OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SPECIAL INSTRUCTION SHEET

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23. Remarks

This Revision 05 updates Determination of Importance Evaluation (DIE) BABEAF000-01717-2200-00011, REV 04/ICN 03, which addresses field activities associated with the Exploratory Studies Facility (ESF) ECRB Cross Drift. This DIE is required to be used as input in field work package, design drawing, and design specification documents that implement ECRB activities addressed herein. This REV 05 is distributed as a controlled document in accordance with AP-6.1Q.

Determination of Importance Evaluation Revision Record

DIE Title Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift		
DI Number (include revision number) BABEAF000-01717-2200-00011 REV 05		
Rev No.	Date	Description of Revision
00	12/11/97	Initial Issue.
01	03/07/98	Revised to incorporate an evaluation of activities associated with Phase II of the ECRB Drift (i.e., from approximately STA 7+73 meters (m)--or the point where the Cross Drift crosses over the Topopah Spring (TS) Main Drift--to the terminus of the drift, at approximately STA 28+23m). Updated throughout to reflect more current information relevant to the ECRB Drift. Incorporated editorial changes throughout. Accession numbers and record package information were added to the reference list (Section 14). Added Attachments III and IV. (Note: Change bars were not added in the new attachments).
02	06/24/98	<p>Changed "ECRB Drift" to "ECRB Cross Drift" throughout for project-wide, consistent identification. Deleted previous Requirement 16 from Revision 01 of this DIE. Incorporated analyses of thermal/structural/seismic impacts on potential waste emplacement (WE) drifts due to ECRB Cross Drift excavation in Section 11.4 and 13. Incorporated test updates due to qualification of NUFT and XTOL analytical software into Sections 5 and 11.1.2. Added new Section 11.1.2.3 and Attachment III for calculation of far-field water loss limit, renumbered previous Attachment III as Attachment V, renumbered previous Sections 11.1.2.3-11.1.2.5 accordingly, and made appropriate annotation and evaluation changes in Section 11.1.2. Removed the previous to-be-verified (TBV) condition on Phase II water loss limit throughout. Incorporated the results of ECRB Cross Drift Phase I testing and the results of Safety Assurance (SA) Department evaluation of ECRB Cross Drift Phase I water loss tracers, fluids, and materials (TFM) reports into Section 1 and 13. Incorporated Interim Change Notices (ICNs) BABEAF000-01717-2200-00011 REV 01/ICN 01 AND BABEAF000-01717-2200-00011 REV 01/ICN 02 as appropriate based on subsequent updates to water and surfactant testing zone locations. Added to Sections 6, 10, 11, and 13 a description and evaluation for auxiliary ECRB Cross Drift excavations, including testing niches and alcoves and operational support excavations. Also, added a new, replacement Requirement 16 for minimizing the potential for test inference associated with ground support in ECRB Cross Drift testing-related niches. Added specific requirements for controlling accuracy of ECRB Cross Drift input and discharge water flow meters to Section 13.3. Clarified in Sections 13.2 and 13.3 that only appropriate meters are to be used for each application. Incorporated an allowance into Sections 13.2 and 13.3 for judgements to estimate water use at very high or very low flow rates, where meter accuracy is questionable. Added to Section 13.2 and 13.3 an allowance for manual operation of conveyor system water spray valves when the automatic system is out of service. Incorporated into Sections 6 and 13 a description and evaluation of muck deposited on the ECRB Cross Drift invert. Also, added specific QA controls to Requirement 5 that mandate removal of muck from the invert beyond STA 7+50m of the ECRB Cross Drift, require installation of an invert collection point at STA 7+50m, require the Test Coordination Office (TCO) to check observation points periodically in the muck prior to STA 7+50m for persistent standing water, require removal of muck prior to STA 7+50m if persistent standing water is observed, and make allowance for the temporary use of muck at the breakouts of auxiliary excavations to ensure stable footing for mechanical excavators during construction. Incorporated a discussion on gas-phase conductivity relative to potential repository performance in Sections 11 and 13.2. Added to Section 13.2 a discussion of confirmatory testing to be conducted in the TS Main Drift at the cross-over point of the ECRB Cross Drift. Updated the approved TFM lists in Attachment II. Replaced, updated, or added several reference in Section 14 in support of the Revision 02 evaluation herein. Incorporated and superceded Category II DIE BABEAF000-01717-2200-00013, REV 00. Incorporated various editorial changes throughout.</p>

Determination of Importance Evaluation Revision Record

DIE Title Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift		
DI Number (include revision number) BABEA000-01717-2200-00011 REV 05		
Rev No.	Date	Description of Revision
03	09/04/98	Incorporated an evaluation of the temporary storage of the ECRB Cross Drift tunnel boring machine (TBM) in a standby condition at approximately STA 28+23m until its ultimate disposition is determined. Clarified in Section 13--including Requirement 5--that invert observation sleeves are not required in segments of the ECRB Cross Drift before STA 7+50m where tunnel muck has been removed to the extent that water flow to periodic invert water collection points is not obstructed. Allocated the evaluation of site-characterization-related testing activities to the DIE for Subsurface Testing Activities (Civilian Radioactive Waste Management System [CRWMS] Management and Operating Contractor [M&O] 1998e). Amended Sections 6, 10, and 13 to allow the use of misted water sprays on the mechanical excavator cutterhead and water sprays on its muck conveyor during the excavation of the access drifts for ECRB Cross Drift niches. Amended Section 13--including the addition of a new Requirement 20--to mandate a QA survey of ECRB Cross Drift auxiliary excavations, such that their locations are accurately integrated into a repository design. Incorporated into Section 11.1.2.2.4 an evaluation of ECRB Cross Drift thermohydrologic effects on repository performance under high infiltration conditions. Clarified the evaluation of mountain-scale thermohydrologic effects on the ECRB Cross Drift on repository performance by addressing the proposed repository thermal loading strategy. Updated or added Section 14 references, as necessary. Incorporated various editorial changes throughout.
04	04/12/99	Incorporated a standardized format throughout, including a major philosophical change in DIE reference list format (Section 14) and individual reference citations format throughout, to satisfy Ensure Defensible Documents initiative requirements. Updated computer software identification information in Section 5, including Computer Software Configuration Identification (CSCI) numbers for NUFT and XTOOL. Revised the description, evaluation, and QA control requirements applicable to the design and construction of ECRB Cross Drift Alcove #8 and Niches #5 and #6, to address current testing criteria. Added ECRB Cross Drift bulkheads at approximately STA 17+00m and 24+50m to the DIE scope. Updated evaluation and QA requirements associated with drill-and-blast excavation techniques. Updated Attachment II and added various approved TFM. Updated Section 13 evaluations and QA controls associated with water reporting and maintenance of components containing TFMs were revised to ensure consistency with the DIE for the Surface ESF (CRWMS M&O 1999a). Incorporated various editorial changes throughout. (Note: Not all format changes were identified by change bars).
05	12/17/01	Incorporated evaluation of core drilling and slot cuts in the ECRB Cross Drift for geomechanical studies, evaluated establishing refuge stations in the ECRB Cross Drift in Alcove #8 and behind the bulkhead at STA 17+63m, use of electrical powered locomotive for materials and personnel transportation, evaluated the effects of reversing the ventilation system fans on ECRB Cross Drift testing activities, evaluated setup of the Cross Drift Thermal Testing (Alcove #10), and evaluated the addition of alarm lights in the ECRB Cross Drift tunnel. Identified limiting effects on lateral dispersion of water movement through Repository Horizon rock strata as modeled by LBNL. Updated or added to Section 14 to include references appropriate to the evaluations within this Revision. Updated Section 13 evaluations and QA controls to address the new evaluations within this REV 05. Updated Attachment II to include the TFMs approved by this REV 05. Addressed DIE concerns related to impacts on waste isolation and test interference directly related to Design Specifications and Drawings. Added Attachment VI to the DIE document as a sketch of the Alcove #8 Refuge Chamber area with test exclusion areas shown, and, incorporated various editorial changes throughout.

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1. PURPOSE AND SCOPE

1.1 PURPOSE

The objective of this DIE is to determine whether the ECRB-Cross-Drift-related activities, as identified in Section 6.0, could potentially impact (1) Yucca Mountain Site Characterization Project (YMP) testing or (2) the waste isolation capabilities of a potential repository at the Yucca Mountain site. Any controls necessary to limit such potential impacts are also identified herein.

1.2 SCOPE

This DIE applies to Phases I and II of the ESF ECRB Cross Drift (also known as the ESF East-West Cross Drift). The ECRB Cross Drift originates on the left rib of the ESF North Ramp and crosses at approximately 15 m to 20 m above the proposed WE zone of the potential repository block (in an east-northeast to west-southwest direction) (Section 6.1). The ECRB Cross Drift will end at a terminal face just west of the western most strand of the Solitario Canyon fault. Phase I is the portion of the ECRB Cross Drift from the end of the ECRB Cross Drift Starter Tunnel to the crossover point of the TS Main Drift. Phase II is the portion of the ECRB Cross Drift from the crossover point of the TS Main Drift to its terminus. This Category III DIE was developed for the ECRB Cross Drift because the waste-isolation-related assumptions and models used in the DIE for the Subsurface ESF (CRWMS M&O 1999a) do not completely bound ECRB Cross Drift activities.

This evaluation applies to all ECRB Cross Drift construction and operation activities. Activities associated with construction/mobilization of testing accommodations—such as borehole drilling or the installation of test instrumentation—throughout the ECRB Cross Drift are also evaluated herein. A brief description of these activities is provided in Section 6.0. Activities associated with the actual conduct of testing are not evaluated by this DIE. The determination of potential test-to-test interference impacts attributable to the conduct of testing activities is the responsibility of the assigned Principle Investigator(s) (PIs) and is addressed in the supporting evaluation(s) for the applicable FWP. Furthermore, the validity and veracity of the test data are also the responsibility of the assigned PIs and are not evaluated in this DIE.

Revision 01 of this DIE incorporated the evaluation of activities associated with Phase II of the ECRB Cross Drift—i.e., the portion of the drift that passes over the potential Waste Emplacement (WE) zone of the repository block.

Revision 02 addressed several key technical considerations. The most significant change associated with Revision 02 was the elimination of the previous Requirement 16 from Revision 01 of this DIE. This requirement imposed a hold on ECRB Cross Drift excavation at Station 7+73 m (i.e., the crossover point of the TS Main Drift). The excavation hold point removal was contingent upon the resolution of four specific criteria. The basis for resolution and closure of each hold contingency and an overview of changes to the evaluation herein, as appropriate, are as follows:

1. The formal evaluation (CRWMS M&O 1998a) of potential thermal/structural impacts attributable to ECRB Cross Drift excavation on WE Drifts within the proposed repository block concluded that there was a negligible potential for impacts. The specific results of these analyses were incorporated into Sections 11.4 and 13.
2. QA program qualification of the hydrologic modeling software, used in Section 11.1.2 of this DIE to evaluate hydrologic conditions, was completed, and appropriate changes were incorporated into Sections 5, 11.1.2, 13, and 14 of this DIE. Further, the software used in Revision 01 of this DIE as the basis for establishing a Phase II far-field water loss limit was replaced by a new hand calculation (Attachment III). The previous computer calculation (Attachment V) provides corroboration for the new hand calculation. The change in basis calculations was also integrated into the evaluations in Sections 11.1.2.2 and 11.1.2.3. The Phase II ECRB Cross Drift water loss limit was not changed as a result of the software qualification effort. Therefore, changes to the Section 13.2 conclusions and the Section 13.3 QA controls were not required, with the exception of removing the TBV condition previously levied by Revision 01 of this DIE. The Revision 01 TBV condition was also removed from Sections 1, 5, and 11.
3. The SA Department reviewed ECRB Cross Drift Phase I testing results (Los Alamos National Laboratory [LANL] 1998a). Phase I testing results confirmed that the water loss limits derived in Section 13 of this DIE were sufficiently conservative to limit potential impacts to waste isolation to the extent practical. Several changes were made throughout Section 13 to integrate ECRB Cross Drift Phase I testing results.
4. The SA Department reviewed records of ECRB Cross Drift Phase I water loss (CRWMS M&O 1998b). Under normal, optimum tunneling operating conditions, water loss within the drift was consistently significantly below the ECRB Cross Drift Phase II water loss limit. Further, CRWMS M&O (1998b) water loss records also demonstrated that the ECRB Cross Drift Phase II water loss limit was consistently met in Phase I drift segments, even with abnormally high water use. Several changes were made throughout Section 13 to integrate these results into the evaluation therein.

Revision 02 also incorporated ICNs 01 and 02 to Revision 01 of this DIE. ICN 01 changed the locations of the ECRB Cross Drift Phase I water testing and surfactant testing zones from original testing locations as evaluated in Revision 01. The point along Phase I the ECRB Cross Drift beyond which surfactant material could not be used without further evaluation by the SA Department was also changed. These changes were necessary to ensure sufficient ECRB Cross Drift space to accommodate complete assembly of the final configuration of the TBM before Phase I testing activities was initiated (CRWMS M&O 1998c). The final configuration of the TBM was important to Phase I testing results, in that this testing was intended to represent normal, optimized TBM tunneling operations. ICN 02 subsequently moved the Phase I water testing and surfactant testing zones from the ICN 01 testing locations to ensure that a scheduled TBM shutdown would not interfere with testing results (CRWMS M&O 1998d). Consequently, ICN 02 also changed the point along Phase I of the ECRB Cross Drift beyond which surfactant material use was prohibited without further evaluation by the SA Department. Ultimately, the actual Phase I testing-zone locations were determined in the field (with TCO concurrence), and

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the actual testing-zone locations (LANL 1998a) were integrated throughout Revision 02 of this evaluation. As such, only the ECRB Cross Drift Phase I surfactant restriction limit change from ICN 02 was incorporated into Revision 02 of this DIE. In addition to the Phase I testing zone changes, ICN 01 generated three clarifications that were incorporated by Revision 02. Specifically, clarifications of: 1) the ECRB Cross Drift TFM water loss reporting requirements; 2) ECRB Cross Drift TFM reporting exemption allowances; and 3) the definition for a liquid-phase water balance were incorporated into Section 13.

A number of other changes were incorporated by Revision 02 as follows. A description and evaluation for the construction of auxiliary ECRB Cross Drift excavations—including operational support excavations and testing niches and alcoves—was incorporated into Sections 6, 10, 11, and 13. A new, replacement Requirement 16 associated with ground support requirements in testing-related ECRB Cross Drift niches was also generated. It should be noted that ECRB Cross Drift niche and alcove testing activities are not evaluated by this DIE and are addressed in a separate DIE. Specific requirements for ECRB Cross Drift supply and discharge water meter flow checks and a clarification that appropriate water meters are to be used for individual applications were added to Section 13. An allowance for using judgement to estimate water use at very high or low flow rates, where meter accuracy is questionable, was also incorporated into Section 13. A new allowance for manual operation of conveyor belt water spray valves during periods of off-normal (i.e., not automatic) operation was addressed in Section 13. A description and evaluation associated with tunnel muck deposited on the invert between cross ties have been addressed in Sections 6 and 13. Specific QA controls were added to Requirement 5 that: 1) mandate removal of muck from the invert beyond Station 7+50 m of the ECRB Cross Drift, 2) require the installation of a invert collection point near Station 7+50 m, 3) require the TCO to check periodic observation points in the invert muck before Station 7+50 m for persistent water collection, 4) require removal of invert before Station 7+50 m if persistent excessive water is observed, and 5) make allowance for using muck at the breakouts of auxiliary excavations to ensure stable footing for road-header-type mechanical excavators during construction. A specific discussion on the effects of the ECRB Cross Drift on gas-phase conductivity associated with the proposed repository block performance was added to Sections 11 and 13. A discussion of the confirmatory testing to be conducted in the TS Main Drift at the cross over point of the ECRB Cross Drift was added to Section 13.2. Several references in Section 14 were replaced, updated, or added in support the Revision 02 evaluations herein. The TFM list in Attachment II was also updated.

Revision 02 of this DIE completely incorporated and superseded the following Category II DIE:

BABEAF000-01717-2200-00013 REV 00, *Determination of Importance Evaluation for ECRB Cross Drift Steel Cross Ties.*

Revision 03 of this DIE addressed (Sections 6 and 13) temporary storage of the TBM at approximately Station 28+23 m of the ECRB Cross Drift, i.e., the terminus of the current ECRB Cross Drift excavation. The TBM will be maintained in a stand-by condition at this location until its ultimate disposition is determined. Revision 03 also clarified the Section 13.2.19 evaluation for segments of the ECRB Cross Drift before Station 7+50 m where muck has been removed. Revision 03 formally allocated the evaluation of ECRB Cross Drift site-

characterization-related testing activities—including testing in ECRB Cross Drift auxiliary excavations—to the DIE for Subsurface Testing Activities (CRWMS M&O 1998e). Revision 03 also amended Sections 6, 10, and 13 and Requirement 5 to allow misted water use within the access drifts of ECRB Cross Drift niches during their excavation. To ensure that accurate line and grade information for ECRB Cross Drift auxiliary excavations is available for integration into a repository design, Revision 03 amended Section 13—including a new Requirement 20—to mandate a QA survey of all auxiliary excavations. Revision 03 incorporated into Section 11.1.2.2.4 an evaluation of ECRB Cross Drift thermohydrologic effects on repository performance under high infiltration conditions. Revision 03 also clarified the Section 11.1.2.2.6 evaluation of mountain-scale thermohydrologic effects of the ECRB Cross Drift on repository performance by addressing the proposed repository thermal loading strategy.

Revision 04 incorporated a new standardized-document format, which is more consistent with other CRWMS M&O documents, pursuant to the requirements of the M&O Ensure Defensible Documents initiative. The reformatting effort included major philosophical changes in the previous DIE reference list format (Section 14) and in reference-citation formats used throughout the text. Revision 04 revised the description, evaluation, and QA control requirements applicable to the design and construction of ECRB Cross Drift Alcove #8 and Niches #5 and #6, to address current testing criteria. ECRB Cross Drift bulkheads at approximate Stations 17+00 m and 24+50 m to facilitate testing were added to the DIE scope under Revision 04. Revision 04 updates the evaluation and QA requirements associated with drill-and-blast excavation techniques. Various approved TFMs were added to Attachment II by Revision 04, and the Attachment II format was modified slightly to ensure consistency with other Category III DIEs. Revision 04 also incorporated various minor editorial changes throughout the DIE.

Further revision of this DIE is not required to support ongoing construction of ECRB-Cross-Drift-related construction activities. Construction of those Alcoves of the ECRB Main Drift for testing studies, are acceptable provided such activities remain consistent with the activity descriptions in Section 6. However, another revision of this DIE would be required if there were changes to the planned ECRB Cross Drift construction activities as currently described and evaluated herein.

2. QUALITY ASSURANCE

evaluation using Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) NLP-2-0, *Determination of Importance Evaluations*, Program (CRWMS M&O 2000). A Technical Work Plan has been prepared for those activities implemented by NLP-2-0 in accordance with AP-2.21Q, *Quality Determination and Planning For Scientific Engineering and Regulatory Compliance Activities*, to evaluate activities described herein in terms of their being subject to QARD requirements (DOE 2000). This establishes the responsibilities and processes for this DIE. This DIE Quality Assurance (QA) program to the evaluated ESF subsurface testing activities to have been 10 of the Regulations, Part 60 (10 CFR 60), Section 15(c)(1), also

DIE. This evaluation was prepared using Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) implementing line procedure Nevada Line Procedure NLP-2-0, *Determination of Importance Evaluations*, subject to the requirements of the United States Department of Energy (DOE) Office of Civilian Radioactive Waste Management Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program (DOE 2000). A Technical Work Plan has been prepared for those activities implemented by NLP-2-0 in accordance with AP-2.21Q, *Quality Determination and Planning For Scientific Engineering and Regulatory Compliance Activities*, to evaluate activities described herein in terms of their being subject to QARD requirements (CRWMS M&O 2000e). This establishes the responsibilities and processes for this DIE. This DIE is quality affecting because it establishes the applicability of the Quality Assurance (QA) program to the evaluated activities associated with the ECRB construction and testing activities. Specific regard is provided to potential impact to site characterization data, the waste isolation capabilities of a potential geologic repository at the Yucca Mountain site, and other permanent, Q-List (YMP 1998a) items (which have been classified QA-1, QA-2, and QA-5, including natural barriers) that have been constructed or installed at the Yucca Mountain site. Pursuant to the requirements of Title 10 of the Code of Federal Regulations, Part 60 (10 CFR 60), Section 15(c)(1), QA controls are provided for minimizing, to the extent practical, any potential for impacts (as identified herein) to permanent, classified items, including potential impacts associated with the use of temporary items, are also established by this DIE.

3. METHODOLOGY

This evaluation was performed in accordance with procedure NLP-2-0, (CRWMS M&O 1998f). It is a Category III DIE because it addresses field activities that are potentially significant with respect to their effects on Q-List (YMP 1998a) items and/or site characterization data and that do not have an applicable Category III DIE or analogous precedent. This DIE was prepared by:

1. Reviewing the best available design information related to subsurface construction, operation, and maintenance activities associated with the ECRB Cross Drift.
2. Evaluating the potential of these activities, including the use of associated temporary items, to affect Q-List (YMP 1998a) items and site characterization testing.
3. Establishing controls as required to minimize, to the extent practical, potential impacts on Q-List (YMP 1998a) items (including the natural barriers) and site characterization testing.

The best available information related to ECRB Cross Drift items/facility construction, operation, maintenance, and testing activities includes but is not limited to preliminary/approved M&O design documents and construction drawings and specifications, FWPs, Site Investigation Study Plans, TCO/PI criteria letters, and applicable Lotus Notes. In cases where inputs from these documents provide critical characteristics that could potentially impact the conclusions and derived requirements of this evaluation, specific reference citations are provided in the text.

After approval of this DIE, implementing documents (e.g., FWPs, design specifications, and design drawings) will be reviewed by the SA Department. These reviews are conducted to:

1. Ensure that the original basis for the evaluation (i.e., best available design information) adequately bounds the final scope of activities to be conducted in the ECRB Cross Drift.
2. Verify that any applicable DIE requirements have been properly integrated into the implementing documents.

4. ASSUMPTIONS

- 4.1 It is assumed throughout this DIE that Phase I (Stations 0+26.4 m to 7+73 m) and Phase II (Stations 7+73 m to 28+23 m) of the ECRB Cross Drift are offset from the closest waste package emplacement area by a minimum distance of 37 m (CRWMS M&O 1999a) and 15 m (CRWMS M&O 1997a), respectively. This assumption establishes bounding conditions for the ECRB Cross Drift analysis.
- 4.2 It is assumed throughout this DIE that ECRB Cross Drift construction activities (e.g., TBM operation and support, utility installation, testing accommodation support/set up, and dust suppression) are conducted in accordance with approved design documents (i.e., specifications and drawings) and FWPs. It is further assumed that design documents and FWPs implement the applicable requirements of the ESF Design Requirements (ESFDR) (YMP 1997), as supplemented by CRWMS M&O (1998g). This assumption is based on the preservation of a conservative design basis, and it establishes the boundary conditions for this DIE.
- 4.3 The TFMs to be used in the ECRB Cross Drift will be those for which data (e.g., Material Safety Data Sheets [MSDSs]) have been provided and reviewed (Attachment II). TFMs that have not yet been reviewed will be evaluated in accordance with the project DIE procedure NLP-2-0. It is assumed throughout this DIE that the MSDS-recommended handling and use practices will be followed for use, storage, handling, ventilation, spills, leaks, and personnel safety. Similarly, Section 13.2 of this DIE specifically exempts certain temporary items/materials from TFM program reporting requirements because their use is evaluated herein to have negligible potential to impact either site characterization data and/or site waste isolation characteristics. This assumption establishes the scope for this DIE with respect to TFMs and is based on the ESFDR (YMP 1997) and Yucca Mountain Administrative Procedure (YAP) YAP-2.8Q (YMP 1998b).
- 4.4 Based on the TFM procedure (YMP 1998b), it is assumed throughout this DIE that water used for fire suppression and control will be treated as a significant spill.

