113 Performance of particular barriers after permanent closure.

(a) General provisions.

(1) Engineered barrier system.

(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantial complete during the period when radiation and thermal conditions in the unerground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. In the case of disposal in the saturated zone, it shall be asumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of the inventory of the radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components.

(a) High-level-waste package design in general.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties:

Reactions of the components of the waste package with groundwater will produce a suite of secondary minerals, aqueous species, colloids and pseudocolloids. Dissolved radionuclides and particulates were discussed in Issues No. 2.13 and 2.18, respectively. Possible changes in the chemical and physical characteristics of the waste form are described in Issue No. 2.14. The production of secondary minerals is discussed in this section.

Experimental studies of hydrothermal reactions between several different waste forms, powdered basalt and groundwater from the Hanford Site are described in several recent publications (DOE/RL 82-3; Coons, W. E.; Apted, 1981 and

Komarneni, S.). These experiments were carried out in closed reaction vessels at high temperatures (200-300°C) and pressures with a variety of rock:water ratios under oxic conditions. During the reactions, the waste form dissolved and an assemblage of secondary alteration phases was produced. Such reactions represent an overall irreversible process which can be understood in terms of the Ostwald step rule (DOE/RL 82-3; Dibble, W.; Fyfe, W.). The transition from the original waste form to a stable equilibrium phase assemblage proceeds via a series of intermediate, metastable products. As the system approaches equilibrium, the solubilities of the major chemical components of the system decrease.

During experiments with supercalcine, basalt, and groundwater, the attainment of steady state was indicated by constant solution composition after 200-400 hours of reaction. Steady-state concentrations of Mo and Rb were approximately 500 and 55 ppm, respectively. The alteration products included pollucite [(Cs, Na)Si $Al_2O_6.nH_2O$], strontium molybdate and ruthenium chloride (Apted, 1981). Pollucite, powellite ($CaMoO_4$) and uraninite were produced in reactions of spent fuel elements with basalt and basaltic phases (Komarneni, S.). Dissolution of simulated borosilicate glass produced powellite and weeksite $(K,Cs)_2(UO_2)_2(Si_2O_5)_3 \cdot 4H_2O$.

Alteration products produced by reactions with actual waste glass may be similar to those described above; however, the exact reaction pathways and steady-state radionuclide concentrations may be very different. It is important to note that much of the available data has been obtained from experiments in deionized water under oxic conditions with water:rock ratios that may not be representative of the waste package environment. The actual post-emplacement waste package system will be subjected to changing temperature, pressure, and radiation fields. It is not possible to extrapolate the available data to probable repository conditions with confidence.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application:

The information described in the previous section has largely been obtained from static, closed system autoclave experiments with non-radioactive materials.

Data from dynamic flow experiments with radioactive waste forms with a variety of temperatures, pressures, water:rock ratios, and particle sizes will be required. Such experiments should be carried out with site-specific groundwater under both reducing and oxidizing conditions. Similar experiments in the presence of bentonite packing material are also necessary. The stability and leachability of the secondary alteration products produced in these experiments must be assessed under the conditions which will persist in the near-field during the period of geologic control. Information concerning the crystallographic sites of radionuclides in the alteration minerals would be useful in assessing the ability of these phases to retain the waste products.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

In Work Element W.1.10.A, the formation of radiocolloids and radionuclide complexes will be studied in basalt-groundwater systems. Solubilities of radionuclides will be evaluated in Work Element W.1.4.A. In W.1.12.A, hydrothermal interaction studies will be carried out with simple binary and complex mixtures of waste package components. The above experiments will be carried out in close (static) systems under ranges of environmental conditions (Eh, pH, temperature, pressure, solution composition) relevant to expected conditions in the repository. The solution chemistry, stability of the packing materials and mineralogy of the alteration products will be examined. The dependence of the results upon temperature and rates of reaction will be evaluated.

In Work Element W.2.4.A, equilibrium sorption/desorption isotherms will be obtained in static cells and retardation factors of radionuclides will be measured in dynamic (flow-through) columns. These experiments will be carried out under ranges of environmental conditions expected at the repository.

The objectives of Work Elements W.3.1.A and W.3.2.A are to provide statistical, kinetic and thermodynamic justification for the extrapolation of the results obtained from short-term laboratory experiments to predictions of long-term repository performance. Flow-through hydrothermal autoclaves will be developed. BWIP staff will determine if the steady-state reaction system will approach chemical equilibrium under different flow rates. The suitability of using nonradioactive simulated waste as analogs for actual waste forms will be examined in Work Element W.3.7. The effect of the radiation field on waste form dissolution and degradation will also be studied.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of of Success:

Data on radionuclide speciation in basaltic groundwater will be obtained in Work Element W.10.A. Work Elements W.1.4.A and W.1.12.A deal with studies of radionuclide solubilities and hydrothermal interactions in the waste package. Plans for none of these Work Elements, however, include examination of radionuclide speciation in groundwater whose chemical composition has been altered by interaction with the packing material, canister and/or waste form. Studies of pseudocolloids in complex waste component systems under different flow regimes should also be included in BWIP plans.

In the repository, radionuclide transport may be dominated by diffusion through pore waters which are saturated or nearly saturated with secondary alteration phases. In the experimental systems described in Work Element W.3.2.A, high flow rates of unsaturated solutions will be used to accelerate chemical reactions. It must be shown that the mechanisms of dissolution and crystal growth in these experimental systems, where mass transfer will be dominated by advection, are the same as those that are important in diffusion dominated systems. The plans for Work Element W.3.2.A do not include a discussion of how this evaluation will be made.

In general, the plans for Work Elements related to this issue are not detailed enough to allow evaluation of their completeness or likelihood of success. In particular, additional information on the nature of tests to be carried out with the hot-cell studies described in Work Element W.3.7.A is necessary. The methods that will be used to characterize the solid phases should be described.

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3. Dibble, W. E. and W. A. Tiller, "Kinetic Model of Zeolite Paragenesis in Tuffaceous Sediments," Clay and Clay Minerals 29, 323-333 (1981).

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Issue No. 2.23

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: Can actinides be concentrated to increase heating in the packing materials or create a potential for criticality?

3. Importance of the Issue to Repository Performance

After loss of containment, concentration of actinides in the packing material may create a potential for a criticality. If a criticality did occur, the temperature of the immediate surrounding area may increase rapidly. Such a rapid increase in temperature may result in melting of the packing material in which the actinides had concentrated and the surrounding host rock.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.111 Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable Environmental Protection Agency.

(b) Retrievability of waste.

(1) The goelogic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained

from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

§ 60.113 Performance of particular barriers after permanent closure.

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other priod as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.131

(a) Radiological Production.

(a)(7) Criticality Control - all systems for processing, transporting, handling, storage, retrieval, emplacement and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent and concurrent or sequential changes have occurred in the conditions essentially to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (Keff) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and uncertainty in the experiment used to validate the method of calculation.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Actinides (plutonium, neptunium and americium) from simulated waste glass have been shown experimentally (IAEA-SM-257/73, 1981) to concentrate as colloids in a porous geologic formation (glauconic sand, which is the porous layer overlying the Boom Clay formation in Belgium) when synthetic groundwater was passed over the waste glass and then through columns of the sand for periods of time ranging up to approximately 90 days.

The sand has 34% porosity, permeability of approximately 10^{-4} meters/second and contains 20.8 weight percent glauconite. The flow rate of the water was 20 meters/year.

The chemical composition of the synthetic water used was the typical composition of the aquifer where the glauconic samples were collected (the water was protected from contact with the atmopshere to control redox and pH) and is shown below:

Water Composition (mg/1)

Ca^{2+}	= 3.03	Cl^-	6.4
Mg^{2+}	= 3.2	SO_4^{-2}	0.5
Fe_{tot}	= 0.1	CO_3^{2-}	201
Na^+	= 55.3	pH	8.35
K^+	= 7.71	Eh	150 mV

The quantity of actinide colloids collected by porous geologic media will depend on the pore size of the media. In the experiment described, 7 and 15 percent of the leached plutonium activity and 40 and 100 percent of the leached americium activity was retained on filters with porosities of 1 micron and 0.1 micron, respectively.

There is uncertainty in applying the experimental data cited above to concentration of actinide colloids in a porous geologic media of a basalt repository. The data apply only to one set of conditions rather than to a range of conditions. Also, the concentration of actinide colloids can depend on the design of the repository and the waste packages. For example, a packing material could be designed to tailor the chemistry of the groundwater and the rate of flow to minimize leaching and to minimize actinide colloids. Carbonates in groundwater are believed to form soluble anionic complexes with the TRU nuclides. The redox potential (Eh), pH and chemical water composition will affect the physico-chemical states (electrical charge) of the nuclides. The charge will determine the partioning of the nuclides between the colloidal and soluble phases. Conversely, the groundwater flow rate controls the rate of travel of the colloids and their subsequent dissolution. It also may be filtered to remove actinide colloids after passing over each waste package or to arrange the storage array to minimize the concentration of these colloids.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>:

The potential for a nuclear criticality could affect the design of the repository. For example, it may not be possible to position spent fuel packages in horizontal columns, end to end. By the time of construction authorization, DOE should have the following information:

1. The transport mechanism and rate of transport of actinides from spent fuel in a saturated repository under the expected conditions of Eh, pH, groundwater chemistry and flow rate. This information should be extrapolated for periods of time from zero to 10,000 years.

2. Based on the above, the quantities of plutonium, americium and neptunium colloids expected to be transproted from a column of failed fuel packages over the same time period.

3. The largest quantity of actinides expected to concentrate in a porous geologic medium and the geometry of the concentrated volume.

4. A nuclear safety analysis for this scenario.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>:

BWIP is conducting laboratory experiments to determine the solubilities and colloidal formation of key radionuclides (the actinides and transurancis in particular) under conditions applicable to a basalt repository. Data from these investigations will be used to estimate the release of radionuclides in the repository.

BWIP also plans to analyze the criticality potential (after containment failure) along a predicted groundwater flow path and include consideration of the sorption capability of the backfill in concentrating fissionable material.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Succes</u>

We believe it is possible to conduct an experimental program that will yield the information necessary to predict the rate of release of radionuclides from the repository. However we cannot predict the success of such programs on the basis of the information provided in the SCR.

An analysis of BWIPs planned approach in (7) for estimating the release of radionuclides in the repository can be made only after review of BWIPs detailed test plans and detailed plan for analysis of the information.

The BWIP SCR (Work Element W...1.10.A) shows intent to determine the formation and stability of radionuclide complexes and/or colloids over expected repository near field and far field conditions. The SCR (Work Element R.1.45) also shows the intent to analyze criticality potential along a predicted groundwater flow path and include consideration of the sorption capability of the backfill in concentrating fissionable material.

Although the criticality potential along a predicted groundwater flow path will be analyzed, an analysis is not necessarily sufficient. The analysis will look into solubilities whereas there is a need to also identify potential flow paths. There is also a need to define the scenario that would lead to a criticality, i.e., the occurrence of "two unlikely events," and a need to consider the statistical probability that these events will occur. The staff defines an "unlikely event" as an event that has less than a 1% probability of occurring. Thus, a test with a system scale model is recommended to investigate accumulation of radionuclides (as described in IAEA-SM-257/73) and to validate the probability of occurrence of the two occurring.

The applicant should also quantify the level of power generation that would result from the postulated criticality.

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Issue No. 2.24

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: How do radionuclides migrate through failed containers and how does this change with time? (Related to Issue No. 2.5)

3. Importance of the Issue to Repository Performance

The migration of radionuclides through failed containers and the change of this process with time must be understood and known to evaluate the relevance of this migration with respect to performance of engineered barrier systems after permanent closure.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(a) General provision.
(1) Engineered barrier system.
(i) The engineered barrier system shall be designed so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long time. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission, provided that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components

(a) <u>High-Level Waste package design in general</u>

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide

retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Present state of knowledge on chemical and physical property changes in container materials and properties is discussed in Issue No. 2.5 and on the flux of radionuclides in Issue No. 2.21. Production of particles and colloids which can hold or transport radionuclides is covered in Issue No. 2.19. However, little is known on radionuclide migration after container failures.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

By the time of construction authorization, DOE should have the following information.

(a) Data characterizing chemical and physical changes in container materials leading to and following container failures (as detailed in paragraph 6 of issue No. 2.5).

(b) Data characterizing the process and path of migration of radionuclides through the container to the very near-field repository environment.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6):

General information needs for this issue can be obtained from the following SCR work elements (WE).

WE 3.3.A Develop and/or use numerical modeling technique to predict the enviromental conditions, package degradation and radionuclide behavior of emplaced waste in or near the engineered system.

WE 3.6 Determine and conduct field engineering and in situ testing as may be appropriate to meet design needs and USNRC proposed requirements.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>:

Both WE stated in paragraph 7 can satisfy information needs of this issue if they include kinematic informations (displacement, velocity, acceleration, and time) on radionuclide migration through the failed containers.

Uncertainties in the numerical modeling of WE 3.3.3 can be minimized as in situ data are obtained to validate the modeling technique. Description of work plans in the SCR is inadequate to insure that the program is complete. The numerical model as well as related in situ data have to be evaluated to determine likelihood of success.

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Issue No. 2.26

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: Does alpha radiation in the waste packing materials affect solution chemistry and hence transport and species identification?

3. Importance of the Issue to Repository Performance

The bentonite/basalt packing is designed to retard radionuclide transport by sorptive processes (Wood 1982). The performance of a sorptive barrier depends upon local chemical conditions and the speciation of ions in the solution. It has been demonstrated that solution chemistry and the speciation of multivalent TRU elements can be selected by alpha-radiolysis. Consequently, a thorough assessment of retardation in the packing must consider whether the radionuclides will exhibit increased mobility due to alpha radiolysis effects. This issue is related to the general question of establishing the significance of radiolytic effects on waste package performance (Issue 2.10).

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(a) General provision.
(1) Engineered barrier system.

(i) The engineered barrier system shall be design so that assuming anticipated processes and events (A) containment of HLW will be substantially complete during the period when radiation and thermal conditions in the underground facility are dominated by fission product decay; (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractuinal releases to the geologic setting over ling time. In the case of disposal in the saturated zone, it shall be assumed in designing the engineered barrier system that partial or complete filling with groundwater of all available void spaces in the underground facility occurs.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be desinged, assuming anticipated processes and events, so that:

(A) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(B) The release rate of any radionuclide from lthe engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in lthe underground facility, that remains after 1,000 years of radioactive decay.

§ 60.135 Criteria for the waste package and its components.

(a) High-level-Waste package design in general.

(1) Packages for HLw shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited toconsideration of the following factors: solubility, oxisation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Reasonably extensive literature exists on alpha-radiolysis effects in pure water (Draganic, 1971). Alpha particles, by virtue of their greater linear energy transfer, have somewhat greater yields than gamma rays for molecular decomposition products of water (i.e., H_2, H_2O_2, etc.). Fundamentally, however, the effects are similar: for both gamma rays and alpha particles, it is ionization which is responsible for the radiolytic effects in solution. Due to the short range (~40μm) of alpha particles in water, however, alpha-radiolysis effects will be restricted to the immediate vicinity of the migrating radionuclides.

Direct measurements (Fried, Rai) indicate that both solution pH and the speciation of plutonium can be affected by solution alpha-radiolysis effects. Specifically, the pH decreases, possibly due to nitric acid formation from atmospheric nitrogen in the presence of moisture. Plutonium (III) is said to undergo successive radiolytic oxidations to plutonium (VI), followed by cyclic oxidation-reduction behavior. This behavior has been interpreted in terms of air initial oxidizing affect of OH radical and a subsequent reducing effect of H_2O_2: Swedish workers (Christensen, H., 1982) have recently calculated that alpha and gamma radiolysis can oxidize Fe(II) to Fe(III) in Swedish repository groundwater.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

While the available evidence indicates that radiolysis may produce an oxidizing environment under certain conditions, the significance of this affect in radionuclide retardation in the packing (and on waste package performance in general) has not been established. Major uncertainties involve the relative contribution of radiolysis effects in comparison to other reactions and processes which may occur in the backfill. Specifically, it must be determined to what extent radiolytically-induced changes in pH and redox behavior will be offset or swamped by the buffering properties of the backfill. For example, if radiolytically-produced oxidants (e.g., OH radical) are effectively scavenged by iron in the basalt or by dissolved H_2, radiolysis effects on redox behavior could be negligible. To determine the significance of radiolysis, effects in the packing data will be needed to estimate the relative formation and scavenging rates for radiolytically-produced species under repository conditions. This should include the effects of temperature and radiation dose rate. In particular, for alpha radiolysis the dose rate will depend critically upon the postulated distribution(s) of migrating transuranic elements in the packing.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Radiation effects studies are to be carried out larely in conjunction with a program of hydrothermal testing incorporating actual waste forms and palicale materials this phase of the testing program is to be carried out in a hot cell, also the radiation environment will be provided by the waste form material. (Work element W.1.3.A) In these tests, solution chemistry measurements will be carried out during the tests, and reaction products will be examined afterwards. Presumably, results will be compared with those obtained in the absence of irradiation to determine if irradiation noticeably affect solution or material properties. No specific comparisons or analytical technique unique to testing for irradiation effects are described in the work element. Presumably, again, techniques and parameters monitored are to be similar to those in the hydrothermal experiments without irradiation (i.e. Eh, pH, characterization of alternation products, determination of elements concentration in solution, etc.)

Other studies are cited in element W.1.3.A. in which corrosion testing is to be carried out in a gamma field, and packing and buffer materials are to be subjected to external gamma irradiation. The test conditions are not explicity defined; they appear to be scoping type tests. Finally work elements W.1.10.A refers to investigation of the possible effects of radiation on radionuclide geochemical behavior, radionuclide complexing and colloid formation. No specific plans or techniques are presented.

8. <u>Analysis of (7) As To Completeness, Practicality and The Likelihood of of Success</u>

At this point, descriptions of the planned approach are very general; it is not clear to what extent, if any, alpha radiolysis effects are to be treated as a separate issue. In general terms the planned approach correctly recognizes the possibility that solution chemistry and radionuclide speciation may be modified by radiation effects. The problem is to be addressed by what appear to be scoping experiments. These may be incomplete in two respects: First, it is not clear that the hydrothermal scoping experiments will include worst case conditions. For example, if the effects of solution radiolysis and of geochemical interactions oppose each other, as has been postulated, the relative rates of the two processes are critical factors. For radiolysis processes, the rate will depend upon local radiation dose rate, and total dose, in particular, these will depend on the detailed distribution of radionuclides in the test facilicy. The mechanism of α-radiolysis may also be somewhat different from gama-radiolysis. Strict equivalence cannot always be assumed. In short, it is not clear that the hydrothermal experiments will bound the extent to which α-radiolysis effects may occur before geochemical action sets in under field conditions. Second, there is no specific mention of how the significance of radiolysis effects on radionuclide speciation and complexing will be determined, particularly for conditions subsequent to the thermal period.

The practicality of carrying out Eh determinations under hydrothermal conditions, in all inhomogeneous system, in a radiation field sufficiently intense to simulate repository conditions remains to be determined. Specific technique are still under development. This is a possible weakness of the approach, in that the major initial radiation test involves a fairly complex facility, incorporating many interactions and somewhat limiting the number of radiological variables. (likelihood of success might be increased by scoping measurements on simpler systems.

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2. Draganic, I. G. and Z. D. Draganic, The Radiation Chemistry of Water, Academic Press, New York, 1971.

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Issue No. 2.27

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What are the conditions which affect criticality?

3. Importance of the Issue to Repository Performance

After loss of containment, concentration of actinides in the packing material may create a potential for a criticality. If a criticality did occur, the temperature of the immediate surrounding area may increase rapidly. Such a rapid increase in temperature may result in melting of the packing material in which the actinides had concentrated and the surrounding host rock.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.111 Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable Environmental Protection Agency.

