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NMSS07

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET

1. QA: QA

Complete Only Applicable Items

2. ☐ Analysis — Check all that apply

Type of Analysis:
- ☐ Engineering
- ☐ Performance Assessment
- ☐ Scientific

Intended Use of Analysis:
- ☐ Input to Calculation
- ☐ Input to another Analysis or Model
- ☐ Input to Technical Document
- ☐ Input to other Technical Products

Describe use:

3. ☒ Model — Check all that apply

Type of Model:
- ☒ Conceptual Model
- ☐ Abstraction Model
- ☐ Mathematical Model
- ☐ System Model
- ☐ Process Model

Intended Use of Model:
- ☐ Input to Calculation
- ☒ Input to another Model or Analysis
- ☐ Input to Technical Document
- ☒ Input to other Technical Products

Describe use:

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Seepage/Invert Interactions

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Enclosure 4

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD

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1. PURPOSE

As directed by a written development plan (CRWMS M&O 1999a), a conceptual model for water entering the drift and reacting with the invert materials is to be developed. The purpose of this conceptual model is to assist Performance Assessment Operations (PAO) and its Engineered Barrier Performance Department in modeling the geochemical environment within a repository drift, thus allowing PAO to provide a more detailed and complete in-drift geochemical model abstraction, and to answer the key technical issues (KTI) raised in the NRC Issue Resolution Status Report (IRSR) for the Evolution of the Near-Field Environment (NFE), Revision 2 (NRC 1999). This AMR also seeks to: 1) Develop a logical conceptual model for physical/chemical interactions between seepage and the invert materials; 2) screen potential processes and reactions that may occur between seepage and invert to evaluate the potential consequences of the interactions; and 3) outline how seepage/invert processes may be quantified.

This document provides the conceptual framework for screening out insignificant processes and for identifying and evaluating those seepage/invert interactions that have the potential to be important to subsequent PAO analyses including the Engineered Barrier System (EBS) physical and chemical model abstraction effort. This model has been developed to serve as a basis for the in-drift geochemical analyses performed by PAO. Additionally, the concepts discussed within this report may also apply to certain near and far-field geochemical processes and may have conceptual application within the unsaturated zone (UZ) and saturated zone (SZ) transport modeling efforts. The seepage/invert interactions will not directly affect any principal factors.

2. QUALITY ASSURANCE

The Quality Assurance (QA) program applies to the development of this conceptual model documentation. The Performance Assessment Operations responsible manager has evaluated the technical document development activity in accordance with QAP-2-0, *Conduct of Activities*. The QAP-2-0 activity evaluation, *Conduct of Performance Assessment* (CRWMS M&O 1999b), determined that the preparation and review of this technical document is subject to *Quality Assurance Requirements and Description* (QARD) DOE/RW-0333P (DOE 2000) requirements.

3. COMPUTER SOFTWARE AND MODEL USAGE

3.1 COMPUTER SOFTWARE

Software requiring development and controls in accordance with AP-SI.1Q, *Software Management*, was not utilized in the development of this document.

3.2 MODELS

The seepage/invert conceptual model was addressed in the geochemical analyses as documented in Chapter 4 of the Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document (TBD) (CRWMS M&O 1998a) in Section 4.2.1.3.2, which discusses the effects of the concrete liner on the fluid chemistry. Since that time, the design of the invert has changed substantially. This conceptual model document is being developed to

reflect the new design elements of the invert (CRWMS M&O 1999d). This conceptual model may eventually become part of a new in-drift coupled geochemical model upon the completion of the GRIM V1.0 software code (CRWMS M&O 1999c).

4. INPUTS

4.1 DATA AND PARAMETERS

This AMR provides a discussion of the conceptual processes that may occur within the invert, and, as such, data were not used as inputs. Therefore, there are no "To Be Verified" (TBV) data associated with this AMR.