5. COMPUTER CALCULATIONS

Analytical computer calculations were performed for the near-field thermohydrologic and far field hydrologic analyses presented in Section 11.1.2. The near-field thermohydrologic calculations were performed using the Nonisothermal Unsaturated-Saturated Flow and Transport Model (NUFT) (Lawrence Livermore National Laboratory [LLNL] 1998a), V2.0h (CSCI: LLYMP9805013). Post-processing manipulations of NUFT output files were performed using XTOOL V7.15 (CSCI: LLYMP9805014) (LLNL 1998b) graphical presentation software. The calculations were performed on Digital Equipment Corporation alpha station 500 and Hewlett Packard PA 8000 J-Series workstations. Corroborative computer calculations for the far-field hydrologic effects of water use were performed using the Unsaturated, Transient Flow Model (UTFM), versions fracmat20, frpmat22, and fmecrb, as described in Section 11.1.2. These calculations were performed on a Dell 286 Megahertz Pentium II, Powerededge 2200 computer. The UTFM software is not currently approved nor controlled under procedure AP-SI.1Q. However, the corroborative computer calculations for the far-field hydrologic effects of water, which were performed by UTFM, were not relied upon as the basis for establishing DIE controls. Therefore, UTFM does not perform a function subject to QA program software requirements.

The input and output files for the calculations presented in this DIE are available on electronic media in the records package for Revision 02 of this DIE. A complete copy of the UTFM code is also available on electronic media in the records package for Revision 02 of this DIE. Discussions concerning the applicability of the calculations to the problems addressed are given in Section 11.1.2. Therefore, the results of the calculations given here—which provide the best available information for this DIE—are preliminary.

No other analytical computer programs were used directly in the preparation of this document. Computer programs have also been used in some of the referenced documents that form the basis for some of the results presented in this DIE. The applicable reference document for each computer calculation details the use of software, including required QA Program documentation.

The industry standard computational software package Macsyma Pro (2.2), version 2.6.1c was used in Attachment III of this DIE. A trapezoidal rule integration routine, "traprule," which is a standard application for this software package, used in numerically evaluated integrals. The use of this software was consistent with its intended application. No special routines or macros were used to perform these calculations.

6. DESCRIPTION OF ITEMS/ACTIVITIES

6.1 OVERVIEW AND PHASE I AND II BOUNDARY DEFINITIONS

This section provides general descriptions of ECRB Cross Drift items/facility construction, operation, maintenance, and testing activities. These activity descriptions establish the general bounding conditions for this DIE. Future activities that are not bounded by these activity descriptions will require a separate SA Department evaluation as required by NLP-2-0 (CRWMS M&O 1998f).

CRWMS M&O (1997a and 1998h) and LANL (1997) describe the layout of the overall ECRB Cross Drift. This drift begins with an approximately 26-m-long ECRB Cross Drift Starter Tunnel, which is located on the left rib of the ESF North Ramp at approximately Station 19+92 m. Activities associated with the ECRB Cross Drift Starter Tunnel have been evaluated by CRWMS M&O (1999a). From the Starter Tunnel, the ECRB Cross Drift extends generally west-southwest for approximately 2823 m, where it terminates underground at a point approximately 50 m west of the western-most strand of the Solitario Canyon fault. The path of the ECRB Cross Drift passes approximately 15 m to 20 m above the proposed WE zone of the potential repository. There is a minimum offset of approximately 53 m between ECRB Cross Drift and the ESF Thermal Testing Facility (TTF), which meets the requirement of a 50-m to 100-m offset as established by the responsible PI (LANL 1997). The excavated invert of the ECRB Cross Drift has a positive slope relative to the ESF North Ramp (i.e., it slopes upward from its origin) until the drift is completely through the proposed WE zone. The excavated invert slope then becomes negative to the west of the proposed WE zone.

At approximately Station 7+73 m of the ECRB Cross Drift, the drift crosses the TS Main Drift (at about TS Main Drift Station 30+61 m) approximately 20 m to 25 m above the TS Main Drift centerline. The portion of the ECRB Cross Drift between the Starter Tunnel and the TS Main Drift crossover point is defined as Phase I (approximately Stations 26.4 m through 7+73 m). Phase II of the ECRB Cross Drift (approximately Stations 7+73 m through 28+23 m) is defined as the portion of the drift between the TS Main Drift crossover point and its terminus.

6.2 CONSTRUCTION

6.2.1 TBM Excavation

From approximately Station 0+26 m of the ECRB Cross Drift, excavation is accomplished by TBM. The TBM is an electric-powered continuous mechanical mining or excavation machine, which consists primarily of a cutting head, shielding, grippers, and several cars of trailing gear—which may accommodate the TBM operating systems. As discussed in CRWMS M&O (1997b), the ECRB Cross Drift TBM is sufficiently similar to the TBM used to excavate the ESF TS Loop so as to be generally bounded by the TBM activity description in CRWMS M&O (1999a), with two exceptions. First, the ECRB Cross Drift TBM has a 5-m diameter cutterhead. Second, the ECRB Cross Drift TBM cutterhead is equipped with a water spray system for controlling dust.

CRWMS M&O (1998i) provides further details on the ECRB Cross Drift TBM, as discussed below. The TBM dust control system consists of water spray nozzles mounted on the cutterhead, water sprays directed onto the conveyor and a dry type filter in the ventilation system. Each of the 10 water spray nozzles on the TBM cutterhead will initially be configured to provide a flow rate of 5 gallons per minute (gpm). The cutterhead nozzles will be operated at different flow rates during Phase I excavation with the intention of determining an optimum flow rate, which maximizes water recovery and removal with tunnel muck via the conveyor belt. Phase I testing activities, as discussed below, may further refine the TBM water spray system flow rates before the excavation of Phase II.

The TBM is equipped with several features designed to minimize the potential commitment of TFMs. Drip pans are installed under all reservoirs except the main hydraulic oil tank, which is impractical. The TBM was retrofit with new hoses. A spill clean up plan is to be in effect during TBM operations. Spill cleanup kits are installed at various locations on the TBM. The main lubrication system is a closed loop. Waste fluids are contained separately and are periodically removed from the ESF/ECRB Cross Drifts. The cooling water system is also a closed loop.

TBM systems that contain/process TFMs are as follows:

1. Main propel and gripper hydraulic system
2. Rock drills hydraulic system
3. Ventilation clamshell hydraulic system
4. Conveyor advancing tailpiece hydraulic system
5. Cooling water system
6. Dust control and general water system, including water used by rock drills
7. Lubrication system

The TFMs used by the TBM and the capacity of each respective reservoir are as follows:

1. AW46 hydraulic fluid:	Main	—	600 gallons (gal)
	Clamshell	—	20 gal
	Rock Drills	—	150 gal
	Conveyor tailpiece	—	10 gal
2. 90W gear oil for lubrication		—	80 gal
3. Water		—	600 gal

Per CRWMS M&O (1998j), a potential extension of the ECRB Cross Drift into the Calico Hills lithostratigraphic unit is not included in the current scope of work. However, a future extension of the drift is not to be precluded. To accommodate this guidance, the TBM will remain at approximately Station 28+23 m of the ECRB Cross Drift, and it will be placed in appropriate graded equipment maintenance/management program. An appropriate auxiliary facility will be excavated to permit access to TBM components and to minimize the effects of ground squeeze. The TBM will be placed in a long-term stand-by status.

6.2.2 Ground Support, Invert, and Rails

Ground support techniques used in the ECRB Cross Drift are sufficiently similar to those used in the ESF TS Loop so as to be completely bounded by the activity description in CRWMS M&O (1999a). However, the invert and rail line for the ECRB Cross Drift differ from the TS Loop configuration. As discussed in CRWMS M&O (1997b and 1998i), the ECRB Cross Drift steel rail line is laid on treated wooden cross ties (with no ballast material) on the excavated rock surface of the drift—with the exception of the first 175 to 180 m of the ECRB Cross Drift (as discussed in the following paragraph). Rails are fastened to the cross ties with steel components. The cross ties are treated with a FR-40 fire retardant coating that is manufactured by Firestop Systems, Inc. Steel cross ties could potentially be used as an alternative to treated wooden cross ties. The cross ties do not bear fully on the invert. A small gap between the center of cross ties

and the invert facilitates the flow of construction water to periodic invert water collection points constructed similar to the sumps in the TS Loop. A grated or perforated metal walkway is installed the entire length of the ECRB Cross Drift on the side of the tracks opposite the conveyor system. An additional configuration option to the grated or perforated metal walkway is a treated wooden walkway (FR-40 fire retardant).

Per CRWMS M&O (1998i), installation of the conveyor belt take-up unit could not be completed until the TBM cutterhead reached approximately Station 1+80 m of the ECRB Cross Drift. Until the final assembly of the conveyor belt take-up unit, tunnel muck was dumped on the invert behind deck 2 of the TBM, picked up by a tunnel mucker, and placed on the conveyor belt in the North Ramp. This operation resulted in a muck ballast being deposited between the cross ties, which remains in place pending the following restrictions (as committed in CRWMS M&O [1998i]):

1. A catchment with pumps, or other water collection/recovery means, will be provided near the Station 1+80 conveyor belt take-up unit to prevent water from being introduced to the invert and lost into the ballast material. Any water collected in this catchment will be removed by the waste water system.
2. Any water used for invert dust control before approximately Station 1+80 m will not be allowed to pond in the ballast material.
3. At 5 locations between approximate Stations 0+26 m and 1+80 m, 12-inch diameter observation sleeves will be installed adjacent to a cross tie to facilitate checking of the invert and the cross tie for water and/or its effects.
4. Should the TCO and/or the SA Department conclude that persistent standing water is creating significant potential for the fire retardant material on the cross ties to leach into the invert, the muck will be removed pending a recommendation from the TCO and/or the SA Department.

6.2.3 Dust Suppression

CRWMS M&O (1997c and 1998i) identify various dust control techniques to be implemented in the ECRB Cross Drift. As noted above, the TBM cutterhead is equipped with water spray nozzles for dust suppression purposes. A surfactant material—specifically, CW-10—will also be used/tested at the TBM cutterhead. Behind the TBM, fog and/or misting nozzles are used for periodic wetting of the invert. Self-cleaning, dry-type spot filters and water sprays (focused directly on the conveyor belt) are used to control dust associated with the muck conveyor system. The conveyor system water sprays are expected to have a flow rate of approximately 250 gallons per meter (gal/m) of ECRB Cross Drift advance, and they are automatically controlled to operate only while the conveyor is operating.

The surfactant material was injected into the water supply line at the cutterhead of the TBM and was applied only through the TBM cutterhead and only in a Phase I testing zone (Section 6.4.1). The purpose of the surfactant was to increase dust suppression effectiveness while reducing the

amount of water required for the control of airborne dust. The ECRB Cross Drift surfactant material was specifically formulated for use in this application (Fogger Systems International 1997). The ECRB Cross Drift surfactant has a relatively low organic material content for surfactant materials, and it was injected into the TBM cutterhead water supply line at a low concentration level (Fogger Systems International 1997, MSDS). The only planned use of the surfactant material in the ECRB Cross Drift was within the designated testing interval of the Phase I portion of the drift (Section 6.4.1).

As the conveyor carries muck out of the ECRB Cross Drift, water applied to the muck evaporates, which may increase the potential for dust generation associated with conveyor operation. To minimize the potential for conveyor-related dust generation, a system for applying a binding agent to the muck may potentially be added to the conveyor water spray system. Application of a binding agent is restricted to the top of the conveyor belt while the conveyor is in operation only.

6.2.4 Other Construction Equipment

CRWMS M&O (1999a) describes and evaluates various TS Loop construction equipment, which is sufficiently similar to equipment used in the ECRB Cross Drift, such that CRWMS M&O (1999a) generally bounds their ECRB-Cross-Drift-related use. Such equipment includes rock drills, diesel locomotives, rolling stock. CRWMS M&O (1998i) specifies that the anticipated quantity of water to be used for rock drilling activities is approximately 60 gal/m of ECRB Cross Drift advance. CRWMS M&O (1998i) also identifies two pieces of equipment that are unique to the ECRB Cross Drift—an elevating platform car and a mapping deck. The platform car has a hydraulic system that contains approximately 20 gal of fluid, while the mapping deck has no fluid containing systems.

6.2.5 Water Recovery

Due to the potential for committed quantities of TFMs—including water-related and dust-suppressant-related TFMs—to impact site characterization data and waste isolation characteristics, various methods for recovering water and surfactant will be implemented. The types of recovery methods are similar to the spill recovery and excess water removal activities used in other ESF alcoves described in CRWMS M&O (1999a). CRWMS M&O (1998i) also addresses an ECRB Cross Drift water recovery system, which includes the construction of periodic water collection points in the invert floor and the installation of pumps. The invert floor is to be kept clean to facilitate the flow of water to the water collection points. Further aspects of the water recovery system may not yet be defined and will be provided in a Constructor submittal to the Architect/Engineer (A/E) for review and approval, if appropriate.

6.2.6 Auxiliary Excavation

Per LANL (1998b), auxiliary excavations off the ECRB Cross Drift (alcoves, niches, etc.) are planned to accommodate characterization testing activities. ECRB Cross Drift testing-related excavation plans include ECRB Cross Over Alcove #8, Crest Alcove #9, Alcove #10, and ECRB Cross Drift Niche #5. Preliminary location, size, excavation, ground support, and utility

requirements associated with these auxiliary excavations are provided in the following paragraphs. Other testing-related requirements for these excavations are outside of the scope for this DIE and must be described and evaluated in a separate DIE, before initiating testing activities. Procedure AP-5.2Q addresses the planned schedules for each of these excavations.

CRWMS M&O (1999c) modified the original requirements for Cross Over Alcove #8. Neither LANL (1998b) nor CRWMS M&O (1999c) specifies a break out location on the left rib of the ECRB Cross Drift for ECRB Cross Over Alcove #8. Rather, LANL (1998b) and CRWMS M&O (1999c) require the alcove to be constructed such that its testing zone, or Drill Room, is oriented directly above Niche #3 (off the TS Main Drift) with the same center line azimuth. The Drill Room for Alcove #8 will extend over the entire excavation footprint of Niche #3 with the following minimum margins of additional excavation beyond the dimensions of Niche #3 (which are provided in CRWMS M&O [1998e]):

1. The terminal face of the alcove should extend 1 m past the Niche #3 centerline breakout point—i.e., above the TS Main Drift.
2. The alcove extends approximately 0.5 m beyond both the right and left ribs of Niche #3, which makes the alcove approximately 1 m wider than the niche.

Per CRWMS M&O (1999c), the Alcove #8 access drift must be constructed by mechanical excavation equipment or controlled drill-and-blast excavation techniques. However, drill-and-blast excavation techniques must be stopped approximately 3 m from the plan view projection of the Niche #3 terminal face. Mechanical excavation equipment must be used to construct the Alcove #8 Drill Room.

The ECRB Crest Alcove breakout from the left rib of the ECRB Cross Drift will be located at approximately Station 18+70 m (LANL 1998b). This alcove is comprised of an access drift (which is a minimum of 20 m in length) and a drill room (which is a minimum of 10 m in length). The access drift has a minimum width and height of 3.7 m. The drill room has a minimum height of 4 m and requires sufficient width to accommodate various construction and testing equipment. Per CRWMS M&O (1999a), similar requirements for alcoves off the TS Main Drift resulted in alcove width of approximately 5 m. CRWMS M&O (1999b) indicates that construction of the ECRB Crest Alcove will not begin until Spring 2001.2002.

The Cross Drift Thermal Testing (CDTT-Alcove 10) is focused on the Topopah Spring lower lithophysal (Tptpl) unit with the primary objective of observing how liquid water from the condensation of rock pore-water vaporized by heat, travels through the rock. Also, whether liquid water can penetrate through a volume of rock heated to above 100°C. Observations in the CDTT on the movement of heat-driven water in Tptpl are expected to confirm the premise that water mobilized by the decay heat from the emplaced waste will drain by gravity through the cooler central regions of the pillar between the drifts to depths below the emplacement horizon.

A block of rock in the Tptpl unit shall be exposed by excavating an L-shaped alcove off the left rib of the ECRB Cross Drift. The rock will be heated by 5-meter long rod heaters placed in parallel holes in a horizontal plane. With the progress of heating, the moisture in the rock surrounding the heaters should be driven off, and a roughly cylindrical volume of dry rock

should develop and grow around each heater. The water from the dried rock is expected to be driven by the heat in all directions and the vapor should condense as the vapor reaches the cooler regions away from the heaters. The condensed liquid is expected to drain downward by gravity via the fractures and other openings in the rock.

Collection holes, which are parallel and perpendicular to the heaters, will be located below the heater plane. These holes are strategically placed immediately below the anticipated boiling zone around the inner heaters, and are designed to intercept any liquid water that may travel to them. Samples of any water collected in these holes may be analyzed in the laboratory.

Tiltmeters capable of recording rock movement of extremely small magnitude will be installed in drillholes in this Alcove #10. The tiltmeter measurements will enable the displacement field caused by the thermal expansion of the heated block to be delineated. This information and the measured temperature field can be used to quantify the coefficient of thermal expansion of the rock mass.

Probes to monitor microseismic or acoustic emissions may also be installed in several holes. The probes would be installed prior to alcove excavation so that microseismic activities caused by the excavation process may be recorded.

It is planned that the heating in the CDTT may be maintained for 9 to 12 months. Toward the end of the heating period, after approximately seven-and-a-half months of heating, water will be released in measured quantities in the injection hole. Water will be released at intervals of 7 to 10 days and its movement through the various sectors of rock heated to different temperatures will be tracked. (YMP 2001).

Per updated information in CRWMS M&O (1999c), Niches #5 and #6 break out from the left rib of the ECRB Cross Drift at approximate Stations 16+20 m and 23+46 m, respectively. Access drifts reaching approximate minimum dimensions of 6-m high by 13.4-m long (as measured along the niche centerline) are required for both niches. The height of the access drift gradually increases from the ECRB Cross Drift breakout height to a minimum of 6 m. Upon reaching 6 m, the height must be maintained for a minimum 7-m horizontal length along the centerline of each access drift. Exact widths for niche access drifts are not specified, but widths must be sufficient to accommodate necessary testing and construction equipment. Niche access drifts must be constructed by mechanical excavation equipment or controlled drill-and-blast excavation techniques. The length of these niches is measured from the ECRB Cross Drift breakout to the terminal face of the niche. Niches are constructed off the terminal face of the niche access drifts. Niches are a minimum of 15 m in length. Drill-and-blast excavation techniques may be used to construct the first 5-m of each niche. However, the remaining 10-m of each niche must be constructed by mechanical excavation equipment. The centerline azimuth for both niches, and their associated access drifts, is about 181 degrees.

LANL (1998b) and CRWMS M&O (1998k) specify several requirements generally applicable to each of the above testing-related excavations. A positive slope (relative to the ECRB Cross Drift) shall be maintained in all ECRB Cross Drift auxiliary excavations to facilitate drainage back to the ECRB Cross Drift water collection points. However, Alcove #8 has a special requirement for an approximate 0.5 percent positive slope (CRWMS M&O 1999c). The use of water for drill-and-blast drill holes is acceptable in both alcove and niche access drifts. Only

mechanical excavation equipment is allowed. Further, dust control associated with the excavation of the access drifts for Niches #5 and #6 is restricted to misted water sprays on the cutterhead of the mechanical excavator and water sprays on its muck conveyor. Water sprays are not to be used within the actual niche excavations. Ground support in Alcoves #8 and #9 are to be installed consistent with previous requirements for testing alcoves, as discussed in CRWMS M&O (1999a). Ground support in the final 15 m of Niches #5 and #6 and the Alcove #8 Drill Room is installed without water—including rock drilling—consistent with previous niche construction requirements, as discussed in CRWMS M&O (1998e). Steel bulkheads are required to minimize air circulation and to restrict access to ECRB Cross Drift niches and alcoves. Shotcrete is used to seal the bulkheads (CRWMS M&O 1999c). The TCO coordinates bulkhead installation and shotcrete placement. Standard water, ventilation, lighting, power, compressed air, and telephone utilities will be supplied for each of these niches and alcoves.

Auxiliary, operational support excavations, which are mined along either rib of the ECRB Cross Drift, may also be necessary to facilitate the installation of ECRB Cross Drift utilities. Appropriate descriptions and requirements for such excavations are already provided in CRWMS M&O (1999a).

6.3 UTILITIES

Per the various utility-related design drawings and specifications identified in CRWMS M&O (1998l), utilities provided in the ECRB Cross Drift include power distribution, electrical grounding, communications, lighting, ventilation, water supply (i.e., non-potable water traced with Lithium Bromide [LiBr])¹, wastewater, fire protection, compressed air, muck conveyor belt, and material handling/personnel transport systems. While sizes of ECRB Cross Drift pipes, cables, etc., may vary slightly, these utilities are comparable to those of the ESF TS Loop (CRWMS M&O 1997d). As such, the individual attributes and activities associated with the ESF TS Loop utilities, as described in CRWMS M&O (1999a), conservatively bound those of the ECRB Cross Drift utilities. The addition of alarm lights in the ECRB Cross Drift tunnel, auxiliary excavationsauxiliary excavations also are bound by, and consistent with, the ESF TS Loop utility parameters and controls. Any constructor-supplied utilities are also bound by all requirements of this DIE and the applicable design specification(s).

¹ Chlorinated potable water that does not contain LiBr tracer is used for drinking and hand wash stations in the ECRB Cross Drift. Ice made from untraced chlorinated potable water may also be used in drinking water coolers underground.

6.4 TESTING

As discussed in CRWMS M&O (1997e and 1998e) and DOE (1997a; 1997b; 1997c; 1997d; and 1998), the following testing activities will be conducted in the ECRB Cross Drift. The test interference and waste isolation evaluations for ECRB Cross Drift site-characterization-testing-related activities, as described in the following subsections, are allocated to the scope of CRWMS M&O (1998e). However, testing activities conducted in the ECRB Cross Drift Phase I water and surfactant testing zones (which confirmed the adequacy of the Phase II water and surfactant testing loss limits) remain within the evaluation scope of this DIE.

Generally, testing activities conducted within the ECRB Cross Drift consist of dry drilling (using rock bolt drills), dry coring, air monitoring, and bulk rock sampling techniques. These general testing activities are described in further detail in CRWMS M&O (1997e and 1998e) and DOE (1997a; 1997b; 1997c; 1997d; and 1998). CRWMS M&O (1999b) also indicates that sealed bulkheads will be installed in the ECRB Cross Drift at approximate Stations 17+00 m and 24+50 m for an approximate 1-year duration. These bulkheads facilitate the collection of data on the hydrologic system across the proposed repository block. Personnel and equipment access will be controlled and limited while these bulkheads are in place. Other tests associated with the ECRB Cross Drift, which are conducted in the ECRB Cross Drift Starter Tunnel and in the ESF TS Loop, are described and evaluated in CRWMS M&O (1998e and 1999a). The following sections provide a general description of currently planned ECRB Cross Drift testing activities.

6.4.1 Moisture Flux Studies

The two major emphases of moisture flux studies in Phase I of the ECRB Cross Drift are hydrologic testing and hazardous mineral (i.e., minerals having the potential to adversely impact waste isolation capabilities) assessment. These tests also generate data used for confirming that the Phase II evaluation of potential waste isolation impacts herein, associated with water and organic material loss, is sufficient to bound Phase II ECRB Cross Drift activities. The general activities associated with moisture flux studies are described in DOE (1998) and CRWMS M&O (1998e, Section 6.10). The following specific ECRB Cross Drift Phase I testing activities are subject to the requirements of DOE (1998).