(b) Retrievability of waste.

(1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

§ 60.113 Performance of particular barriers after permanent closure.

(a) Containment of HLW within the HLW waste packages will be substantially complete for a period of 1,000 years after permanent closure of the geologic repository, or such other period as may be approved or specified by the Commission.

(b) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at

1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

§ 60.131

(a) Radiological Production.

(a)(7) Criticality Control - all systems for processing, transporting, handling, storage, retrieval, emplacement and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (Keff) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and uncertainty in the experiment used to validate the method of calculation.

5. Summary of the Present State of Knowledge With Analysis of Uncertainties

In order for a mass of fissile material to achieve and maintain a critical chain reaction, several conditions must be met simultaneously, e.g., the proper geometric configuration, the presence of a neutron moderator and reflector and the absence of neutron poisons. Redistribution of the fissile material in the waste package or package, either within the canister or external to it, into a more optimum configuration is the prime requisite in it, into a more optimum configuration is the prime requisite in achieving criticality. The only mechanisms deemed significant to redistribution are intrusion of groundwater and a severe natural phenomena, such as an earthquake. These mechanisms would have to bring together over 40 spent fuel canisters into an optimum, close-packed arrangement, free of neutron poisons. Otherwise, several uncontrolled natural events must occur in a proper sequence and within a specific period of time. These are:

a. Water must enter the repository in the required volume.
b. The waste canister and/or cladding must fail.
c. The matrix in which the fissile isotopes are held, i.e., glass for the high level waste and the sintered oxides for the fuel elements, must be physically removed or destroyed, or selective fissile isotopes leached out (as long as the fuel material remains homogeneously distributed it will not go critical). Fissile plutonium must enter the leachant as a colloid.
d. The packing material surrounding the waste packages must be absent (never placed or washed away).
e. After flowing for long periods of time over a series of waste packages with exposed spent fuel or solidified high level waste, the leachant must pass through an intact plug of clay.
f. The fissile plutonium colloids must be filtered by the clay and retained, so that over a long period of time a critical mass is accumulated on the clay in an optimum geometric configuration.
g. Water must be present in quantities sufficient to moderate and reflect neutrons so that a criticality occurs.
h. Neutron poisons must not be present.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>:

The potential for a nuclear criticality could affect the design of the repository. For example, it may not be possible to position spent fuel packages in horizontal columns, end to end. By the time of construction authorization, DOE should have the following information:

1. The transport mechanism and rate of transport of actinides from spent fuel in a saturated repository under the expected conditions of Eh, pH,

groundwater chemistry and flow rate. This information should be extrapolated for periods of time from zero to 10,000 years.

2. Based on the above, the quantities of plutonium, americium and neptunium colloids expected to be transproted from a column of failed fuel packages over the same time period.

3. The largest quantity of actinides expected to concentrate in a porous geologic media and the geometry of the concentrated volume.

4. A nuclear safety analysis for this scenario.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>:

BWIP is conducting laboratory experiments to determine the solubilities and colloidal formation of key radionuclides (the actinides and transuranic is in particular) under conditions applicable to a basalt repository. Data from these investigations will be used to estimate the release of radionuclides in the repository.

BWIP also plans to analyze the criticality potential (after containment failure) along a predicted groundwater flow path and include consideration of the sorption capability of the backfill in concentrating fissionable radionuclides.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Succes</u>

We believe it is possible to conduct an experimental program that will yield the information necessary to predict the rate of release of radionuclides from the repository. However, we cannot predict the success of such programs on the basis of the information provided in the SCR.

An analysis of BWIP's planned approach in (7) for estimating the release of radionuclides in the repository can be made only after review of BWIP's detailed test plans and detailed plan for analysis of the information.

The BWIP SCR (Work Element W...1.10.A) shows intent to determine the formation and stability of radionuclide complexes and/or colloids over expected repository near field and far field conditions. The SCR (Work Element R.1.45) also shows the intent to analyze criticality potential along a predicted groundwater flow path and include consideration of the sorption capability of the backfill in concentrating fissionable radionuclides.

Although the criticality potential along a predicted groundwater flow path will be analyzed, an analysis is not necessarily sufficient. The analysis will look into solubilities whereas there is a need to also identify potential flow paths. There is also a need to define the scenaro that would lead to a criticality, i.e., the occurrence of "two unlikley events," and the statistical probability that these events will occur. The staff defines an "unlikely event" as an event that has less than a 1% probability of occurring. Thus, a test with a system scale model is recommended to investigate accumulations of radionuclides (as described in IAEA-SM-257/73) and to validate the probability of occurrence of the two occurring.

The applicant should also quantify the level of power generation that would result from the postulated criticality.

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Issue No. 3.1

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What is the expected solubility of released radionuclides in the near-field and the far-field through time, excluding the waste package?

3. Importance of the Issue to Repository Performance

The rate at which radionuclides are transported to the accessible environment will be determined by their solubility, the rate and path of groundwater movement and the reactions (retardation) of the radionuclides with minerals in the backfill, in fractures in the host rock, and in the host rock itself. Theoretical analysis of potential solution species and solubilities (under reducing conditions) suggest that certain radionuclides could be in solution at permissible levels. Measurements of solubilities as low as those of interest for waste isolation purposes is very difficult, however, and uncertainties are not surprising. In aqueous media in formations, the presence of complexing ions, such as carbonate, fluoride and silicate, increases uncertainty. Allard (1982) is far from alone among the compilers of thermodynamic data in warning that solubilities computed from them as frequently in disagreement with experimental values. Therefore, the determination of radionuclide aqueous speciation in addition to radionuclide solubilities and other supporting thermodynamic data are necessary to assess the importance of geochemical reactions in controlling radionuclide migration over the time frame of thousands of years for the conditions to be expected.

4. Portions of 10 CFR Part 60 that are directly connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure (b)(3) The geochemical characteristics of the host rock;

§ 60.122 Siting Requirements

(b) Favorable Conditions

(1) The nature and rates of tectonic, hydrogeologic, geochemical and geomorphic processes operating within the geologic setting during the Quaternary Period would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(4) Geochemical conditions that -- (i) promote precipitation or sorption of radionuclides; (ii) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(5) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(c) Potentially Adverse Conditions

(9) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could affect the solubility of the waste form or chemical reactivity of the engineered barrier system so as to increase the difficulty of designing the engineered barrier system to meet the performance objectives of Sect. 60-112 and 60.113.

(11) For disposal in the saturated zone, ground water conditions in the host rock that are not reducing.

5. Summary of the Present State of Knowledge, with Analysis of Uncertainties

A major mechanism for controlling release of radionuclides from a repository in basalt is the precipitation or incorporation of radionuclides into new mineral phases, i.e., solubility constraints. Assuming steady state

conditions, radionuclide solubilities can be used to calculate the maximum possible concentration, and therefore release, of a radionuclide in a specific system. Radionuclide solubilities reported in section 6.4.1 (Figure 6-15) of the BWIP Site Characterization Report appear to demonstrate that 'maximum possible" release rates for all radionuclides will be below NRC and EPA maximum permissible discharge levels. This conclusion was reached in part of the basis of the following assumption and/or conditions:

1. repository redox conditions are reducing

2. oxide phases are phases that will precipitates under repository conditions

3. the effect of complexing ligands such as CO_3— was not considered

4. Am concentratjions were calculated from apparent sorption coefficients

5. absence of significant uncertration increase due to complex or colloid formation

6. crtstalline solids control solubility

The specilatial nature of then assumptions/conditions greatly reduces confidence that compliance with NRC and EPA release criteria was actually reached.

Radionuclide solubility, like sorption is highly dependent on environmental conditions such as Eh, pH and groundwater composition.[2] At this time, there are few solubility data available for conditions relevant to a repository in basalt, particularly at elevated temperatures. Based on available thermodynamic and laboratory data, solubilities have been estimated for the basalt geohydrologic system.[3] These solubility estimates[3] show that under reducing conditions anticipated for basalt, UO_2 and $USiO_4$ have solubilities on the order of 10^{-8} moles/L, whereas NpO_2 and SeO have solubilities of approximately 10^{-15} moles/L.

Dissolution of the waste form (solubilization) leads to the question of whether an element that has been released from a solid phase will remain in a groundwater as a dissolved species (speciate).[3] Speciation is a function of groundwater characteristics, temperature, pressure and interactive effects between the aqueous phase and any solid along the transport path. The ground-water characteristics also determine whether the element will occur in solution as a simple or complex ion. The level of knowledge about speciation and the amount of thermodynamic data needed to calculate a solution chemistry, not only at 25°C and 0.1 MPa but also with increased temperature and pressure, are highly variable for each elements. Reasonably complete data bases are available for all elements except Tc, Pu, Np, Am, Cm, Se, Pa, Ru, Pd, Sr, Zr, and REE (see e.g., Ref. 5, 6, 7, 8, 9, 10). Most studies have demonstrated that uranium and actinide ions, regardless of valence state, tend to form complexes of varying stability in aqueous solution with all major ligands found in groundwater (e.g., CO_3, F, PO_4, SiO_4, Cl, OH). Relationships between dissolved ionic species and possible natural amorphous or crystalline phases which can precipitate from ground waters have been calculated assuming equilibrium for both general geologic environments[11] and for basalt aquifers in the Columbia Plateau.[12]

Precipitation of a radionuclide can occur forming, for example, insoluble oxides, hydroxides, carbonates, sulfates, phosphates, silicates, and sulfides.

In addition, radionuclides can co-precipitate in minerals formed during alteration of the backfill or the host basalt itself. Except for some data on Th and U,[13,12] thermodynamic information on the complex mineral phases the actinides might ultimately form, or the partitioning of trace actinides into phases formed as a consequence of waste/basalt/ground water interaction, are non-existent.

Radionuclides can also precipitate out of the groundwater as extremely fine-grained colloids.[14] Many highly charged cations have a tendency to form polymeric hydroxides. This is particularly true for tetravalent actinides (Johnson and Toth[15]). Hydroxy colloids may be regarded as highly polymerized species with large residual charges, which due to electrostatic repulsion prevent them from aggregation. Thus, an apparent solubility, which can exceed the solubility product, may be achieved. Works by Benes and Majer[16], Oloffson et al.[17], and Starik[18] have shown that actinide colloids have a strong tendency to sorb on exposed mineral surfaces in the neutral to slightly acid pH range. However, at high pH as expected in the basalt repository[2], stable species can be formed that carry a residual negative charge, leading to a decrease in their sorption.

6. Summary of the Additional Information Needed to Resolve the Time by the Time of Construction Authorization Application

The following areas (in order of priority) should be addressed before the issue can be closed out:

(a) The reliability of the equilibrium constants (or free energies) used in solid-solution modeling needs to be established for conditions dominating the basalt repository environment. It is quite common for experimental solubility product constants and complex formation constants to vary by 1 to 3 orders of magnitude. Quite clearly this amount of uncertainty can cause large differences in the computed results and probably contributes the largest single source of error.

(b) Since solubilities are in general a function of temperature, efforts should be directed toward measurements of solubilities as a function of temperature for critically important solid phases and aqueous species.

(c) The formation of colloids and their influence on solubility in waste/basalt/groundwater interactions are, at present, poorly understood and should receive more attention. Measurements are needed on the nature, radionuclide content and migration properties of colloidal forms produced through degradation of proposed high level waste forms. In addition, the nature, concentrations, particle size distribution and migration properties of naturally occurring colloidal material suspended in the subsurface waters should be evaluated.

7. <u>Summary of the Planned Approaches to Testing, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

In order to overcome the handicap of a limited data base, the BWIP proposes to experimentally measure the solubilities of compounds of uranium, plutonium, americium, and other key radionuclides under the exact site-specific conditions anticipated to occur in the basalt repositories (i.e., low Eh, high temperature, high radiation field, and complexing ligands). Specifically, they intend to:

(1) continue experiments already initiated on the interactions between the waste form, basalt and groundwater over the temperature, pressure, and Eh-pH conditions expected for the repository,

(2) use data supplied by other laboratories from long-term static and low flow rate dynamic leach tests on simulated spent fuel and borosilicate glass,

(3) experimentally identify the dominant radionuclide species in basalt groundwater, and to evaluate conditions that could lead to possible radionuclide colloid formation and subsequent particulate transport,

(4) investigate the possible effects of the radiation field on radionuclide geochemical behavior.

The solubility, speciation and colloid data will be coupled with an uncertainty analysis to insure the successful prediction of radionuclide concentrations in the basalt groundwater.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

The plans for determining solubilities, speciation and colloid transport are not detailed enough for the NRC to access whether they are adequate. This statement is based on the following observations:

(1) A detailed description of experimental and analytical techniques is not provided. In order to characterize solubilities, experiments should be bracketed by coming from both under- and oversaturation.

(2) A decision on which radionuclide compounds are to be used in the solubility experiments is not provided. In addition, it is not clear whether they will examine the compounds one at a time, or as they aggregate.

(3) They are considering only reducing conditions in their experiments. They should also consider oxidizing conditions which may be encountered in the near-field immediately after waste emplacement or in the far-field environment.

(4) No strategy was given for determination of the speciation of critical radionuclides. Speciation can be determined from solubility experiments, spectroscopic analysis, acid-base potentiometric titrations and polarography. Calculations to date have considered only simple oxide species.

(5) The types of colloids expected to form are not discussed (e.g., oxides, hydroxides, oxhydroxides, organics). Colloids can form from solution as the result of oversaturation or from physical degradation of the basalt (i.e., particulate exfoliation).

(6) The expected influence of the radiation field on radionuclide behavior at high P-T is not discussed.

(7) The methods of insuring compatibility between BWIP data and data generated by other labs trying to simulate the in situ conditions of the basalt repository are not described.

(8) There was no discussion concerning the methods of assessment of uncertainties on existing data or data to be obtained.

(9) The development of computational schemes required to address solubility, speciation, and colloidal transport in a complex fluid flow regime was not considered.

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Issue No. 3.2

1. Name of the Site: Basalt Waste Isolation Project (BWIP), Rockwell Hanford Operations, Richland, Washington

2. Statement of the Issue: What is the expected geochemical retardation of released radionuclides in the near-field (excluding the waste package) and the far-field through repository containment time?

3. Importance of the Issue to Repository Performance

The retardation of released radionuclides by geochemical conditions and processes in the repository near-field, including the backfill, and far-field are major modes which restrict the migration of radionuclides released from the waste package to the accessible environment. For this issue discussion, retardation is defined to include the solubility limit condition and the sorption process effect on both dissolved and colloidal/particulate radionuclides. The parameters which affect solubility, sorption, and colloids/particulates in the near-field and far-field must be carefully identified and defined in order to establish a credible and defensible position on performance assessment for both expected and worst-case behavior through time at the BWIP.

4. Portions of 10 CFR Part 60 That Are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(b)(3) The geochemical characteristics of the host rock;

§ 60.122 Siting requirements

(b) Favorable conditions

(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes operating within the geologic setting during the Quarternary Period would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(4) Geochemical conditions that -- (i) promote precipitation or sorption of radionuclides; (ii) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(5) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(c) Potentially adverse conditions

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

(11) For disposal in the saturated zone, groundwater conditions in the host rock that are not reducing.

5. <u>Summary of the Present State of Knowledge, With Analyses of Uncertainties</u>

Backfill will probably consist of more than one component [Beall and Allard (1982); Wood (1982)]. Crushed basalt and bentonite are under consideration [SCR, (1982); Wood and Coons (1982)]. Uncertainties include the ability of bentonite to withstand the thermal pulse, and of basalt to satisfactorily retard radionuclide migration. Far-field mineralogy and near-field mineralogy have been investigated [Myers and Price (1981); Noonan, Frederick, and Nelson (1980); SCR (1982)]. Sorption of radionuclides onto near-field and far-field components has been measured (Ames and McGarrah (1980); Barney (1981); Benson

(1980); Salter, Ames, and McGarrah (1981b); SCR (1982)]. Uncertainties include the repository conditions (Eh, in partiuclar) and distribution coefficients obtained under those conditions. The ability of basalt to adsorb anions seems poor although most cations give favorable distribution coefficients. Soubility/concentration migration constraints are covered under issue 3.1. Very little information has been developed concerning possible colloid/particulate formation process or their removal by sorption or filtration processes.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

In order to establish the radionuclide retardation to be expected in the near-field, including the backfill, many engineered system parameters and components must be defined. These include waste form and load, use of an overpack, and backfill components. Only after these are finalized can the form of radionuclides which might be released from the waste, the thermal and radiation pulse, and the expected radionuclide retardation be quantified. Additional experiments under expected repository conditions will be necessary to define radionuclide retardation in the near-field. In the far-field, additional work to define sorption values at expected far-field parameters of Eh, etc., may be needed. The limiting solubilities of radionuclides to be expected in either the near-field or far-field will require substantial additional work (see issue 3.1). The entire question of colloid/particulate transport must be defined and quantified.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of 6

Backfill, its role in helping isolate the waste package from groundwater intrusion, and in retarding radionuclide migration from the waste package to the near-field in a groundwater-intrusion -- waste-package-failure event, is thoroughly covered in the Site Characterization Report [SCR, (1982)]. Issue W.1.B, "Is a unique borehole backfill required?", and the work elements related to this issue, address plans to establish backfill requirements and to identify material(s) which will satisfy these requirements. The expected temperature and radiation regime to be experienced by backfill and the water-exclusion and radionuclide-sorption properties needed are thoroughly addressed in various work elements.

Near-field mineralogy and its influence on radionuclide migration is not specifically addressed as an issue in the Site Characterization Report [SCR, (1982)]. However, the use of mineralogical information and the impact of mineralogy on the parameters that control geochemical processes and radionuclide migration are well recognized and identified in a number of work elements which are components of Issue W.1, "Design," Issue W.2, "Site Geochemistry," and Issue W.3, "Testing and Performance Confirmation." Under Issue W.2.A, "Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. NRC proposed waste isolation requirements?", plans for additional petrography and mineralogy activities are identified.

Far-field mineralogy and its influence on radionuclide migration is not specifically addressed as an issue in the Site Characterization Report [SCR, (1982)]. However, as in the near-field, the use of mineralogical information in determining the parameters which control geochemical processes and radionuclide migration are well recognized. Plans for resolution of Issue W.2.A, "Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. NRC proposed waste isolation requirements?", and Issue W.2.C, "Can valid Eh measurements for the candidate repository horizons in the reference repository location be made either by potentiometric measurement or indirectly by measurement of dissolved redox couples?", address needed additional mineralogical information.

The geochemical process of sorption is not specifically addressed as an issue in the Site Characterization Report [SCR, (1982)]; however, the need to develop additional sorption data is identified in work elements under Issue W.2.A, "Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. NRC proposed waste isolation requirements?", and the utilization of sorption data in modeling and analysis is treated under Issue W.3.A, "Testing and Performance Confirmation." Planned work for additional sorption experiments include investigation of irreversible phenomena and the effect of multiple speciation. Confirmation of the distribution coefficients and sorption isotherms obtained in the laboratory by field migration tests may also be conducted.

Colloid/particulate formation by groundwater interaction with the waste form or dissolution/precipitation phenomena, as well as the transport of radionuclides as colloids or particulates, is only superficially treated in the Site Characterization Report [SCR, (1982)]. It is mentioned under Work Element W.1.10.A, "Determine the formation and stability of complexes and/or colloids over expected repository near-field and far-field conditions." In the section on plans, only one sentence is devoted to colloid formation and particulate transport.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

The approach to backfill development appears to be technically sound and seems likely to succeed in developing a satisfactory backfill. The greatest uncertainty which will impact on the likelihood of success lies in the area of the waste form and load. Spent fuel elements and glass or ceramic waste forms could require different backfill materials due to different behavior in the presence of groundwater. Also, the waste load has not been finalized, and this also will influence the backfill requirements and materials. The work elements in the Site Characterization Report probably cover a great enough range of possible parameters to develop either a superior backfill which can satisfy all possible situations, or a number of backfills for different situations. The issue of a backfill is well treated in the Site Characterization Report.