The currently proposed invert has two components: 1) Crushed Topopah Spring Tuff (host rock) which has been crushed to gravel-sized particles ranging in size from 9.5 mm to 19 mm (CRWMS M&O 1999d), hereafter referred to as "ballast"; and 2) metal components that support the waste package once it is in position. The metal components (composition and quantity) of the invert are summarized in CRWMS M&O 1999g. The mineralogy of the ballast is the same as reported for the tuff from which it is made (CRWMS M&O 1999d). Since this AMR is strictly a qualitative discussion of potential processes and the consequences, the actual mineralogy of the tuff and composition of the metal components are of secondary importance and will not be provided in this document.

4.2 CRITERIA

Programmatic requirements for this document are listed in the Development Plan (CRWMS M&O 1999a), which covers eight tasks needed to provide the sub-models for the performance assessment Physical and Chemical Environment Abstraction Model. That Development Plan specifies that this document and all analyses described herein must adhere to the requirements of AP-3.10Q, *Analyses and Models*, and must address applicable NRC issue resolution status report (IRSR) criteria (NRC 1999).

The applicable NRC review methods and acceptance criteria outlined in the IRSR that apply to model development for the following near-field environment (NFE) key technical issue (KTI) sub-issue effects: (a) coupled thermal-hydrologic-chemical (THC) processes on the waste package chemical environment, (b) coupled THC processes on the chemical environment for radionuclide release, and (c) coupled THC processes on radionuclide transport through engineered and natural barriers (NRC 1999). Also included below is a listing of the project features, events, and processes (FEP's) that apply to this report.

4.2.1 YMP Features, Events and Processes (FEP's)

Table 1 below gives a listing of Yucca Mountain Project FEP's (CRWMS M&O 1999f) that are or may be potentially discussed in this document. YMP FEP # and NEA Category are part of the database search properties and are provided for convenience.

Table 1. A listing of YMP FEP's that pertain to this document.

YMP FEP #	NEA Category	FEP Name
2.1.02.02.09	2.1.09z	Dissolution chemistry (in waste and engineered barrier system)
2.1.09.02.00	3.2.01i	Interaction with corrosion products
2.1.09.02.02	2.1.09bd	Effects of metal corrosion (in waste and engineered barrier system)
2.1.09.04.02	2.1.09r	Speciation (in waste and engineered barrier system)
2.1.09.04.09	3.2.02h	Solubility and precipitation (contaminant speciation and solubility)
2.1.06.06.00	WP-1	Effects and degradation of drip shield
2.1.12.03.01	2.1.12ai	Chemical effects of corrosion
2.1.06.05.00	2.1.05p	Degradation of invert and pedestal
2.1.03.01.00	2.1.03a	Corrosion of waste containers
2.1.08.07.02	2.1.03ay	Properties of failed canister
2.1.09.02.04	2.2.08v	Chemical buffering
2.1.12.03.01	2.1.12ai	Chemical effects of corrosion
2.1.09.05.00	2.1.09bm	In-drift sorption
2.1.09.05.02	3.2.03b	Sorption

Any resolution of these FEP's is discussed in Section 7.6 below.

4.3 CODES AND STANDARDS

4.3.1 Codes

This AMR was prepared to comply with the DOE interim guidance (Dyer 1999) which directs the use of the proposed NRC high-level waste rule, 10 CFR Part 63 (64FR 8640). Relevant requirements for performance assessment from Section 114 of that document are: "Any performance assessment used to demonstrate compliance with Sec. 113(b) shall: (a) Include data related to the geology, hydrology, and geochemistry ... used to define parameters and conceptual models used in the assessment. (b) Account for uncertainties and variabilities in parameter values and provide the technical basis for parameter ranges, probability distributions, or bounding values used in the performance assessment.... (g) Provide the technical basis for models used in the performance assessment such as comparisons made with outputs of detailed process-level models...."

4.3.2 Standards

ASTM C 1174-97 *Standard Practice for Prediction of the Long-Term Behavior of Materials, Including Waste Forms, Used in Engineered Barrier Systems (EBS) for Geological Disposal of High-Level Radioactive Waste* was used as guidance in the preparation of this conceptual model.