1. After TBM operation has commenced, a single approximately 1.5-inch diameter by 2-m deep dry-drilled hole using one of the TBM-mounted rock drills will be drilled about every 25 m of excavation of the ECRB Cross Drift. These boreholes are drilled into the left rib of the drift at a height accessible from the invert. An instrument package (heat dissipation probe) will be placed into each of these boreholes by the PI as quickly as practical after the cutterhead exposes the rock matrix. This testing activity will also be conducted in the Phase II portion of the ECRB Cross Drift, maintaining the approximate 25-m interval spacing as established during Phase I testing.
2. After TBM operation has commenced, a single HQ-sized by about 2-m deep dry-drilled/cored borehole will be drilled at approximately 50-m intervals of the drift excavation. These boreholes are drilled/cored into the left rib of the drift at a height accessible from the invert using a core rig. Neutron logging will be conducted in these

boreholes at predetermined time intervals. This testing activity will also be conducted in the Phase II portion of the ECRB Cross Drift, maintaining the approximate 50-m interval spacing as established during Phase I testing.

3. After TBM operation has commenced, a single HQ-sized by about 6-m deep dry-drilled/cored borehole will be drilled at approximately Station 5+00 m of the Phase I ECRB Cross Drift excavation. This borehole is also drilled/cored into the left rib of the drift at a height accessible from the invert using a core rig. Neutron logging will be conducted in these boreholes at predetermined time intervals. This testing activity will also be conducted in the Phase II portion of the ECRB Cross Drift beginning at approximately Station 10+00 and at approximately 500-m intervals thereafter.
4. Beginning at approximately Station 2+38 m, an approximate 50-m test area has been established in which the constructor uses water at an application rate that is calculated based on both machine optimization and dust abatement requirements. In this test area, three HQ-sized boreholes will be dry drilled/cored in an array from a core rig mounted on a flat car. These boreholes are arranged such that one borehole is drilled/cored in each of the following configurations: (1) approximately 2 m deep into the left rib below springline, (2) approximately 6 m deep into the left rib above the invert, and (3) 10 m deep into the bottom of the invert. These boreholes will be drilled/cored immediately after the TBM trailing gear has passed. About one week later, a 15-m HQ-sized dry-drilled/cored borehole will be drilled/cored into the bottom of the invert in the same array. Cores will be collected, and neutron logging will be conducted in these boreholes at predetermined time intervals.
5. Beginning at approximately Station 2+88 m, an approximate 50-m test area has been established in which the constructor uses an approved organic surfactant during TBM operations. In this "test area," three HQ-sized boreholes will be dry drilled/cored in an array from a core rig mounted on a flat car or on the TBM. These boreholes are arranged such that one borehole is drilled/cored in each of the following configurations: (1) approximately 2 m deep into the left rib below springline, (2) approximately 6 m deep into the left rib above the invert, and (3) 10 m deep into the bottom of the invert. These boreholes will be drilled/cored immediately after the TBM trailing gear has passed. About one week later, a single 15-m HQ-sized dry-drilled/cored borehole will be drilled/cored into the bottom of the invert in the same array. Cores will be collected, and neutron logging will be conducted in these boreholes at predetermined time intervals.
6. Throughout ECRB Cross Drift construction activities, construction support will be requested by the TCO to install simple hangers for testing instrumentation including temperature, humidity, and air monitoring stations. Periodically, the TCO may request that the conveyor belt be stopped temporarily to collect muck samples.

6.4.2 Perched Water Testing

Should perched water be encountered in the ECRB Cross Drift, it is tested as described by (DOE 1997b). The general activities associated with perched water testing are described in CRWMS M&O (1998e, Section 6.3).

6.4.3 Consolidated Sampling

Consolidated sampling is a general testing activity that is conducted throughout the subsurface ESF, including the ECRB Cross Drift. The typical activities associated with consolidated sampling are described in CRWMS M&O (1998e, Section 6.2). ECRB Cross Drift consolidated sampling activities will be conducted as required by DOE (1997c).

6.4.4 Construction Monitoring

Construction monitoring is another group of general testing activities that is implemented throughout the subsurface ESF, including the ECRB Cross Drift. These testing activities are controlled by the requirements of DOE (1997d) and are described in CRWMS M&O (1998e, Section 6.9).

6.4.5 Geologic Mapping

Geologic mapping is to be performed throughout the entire ECRB Cross Drift. Typical geologic mapping activities are described in CRWMS M&O (1998e, Section 6.1) and are conducted as described by DOE (1997a). Per CRWMS M&O (1998i), approximately 50 gal/m of ECRB Cross Drift advance are expected to be used for the wall washing activity associated with geological mapping. To address a concern over excessive dust generated by the previously evaluated (CRWMS M&O 1998e) water/air mixture wall washing technique, CRWMS M&O (1998m) describes the use of a low-flow pressure washer in the ECRB Cross Drift. This pressure washer has a constrictive nozzle aperture that applies only water (i.e., not mixed with air).

6.4.6 Core Drilling and Slot Cuts in the ECRB for Geomechanical Information

In-situ field tests are to provide data to subsurface design and other Yucca Mountain Project (YMP) departments to enhance the understanding of the mechanical and thermomechanical processes of the potential repository for ground control assessments. This information is also of value for conducting drift degradation analyses, and ground support design. These tests will support the YMP in resolving U.S. Nuclear Regulatory Commission (NRC) Key Technical Issues (KTI) related to thermomechanical behavior of the proposed repository host rock horizon.

Core drilling has been conducted using water for lubrication and cuttings removal between STA 14+40 to 24+00 in the ECRB. Cored specimens are being provided to laboratories for testing of a variety of parameters including joint properties, creep and thermal expansion. Slot cuts are also being developed in this same length of ECRB tunnel to allow installation of instruments which can determine rock stress. These slot cuts will allow testing utilizing a series of pressurized slot flatjacks used to measure the stress and deformability of the rock near an

underground opening. This technique consists of cutting large slots in the tunnel wall using a rock saw cooled with water. Water from this saw will be collected and reused at each slot site. Each slot will have a flat jack installed within the slot. These flat-jacks will be used in conducting load-unload cycles accompanied with rock-mass deformation measurements. The pressure/deformation history is then evaluated to determine rock mass deformation modulus.

6.5 TFM'S

TFM usage has been discussed in the text of Sections 6.1 through 6.4, as appropriate. For TFMs, which were not specifically/individually discussed in Sections 6.1 through 6.4, CRWMS M&O (1998e and 1999a) have evaluated an extensive list of TFMs that are approved for use in the subsurface ESF. Attachment II contains a comprehensive list of TFMs (i.e., a list of TFMs that have been either previously evaluated by CRWMS M&O (1999a) or specifically evaluated by subsequent sections of this DIE), which are approved for use in ECRB-Cross-Drift-related activities evaluated in this DIE. However, Attachment II TFMs are approved for use in ECRB Cross Drift activities, provided their use and quantities are consistent with the restrictions established in Section 13.3 of this DIE.

As stated in Assumption 4.3, the use of TFMs is controlled by the requirements of the DIE procedure NLP-2-0. The use of any TFM within the subsurface ESF, which is not listed in Attachment II, is evaluated as required by NLP-2-0 before its use. However, only those TFMs that are permanently committed within the subsurface ESF are to be reported, as required by YMP (1998b).

6.6 EMERGENCY REFUGE STATIONS (ERS) IN THE ECRB CROSS-DRIFT.

The purpose of designating Alcove #8, and the area behind the bulkhead at STA 17+63 as ERS locations is to allow personnel underground to be able to readily access a fresh air zone during conditions when personnel are prevented from exiting the tunnel, or smoke is entering the heading. Employees are to proceed to the bulkhead or the face of the heading per Procedure AP-ESH-011 BSC, *Abnormal Events Response Procedure*, and are to remain in the fresh air zone until help arrives.

Design specifications identify the initial design requirements for refuge stations, including the client requirements, standards, codes, laws, and regulations, general discipline design criteria, and design basis events and hazards.

7. DESIGN EVENTS

The following events and activities were considered for potential evaluations: earthquake, rockfall, use of and inadvertent spills of oil or other fluids from construction equipment, fires and use of underground refuge chamber/areas, explosions, ground water inflow, TBM operation, conveyor operation, ground support installation, rail haulage (including use of locomotives), use of water and compressed air, and drill-and-blast operations. These events and activities, which

include the use of the temporary items, are evaluated in accordance with procedure NLP-2-0 (CRWMS M&O 1998f).

Fire and explosions are evaluated with regard to potential impacts. Disruption of other items as a result of earthquakes, fires, and explosions are not specifically evaluated in this DIE.

This DIE evaluates potential spills of quantities of fluids of concern (other than water), which could be released in a credible equipment or vehicle accident or failure, and determines their potential to impact site characterization testing activities and waste isolation. An example of such credible accidents or failures is the rupture of an oil tank or fuel tank on a locomotive.

8. AFFECTED Q-LIST ITEMS

8.1 REPOSITORY INTERFACES

8.1.1 Proximity to Repository

As discussed in CRWMS M&O (1998h), the ECRB Cross Drift construction begins with a breakout in the left rib at about Station 19+92 m and at approximate elevation 1082 m along the ESF North Ramp. The ECRB Cross Drift Starter Tunnel trends southwestward (at an approximate centerline azimuth of 254 degrees) to approximately Station 0+26 m. From Station 0+26 m, the TBM excavates along the same approximate 254-degree centerline azimuth to about Station 1+82 m. At approximately Station 1+82 m of the ECRB Cross Drift, the TBM begins a turn to the left and at approximately Station 3+15 m, it reaches an approximate centerline azimuth of 229 degrees and continues to approximately Station 7+73 m, a point just before crossing over the TS Main Drift (CRWMS M&O 1998h).

After crossing the TS Main Drift, the ECRB Cross Drift excavation continues along the same 229-degree centerline azimuth at approximately 15 m to 20 m above the potential WE zone of the repository block (CRWMS M&O 1997a). At approximately Station 23+20 m of the ECRB Cross Drift, the TBM begins a turn to the right and at approximately Station 26+40 m, it reaches an approximate centerline azimuth of 289 degrees (CRWMS M&O 1998h). Excavation continues on this heading until the ECRB Cross Drift termination point of approximately Station 28+23 m. The terminus of the ECRB Cross Drift is approximately 50 m west of the western most strand of the Solitario Canyon fault (LANL 1997). A discussion of the hydrologic and geologic conditions (i.e., of the natural barrier of the proposed repository horizon) that are encountered by the ECRB Cross Drift is included in Section 9.0 of this DIE, including elevations and locations.

8.1.2 Proximity to Planned and Existing Boreholes

CRWMS M&O (1997f) lists existing and planned boreholes in the vicinity of the ECRB Cross Drift. Surface-based testing (SBT) site characterization activities range from surface geologic mapping and sampling to the drilling and instrumentation of boreholes at water-table and greater depths (Robinson 1998). SBT activities with potential sensitivity to the underground

construction and/or testing activities conducted in the ECRB Cross Drift are: (1) tests conducted in proximity to the hydrogeologic unit penetrated by the TBM and (2) tests sensitive to mechanical vibration, mechanical stress, and/or the electromagnetic fields created by electrical equipment used in the ECRB Cross Drift. An evaluation of potential impacts on site characterization testing (including SBT) is included in Section 10.0 of this DIE.

8.1.3 Planned and In-Process Tests

Approximately fifty tests are or have been planned for the ECRB Cross Drift. Five FWP's (DOE 1997a; 1997b; 1997c; 1997d; and 1998) describe these testing activities in greater detail. However, further tests could be required in the future, such as in response to the requirements of regulatory agencies or to changing programmatic requirements. Thus, a conservative approach, in which reasonable efforts are taken to minimize changing the general characteristics of the ECRB Cross Drift and surrounding rock is advantageous. The M&O TCO has examined the testing requirements for each test in the five FWP's previously discussed and has identified potential construction constraints.

8.2 POTENTIALLY AFFECTED Q-LIST ITEMS

The proposed activities will affect the Topopah Spring welded, lithophysae-rich (TSw1) and Topopah Spring welded, lithophysae-poor (TSw2) thermal/mechanical (TM) units. Additional underlying TM units may also be affected, depending on the quantity and behavior of the applied construction water and TFMs. The Topopah Spring welded (TSw1,2,3) TM units are on the Q-List (YMP 1998a). In addition, the engineered items on the Q-List (YMP 1998a) that may be affected include the Underground Excavations, the Waste Ramp or the Tuff Ramp, and the Seals. The planned excavation activities may affect permanent items including ground support and underground openings.

9. EXPECTED CONDITIONS

The ECRB Cross Drift excavation is entirely in the unsaturated zone, beginning from the left rib of the ESF North Ramp at approximately Station 19+92 m at an elevation of about 1082 m, crossing (at an elevation of about 1093 m) approximately above Station 30+61 m of the TS Main Drift, proceeding through the potential repository block (above the potential WE zone) to an elevation of about 1114 m, and ending at an elevation of about 1103 m at approximately Station 28+23 m of the ECRB Cross Drift (CRWMS M&O 1998h). The water table under the portion of the ECRB Cross Drift, located east of the TS Main Drift, is nearly flat and lies at an elevation of approximately 730 m (Robison et al. 1988 and CRWMS M&O 1997g). To the west of the TS Main Drift, the water table rises from approximately 730 m to about 770 m at the termination point of the ECRB Cross Drift (Robison et al. 1988 and CRWMS M&O 1997g). Therefore, the water table lies approximately 352 m below the ECRB Cross Drift Starter Tunnel and approximately 333 m below the western end of the ECRB Cross Drift.

9.1 SIGNIFICANT GEOLOGIC FEATURES

The ESF TS Loop excavation is discussed in CRWMS M&O (1998n) and Bureau of Land Reclamation (BLR) (1996a; 1996b; 1997a; and 1997b) relative to the major geologic strata in terms of both the revised lithostratigraphic nomenclature and the TM nomenclature for the rock units used in the three-dimensional site model by the United States Geologic Survey (USGS). The lithostratigraphic units along the ECRB Cross Drift will be the same as encountered by the TS Loop and an accurate geologic cross section can be produced using the extensive geologic information obtained during the TS Loop construction. The lithostratigraphic units along the TS Loop include three groups (in descending order): the Timber Mountain Group; the Paintbrush Group, which includes five ash flow tuffs separated by bedded tuffs; and the Crater Flat Group. The ECRB Cross Drift excavation begins within the Topopah Spring Tuff upper lithophysal (Tptpul) of the Paintbrush Group and ends within this same unit (west of the Solitario Canyon fault) after crossing through the crystal-poor, middle nonlithophysal (Tptpmn), crystal-poor, lower lithophysal (Tptpll), and the crystal-poor, lower nonlithophysal (Tptpln).

Yucca Mountain Lithostratigraphy

The Timber Mountain Group is comprised of the Rainier Mesa Tuff (**Tmr**) and pre-Rainier Mesa Tuff bedded tuff (**Tmbt1**) within the TS Loop.

In order of descending stratigraphy, the Paintbrush Group includes:

Tuff Unit "X" (**Tpki**)

Pre-Tuff Unit "X" bedded tuff (**Tpbt5**)

Tiva Canyon Tuff (which is broken into three units: crystal-rich—**Tpcrv**; undifferentiated, devitrified—**Tpcun**; and crystal-poor, vitric, nonwelded—**Tpcpv**)

Pre-Tiva Canyon Tuff bedded tuff (**Tpbt4**)

Yucca Mountain Tuff (**Tpy**)

Pre-Yucca Mountain Tuff bedded tuff (**Tpbt3**)

Pah Canyon Tuff (**Tpp**)

Pre-Pah Canyon Tuff bedded tuff (**Tpbt2**)

Topopah Spring Tuff (which is broken into eight units: crystal-rich, vitric, non- to moderately welded—**Tptrv**; crystal-rich, devitrified, nonlithophysal—**Tptrn**; crystal-poor, upper lithophysal—**Tptpul**; crystal-poor, middle nonlithophysal—**Tptpmn**; crystal-poor, lower lithophysal—**Tptpll**; crystal-poor, lower nonlithophysal—**Tptpln**; crystal-poor, densely-welded subzone—**Tptpv3**; and crystal-poor, vitric, non- to moderately-welded—**Tptpv1** and **Tptpv2**)

Pre-Topopah Spring Tuff bedded tuff (Tpbt1)

In order of descending stratigraphy, the Crater Flat Group consists of the Calico Hills Formation (**Tac**) and the Prow Pass Tuff (**Tcp**), both of which contain basal bedded tuffs.

The lithostratigraphic units are grouped into TM units by the USGS, which are summarized in CRWMS M&O (1998n). Because the TM units are based on properties which result from processes in addition to petrogenesis, the boundaries of these units do not correspond directly to formational boundaries but do, in general, correspond to rock unit boundaries. In order of descending stratigraphy the TM units are:

Undifferentiated overburden (**UO**) that includes the Tmr, Tmbt1, Tpki, Tpbt5, and Tpcrv

Tiva Canyon welded unit (**TCw**) that is equivalent to the Tpcun

Upper Paintbrush nonwelded unit (**PTn**) comprised of the Tpcpv, Tpbt4, Tpy, Tpbt3, Tpp, Tpbt2, and Tptrv

Topopah Spring welded, lithophysae-rich unit (**TSw1**) that includes the Tptrn and Tptpul

Topopah Spring welded, lithophysae-poor unit (**TSw2**) that includes the Tptpmn, Tptpll, and Tptpln

Topopah Spring welded, vitrophyre (**TSw3**) that is equivalent to the Tptpv3

Lower Topopah Spring non-welded unit and Calico Hills Tuff non-welded (**CHn**) that is comprised of the Tptpv1, Tptpv2, Tpbt1, Tac, and Tcp

9.2 SIGNIFICANT HYDROLOGIC FEATURES

The TM units are closely related to the hydrogeologic units and the designators used here to refer to the hydrogeologic units are taken to refer to the corresponding TM units: TCw – Tiva Canyon welded, PTn – Paintbrush nonwelded, TSw (1,2,3) – Topopah Spring welded, and CHn – Calico Hills nonwelded. Because information concerning the thickness and extent of the basal Tiva Canyon units (Tpcpv and Tpbt4) and the Topopah Spring caprock (Tptrv) zones is not available in all cases, the PTn hydrogeologic unit (for this evaluation) consists of the Yucca Mountain and Pah Canyon members of the Paintbrush Tuff (Tpy, Tpbt3, Tpp, and Tpbt2), at a minimum.

The distances to geologic and hydrologic features along the ECRB Cross Drift (as measured along the tunnel excavation) and the minimum distance from each geologic and hydrologic feature to potential WE areas (i.e., the minimum offsets from potential WE areas) are given in Table 9-1 (CRWMS M&O 1997g and 1997h). The spatial relation between the ECRB Cross Drift and the current conceptual design of the potential repository is extrapolated from CRWMS M&O (1997g) and the latest design drawings available for the locations of potential expansion area WE Drifts (CRWMS M&O 1997h). The ECRB Cross Drift will be kept a minimum of 15 m to 20 m from potential WE zones within the primary WE area. Potential expansion areas (CRWMS M&O 1997g and 1997h) that may be used as part of the potential repository lie

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beneath the Phase I section of the ECRB Cross Drift (0 – 476 m) east of the Ghost Dance fault. The closest potential WE zone under the Phase I section of the ECRB Cross Drift is assumed to be the contact between the upper lithophysal (Ttpul), and the middle nonlithophysal (Ttpmn) zones of the TS Formation, which constitutes the TSw1 - TSw2 contact (CRWMS M&O 1997g). This contact represents approximately the uppermost boundary of potential WE expansion areas beneath the Phase I section of the ECRB Cross Drift.

Table 9-1. Geologic and Hydrologic Features along the ECRB Cross Drift

Geologic/Hydrologic (G/H) Feature	Location of G/H Feature Along ECRB Cross Drift (m)	Minimum Distance From G/H Feature to Potential WE Area ² (m)
Phase I ECRB Cross Drift		
TSw1	0 - 773	~37
Drill Hole Wash faults	67 - 146	60
Ghost Dance fault	536 - 542	60
Phase II ECRB Cross Drift		
TSw1	773 - 1036	15-20
TSw2	1036 - 2540	15-20
Solitario Canyon fault splays	2540 - 2552	60
TSw1	2552 - 2674	62
TSw2	2674 - 2753	147
Solitario Canyon fault	2753 - 2758	221
TSw1	2758 - 2815	226

9.3 FRACTURE CONDITIONS

During excavation, a number of geologic faults and fault systems were encountered in the ECRB Cross Drift (BLR 1996a; 1996b; 1997a; and 1997b). The following discussion, which represents expected conditions before the ECRB Cross Drift was excavated, is summarized from the geologic information obtained during the excavation of the TS Loop of the ESF. Both encountered conditions and the features of the Solitario Canyon faults are discussed. These conditions and features were not encountered in the TS Loop excavations, but they have been studied from the site surface. The following sections will continue to reflect information in the context of expected conditions until qualified information is available.

² Approximated by determining "straight-line" distance to closest waste package using a right triangle.

9.3.1 Drill Hole Wash Fault

The Drill Hole Wash fault is comprised of two distinct faults encountered at Stations 19+01 m and 19+43 m from the North Portal along the TS Loop, with a strike of 316 and 150 degrees, respectively. Both faults dip steeply to the west. Approximately 4 m of normal movement (i.e., vertical offset) has been measured along this fault, with an indeterminate amount of associated lateral movement. The fault system is expected to be encountered during Phase I of the ECRB Cross Drift between 67 m and 146 m from the start of the ECRB Cross Drift.

9.3.2 Ghost Dance Fault

The Ghost Dance fault was encountered at Station 57+30 m along the TS Loop and in Alcove #6. The Ghost Dance fault is a normal fault that crosses the TS Main Drift at Station 57+30 m. It has a strike of approximately 205 degrees and about 1.2 m of offset downward to the west. The fault zone consists of a clast-supported breccia with angular to subangular clasts of Tptpmn and Tptpll ranging from less than 0.5 centimeters (cm) to 15 cm. Both the hanging wall and the footwall are moderately to intensely fractured with the fracture zones extending away from the fault. The fault system is expected to be encountered during Phase I of the ECRB Cross Drift between 536 m to 542 m from the start of the ECRB Cross Drift.

9.3.3 Solitario Canyon Fault System

The Solitario Canyon fault system was not encountered during the TS Loop excavation of the ESF. Information concerning the Solitario Canyon fault and associated splays has been compiled by surface geologic mapping and trench studies. The Solitario Canyon fault system is generally a north-south trending westward dipping fault with associated splays. Greater than 10 m of offset is predicted for the main fault within Solitario Canyon. Two splays of the fault system are expected to be encountered during excavation of the ECRB Cross Drift between Stations 25+40 m and 25+52 m and between Stations 27+53 m and 27+58 m of the ECRB Cross Drift. This fault system will be encountered during the excavation of the Phase II section of the ECRB Cross Drift.

9.3.4 Fault Fracture Densities

Fracture densities are generally higher in the vicinity of these faults and fault systems. As such, these fault systems have the potential to act as faster pathways for fluid flow, perhaps providing test access to the water table. Fracture densities expected for the hydrogeologic units discussed previously are given in CRWMS M&O (1996a) as 10 to 20 fractures/cubic meter (m^3) for the TCw, 1 fracture/ m^3 for the PTn, 8 to 40 fractures/ m^3 for the TSw, and 2 to 3 fractures/ m^3 for the CHn.

9.4 HYDROGEOLOGIC, GEOCHEMICAL, AND GEOMECHANICAL CHARACTERISTICS

Beneath the ECRB Cross Drift excavation, the water table is relatively flat on the east side of the TS Main Drift, with an increase in gradient to the west of the TS Main Drift. It lies primarily in

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the CHn hydrogeologic unit (Robison et al. 1988 and Ervin et al. 1993). The groundwater table lies in the TSw3 formation west of the Bow Ridge fault and in the CHn east of the Bow Ridge fault (Ervin et al. 1993). The saturated groundwater flow in this area is inferred to be in a southeasterly direction from the conceptual repository (Ervin et al. 1993).