Near-field and far-field mineralogy in the Columbia River basalts is already fairly well developed, and the limited additional testing indicated is probably adequate to meet the information needs. More detailed mineralogical data in the near-field vicinity of the planned repository is desirable. Samples for this need can only be obtained after the test shaft is drilled into the Umtanum flow. The issue of near-field mineralogical information and its use in determining radionuclide migration data or predictions seems adequately covered in the Site Characterization Report.

The plans in the site Characterization Report for development of additional sorption data seem adequate in most respects. Additional emphasis should be given to maintaining a reducing environment during the tests, as would be expected in the repository. Determination of solubility/concentration information may require substantial additional work and possibly a shift in the approach (see Issue 3.1).

The colloid/particulate radionuclide transport discussion in the Site Characterization Report is confused and intermixed with a general discussion of complex ions and sorption phenomena. The treatment is inadequate and the issue cannot be resolved by the given approach or plans. It is not possible to estimate when an understanding of colloid/particulate migration/retardation may be completed since a practical approach has yet to be developed.

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Issue No. 3.3

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: How is the migration behavior (including solubility and retardation) of radionuclides being validated/verified?

3. Importance of the Issue to Repository Performance

The primary geochemical mechanisms for controlling the transport rate of radionuclides to the biosphere are the insolubility of the radionuclides and the retardation of the radionuclides during migration through the geosphere. The solubility and retardation of the radionuclides are established by the geochemical conditions (e.g., pH, Eh) along the migration path and the extent to which the speciation reflects equilibrium conditions as opposed to the initial state (i.e., kinetics). Parameters characterizing the solubility (e.g., solubility products) and retardation (e.g., sorption isotherms) are being measured in the laboratory and subsequently used in predicting the performance of the repository. In order for these predictions to be satisfactory, these solubility and sorption values must be validated/verified to show that they accurately represent or are more conservative than the actual situation in a waste repository.

4. Portions of 10 CFR Part 60 That Are Directly Connected To The Issue

§ 60.21 Content of application

(c) The Safety Analysis Report

(1)(ii)(F) An explanation of measures used to confirm the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using such methods as field tests, in-situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

§ 60.122 Siting requirements

(b) Favorable conditions

(4) Geochemical conditions that - (i) promote precipitation or sorption of radionuclides; (ii) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(c) Potentially adverse conditions

(9) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could affect the solubility of the waste form or chemical reactivity of the engineered barrier system so as to increase the difficulty of designing the engineered barrier system to meet the performance objectives of Sects. 60.112 and 60.113.

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

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Very little work has been done concerning the validation/verification of parameters related to the migration behavior of radionuclides in basalt (Refs. 1, 2) except a limited study done at the National Reactor Testing Station in Idaho (Refs. 3, 4) (see Attachments 1 and 2). Furthermore, it is not currently evident what validation/verification framework is planned by the BWIP. Potential validation/verification alternatives include:

(a) in-situ measurements in the formation of interest and under the conditions of interest;

(b) use of a "bounding" approach to the migration parameters employed in the performance assessment based on analytical evaluation of pertinent processes and conditions; and/or

(c) a statistical approach that correlates migration parameters measured under a variety of conditions (Ref. 5).

Resolution of this issue promises to be difficult in a nominally unperturbed repository geology and even more so in a respository undergoing interaction with the radioactive waste package.

6. <u>Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application</u>

The most immediate need is to have the approach(es) to be employed in the BWIP for validation/verification of migration parameters and the program for their implementation identified to the NRC. Knowledge of this overall framework is required to further specify information requirements, but the following are typical of anticipated information needs:

(a) in-situ measurements -- adequacy and reproducibility of methods used;

(b) bounding approach -- address the closure aspect (have all mechanisms and interactions been accounted for); and

(c) statistical approach -- what amount and type of data will form the basis of the correlation.

Following this, specific validation/verification methodologies must be identified for each important geochemical mechanism or parameter to be employed.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

The BWIP approach(es) to validation and verification of geochemical parameters related to radionuclide migration have not been described in consolidated form in the SCR (Ref. 6). Certain specific BWIP work elements (e.g., W.1.4.A, W.2.4.A, W.2.10.C, W.3.A) allude to verification/validation in the context of in-situ experiements. However, the nature of these experiments is not defined except in the case of Eh. The SCR contains a lengthy section on in-situ test facilities (Sect. 17.2), but the geochemical aspects of the repository have not been addressed here. Evaluation of practicality and likelihood of success is not possible pending identification of the validation/verification framework and specifics.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

As noted above, the desire for validation/verification is evident in several places in the SCR. However, the planned approach(es) of BWIP to validation and verification of geochemical parameters must be regarded as incomplete at this time since (1) the overall framework for validation/verification has not been identified in the SCR, and (2) specific validation/verification methodologies are not mentioned.

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Issue No. 3.4

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: How are the geochemical data that have been and will be gathered shown to be appropriate for use in anticipated performance assessment?

3. Importance of the Issue to Repository Performance

Performance assessment is the tool used to determine whether or not a waste repository satisfies the applicable criteria for health and safety. As used here, appropriate data relates to its compatibility and sufficiency for use in the performance assessment, which involves computer models of the groundwater hydrology and radionuclide transport and retardation mechanisms. The primary geochemical parameters required are the retardation functions, either as a constant or a concentration dependent isotherm, and the solubility of each radionuclide or a fixed initial concentration at the point of release from a waste package. Thermodynamic data on speciation and equilibrium constants, and data on sorption mechanisms, geochemical conditions and chemical reactions in all regions aid in providing the means of establishing (or bounding) the solubility and retardation parameters used in the performance assessment.

4. Portions of 10 CFR Part 60 That Are Directly Related To The Issue

§ 60.21 Content of application

(c) The Safety Analysis Report

(1)(ii)(B) Analyses to determine the degree to which each of the favorable and potentially adverse condltions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation. For the purpose . . .

(1)(ii)(D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis . . .

(1)(ii)(F) An explanation of measures used to confirm the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using such methods as field tests, in-situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

§ 60.122 Siting requirements

(b) Favorable conditions

(4) Geochemical conditions that -- (i) promote precipitation or sorption of radionuclides; (ii) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(c) Potentially adverse conditions

(9) Ground water conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could affect the solubility of the waste form or chemical reactivity of the engineered barrier system so as to increase the difficulty of designing the engineered barrier system to meet the performance objectives of Sects. 60.112 and 60.113.

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

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

The data requirements for existing performance assessment codes are well known. Exampes of these codes or code systems are SWIFT (Ref. 1) and NWFT/DVM (Ref. 2) developed for use by the NRC, and the WISAP consequence analysis codes (Ref. 3), developed for use by DOE. Although a preliminary performance assessment of the basalt site was made by Salter et al (Ref. 4), and analysis of the appropriateness (compatibility and sufficiency) of the geochemically-based migration parameters for use in these codes have not been made for BWIP.

The retardation of radionuclides (see NRC Issue 3.2) is generally modeled using the assumption that retardation is comprised of only sorption effects and that these effects are linear and fully reversible. However, the experimental data used as input to the performance analysis codes (i.e., K_d-based retardation factors) included effects other than sorption and the sorption effects have been shown to be very different depending on the direction of the reaction (Refs. 5 and 6). Both retardation and solubility effects are functions of time and location, and should be determined in this manner. However, current performance assessment codes generally cannot accommodate this kinetics-type data.

The migration of radionuclides through the BWIP geosphere will more likely involve fractured flow as opposed to flow through a porous medium, and geochemical data should be generated using rock surface/water volume ratios appropriate for this flow regime. Almost all of the available information on distribution coefficients (K_d) was determined using standard methods involving intimate contact between finely ground rock and liquid. The results from these standard methods may not be applicable to fractured basalt and be non-conservative, i.e., the experimentally effective K_d is higher than that which would exist in the actual system.

Another major mechanism for controlling release of radionuclides from a repository is the precipitation or incorporation of the radionuclides into new mineral phases (see Issue No. 3.1). The solubility of a particular nuclide represents an upper bound in concentration for the expected low flow rates.

In the case of unexpected high flow rates (such as for serious breach scenarios), the leach rate of the waste would tend to be the controlling mechanism in determining the radionuclide concentration (Ref. 7). (See issues involving the waste package for a discussion of leach rates.)

The solubilities of the radionuclides that are input parameters to the performance assessment codes will be both experimental and calculated. The experimental values will possess uncertainties due to the limitations involved in duplicating in-situ conditions. The calculated values will also possess uncertainties due to similar limitations which are complicated by colloid formation and complexiation. In addition, the equilibrium assumption that is necessary in these complicated calculations add further to uncertainties and the question of appropriateness of the data, particularly in the case of flow through the fractured and jointed basalt.

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

Based on the foregoing, it would appear that the appropriateness of the geochemical data generated in the past is questionable. Additionally, the type of geochemical information that should (or should not) be obtained in the future must be tailored to meet the needs of existing and anticipated performance assessment tools.

The ultimate judge in the appropriateness of the geochemical data is the successful application of the performance assessment techniques to laboratory experiments, in-situ experiments, and other field tests (see Issue 3.3).

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

Satisfying the information needs for this issue involves many geochemical parameters and many work elements outlined in the SCR. The work elements most pertinent to this issue are listed below.

Work Element W.1.4.A -- Determine the projected solubilities, kinetic behavior, and distribution for key nuclides which might be released from the waste package (see attached material from the SCR for details).

Work Element W.1.10.A -- Determine the formation and stability of radionuclide complexes and/or colloids over expected repository near-field and far-field conditions (see attached material from the SCR for details).

Work Element W.1.12.A -- Determine the extent to which the interaction between the canister materials, waste form, backfill, and host rock in a saturated environment results in retardation of radionuclides (see attached material from the SCR for details).

Work Element 2.4.A -- Demonstrate that geochemical conditions in the near- and far-field are such that transport of radionuclides is retarded for sufficient time to satisfy waste isolation requirements (see attached material from the SCR for details).

Work Element W.2.13.D -- Determine to what degree the characteristics of the geologic setting complement the engineered system (see attached materials from the SCR for details).

Work Element W.3.2.A -- Determine the thermodynamic and kinetic arguments that can be used to extrapolite short-term (less than two years per experiment) materials test (see attached material from the SCR for details).

In addition to these specific work elements, Performance Assessment Activity 14 (Perform Postclosure Repository Performance Assessment) is pertinent to this issue. This activity will be initiated on completion of verification, validation, benchmarking, the documentation of all codes. The main elements (see attached material from the SCR for details) include:

- o Post-Waste-Emplacement Numerical Modeling
- o Uncertainty Analyses
- o Consequence Analyses

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

The planned approaches to extending and complementing the thermodynamic data base and retardation mechanism should be adequate for the purpose of judging the appropriateness of the geochemical data for use in the anticipated performance assessment. However, a specific work element for resolving this issue should be included in the plans.

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Issue No. 3.5

1. Name of Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What is the mineralogy/petrology/chemistry of the backfill prior to waste emplacement?

3. Importance of the Issue to Repository Performance

Backfilling, as discussed here, refers to materials used to plug shafts, tunnels, and disposal rooms. These large man-made cavities, including basalt fracturing around these cavities, represent a broad and short pathway to the biosphere for radionuclides released from the waste package. These pathways must be blocked with engineered barriers that are essentially impervious (except for slow diffusional processes) to radionuclide migration to eliminate this short circuit to the biosphere.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.122 Siting requirements

(b) Favorable conditions

(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes operating within the geologic setting during the Quarternary Period would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(5) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(c) Potentially adverse conditions

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

§ 60.140 General requirements [of the performance confirmation program]

(d) The program shall be implemented so that:

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

5. Summary of the Present State of Knowledge, with Analysis of Uncertainties

An extensive engineered barrier program (Ref. 1), which includes borehole plugging studies, is in place at BWIP with the objective to develop, test, and demonstrate materials, equipment, and techniques for plugging the various man-made openings (boreholes, shafts, and tunnels) in and around the repository. The program, methodology, and accomplishments in regard to materials screening (including geochemical factors) and plug designs are presented. Three other publications (Refs. 2, 3, and 4) discuss the engineered barrier/borehole plugging program in less detail.

The results of the plugging studies indicate that a zone of construction disturbance with relatively high permeability will exist and impact on plug designs. Plans are to grout the fractured zone prior to the plug emplacement. A conceptual plug design for tunnels includes zones of concrete and mortared basalt blocks, interrupted at intervals along their length by seepage cutoff collars of clay-sand slurry, which extends throughout the disturbed zone. The design for shafts has only zones of compacted clay-sand mixtures and concrete seepage cutoff collars. (See attached figures from the SCR showing some conceptual plug designs.) The scheme for borehole plugging included alternating zones of gravel and clay slurry containing bentonite pellets and cement grout. The recommended backfill is Na-bentonite whose principal component is the smectite clay, montmorillonite. This clay has been well characterized generically (Refs. 5 and 6) and it is well known that bentonite has a sorptive capacity for many chemical species and swells on hydration. The Swedes (Refs. 7 and 8) have been studying the use of bentonite for a number of years in their disposal program. Wood et al. (Ref. 9) evaluated the use of bentonite-sand mixtures for a basalt repository and recommended a 50-50 mixture of bentonite and sand or crushed basalt. Other possibilities include the use of local glaciofluvial sand. Preliminary tests (Ref. 4) using plug models indicate that it is possible to design mixtures of candidate plug materials with permeabilities of $<10^{-8}$ cm/sec and also form acceptable bond strengths with the host rocks.

No significant uncertainties should exist from a geochemical standpoint prior to waste emplacement. Uncertainties in the efficacy of sealing due to installation problems could occur. Uncertainties with regard to barrier effectiveness will develop with time; minimization of these uncertainties is part of the engineered barrier program.

6. Summary of the Information Needed to Resolve the Issue by the Time for Construction Authorization Application

The conceptual designs for plugging openings seem adequate since the plugs are less permeable and have generally higher sorptive capacity than the host basalt being replaced. The potential weak link is the interface between the plug and the host rock, but the swelling of the clay should insure a good bond provided that deleterious geochemical reactions do not occur between the backfill and host rock and create a short-circuit flow path to the biosphere. Final decisions are required on the materials for use in the various plugs, seals, bulkheads, and backfilling. Laboratory and field tests are required to demonstrate the efficacy of the materials used, particularly in regard to long-term stability and interactions with the host rock.

On the basis of present knowledge, it appears that potential engineering difficulties are more of a problem than geochemical considerations.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

A large number of work elements are devoted to tunnel, shaft, and borehole sealing which implicitly include geochemical effects. The work elements more directly concerned with geochemical effects include:

1. Work Element R.1.19.D - Select materials and develop testing techniques requried to meet repository room and tunnel sealing criteria.

2. Work Element R.1.20.D - Determine the effect of temperature, rock-mass deformation, groundwater flow, and groundwater chemistry on materials used for seals.

3. Work Element R.1.21.D - Develop grouts and grouting techniques that ensure acceptable sealing of disturbed rock zone.

4. Work Element R.1.23.D - Select materials and develop testing techniques required to meet repository room and sealing criteria.

The results of the foregoing work elements and others will be the input data for Work Element R.1.25.D, which is to prepare final specifications for sealing boreholes, tunnels, shafts, and rooms.

The final specifications will be based on field test results of selected seal methods and materials tested under repository operating conditions. The test results will be compared with performance assessment tests and the specifications revised if necessary. These specifications will become the basis for the final design of sealing techniques.

8. <u>Analysis of (7) as to Completeness, Practicality, and Likelihood of Success</u>

A considerable effort is to be devoted to sealing the boreholes, tunnels, shafts, and disposal rooms for a waste repository in basalt. The program outlined by Smith et al. (Ref. 1) which includes a planned suite of field tests, seems adequate. The individual work elements of the SCR seem to cover the geochemical aspects in general. However, the potential geochemical reactions at interfaces of the backfill or plugging materials with the host rock, which could create a potential path to the biosphere, are not discussed specifically in the SCR.

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Issue No. 3.6

1. Name of Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What is the mineralogy/petrology/chemistry of the nearfield/farfield host rock prior to waste emplacement?

3. Importance of the Issue to Repository Performance

The host rock is the primary barrier in geologic waste isolation. Knowledge of the mineralogy, petrology, and chemical composition will lead to a better understanding of the genesis and the future geochemical stability of the host rock, aid in the evaluation of the effects of waste/rock interactions, and provide information for interpreting the groundwater chemistry.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(b)(3) The geochemical characteristics of the host rock;

§ 60.122 Siting requirements

(b) Favorable conditions

(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes operating within the geologic setting during the Quarternary Period would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(5) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(c) Potentially adverse conditions

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

§ 60.140 General requirements (of the performance confirmation program)

(d) The program shall be implemented so that:

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

5. Summary of the Present State of Knowledge, with Analysis of Uncertainties

Considerable information is available in the literature on basalts in general (e.g., Refs. 1, 2, and 3) and the flood basalts of the Columbia River Group of the Pasco Basin (e.g., Refs. 4 and 5). In the latter reference, these flood basalts were identified and correlated on the basis of stratigraphic position, chemistry, paleomagnetic properties, and borehole geophysical log character which have proved useful for correlation of major units over long distances. More recent details on the lithology, stratigraphy, and some interbed characteristics of Grande Ronde Basalts are discussed by Long and Davidson (Ref. 6) and Long and Landon (Ref. 7). Most of the previously discussed information has been summarized by Guzowski et al. (Ref. 8). Long et al. (Ref. 9) also reported stratigraphic conclusions based upon 250 major element chemical analyses of samples of the Grande Ronde Basalt. (See attached material from the SCR giving a brief description of the mineralogy and figures showing the stratigraphy and intraflow structure.)

Noonan et al. (Ref. 10) determined chemical compositions of the major silicate minerals of the Umtanum obtained from the colonnade and entablature interflow structural types and associated glass phases.

The mineralogy of core samples from five core wells was examined in detail by Ames (Ref. 11). From the data, a firm understanding of the average Hanford basalt flow primary mineralogy was obtained. A study of the statistical relationships of the flow unit chemical constraints showed that flow unit constituents could be roughly correlated between wells. An earlier published study of the mineralogy and rock-water-nuclear waste interactions was made by Benson and Teague (Ref. 12) as part of a larger program involving the development of a model simulating basalt diagensis in the Pasco Basin (Ref. 13).

The uncertainties connected with the mineralogy/petrology/chemistry of the host rock are minimal since the core samples can be characterized in detail. Any uncertainties resulting from insufficient sampling can be resolved in the excavation phase.

6. Summary of the Information Needed to Resolve the Issue by the Time for Construction Authorization Application

All the available information on this issue needs to be thoroughly correlated with new data to be obtained to ensure the understanding of the petrology, mineralogy, and chemical compositions in the horizontal and vertical directions in, and from, the repository horizon (Umtanum flow or the middle Sentinel Bluffs flow) is sufficient for safety assessment purposes and understanding of the regional diagenesis.

The stratigraphy and mineralogy below the Grande Ronde is not sufficiently characterized. This may not be important, but it could be important if migration downwards of released radionuclides occurs, a possibility that Guzowski et al. (Ref. 8) concluded does exist based on the available hydrologic data. In addition, more information is required to fully characterize the flow tops and interbed minerals since these are potential paths to the biosphere.

7. <u>Summary of the Planned Approaches to Testing Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

The general mineralogy, petrography, and chemistry of the Grande Ronde Basalt are well known but more detailed and extensive data in the candidate flows (Umtanum and middle Sentinel Bluffs) and the flows above and below them are required (Ref. 14).