5. ASSUMPTIONS

5.1. Thermodynamic equilibrium is assumed within the emplacement drift. The basis for this assumption is that it is bounding and allows generalizations to be made about possible chemical reactions without the need to discuss a time frame, i.e., kinetics, for the reactions. The assumption is used as a basis for identifying phenomena that need to be addressed by the conceptual model. Sections 6.2 and thereafter.

5.2. Two periods of repository performance will be considered without regard to their duration: The first, or "thermal" period, when the decay of waste has raised temperature in the invert above the natural, undisturbed temperature of the repository host rock environment, and the second, or "ambient," period when the temperature in the invert is at or very near the natural temperature of the repository host rock. This assumption is bounding and justified by the fact that radiogenic heating is by nature transient, and that any thermal pulse generated by radioactive decay will eventually diminish and return to undisturbed conditions. Sections 6.2 and thereafter.

5.3. It is assumed that during the thermal period it is possible for the seepage flux to exceed the evaporation flux. The basis for this assumption is that it is a conservative bounding condition, in that it allows for a greater possible number of scenarios to be considered. Sections 6.2 and thereafter.

5.4. The partial pressure of oxygen and carbon dioxide is homogeneous throughout the drift. The assumption causes focus on the general processes at work in the system and allows possible, localized perturbations to be ignored. This is a bounding assumption. Sections 6.2 and thereafter.

5.5. The composition of seepage entering the drift is that of J-13 groundwater. The basis of this assumption is maintaining consistency with the other EBS sub-models. This is a bounding assumption. Sections 6.2 and thereafter.

5.6. Waste package breach does not occur until repository thermal conditions return to ambient. This assumption is based on the conditions simulated in the *Summary of In-Package Chemistry for Waste Forms* (CRWMS M&O 2000d), which only considered WP breach under ambient conditions. This is a bounding assumption. Sections 6.2 and thereafter.

5.7. Seepage reactions with invert steel may be conceptualized by considering reaction with pure iron. The basis for this assumption is that it is conservative and bounding, in that iron is more reactive with seepage than the alloys used in the construction of the invert. Also, as a simplifying assumption, it allows the conceptual model to generalize the primary effects of interaction with steel without being forced to focus on minor and trace components of steel. (Sections 6.2 and thereafter).

5.8 The titanium drip shield is chemically inert, in that it is passivated by the formation of a titanium oxide film. The basis for this assumption is that titanium oxide is highly corrosion resistant (CRWMS M&O 1999g), and hence its choice as a design component.

This is a bounding assumption. Section 6.2.3.2 but is implicit in Sections 6.2 and thereafter.

6. ANALYSIS/MODEL

6.1 PREVIOUS WORK

The conceptual model documented below is a new model that reflects considerations driven by the current invert design. Previous models that considered interactions with the earlier invert design (e.g. CRWMS M&O 1998a) do not apply directly to this model. For example, the TSPA-VA model (CRWMS M&O 1998a and 1998b) did not explicitly deal with processes that may occur in the invert as currently conceived, nor did that model consider how likely chemical reactions might affect the physical integrity of the invert or change the chemistry of the liquid that exits the invert. Rather, in the TSPA-VA the seepage/invert model was included within the concrete model because concrete was used in the VA design for construction of the invert, as well as the tunnel liner (CRWMS M&O 1998a).

6.2 CONCEPTUAL MODEL

The conceptual model for seepage/invert interactions will be developed by discussing pathways for liquid flow to the invert and the physical/chemical processes that may occur in the invert and how they may affect the physical properties of the invert and/or the chemistry of the liquid exiting the invert. The purpose of this AMR is to develop a logical conceptual model for interactions between seepage and the invert materials to screen potential processes and reactions that may occur, and to evaluate potential consequences of the interactions. The screening process is important to efficiently assess interactions that may not substantially alter the geochemical or hydrologic environment, or otherwise affect performance of the EBS. Figure 1 is a schematic representation of the seepage pathways and the processes that may be active in the invert during the lifetime of the repository. In Figure 1, the diamonds, or "decision" boxes, represent processes that may or may not be active. These decision boxes are linked to either other decision boxes or to "consequence" boxes. The consequence boxes represent secondary processes that may occur, and the effect they may have on the chemistry of fluid exiting the invert and/or the physical properties of the invert.