Water entering the TSw hydrogeologic units along the ECRB Cross Drift may result in water movement through fractures, matrix, or some combination of the two paths (Fischer et al. 1979). The degree to which water movement in fractures is attenuated by capillary imbibition into the matrix is poorly understood at present. Although it is possible to identify qualitatively the potential impacts from perturbations to the geochemical characteristics of the Yucca Mountain site, in many cases the data to quantify each causal link along the path to radionuclide release are not available. For example, dissolved organic carbon (DOC) may become a nutrient source for microbes. These microbes may cause changes in water chemistry that may enhance corrosion of the waste package or assist in radionuclide solubility and transport. Because the quantitative data are not available for these relational links, it is not currently possible to evaluate the potential TFM impacts at the level of consequence to radionuclide releases. Therefore, surrogate performance measures have been adopted as the criteria for indicating that an item/activity may impact waste isolation.

In general, such surrogate criteria are based on the idea that potential local perturbations to ambient site conditions that are below the level of the natural system variability would be indistinguishable from the ambient system. For cases in which site data are not available to quantify the ambient system variations, the variability of aqueous geochemical parameters across the site is assumed to be at least 10 percent of ambient conditions. One example of such a surrogate criterion is the 10-percent increase in background aqueous nitrate concentrations used as the limit for local perturbations to the nitrogen system. This type of evaluation produces recommended limitations based on the local perturbations to the geochemistry at the closest waste package—if changes were expected across the entire conceptual repository, then these types of surrogate criteria would not be appropriate. As such, these evaluations produce recommended limits showing local geochemical perturbations that are within the noise of the ambient geochemistry. The average concentrations, in parts per million (ppm), and standard deviation of measurements (Yang et al. 1988 and 1990) for five constituents of unsaturated zone fluids are shown in Table 9-2.

Table 9-2. Unsaturated Zone Dissolved Ion Concentrations: Sample Average, Sample Standard Deviation, and Percent Uncertainty

Ion	Average Concentration ³ (ppm)	Sample Standard Deviation ³ (ppm)	Standard Deviation (Percent of Average)
SO ₄ ⁼	92	53	58
Cl ⁻	70	25	36
Ca ²⁺	60	30	50

³ Values calculated from data given in Yang, et al. (1988 and 1990) and LANL (1994a).

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Mg ²⁺	11	4.7	43
Na ⁺	45	15	33

Although data are limited for dissolved constituent concentrations in unsaturated zone water, the available data indicate that a 10-percent perturbation of the average ambient value is limited which allows for the following assumption. The assumption is made that using a 10-percent perturbation of the average ambient value is, in general, a conservative criterion for being within the noise of the natural system. In addition, as pointed out by Yang et al. (1988 and 1990), the analytical uncertainties for values of the concentrations in the unsaturated zone waters are ± 5 percent in general and ± 10 percent for sulfate. Based on these data, it is reasonable to make the assumption that local perturbations to the ambient geochemistry of 10 percent or less cannot be differentiated from the natural system variation.

10. IMPACT ON SITE CHARACTERIZATION TESTING

10.1 INTRODUCTION

The ECRB Cross Drift is designed as an underground facility for conducting tests and collecting scientific and engineering data to be used for:

1. Assessing the suitability of the Yucca Mountain site for the disposal of radioactive waste.
2. Providing design information for construction of the potential repository.

Site characterization activities are planned along the ECRB Cross Drift and in associated testing alcoves and niches where most of the long-term testing activities will be conducted. Such testing activities are evaluated by CRWMS M&O (1998e). Geologic sampling, hydrologic sampling, and geologic mapping will be conducted in the ECRB Cross Drift behind the TBM. ECRB-Cross-Drift-specific design specifications and drawings describe the systems, subsystems, and components required to meet the needs of the underground site characterization testing program during construction, maintenance, and testing activities. Simultaneously, SBT activities will be on-going in the Conceptual Controlled Area Boundary.

10.2 TESTING ACTIVITIES POTENTIALLY IMPACTED

10.2.1 Thermal Testing Facility Testing

The TTF (Alcove #5) is the current ESF testing facility nearest to the ECRB Cross Drift. As discussed in LANL (1997), the minimum offset distance between the TTF and the ECRB Cross Drift has been established as 50 m. Subsequent evaluation has verified this as a reasonable distance given the limits in lateral dispersion identified in the LBNL study (Liu, H. H. 2001). LANL (1997) also established a maximum offset distance of 100 m to facilitate possible borehole drilling between the two facilities. Compliance with these constraints will not incur any construction-to-test or test-to-test interference.

10.2.2 Moisture Flux Studies

Within the TS Main Drift, there are several ongoing moisture flux studies. The nearest moisture flux testing sites are located in the TS Main Drift near the crossover point of the ECRB Cross Drift. These testing sites are located at approximately Station 28+30 m (LB50) and Station 35+00 m (LB40) of the TS Main Drift. Within this same interval of the TS Main Drift, located at approximately Station 29+00 m, is an anemometer mounted in the upper quarter of the right rib. No construction-to-test or test-to-test interference with these tests and measurements, associated with the construction of or testing activities in the ECRB Cross Drift, is anticipated due to the distance separating these moisture flux testing locations and the ECRB Cross Drift crossover location given the limits in lateral dispersion identified in the LBNL study (Liu, H. H. 2001).

Within the Phase I testing intervals of the ECRB Cross Drift (and potentially at other locations within the drift), moisture studies testing activities involve the drilling of downward (i.e., nearly vertical boreholes in the invert of the drift (Section 10.4). These boreholes are located in the bottom of the invert, by design, to be the lowest possible point in the drift. The quantity of fluids introduced into these testing boreholes should be minimized to limit test interference.

10.2.3 Surface-Based Testing Boreholes

As discussed in CRWMS M&O (1997f), SBT boreholes (with their approximate Nevada State Plane coordinates) that are located within 500 m of the entire ECRB Cross Drift track include: hydrologic test borehole, USW H-5 (766634N, 558909E); geologic exploratory borehole, UE-25 a#4 (767972N, 564472E); North Ramp geologic borehole, UE-25 NRG-5 (767890N, 564770E); north ramp geologic borehole, USW NRG-7 (768804N, 571172E); North Ramp geologic borehole, USW NRG-7a (768768N, 570269E) and geologic borehole, USW SD-9 (767999N, 561818E). Of these, SD-9, NRG-5, NRG-7, NRG-7a, and UE-25 A-4 have been evaluated for their proximity to the ESF North Ramp and TS Main Drift. Borehole H-5 lies approximately 500-m northwest of the ECRB Cross Drift track. Due to the offset distance between the testing activities being conducted in these boreholes and the ECRB Cross Drift, no construction-to-test interference is anticipated given the limits in lateral dispersion identified in the LBNL study (Liu, H. H. 2001). With respect to test-to-test interference, potential impacts to SBT are taken into consideration in each applicable FWP as tests are planned. Further, the TCO ensures that FWPs—for new testing activities such as those in the ECRB Cross Drift—are reviewed by PIs responsible for concurrent testing activities in SBT boreholes, which could potentially be impacted by these new testing activities. No other interferences with SBT activities in the area have been identified. Future borehole drilling in the vicinity of the ECRB Cross Drift is dependent on funding from DOE and cannot be accurately predicted at this time. Should any future surface drilling be planned, test interference due to the proximity of the ECRB Cross Drift will be addressed in the evaluation for the specific FWP (or equivalent documentation) for those boreholes.

10.3 WATER TABLE

The ECRB Cross Drift varies between approximately 333 m and 352 m above the water table (Section 9). Negligible test interference from construction is expected to SBT tests planned in

the saturated zone because of the distance of separation given the limits in lateral dispersion identified in the LBNL study (Liu, H. H. 2001).

10.4 UNDERGROUND CONSTRUCTION

The excavation of the ECRB Cross Drift by the TBM will occur concurrently with the installation and operation of the required construction utilities and TBM support accommodations. Other underground construction activities in the ECRB Cross Drift area may include drill-and-blast or mechanical excavation of operation and test support areas.

Moisture Flux Studies

Moisture flux studies planned for the entire ECRB Cross Drift are described in Section 6.4. These activities should be conducted as soon as practical after the TBM passes. Instrumentation in support of these tests may be placed inside or outside of boreholes that were specifically drilled for moisture flux studies or boreholes that are not being used for other testing activities (DOE 1998).

To facilitate the flow of information from Phase I ECRB Cross Drift moisture flux testing activities, water use information, that is compiled by the Constructor, should be submitted directly to the SA Department. This will ensure that the PIs have access to the most complete set of water use data. Accurate water use data were critical to ensuring a valid PI interpretation of ECRB Cross Drift Phase I moisture flux studies data (i.e., data on the amount of water actually committed to the site during excavation activities). These data were ultimately used to validate the ECRB Cross Drift Phase II limits placed on the loss of water and organic material by this DIE. This validation was required before advancing the TBM beyond ECRB Cross Drift Station 7+73 m.

Perched Water Testing in the ECRB Cross Drift

Should perched water be encountered, it should be sampled and examined as soon as practical after being encountered. The CMO should notify the TCO when perched water is encountered to facilitate sampling. When perched water is detected (as indicated by flowing water), the TCO, in conjunction with the PI and the CMO, will decide whether excavation operations should be suspended to facilitate more complete testing and sampling. Small-flow perched water zones may only require that water samples be collected along with an estimate of the flow rate and total volume of water produced. Access may be needed for long-term sampling and monitoring of perched water zones, which will continue until the nature of a perched water zone is determined and all test-related quality-affecting activities are completed (DOE 1997b).

Consolidated Sampling

Access is needed to locations identified as deferred sample collection areas during geologic mapping or other testing activities. Some samples, such as gels, may need to be collected as soon as practical after they are detected in a new exposure. Such sample collections should occur before installation of ground support and wall washing. No water or tracer, other than the traced

construction water and air-misted water used for cleaning the tunnel wall, should be used in the immediate vicinity of a sampling location without the approval of the PI. At the present time, LiBr is the only approved tracer to be used in construction and cleaning water in subsurface ESF activities. The use of TFMs, especially during construction, in the proximity of the sampling location should be documented (DOE 1997c).

Construction Monitoring

Access is required to allow for the drilling of boreholes and installation of instrumentation to accommodate construction monitoring. The field activities and the requirements for borehole locations, drilling and coring, instrument installation, data collection, and reporting are described in DOE (1997d). No test interference impacts attributable to construction monitoring activities have been identified. The use of TFMs, especially TFM use associated with construction activities, in the proximity of a sampling location should be documented (DOE 1997d).

Geologic Mapping Associated with TBM Operations

Geologic mapping is a subsurface ESF site characterization activity that may conflict with the installation of required ground support. The ECRB Cross Drift crown and ribs require the installation of rockbolts for stability. Where necessary, straps, ring beams, steel lagging, steel sets, wire mesh, interlocking wire mesh, shotcrete, and/or full concrete lining may also be installed. Because geologic mapping is a photographic and observational activity, which is best performed as soon as practical following excavation, immediate installation of ground support could obscure geological details. As such, ground support installation should be performed, to the extent practical, after geologic mapping has been completed (DOE 1997a). Thus, for normal mapping operations, nothing more than pattern bolting and, if necessary for safety concerns, approximately 15.2-cm square or greater wire mesh should be used. If additional ground control (such as steel rings, lagging, mesh less than 15.2-cm square, and/or shotcrete) is necessary due to poor ground conditions, the TCO and the mapping PI will confer with the CMO to identify if the needed ground support can be installed in a manner that allows the collection of geologic data to the extent practicable (LANL 1994a).

Water used to clean the tunnel and alcove walls for geologic mapping should be traced with a LiBr tracer and an air/water mixture or a low-flow water spray should be used to minimize water loss. An air/water spray or a low-flow water spray will be used for cleaning excavated ECRB-Cross-Drift-related tunnel walls.

10.5 OPERATION AND TEST SUPPORT AREA EXCAVATION

The ECRB Cross Drift is a test support area (with respect to the overall ESF). The construction of other test support areas—i.e., alcoves and niches off the ECRB Cross Drift—are also planned (CRWMS 1999b; 1999c; LANL 1998b; and Section 6.2.6 of this DIE). Testing activities planned within these auxiliary ECRB Cross Drift excavations are evaluated by the SA Department in CRWMS M&O (1998e).

10.5.1 Mucking of Broken Rock

The clean up of muck spills that are excessively wet may be necessary to limit exposure of *in situ* rock to water or other contaminants. Diesel-fueled equipment may be used to remove muck from the excavated areas of the ECRB Cross Drift Starter Tunnel or other locations within the ECRB Cross Drift, as required (Section 10.6.6 and CRWMS M&O 1999a, Section 6.9). Use of hydrocarbons, such as lubricants, engine oil, and coolants for this equipment should be controlled to the extent practical to prevent and mitigate releases to the subsurface environment. No test interference potential is expected from the use of operating fluids as long as they are not spilled or spills are cleaned up to the extent practical. Refueling, routine maintenance that involves lubricants, engine oil or coolants, and repair should be performed carefully to minimize the potential for spills. Spills should be reported in accordance with the TFM procedure (YMP 1998b).

10.5.2 Excavation Techniques

The ECRB Cross Drift and the ECRB Cross Drift Starter Tunnel may be excavated by using a TBM, by using controlled drill-and-blast techniques (which are developed and modified as work progresses), or by using a road-header-type, mechanical excavator. Blast monitoring, blast damage assessment, and blast residue require monitoring as part of the construction monitoring testing activities (DOE 1997d). For any drill-and-blast activities conducted as a part of ECRB Cross Drift excavation, accurate records should be maintained of the time, location, type of explosive used, and size of each blast, and the records submitted to the appropriate project records system. These data may be of interest to PI(s) who may need to address the blasting in the tunnel in the analyses of their data. Furthermore, TCO review of and concurrence with blasting plans, blasting patterns, and blasting materials are also necessary to minimize the potential for test interferences attributable to controlled drill-and-blast activities.

Excavation of certain portions of ECRB Cross Drift testing-related alcoves and niches (Section 6.2.6) should be mined only by a mechanical excavator (LANL 1998b). Furthermore, the use of dust suppression water for ECRB Cross Drift niche excavations should be restricted. Per CRWMS M&O (1998k and 1999c), only drill water for blast holes, misted water from cutterhead spray nozzles and conveyor water sprays associated with the mechanical excavator are recommended, during the excavation of the final 15-m of Niches #5 and #6. Spray head types, flow rates, and procedures for maintaining the spray system should be submitted to and approved by the A/E before use within niche access drifts. Drill-and-blast excavation techniques may be used in niche and alcove access drifts and for the first 5-m segment of the niches. Mechanical excavation equipment has been used to construct approximately the final 3-m segment of the Alcove #8 access drift, the entire Alcove #8 Drill Room, and the final 10-m segment of the niches. Testing-related alcoves and niches may have a slight positive slope relative to the ECRB Cross Drift. To minimize the potential for interference with tests planned for ECRB Cross Over Alcove #8, the slope of this alcove has been limited to approximately + 0.5 percent in that the injection test beds are constructed in the floor of the Alcove with preferred direction of traced water flow downward into the rock environment.

10.5.3 Ground Support Concerns

The installation of grouted rockbolts and the application of shotcrete have the potential to alter gas sample and hydrologic data and to obscure lithology and structures of interest to mapping activities. Therefore, grouted rockbolts and shotcrete should not be used in the ECRB Cross Drift to avoid potential test interference, except as necessary to meet safety standards and/or as approved by the TCO. Split sets, other mechanical bolts, wire mesh, steel sets, or other materials (if approved in accordance with the TFM procedure) are acceptable for ground support. Before placing any shotcrete or other cementitious material in the alcoves for personnel safety, ground support, or other purposes, the field operator should coordinate through the TCO. The TCO will provide PI concurrence and special instructions (if any) to minimize testing impacts.

To limit the potential for construction-to-test interference, ECRB Cross Drift testing-related niche and alcove ground support installation should be controlled. Ground support installation for the Alcove #8 Drill Room and Niches #5 and #6 (including both access drift and niche segments) should be consistent with practices used in previous TS Main Drift niches, as discussed and evaluated in CRWMS M&O (1998e and 1999a) (CRWMS M&O 1999c). Ground support installation for the Alcove #8 access drift and all of Alcove #9 should be consistent with practices used in previous TS Loop alcoves, as discussed and evaluated in CRWMS M&O (1999a) (CRWMS M&O 1999c and LANL 1998b). The location of niche-related ground support boreholes should be coordinated with the TCO to minimize potential test interference.

10.6 OTHER TEST INTERFERENCE CONCERNS

It is judged that the coordination between the CMO and the TCO will be sufficient to address potential testing interference considerations such as those identified in the following sections:

10.6.1 Fire Protection System

The use of fire suppressing/retarding agents (including water) should be treated as a spill and dealt with accordingly. Fire suppressing dry chemicals proposed for the fire extinguishing system are considered in terms of TFM parameters by this evaluation (see Attachment II). In addition, the fire retardant material FR-40 is to be applied on wooden cross ties that will be in direct contact with the excavated invert. FR-40 is expected to have negligible test interference impacts.

It is anticipated that the TFM products that will be used to provide fireproofing of the Alcove #8 bulkhead, and the bulkhead at STA 17+63, for the purpose of personnel refuge chambers, will be Interam™ Firedam 150 caulk, Interam™ E-5 mats, Interam™ T-49 tape, and Interam™ graphite intumescent seal (GIS). In addition, the TFM-Activated Lightsticks, has been evaluated for potential use by personnel in the ECRB Refuge Chamber areas (Cunningham 2001) should emergency lighting be needed. It has been determined there are no test interference issues with the use of these items (Mitchell 2001a), and that there are no waste isolation issues with the use of these items (Matties 2001a, 2001b). This evaluation has determined there is no opportunity for these TFMs to have direct contact with the rock surfaces or test beds. The only controls on using these TFMs are that these materials need to be removed as soon as practical (it is assumed there

will be removal of these TFMs from the ECRB tunnel/Alcove #8 when the bulkhead doors are removed), and that the Lightsticks be kept in a closed container.

Quantities of all fire suppressant/retardant materials used should be reported in accordance with the TFM procedure (YMP 1998b). If additional fire suppression agents are selected for use, their potential impact on site characterization activities should be evaluated in accordance with YMP (1998b).

Test interference concerns exist in the installation of the fireproofing on the bulkheads at STA 17+63 and in Alcove #8 due to current ongoing hydrologic and other types of testing. This testing requires maintaining, to the extent possible, stable relative humidity levels behind the respective bulkheads. There is an observation window in the bulkhead in Alcove #8 to allow observation of personnel operating behind the bulkhead and to avoid leaving the bulkhead door standing open during testing activities. Leaving the bulkhead door open can cause fluctuations in the high humidity being maintained for the testing environment behind the bulkhead. The bulkhead at STA 17+63 is to be closed and sealed for a period of several months. The Alcove #8 bulkhead will also be closed with very limited access. In order to minimize opening bulkhead doors for access and egress, all planned entrances through the testing bulkheads in the ECRB require coordination and concurrence with the TCO. There is concern in Alcove #8 that in-place panels of instruments, water holding tanks, and testing beds may be disturbed by dust generated by installation activities, physical jostling of sensitive recording instruments, and/or, disturbance of electrical and hydraulic connections between these instruments, testing hardware, and the test beds. The TCO needs to be notified and concurrence received should there be a need to disturb existing equipment and instruments in Test Exclusion Area #1, or accessing Test Exclusion Area #2 (Attachment #6). Another consideration of possible test interference is that the invert in Alcove #8 has been cleaned of dust and foreign material to avoid possible contamination of the testing beds in Test Exclusion Area #2. All installation processes needed for establishing the Refuge Chamber in Alcove #8 must avoid the introduction of dust, water, or foreign materials on the invert in Alcove #8. The bottled air racks need to be secured in Alcove #8 to the rock. The location of items in Alcove #8 needs to be coordinated with, and approved by the TCO. In addition, SOP construction, SOP operations, and SOP maintenance activities are to not enter Test Exclusion Area #2 (Attachment #6) unless approved by the TCO.

10.6.2 Subsurface Conveyor System

As discussed in Section 6.0, the conveyor system is equipped with a dust control and suppression system to contain the dust generated by the handling and conveying of muck. As part of this system, water sprays are installed at loading and transfer points. LiBr is added as a tracer to water used for dust control, as well as for other underground construction. Water volumes used for dust control should be measured (e.g., cumulating flow meters) and records should be maintained and recorded routinely, identifying the quantities. A binding agent may also be added to water that is applied directly to the muck on the conveyor. In addition, a surfactant material was added to the dust suppression water between approximate Stations 2+88 m and 3+38 m of the ECRB Cross Drift (i.e., the Phase I surfactant testing zone).

It is expected that the water used for conveyor system dust control will be applied directly to the muck on the conveyor belt and will be removed with the muck. The system designed for general dust control uses spray heads constrained to the muck inside the belt, which minimizes the amount of water introduced into the subsurface environment—thereby avoiding excessive water use. However, conveyor system spray nozzles may also be used to apply a water/binding agent mixture to the muck on the belt. Since most of the water used for dust control is expected to be removed with the muck, no construction-to-test or operation-to-test interference is anticipated as a result of this activity. Similarly, since nearly 100 percent of the binding agent is expected to be removed with the muck, no construction-to-test or operation-to-test interference is anticipated. Since the surfactant material is to be applied by the spray nozzles on the TBM cutterhead, an indeterminate amount of the surfactant material will not be captured in the muck and hence will not be removed by the conveyor system. A small portion of the remaining amount surfactant material is expected to be captured and removed by the ventilation system. The residual amount of surfactant material, which is assumed to be committed to the environment after construction activities are completed, was the focus of an ECRB Cross Drift Phase I testing activity. Since the quantity of residual surfactant material and surfactant-testing data validity are dependent upon the amount of surfactant material that was applied, a record of the amount of surfactant material used was maintained. No other construction-to-test or operation-to-test interference associated with surfactant material use is anticipated.

10.6.3 Power Distribution System and Lighting

As discussed in CRWMS M&O (1999a, Section 6), conveyor and ventilation system components are electrically grounded at designed intervals. The electrical ground enhancing material to be used should not contain chlorides, such as the coal-derivative GEM® to avoid potential test interference impacts if the ground enhancing material contains chloride. The TCO ensures that, during the development of each FWP (as applicable), the responsible PIs coordinate with the A/E to survey the specific location where test equipment is located (as necessary) and determine whether additional electromagnetic protection is required. Due to this coordination effort, no test interference is expected to occur from installation and operation of the power distribution and lighting systems. The constructor may be required to install EMI shielding or other mitigation measures as part of the implementation of the FWP.

Uninterruptible power supply and emergency lighting systems may be used as long as spills (e.g., battery acid) are avoided. If spills occur, they must be cleaned up as soon as practical. The volumes and locations of any spills must be documented and reported in accordance with the TFM procedure (YMP 1998b).

10.6.4 Subsurface Water Distribution System

As discussed in Section 6.0, the water distribution system supplies traced, nonpotable water to the ECRB Cross Drift. Spill and leak control measures are incorporated into the design to minimize or avoid the potential for test interference. No test interference due to the operation of the underground water distribution system is anticipated as long as leaks and spills are (1) avoided to the extent practical and (2) identified, mitigated, and cleaned up as soon as practical.

10.6.5 Ground Support and Rockbolt Grouting

As described in CRWMS M&O (1999a, Sections 6 and 10.6.10), steel sets, lagging, grout, shotcrete, mesh, steel straps, and/or rockbolts may be used for ground support. Boreholes for rockbolts, anchor-bolts, and other ground support bolts are drilled into the tunnel walls. Compressed air used for general construction drilling and construction does not contain tracer (LANL 1994b). If water usage is necessary for drilling, the amount of water should be kept to a minimum; water allowed to be lost to the subsurface environment should be minimized, and the water should be traced.