Additional information on the composition, abundance, and texture of primary and secondary phases in the candidate flows will be determined in samples from existing and planned core holes (Ref. 15). Techniques used to obtain these data will be electron microprobe analysis, analytical scanning-transmission electron microscopy, X-ray diffraction, modal analysis (point counting), and image analysis.

Similar data are currently being collected on samples from a surface outcrop of the Umtanum flow, located at McCoy Canyon on Umtanum Ridge. The approach used to analyze primary mineral phases will be the collection of compositional data for approximately 20 samples each from the Umtanum Ridge exposure and core hole RRL-2, followed by the collection of data for approximately four samples each from additional core holes near the reference repository location.

The following information will be collected for the flows above and below the candidate horizons that are penetrated by boreholes DC-2, -4, -5 (as deepened), -12, -16A, RRL-2, and -14: (1) qualitative description of intraflow structures, (2) reconnaissance petrographic data including quantitative modal analysis, and (3) mineralogic analysis of selected samples of both primary and secondary minerals.

The mineral characterization of the candidate flows is covered in Work Element S.1.6.A and the upper and lower flows in Work Element S.1.8.

8. Analysis of (7) as to Completeness, Practicality, and Likelihood of Success

The assessed needs for additional bore holes to support site characterization (Ref. 14) and the test plan (Ref. 15) seem adequate with a possible exception being the characterization of the interbed minerals and rocks. Except by implication, the various work elements do not include interbed characterization. The discussion of the interbed materials in Chapter 6 is in general terms and no references are given. Corroboration of the data for the repository horizon, as well as additional information, can be obtained by analyses of samples taken from the initial drifts off the shafts. For completeness, a specific work element for this latter work should be included in the work breakdown structure.

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Issue No. 3.7

1. Name of the Site: Basalt Waste Isolation Project (BWIP) - Hanford, Washington

2. Statement of the Issue: What is the mineralogy/petrology/chemistry of secondary minerals of the near-field/far-field host rock prior to waste emplacement?

3. Importance of the Issue to Repository Performance

The Grande Ronde basalts have a fractured/jointed structure interspersed with vugs and possess relatively porous vesicular flow tops and bottoms. These host rock openings are generally filled with secondary minerals that are derived mostly from the alteration of basalt by circulating ground water. These joints, fractures, and vesicular flow regions are potential pathways for circulating ground water carrying radionuclides leached from the waste. The secondary mineral content is expected to be a primary sorption medium (Ref. 1) in the retardation of radionuclides.

Understanding of the diagenesis of basalt alteration and secondary mineral formation will aid in interpreting the ground water chemistry, and defining the sorptive properties of the host rock prior to waste emplacement.

4. Portions of 10 CFR 60 that are Directly Connected to the Issue

§ 60.113 Performance of particular barriers after permanent closure

(b)(3) The geochemical characteristics of the host rock;

§ 60.122 Siting requirements

(b) Favorable conditions

(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes operating within the geologic setting during the Quarternary Period would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(5) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(c) Potentially adverse conditions

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

§ 60.140 General requirements (of the performance confirmation program)

(d) The program shall be implemented so that:

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

5. <u>Summary of the Present State of Knowledge, with Analysis of Uncertainties</u>

An early review of the secondary mineral phases present at depth in the Pasco Basin was made by Benson (Ref. 2). He found that silica, clinoptilolite (a zeolite) and smectite clays are the most common secondary minerals. The later two minerals will act as sorptive materials for positively charged nuclear species.

An initial study on the nature of the minerals lining vesicle and fracture surfaces was made by Benson et al. (Ref. 3) on samples from a single core (DC2). In a later study Benson and Teague (Ref. 4), using samples from five cores, determined the relative amounts, crystallization sequence, and compositions of secondary minerals found lining vesicle and fracture surfaces.

Using the same five cores, Ames (Ref. 5) characterized the secondary minerals in great detail. (See attached materials giving a brief description of the mineralogy and figures showing the stratigraphy and intraflow structure.)

Teague (Ref. 6) examined the mineral assemblages in two slant cores drilled off the vertical core DC2 (Ref. 3). Some differences were found between the slant and vertical cores which was postulated to be due to variations in the vertical distribution of samples and the fewer slant core samples studied. The data obtained by Teague and others support a preliminary conclusion that secondary mineralization is laterally continuous, and secondary mineral assemblages and morphologies in all cores are similar.

The uncertainties connected with the mineralogy/petrology/chemistry of the secondary minerals can be minimized with detail study of core samples. Any uncertainties in the characterization of the secondary minerals in the fractures, joints, and vugs in the disposal horizon can be resolved in the excavation phase. However, minimizing uncertainties in characterizing secondary minerals in flowtops and interbeds requires wider ranging core sampling.

6. Summary of the Information Needed to Resolve the Issue by the Time Construction Authorization Application

The information available, along with that which is certain to be obtained when excavating into the grande Ronde Basalts, should characterize the secondary mineralization reasonably well with the possible exception of flowtops and interbeds. Wider ranging core samples of the flowtop and interbeds along potential flow paths may be required.

The degree of uncertainty tolerable in characterizing the secondary minerals is mostly a function of the relative importance attached to radionuclide retardation by sorption, the effect on solubility, and the understanding of the evolution of diagenesis in the Grande Ronde Basalts, which involves complex mass transfer modeling (Ref. 7). Consequently, a detailed performance assessment for a specific site seems necessary to determine the relative importance of the secondary mineralogy.

7. <u>Summary of the Planned Approaches to Testing Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

The generaly mineralogy, petrography, and chemistry of the secondary minerals in the Grande Ronde Basalt are well known, but more detailed and extensive data in the candidate flows (Umtanum and middle Sentinel Bluffs) and the flows above and below them are required (Ref. 8).

Additional information on the composition, abundance, and texture of primary and secondary phases in the candidate flows will be determined in samples from existing and planned core holes (Ref. 9). Techniques used to obtain these data will be electron microprobe analysis, analytical scanning-transmission electron microscopy, X-ray diffraction, modal analysis (point counting), and image analysis.

Similar data are currently being collected on samples from a surface outcrop of the Umtanum flow, located at McCoy Canyon on Umtanum Ridge. The approach used to analyze primary and secondary mineral phases will be the collection of compositional data for approximately 20 samples each from the Umtanum Ridge exposure and core hole RRL-2, followed by the collection of data for approximately four samples each from additional core holes near the reference repository location.

The following information will be collected for the flows above and below the candidate horizons that are penetrated by boreholes DC-2, -4, -5 (as deepened), -12, -16A, RRL-2, and -14: (1) qualitative description of intraflow structures, (2) reconnaissance petrographic data including quantitative modal analysis, and (3) mineralogic analysis of selected samples of both primary and secondary minerals. Particular attention is to be paid to variation in secondary minerals and abundance with depth, as this could provide important input to the variation of sorptive properties as a function of depth.

The secondary mineral characterization of the candidate flows is covered in Work Element S.1.6.A and the upper and lower flows in Work Element S.1.8.

8. <u>Analysis of (7) as to Completeness, Practicality, and Likelihood of Success</u>

The assessed needs for additional bore holes to support site characterization (Ref. 8) and the test plan (Ref. 9) seem adequate, with a possible exception being the characterization of the interbed secondary minerals and rocks. Except by implication, the various work elements do not include interbed characterization. The discussion of the interbed materials in Chapter 6 is in general terms and no references are given. Corroboration of the data for the repository horizon, as well as additional information, can be obtained by analyses of samples taken from the initial drifts off the shafts. For completeness, a specific work element for this latter work should be included in the work breakdown structure.

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Issue No. 3.8

1. Name of the Site: Basalt Waste Isolation Project (BWIP) -- Hanford, Washington

2. Statement of the Issue: What are the geochemical conditions expected under anticipated repository scenarios over time at the outer package interface with the host rock and backfill, in the near-field and in the far-field?

3. Importance of the Issue to Repository Performance

Geochemical conditions, in particular temperature, pH, Eh, ionic strength, and presence of complexing ligands, determine which chemical species of radionuclides are most likely to form and determine what reactions are likely to occur. Reactions of radionuclides in solution with components of the backfill, the near-field and far-field host rock including adsorption and precipitation will determine the limiting concentrations of soluble species.

If the transport pathways involve relatively large openings such as occur in vesicular basalts or within colonnade structures, geochemical conditions leading to the formation and geochemical stability of colloids and fine particulates may become very important to the prediction of rates of transport of radionuclides.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.113 Content of application

(c) The Safety Analysis Report

(1)(ii)(C) An evaluation of the performance of the proposed geologic repository for the period after permanent closures, assuming anticipated processes and events, giving the rates and qualities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

§ 60.113 Performance of particular barriers after permanent closure

(b)(3) The geochemical characteristics of the host rock;

§ 60.122 Siting Requirements

(b) Favorable Conditions

(4) Geochemical conditions that -- (i) promote precipitation or sorption of radionuclides; (ii) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(c) Potentially adverse conditions

(9) Ground water conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could affect the solubility of the waste form or chemical reactivity of the engineered barrier system so as to increase the difficulty of designing the engineered barrier system to meet the performance objectives of Sects. 60.112 and 60.113.

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

§ 60.135 Requirements for the waste package and its components

(a)(1) Packages for HLW shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

5. Summary of the Present State of Knowledge, with Analysis of Uncertainties

Information available thus far on repository geochemical conditions is derived from three sources: (1) analyses of ground water from wells in Grande Ronde basalt adjacent to the reference repository area (Gephart et al. 1979), (2) theoretical calculations based on the mineralogy (e.g., Ames 1980; Teague 1980) of the Grande Ronde basalt (Smith et al. 1980; Jacobs and Apted 1981, BWIP SCR Sec. 11.4) and (3) results of hydrothermal experiments with crushed Grande Rone basalt (Barnes and Scheetz 1979; Wood et al. 1982). Ambient temperatures in the reference repository horizons in the Grande Ronde have been estimated to range from 51 to 58¼C with the maximum temperature during the thermal period projected not to exceed 300¼C. Ground water pH is hypothesized to be controlled by the most reactive basalt component -- glass and the in-situ values are pH=9.5±0.5. Increased temperature and pressure will cause lowering of pH (to pH ∿ 6) due to increased solubility of silicic acid (Barnes and Scheetz 1979; BWIP SCR Sec. 11.4). Measured Eh values in Grande Ronde basalt ground water range from -0.22 to +0.21 but are considered imprecise with currently available instrumentation. Thermodynamic calculations, based on the assumption that iron-bearing minerals in the host rock control redox potential, yield predicted Eh values near -0.45 volts. Uncertainty concerning both measured and calculated Eh values currently constitutes a major obstacle to prediction of repository performance. Critical ligands in ground water from Grande Ronde basalt are fluoride and carbonate-bicarbonate species because of their potential to form soluble complexes with actinides and increase the mobility of Pu, for example (Cleveland 1982). Geochemical conditions have been summarized by Smith et al. (1980). An excerpt from the

BWIP SCR is attached which provides a succinct summary of the current state of knowledge.

6. Summary of the Additional Information Needed to Resolve the Issue By The Time of Construction Authorization Application

Geochemical conditions of the backfill are, strictly speaking, unknown until the backfill is selected. If, as is probable, crushed basalt from the site and bentonite are used, definition of backfill initial conditions could be straightforward. The nature of changes in conditions brought about by waste disposal activities such as excavation, and wast and backfill emplacement need to be specified, especially changes which may alter radionuclide mobility. The poising (i.e., identification of Eh controlling reactions) of the geochemical conditions and the rate of return to equilibrium after repository closure also need to be determined. Identification of conditions favorable to formation of colloids in the repository needs to be addressed.

7. Summary of the Planned Approaches to Testing, Test Methods and Investigations to Provide the Information Needs of (6)

BWIP plans to experimentally determine more precisely the geochemical conditions (ambient) present in the basalt ground water system including collection of in-situ data from drill holes for temperature, pressure, pH and Eh. Critical Eh values will be estimated in several ways (W.2.10.C) including (1) down-hole potentiometric methods using reversible electrodes, (2) redox indicator dyes and (3) measurement of selected redox couples (e.g., As^{3+}/As^{5+}) in ground water. Post-closure conditions will be extrapolated from experimental data from autoclave tests (elevated temperature and pressure) using basalt and/or mineral assemblages and site ground mechanisms and the kinetics of changes from oxidizing to reducing conditions.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

The plans for better definition of geochemical conditions both pre-emplacement and post-closure are generally adequate, but sometimes presented in a vague manner. The practicality of some of the proposed approaches to estimating Eh may be questionable. For example, it seems unlikely that attempts to make down-hole potentiometric measurements will be successful, or if such measurements are obtained, that their credibility and meaning will be established unequivocably. Indirect approaches to Eh estimation, and direct measurements at the well-head, are more likely to be successful. Plans to define Eh-pH controlling mechanisms and the kinetics of changes from oxidizing (repository operation period) to reducing (post-closure period) conditions, although not given in much detail, represent the only practical approach to assess post-closure conditions. The experimental plans presume that the rate of return to equilibrium conditions (reducing) will be rapid enough to be detectable in laboratory hydrothermal experiments and preliminary experiments seem to confirm this (BWIP/SCR, 1982). Identification of conditions favorable to colloid formation is not addressed directly but may be imbedded in related work elements.

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Issue No. 3.9

1. Name of Site: Basalt Waste Isolation Project (BWIP) -- Hanford, Washington

2. Statement of the Issue: What are the chemical reactions expected under anticipated repository scenarios over time at the outer package interface with the host rock and the backfill, in the near-field and in the far-field?

3. Importance of the Issue to Repository Performance

Repository excavation and waste emplacement will perturb the ambient chemical equilibria established over geologic time in host rock and will introduce alien materials which may not be stable over long periods in the form introduced. Chemical reactions, including dissolution, precipitation, oxidation-reduction, hydrolysis, radiolysis, complexation and sorption, among components of ground water, host rock, backfill and outer waste package will determine the formation and removal of mobile chemical species in ground water intruding into the waste repository. Identification of all chemical reactions of importance to radionuclide mobility along with quantification of rates of reaction represents a practical means of predicting the geochemical aspects of repository performance over long time periods.

4. Portions of 10 CFR 61 That Are Directly Connected To The Issue

§ 60.21 Content of application

(c) The Safety Analysis Report

(1)(ii)(C) An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, giving the rates and quantities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

§ 60.113 Performance of particular barriers after permanent closure

(b)(3) The geochemical characteristics of the host rock

§ 60.122 Siting Requirements

(b) Favorable Conditions

(4) Geochemical conditions that -- (i) promote precipitation or sorption of radionuclides; (ii) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) inhibit the transport of radionuclides by particulates, colloids, and complexes.

(5) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(c) Potentially adverse conditions

(9) Ground water conditions in the host rock, including chemical composition, high ionic strength or ranges of EhpH, that could affect the solubility of the waste form or chemical reactivity of the engineered barrier system so as to increase the difficulty of designing the engineered barrier system to meet the performance objectives of Sects. 60.112 and 60.113.

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

(11) For disposal in the saturated zone, ground water conditions in the host rock that are not reducing.

§ 60.135 Requirements for the waste package and its components

(a)(1) Packages for HLW shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

The nature of important reactions within the repository are thought to depend chiefly on specific characteristics of the host basalt, particularly its secondary mineralogy, and on ground water properties (Barney 1981a, b; Benson and Teague 1979). Proximity to the waste form (thermal and radiation gradients) and the final choice of components for the engineered barrier system will also define reactions. The present state of knowledge of solubility (dissolution and precipitation) and sorption reactions relevant to BWIP are summarized in Issues 3.1, 3.2 and 3.3 and need not be repeated here.

A variety of candidate reactions between host rock and ground water have been identified which may control intensive variables such as pH and Eh known to be important in determining radionuclide mobility. For example, Smith et al. (1980) have proposed that at elevated temperatures hydrolysis of the glassy component of Hanford basalt and precipitation of clay are the principal controls on pH. These reactions occur at different rates and have opposite effects leading to complex variation of ground water pH with time. At low water: rock ratios (equivalent to low ground water flow rates) simply dissociation of silicic acid appears to control pH. Hydrothermal experiments up to 300°C (Barnes and Scheetz 1979) confirm this hypothesis suggesting that uncertainty on this aspect is low.

Eh control is hypothesized by Smith et al. (1980) to derive from Fe(II)-bearing secondary minerals in the Hanford basalts which control oxygen fugacities. The predicted Eh range for a closed repository according to this model is from -0.45 to -0.55 volts depending on temperature (60 to 300°C). Much uncertainty surrounds this prediction because it is ased on an assumption of a very specific mineral assemblage (quartz-fayalite-magnetite) as being redox-active. Other assemblages are also possible and would lead to different calculated Eh ranges. Actual Eh measurements, although considered imprecise, suggest more oxidizing conditions (BWIP/SCR 1982). Additional uncertainty arises in considering how rapidly Eh values will return to equilibrium (or geologic control) after repository closure. Detailed reaction kinetics are lacking but results of preliminary ground water experiments (Wood et al. 1982; BWIP SCR, 1982) have suggested that return to strongly reducing conditions is rapid (hours to months), at least for experiments using crushed basalt (i.e., possible analog of backfill).

Radiolysis reactions in aqueous solutions yield, among other things, the long-lived molecular produces H_2 ad H_2O_2. Depending on conditions, oxidation potential (Eh) of the solution may either increase or remain constant. The BWIP SCR (1982) suggests that under the highly reducing environment of a sealed and decomissioned repository in basalt, a high H_2 fugacity will suppress the tendency of Eh to increase in irradiated ground water. In the absence of experimental verification some uncertainty must be assigned to this hypothesis, especially because the re-establishment of highly reducing conditions has not been demonstrated with certainty.

Short-term hydrothermal tests (Barnes and Scheetz 1979) have been conducted to determine the mineral alteration phases at temperatures expected in the repository backfill and near-field. Thus far these studies have suggested that alteration phases at up to 300°C are similar to the secondary mineral assemblages present in the original basalt.

6. <u>Summary of the Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application</u>

Identification of mineral-water reactions that control Eh in various zones of the repository represents the most important needed information (see Attachment A). The effect of ground water radiolysis on Eh values also needs to be examined experimentally. The kinetics by which repository conditions (especially Eh) will return to original equilibria, or evolve to new equilibria imposed by repository construction and waste emplacement is virtually unkown but is vital information to close out this issue. It must also be confirmed that key radionuclide redox couples, e.g., Tc(VII)/Tc(IV), will be reactive (i.e., exhibit equilibrium) with the mineral redox couple controlling repository Eh (see Attachment A). Non-equilibrium between these couples will invalidate predictions of repository performance over time which are based on Eh values derived from the mineral couple. Another sub-issue, as yet unresolved, pertains to whether accelerated dissolution of K from basalt backfill (due to elevated temperatures) will lead to degradation of the Na-bentonite additive proposed for use in the backfill. The concern here is that leached K will replace Na in the bentonite and reduce its desirable swelling properties.

7. <u>Summary of the Planned Approaches to Testing, Test Methods and Investigations to Provide the Information Needs of (6)</u>

BWIP plans to approach the definition of Eh controlling reactions using a combination of geochemical modeling and hydrothermal experiments (W.1.5.A). The modeling will be accomplished utilizing mineralogy, water chemistry, dissolved gas and thermodynamic data to develop a model that realistically describes Eh and pH as a function of temperature. Data from hydrothermal experiments for the basalt ground water system will be compared and contrasted with data from drill holes. The hydrothermal experiments are also expected to yield sufficient reaction rate information to allow estimation of changes in repository Eh values following repository closures. Effect of radiolysis on solution chemistry (presumably including redox conditions) will be determined using hydrothermal testing on radionuclide waste forms, packaging and host rock (W.1.3.A). Effect of accelerated K leaching from basalt at elevated temperature on the stability of Na-bentonite will apparently be examined under Work Element W.1.12.A but is not mentioned specifically.