The current seepage/invert conceptual model will not present detailed discussions of reactions with the minor or trace metal components of the invert, nor precipitation of salts in the invert because these are discussed in CRWMS M&O 2000a and CRWMS M&O 1999g.

6.2.1 Rationale for Eliminating Some Seepage/Invert Interactions

If seepage/invert interactions merely reproduce interactions that will be accounted for elsewhere, then the small mass of invert (relative to host rock, steel ground support and waste package components, etc) argues that seepage/ invert interactions are not likely to be consequential with respect to the fluid exiting the drift or the properties of the invert. The potential is high for host rock-groundwater interactions to replicate seepage/invert interactions because the current invert design is composed of local Topopah Spring Tuff (for use as invert ballast) and steel (for use as invert and rail support). Both of these materials will be present in and around waste

emplacement tunnels in much greater quantities than will be present in the invert. Therefore, if the material selected for the invert were crushed tuff then it may be argued that the invert will have little, if any, impact on the chemistry of the fluid exiting the drift.

For example, the mass of steel in a representative waste package is about 25,619 Kg (CRWMS M&O 1999e). This compares to about 3,892 kg in the invert over the same increment of tunnel (CRWMS M&O 1999d). The mass of steel in a WP is 6.6 times that of the invert over the same increment of tunnel, therefore, it may be stated that further reaction of seepage with invert steel is unlikely (Section 5.1).

The only new chemical component added by the invert materials and not present elsewhere in the drift is copper. The addition of copper in the invert may result in the formation of mineral phases that are not present in other locations within the drift. However, given its relatively small quantity it is not foreseen that the copper will compromise repository performance in any way.