Rockbolts may be cement grouted in the ECRB Cross Drift; however, this was not the general practice throughout the TS Loop (CRWMS M&O 1999a). Use of cement grout poses potential test interference concerns due to possible alteration of the *in situ* pH of water/moisture in contact with the grout. Cement grouting pressures and quantities shall be done in accordance with applicable procedure(s). Rockbolts should not be grouted in the ECRB Cross Drift, to the extent that safety concerns allow, without TCO approval. Because testing activities can potentially be moved to a location further away from an area where grout is required to be injected for safety reasons, no test interference is anticipated as long as the TCO is consulted.

Mixing water for grout and pre-mixed (wet) shotcrete is not required to contain tracer for test interference purposes (LANL 1994b). Grout additives should not contain chloride to the extent practical to minimize the potential of affecting chlorine-sensitive site characterization testing.

Ground support should be installed after geologic mapping and sampling activities are completed, to the extent practical. If the encountered ground conditions require ground support in excess of the existing design (CRWMS M&O 1999a, Section 6.5), the impact of suggested remedial activities (i.e., chemical grout injection) should be addressed in a separate evaluation.

ECRB Cross Drift testing includes monitoring of the installed ground support systems. Access to selected rockbolts should be provided for installation of load cells. This activity is coordinated between the TCO and the CMO and is controlled in the applicable FWP.

10.6.6 Use of Diesel-Powered Equipment

Diesel-powered equipment is used underground—including the ECRB Cross Drift—alcove excavation, and material and personnel transportation; it may also be used for muck haulage. Diesel exhaust mixes with outside air, which circulates through the tunnel, due to a negative pressure at the tunnel face that is created by exhaust fans. The gaseous oxides of carbon and diesel particulate matter (DPM) in the diesel exhaust could potentially impact site characterization testing that (1) is sensitive to microorganisms that feed on carbon compounds, or (2) is based on chemical analyses of carbon compounds where the diesel products may have penetrated into the wall rock and contaminated the *in situ* gases collected for site characterization. No test interference due to the generation of DPM was identified for the planned site characterization tests in the ECRB Cross Drift.

Because the ventilation system maintains the tunnel atmosphere at slightly less than atmospheric pressure, it is hypothesized that the diesel-contaminated tunnel atmosphere will be exhausted from the tunnel, without advective inflow into the fractures and rock matrix, for much of the time while the ventilation system is operating. However, since expected variability of atmospheric pressure is an order of magnitude greater than the ventilation induced pressure difference, there could be advective air flow from the tunnel into fractures and the rock matrix as barometric pressure rises after an interval of low pressure (e.g., a winter storm).

Presently, there may be enough data on the permeability of the rock mass, fracture flow, the interconnectivity of fractures, and the magnitude of this pneumatic pressure difference to assess this impact, but such an analysis has not been carried out. Diesel usage in the ESF—including the ECRB Cross Drift—can provide an opportunity to collect test and monitoring data to better define these parameters. A testing program was implemented by the scientific testing participants to use this opportunity to collect data in parallel with the use of diesel-powered equipment in the excavation of the TS North Ramp. Monitoring and testing of diesel emissions should consider emissions of carbon gases. Diesel testing (required before using diesel in the affected areas of the potential WE zone [i.e., in the track of the ECRB Cross Drift] [CRWMS M&O 1998h]) provided data. This data, in conjunction with continued diesel emission monitoring, diesel use records, and other planned site characterization testing data, will allow testers to assess any potential impact on site characterization testing activities. In addition, the diesel use records should record the type of engine or equipment that consumed the diesel fuel, the volume of fuel used, and the number of hours the equipment was operated underground.

The potential use of A-55 clean fuel as a substitute for diesel fuel has been proposed for the ECRB Cross Drift. As discussed in Section 11.3.2, A-55 clean fuel should reduce DPM. However, A-55 clean fuel use should be subject to the same emission monitoring and use records requirements as noted for diesel fuel above.

10.6.7 Materials and Personnel Transportation

Rolling stock is described in CRWMS M&O (1999a, Section 6.9). The electric hydraulic scissor lift cars, along with the maintenance/lube car, have the potential for leaks or spills from the car mechanisms. No interference due to rail car use is anticipated as long as leakage and spillage is avoided to the extent practical; and leaks and spills are identified, mitigated, and cleaned up as soon as practical. The volumes and locations of any spills should be documented and reported in accordance with the TFM procedure (YMP 1998b).

10.6.8 Subsurface Sanitary Facilities

Portable self-contained chemical toilets may be provided at appropriate locations in the ECRB Cross Drift. As long as spills are avoided and cleaned up to the extent practical, should they occur, no test interference is anticipated. The volumes and locations of any spills should be documented and reported in accordance with the DIE procedure NLP-2-0.

10.6.9 Communications Systems

No test interference concerns have been identified with regard to communication systems at the present time. Should the PIs determine that the communications systems may be causing test interference to any ECRB Cross Drift data acquisition system (after these systems are in place), further electromagnetic shielding may be installed to one or both of these systems. It is the responsibility of the PIs to identify additional shielding requirements in the preparation of the applicable FWP (see Section 10.6.3).

10.6.10 Compressed Air Distribution System

Provision will be made in the applicable FWP to prevent the introduction of water from the compressed air supply into tests that are sensitive to water, such as radial borehole tests. No other test interference concerns are expected since the accumulated oil and water from the air treatment process will not be used underground and are required to be disposed of in accordance with environmental regulations. It is the responsibility of PIs to ascertain whether compressed air treatment is adequate. Compressed air used in the collection of core and in the conduct of experiments and testing for site characterization may be tagged with a chemical tracer. Since this is not a construction-to-test interference requirement but a potential prerequisite for specific site characterization testing activities, any tagging requirements will be addressed by the applicable FWP for the specific test.

10.6.11 Use of Electrically Powered Locomotives for Materials and Personnel Transportation

Use of electrically powered locomotives may occur in the foreseeable future in movement of personnel and materials within the ECRB. The electric locomotive has the potential for leaks or spills from the locomotive battery system. No interference due to use of the electric locomotive is anticipated as long as leakage and spillage is avoided to the extent practical; and leaks and spills are identified, mitigated, and cleaned up as soon as practical. The volumes and locations of any spills should be documented and reported in accordance with the TFM procedure (YMP 1998b)(Requirement 6h).

10.6.12 Reversal of the Ventilation System Fan #1 to verify Reversible Capability

The reversing of the ventilation system fans is a Department of Energy safety requirement. It is currently planned to stop fans 1, 2, 3, A, B, and C, then turn fan #1 in reverse. Air pressure readings will be taken at the ESF North Portal and at the beginning of the ECRB Cross Drift. The test interference concern is the dust generated by this reversal process. The TCO and PIs want to protect ongoing testing locations, test data recording and control instruments, and test beds from possible contamination from this airborne dust.

10.7 TRACERS, FLUIDS, AND MATERIALS

A variety of TFM's will be used during TBM operations, installation and operation of utilities, and support for TBM operation. All construction materials or substances used underground

should first be reviewed for potential effects on the Engineered Barrier System (EBS), waste isolation, and on-site characterization activities. The DIE procedure NLP-2-0 adequately provides for this evaluation through DIEs. The presence of combustible materials in the ECRB Cross Drift should be controlled and limited such that testing is not adversely affected. Attachment II lists those TFMs that were reviewed for this evaluation and indicates identified special handling or storage requirements from a test interference perspective. Potential causes of test interference due to TFMs are discussed in the following section.

Use of TFMs should be documented in detail and reported in accordance with YMP (1998b). Samples of TFMs used in ECRB Cross Drift construction and testing-related-construction-support activities are available for examination by PI(s) upon request.

10.7.1 Tracers

The addition of a universal tracer (LiBr is currently the preferred tracer used in water) is required for water used underground in dust suppression, wall cleaning before mapping, and other construction applications. It is not required in water used in concrete, grout, or shotcrete mixtures, except when grout may be used in the vicinity of any perched water location as identified by the TCO (LANL 1994b). The LiBr tracer concentration in construction and mapping water should be within a maximum range of 10 ppm to 20 ppm, not to exceed 30 ppm and are controlled by the requirements in CRWMS M&O (1999a).

Compressed air used in borehole drilling does not require tracing with a chemical tracer. If required for testing purposes, the compressed air may be traced. The common tracer used in air is sulfur hexafluoride (SF_6). Attachment II also identifies SUVA-COLD MP[®], the noble gases helium (He), neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe), and nitrogen gas (N) as acceptable tracer gases. Since the use of tracers, and concentrations thereof, can impact nearby testing activities, the use of any additional tracer, as needed for ECRB Cross Drift testing, will be identified and evaluated in the specific FWP for each respective test and in the applicable DIE before the use of tracer gases.

10.7.2 Fluids Used in Operation of the TBM

No test interference from TBM operational fluids is anticipated as long as any leaks and spills are cleaned up to the extent practical. Periodic checks are made to detect leaks and spills, and spills are cleaned up as soon as possible. The volumes, locations, and results of mitigation of any spills shall be documented and reported in accordance with the TFM procedure (YMP 1998b).

10.7.3 Chloride-Based Materials

The use of chloride-based materials (e.g., sodium chloride, potassium chloride, magnesium chloride) should be coordinated with the TCO because of the potential impact on chlorine-sensitive site characterization testing such as Chloride-36 studies. The use of chloride-based additives to cementitious materials such as shotcrete or grout should be controlled to prohibit use in sensitive or potential testing areas.

10.8 SUBSURFACE ESF TESTING INTERACTIONS

In developing controls specific to the ECRB Cross Drift, this evaluation incorporates design and/or construction constraints identified in the ESFDR (YMP 1997) with regard to the interface between testing and various excavation activities. Thus, this evaluation does not specifically include testing-related activities in the ECRB Cross Drift after it is constructed and its testing accommodations have been installed. However, specific construction constraints applicable to the fielding of the tests, such as whether tracer gas is required in the drilling of boreholes, will be addressed in the individual FWP's for those activities. ECRB Cross Drift testing sites are selected by the PI(s) in coordination with the TCO. The selection process takes into account potential interference from and with other test activities. As such minimal test-to-test interferences associated with subsurface ESF testing activities are anticipated. FWP's ensure that potential interference from and with other test activities are minimized. FWP's are developed by the TCO. The TCO is the field-coordinating agency for ECRB Cross Drift test implementation and represents the interests of both the DOE and the PIs with respect to site characterization testing activities and potential test interference issues.

Given test interference concerns related to ESF construction, operations, and/or maintenance activities, the TCO will establish test exclusion areas which are to be avoided to the extent possible.

Ideally, the goal of ECRB Cross Drift testing activities is to expedite the acquisition of scientific data through testing and monitoring activities. Maximizing the potential of these goals requires close coordination between all affected organizations. The coordination between construction, and ESF testing and SBT resides with the Slight Operations Projects (SOP) and TCO. The SOP and TCO jointly derive a working construction schedule that defines construction/test sequence for test support. Test specific construction support requests from the TCO are communicated to the SOP and implemented through FWP's.

11. IMPACT TO WASTE ISOLATION CHARACTERISTICS

The ECRB Cross Drift is a northeast-southwest trending tunnel beginning from the ESF North Ramp proceeding to the TS Main Drift and above the proposed location of the potential repository block. This tunnel excavation will be directly over WE areas within the potential repository block and expansion areas. The Phase I ECRB Cross Drift evaluation addresses the sensitivity of the proposed WE areas to the addition of TFMs and/or alterations to the rock units associated with excavation and testing from the ECRB Cross Drift Starter Tunnel to the intersection of the ECRB Cross Drift and TS Main Drift. The ECRB Cross Drift Phase II evaluation addresses the excavation and testing beginning at the intersection of the ECRB Cross Drift and the TS Main Drift and continuing over the potential WE area.

Waste isolation effects from construction and testing during Phase I of the ECRB Cross Drift (approximate Stations 0+26 m to 7+73 m) can be generally addressed using the assumptions and analyses developed for the Subsurface ESF DIE (CRWMS M&O 1999a). Because the Phase I DIE addresses the construction/testing activities only until the excavation has proceeded as far as

its intersection with the TS Main Drift (without exceeding a minimum offset of approximately 37 m from the potential WE areas), the assumptions used for the CRWMS M&O (1999a) analyses are used here to conservatively bound the waste isolation effects of Phase I of the ECRB Cross Drift.

Waste isolation effects from construction and testing during Phase II of the ECRB Cross Drift (Stations 7+73 m to 28+23 m) have required new analyses for thermohydrologic effects and impacts to flow and transport in the unsaturated zone. Other analyses addressing emplacement materials are based on assumptions and analyses developed for the Subsurface ESF DIE (CRWMS M&O 1999a) account for a minimum offset of 15 m from closest potential WE location.

Phase I of the ECRB Cross Drift provides a unique opportunity to test and evaluate the potential waste isolation effects of construction methods before the excavation proceeds through the repository block. Previous methods used to quantify committed TFMs during ESF construction resulted in limited information, which in most cases was insufficient to determine the actual TFM loss. As a result, TFM usage during ESF construction was limited to the maximum committable quantities that could be lost with negligible waste isolation effects. In previous DIEs, this maximum quantity was generally well below the amount necessary for the construction or testing activity. For example, water use and organic input were strictly limited during the ESF tunnel construction due to the sensitivity of the site to these parameters. As a result, dust suppression within the tunnel has proven to be a problem. Better quantification of uncertainties like water use and recovery during tunnel excavation and construction could drastically change the controls developed for the construction of the potential repository. With the large offset of Phase I of the ECRB Cross Drift from the potential repository block and expansion areas, new construction and testing methods will be developed and tested during this interval to help quantify the amount of committed TFMs during construction. It is not likely that a better quantification of the amount of committed materials from construction activities will affect the waste isolation analyses contained herein, rather, it could potentially provide the basis to validate new construction activities. These activities may include more water use and the use of organically-based surfactants (if it can be shown that the recovery of these TFMs results in a committed amount below the maximum limits for negligible waste isolation effects).

In the following sections, the evaluations of potential hydrologic, geochemical, and thermal/mechanical perturbations that could affect impacts to waste isolation are discussed. In the specific geochemical evaluations discussed in Section 11.3 of this DIE, the conclusions were based on scenarios that should conservatively bound potential perturbations to ambient conditions. If such conservative calculations indicate that the items/activities are not likely to impact the ambient conditions above the level of the chosen surrogate criterion (as discussed in Section 9.4), it can be reasonably concluded that the items/activities can be used/performed with negligible risk for potential impact to waste isolation from any reasonable scenario (with only those controls that are applied in this evaluation). Because the specific evaluations discussed in Section 11.3 of this DIE are conservative bounding scenarios based on surrogate criteria, it cannot be concluded that impacts to waste isolation are assured for cases where results exceed the surrogate criterion for negligible perturbations to ambient conditions. However, it can be

reasonably assumed that the potential impacts to the surrogate performance parameters resulting from the geochemical changes in these scenarios represent upper bounds for impact for any plausible scenario.

To provide a consistent approach to evaluating the potential impacts in all cases, an effort is made to choose a reasonable bounding scenario. The bounding scenario is not taken from a subjective consideration of the most probable case, nor is it assigned from identification of the worst case. In many cases, the most probable scenario cannot be identified quantitatively because lack of appropriate information precludes quantifying such probabilities. In addition, uncertainties in identification of the worst case, and quantification of resulting effects, preclude using the worst case to constrain these evaluations in most cases. The bounding case is chosen, in part, because it can be quantified in a straightforward manner and includes conservative assumptions to ensure that it encompasses the potential impacts from virtually all reasonable scenarios. In all cases, it will be necessary for a future evaluation of the consequences to waste isolation resulting from the committed items and actual configuration of any final constructed facility.

Several full-page tables and figures are used to support the evaluation in the following subsections. These tables and figures comprise Attachment IV of this DIE. Unless specifically noted in the text, Attachment IV citations throughout the remainder of this section equate to Attachment IV of this DIE.

11.1 HYDROLOGIC EVALUATIONS

To establish the bounding conditions for the following subsections, the hydrologic calculations herein do not address pre-closure dryout of rock in the vicinity of the ECRB Cross Drift excavation. This analytical approach is used to ensure the conservatism of the evaluation herein, in that an appropriate quantitative model for evaluating pre-closure dryout is not available at this time. However, the hydrologic calculations herein do address changes in the ambient, undisturbed saturation levels of the rock formation associated with water release during ECRB Cross Drift activities and post-closure dryout due to repository heating.

11.1.1 ECRB Cross Drift Phase I

11.1.1.1 Effects of Irretrievably Lost Water on Potential Repository Performance

The performance of a conceptual nuclear waste repository at Yucca Mountain is based on the strategy of waste containment, isolation, and attenuated exposure. Containment refers to keeping the waste inside waste packages (e.g., steel canisters), while isolation refers more generally to keeping the waste from reaching the accessible environment. Attenuation of exposure is a result of delay in the release and transport of radionuclides to the accessible environment and dilution of the radionuclides in the water. The accessible environment is where the public is potentially exposed to the waste. These three elements of the nuclear waste disposal strategy (i.e., containment, isolation, and attenuated exposure) are intimately related to the occurrence and behavior of water in the subsurface environment. Containment of waste is affected by water through the role water plays in corrosion and failure of waste containerskages, dissolution of

radionuclides, and migration of dissolved radionuclides from inside waste packages to the surrounding geologic environment. The principal avenue for migration of the radionuclides from the rock at the potential repository to the accessible environment is by advective transport in water. Similarly, the travel times for radionuclides to reach the accessible environment are affected by advective transport in water. Finally, the dilution of released radionuclides that reach the accessible environment depends on the flow, the flowpaths, and mixing of water (CRWMS M&O 1999a).

One of the important characteristics of Yucca Mountain as a potential nuclear waste repository is that it has a relatively large zone of partially saturated rock (about 600 m of vertical thickness in the primary WE block [CRWMS M&O 1996a]). This zone lies between the surface and the water table, and is found to have a wide variety of water saturations (ranging on average from about 30 percent to 90 percent of the pore space [CRWMS M&O 1996a]). For unsaturated conditions, most of the ambient water is confined to the smaller interstices of the rock matrix, limiting its ability to interact with the waste container and waste forms. Water, being the wetting phase against air, tends to first occupy the smaller interstices of the rock matrix and fill larger ones as the water saturation increases. As a result, lower water saturations may result in lower rates for corrosion, dissolution, and transport processes. Therefore, unsaturated conditions are considered an important attribute for repository performance, and lower water saturations are expected to provide better performance.

Water in the potential repository environment is expected to be redistributed by the effects of heat produced by the radioactive waste. The heat enhances vaporization of water and gas-phase movement, which tend to create either global or local zones of lower water saturation in the potential repository depending on the density and configuration of WE, background infiltration rate, and other factors. The thermohydrologic behavior of the potential repository system is currently the subject of detailed process-level calculations. At present, these calculations do not incorporate the potential effects of water lost during construction activities as part of the ambient conditions. In addition, these calculations have a large degree of uncertainty due to the complex processes involved, such as vaporization/condensation phenomena; transient, unsaturated, nonequilibrium flow in fractured rock; and uncertainties regarding specifics of the potential repository design. Therefore, such detailed calculations are not yet considered appropriate for the Phase I ECRB Cross Drift evaluation.

Depending on a variety of factors, the water lost in the Phase I portion of the ECRB Cross Drift may be redistributed within the geologic environment by the effects of repository heating. Under certain conditions, heating may tend to redistribute and combine the water lost in Phase I of the ECRB Cross Drift with a much larger mass of water in a zone of condensation outside the dry-out region and the water lost due to the TS Loop excavation. In this case, the effects of the water lost from both Phase I of the ECRB Cross Drift and the other ESF excavations are expected to be negligible in comparison with the much larger volumes of natural ambient water redistributed around the potential repository. The limitations for flow of lost ECRB Cross Drift Phase I water directly toward potential WE locations (per dispersion effects of water in the unsaturated rock horizon (Liu 2001)) is used to bound the effects of lost water on the potential near-field repository performance.

Water is used for a variety of purposes to facilitate underground construction. The primary use is for dust control during rock excavation and removal. Water is also used to drill holes for emplacement of rockbolts and testing apparatuses. The underground use of water has no effect on the potential performance of a nuclear waste repository unless that water is irretrievably lost to the environment. An evaluation of this lost water on the potential repository performance is presented in the following sections. Uncertainty exists in these evaluations because of the precision and accuracy of measuring natural variability and the application of various modeling techniques. However, uncertainty of no greater than 10 percent would not substantively affect the conclusions of this evaluation.

11.1.1.2 Waste Package Corrosion

The waste package, waste form, backfill (or packing), invert, ground support, WE Drift, drip shield, and other engineered items in the potential repository constitute the EBS. Corrosion of the waste package is a process that affects waste containment and is currently modeled as a function of relative humidity and temperature (CRWMS M&O 1995a). The corrosion model is split into two regimes: humid air corrosion for a relative humidity of less than 85 percent, and aqueous corrosion for a relative humidity of greater than or equal to 85 percent (CRWMS M&O 1995a).

The relative humidity at ambient conditions is reported in CRWMS M&O (1999a, Attachment III), showing that at ambient conditions, the relative humidity is about 99 percent. Additional water in the rock matrix surrounding the WE Drifts could cause a variation in the relative humidity between 99 percent and 100 percent. Because aqueous corrosion is insensitive to the relative humidity, the increase in water saturation due to additional water lost in the ECRB Cross Drift would have a negligible effect on corrosion of waste packages.

11.1.1.3 Spent Nuclear Fuel Dissolution and Engineered Barrier System Transport

Spent nuclear fuel (SNF) dissolution rates, in some cases, affect the rates of radionuclide release from the EBS. The SNF dissolution rate model used in CRWMS M&O (1995a) is not dependent on water saturation or humidity, although if this rate is high enough, the mobilization rate will be a function of the radionuclide flux through the waste canister. This flux through the rock is dependent on diffusive and advective transport processes, which may be sensitive to local hydrologic conditions. Specific information on these transport processes within EBS materials is very limited. Diffusive radionuclide transport in the local rock matrix may be considered an analog for diffusive EBS radionuclide transport processes (see Section 11.1.1.4), and is used to evaluate potential changes in performance due to increased local water saturations. Advective transport processes in the EBS are expected to be driven by advective flux occurring in the local rock fractures and matrix (CRWMS M&O 1995a). A discussion of this sensitivity is given in Section 11.1.1.4. Therefore, the sensitivity of EBS radionuclide transport to water saturation is assumed to be captured through analysis of radionuclide transport in the local rock mass surrounding the EBS.

11.1.1.4 Aqueous Radionuclide Transport in the Near-Field

As in CRWMS M&O (1999a), the definition of 'near-field' used in this evaluation is the transport pathway through the rock matrix to fractures. This near-field movement may be critical if the bulk of the radionuclide transport through the unsaturated zone occurs in fractures and is limited by radionuclide access to fracture pathways. If not, then the analysis of far-field transport (see Section 11.1.1.5) becomes critical.

The effects of water on the near-field are conservatively restricted to a 5-m wide enhanced saturation zone. The use of a 5-m wide zone is a nominal, but conservative, width of the enhanced saturation region corresponding to the diameter of the ECRB Cross Drift excavation. This is conservative because smaller quantities of water will have a larger effect on saturation if restricted to this zone rather than more widespread dispersal in the geologic environment. Discharged water may propagate from its discharge point in the ECRB Cross Drift to the nearest potential WE zones. The tunnel diameter is used as the length scale appropriate to the introduction of water discharged in the tunnel to the geologic environment.