8. Analysis of (7) as to Completeness, Practicality and Likelihood of Success

The plans for identifying important chemical reactions under anticipated repository scenarios over time are generally adequate, although not always presented in enough detail to permit evaluation. The proposed extensive use of hydrothermal studies with the host basalt and ground water is a reasonable approach but experimental materials and condtions need to be carefully chosen to be relevant. For example, whereas crushed basalt may be relevant for defining backfill chemical reactions, an assemblage of secondary minerals known to be major components of fracture fillings in the near-field and far-field is relevant to define reactions in these zones. Two subissues alluded to briefly in the BWIP/SCR (1982), effect of radiolysis on Eh values and effect of ground water K concentrations on Na-bentonite stability, are not dealt with explicitly in BWIP plans but seem important enough that investigation should be assured. No plans were given which would approach the questions of presumed equilibrium between radionuclide redox couples and the predominant mineral redox couple controlling Eh within various zones of the repository. Predictions of repository performance for redox sensitive radionuclides based on use of mineral couple data will not be reliable if equilibrium cannot be demonstrated (Morris and Stumm 1966). Furthermore, there is experimental evidence that equilibrium between soluble Pu(IV) and Pu(V) does not always prevail (Attachment B). A possible approach to this question could involve comparison of measured redox speciation for both the mineral couple and radionuclide couples as part of the hydrothermal testing program.

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Issue No. 4.1.2

1. Name of the Site: BWIP - Handford Site

2. Statement of the Issue: How do the design criteria, conceptual design, and functional description accommodate the retrievability option so as to be complete and accurate with respect to the performance objectives?

3. Importance of the Issue to Repository Performance

The retrievability option provides the Commission, after placement of wastes, to obtain further information concerning the workability of the repository and to use this information in making its final decision on the acceptability of permanent closure. Additionally, the staff considers that the option to retrieve the wastes must be preserved long enough to complete a program of monitoring and verification of repository performance. The design must also ensure that the option is preserved long enough to permit a decision to permanently close the repository or to take any corrective actions shown to be necessary by the verification and monitoring program. Since some of the assumptions and issues that will need to be verified and resolved by the monitoring program may not be identified until the underground facility is excavated, it is not possible to specify prior to construction the complete content of the verification program or how long it will take.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

Draft 10 CFR Part 20: Standards for Protection Against Radiation
Draft 10 CFR Part 60.111(2): Retrieval of Wastes
Draft 10 CFR Part 60.132(d): Underground Facility Design 10 CFR Part Draft
Draft 10 CFR Part 60.132(g): Water and Gas
Draft 10 CFR Part 60.132 j(2): Provision for Handling Systems to Minimize Operator Error

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Although emplacement of canistered waste in a geologic repository is intended to be permanent, provision to retrieve the canisters must be made.

Each aspect of the various repository, early conceptual design elements has to be fully evaluated for its retrievability impacts. Many underground openings and mines have been in continuous service for 50 years or more, but none with the thermal loading requirements of a repository. The phenomena of long-term thermal loading is under intensive study at the Hanford Site where large-scale field tests are currently underway. Preliminary indications, based on data obtained in the Hanford Near Surface Test Facility, is that little or no thermal effect has been observed on the basalt rock mass behavior or stability during the term of the test period at the thermal loadings investigated. (Ref.9)

The staff feels that remining of backfill to retrieve waste canisters stored for some time is probably beyond present technology owning to the evaluated temperatures and possible radiological contamination present during remining. To the best of the staff's knowledge, equipment intended for such use has not yet been successfully developed or demonstrated.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

a. Assessment of the final retrieval scenario on the ventilation system, mining environment, air scrubbing system and, if groundwater will be present in the repository, the methods and procedures for treatment of the radionuclides present in the groundwater.

b. Contingency plans for identifying and removing canisters not practically retrievable, and retrievable of less than the entire inventory (especially only a few canisters) and retrieval of damaged, and/or breeched canisters.

c. Operational procedures for remining backfill (if necessary) to affect retrieval.

d. Predictions of the repository physical environment based on in situ testing, (Attachment 1) and data obtained during ES II (attachment 2).

e. Approved plans and proceedures for health and safety of personnel during retrieval operations related to material handling, environmental monitoring, and anticipated remining problems.

f. Criteria and performance objectives for emplacement and retrieval equipment operation during likely scenarios, including remining of backfill, should remining be preserved as an option, however remote.

g. The staff offers the opinion that the logic and/or methodology of how the additional information needs (noted above) be achieved during the Site Characterization Process should be included in future amendments to the SCR.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

Thermomechanical models will be utilized to determine waste package borehole deformations as they may affect retrieval (R.1.3.A). Analyses are planned to determine that all repository systems are consistent with the retrieval option during construction (R.1.59). Assessments are planned of rock support long-term performance through the retrieval period to be supplemented by field tests (R.1.61). Retrieval procedures and equipment will be defined and designed during the final design stage (R.1.62). A detailed listing and analysis of equipment requirements will be made during the final design stage (R.1.68).

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of of Success</u>

The SCR plans for further work to fulfill the information needs are complete, but not developed in sufficient detail so that the likelihood of success and thoroughness can be assessed presently. The practicality of the plans seems

Attachment 1

Attachment 2

adequate, however, much reliance is being placed on tests, evaluations, and assessments at a late stage during final design, at which point changes to allow enhanced retrieval capability may be much more difficult and costly. The environment in the repository during retrieval, including ventiltaion, heat, water, and radiological conditions, is included in these plans, but apparently not with full and thorough consideration.

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Issue No. 4.2.2

1. Name of the Site: BWIP.

2. Statement of the Issue: What are the stress conditions at the repository location, and how do they vary with time and temperature?

3. Importance of the Issue to Repository Performance:

The existing state of stress at the repository level will be an important consideration for accepting or rejecting a rock formation for the repository location. Changes in the existing stress conditions due to (a) excavation and other construction activities; (b) temperature increase resulting from waste emplacement and eventual cooling off to preconstruction conditions; (c) time effects; and (d) any other human-induced or natural causes; have to be taken into account in designing the repository. Stability of underground openings during construction and operation, integrity of the waste canisters, and thus, the isolation capability of the repository will be affected by the pre-excavation stress conditions and their subsequent changes. Therefore, this is an important issue in the design, construction and performance of the repository.

4. Portions of 10 CFR 60 that are Directly Related to the Issue:

§60.133 Additional design requirements for the underground facility.

(a) General criteria for the underground facility.

(1) The underground facility shall be designed to provide for structural stability, control of groundwater movement and control of radionuclide releases, as necessary to comply with the performance objectives of §§60.111, 60.112, 60.113.

(2) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(b) Flexibility of design. The underground facility shall be designed with sufficient flexibility to allow adjustments, where necessary, to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(e) Design of subsurface openings.

(1) Subsurface openings shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will reduce the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment.

(i) Design for thermal loads. The underground facility shall be designed so that the predicted thermal and thermomechanical response of the host rock and groundwater system will not degrade significantly the performance of the geologic repository.

§60.140 General requirements.

(a) The performance confirmation program shal provide data which indicates, where possible, whether--

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

(b) The program shall be started during site characterization and it will continue until permanent closure.

(c) The program shall include in situ monitorign, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository to a significant degree.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§60.141 Assessment of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed to accommodate actual field conditions encountered.

(b) Surburface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacements, changes in rock stresses and strains, rate and location of water inflow into subsurface areas in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure tha the performance of the natural and engineering features are within design limits.

5. Summary of Present State of Knowledge, with Analysis of Uncertainties

The present state of knowledge supported by limited in situ stress measurements using hydrofracturing method at the repository horizon indicates that the horizontal stress is of the order of twice the vertical stress. Core discing observed during site investigation also supports this conclusion regarding the anisotropic stress conditions. There are many uncertainties in the measuring techniques, performance of test equipment and analytical techniques employed in the interpretation of data for estimating the in situ stresses. Even though detailed geotectonic modeling studies have not been performed, certain correlations between the surface geology and the orientation of stresses have been established. However, a detailed knowledge of the origin of the high horizontal stresses has not yet been established.

Most of the analyses in the conceptual design have been performed assuming a linearly elastic stress-strain relationship for basalt. A failure criterion based on maximum compressive stress at some critical point is used. Analytical techniques are available to study the thermal and thermomechanical stress conditions, excavation-induced stresses and stress changes with time. However, the input parameters that are required to perform the analyses will have to be measured in-situ and supplemented by laboratory measurements. It is possible, using the existing numerical models, to account for discontinuities, inhomogeneity, anisotropy and nonlinear and time dependent behavior of rocks.

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

Any assumptions made in the conceptual design of the repository regarding the state of in situ stress and changes of stresses with time ought to be verified by performing suitable experiments and analyses. Uncertainties in measuring techniques and analytical techniques should be identified and their effect on repository design should be bracketed by means of appropriate sensitivity analyses. All the thermal and mechanical processes inducing stresses and changing stresses over long time periods should be analyzed.

Whenever standardized techniques for either testing or analysis do not exist, standardized procedures should be developed, reviewed and documented. Sound Quality Assurance procedures should be developed in order to achieve traceability of data and reproducibility of test results within allowable margin of scatter.

In situ stress should be measured at depth to confirm the results obtained from drill holes. Stress measurements should be made in the underground test facility to determine the variation of stress with time and excavation methods. Spatial variations of stress should also be evaluated.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

The variability of in situ stress in the reference repository location (RRL) will be measured by conducting hydrofracturing tests in boreholes RRL-2, DC-4, DC-16A, and DC-17. Further tests will be conducted in the in situ test facilities in the candidate repository horizons when these facilities become available. Several in situ stress measurement techniques are being evaluated in the Near Surface Test facility (NSTF) for possible use underground. These include stress relief methods using the U.S. Bureau of Mines gage, Commonwealth Scientific and Industrial Research Organization hollow inclusion gage, door stopper, Swedish _____ cell, and cost inclusion call. In addition, the feasibility of using geophysical methods and the acoustic emission method are being investigated (R.1.14.C). Methods for validating measured in situ stress data are being developed (R.1.15.C).

8. Analysis of (7) As To Completeness, Practicality and Likehood of Success

The hydrofracturing method is the only technique that is available for measuring preexcavation in situ stresses at the repository horizons. The technique has to be used with caution because it has limitations when measuring high horizontal stresses which are greater than the vertical stress. Stress relief methods being considered for the in situ test facility have severe limitations due to the fractured nature of the basalt. Geophysical methods and the acoustic emission method may be useful in measuring in situ stress changes, but will not provide data on the magnitude and direction of in situ stresses. If in situ stress measurements cannot be validated by stress relief methods or by hydraulic fracturing, then a mine-by test with detailed monitoring of the deformation and stress changes will be necessary. Such a contingency plan is lacking in the SCR. The limitations of in situ stress measurement techniques, and the sensitivity of the design to the in situ stress data have not been fully discussed in the SCR.

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Issue No. 4.2.3

1. Name of the Site: BWIP

2. Statement of the Issue: What are the rock mass strength properties and how do they vary with time and temperature?

3. Importance of the Issue to Repository Performance

Rock mass strength determines the limits to which the critical stress combinations (net effective stress resulting from lithostatic stresses, in situ stresses of tectonic origin, construction/excavation induced stresses, thermally induced stresses and other stresses resulting from any other events initiated by human beings or nature) can be allowed to reach without causing some sort of instability of underground openings. Therefore, the issue of rock mass strength properties and their variation with time is very important to the understanding of the design construction and performance of the repository.

4. Portions of 10 CFR 60 that are directly related to the Issue

§60.133 Additional design requirements for the underground facility.

(a) General criteria for the underground facility.

(1) The underground facility shall be designed to provide for structural stability, control of groundwater movement and control of radionuclide releases, as necessary to comply with the performance objectives of §§60.111, 60.112, 60.113.

(2) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(b) Flexibility of design. The underground facility shall be designed with sufficient flexibility to allow adjustments, where necessary, to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(e) Design of subsurface openings.

(1) Subsurface openings shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will reduce the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment.

(i) Design for thermal loads. The underground facility shall be designed so that the predicted thermal and thermomechanical response of the host rock and groundwater system will not degrade significantly the performance of the geologic repository.

§60.140 General requirements.

(a) The performance confirmation program shal provide data which indicates, where possible, whether--

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

(b) The program shall be started during site characterization and it will continue until permanent closure.

(c) The program shall include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository to a significant degree.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§60.141 Assessment of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed to accommodate actual field conditions encountered.

(b) Surburface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacements, changes in rock stresses and strains, rate and location of water inflow into subsurface areas in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

5. Summary of Present State of Knowledge, with Analysis of Uncertainties

Rock shear strength in general, has two components - the frictional component and the cohesion component. Rock mass strength is a combination of the individual strength components of the 'intact' rock, the joints/discontinuities, and the interstitial fillings. Of the three general modes of strength measurements - compressive, tensile and shear - the shear strength is of greater significance in the stability analyses of underground openings even though failures do occur in the other two modes. Shear strength of the intact rock, the joints and the intersitial fillings can be experimentally determined both in the laboratory and in situ. A wide range of strength values can result by performing tests on different sizes of samples and by imposing different boundary conditions during testing. Different procedures exist for accounting for the fractures and other imperfections and estimating the rock mass strength from small scale testing. Experience with large scale laboratory and in situ testing is limited because of the time and money involved in such testing programs.

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

A good estimate of rock mass strength of basalt in the repository horizon is needed. Joint spacings, fracture patterns, nature of interstitial fillings and their spatial variability should be established during site characterization.

Upper and lower bounds of strength parameters should be established by means of a detailed laboratory and in situ testing program. Effects of time and temperature on strength properties should establish. If standardized testing techniques are not available, standardized procedures should be developed, reviewed for quality and documented in order to achieve traceability of data and reproducibility of test results within allowable margin of scatter.

7. Summary of Planned Approaches to Testing, Tests, Test Methods, and Investigatons to Provide the Information Needs of (6)

Laboratory tests will be conducted on candidate repository horizon samples obtained from the principal boreholes (RRL-2) and from the exploratory shelf testing program. These tests will provide laboratory seal strength properties for the anticipated repository conditions, including time dependence, pore pressure, and pointing effects. These tests results will be supplemental with rock mass geologic characterization information, and appropriate rock-mass tests to be selected on the basis of results from the Near Surface Test Facility (NSTF). Rock mass test results will be correlated with geologic mapping and laboratory physical and mechanical property tests of rock from the rock mass test location. Results from this correlation effect will establish the spatical variation of rock mass behavior within the reference repository.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

Rock mass strength determination can only be made with rock mass test data from the exploratory shafr testing program. Laboratlry test results supplemented with rock mass geologic characterization information can provide estimates of rock mass strength. Hence. the NRC will have to review the rock mass testing program to be condicted from the exploratory shaft to evaluate its completeness and applicability to the repository design effort. The in situ test program will establish the spatial variabilty of rock mass behavior in as 125,000 square foot area of the RRL.

Spatial variability within the RRL can be determined only from laboratory rock strength tests on core from horeholes drilled in other areas of the RRL, supplemented with a strength reduction factor for the basalt that has been obtained from the in situ rock mass tests. The effect of temperature time, and moisture on rock mass strength can be determined from the testing program to be conducted from the exploratory shaft, which is yet to be supplied by the BWIP to the NRC.

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Issue No. 4.2.4

1. Name of the Site: BWIP.

2. Statement of the Issue: What are the rock mass deformation characteristics that may affect stability and how do they vary with time and temperature during construction and operation of the repository?

3. Importance of the Issue to Repository Performance

A meaningful analysis of the stability of underground openings can be made only after establishing what constitutes instability or failure. That is, establishing the level of deformation that can be tolerated within which no significant damage can occur to the underground opening. Establishing representative stress-deformation characteristics of the rock mass is a first step in assigning limits for tolerable levels of deformation, and thus defining 'failure.'

The essential steps in the stability analysis of underground openings are: (a) computing critical stresses at critical points in the rock mass; (b) estimating rock mass strength at those critical points; (c) comparing stresses and strengths to determine if stresses are within the strength values; (d) estimating deformation to determine if the resulting deformations are within tolerable limits; and thus (e) establishing an overall margin of safety. Deformation analysis based on experimental data and analytical models, thus becomes a very important issue in designing the repository and assessing its performance through time.

4. Portions of 10 CFR 60 that are Directly Related to the Issue

§60.133 Additional design requirements for the underground facility.

(a) General criteria for the underground facility.

(1) The underground facility shall be designed to provide for structural stability, control of groundwater movement and control of radionuclide releases, as necessary to comply with the performance objectives of §§60.111, 60.112, 60.113.

(2) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(b) Flexibility of design. The underground facility shall be designed with sufficient flexibility to allow adjustments, where necessary, to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(e) Design of subsurface openings.

(1) Subsurface openings shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will reduce the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment.

(i) Design for thermal loads. The underground facility shall be designed so that the predicted thermal and thermomechanical response of the host rock and groundwater system will not degrade significantly the performance of the geologic repository.

§60.140 General requirements.

(a) The performance confirmation program shall provide data which indicates, where possible, whether--

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

(b) The program shall be started during site characterization and it will continue until permanent closure.

(c) The program shall include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository to a significant degree.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§60.141 Assessment of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed to accommodate actual field conditions encountered.

(b) Surburface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacements, changes in rock stresses and strains, rate and location of water inflow into subsurface areas in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

5. Summary of the Present State of Knowledge, with Analysis of Uncertainties

General stress-deformation characteristics for different rock types have been studied in the laboratory for quite some time. However, most studies have dealt with intact rock specimens of very small sizes. The actual stress-deformation behavior will be controlled by the imperfections such as the joints, fractures and the strength of the interstitial fillings and these cannot generally be represented in small scale test specimens. Rock mass may also exhibit time dependent deformations even if no additional loads are imposed on it. The rate of deformation may vary with the stress level (nonlinearity) and the temperature level. Stress-deformation characteristics may be different in different directions (anisotropy) and vary from point to point (inhomogeneity).

Linearly elastic stress-strain behavior has been assumed in the conceptual design of the repository without taking into account the deformability of the rock mass. Such an analysis does not represent a realistic situation for the jointed rock.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Stress-deformation characteristics for the intact rock and the rock mass have to be established by means of large scale in situ testing supplemented by small scale laboratory tests. Nonlinearity, time dependence and spatial variability will have to be characterized so that a representative set of input parameters can be used in the repository design. The establishment of a limit to allowable deformations should be the most essential objective of the experimental investigation to understand any underground opening behavior. Thermal stresses and resulting deformation in a repository must be measured by conducting heater tests in situ. Large scale in situ tests supplemented by small scale laboratory tests will be neededto bracket the range of anticipated rock mass behavior.

7. Summary of the Planned Approaches to Testing, Test Methods, and Investigations to Provide the Information Needs of (6)

Constitutive models will be developed for predicting rock mass deformations, and sensitivity analyses will be completed to examine the relationship between the natureal and engineered systems. A failure criterion will also be developed to incorporate the rock mass features. The jointed block test in the NSTF will continue to investigate time and temperature effects on deformations. Laboratory tests on cores extracted from candidate horizons will also continue. Full-scale rock mass deformation tests and measurements will be made in the exploratory shaft, and additional samples will be made available for laboratory tests. Rock mass deformation resulting from excavation will be measured in situ, and small scale heater tests will be conducted to determine the applicability of the NSTF heater test results to the candidate horizon.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

A carefully developed constitutive model or models that recognize the spatial variability of rock properties, can, when considered with results of measurements, provide useful predictor of rock mass deformations. The complete rock mass deformation history resulting from excavation is very difficult to measure in the field due to (1) the "uncertainty principle" in that the act of measuring or accessing the measurement disturbs the media leading to an inaccurate measurement, and (2) the rock mass deformations resulting from excavation are very nearly instantaneous for the elastic deformations, and more time-dependent for the plastic deformations. Thus the complete rock mass deformations that result in rock mass dilation and closure may not be measured unless great care and prior planning for access are allowed. Deformations in the basalt rock mass could be small, so care must be taken to initially assess the likely magnitudes so that actual deformations are well within the range of the planned equipment.