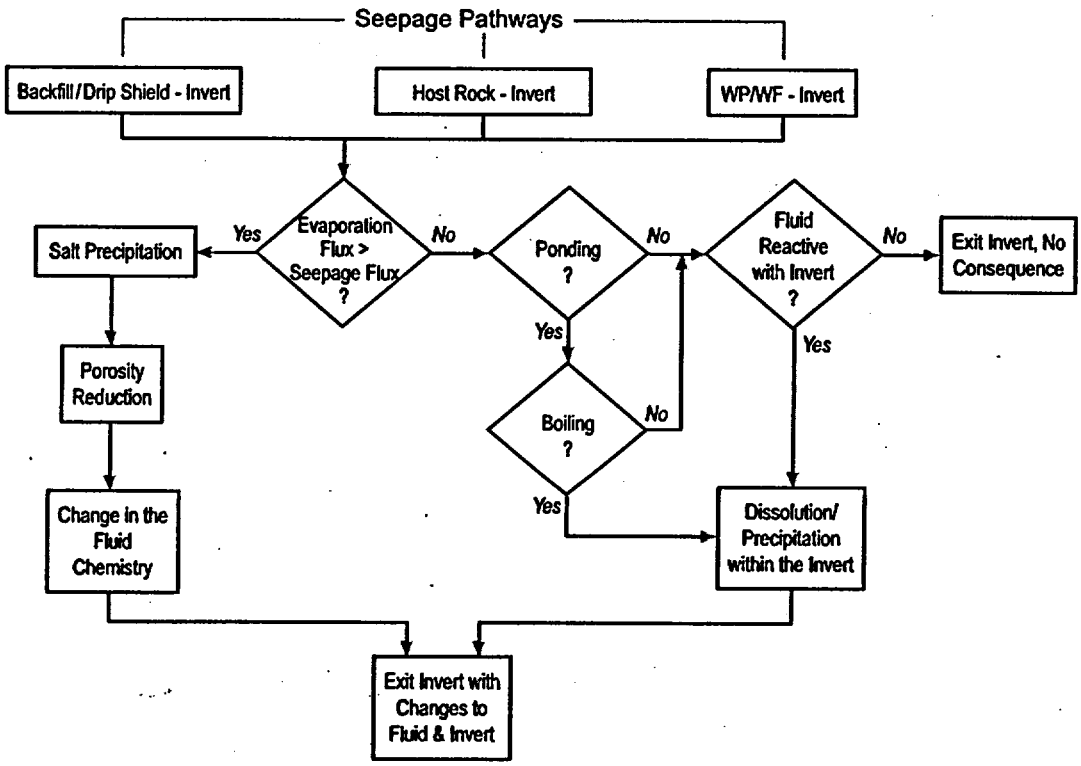

Figure 1. Schematic of the seepage/invert conceptual model.

6.2.2 Rationale for Screening All Seepage/Invert Interactions

Despite the reasoning summarized in Section 6.2.1, the question of whether or not seepage/invert reactions have a negative impact on repository performance cannot be scientifically resolved without analysis. For example, if identical reactants (e.g. tuff, steel, and water) are reacted under

different temperature conditions, then it is possible that the resulting products would be quite different for each temperature.

Variables such as temperature, pH, sulfate activity, and carbon dioxide fugacity (hereafter Master geochemical variables) are expected to be significantly different in the environment of the waste emplacement tunnels than in the host rock environment (outside the waste emplacement tunnels). For example, as temperature in the drift initially rises and then falls during the thermal period (Section 5.2), the pH of the seepage into the tunnels is expected to rise about 2 units from the ambient (i.e host rock) pH (CRWMS M&O 1998a Chapter 4,Table 4-43).

In addition to the Master geochemical variables, the ratio of water to solid may also be very important to seepage/invert reactions. The water:solid ratio will exert controls on the masses of materials that can be transported. If, for example, the amount of water available to seepage/invert interactions is small, then the potential mass of materials that can be transported away from the waste containers is also small. In such an instance, the reactive surface presented by the invert may be sufficient to exert a strong chemical control on the concentration of various ions released into the host rock. In contrast, if the amount of water circulating through the drifts is very large, then the importance of the invert will be diminished.

6.2.3 Significance of Seepage Pathways To Evaluating Seepage/Invert Interactions

In addition to the Master geochemical variables and water:solid ratio, another potentially important input to seepage/invert interactions is the pathway taken by the seepage to reach the invert and the chemical reactions that occur along the way. Seepage pathways include host rock to invert, backfill/drip shield to invert, and Waste Package/Waste Form (WP/WF) to invert. These pathways are expected to produce seepage in differing amounts and of different compositions. Moreover, the composition and volumes associated with each of these seepage paths is anticipated to vary with time because temperature and seepage flux will vary with time. This variability may cause geochemical processes that may occur in the invert (e.g. sorption, precipitation, flocculation of colloids, etc) to be operative at one time and inoperative at another.

6.2.3.1 The Host Rock to Invert Pathway

The host rock to invert pathway considers what processes occur when J-13 water (Section 5.5) flows from the host rock to the invert during the thermal and ambient regimes and the possible consequences to composition of the fluid and the properties of the invert.

6.2.3.1.1 Thermal Period

As the repository is heating, water flowing toward the invert will react with the host rock minerals and the ionic strength of the seepage will increase. The composition of the seepage can only be determined by detailed geochemical modeling, but increased concentrations might be expected for elements that are not tightly bound in crystalline lattices (e.g. components of glass) and/or are readily exchanged (e.g. alkali's). Upon entering the invert from the host rock, and dependent on the ratio of seepage flux to evaporative flux two possible outcomes may occur to the seepage. If the seepage flux is less than the evaporative flux then the water will vaporize and mineral salts will precipitate (CRMWS M&O 2000a). If the seepage flux is greater than the

evaporative flux then the seepage may flow through the invert or accumulate in the invert (Section 5.3).