Although both advection and diffusion mechanisms are likely to be involved in radionuclide transport, these mechanisms are not necessarily contributing equally to the overall radionuclide transport rate. A comparison of advective and diffusive transport rates at different levels of water saturation is given in CRWMS M&O (1999a, Attachment IV). Transport rates are probably diffusion dominated at lower saturations, but at elevated saturations advection and diffusion transport rates are expected to be similar. Therefore, the effects of added water in the ECRB Cross Drift on near-field advection and diffusion must be considered.

The general approach is to consider the estimated natural variability in processes related to near-field radionuclide transport and then compare with the change in average behavior due to an increase in water saturation from the average undisturbed ambient water saturation. If the increase in average transport rate lies within the natural variability of the existing condition, then the saturation increase is not expected to noticeably affect near-field radionuclide transport. The analysis of the natural variations in ambient diffusive transport compared with average diffusive transport behavior under elevated water saturations is given in CRWMS M&O (1999a, Attachment V). The results of this analysis indicate that diffusive transport is not sensitive, relative to natural variations in diffusive transport at ambient conditions, to increases in water saturation from the average ambient water saturation to saturated conditions.

A similar analysis for advective transport is presented in CRWMS M&O (1999a, Attachment VI), and finds that advective transport is not sensitive, relative to natural variations in advective transport at ambient conditions, to an increase of water saturation from the average ambient water saturation to an average water saturation of 0.99, but marginally sensitive to saturated conditions. Because the transport process will disperse the saturation levels due to added water, the limiting quantity of added water in the ECRB Cross Drift is assumed to be the amount required to saturate the rock lying between the nearest potential WE location and the ECRB Cross Drift excavation. This quantity of water lost per unit length of excavation, Q_L , is $(1 - S_i) * \phi * W * D_o$, where S_i is the initial (undisturbed) water saturation, ϕ is the porosity, D_o is the

minimum offset between the ECRB Cross Drift excavation and potential WE locations, and W is the width of the saturated zone. Given $W=5$ m (see Section 6.2), $\phi = 0.13$, $S_i = 0.74$ (CRWMS M&O 1996a), and $D_o = 37$ m (Table 9-1), the limiting quantity of water discharged per unit length $Q_L = 6.25$ cubic meters per meter (m^3/m) or about 1650 gal/m.

11.1.1.5 Aqueous Radionuclide Transport in the Far-Field

The definition of far-field used in this evaluation is the transport pathway through the unsaturated zone to the water table. Although added ECRB Cross Drift construction and testing water may move through fractures, this water is not expected to remain in fractures for future potential interaction with radionuclides. The water entering fractures will either drain (relatively quickly) to the saturated zone or be absorbed into the ambient unsaturated rock matrix. Water that drains through fractures to the saturated zone will have a negligible effect on radionuclide transport to the saturated zone. Water that is held in the unsaturated rock matrix may affect far-field transport. A bounding calculation for far-field transport effects of the ESF tunnel construction water is given in CRWMS M&O (1999a, Attachment VII), that considers the effects of an initially saturated zone 37 m thick with a tracer added to the leading edge of the saturated zone. The travel times for the tracer with and without the disturbance to the flow field are calculated, giving a reduction in travel time of about 15 percent for the disturbed flow case. This reduction as a result of additional water from the ESF tunnel was determined to be negligible in comparison with the travel time variations that are expected. For example, the variation in travel time through matrix in the unsaturated zone may be computed from velocity and distance data given in Tables 7.2-4 and 7.4-1 in CRWMS M&O (1995a). The ratio of maximum to minimum travel times of non-retarded species in the six stratigraphic columns used for the high-thermal-load case is a factor of 13 to 39. Likewise, the ECRB Cross Drift is expected to have a negligible effect on the far field travel times.

11.1.1.6 Aqueous Radionuclide Transport in the Saturated Zone

The quantities of water found to potentially affect aqueous radionuclide transport in the unsaturated zone are far smaller than the quantities of water that would be expected to have a non-negligible effect on aqueous radionuclide transport in the saturated zone. An analysis of perched water flowing down a borehole to the saturated zone was evaluated in terms of its effects on the saturated zone hydraulic gradient, which is proportional to the flow velocity and inversely proportional to the aqueous radionuclide travel time (CRWMS M&O 1997f). This analysis found that a groundwater mound resulting from the loss of $36,500 \text{ m}^3$ over one year in a single borehole that penetrated the saturated zone would dissipate to negligible levels in less than four years. This may be compared with the limiting quantity of water spread throughout the entire 773 m of Phase I of the ECRB Cross Drift, based on a limiting rate of $6.25 \text{ m}^3/\text{m}$, giving a total of $4,831 \text{ m}^3$. Therefore if the quantity of water lost in the Phase I ECRB Cross Drift is limited to $6.25 \text{ m}^3/\text{m}$ (or about 1650 gal/m) of tunnel excavation, any effects of this water on potential aqueous radionuclide transport in the saturated zone is expected to be negligible.

11.1.1.7 Gaseous Radionuclide Transport in the Unsaturated Zone

The addition of water will affect gaseous radionuclide transport in the unsaturated zone. An increase in water saturation will always reduce the diffusive transport rate in the gas phase (Marshall and Holmes 1979, p. 271), or increase the diffusive travel times of gaseous radionuclides. Therefore, gaseous radionuclide transport effects caused by the addition of water is not expected to adversely affect potential repository performance.

11.1.2 ECRB Cross Drift Phase II

11.1.2.1 Effects of Irretrievably Lost Water on Potential Repository Performance

The performance of a conceptual nuclear waste repository at Yucca Mountain is based on the strategy of waste containment, isolation, and attenuated exposure. Containment refers to keeping the waste inside waste packages, for example steel canisters, while isolation refers more generally to keeping the waste from reaching the accessible environment. Attenuation of exposure is a result of delay in the release and transport of radionuclides to the accessible environment and dilution of the radionuclides in the water. The accessible environment is where the public could potentially be exposed to the waste. These three elements of the nuclear waste disposal strategy, containment, isolation, and attenuated exposure, are intimately related to the occurrence and behavior of water in the subsurface environment. Containment of waste is affected by water through the role water plays in corrosion and failure of waste packages, dissolution of radionuclides, and migration of dissolved radionuclides from inside waste packages to the surrounding geologic environment. The principal avenue for migration of the radionuclides at the potential repository to the accessible environment is by advective transport in water. Finally, dilution of the released radionuclides that reach the accessible environment depends on the flow and mixing of water.

One of the important characteristics of Yucca Mountain as a potential nuclear waste repository is that it has a relatively large zone of partially saturated rock (about 600 m of vertical thickness in the primary WE block [CRWMS M&O 1996a]). This zone lies between the ground surface and the water table, and is found to have a wide variety of water saturations (ranging on average from about 30 percent to 90 percent of the pore space [CRWMS M&O 1996a]). Under unsaturated conditions, most of the ambient water is confined to the smaller interstices of the rock matrix, limiting its ability to interact with the waste container and waste forms. Water, being the wetting phase against air, tends to first occupy the smaller interstices of the rock matrix and fill larger ones as the water saturation increases. Therefore, lower water saturations may result in lower rates for corrosion, dissolution, and transport processes, and ultimately, improved repository performance.

Water in the potential repository environment is expected to be redistributed by the effects of heat produced by the radioactive waste. The heat enhances vaporization of water and gas-phase movement, which tend to create either global or local zones of lower water saturation in the potential repository depending on the density and configuration of WE, background infiltration rate, and other factors. The thermohydrologic behavior of the potential repository system in combination with the Phase II ECRB Cross Drift, which overlies potential WE Drifts is analyzed

in detail using the thermohydrologic model, NUFT (LLNL 1998a). To encompass the uncertainty associated with quantitative predictions of thermohydrologic processes, a large number of calculations have been performed using a wide variety of conditions.

Water is used for a variety of purposes to facilitate underground construction. The primary use is for dust control during rock excavation and removal. It is also used to drill holes for emplacement of rockbolts and testing apparatuses. The underground use of water has no effect on the potential performance of a nuclear waste repository unless that water is lost to the environment. An evaluation of this lost water on the potential repository performance is given in the following sections.

11.1.2.2 Thermohydrologic Interaction with the Potential Repository

11.1.2.2.1 Evaluation Approach for Near-Field Thermohydrologic Effects

The thermohydrologic conditions around the potential WE Drift can affect waste package corrosion, spent fuel dissolution, and transport through the EBS. Corrosion of the waste package is a process that affects waste containment and is currently modeled as a function of relative humidity, temperature, and local water flux (CRWMS M&O 1998o). Waste form degradation, mobilization, and transport, through the EBS transport, are also modeled as functions of these conditions (CRWMS M&O 1998p). Therefore, the key thermohydrologic conditions that may influence these processes are temperature and relative humidity inside the potential WE Drift and water flux in the rock immediately surrounding the drift. Each of these conditions have been investigated in a comparative way for the conceptual repository system with and without the ECRB Cross Drift. The location and orientation of the ECRB Cross Drift as well as some of the ambient conditions within the model (infiltration flux and liquid saturations) were varied to determine the sensitivity of the results to these changes.

The investigations were carried out using drift-scale thermohydrologic simulations. The thermohydrologic simulations were performed using the integrated finite-difference code NUFT (LLNL 1998a). The procedure by which the various sensitivities were implemented into the NUFT code is described in the following sections and is consistent with the current thermohydrologic modeling used in support of the Total System Performance Assessment - Viability Assessment (TSPA-VA) calculations (CRWMS M&O 1997i). The output data from the NUFT calculations were then processed by XTOOL software (LLNL 1998b) to generate the graphical representations (i.e., Figures IV-8 through IV-31 in Attachment IV of this DIE) that were necessary to evaluate the NUFT model results.

11.1.2.2.2 Thermohydrologic Model

TSPA-VA Study

To maintain consistency with TSPA-VA analyses, one of the TSPA-VA equivalent-continuum thermohydrologic models was selected as the starting point for the ECRB Cross Drift study. Detailed descriptions of the various model components and the assumptions that went into generating the components are included in Yucca Mountain Project Milestone SLX09J2

(CRWMS M&O 1997i). The detailed information contained in this milestone is summarized in the following paragraph, which provides a brief description of the model components of specific interest to the ECRB Cross Drift study.

The drift-scale thermohydrologic model selected for the ECRB Cross Drift study consisted of an areal mass loading of 85 metric tons of Uranium (MTU)/acre (63,000 MTU over 741.2 acres) with a total thermal load of 99.4 kilowatts/acre. The waste packages are modeled using a "point" loading repository design, i.e., the waste packages are spaced along the drift such that there is a substantial variation in thermal output along the drift. Also, the waste packages are arranged in a "center" configuration, i.e., placed centrally in the drift as viewed in a cross-section orthogonal to the drift axis. The infiltration flux boundary condition along the upper boundary of the model is set to a value 11.5 millimeters per year (mm/yr). The WE Drifts are currently planned with a 28-m spacing and consist of a 5.5-m outside-diameter drift (cross-sectional area = 23.768 m^2), with a 0.2-m thick concrete-liner and an additional 0.655-m thick concrete invert on the bottom of the drift. These circular dimensions were translated into an equivalent volume, rectangularly gridded model. The WE drift model consists of a 4.874 by 4.874 m square drift (cross-sectional area = 23.756 m^2) with a 0.177-m thick concrete liner and a 0.34-m thick invert. To simulate the thermal response in the center of the repository area, a drift model was developed to be representative of the center of the repository. A total of seven waste packages were incorporated into the model along the long axis of the drift (Figure IV-1). Commercial spent nuclear fuel (CSNF) was included in five and one-half waste packages (specifically, three 21-Pressurized-Water Reactor [PWR], two 44-Boiling Water Reactor, and one-half 12 PWR fuel assembly configurations). The remaining one and one-half packages included direct-disposal packages of DOE SNF and co-disposal packages comprised of defense high level waste. No-flow boundary conditions were applied to all four vertical sides of the 3-dimensional model domain, resulting in symmetry in the horizontal direction. Therefore, only half waste packages were required on the lateral ends of the modeled drift. One of the 21-PWR CSNF packages was configured as a design-basis fuel in which the heat output is larger than that of the average 21 PWR waste package and is included to represent a potential maximum initial output. Bodvarsson et al. (1997) and Sandia National Laboratories (SNL) (1997a) provide the basis for the selection of the thermal and hydrologic parameters assigned to the various components of the drift-scale thermohydrologic models (CRWMS M&O 1997i).

ECRB Cross Drift Study

The TSPA-VA drift-scale thermohydrologic model described above was selected as the basis on which the ECRB Cross Drift models would be developed. Modifications to this TSPA-VA model consisted of modifying several grid layers within the TS_w unit. These modifications were necessary to include the ECRB Cross Drift 15 m above the WE Drift and to provide for the proper cross-sectional area of the ECRB Cross Drift. The grid block thicknesses parallel to the WE Drift (Y direction) and perpendicular to the WE Drift (X direction) were not modified to maintain consistent drift spacing and waste package dimensions.

Figures IV-2 and IV-3 present schematics of the Y-Z and X-Z grids, respectively, in the region of the WE Drift. The grid-block dimensions are the same for the base case and all sensitivity

models, with only the grid-block material designations changing between models for certain grid blocks (i.e., drift or rock properties). The grid-block material designations in the Y direction include identifiers for each waste package. The CSNF packages are denoted by "cf#" and the direct and co-disposal packages denoted by "df#." The grid-block material designations in the Z direction include identifiers for the rock formation based on the hydrogeological units from the site-scale unsaturated zone model developed at Lawrence Berkeley National Laboratories (LBNL) (Bodvarsson et al. 1997). The LBNL model layer identifiers for the TSw unit are designated as "Tsw31" through "Tsw37." For the ECRB Cross Drift model, the designations have been shortened to "Tsw1" through "Tsw7," with model layers Tsw4, Tsw5, Tsw6, and Tsw7 being specifically applicable to this analysis.

11.1.2.2.3 ECRB Cross Drift Thermohydrologic Models

The ECRB Cross Drift was incorporated into the base-case thermohydrologic model to determine its effects, if any, on the WE Drift conditions affecting waste-package degradation, mainly temperature and relative humidity, and on the conditions within the TSw unit, mainly temperature, liquid saturation, and liquid flux. The current design is for the ECRB Cross Drift to be oriented at an angle to the WE Drifts. However, due to the symmetrical nature of the base-case model, the ECRB Cross Drift was modeled as perpendicular or parallel to the WE Drift to look at the effects of orientation. In the perpendicular orientation, the symmetry of the model requires that additional ECRB Cross Drifts be located across the no-flow boundaries at either end of the WE Drift. However, the effects of these mirrored ECRB Cross Drifts were assumed to not have a significant effect on the overall results.

Perpendicular Orientation

The ECRB Cross Drift was put into the model, perpendicular to the WE Drift, at two locations (Figure IV-4). The first location was directly above the CSNF design-basis fuel 21-PWR waste package, denoted as "cf3." This model is designated the CF3 case. The second location was directly above the CSNF average 21-PWR waste package, denoted as "cf4." This model is designated as the CF4 case. Figure IV-4 presents a portion of an Y-Z cross-section through the model grid along the centerline of the WE drift ($n_x = 1$). The heavy outlined boxes at n_y of 8 to 9, n_z of 25 to 26, and n_y of 14 to 15, n_z of 25 and 26, represent the location of the ECRB Cross Drifts with the two different models. The ECRB Cross Drifts located above the cf3 and cf4 package had a cross-sectional (horizontal) width of 5.3 m. This is approximately six percent larger than the actual 5-m diameter of the ECRB Cross Drift. The larger drift was employed as a matter of convenience with respect to the numerical grid, and it is expected to result in a conservative calculation relative to the effects of the ECRB Cross Drift on thermohydrologic behavior. However, the actual differences in the results between a 5.3-m drift and a 5-m drift are expected to be very minor. Figure IV-5 presents a portion of an X-Z cross-section through the model grid perpendicular to the WE Drift ($n_y = 8$ and 14), showing the ECRB Cross Drift extending from drift centerline to pillar centerline. The text notations within the outlined ECRB Cross Drifts, the formation between the ECRB Cross and WE Drifts, and within the WE Drift, identify the grid blocks in which model results will be presented in the following sections.

Parallel Orientation

The ECRB Cross Drift was then modeled as parallel to and along the centerline of the WE. This model configuration was designated the WE case. Figure IV-6 presents a portion of an Y-Z cross-section through the model grid along the centerline of the WE drift ($n_x = 1$) showing the location of the ECRB Cross Drift (heavy outlined boxes). Figure IV-7 presents a portion of an X-Z cross-section through the model grid perpendicular to the WE drift ($n_y = 8$ and 14), showing the ECRB Cross Drift location. Because of a line of symmetry located along the centerline of the WE drift, only one-half of the drift is included in the model. The cross-sectional (horizontal) width of the ECRB Cross Drift is 4.9 m, which is two percent smaller than the 5-m diameter circular drift. This difference was considered to be acceptable for the objectives of this study.

Variations in Selected Initial Conditions

Several sensitivity simulations were conducted to determine the effects of different initial conditions within the thermohydrologic models. The first variation was a decrease in the constant infiltration flux specified across the upper atmospheric boundary. The base case infiltration was decreased from 11.5 mm/yr to 6.5 mm/yr. New ambient pressure, temperature and liquid saturation versus depth profiles were generated and input as the new initial conditions. The rock properties were not modified for this lower infiltration simulation. The lower infiltration simulations were conducted for the base case, CF4, and WE configurations.

The second variation consisted of increasing the initial liquid saturation in the grid blocks between the ECRB Cross and the WE Drifts to near saturation (0.99) to investigate the potential effects of excess construction water saturating the formation beneath the ECRB Cross Drift. Simulations with increased initial liquid saturation were conducted for the base case, CF4, and WE configurations.

ECRB Cross Drift Properties and Initial Conditions

The WE drift consists of the concrete liner, invert, waste package, and unoccupied space termed "drift." Within the ECRB Cross Drift, no concrete liner was included and only drift properties were assigned. The thin concrete liner was excluded from the ECRB Cross Drift so that additional grid refinement was not necessary in the horizontal direction. The WE and ECRB Cross Drifts were assigned a high effective thermal conductivity to mimic the heat transfer mechanism through the unoccupied drift grid blocks. This is consistent with the heat transfer mechanism implemented in the WE drift for the current unsaturated zone thermohydrology drift scale calculations (Dunlap et al. 1997). The liquid saturation within the ECRB Cross Drift grid blocks was initialized to zero. The temperature with the ECRB Cross Drift was set based on the ambient thermal gradient and allowed to vary during the simulation.

11.1.2.2.4 Thermohydrologic Model Results

Each of the ECRB Cross Drift thermohydrologic models was run to 100,000 years. The results presented below show the changes in selected model input parameters at a consistent set of grid blocks. Depending on the selected ECRB Cross Drift model, some grid blocks may contain

Tsw4 properties or ECRB Cross Drift properties. The figures to be presented will show the temperature and relative humidity profiles within the selected WE Drift grid blocks, the temperature within the selected formation and ECRB Cross Drift grid blocks, and the vertical liquid flux across selected model layers. The descriptive text below assumes 11.5 mm/yr and ambient initial saturation conditions unless otherwise noted.

Figures IV-8 and IV-9 present the temperature and relative humidity profiles for the selected WE Drift grid blocks for the 11.5 mm/yr base case (i.e., without ECRB Cross Drift), CF3, CF4, and WE models. The symbols represent the base case parameter values for the three selected grid-block locations and the three line types refer to three ECRB Cross Drift cases. Figure IV-8 shows that the results from the three ECRB Cross Drift cases overlie each other at the three grid-block locations, with no significant change in the thermal profile. (The deviation in the results for the CF3 case from 3000 to 10,000 years and from 30,000 to 100,000 years is due to a reduction in the number of data points captured.) Figure IV-9 does show some variation in the relative humidity between 100 and 1000 years for the near the cf4 and d2 waste packages, but the change does not significantly differ from the base-case results.

Figures IV-10 and IV-11 present temperature profiles at the selected tsw5 grid block located above the cf3 and cf4 waste packages, respectively, for the base case, CF3, CF4, and WE models. These plots show that there is an increase in grid block temperature by less than ten percent when the ECRB Cross Drift is located above the grid block. Figure IV-12 presents the temperature profiles for the selected tsw4 grid blocks for the base-case model, and the profiles at the same grid blocks (tsw4 or ECRB Cross Drift properties) for the CF3, CF4, and WE models. These results show that there is no change in the grid-block temperature due to the presence of the ECRB Cross Drift.

Figures IV-13 through IV-15 present the temperature and relative humidity profiles for the selected grids for both the 11.5 mm/yr and 6.5 mm/yr base-case models. These figures demonstrate that the lower infiltration results in a slightly higher temperature within the WE Drift and tsw5 model layer, along with a corresponding decrease in the WE Drift relative humidity.

Figures IV-16 and IV-17 present the temperature and relative humidity profiles at the selected WE Drift grid blocks for the 6.5 mm/yr base case, CF4, and WE models. (A CF3 model with an infiltration of 6.5 mm/yr was not conducted.) As with the 11.5 mm/yr cases, there are no significant differences in the temperature or relative humidity between the three cases. Figures IV-18 and IV-19 present temperature profiles at the selected tsw5 grid block located above the cf3 and cf4 waste packages, respectively, for the 6.5 mm/yr base case, CF4, and WE models. These results are also similar to the comparison of the 11.5 mm/yr models.

Figures IV-20 and IV-21 present the temperature and relative humidity profiles at the selected WE drift grid blocks for the 11.5 mm/yr base-case and the CF4 and WE models with an initial grid-block liquid saturation of 0.99. (A CF3 model with increased initial liquid saturation was not conducted.) These results show no significant differences in the temperature or relative humidity between the three cases. Figures IV-22 and IV-23 present temperature profiles at the

selected Tsw5 grid block located above the Cf3 and Cf4 waste packages, respectively, for the same three models. These results also show no significant deviation from the base-case results.

Figure IV-24 presents a plot of the vertical liquid flow rate at four different times along a slice parallel to the WE Drift through the grid layer which contains the selected tsw5 grid blocks, for the 11.5 mm/yr base-case model. The plot shows an increase in the downward movement of liquid during the heating phase (10 and 30 years) as a result of the capillary suction from the dryout region. As the dryout region decreases in size, the vertical flow rate decreases as seen by the results at 300 years. Figure IV-25 presents a similar plot of the vertical liquid flow rate for a slice through the same Tsw5 layer but oriented perpendicular to the WE drift and at a distance between the Cf3 and Cf4 waste packages. This figure shows the similar increase in vertical liquid flow rate during the heating phase.

Figures IV-26 and IV-27 present a comparison of the vertical liquid flow rate for the 11.5 mm/yr base-case and CF4 models. Figure IV-26 shows that the presence of the ECRB Cross Drift creates a decrease in flow rate directly beneath the drift along with a shedding effect around the drift as seen by the increase in flow rate on both sides of the ECRB Cross Drift. However, this modification in the flow rate is not observed over more than 5 m on either side of the ECRB Cross Drift. This is seen in Figure IV-27 where there is no change in the flow rate along the slice perpendicular to the WE Drift. This slice is parallel to the ECRB Cross Drift but approximately 8 m away from the drift.

Figures IV-28 and IV-29 compare the vertical liquid flow rate slices for the 11.5 mm/yr and 6.5 mm/yr CF4 model. These results show that the overall magnitude of the flow rate is decreased due to the decreased infiltration. Also, the magnitude of the flow rate modification due to the presence of the ECRB Cross Drift is negligible.

Figures IV-30 and IV-31 compare the vertical liquid flow rate slices for the 11.5 mm/yr CF4 models with ambient and initial liquid saturation conditions. Figure IV-30 shows that after approximately one year, the heating pulse removes any effects of the initial liquid saturation between the ECRB Cross and the WE Drifts.