Small-scale heater tests to assess the relevance of the NSTF results to the candidate horizon must be performed with great care, so that the differences of water, initial temperature, and stress state are recognized.

The likelihood of success of the planned approaches and tests is high, provided the several points rasied above are investigated and incorporated as appropriate into the program.

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Issue No. 4.3.1

1. Name of the Site: BWIP

2. Statement of the Issue: How does construction modify the groundwater flow characteristics in and around the underground facility as related to long-term isolation capability in the presence of coupled in situ, excavation induced, and thermal stresses?

3. Importance of the Issue to Repository Performance

Construction of the underground facilities will affect long-term performance of 1the repository because construction will modify the groundwater flow characteristics. Isolation and release rates of radionuclides are strongly influenced by these groundwater flow characteristic. Predictive models will be required because of lack of experience with the time frames included. Predictive models will require reliable input to assess the effects of construction on the groundwater required through time.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.112 Overall Performance Objective
§ 60.133(d) Control of Water and Gas

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Present knowledge relevant to this issue includes:

- o Hydraulic Heads - existing data are questionable because of the measurement technique (i.e., using packers). The effects of repository construction on the existing groundwater regrime, once known, can be estimated reasonably well.

- Horizontal Hydraulic Conductivity - existing measurements may not be representative bulk values. The effects of repository construction on this parameter have been estimated but are not well known.

- Vertical Hydraulic Conductivity - no measurements exist. The effects of repository construction on this parameter have been estimated but are largely unknown.

- Specific Storage - one reliable measurement exists from the DC-7/8 pump test. Less reliable measurements elsewhere in the Grand Ronda basalts also exist. This is not considered a critical parameter and will probably not be significantly affected by repository construction.

- Geology - regional geology is well-known. Specific depths, thickness, and structure of the candidate repository horizons are variable and not very well known.

- Repository Design - overall design is well known although some specific details have not been determined. (e.g. the exact distance between the repository roof and the candidate flow top.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

The major knowledge gap is related to the lack of understanding of the groundwater flow system. Representative bulk values of hydraulic conductivity (vertical and horizontal) headings and specific storage are lacking.

Effects on the groundwater system caused by the construction of a repository are fairly well-known qualitatively although quantitative information is lacking because of the poor understanding of the flow system properties. A predictive model will be needed to assess the effects of construction on the grondwater regime through time. Further study of alternative designs for waste placement (vertical vs horizontal) should be made with the predictive model to assess the influence of lthe effectiveness of the engineered barrier System in light of anticipated post-closure vertical groundwater flow.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Some limited testing for bulk hydrogeologic parameters is planned such as at the DC-16 A, B, and C well cluster. Heads will continue to be measured using packer techniques during the drill and test sequence.

The effects of construction on the ground water regime will be evaluated by instrumenting and testing in the exploratory shaft and test facility. Effects will also be predicted using near-and-far-field groundwater flow models.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

Proposed investigations are inadequate to evaluate the groundwater flow system. More bulk measurements of hydraulic parameters and reliable, time coincident head measurements are required.

Predictions of the effects of repository construction on the groundwater regime can be made reasonably well with existing models and can then be compared to effects measured in the exploratory shaft and test facility. Prediction of the thickness of the candidate repository horizons will probably be very difficult or impossible but is needed to understand the groundwater regime.

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Issue No. 4.3.1.1

1. Name of the Site: BWIP

2. Statement of the Issue: What will be the rate of groundwater inflow (recharge) of the underground facility as related to long-term isolation capability in the presence of coupled in sitr, excavation induced, and thermal stresses?

3. Importance of the Issue to Repository Performance

Groundwater inflow will affect conditions of long term preformance in that inflow rate will affect the commencement of saturation of the decommissioned repository and flow away from lthe repository

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.133(d) Control of Water and Gas

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Present knowledge of the proposed geometry of the repository is reasonably good although the distance from the repository roof to the Umtanum or middle Sentinel Bluffs flow top has not been currently predicted accurately and may vary considerable. Existing hydrologic heads are know well enough to make preliminary predictions of inflows. Properties of the backfill have been measured under laboratory conditions. These properties will allow prediction or analysis of the saturation times through the repository.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Applicable

The major gap is the lack of a bulk value for vertical permeability of the candidate repository horizons. Other less important gaps include the lack of exact information on the dense Umtanum or middle Snetinel Bluffs flow thickness and the effects of temperature and stress upon permeability.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Proposed investigations include an exploratory shaft and test facility in which hydrogeologic tests will be conducted.

8. Analysis of (7) As To Completeness, Practicality and Likelihood Success

The proposed investigations should resolve this issue providing that the design and instrumentation of the exploratory shaft and test facility are sufficient to obtain bulk measures of vertical permeability. Prediction of the thickness of the candidate repository horizons will probably remain extremely difficult although this will not have a critical impact upon water inflow unless the excavation penetrates the flow top or distrubs the dense enough to cause significant inflow.

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Issue No. 4.3.3

1. Name of the Site: BWIP

2. Statement of the Issue: What are the physical conditions (e.g. temperature, pressure, stress, permeability, etc) anticipated in and around the underground facility through time as related to long term isolation capability?

3. Importance of the Issue to Repository Performance

These physical conditions must be predicted through post-closure time since they will affect the long term performance of thel repository. They will also materially affect the long term performance of the engineered barrier system depending on geochemical and geohydrologic assumptions.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.111 Performanced through Permanent Closure
§ 60.112 Overall Performance Objective
§ 60.113 (a) General Provisions
§ 60.133 Additional Design Requirements for the Underground Facility
§ 60.134 Design of Seals for Shafts and Boreholes
§ 60.140 Performance Confirmation Progran - General Provisions

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Present knowledge that could influence repository design related to these physical conditions has cnsiderable undertainty becuase man has not sesigned facilities in the past for the time frames associated with repositories. Critical uncertainty is related to heat load and performance of the engineered barrier system to include maintaining the integrity of the waste packages. Present knowledge of these physical conditions includes:

- In Situ Stress Distribution Indirect indicators of hogh horizontal stresses are evidence by core disking. Hydro fracturing estimates of in situ stress has also been performed in two holes. These results indicate that at least in the Umtanum flow there are driving possibilities of the ratio of the vertical to horzontal stresses exceeding 2 to 1 and perhaps reaching values of 3 to 1 or higher. The current uncertainties in these values of in situ stress are important since they directly relate to heat load and excauation induced stresses.

- In Situ hydrologic heads and permeability Existing hydrologic heads are known well enough to make preliminary predictions of flow. A major gap is the lack of a bulk valve for vertical permeability of the candidate repository horizons. Permeability will very with geochemical stress loads but the relationship is not fully understood.

- Thermal Conductivity - this has been measured in the lab for intact samples of Columbia River basalts. The in situ thermal conductivity will also depend on the nature and geometry of the fracture system.

- Heat Capacity - this has been measured in the lab for intact samples of Hanford basalts with unspecified degrees of saturation. Heat capacity increases with temperature.

- Thermal Expansion Coefficient - this has been measured in the lab for samples of intact Hanford basalts. The in situ value will be affected by the presence of large and small scale discontinuities.

- Waste Package Heat Generation - this has been calculated as a function of time for the expected radioactive waste content and age.

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>

Current knowledge gaps include:

- <u>In Situ Stress</u> - the horizontal stress field and its variation with direction is not known.

- <u>Thermal Conductivity</u> - the in situ value for the candidate repository horizons not been determined, but is expected to be close to the laboratory determined value.

- <u>Vertical Permeability</u> - A bulk valve for the vertical permeability in the rock mass of the candidate repository horizons is not available.

- <u>Heat Capacity</u> - the in situ value for the candidate repository horizons has not been determined, but is expected to be close to the laboratory determined value.

- <u>Thermal Expansion Coefficient</u> - the in situ value for the candidate repository horizons has not been determined. The effects of fractures and discontinuities are expected to be significant.

- <u>Repository Construction</u> - the method of repository construction has not been decided. The extent of the disturbed zone around the rooms and tunnels will depend on the construction method.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

Additional laboratory in situ tests are planned to include time effects; both at the Near Surface Test Facility and at-depth. At-depth testing will include additional hydrofracturing and various overcoring techniques in the underground test facility.

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

Investigations other than the at-depth in situ tests should be used primarily to refine procedures. At-depth in situ testing is required for appropriate design values.

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Issue No. 4.4.3.1

1. Name of the Site: BWIP

2. Statement of the Issue: What are the physical conditions (e.g., temperature, pressure, stress, permeability, etc.) anticipated in the backfill through time as related to compliance with radionuclide release rates from the engineered system and overall system.

3. Importance of the Issue to Repository Performance

The physical conditios in back fill will influence the degree to which this component of the engineered system will limit or control the release of radionuclides.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

§ 60.112 Overall Performance Objective
§ 60.113(a)(1) Engineered Barrier System
§ 60.133(h) Engineered Barriers
§ 60.140 Performance Confirmation Program - General Provisions

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Proposed backfill materials which may fill the emplacement holes around the waste package and possibly to fill the tunnels are mixtures of crushed basalt, bentonite, and water in basalt/bentonite ratio 75/25 to 50/50. Present knowledge of backfill properties includes:

- Deformation Modulus - drained and undrained initial tangent moduli have been reported for a variety of materials used in embankment dams.

- Thermal Conductivity - this has been measured for a number of bentonite/sand ratios. Reported values decrease with increased bentonite content and increase with increased water content.

- Long-term Stability - very little data, exists on long-term changes in backfill properties caused by radiation, elevated temperatures or leaching.

- Clay Swelling Pressure - this has been measured in the laboratory for some potential backfills.

- Hydraulic Conductivity - this has been measured in the laboratory for a number of bentonite/sand mixtures. The value determined depends on the imposed hydraulic gradient, temperature, composition of permeating fluid, the radiation and thermal history of the backfill, and the composition and density of the backfill material.

6. Summary of the Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

To determine the physical conditions anticipated in the selected backfill through time the deformation moduli, thermal conductivcity, heat capacity, long term stability, clay swelling pressures and volume change capacity, and hydraulic condictivity of the backfill are required. This data must be determined for the coupled stress, temperature and hydraulic gradient conditons expected in the vicinity of the waste packages in the repository. The physical properties of the backfill will depend strongly on the gradation and type of backfill and the placement and compaction methods used. Knowledge gaps include:

- Deformation Modulus - this has not been measured for the proposed basalt/bentonite backfills. It should be determined for the anticipated repository conditions.

- Heat Capacity - no information.

- <u>Thermal Conductivity</u> - this has not been determined for the proposed basalt/bentonite backfills under anticipated repository conditions.

- <u>Long Term Stability</u> - this has not been determined for the basalt/bentonite backfills.

- <u>Clay Swelling Pressure</u> - this has not been measured for the basalt/bentonite backfills under anticipated repository conditions.

- <u>Volume Change Capacity</u> - the swelling (or shrinking) of the basalt/bentonite backfills due to changes in moisture content and temperature must be determined for anticipated repository conditions.

- <u>Hydraulic Conductivity</u> - this has not been measured for the basalt/bentonite backfills under anticipated repository conditions.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

The properties and anticipated physical conditions of the selected backfill will be analyzed in the laboratory and in test sections in the underground test facility.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>

Proposed investigations are generally adequate, however, it is not clear that the results will be available for the Safety Analysis Report prior to licensing. This is important because decisions will have to be made in a timely manner on items such as the selection of backfill around the waste package and the selection for backfill in the tunnel (if needed).

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Issue No. 4.5.1

1. Name of the Site: BWIP - Hanford Site

2. Statement of the Issue How is repository performance expected to be affected by construction of the Exploratory Shaft?

3. Importance of the Issue to Repository Performance

The exploratory shaft is the first major repository construction activity to occur at the BWIP site. The shaft will be constructed within a candidate area selected for the construction of the repository and will probably be incorporated into the final repository design. Therefore, it is very important that the impact of exploratory shaft construction on repository performance be examined very carefully by NRC and DOE.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

60.11(6)(iii)

... The (Site Characterization) report shall include ....provisions to control any adverse safety-related effects from site characterization...

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Experience in sinking a shaft in basalt to a depth of approximately 4000 feet is very limited. The amount of fracturing of host rock during excavation, or after excavation due to stress redistribution ia uncertain. Sealing of aquifers, sealing of liner to host rock, and methods of verifying rock characteristics and seal integrity are areas of uncertainty. The technology for sinking a shaft of the proposed diameter does exist (e.g. drill and blast method). However, the technology is not proven for boring very deep shafts in basalt (NUREG/CR-2854).

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Long-term performance of the repository could be affected by the excavation of the exploratory shaft. Since excavation of the exploratory shaft is scheduled to occur within the next year, DOE needs to address this issue at an early date in site characterization. Seals must be constructed so as not to create preferental pathways for groundwater or radioactive waste migration that could compromise the repository. To insure the effectiveness of shaft sealing, these are a number of areas that require further investigation. Of major concern is the long-term stability of seals, the test methods to measure seal degradation, and an analytical procedure to extrapolate test results to the long term. Other concerns requiring study are wall rock damage caused by eccavation andstress redistribution, grout material optimization for fractures and large openings, placemeent techniques, and methods of measuring seal reliability. DOE needs to address these concerns early as after-the-fact remedies may have an irreversible impact on the quality of the repository.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

Blind-boring with a big-hole drill rig is the method proposed for shaft sinking the exploratory shaft. A steel casing with integral portholes will be segmentally assembled on the surface, floated into position, and then fully grouted in place from the drilled depth to the surface (RSD -BWI-TP-007, 1981). The construction affected zone around the exploratory shaft will be characterized by extending some test holes through the this disturbed zone. Examination of core and in-hole tests will provide information on the extent, character, and permeability of the construction-affected zone.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>

The technology for sinking a 9-foot diameter shaft to 4000 feet is not proven and will require state-of-the-out technology. Even if the shaft can be successfully drilled, there is insufficient information in SCR plans to assess the likehood of success in minimizing its impact on the repository. In flow of water from acquipers is not well known, the examination of grout rocks interpers at selected portholes does not insure a good seal over the length of the shaft, revised examination of rock cores from portholes may not be indicative of the critic distributed zone around the shaft, and there is not an adequate quality insurance program to insure the effectiveness of shaft seals. The seal design shown in figure 10-14b utilizing basalt blocks and copper seals have no current design basis. The 10 work elements listed in table 14-2 outline the many concerns of scaling, but there is no logical approalch presented on how this information will be commected or how it will be used to design a sealing system.

Magor questions still remain unanswered as to the long-term stability of seals, the tests to measure seal degradation, the analytical procedures needed to extrapolate short-term behavior to long-term performance, great material and placement optimization, methods to measure seal reliability, and the effects on shaft stability and seal performance of lines removal during final closure operations.

References:

RSD-BWI-TP-007, 1981, "Test Plan for the Exploratory Shaft Test Facility I in Basalt," Rockwell Hanford Operations, Hanford, Washington.

NUREG/CR-2854, 1982, "Evaluation of Alternative Shaft Sinking Techniques for High-Level Nuclear Waste (HLW) Deep Geologic Repositories," Golder Associates for the Nuclear Regulatory Commission, Washington, DC.

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BWIP DSCA/SIA 4.5.2/RHODERICK

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Issue No. 4.5.2

1. Name of the Site: BWIP - Hanford Site

2. Statement of the Issue:

6.2 How is repository performance expected to be affected by repository shafts?

3. Importance of the Issue to Repository Performance:

Constucting shafts, tunnels, and boreholes in geologic media alters the natural setting and creates preferential pathways to groundwater flow and consequently migration of radionuclides. Since these represent a path of least resistance (unless sealed properly) they could adversely affect the containment capabilities of the repository over the long term.

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue:

§60.133 Additional design criteria for the underground facility.

(a) General criteria for the underground facility.

(f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment.

§60.134 Design of seals for shafts and boreholes

(a) General design criterion. Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that will compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure.

(b) Selection of materials and placement methods. Materials and placement methods for seals shall be selected to reduce, to the extent practicable, (1) the potential for creating a preferential pathway for groundwater; or (2) radioactive waste migration through existing pathways.

§60.142 Design testing

(a) During the early or developmental stages of construction, a program for testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted to the extent propropriate, the testing program shall be conducted in situ.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectivenwss of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation to seal boreholes and shafts.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Several technical areas must be addressed to resolve this issue. The major areas are discussed below:

1. Design of Shafts with Consideration for Long-Term Sealing. The amount of information on damage to the host rock due to excavation and construction of large underground openings is limited. If the host rock is extensively fractured during excavation, or after excavation due to stress redistribution, the effectiveness of the plugging system to retard flow will be diminished by flow bypassing the plug

(Taylor, 1980). This could be a problem at BWIP due to the high horizontal stresses in the host rock and the closely-spaced fracture patterns in some of the basalt flows. If the combination of these two phenomena cause significant fracture operatures to form, vertical flow could increase in the surrounding rock, circumrenting the sealing system. Also, if shaft freezing is necessary for sinking the repository shaft through acqufer zones, it may become very difficult to repair the damage to the host rock caused by freezng the rock. The damaged area around boreholes is not as signficant as around shafts and tunnels, based on current research (Daemen, 1982).

2. Installation Procedures for Sealing. The placement techniques used for sealing openings could be a controlling factor in seal performance (D'Appolonia, 1979). Several preconceptual design reports have established possible procedures and identified the equipment to be used in sealing openings (Taylor, 1980; Fernandez, 1976). However, only one field test in sealing openings has been performed. Therefore, most of the techniques are not field tested.

3. Compatibility of Seal Materials to the Host Rock and the Repository Environment. The compatiblity of the physical and chemical characteristics of the seal material to the host rock and the repository environment is an important parameter in seal design (D'Appolonia, 1980). Incompatibility could result in extensive seal deterioration through chemical and physical processss. This has been the main area of sealing investigations by DOE. Technical areas which still remain unresolved are; 1) achieving low permeabilities in the sealed area and, 2) the impact of waste induced thermal loading on the seal materials.

4. Importance of Repository Sealing to Repository Performance. The importance of repository sealing to repository performance must be determined to provide performance objectives and design criteria for the repository sealing system. This can ber accomplished by

sensitivity studies and consequence analyses of repository performance under varying degrees of repository seal performance. These studies must be based on reliable site information in order to be useful.

5. Long-Term Stability of Seals. The performance of the sealing system must be adequate over a time span which exceeds any reasonable test time period. Therefore, alternative analytical methods must be utilized, based on laboratory and field data to adequately characterize the integrity and adequacy over long time periods.

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

Long-term performance of the repository could be affected by the type of excavation methods used. Since excavation of the exploratory shaft is scheduled to occur within the next year, DOE needs to address this issue at an early date in site characterization. The additional information needs outlined under Section 6 of Site Issue Analysis No. 4.5.1 will be relevant to the repository shafts. This information includes long-term stability of seals, rock characterization around the opening before and after excauation, selection of optimum seal materials, development of optimum placement techniques, and methods to evaluate seal effectiveness. Assuming that this information is obtained information will be needed prior to the time of construction authorization. This will include:

1. The scale-up effects of sealing shafts to 19 feet in diameter,

2. Characterizing the rock in the vicinity of the shafts,

3. Determining the increase in the zone of disturbance caused by the size increase and alternative methods of construction

4. Effect of freezing on point disturbance and seal effectiveness, and

5. Effect of possible freezing on lthe foundation design of surface facilities.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

The SCR outlines a test program in the description of the exploratory shaft in Chapter 17. This includes determining the extent and character of the distrubed zone, water inflow pressure and permeability, grout homogeniety, and grout strength. Computer modeling will be done to define an acceptable flow rate for the seal system (Chapter 10). A proposed seal design is shown in Figure 10-146. Table 14-2 in Chapter 14 outlines 10 work elements designed to resolve the key BWIP sealing issue.