If during the thermal period the seepage flux exceeds the evaporation flux, then there is a potential for ponding of water in the invert. If the water ponds, then boiling may take place in the invert, which would result in a complex series of geochemical reactions. Speculatively, boiling would reduce CO_2 solubility, thus increasing pH, perhaps precipitating carbonate phases, and resulting in an increase in silica solubility via pH elevation. The resulting solution chemistry may have a basic pH, be depleted in calcium and magnesium (via precipitation of carbonate phases), and be enriched in sodium, potassium, and silica. However, in the absence of laboratory studies and/or detailed geochemical modeling it is impossible to say what the resulting fluid composition and phase assemblage for such a scenario would be. Likewise, it is also difficult to say how boiling would affect the physical properties of the invert given that some phases would precipitate and others dissolve such that there may be no net change in the porosity/permeability of the invert.

On the other hand, if the seepage flux exceeds the evaporation flux and fractures/matrix are not plugged with mineral precipitates, then ponding may not occur. If this were to be the case then changes to either the fluid chemistry exiting the invert or the properties of the invert itself should be minimized.

In the case where the evaporative flux exceeds the seepage flux it is expected that the precipitation of salts following the reaction path described in the *In Drift Precipitates/Salts Analysis* (CRWMS M&O 2000a) AMR would occur. The net result would be a decrease in the porosity and perhaps permeability of the invert ballast and perhaps the adjacent host rock via pore space infilling with precipitate phases.

In the current design, the invert is confined at the bottom and along its sides by the host rock, and from above by the backfill. However, under the drip shield, the invert is not confined. Thus, seepage/invert interactions will tend to create a hydrologically heterogeneous platform, where lower permeability zones may form around the periphery of the tunnel and higher permeability material directly under the waste package. Salt precipitation within the invert may produce solid phases that have larger molar volumes (i.e. that occupy more space) than the original reactants. When the invert is contained in a confined volume, precipitation will tend to decrease the porosity of the invert and may create a material with lower permeability. When the invert is not physically confined phase precipitation may not reduce the porosity/permeability to the extent as in a confined system.

A fraction of the porosity reduction in the invert may be temporary in nature, because as the repository cools and the humidity increases and the seepage flux increases relative to the evaporation flux the highly soluble salt fraction (e.g. nitrate salts, alkali salts etc.) will be available to re-dissolve and form a brine (CRWMS M&O 2000a) and exit the invert. The less soluble fraction of the precipitated minerals (carbonates, silicates, etc.) (CRWMS M&O 2000a) may present a longer lasting reduction to the porosity/permeability of the invert. It should be noted that these processes will occur regardless of the materials selected to construct the invert, however, the choice of invert materials will have an effect on the resulting precipitates and fluid chemistry.

Reaction of seepage with the metal components of the invert might be expected to produce a host of phases such as goethite or hematite on or near the metal surfaces (Section 5.7). In a similar way, interaction of the seepage with the copper might be expected to produce cupric hydroxide, cupric sulfate, or cupric chloride. Under oxidizing conditions it is not expected that the metal components would significantly alter the composition of the seepage.

6.2.3.1.2 Ambient Period

At some time after the waste is emplaced the repository will cool, and the seepage flux will exceed the evaporative flux. Highly soluble salts previously deposited in the invert will tend to dissolve, thus raising the ionic strength of the seepage leaving the invert. This increase in ionic strength will be a transient effect that will last as long as highly soluble mineral phases are available. Following this peak in the ionic strength the composition of the water exiting the invert will slowly return to J-13 composition (Section 5.5). It is believed that the less soluble phases (carbonate, silicates, etc) precipitated in the invert during the thermal period will slowly redissolve into the seepage as ambient conditions return to the drift. The dissolution of the less soluble phases is likely because they were formed in a higher temperature regime and are likely to be out of equilibrium with respect to ambient J-13 water.

The initial elevation of the ionic strength of the seepage may be significant to the suppression of colloids because colloids tend to flocculate (i.e. settle out) in solutions of higher ionic strength (CRWMS M&O 2000c), thus removing them as agents of transport. High ionic strength seepage will also tend to saturate sorption sites in the invert ballast, thus reducing the sorptive capacity of the invert. As time goes on and the initial peak in the ionic strength passes sorption sites previously saturated will become available as sites reequilibrate with dilute J-13 composition water (Section 5.5).