A case having significantly higher infiltration than the cases discussed above was also considered (see Figure IV-39). For this calculation, we used the CF4 model with an infiltration flux of 59.21 mm/yr, which is more than 5 times higher than the highest infiltration rate considered above. We also calculated the behavior out to 100,000 years after waste emplacement to check the behavior of infiltration diversion around the ECRB after thermal effects have dissipated. As for the other CF4 models, the ECRB Cross Drift creates a flux shadow directly below the drift, and enhanced flux where infiltration "shedding" has occurred (see Figures VI-25 through VI-31). The enhanced flux is very localized (only extends about 5 m to either side of the shadow), with a peak flux that is about a factor of 1.7 times the ambient flux. The variability of the natural infiltration flux (as discussed in detail in Section 11.1.3.2.1) is found to have a geometric standard deviation of a factor of 1.5 to 2.0. Therefore, the enhanced flux over a very small region lies within the range of natural variability expected for the system, and should have a negligible effect on the system performance.

11.1.2.2.5 Discussion and Conclusions Regarding Near-Field Thermohydrologic Effects

As stated above, the objectives of this thermohydrologic study were to investigate the potential changes in the WE drift conditions and the conditions within the TSw unit between the WE and ECRB Cross Drifts, due to the presence of the overlying ECRB Cross Drift. To accomplish these objectives, a suite of thermohydrologic models were run. The results of the model calculations provided information on the response of the physical system to the presence of just the WE Drift, to the presence of the WE and ECRB Cross Drift, and to the changes in certain initial conditions. Comparisons of the temperature and relative humidity at certain locations within the WE Drift were presented to determine if significant potential changes in waste-package degradation would be expected due to the overlying ECRB Cross Drift. Also, comparison of the temperature and vertical liquid flux within certain formation grid blocks at and between the ECRB Cross and WE Drifts were conducted to determine if any significant redistribution of water can occur near the WE Drift as a result of the ECRB Cross Drift.

In general, the analysis is based on identification of the differences in temperature, relative humidity, and water flow rates that are caused by the presence of the ECRB Cross Drift. A conservative way to evaluate if the differences found are important to the potential repository performance is to compare the differences with local differences in these quantities due to variations in waste package thermal behavior. If the perturbations introduced by the presence of the ECRB Cross Drift are small compared with the local variations expected in the potential repository in the absence of the ECRB Cross Drift, then these variations should have a negligible effect on performance. For example, the differences with and without the ECRB Cross Drift in Figure IV-8 are very small compared with the differences near the different waste packages. In Figures IV-10 and IV-11, the differences with and without the ECRB Cross Drift are very small except for the first 100 years. During this early time period differences resulting from the ECRB Cross Drift are comparable to differences between locations above the CF3 and CF4 waste packages without the ECRB Cross Drift.

The results demonstrated that, within the WE Drift, no significant changes in the temperature or relative humidity were observed due to the presence of the overlying ECRB Cross Drift. This was observed for both the perpendicular and parallel orientation of the ECRB Cross Drift relative to the WE Drift. Therefore, no significant changes in the waste package degradation would be expected due to the presence of the ECRB Cross Drift.

The temperature results demonstrate that there is a localized increase in the temperature within the formation directly beneath the ECRB Cross Drift. The vertical liquid flux results demonstrate that there is a decrease in liquid flux directly beneath the ECRB Cross Drift location and an increase in flux extending not more than 5 m on either side of the drift. As a result of the ECRB Cross Drift, a shedding effect is generated around the drift. This happens when water is being drawn towards the WE Drift during the heating phase and is diverted around the ECRB Cross Drift. This decrease in the amount of water directly beneath the ECRB Cross Drift requires less thermal energy for vaporization. Therefore, the temperature within the grid blocks is found to increase. Differences found all lie within the variability of the system without the ECRB Cross Drift, except for the "shadow" in the vertical liquid flux between the ECRB Cross

and WE Drifts at early times (see Figure IV-26). However, this flux deficit is not expected to have adverse effects on performance because reduced flux over the WE drift is favorable and the duration of this effect as a significant difference is less than 100 years.

The decrease in the ambient infiltration from 11.5 mm/yr to 6.5 mm/yr resulted in changes in the temperature, relative humidity, and liquid flux. However, the overall effects on these quantities due to the presence of the ECRB Cross Drift was not significantly affected by the decreased infiltration. The use of an increased initial liquid saturation in the grid blocks between the ECRB Cross and WE Drifts did not have an observable effect on the physical system beyond first year of the simulation.

11.1.2.2.6 Mountain-Scale Thermohydrologic Effects

Detailed analyses (as performed for the near-field thermohydrologic effects) were not performed to investigate mountain-scale effects of the ECRB Cross Drift. The ECRB Cross Drift may represent a gas-phase pathway, however the release of gas-phase radionuclides has been found to have little consequence relative to population dose (CRWMS M&O 1995a). For this reason, the current Total System Performance Assessment (TSPA) models treat potential gas-phase radionuclides as partitioned entirely to the aqueous phase to conservatively bound the effects of these nuclides on population dose. Therefore, the existence of an additional gas-phase radionuclide pathway is not considered important.

The ECRB Cross Drift also would introduce a perturbation to the behavior of the mountain-scale thermohydrologic behavior due to potential gas-phase convection through the drift (if not sealed). For the ECRB Cross Drift, it may be argued that on a mountain scale, any tendency for lateral gas-phase convection through the drift would be completely overwhelmed by the laterally extensive connectivity resulting from the potential WE Drifts. The ECRB Cross Drift could potentially be a pathway for gas-phase thermal convection cells, given a configuration of the waste heat relative to the ECRB Cross Drift that favors such a flow pattern. This single drift overlying a relatively small number waste packages is not expected to have a noticeable effect on thermohydrologic behavior or on the potential repository performance. However, if future analyses should find that the ECRB Cross Drift may have an adverse effect on gas-phase thermal convection relative to potential repository performance, then the drift should be sealed to a level comparable to the bulk rock permeability (i.e., the fracture permeability) before WE.

One issue related to the interaction of the ECRB Cross Drift with multiple WE Drifts is the possibility that adjacent WE Drifts may have significantly different thermal loadings. Such a condition could lead to asymmetric behavior in which water vapor driven from the hotter drift may migrate to, and condense over, the cooler drift. The additional water drainage over the cooler drift could have adverse effects on potential repository performance. The near-field thermal-hydrologic modeling analyses (Sections 11.1.2.2.1 through 11.1.2.2.5) assume a uniform thermal load from drift to drift. This assumption is expressed in the assumed symmetry along the vertical boundaries (Section 11.1.2.2.2). Ways to achieve a uniform thermal load have been identified in a recent design analysis (CRWMS M&O 1998q), such that, if the uniformity of the

thermal load is found to be significant for the performance of the potential repository, the design and operational features needed to achieve a uniform thermal load can be implemented.

11.1.2.2.7 Near-Field Hydrologic Effects on Radionuclide Transport

The effects of enhanced water saturation in the rock matrix surrounding the potential WE Drifts has been analyzed in CRWMS M&O (1999a) relative to impacts to aqueous radionuclide transport. However, analyses of flow and radionuclide transport patterns (CRWMS M&O 1998r and 1998s), under currently expected and future conditions, suggest that, in the geosphere (outside the EBS), advective transport through fractures dominates. These analyses further suggest that enhanced advection and diffusion in the matrix, if anything, is beneficial to retarding radionuclide transport. Therefore, the comparison of enhanced transport relative to changes in the near-field matrix hydrologic conditions is not considered further.

11.1.2.3 Disposition of Construction Water in the Far-Field Unsaturated Zone and its Potential Effects on Radionuclide Transport

Water discharged and lost to the geosphere during ECRB Cross Drift construction and characterization activities may affect the far-field hydrogeologic conditions along potential radionuclide pathways. The potential repository is in the unsaturated zone at Yucca Mountain, and the hydrogeologic conditions that affect potential radionuclide transport are sensitive to the addition of water. Generally speaking, the addition of water could adversely affect repository performance if the flux of water in the unsaturated zone is enhanced due to the loss of water in the ECRB Cross Drift.

The definition of the far-field used here is the potential radionuclide transport pathway through the unsaturated zone, outside the potential emplacement drift boundary, to the water table. Introduced water will cause a perturbation to the ambient flow system, currently modeled in TSPA as a steady flow system (CRWMS M&O 1998r). This perturbation is treated as a single transient flow event, superimposed on the existing steady flow field, that starts from the potential repository horizon and propagates to the water table. The duration and magnitude of changes in water flux at the water table are modeled and compared with the expected variability in percolation flux over the potential repository emplacement area. The changes in flux due to the introduced water are compared with natural variations at a time period of 300 years following the ECRB Cross Drift construction. This time frame is selected because of the regulatory requirement for substantially complete containment of the waste over a period of 300 years (10CFR60).

To assess the effects of water use on potential repository performance, we develop a rationale for potential impact and derive quantitative limits on changes to the geohydrologic system. In section 11.1.2.4.1, we develop a model for the migration of water discharged in the ECRB Cross and lost to the geologic environment. This model, combined with the criterion for impact, may be used to define a conservative limit for the loss of water, i.e., if water loss is held below the identified level, then the effects of this water loss on potential repository performance should be negligible.

11.1.2.3.1 Establishing a Criterion for Evaluation of Impact

A calculation of the changes in unsaturated zone flow below the ECRB Cross Drift, due to the introduction of construction water, does not, in itself, reveal if those changes are important to potential repository performance. The present total system performance model would require modifications to capture the effects of perturbing a small, discrete, portion of the unsaturated zone on bottom-line performance criteria such as dose or cumulative release to the accessible environment. However, we may argue more simply that if a small portion of the unsaturated zone flow field (i.e., the zone below the ECRB Cross Drift) is perturbed (after a specified minimum time) to some level less than the (estimated) natural variation in percolation flux across the potential repository block, then the effects of that perturbation on performance are negligible. Clearly, some minimum offset in time is required because at the time of emplacement the construction water may significantly alter the local unsaturated zone flow. However, because the application of construction water is localized in time, the effects of such an introduction of water are expected to diminish with time. The time offset picked, 300 years, is based on the 10CFR60 requirement for substantially complete containment of radioactive waste by the waste package for no less than 300 years. Therefore, we will evaluate the changes in the unsaturated flow system 300 years after introduction of construction water, relative to the estimated natural variability in percolation flux.

Variability in percolation flux at the repository may be obtained using the three-dimensional, steady, unsaturated zone flow model calculations reported by Bodvarsson et al. (1997). The frequency distribution for percolation flux at the repository horizon are shown in Figures IV-32 through IV-34 of this DIE (Bodvarsson et al. 1997). These three figures represent the TOUGH2 model calculations for percolation flux at the potential repository horizon using three different hydrogeologic parameter sets. The parametric descriptions for these frequency distributions are approximated by log-normal probability distributions. Figure IV-32 is seen to follow a log-normal distribution reasonably well, while Figures IV-33 and IV-34 show the percolation flux frequency distribution to flatten out (relative to the log-normal fit) at lower values of flux. Nevertheless, the geometric mean and standard deviations for the fitted distributions are believed to be reasonably representative of the overall range of variation of the percolation flux frequency distributions. The geometric standard deviation (σ_g) is representative of the "spread" of the distribution. A value one standard deviation above the mean is computed by multiplying the geometric mean by the geometric standard deviation. The value of the geometric standard deviation is found to have values of 2.0, 1.65, and 1.5 for Figures IV-32 through IV-34, respectively. We may conservatively conclude a natural variation in percolation flux to be at least a factor of 1.5 to the geometric mean.

It is reasonable to assert that the greatest impact for a given quantity of water introduced to the geosphere through construction and testing activities in the ECRB Cross Drift would be for the natural system at its lowest potential natural percolation flux. Current hydrologic estimates of infiltration suggest that the lowest reasonable flux expected for the natural system is 0.0014 m/yr. This figure is derived from the current best estimate of 0.007 m/yr averaged over the potential repository block under present climate conditions. The estimated uncertainty range for the average infiltration rate is $5 \times 0.007 = 0.035$ m/yr as the upper bound and $1/5 \times 0.007 =$

0.0014 m/yr as the lower bound. It should also be mentioned that the present climate conditions are the driest conditions expected to occur at Yucca Mountain. Local perturbations to the existing hydrologic conditions (e.g., the percolation flux) may be argued to be negligible if they lie within the natural variation in the system. This is because it would, in fact, be difficult to detect such a local perturbation through hydrogeologic measurements, because the perturbation would lie within the "noise" of natural variability for the system. Therefore, we expect that a local perturbation to the percolation flux that lies within 1.5 of the natural value should have negligible impact to potential repository performance. Therefore, for a natural percolation flux of 0.0014 m/yr, the highest allowable perturbation to percolation flux 300 years or more following construction of the ECRB Cross Drift should be 0.0021 m/yr.

11.1.2.3.2 Model for Calculating the Hydrologic Effects of an Introduced Pulse of Water

The hydrogeologic units below the ECRB Cross Drift within the unsaturated zone are the TSw, CHn, and the Crater Flat undifferentiated (CFu) units. The TSw unit is highly fractured, having fracture permeabilities that are orders of magnitude larger than the matrix permeabilities (Bodvarsson et al. 1997). The CHn is subdivided based on alteration of vitric tuffs into zeolitic tuffs. The unaltered, or vitric, tuffs in the Calico Hills have large matrix permeabilities that are roughly as large as the fracture permeabilities (Bodvarsson et al. 1997). The zeolitic, or altered, tuffs in the Calico Hills have low matrix permeabilities, similar in magnitude to the matrix permeabilities in the TSw. Investigations into the flow of water through these units indicate that water flux in excess of a few mm/yr will necessarily be dominated by fracture flow in the welded rocks (Bodvarsson et al. 1997). Similarly, water flux in excess of a few mm/yr is expected to either laterally divert around the zeolitic rock or be carried by fracture flow through these units, due to their low matrix permeabilities. On the other hand, the unaltered Calico Hills nonwelded vitric rock has saturated hydraulic conductivities on the same order of magnitude as the fractures, is relatively porous and has relatively low water saturations under present-day conditions (Bodvarsson et al. 1997).

These observations lead to the following conclusion: given that the relatively intense (but short duration) releases of water in the ECRB Cross Drift are likely to migrate through fractures in the TSw and the zeolitic portion of the CHn, due to the low matrix permeabilities and relatively high water saturations. Should the water also migrate preferentially through fractures in the vitric portion of the CHn, then the time for drainage of this introduced water—such that the flux at the water table is within 150 percent of the undisturbed, natural value—is found to be small (Attachment III). This drainage is fast because of the high fracture permeabilities and low fracture porosities. In fact, the fractures between the ECRB Cross Drift and the water table are expected to have less than 1 cm of pore volume per unit area. The expected behavior is for the water flowing through the vitric portion of the CHn to be imbibed by the matrix. The additional water imbibed due to water from the ECRB Cross Drift will require time to drain such that the flux of water at the water table is within 150 percent of the undisturbed, natural water flux. Therefore, a calculation for the drainage time for additional (i.e., ECRB Cross Drift losses) water imbibed by the vitric portion of the CHn is needed. A conservative model of the drainage time for additional water introduced to the vitric portion of the CHn (i.e., that amount in excess of the undisturbed percolation) is derived in Attachment III. The drainage time for the introduction of

the 0.5 m column of water, such that the flux at the water table is within 150 percent of the undisturbed condition, is found to be about 300 years. Therefore, water loss per m² of ECRB Cross Drift floor area is limited to 0.5 m³ over the lifetime of Phase II of the ECRB Cross Drift. This 0.5 m column of water limit is converted into a volumetric water loss limit per m of ECRB Cross Drift advance as follows: (0.5 m column of water x 5 m drift width x 1 m of depth ECRB Cross Drift advance)/1 m of ECRB Cross Drift advance = 2.5 m³/m of ECRB Cross Drift advance (or approximately 660 gal/m). For excavations having a variable cross-sectional dimension, the limit for water loss (in m³/m of excavation length) may be calculated from the product of 0.5 and the applicable cross-sectional dimension (in m).

11.1.2.4 Alternative, Corroborating Evaluation Approach for Far-Field Hydrologic Effects

The previous method discussed above relied on the assumption of quasi-steady flow. As an alternative calculation, we consider the problem including the effects of transient flow in a fracture/matrix system. Water introduced during construction and testing activities, will cause a perturbation to the ambient flow system, currently modeled in TSPA as a steady flow system (CRWMS M&O 1998r). In this analysis, the introduced water is treated as a single transient flow event, superimposed on the existing steady flow field, that starts from the potential repository horizon and propagates to the water table. The duration and magnitude of changes in water flux at the water table are modeled and compared with the expected variability in percolation flux over the potential repository WE area. The changes in flux, due to the introduced water, are compared with natural variations at a time period of 300 years following the ECRB Cross Drift construction. This time frame is selected because of the regulatory requirement for substantially complete containment of the waste over a period of 300 years (10CFR60). The effects of the introduced water are considered for the expected value infiltration and for a lower level of infiltration. As may be expected, the effects of introduced water are more prominent for a system with lower levels of natural percolation. Therefore, the requirements for introduced water in the ECRB Cross Drift are based on its effects on hydrologic conditions for the lower percolation flux case.

11.1.2.4.1 Model for Calculating the Hydrologic Effects of an Introduced Pulse of Water

Episodic transient flow in a fracture/matrix system presents variations in the dependent variables (e.g., saturation and concentration) that operate over a wide range of length and time scales. For example, a saturated pulse of water may move quickly through a fracture system, having a relatively sharp saturation gradient associated with the leading edge of the pulse. On the other hand, the water imbibed into the matrix, from the episodic event in the fracture system, will redistribute within the matrix over time scales much longer than the duration of the main part of the episodic event into the fractures and will display relatively smaller spatial gradients of saturation. The extreme disparity in length and time scales for transient flow events in the fractures and matrix are difficult to capture using traditional numerical solution methods, especially for large systems operating over long time frames, such as Yucca Mountain.

One way to abstract the disparity in time scales for episodic processes in the fractures and the matrix is to assume that the processes occurring in the fractures take place over a sufficiently short time, such that the hydrologic conditions of the matrix are static. Due to fracture/matrix interaction that occurs during the episodic fracture flow event, this assumption also relies on the fact that any specific event will have only a small affect on the hydrologic conditions of the matrix. In other words, the quantities of water exchanged, during an episodic event, result in small changes to the hydrologic state of the matrix. Therefore, we may approximate a complete cycle as a relatively short, transient flow event in the fracture system, which allows for exchange with a static reservoir of water within the matrix, followed by a much longer period where water redistributes within the matrix, including flow from the matrix back to the fracture system.

We construct the abstracted model by first deriving governing differential equations for one-dimensional, heterogeneous, episodic transient flow through the fracture/matrix system using the time-scale abstraction discussed above. Further, we approximate the fracture flow system to be dominated by gravity (no capillary pressure effects in the fractures), and that the exchange rate of water may be approximated as a linear function of the saturation differences across the matrix block. Finally, we assume the fracture/matrix contact area is proportional to the fracture relative hydraulic conductivity, as discussed in Bodvarsson et al. (1997, Chapter 5).

This formulation leads to a semi-analytical solution for the episodic fracture flow processes. We refer to the episodic fracture flow as primary fracture flow. Over the time between episodic events, we formulate the matrix redistribution of water using a simple finite difference approximation. We include, as part of this redistribution, flow from the matrix to the fractures during periods between episodic events, using the fracture flow model. This abstracted flow model is named UTFM. The details of this modeling approach are presented in Attachment V.

11.1.2.4.2 Establishing a Criterion for Evaluation of Impact

An accurate calculation of the changes in unsaturated zone flow below the ECRB Cross Drift, due to the introduction of construction water, does not, in itself, reveal if those changes are important to potential repository performance. The present total system performance model would require modifications to capture the effects of perturbing a small, discrete, portion of the unsaturated zone on bottom-line performance criteria such as dose or cumulative release to the accessible environment. However, we may argue more simply that, if a small portion of the unsaturated zone flow field (i.e., the zone below the ECRB Cross Drift) is perturbed (after a specified minimum time) to some level less than the (estimated) natural variation in percolation flux across the potential repository block, the effects of that perturbation on performance is negligible. Clearly some minimum offset in time is required because at the time of emplacement the construction water may significantly alter the local unsaturated zone flow. However, because the application of construction water is localized in time, the effects of such an introduction of water are expected to diminish with time. The time offset picked, 300 years, is based on the 10CFR60 requirement for substantially complete containment of radioactive waste by the waste package for no less than 300 years. Therefore, we will evaluate the changes in the unsaturated flow system 300 years after the introduction of construction water, relative to the estimated natural variability in percolation flux.

Variability in percolation flux at the proposed repository horizon may be obtained using the three-dimensional, steady, unsaturated zone flow model calculations reported by Bodvarsson et al. (1997). The frequency distribution for percolation flux at the proposed repository horizon are shown in Figures IV-32 through IV-34. These three figures represent model calculations for percolation flux at the potential repository horizon using three different hydrogeologic parameter sets. The parametric descriptions for these frequency distributions are approximated by log-normal probability distributions. Figure IV-32 is seen to follow a log-normal distribution reasonably well, while Figures IV-33 and IV-34 show the percolation flux frequency distribution to flatten out (relative to the log-normal fit) at lower values of flux. Nevertheless, the geometric mean and standard deviations for the fitted distributions are believed to be reasonably representative of the overall range of variation of the percolation flux frequency distributions. The geometric standard deviation (σ_g) is representative of the "spread" of the distribution. A value one standard deviation above the mean is computed by multiplying the geometric mean by the geometric standard deviation. The value of the geometric standard deviation is found to have values of 2.0, 1.65, and 1.5 for Figures IV-32 through IV-34, respectively. We may conservatively conclude a natural variation in percolation flux to be at least a factor of 1.5 to the geometric mean.

11.1.2.4.3 Results of the Transient Flow Model

The hydrologic parameter set used for the calculations is taken from Robinson et al. (1997) (parameter set 6412b), which is based on property set 6412b from Bodvarsson et al. (1997). The layer depths are taken from SNL (1997b), which used measurements from borehole SD-9. The results of the transient flow calculations are shown in Figures IV-35 through IV-37. Figure IV-35 shows results for an undisturbed, steady percolation rate of 7.24 mm/yr. Figures IV-36 and IV-37 are for an undisturbed, but lower steady percolation rate of 1.448 mm/yr. These percolation values correspond to infiltration values being used for current total system performance calculations. The results shown in these figures require a two-step calculation procedure. First, the background infiltration rate is equilibrated for 50,000 years to approach a steady flow condition throughout the unsaturated zone. This calculation is for the entire unsaturated zone (ground surface to the water table) and is also used to establish the flow distribution between fractures and matrix at the repository horizon (using UTFM version *fmecrb*). This steady flow is used as an upper boundary condition and initial saturation condition for a second calculation that starts with a specified flux at the potential repository horizon. In the second calculation, steady flow, at the rates prescribed by the results of the first calculation, is introduced at the repository horizon for 10,000 years (using version *frmat20* for the high infiltration rate and version *frmat22* for the low infiltration rate). At 10,000 years, a particular quantity of construction water is introduced over a period of five days. The five day period is an approximate time period over which the excavation and (and therefore excavation water) is concentrated at a particular point.

For the higher natural percolation rate of 7.24 mm/yr, UTFM calculates a steady discharge into the water table (just before introduction of the construction water) of 7.24263 mm/yr. Therefore, the UTFM calculation is within about 0.04 percent of the theoretical steady flow condition, before introduction of construction water. For the lower natural percolation rate investigated

(1.448 mm/yr), UTFM calculates a steady discharge into the water table of 1.45207 mm/yr. In this case, the UTFM calculation is within about 0.3 percent of the theoretical steady flow condition before introduction of construction water.