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>

These are a number of deficiencies in the DOE plan for sealing. First, there is no distinction between sealing boreholes and sealing shafts. Although the materials may be the same for both, placement techniques, environmental conditions, and testing techniques may be very different. Second, Table 14-2 in Chapter 14 does not lay out a logical approach for seal investigation nor does it specify how the information will be used in seal design. Third, there is no procedure presented for estimating the long-term effectiveness of grouts. Fourth, theere is no quality assurance program established for determining the effectiveness of the grouting operation. Fifth, there is no mention of research to evaluate the scale up effects of sealing for repository shafts. Last, the schedule for the development of seal materials does not show selection of candidate sealing materials until 1984. This seems late both for the exploratory shaft and repository shaft construction.

References:

Daemen, Jack J.K., 1982, "Quarterly Report, December 1, 1981-February 28, 1982, Rock Mass Sealing," NRC Contract number NRC-04-78-271, University of Arizona, Tucson, Arizona.

D' Appolonia Consulting Engineers, Inc., 1979, "The Status of Borehole Plugging and Shaft Sealing for Geologic Isolation of Radioactive Waste," ONWI-15, prepared for Office of Nuclear Waste Isolation, Columbus, Ohio.

D' Appolonia Consulting Engineers, Inc., 1980a, "Repository Sealing Design Approach - 1979," ONWI-55, prepared for Office of Nuclear Waste Isolation, Columbus, Ohio.

Fernandez, R., 1976, "Borehole Plugging by Compaction Process, Final Report," Y/OWI/Sub-7087/1, The Charles Stark Draper Laboratory, Inc., Cambridge, Massachusetts.

Taylor, C., and O'Rourke, J.E., 1980, "Preconceptual Systems and Equipment for Plugging Man-made Accesses to a Repository in Basalt," RHO-BWI-C-67, Woodward - Clyde Consultants, prepared for Rockwell Hanford Operations, Hanford, Washington.

Document Name: ~~#~~5
BWIP DSCA/SIA ~~6~~.1/PRESTHOLT

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Issue No. ~~5~~ 4.1

1. Name of the Site: BWIP

2. Statement of the Issue: What are the structural discontinuities of the Pasco Basin under present conditions?

3. Importance of the Issue to Repository Performance

Identifying and evaluating structural discontinuities in the Pasco Basin is significant to repository performance because structures, such as faults or fracture zones may impact regional groundwater flow creating pathways for radionuclide migration and may impact constructability and design of the repository.

4. Portions of 10 CFR Part 60 That Are Directly Related To The Issue

60.122(c)

(b) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system.

(21) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(22) Geomechanical properties that do not permit the design of underground openings that will remain stable through permanent closure.

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

In selecting ~~in~~ a reference repository location, the following investigations have been undertaken to evaluate the structural setting of the Pasco Basin:

surface geologic mapping, structural analysis of Yakima Folds, borehole geologic studies and geophysical surveys. The results of these investigations have been integrated to identify relatively intact blocks of Saddle Mountains, Wanapum, and upper Grande Ronde basalt bounded by known or inferred geologic structure (C.W. Meyers, 1981).

A major assumption in the interpretation of bedrock structure in the Pasco Basin is that major geologic structures in the Grande Ronde basalt have deformed the uppermost Saddle Mountains basalts. Using this assumption, a structure contour map on the top of the Grande Ronde was developed by extrapolating from the top of bedrock structure contour combined with isopachs maps of Saddle Mountain and Wanapum basalts.

One uncertainty associated with this analysis is the basic assumption that structure in the Grande Ronde will be reflected in the uppermost Saddle Mountain basalts. Recent investigations (U.S. NRC, 1982) indicate that the Umtanum Ridge Structure may be part of an imbricate thrust zone and that the uppermost .6 MY old, basalts are not involved in thrusting and/or folding. Therefore, structure at depth is not necessarily reflected in the uppermost basalts.

A second uncertainty in this analysis is the validity of the top of rock as a structural datum and the extrapolation of this datum to deeper horizons. Top of rock in the Pasco Basin is in places an erosional unconformity. To determine where the top of bedrock is an erosional surface, the uppermost basalt unit was identified, but cores were available from only approximately 5% of the borings that intersected the basalt/sediment contact. Although this procedure is necessary, given the limited (approximately 15) boreholes that intersect the top of the Grande Ronde basalt, it introduces uncertainty into the accuracy of the structure contours. It is not clear whether or not any attempt has been made to reconstruct the paleotopography of the bedrock surface or of the Rinfold surface to define paleodrainage channels that modify the top of bedrock. In addition, these investigations have been aimed at the identification of major structures. Subtle faults and fracture zones may not have been detected.

6. <u>Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application</u>

Additional borings and geophysical surveys will be needed to investigate inferred structures identified in the Cold Creek syncline. Structures inferred from aeromagnetic anomalies may in fact represent stratigraphic discontinuities such as flow pinchouts or steeply dipping flanks of folds. This work should be coupled with hydrogeologic testing to determine whether or not major structures affect regional groundwater flow. In addition, borings and geophysical surveys will be needed to identify faults and/or fracture zones that were not detected in previous investigations aimed at identifying major structures.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

To assess structural discontinuities in the Pasco Basin the following investigations are planned:

1. Detailed logging and petrographic analysis of core from additional borings and detailed fracture and lithologic logging of exposures of the candidate repository horizons to determine the primary internal structure of the candidate repository horizons in the Reference repository location (RRL).

2. Review existing mapping and complete local shallow geophysical surveys to define northwest trending structure. Areas of focused investigation include Hog Ranch axis, Jackass monocline and Snively Basin.

3. Geologic mapping, ground geophysics and re-examination of existing drill-core data will be accomplished to determine the nature of brachyanticlines southeast of Rattlesnake Mountain and at Gable Butte-Gable Mountain.

4. Analyze tectonic fractures in the Grande Ronde Basalt in exposures north of Vantage and in synclinal areas west of the Pasco Basin to determine the orientation and spacing of tectonic fractures and breccia in the Cold Creek Syncline. ~~(relatively underground areas)~~

5. A gridded gravity survey is being completed in the reference repository location. This data will be evaluated along with seismic refraction data and vertical seismic profile data to evaluate geophysical anomalies in the ~~reference repository location.~~ RRL.

6. Additional data from boreholes RRL-2 and DC-16A will be analyzed to further define the strike, dip, fold amplitude and wavelength in the Umtanum flow in the ~~reference repository location.~~ RRL.

7. Exposures at Sentinel Gap, Smyrna Bench, Rattlesnake Mountain and Snively Basin will be mapped. In addition, geophysical surveys and possibly trenching and shallow drilling will be completed. These studies are aimed at an evaluation of the geometry, displacement, and age of faults in the Pasco Basin.

8. Analysis of (7) as to Completeness, Practicality, and Likelihood of Success

To date, significant structural discontinuities, such as the known and inferred structures defining intact blocks of basalt in the ~~reference repository location~~ RRL, have not been completely identified and characterized by geologic and geophysical investigations completed by the DOE. Planned geologic and geophysical studies may not successfully characterize these structures. After evaluation of various geophysical surveys at Gable Butte anticline, Cochran (ST-14, Appendix E) states that "it is difficult to say without additional drill hole information whether the northern limb of the structures has been disrupted by faulting." Evaluating gravity surveys at the eastern end of Yakima Ridge anticline, Cochran (1982) states that the "complex relationship between basalt surface elevation and Bouguer Gravity emphasizes the need for borehole control before making absolute interpretations from gravity data." It appears that the planned geologic and geophysical investigations described in chapter 13 of the SCR will not fully characterize the known and inferred structures in the Cold Creek syncline.

Limited data exists on the nature of small scale faults and fractures in the Cold Creek Syncline. The predictability of these features may be impossible. Data collected from outside of the Pasco Basin, i.e., north of Vantage, will be of little use in defining similar features on the basalts in the Cold Creek Syncline. In addition, data from vertical boreholes on basalt are biased against vertical fracturing.

References:

1. Myers, C. W., 1981, "Bedrock Structure of the Cold Creek Syncline Area," in Myers, C. W. and Price, S. M., eds., Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

2. U.S. Nuclear Regulatory Commission, NUREG-0892, "Safety Evaluation Report related to the operation of WPPSS Nuclear Project No. 2," 1982.

3. Price, E. H., 1982, "Distribution of Strain Features Criteria selected Yakima fold structures and extrapolation of their nature into the Cold Creek Syncline area," in Myers, C. W. and Price, S. M., eds., Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

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Issue No. ~~8~~ ~~4~~ 5.2

1. Name of the Site: BWIP

2. Statement of the Issue: What is the lateral continuity and variation in thickness of the Umtanum Flow and the ~~m~~Middle Sentinel Bluffs flow?

3. Importance of the Issue to Repository Performance

Variations in lateral continuity and thickness of the host rock will impact constructability, groundwater inflow into shafts and drifts and regional groundwater flow (refer to issue 1.1.7).

4. Portions of 10 CFR Part 60 That Are Directly Related To The Issue

60.122(c)

(21) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(22) Geomechanical properties that do not permit the design of underground openings that will remain stable through permanent closure.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

Individual flows in the Pasco Basin have been identified using a combination of chemical stratigraphy, geophysical logs, paleomagnetic data and visual inspection of core. The Umtanum Flow was initially identified as the target horizon because of its "systematic occurrence in deep boreholes throughout the Pasco Basin" (NAS, 1981) and "on the basis of its depth, thickness, and overall density" (NAS, 1981).

Preliminary conclusions on the thickness and lateral continuity of individual basalt flows are based on a limited data base from outcrops and widely spaced borings. Three general types of intraflow structure have been identified: flow top breccia, entab~~u~~lature, and basal colonnade. In addition to overall variations in the thickness of the Umtanum Flow, the thickness of intraflow structures varies within the Pasco Basin. Maximum thickness of flow top breccia is approximately 100 feet at the Emerson Nipple outcrop and 137 feet in RRL-2. The occurrence of thick flow top breccia and correspondingly thin dense interior (entab~~u~~lature) in the RRL ~~reference repository location~~ points to the lack of definitive stratigraphic control in the Grande Ronde, and specifically in the Umtanum Flow in the vicinity of the proposed repository depth.

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application

Additional stratigraphic control needs to be developed in the reference repository location with particular emphasis on the target host rock. The dense interior of the host rock needs better definition to establish that there is sufficient thickness and lateral continuity to accommodate a repository.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

To answer the lateral continuity and variation in thickness of the Umtanum flow the following investigations are planned:

1. Measure thickness of the candidate horizons in boreholes RRL-2, -6, -14 and DC-16A.

2. Determine the lateral extent of the candidate horizons in the Pasco Basin using x-ray fluorescence and paleomagnetic analyses.

3. Complete detailed logging and petrographic analysis of core from additional boreholes penetrating the Umtanum and the middle Sentinel Bluffs flow to characterize primary internal structures (flow top, entabulature, and colonade; zones of vesiculation and brecciation).

4. Completed detailed fracture and lithologic logging in outcrop and in existing boreholes.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

Limited data exists on the variation of thickness of intraflow structures and the presence of stratigraphic anomolies such as flow pinch-outs. Planned geologic studies of core and exposures while adding to the existing data base, will not provide the information necessary to fully characterize stratigraphic discontinuities in the Umtanum Flow and the middle Sentinel Bluffs flow. The predictability of these fractures features? is poor, and many of these small scale features will not be detected by the planned investigations.

References:

1. Long, P. E. and R. D. Landon, 1981, "Stratigraphy of the Grande Ronde Basalt," in Myers, C. W. and Price, S. M., eds., Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

2. Long, P. E., 1978, Characterization and Recognition of Intraflow Structures, Grande Ronde Basalt, RHO-BWI-LD-10, Rockwell Handford Operations, Richland, Washington.

3. Moak, D. J., 1982, "Borehole Geologic Studies," in Myers, C. W. and Price, S. M., eds., Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

4. National Academy of Sciences, 1981, BWIP presentation to the National Academy of Sciences, June 11, 12 and 13, 1981, Rockwell International.

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Issue No. ~~5~~.3.1

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue

5.1.1 What is the probability and nature of earthquake activity in or near the Pasco Basin that would affect repository performance?

3. Importance of the Issue to Repository Performance

Macro ($>M_s=3$) and Micro ($<M_s=3$) seismic events in or near the Pasco Basin are important to repository performance because such events have the capacity (depending on magnitude and epicenter location) to a) damage or destroy the engineered systems in the repository, b) change or modify groundwater paths through movement on faults and fractures and c) interupt waste emplacement by damaging surface facilities.

4. Portions of 10 CFR 60 That Are Directly Related To The Issue

60.122(c)

(a) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the seasonal groundwater flow system.

(b) Potential for changes on hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(13) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

In the Pasco Basin there is an extensive history of microseismic events called earthquake swarms (for a definition see appendix ~~AA~~ N). Also, the Rattlesnake-Wallula lineament (RAW) is 12 to 15 km from the Reference Repository Location (RRL) and is considered a fault zone capable of generating an Ms=6.5 earthquake (NRC, 1982 ~~and personal communication, J. Kimball~~).

Earthquake swarms have occurred within the controlled zone with epicenters near the elevation of the proposed repository (Woodward-Clyde, 1981). The largest earthquake swarm event near the 200 ~~W~~ area (within the RRL) was the Mc=2.44 event on September 8, 1979, while the largest swarm earthquake recorded in the Columbia River Plateau was the December 20, 1973 Mc=4.38 Royal Slope event (Appendix ~~AA~~ N).

A~~n~~ Ms=6.5 event on the RAW at a distance of 15 km from the RRL (RAW approaches within 12 to 15 km of the RRL) could result in a peak acceleration of .32g on the 84th percentile (Attachment 1). This impacts on the seismic design of the surface facilities supporting the repository.

Three seismic hazard studies (Woodward-Clyde, 1980 and 1981; USGS, 1980) that discuss seismic exposure of the Hanford region over time are discussed in appendix ~~X~~ M. These studies conclude that return periods of mean peak accelerations ≥.25g in 10,000 years are possible. All three studies are flawed (appendix ~~X~~ M) and sensitivity tests must be completed before confidence in the results of these studies is gained (NRC, 1982).

6. Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization

The mechanisms triggering earthquake swarms in the controlled zone must be determined. An analysis of the possibility that construction of a repository will trigger swarms must be completed. The geologic features on which the swarms occur (faults, fractures) must be ascertained and the methodology for predicting the occurrence of a microseismic event must be tailored to the medium (microseismic monitoring in basalt). This probability of occurrence and the effect on surface and subsurface structures of an earthquake of Ms $\geq$6.5 within 15 km. of the RRL must be assessed.

T - Spacing

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

Earthquake activity (seismicity) data for the Pasco Basin are being collected to support modeling efforts in repository design (work elements R.1.29 and R.1.30) and pre and post closure performance assessment (work element S.1.16.B). Regional (Columbia Plateau) seismic monitoring by the University of Washington and operation of the two supplemental networks within the Pasco Basin will be continued. In addition, a seismometer has been placed at a depth of 1100 meters in borehole DC-3. This seismometer is designed to provide underground data on ground vibration at repository depths. These seismic monitoring networks are designed to determine the following earthquake swarm parameters: 1) area of causative fault, 2) the stress released, and 3) the amount of displacement of the fault surface.

Research is planned to develop techniques to analyze the long-term effect of seismic events on deep excavations. Research into damage incurred by an underground facility as a result of seismic or similar underground event will continue. In the laboratory, shake table tests will apply dynamic loads to the interface between basalt and proposed shaft sealing materials. This testing program will determine the reaction of the different proposed sealing materials to seismic accelerations.

8. <u>Analysis of (7) as to Completeness, Practicality and Likelihood of Success</u>

The investigation plans and testing programs outlined in the SCR to address the problem of seismicity in the Pasco Basin are complete and practical with the following exceptions:

1. There are no plans to assess the possibility of a seismic event as large as Ms=6.5 on RAW. Macro-seismicity in the Pasco Basin is largely ignored. This problem impacts seismic design.

2. There are no specific plans to investigate microearthquake triggering mechanisms in the controlled zone. An example might be waste water disposal in the 200 W area.

3. There are no explicit plans for determining the size and frequency of occurrence of the structures (faults, fractures) on which earthquake swarms occur.

References:

1. United States Nuclear Regulatory Comm., 1982, Safety Evaluation Report related to the operation of WPPSS Nuclear Project No. 2, NUREG-0892, Supp. No. 1.

2. United States Geological Survey, 1980, Probabilistic Estimates of Maximum Seismic Horizontal Ground Motion on Rock in the Pacific Northwest and the Adjacent Outer Continental Shelf, Open-File Report 80-471.

3. Woodward-Clyde Consultants, 1980, Factors Influencing Seismic Exposure of the Southeast Washington Region, prepared for WPPSS.

4. Woodward-Clyde Consultants, 1981, Seismic Exposure Analysis for the WNP-2 and WNP-1/4 site, Appendix 2.5K, Amendment 18, WNP-2 FSAR.

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Issue No. ~~4~~ 5.3.2

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue

~~4~~ 5.3.2 What is the probability and nature of volcanism in or near the Pasco Basin which could affect repository performance?

3. Importance of the Issue to Repository Performance

In the event of major volcanic activity in the Pacific Northwest, two major ~~types of~~ impacts on the repository could occur. Volcanically induced surface flooding might cause rock stress changes from water loading and also change the groundwater flow at or near the repository site. Surface flooding could be caused by river damming from thick air fall (tephra), ash flows, or lava flows. Another possibility is a breach of the repository by a dike or a fissure.

4. Portions of 10 CFR 60 That Are Directly Related To The Issue

(Draft) - 60.122 (b)

(1) The nature and rates of tectonic, hydrogeologic, geochemical and geomorphic processes (or any such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

60.122(c)

(~~3~~ 4) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(16) Evidence of igneous activity since the start of the Quaternary Period.

5. Summary of the Present State of Knowledge, with Analysis of Uncertainties

Ash falls from many volcanic eruptions from the Cascade Mountains to the west are deposited on the Columbia Plateau. The eruption of Mt. Mazama about 6,600 yrs ago produced the Crater Lake Cauldera and an extensive air fall tuff. Several potential volcanic sources such as Mt. St. Helens, Mt. Hood, and Mt. Adams are close enough to possibly block the Columbia River and cause flooding in the Pasco Basin.

Flood basalts through linear fissures (vents) have occurred in the Columbia Plateau. Most basalt flood type flows of the Columbia Plateau are older than 5 million years. The most recent of these major flood basalts erupted through N-NW trending vent systems now preserved as dikes. There is evidence to suggest that limited basalt flows have occurred in or near the Columbia Plateau about 1 million years ago, during the Quaternary Period (~~ref.~~ RHO-BWI-ST-4, October 1979, p. II-10, 11).

An association may exist between flood basalt volcanism and eruptions in the Cascade Range. Historical geologic evidence suggests that basalt flow volcanism on the Columbia Plateau and eruptions in the Cascade Range coincide about every 5 million yrs (~~ref.~~ RHO-BW-CR-130P). However, not enough is known about volcanism in the Pacific Northwest to determine whether eruptions in the Cascade Ranges will be extensive or will be associated with renewed Columbia Plateau or Pasco Basin volcanism.