The invert ballast is derived from the host rock; therefore, under ambient conditions seepage/invert reactions are expected to strongly resemble groundwater/host rock reactions. During the ambient period, flow through the host rock should produce the same reactions as flow through the invert. Therefore, no significant alteration the chemical composition of the fluid exiting the invert or the properties of the invert is expected during the ambient period.

6.2.3.2 The Backfill/Drip Shield to Invert Pathway

Along this flow path the backfill and the drip shield are considered together because of their proximity and because the drip shield is assumed chemically inert (Section 5.8). The primary role of the drip shield in this scenario would be to divert seepage to the margins of the tunnel rather than allowing the seepage to flow onto the waste package.

The behavior of the seepage is expected to resemble that described for the host rock/invert pathway. The primary differences being the potential for the seepage to react with the quartz sand which may comprise the backfill.

6.2.3.2.1 Thermal Period

The ratio of seepage flux to evaporation flux will determine if seepage entering the drift in the vicinity of the backfill/drip shield will reach the invert or if it will evaporate in/on the backfill/drip shield.

For the case where the seepage flux is less than the evaporation flux the seepage entering the drift will evaporate before entering the invert. If quartz sand is used as backfill, then the *Seepage/Backfill Interactions Analysis* AMR (CRWMS M&O 2000b) predicts that there will be no dissolution of the backfill during the thermal period, but rather precipitation of opal. In addition to the formation of opal the same process described for salt precipitation in the *Seepage/Backfill Interactions Analysis* AMR (CRWMS M&O, 2000b) and the *In Drift Precipitates/Salts Analysis* AMR (CRWMS M&O 2000a) will also be active.

Based on Assumption 5.3 it is possible for the seepage flux to exceed the evaporation flux during the thermal period. Therefore, opal saturated seepage may infiltrate through the backfill and be diverted by the drip shield to accumulate in the invert along the margins of the drift. It is possible that the temperature in the invert will be great enough to support boiling of this silica rich fluid. Should this occur then a more detailed geochemical analysis will be required to ascertain the resulting fluid composition and mineral assemblage.

6.2.3.2.2 Ambient Period

As described in Section 6.2.3.1.2, the thermal conditions within the drift will return to ambient and the seepage flux will exceed the evaporation flux. Phases previously precipitated will redissolve and there will be a transient in the chemistry of the solution exiting the drift (Section 6.2.3.1.2).

It is shown in the *Seepage/Backfill Interactions Analysis* AMR (CRWMS M&O 2000b) that under ambient conditions there should be little or no tendency for J-13 water to interact with the quartz backfill material. Therefore, water entering the invert from the backfill during the ambient period will be of similar composition as that entering from the host rock (Section 6.2.3.1.2).

6.2.3.3 The Waste Package to Invert Pathway

Seepage of water from breached waste packages is not considered for the thermal period, but only for the ambient period (Section 5.6). This assumption is consistent with assumptions made in the *Summary of In-Package Chemistry for Waste Forms* AMR (CRWMS M&O 2000d). Table 2 summarizes the expected in-package chemistry for the commercial spent nuclear fuel (CSNF), and for the co-disposal packages (CDSP) (CRWMS M&O 2000d).

Table 2. Range of In-Package Fluid Compositions in mol/l, except for Eh (volts) and pH (standard units) (source Table 3 CRWMS M&O 2000d, ACC: MOL. 20000217.0217).

Variable	CSNF	CDSP
pH	3.6-8.1	4.8-10.0
E_H	0.7-1.0	0.6-0.9
I	0.003-1.7	0.003-5.8
Ca	3.9E-6 - 0.00032	3.0E-7 - 0.02
C	2.8E-5 - 0.002	3.5E-5 - 0.5
Pu	0 - 5.6E-9	0-1.0E-4
Si	3.7E-10 - 1.9E-4	5.3E-10 - 1.9E-4
U	0 - 5E-3	0 - 1.1E-3