6. <u>Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application</u>

a. Numerous scientific studies of past and present volcanism in the Cascades and other parts of the Pacific Northwest which may be of interest are continuing. Based on these studies, updated interpretations are needed and the impacts that the new information may have on assumptions used in older probability calculations needs to be considered.

b. Analyses are needed on the causes and locations of past (predominantly N-NW) linear venting in and near the Pasco Basin and whether similar causes could develop.

c. Analyses are needed of the probabilities that water loading from volcanically caused flooding will change rock stresses and the effects such changes might have on the repository.

d. Analyses are needed of possible causes for an association between flood basalt flows and coinciding eruptions in the Cascade Mountains. Attempts, such as the collection of thermal data ~~or other means,~~ should continue to be made to detect potential ongoing magmatic activity beneath the Columbia Plateau.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

DOE plans to periodically review and update the information on igneous activity within and in the vicinity of the Pasco Basin. Other plans are to collect and assess additional geothermal gradient and heat flow data. Also, they will develop a refined tectonic setting for the reference repository.

As part of the study of tectonic processes, the following are planned: 1) through evaluations of recent geologic maps; 2) evaluations of photolineament maps of the Columbia Plateau carried out in conjuction with data available for the Pasco Basin and the Cold Creek syncline; 3) areomagnetic and reflection seismic surveys; 4) detailed studies of Grande Ronde Basalt exposures and Yakima fold belt exposures; 5) gridded gravity survey, seismic refraction, and downhole vertical seismic profile data will be used to evaluate geophysical anomalies; 6) geodetic monitoring will continue to assess crustal deformation; 7) periodic resurveys of the Hanford trilateration array and newly established arrays will be used to determine deformation rates; 8) seismic monitoring will also be evaluated with in-situ stress data gathered under the repository program.

8. Analysis of (7) as to Completeness, Practicality and the Likelihood of Success

DOE's plans are comprehensive and are expected to obtain needed information. There are two areas that NRC needs clarification (about from DOE.) ~~by NRC~~. One of these areas is on plate tectonics and the second on water loading effects on rock stress.

The nature of volcanism in the Columbia Plateau region cannot be adequately determined until past and present plate subduction and its relationship to the Cascade Mountains and to the Columbia Plateau flood basalt eruptions is assessed and the new information applied to older frequency based assumptions (such as Johnpeer et al., 1981).

It is recommended that DOE use worst case scenarios for water loading effects on rock stress and actually estimate stress changes and subsequent impacts on the repository. This is not included in DOE's plans because they consider it unlikely to affect the repository at ~~their~~ proposed repository depths.

Bilbilography

Issue: Volcanism

TD-812-N213 (unclassified), Apr. 1978, Panel on Hanford Wastes, "Radio Active Wastes at the Hanford Reservation - A Technical Review," p. 6, p. 98.

RHO-BW-CR-130P, August 1981, J. D. Johnpeer, D. Miller, G. Goles, "Assessment of Potential Volcanic Hazards - Pasco Basin, Washington" 31 p.

RHO-BWI-ST-4 (unclassified), October 1979, C. W. Myers, S. M. Price, J. A. Caggiano, M. P. Cochran, W. J. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman, "Geologic Studies of the Columbia Plateau, A Status Report" p. (II-3), p. (II-8)-(II-11), p. (II-71).

RHO-BWI-ST-14 (unclassified), July 1981, C. W. Myers, S. M. Price, "Subsurface Geology of The Cold Creek Syncline," p. (3-4), p. (7-11), p. (8-17).

RHO-BWI-CR-128 P (unclassified), Aug 1981, P. J. Murphy, G. D. Johnpeer, "An Assessment of Geothermal Resource Potential Pasco Basin and Vicinity, Washington" p. 1, p. 8.

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Issue No. 5.3.3

1. Name of the Site: BWIP - Hanford Washington

2. Statement of the Issue

5.3.3 What is the probability of glaciation on or near the Pasco Basin?

3. Importance of the Issue to Repository Performance

If climatic change resulted in renewed glaciation on or near the repository site, glacial ice dammed lakes could cause surface flooding and change rock stresses by water loading and also change groundwater flow. Another possibility is glacial ice causing subsidence of the Pasco Basin. This subsidence might cause subsurface deformation or slippage along new or existing fractures and alter the repository waste containment performance.

4. Portions of 10 CFR 60 That Are Directly Related To The Issue

(Draft) - 60.122(b)

(1) The nature and rates of tectonic, hydrogeologic, geochemical and geomorphic processes (or any such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

60.122(c)

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(~~3~~) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments

could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(~~7~~ 8) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic change.

5. <u>Summary of the Present State of Knowledge, with Analysis of Uncertainties</u>

The present topography of the Columbia Plateau and Pasco Basin has, to some degree, been formed by glacial and glacial flood processes active during Quaternary-Pleistocene time. The last major catastrophic flood deposits on the Columbia Plateau are about 13,000 years old. The Pasco Basin has never been covered by an ice sheet but the northwestern part of the Columbia Plateau was covered by the Okanogan lobe of the Cordilleran Ice Sheet (15-20 thousand years ago). During Pleistocene time an ice dam at Wallula gap temporarily impounded a lake reaching an elevation of (approx.) 365 m above present ground level in the Pasco Basin.

It is not known if another period of glaciation will occur within the next 10 thousand years. If glaciation did occur it is not known what the southern limits might be. The mechanical loading effects would depend on the depth of ice or water and the length of time the various volumes covered the Pasco Basin. These variables are difficult to assess.

6. <u>Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application</u>

a. Analyses are needed of the various major scientific interpretations on global climatic changes, including discussions of the supporting evidence for the major studies.

b. Analyses are needed of the effects of differential glacial ice loading on rock stress and subsequent impacts on the repository.

c. Analyses are needed of the effects ~~that~~ of water loading from ice melt flooding ~~could have~~ on rock stress and subsequent impacts on the repository.

7. Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)

DOE plans to construct a Meterology Tower (to USNRC guidelines) for additional data collection at the Hanford site. DOE has concluded that ice may reach the repository site within 10,000 years. They do not believe that ice loading will change rock stress at significant depths. Ice melt changes on rock stress was not addressed.

8. Analysis of (7) as to Completeness, Practicality and the Likelihood of Success

DOE's planned Meteorology Tower will provide onsite data collection. DOE recognizes renewed glaciation as ~~a~~ likely ~~event~~ if present cooling trends continue but this is viewed as a distant possibility. ~~and would not be a sudden event.~~ DOE's plans for a Meteorlogy Tower are practical and ~~have high reliability for information collected~~ data from such towers are highly reliable.

There are a few aspects of this issue that need additional plans. ~~planning.~~ It is recommended that DOE continue to analyze ongoing studies of major climatic changes and provide a detailed update at the time of license application. Also, DOE should use worst case scenarios for ice loading and ice melting and actually estimate rock stress changes and subsequent impacts on the repository.

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Issue: Glaciers

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TD-812-N213 (unclassified), Apr. 1978, Panel on Hanford Wastes, "Radio Active Wastes at the Hanford Reservation - A Technical Review," p. 93-94, p. 103, P. 145-146.

RHO-BWI-ST-4 (unclassified), October 1979, C. W. Myers, S. M. Price, J. A. Caggiano, M. P. Cochran, W. J. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman, "Geologic Studies of the Columbia Plateau, A Status Report" p. (II-6), p. (II-67)-(II-69), p. (III-171)-(III-174).

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Issue No. ~~5~~.3.4

1. Name of the Site: BWIP

2. Statement of the Issue: What is the probability and nature of fu~~sis~~ture faulting and folding in the Pasco Basin that would affect repository performance?

3. Importance of the Issue to Repository Performance

Recent deformation is indicative of potential tectonic instability. Various lines of evidence are indicative of ongoing tectonic activity in the Pasco Basin. Examples of these indicators are 1) offset of late Pleistocene sediments along the Rattlesnake-Wallula alignment (RAW), 2) historic seismicity associated with faults on east-west trending folds at Toppenish Ridge to the southwest, micro-earthquake swarms ~~associated with Saddle Mountains~~, and probable late Pleistocene displacement on the South Fault at Gable Mountain. Structural deformation may adversely affect the integrity of the repository over the long term and/or modify regional groundwater flow creating pathways for radionuclide migration.

4. Portions of 10 CFR Part 60 That Are Directly Related To The Issue

60.122(b)

(1) The nature and rates of tectonic, hydrogeologic, geochemical and geomorphic processes (or any such processes operating within the geologic setting during the Quaternary Period, when projected, would not affect or would probably affect the ability of the geologic repository to isolate the waste.

(5) Structure deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the ~~research~~ regional groundwater flow system.

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

5. Summary of the Present State of Knowledge with Analysis of Uncertainties

Deformation of the Columbia River Basalts in the Pasco Basin peaked between 10 and 5 million years before the present, but the region is presently undergoing north-south compressive strain at low ratio. Strain may be localized along RAW and ridges at the north-east and southwest edges of the Yakima Fold Belt (U.S. NRC, 1982). Within the Pasco Basin, the major structur~~e~~al feature is the anticlinal ridge and synclinal valley system. Deformation has resulted in uplift along anticlinal ridges and subsidence in synclinal troughs. Preliminary calculations indicate that subsidence in the Cold Creek Syncline may continue at a rate of 40 meters per million years (Raidel, S. P. and K. R. Fecht, 1982).

Preliminary source parameter calculations (Caggiano, J. A., 1982) during a "single displacement episode on a new fault indicate JC ≤1meter of displacement could occur on a steeply dipping east-west or north-west trending reverse fault ≤50 km in length." Although faults of this size have not been identified in the Reference Repository location, the geologic data do not preclude the possibility of undetected faults or development of new faults in the area of the reference repository location.

Core discing, identified in deep borings in the Cold Creek Syncline 2nd is indicative of high horizontal stress, has not been related to the regional stress field or to structures identified through geophysical surveys (Moak, B. J., 1982).

Uncertainties in the probability and nature of faulting and folding in the Pasco Basin arise from the preliminary interpretations of structural processes.

While the Untanum Ridge is interpreted as folded basalt that has been subsequently faulted (Price, E. H., 1982), the structure may alternatively be interpreted as part of an imbricate thrust zone (primary faulting, secondary folding) (U.S. NRC, 1982) with the uppermost basalts not involved in faulting and/or folding. Inferred structures in the vicinity of the Reference Repository Location, such as the possible structure indicated by the N-96 to N-84 linear and the northwest trending structure that appears to cross-cut the Yakima Ridge Structure, lack definition. These structures create uncertainties in the tectonic model of the Pasco Basin and uncertainties that the controlled zone is free of major structure.

6. <u>Summary of Additional Information Needed to Resolve the Issue by the Time of Construction Authorization Application</u>

To limit the uncertainties in preliminary interpretations of folding and faulting in the Pasco Basin, additional data should be collected and analyzed to bound the geologic constraints of the tectonic model(s) of the Pasco Basin. Continued geologic mapping, geophysical and geodetic surveys, additional borings, in situ stress measurements, and refined fault plane solutions should be completed. This work is essential to 1) decrease uncertainties that existing structures will impact repository construction or regional groundwater flow paths and 2) decrease uncertainties of renewed movement on existing structure and development of new faults.

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods and Investigations to Provide the Information Needs of (6)</u>

A number of investigations are planned to develop a data base to input to a theoretical mechanical model (presently undetermined) of past, present, and future tectonic development of the Pasco Basin:

1. Review of existing regional geologic studies, including geologic and remote sensing maps. Based on this review, additional study areas may be selected.

2. Kinematic analysis at Sentinel Gap, Smyrma Bench, Snively Basin, Wallula Gap and Horse Heaven Hills to determine if Untanum Ridge is representative of Yakima Folds and to develop a reasonable model of Yakima Fold Belt deformation. Areas to the west of the Pasco Basin may be included.

3. Paleomagnetic analysis to determine horizontal rotation.

4. Interpretation of existing magnetotelluric data integrated with gravity data to evaluate influence of inferred basement structure on deformation of the basalts. If necessary, additional magnetotelluric surveys will be planned.

5. Exposures at Sentinel Gap, Smyrma Bench, Rattlesnake Mountain and Snively Basin will be investigated to determine the geometry, displacement history, and age of faulting. Mapping and geophysical surveys will be completed. If appropriate, trenching and shallow (Miocene and younger strata) boreholes will be planned. Particular emphasis will be placed on the continuity of faulting along the Cle Elum-Wallula lineament.

6. To evaluate the rate of deformation, stratigraphic data, including thickness, depth, and continuity of Miocene through recent stratigraphic units, will be analyzed. In addition, data from geodetic monitoring and in-situ stress measurement will be analyzed along with estimates of fault slip rate and seismic moment and focal mechanism solutions.

7. Investigation planned discussed in 5.1.

8. <u>Analysis of (7) as to Completeness, Practicality, and Likelihood of Success</u>

Planned approaches to investigations summarized in (7) appear to be adequate, but lack the level of detail necessary to evaluate completeness of the planned investigations. The success of the planned studies will depend, in part, on additional study areas that have not yet been identified.

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Issue No. 6.1

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: How did DOE selection the Pasco Basin from among other candidate areas?

3. Importance of the Issue to Repository Performance

The NRC will be required to prepare an environmental impact statement (EIS) to support its decision to grant DOE a construction authorization when DOE submits an application for a geologic repository. Under the provisions of the National Environmental Policy Act (NEPA), an EIS must "rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated." (43 FR 55996)

In order to comply with its NEPA obligations to consider alternative sites, the NRC has required DOE to submit site characterization reports for at least three sites (40 FR 13972). Each of these sites must be among the best that can reasonably be found (40 FR 13973). This process will ensure that there is sufficient information for NRC to be able to evaluate real alternatives, in a timely manner, in accordance with NEPA when DOE files an application for a construction authorization.

The NRC's site characterization analysis (SCA) must determine if the Pasco Basin (i.e., the Hanford Site) is among the best candidate locations that can reasonably be found in the United States. To make this determination, the NRC must:

1. evaluate the factors in the site screening process which led to the Hanford location; and

2. compare the environmental characteristics of the Hanford location with other candidate locations in the U. S. to ensure that it is a reasonable alternative (i.e., the Hanford location should be among the best that can reasonably be found and that none of the alternative locations are obviously superior to it).

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

1. 45 FR 13972 - Site Characterization
2. 45 FR 13973 - The "Best" Site
3. 10 CFR 60.11(a)
4. 10 CFR 60.31(c)
5. 10 CFR 51

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

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Issue No. 6.2

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: How did DOE select the reference repository location (RRL) from among the other sites in the Pasco Basin?

3. Importance of the Issue to Repository Performance

The NRC will be required to prepare an environmental impact statement (EIS) to support its decision to grant DOE a construction authorization when DOE submits an application for a geologic repository. Under the provisions of the National Environmental Policy Act (NEPA), an EIS must "rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated." (43 FR 55996)

In order to comply with its NEPA obligations to consider alternative sites, the NRC has required DOE to submit site characterization reports for at least three sites (40 FR 13972). Each of these sites must be among the best that can reasonably be found (40 FR 13973). This process will ensure that there is sufficient information for NRC to be able to evaluate real alternatives, in a timely manner, in accordance with NEPA when DOE files an application for a construction authorization.

The NRC's site characterization analysis (SCA) must determine if the reference repository location at Hanford is among the best sites that can reasonably be found in the Pasco Basin. To make this determination, the NRC must:

1. evaluate the site screening process which leads to the RRL site; and

2. compare the enviornmental characteristics of the RRL site with other candidate sites in the Pasco Basin to ensure that it is a reasonable alternative (i.e., the RRL site should be among the best that can reasonably be found and that none of the alternative sites are obviously superior to it).

4. Portions of 10 CFR 60 That Are Directly Connected To The Issue

1. 45 FR 13972 - Site Characterization
2. 45 FR 13973 - The "Best" Site
3. 10 CFR 60.11(a)
4. 10 CFR 60.31(c)
5. 10 CFR 51

5. Summary of the Present State of Knowledge, With Analysis of Uncertainties

6. Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application

7. Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)

8. Analysis of (7) As To Completeness, Practicality and Likelihood of Success

References

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Issue No. 6.3

1. Name of the Site: BWIP - Hanford, Washington

2. Statement of the Issue: Are there any obvious environmental concerns that could preclude the reference repository location (RRL) at Hanford from being considered as one of the candidate sites in DOE's subsequent application for authorization to construct a geologic repository?

3. Importance of the Issue to Repository Performance

The NRC will be required to prepare an environmental impact statement (EIS) to support its decision to grant DOE a construction authorization when DOE submits an application for a geologic repository. Under the provisions of the National Environmental Policy Act (NEPA), an EIS must evaluate reasonable alternatives to the proposed action (43 FR 55996). Since DOE, in its Site Characterization Report, is proposing that the RRL site at Hanford be considered as one of the alternative sites that will eventually be considered at the construction authorization stage of licensing, it is incumbent on the NRC to assure itself that the RRL site is a "reasonable" alternative. This assurance can be provided at this time by examining the site for obvious enviornmental flaws that would prevent the site from becoming one of several candidate sites considered in DOE's subsequent license application for an authorization to construct a geologic repository.

To make this determination, the NRC will:

1. Evaluate those sections of the Site Characterization Report that deal with environmental characteristics of the RRL.

2. Evaluate the Environmental Assessment (EA) which has been prepared by DOE on the construction of an exploratory shaft at the RRL.

3. Make a visit to the site and to the alternative areas to observe their environmental characteristics.

4. <u>Portions of 10 CFR 60 That Are Directly Connected To The Issue</u>

1. 45 FR 13972 - Site Characterization
2. 45 FR 13973 - The "Best" Site
3. 10 CFR 60.11(a)
4. 10 CFR 60.31(c)
5. 10 CFR 51

5. <u>Summary of the Present State of Knowledge, With Analysis of Uncertainties</u>

Constructing and operating a repository at the RRL site will affect the environment. From our review of the literature, we have found that the following environmental and institutional areas could be particularly sensitive to the construction and operation of a geologic repository at the RRL site.

1. Will the reference repository location (RRL) at Hanford adversely affect the Rattlesnake Hills Critical Wildlife Habitat at the Cold Creek Critical Wildlife Habitat?

2. Will Constructing and operating a repository adversely affect six species of rare, threatened or unique birds, which have been identified on or near the Hanford Reservation?

3. Could a repository at Hanford, particularly during construction generate dust which would degrade the air quality?

4. Will dust affect three species of endangered/threatened plants within the Arid Lands Ecology Reserve?

5. During construction, water will be needed for drilling and dust control. Given the arid environment of the Pasco Basin, could a repository compete with irrigated agriculture for a limited supply of water?

6. Hould will the public react to transportation impacts since HLW must be transported across the nation to reach a repository at Hanford, Washington?

7. Will the public accept the RRL site as one of the best sites that can reasonably be found?

6. <u>Summary of the Additional Information Needed to Resolve the Issue By the Time of Construction Authorization Application</u>

7. <u>Summary of the Planned Approaches to Testing, Tests, Test Methods, and Investigations to Provide the Information Needs of (6)</u>

8. <u>Analysis of (7) As To Completeness, Practicality and Likelihood of Success</u>

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1. Carrell and Jones, "Environmental Issue Identification For the Basalt Waste Isolation Project," RHO-BWI-LD-25, April, 1980.

2. "Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction," DOE/EA-0188, September 1, 1982.

3. W. C. C., "Study to Identify a Reference Repository Location for a Nuclear Waste Repository for a Nuclear Waste Repository on the Hanford Site," RHO-BWI-C-107, Volume I, May, 1981.

4. 40 CFR 1500, "National Environmental Policy Act Implementation of Procedural Provisions," November 29, 1978.