It would appear that there is the potential for reactions to occur between the invert ballast and effluent from the waste package. Low pH values would be conducive to dissolution of secondary carbonates in the invert and hydrolysis of glassy/feldspathic phases. Higher pH values, observed in the CDSP effluent, would increase the silica solubility of the invert materials, but might promote carbonate production. In the absence of geochemical modeling results or laboratory studies it is not possible to postulate on all of the potential reactions that could occur between the failed waste package effluent and the invert ballast. However, the extreme values of the chemistry reported in Table 2 suggest that reaction is almost certain to occur. It is not possible to determine the balance between solid removal processes (such as dissolution) and solid production processes (such as precipitation), therefore, it is not possible to state whether the porosity of the invert would be increased, decreased or affected at all by interactions with waste package effluent.

7. CONCLUSIONS

7.1 CONCEPTUAL MODEL-SUMMARY

The conceptual model for seepage/invert interactions centers around discussions of the seepage flow pathways to the invert, the seepage chemistry associated with each pathway, and how the processes that can occur in the invert may affect the physical properties of the invert and/or the chemistry of the liquid exiting the invert. The purpose of this AMR was to develop a logical conceptual model for interactions between seepage and the invert materials to screen potential processes and reactions that may occur, and to evaluate potential consequences of the interactions.

7.2 EXPECTED IMPACT ON THE IN-DRIFT CHEMICAL ENVIRONMENT

The following list offers the expected consequences of seepage/invert interactions:

- The invert component parts (ballast and metal materials) are not present in significant quantities with respect to the host rock and other introduced in-drift materials to exert a significant influence on the chemistry of the seepage exiting the drift.

- Transient changes to the physical properties (porosity/permeability and sorptive capacity) of the invert are expected to occur during the thermal period. These changes will occur via mineral precipitation as the water fraction of the seepage is vaporized. When conditions within the drift return to ambient it is expected that through flow seepage will dissolve the mineral precipitates such that there may be no long term change to the properties of the invert.

- Due to mineral precipitation during the thermal period and re-solution during the return to ambient temperature conditions it is expected that a period of elevated ionic strength seepage will exit the drift through the invert. It may stated with confidence that this condition would prevail regardless of the material used in the construction of the invert, i.e., it is not caused by the invert.

7.3 EVALUATION OF NRC ISSUE RESOLUTION STATUS REPORT CRITERIA

As this documentation contains only the conceptual discussions of the seepage/invert interactions submodel of the PAO EBS Physical and Chemical abstracted model, and as such the criteria in Section 4.2 were not evaluated nor do they all apply at this time.

7.4 RECOMMENDATIONS FOR FUTURE WORK

Clearly, the concepts discussed herein are of benefit to current analyses as this document provides some basis for assumptions that must be made in other in-drift modeling efforts. Although major impacts to the bulk in-drift geochemical environment are not foreseen, further work is justified. There is not a definite understanding of the processes that may occur within the invert and/or the chemistry of the seepage resulting from the various pathways throughout the lifetime of the repository.

Further work should consist of a) geochemical modeling the potential seepage compositions with the invert materials under differing gas compositions and temperatures; b) evaluation of the effects of mixing the seepage from the various flow paths on the resultant chemistry and properties of the invert; c) incorporation of the seepage/invert submodel into a model which couples the in-drift models; and e) validation of the constructed model.

It is not possible to validate a discussion of a conceptual model with further discussion, therefore, the only possible method that could be used in validation of the seepage/invert interactions model would be implementation of this model. Such a step would require information on the time history of the input parameters, gas composition, seepage flux and composition from each pathway, and temperature. In this way a model could be built such that various scenarios could be simulated which would result in a range of possible outcomes such that bounds could be set on the effects of seepage/invert interactions.

7.5 TO BE VERIFIED (TBV) IMPACT

There are no TBV's in this document, therefore this section is N/A.

7.6 FEP'S EVALUATION

Although the issues found in Table 1 are discussed in this conceptual model, the issues cannot be fully resolved until this conceptual model is utilized in further modeling work.

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

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8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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8.3 SOURCE DATA

No data are used in this conceptual model.