Figures IV-35 through IV-37 indicate how the flow rates vary during the transient period, starting at time 0, when the construction water is introduced. Flow rates for primary fracture flow, secondary fracture flow, matrix flow, and total flow at the water table are displayed. The primary fracture flow refers to water introduced at the top boundary (which in this case is the repository horizon) in the fractures, which flows to the water table without ever entering the matrix. Secondary fracture flow is water that enters the water table in the fractures but was in the matrix for some portion of trip through the unsaturated zone. The secondary matrix flow is identified during by the flow redistribution model that computes the flows in the fractures and matrix between episodic flow events. Matrix flow is the flux of water from the matrix at the water table.

The calculation results shown in Figure IV-35 are for introduction of 1 m of construction water at the potential repository horizon. In this case, the natural background percolation flux is 7.24 mm/yr. Approximately 30 percent of the 1-m pulse penetrates to the water table in the first year without entering the matrix. A strong initial response is found for both the primary and secondary fracture flow; however, the secondary fracture flow quickly returns to a value near the steady flow condition. The primary fracture flow is found to be substantially affected for a more prolonged time period. This increase in the primary fracture flux is a consequence of the higher matrix saturations following the pulse input, reducing the amount of imbibition from subsequent fracture flows. The system gradually returns to the equilibrium condition as the secondary fracture flux and matrix flux drain the excess water saturation from the matrix.

The behavior of the introduced pulse into the same system with a lower natural percolation flux (1.448 mm/yr) responds in a different manner, as shown in Figure IV-36. Less than 1 percent of the 1-m pulse penetrates to the water table without entering the matrix. Nearly all of the initial pulse is absorbed by the relatively dry matrix (particularly CHn unit). After imbibition of the primary fracture flux, the additional water in the matrix is slowly released to back into the fracture flow system, as a relatively large, prolonged increase in secondary fracture flow and a small increase in matrix flow. The total flux is seen to return to values below the "threshold" between 500 and 600 years after introduction of the water.

A smaller quantity of introduced water results in a shorter period of flow perturbation. Qualitatively, the response to 0.5 m of construction water is similar to that for 1 m of water introduced as seen by comparing Figures IV-36 and IV-37. However, the duration and magnitude of the perturbation are smaller for the smaller quantity of introduced water, as expected. In this case, the flux at the water table falls below the threshold value before 300 years. From these analyses, we conclude that limiting the cumulative quantity of construction water lost to the environment to 0.5 m or less should have a negligible impact on the potential performance of the repository. Therefore, we find that the water loss limit found using this calculation method is consistent with the water loss limit derived by another means in Section 11.1.2.3.

11.1.2.5 Aqueous Radionuclide Transport in the Saturated Zone

The quantities of water found to potentially affect aqueous radionuclide transport in the unsaturated zone are far smaller than the quantities of water that would be expected to have a non-negligible effect on aqueous radionuclide transport in the saturated zone. An analysis of perched water flowing down a borehole to the saturated zone was evaluated in terms of its effects on the saturated zone hydraulic gradient, which is proportional to the flow velocity and inversely proportional to the aqueous radionuclide travel time (CRWMS M&O 1997f). This analysis found that a ground-water mound resulting from the loss of 36,500 m³ over one year in a single borehole that penetrated the saturated zone would dissipate to negligible levels in less than 4 years. This may be compared with the limiting quantity of water spread throughout the entire 2,823 m of the ECRB Cross Drift, based on a limiting rate of 6.25 m³/m, giving a total of 17,644 m³. Therefore, if the quantity of water lost in the TS Loop is limited to 6.25 m³/m of tunnel excavation, any effects of this water on potential aqueous radionuclide transport in the saturated zone is expected to be negligible.

11.1.2.6 Gaseous Radionuclide Transport in the Unsaturated Zone

The addition of water will affect gaseous radionuclide transport in the unsaturated zone. An increase in water saturation will always reduce the diffusive transport rate in the gas phase (Marshall and Holmes 1979, p. 271), or increase the diffusive travel times of gaseous radionuclides. Therefore, in terms of the gas-phase transport, the addition of water is not expected to adversely affect potential repository performance. Also, as noted previously, the human dose due to releases of gaseous radionuclides is expected to be insignificant (CRWMS M&O 1995a).

11.2 TRACERS, FLUIDS, AND MATERIALS

The following discussion of potentially-retained constituents from various fluids and materials was taken largely from the Package 2C evaluation covering the ESF North Ramp (CRWMS M&O 1995b) as well as the DIE for the Subsurface ESF (CRWMS M&O 1999a), because of the similarity of substances to be considered for the ECRB Cross Drift. Additional discussion and detailed references can be found in the corresponding sections of those documents. Tracers are viewed entirely as retained substances and so are not discussed further here but are evaluated in Section 11.3 of this DIE. The specific TFM's listed in Attachment II have been reviewed to ensure that they fall into the groups defined in the following section and are therefore covered by any applicable controls.

11.2.1 Fluids and Materials

The only ECRB Cross Drift items that are planned to be incorporated into the potential repository (i.e., planned permanent items) are (YMP 1998a) underground openings and ground support. Items that are left (intentionally or unintentionally) at the site post-closure (above and below ground) are defined as committed items in an evaluation of surface-based fluids and materials usage (CRWMS M&O 1994a). Non-committed substances are only those fluids and materials that are not being emplaced into the environment in such a way as to become a

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committed part of that environment. Such non-committed substances are those that are planned to be removed from the site at or before the time of closure, and are not expected to leave behind noticeable, non-removable residues. Because of the condition of removal before closure, some solid materials are excluded from this evaluation designation of non-committed (e.g., salt) because they are soluble to the extent that they have the potential to dissolve into the environment over a relatively short time period (i.e., days to a few months). Based on the reasoning given in the evaluations of the Package 1A TFM's (CRWMS M&O 1994b), the surface-based non-committed fluids and materials (CRWMS M&O 1994a), and the Package 2C TFM's (CRWMS M&O 1995b), non-committed items are assumed to have negligible impact on waste isolation and are not evaluated further.

Substances considered committed items and evaluated here for the ECRB Cross Drift are steel sets, lagging (wood and steel), wood blocking, lubricating oil retained (from cutting) on steel sets, rockbolts, wire mesh, shotcrete and/or fibercrete, cementitious grout, oil mist from compressed-air system, steel, concrete, concrete admixtures, and galvanized steel. In addition, because diesel equipment will be employed during construction of the Starter Tunnel (and perhaps several proposed niches), and some of the exhaust constituents (both inorganic and organic) may become committed to the underground, the potential impacts of these constituents were explicitly analyzed for use in the TS Loop in the Package 2C evaluation (CRWMS M&O 1995b) and this same analysis is used for the ECRB Cross Drift to develop controls on the quantities of materials committed as discussed in Section 11.3 of this DIE. Furthermore, in the event of a fire, combustion products and fire-suppression substances may become committed items. Therefore, the potential impacts to waste isolation from the proposed fire-suppression substances were also explicitly evaluated using a bounding scenario in the Package 2C evaluation (CRWMS M&O 1995b). In the event of an actual fire, the specific materials that burn should be evaluated for potential impacts to waste isolation. In the CRWMS M&O (1995b) evaluation, substances produced from fires were assumed to be close enough to the constituents produced in diesel exhaust that evaluation of exhaust constituents bounds the potential impacts to waste isolation of fire products. Because fire products are not planned to be incorporated into a potential repository, a more general waste isolation evaluation should be performed if there is a need to further evaluate such potential impacts.

As discussed in detail in the Package 2C evaluation (CRWMS M&O 1995b), explosives are not considered committed items because most of their residues are expected to be removed either as volatiles or within the excavated materials.

It was concluded in the Package 2C evaluation (CRWMS M&O 1995b) that fluids which are not planned to be dispersed into the environment (e.g., diesel fuel, lubricants, coolants, battery acid, and cleaning solvents) are expected to have negligible impact, provided that a plan for spill containment and clean-up exists. In accordance with the YMP QA procedures for recording TFM use at the site, any planned non-committed fluids or materials that become retained intentionally or unintentionally as part of the committed environment require documentation of the amounts of substance retained in the environment and evaluation of the potential waste isolation impacts of that specific retention. The evaluation of specific materials that become part of the committed environment will be part of the TSPA evaluations.

11.2.2 Committed Inorganic Substances

Items such as steel sets, rebar, lagging (steel), rockbolts, wire mesh, shotcrete and/or fibercrete, cementitious grout, and galvanized steel (in general, steel, concrete, and shotcrete) are expected to have negligible impact on waste isolation resulting from perturbations to the near-field geochemistry because their use near potential WE sites (i.e., within potential repository drifts) is expected to overshadow any effects resulting from their use in the ECRB Cross Drift. These near-field effects include raising the pH from 11 to 13 and the potential for generation of colloids from the cementitious material. The former may enhance some dissolved radionuclide concentrations, whereas the latter may provide an additional mobile component for some radionuclides. In addition, potential effects on far-field geochemistry caused by dissolved a calcium ion introduced from cementitious material are expected to be negligible because mineralogic controls exerted through fluid-rock reaction should constrain large deviations in the calcium ion concentrations to close proximity to cementitious materials via calcite precipitation.

In general, water used in cementitious materials is not expected to migrate, however, zones affected by thermal dryout due to repository heating may result in substantial movement of the cementitious water to the surrounding rock. Therefore, water used in cementitious materials within the region of thermal dryout should be counted as water lost to the environment. The thermal dryout zone depends on potential repository design, however, the dryout is not expected above the PTn hydrogeologic unit (Eaton 1994 and Buscheck and Nitao 1993). A more detailed analysis of these qualitative issues would be required if there was to be a large increase in the amount of committed cementitious materials in the ECRB Cross Drift (i.e., more than an order-of-magnitude increase over the current plans for shotcrete and grouting), as discussed in CRWMS M&O (1999a, Section 6).

11.2.3 Committed Organic Substances

Because of the numerous qualitative issues regarding committed organic materials (e.g., dissolved organic enhanced solubility and transport of radionuclides and microbial effects), use of such materials in potential repository drifts is unknown. Therefore, the previously stated reasoning on committed inorganic substances does not apply to any organic materials that might be contained within cementitious materials as a result of the addition of admixtures. In addition, this discussion covers the previous specific evaluations of discrete sources of aqueous nitrates (NO_3^-), sulfates (SO_4^{2-}), and phosphates (H_2PO_4^-) addressed in the Package 2C evaluation (CRWMS M&O 1995b) of diesel exhaust constituents and fire-suppression materials. These materials are potential sources of nutrients for microbes and H_2PO_4^- has the potential for readily complexing radionuclides (specifically actinide elements). If retained in large quantities, these constituents may also be a concern for generating low pH (i.e., acid) conditions. Constraints based upon the other concerns, however, should conservatively bound any potential pH perturbations because of the large pH-buffering capacity of the geologic system.

As pointed out in the Package 2C evaluation (CRWMS M&O 1995b), organic compounds may accelerate waste package corrosion through enhanced microbial activity and/or facilitate radionuclide transport in the geosphere via complexing of cations (CRWMS M&O 1995b). This

previous evaluation indicated these effects are constrained by the ability of deposited organic materials to migrate to either waste package locations or radionuclide pathways in sufficient concentration to have a significant impact.

A previous bounding calculation (discussed below in Section 11.3) was performed to determine the potential influence of retained organic substances within the ESF North Ramp (CRWMS M&O 1995b). CRWMS M&O (1995b) also generated controls that should result in negligible impact to waste isolation due to the use of committed organics throughout this region of the TS Loop. In that analysis, the retained organic materials were assumed to convert completely to DOC and to migrate toward potential waste package emplacement sites within the TS_{w2} horizon. All committed organic fluids and materials were considered as behaving identically. The same analysis may be extended and used, as shown below, for the ECRB Cross Drift.

The total organic budget includes all sources of committed organics in the ECRB Cross Drift. Examples of such sources are wood blocking/lagging for steel sets, oil mist from the compressed air system, lubricating oil (for cutting) retained on steel sets, organic diesel exhaust components, and concrete admixtures used in shotcrete. In addition to these introduced sources of organics, opening the mountain to the external environment allows the introduction of potentially committed organic materials in the form of airborne particles in the ventilation air and in the form of organisms that may inhabit, and deposit organic residue in, portions of the tunnel.

Accidental loss of any organic fluid such as fuels, lubricants, or coolants used in equipment necessitates documentation and evaluation of the specific unintentional releases, and incorporation of the retained amounts of committed organic fluids into the evaluation of the final configuration of the potential repository.

11.3 GEOCHEMICAL EVALUATIONS

11.3.1 Tracers

As discussed in CRWMS M&O (1994b and 1995b), LiBr, proposed as a tracer for construction water, will be added at a maximum concentration of 30 ppm (minimum 10 ppm), with a target concentration of 20 ppm (± 2 ppm). In addition, SF₆ will be added at concentrations not to exceed 20 ppm to air used for drilling test boreholes if requested by the TCO. It was concluded in both these previous evaluations that because of the low concentrations and limited quantities used, these tracers are expected to have only negligible effects on the geochemistry near potential WE sites, or along potential gaseous and aqueous radionuclide pathways.

Tetra fluoroethane (SUVA-COLD MP®) has been evaluated for use in conducting tracer tests to estimate the tortuosity and effective porosity of faults and their associated fault zones. Given a borehole diameter of 2 inches, the total volume of gas per 20-m segment of borehole depth is $4.0536 \times 10^{-4} \text{ m}^3$ ($V = \pi r^2 h$). The molecular volume of an ideal gas at standard pressure and temperature (V_m) is $0.0224414 \text{ m}^3/\text{mol}$; thus, the total number of gas moles per 20-m segment is equal to 0.008085. With the concentration of this gaseous organic tracer not exceeding more than 30 ppm (see Section 11.3.1 of CRWMS M&O 1998e) the total number of moles of tetra fluoroethane is equal to 2.4255×10^{-7} moles. Because of the low quantities used, tracers are not

expected to have significant effects on the geochemistry near potential WE sites, nor along potential gaseous and aqueous radionuclide pathways.

In addition, noble gases (i.e., He, Ne, Ar, Kr, and Xe) and N have been proposed for use as tracer gases to support ESF subsurface testing activities—potentially including the ECRB Cross Drift. These gases have a lesser potential to cause waste isolation impacts than either SF₆ or tetra fluoroethane due to their extremely stable chemical state. The evaluation of SF₆ as a tracer gas is conservatively considered to be a bounding evaluation for the use of He, Ne, Ar, Kr, Xe, and N as tracer gases within the ECRB Cross Drift. Therefore, these tracers are expected to have negligible effects on the geochemistry near potential WE areas or along aqueous or gaseous radionuclide pathways.

11.3.2 Diesel Exhaust

In a previous evaluation of committed components from diesel exhaust (i.e., sulfur oxide gases, nitrogen oxide gases, and DPM) in the ESF North Ramp (CRWMS M&O 1995b), it was indicated that potential impacts were bounded by an analysis showing that retention of these materials within the ESF North Ramp for the planned usage of diesel equipment will not impact potential radionuclide release and transport over a 10,000-year time period, provided that the local perturbations to the near-field water compositions at the closest waste package were kept at or below a value of 10 percent of ambient concentrations of their corresponding dissolved constituents (SO₄²⁻, NO₃⁻, and DOC, respectively). This evaluation was based on the estimated distribution of diesel usage throughout the ESF North Ramp and assumed that relatively insoluble constituents, which remain in the gas phase, would be removed via the planned ventilation system. In this previous evaluation, it was concluded that although carbon monoxide and carbon dioxide may be retained, the natural aqueous and gas phases have concentrations of carbon dioxide that are sufficiently high that these constituents would produce negligible perturbation to the natural system. The proposed use of A-55 clean fuel in place of diesel should further reduce the emissions within the ECRB Cross Drift. A bounding analysis concerning the effects of the cumulative quantities of DOC, SO₄²⁻, and NO₃⁻ from all sources (including diesel exhaust) is provided in the next section.

11.3.3 Fire-Suppression/Retardant Materials

The specific material designed for use as the primary fire-suppressant material is the dry chemical trade named *Ansul Foray*, which represents a potential source of aqueous NO₃⁻,

SO₄²⁻, and H₂PO₄⁻, was specifically analyzed in the previous Package 2C evaluation (CRWMS M&O 1995b). In this previous evaluation, it was indicated that potential impacts were bounded by an analysis showing that retention of fire-suppression materials within the ESF North Ramp will not impact potential radionuclide release and transport over a 10,000-year time period. Release of H₂PO₄⁻, NO₃⁻, and SO₄²⁻ will not impact radionuclide release and transport, provided a reasonable clean-up of the material can be achieved following a fire that necessitated the simultaneous discharge of the automated systems (i.e., the systems that protect the hydraulic oil tank and the lubrication system on the TBM). In the previous analysis (CRWMS M&O 1995b), it was estimated that the 90 percent of the dry chemical can be removed by simple vacuuming

and that half of the remainder of the material will be adhered to equipment and could be removed in the cleanup of that equipment. Therefore, it was noted that if water is used in conjunction with the dry-chemical, clean-up may be much reduced as the water could wash the dry chemical into fractures, and most of the material would therefore become potentially committed to the environment. It was recommended, therefore, that water be used in conjunction with this fire-suppression material only if necessary for safety.

The use of fire suppression materials is not planned, but their use is contingent upon an unplanned fire event in the ECRB Cross Drift. The previous evaluation of fire-suppression material (CRWMS M&O 1995b) analyzed its impacts throughout the ESF North Ramp based on the minimum 37 m offset to the closest potential waste package (Assumption 4.1), with a bounding scenario of a TBM fire. Although the closest approach to potential WE zones in Phase II of the ECRB Cross Drift is 15 m, instead of 37 m, the same recommendations, as given in the CRWMS M&O (1995b) evaluation, should be applied to the entire ECRB Cross Drift to minimize the potential effects of a fire retardant material release in the ECRB Cross Drift on potential radionuclide release and transport.

The fire retardant material FR-40 will be applied to wooden cross ties that will be in direct contact with the excavated invert. FR-40 could also be used to treat individual components of a wooden walkway attached to the top of the cross ties, should a wooden walkway become preferable to the steel walkway described in Section 6.2.2. There is negligible potential for organic materials, such as FR-40, to impact waste isolation if they are not committed to the site. Therefore, if the treated cross ties, or treated components of a wooden walkway (if applicable), are fully cured before their use in the ECRB Cross Drift, the potential for committing any of the material to the site is negligible.

11.3.4 Committed Substances in ECRB Cross Drift Phase I

11.3.4.1 Committed Organics

The negligible impact level for DOC was defined as local groundwater perturbations of 0.1 ppm (References 14.1 and CRWMS M&O 1994b). In those evaluations, it was assumed that:

1. The retained organic material represents a point source
2. The dissolution of the organic point source is complete and instantaneous
3. Dispersion of the organic source occurs via saturated flow toward potential WE zones
4. No reactions to degrade the concentration of total DOC occur.

These evaluations concluded that, for the TS Loop (CRWMS M&O 1994b and 1999a):

1. If the total retained organic materials in the ESF Starter Tunnel and Alcove #1 is less than 420 kg, it is expected that there should be negligible impact to the geochemistry of groundwater within the Potential Expansion Areas Boundary (i.e., perturbations to fluid compositions should be less than 0.1 ppm DOC).

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2. If the total retained organic materials in the ESF Starter Tunnel and Alcove #1 is less than 2500 kg, it is expected that the impact to the geochemistry of groundwater within the Proposed Repository Outline should be negligible, although there is some potential for impact to the groundwater geochemistry within the Potential Expansion Areas 2, 3, and 6.
3. If the total committed DOC was kept at or below the following for the TS Loop: 95 grams per meter (g/m) from Station 0+00 m to 13+11 m, 28 g/m from Station 13+11 m to 18+59 m, 13 g/m from Station 18+59 m to Station 24+08 m, and 10 g/m for the remainder of the tunnel, it is expected that there should be negligible impact to the waste isolation capabilities of the potential repository.

The ECRB Cross Drift Starter Tunnel and Phase I of the ECRB Cross Drift are a total of approximately 773 m long, beginning from the left rib of the ESF North Ramp at approximately Station 19+92 m and ending at the cross over with the TS Main Drift. When differences in the tunnel size are taken into account, the analyses within Attachment II of CRWMS M&O (1995b) for the TS Loop can be applied to Phase I of the ECRB Cross Drift to develop controls for the use of organic substances for testing and construction to avoid potential impacts to the waste isolation capabilities of the potential repository.

Scaling the CRWMS M&O (1995b) analysis for the smaller diameter ECRB Cross Drift yields an organic limit of 6.51 g/m at a 37 m offset (at the closest distance to potential WE expansion areas for Phase I of the ECRB Cross Drift) as a conservative organic limit for the entire length of Phase I of the ECRB Cross Drift. There should be no significant waste isolation effects (1) due to the large offset between Phase I of the ECRB Cross Drift and any WE areas, and (2) since organic use during Phase I construction is not expected to exceed these limits except during a 50-m testing interval (see Sections 6.4 and 11.3.5 of this DIE).

It should be reiterated here that this evaluation does not indicate that an impact to waste isolation will occur if these limits are exceeded, but only that the potential for impacts to waste isolation exist. However, controls developed from constraints on potential impacts from this case are expected to minimize impacts from any reasonable flow scenario (this excludes the worst-case of disequilibrium fracture-flow).

11.3.4.2 Other Source Constraints

The same approach used for diesel exhaust constituents was applied to evaluate the limits on NO_3^- and SO_4^{2-} from all sources in the ESF North Ramp (CRWMS M&O 1995b), where it was indicated that potential impacts were bounded by an analysis showing that retention of these materials within the ESF North Ramp from all sources will not impact potential radionuclide release and transport over a 10,000 year time period, provided that the local perturbations to the near-field water compositions at the closest waste package were kept at or below a value of 10 percent of ambient concentrations of these dissolved constituents (see Attachment II of CRWMS M&O (1995b) and Equation (11-1) in Subsection 11.3.4.3 of this DIE). Because other materials may be used in different distributions (i.e., not necessarily in the proportions assumed for diesel emissions in the previous CRWMS M&O (1995b) evaluation). The previous analysis assumed

that the major impact for peak concentration perturbation at any point is due to the source density (parameter d in Equation [11-1]) associated with the closest portion of the tunnel (parameter h in Equation [11-1]).

Based on this previous analysis (Equation [11-1]), substituting in minimum offset distance and tunnel radius (R) for the ECRB Cross Drift provided general constraints for the total source constraints on NO_3^- and SO_4^{2-} . These limits are spatially dependent, so the limits for which potential WE zones are at the minimum 37-m offset from the TS Loop were used to constrain the potential waste isolation impacts from the ECRB Cross Drift. Therefore, the conservative limits for negligible impacts on committed quantities for these constituents in Phase I of the ECRB Cross Drift are provided in Table 11-1 below.

Table 11-1. Phase I ECRB Cross Drift Recommended Limits (g/m)

DOC	NO_3^-	SO_4^{2-}
6.51	65	241

11.3.4.3 Use of Organic Surfactants

Two testing intervals of approximately 50 m have been proposed as part of Phase I of the ECRB Cross Drift. Within the second testing interval (i.e., from approximately Station 2+88 m to Station 3+38 m), organic surfactants have been proposed to be tested as a means of dust control within the tunnel. The committal of the organic material will also be measured to quantify the amounts committed by the use of these materials. Over this interval the maximum source density (d) of organic applied within the ECRB Cross Drift can be calculated using the analysis in CRWMS M&O (1995b, Attachment II, Equation 17) and substituting the appropriate parameters for the ECRB Cross Drift, as shown in Equation (11-2). Thus, when differences in the tunnel size are taken into account, the CRWMS M&O (1999a) analyses for the TS Loop can be applied to Phase I of the ECRB Cross Drift, and controls for the use of organic substances associated with testing and construction activities can be developed, which minimize the potential for impacts to the waste isolation capabilities of the potential repository.

$$C_p(d, h, \phi) = \left[\frac{d}{\phi(4\pi h a_s)^{\frac{1}{2}}} \right] \quad (\text{Eq. 11-1})^4$$

where,

- l = $d * 2\pi R$ (linear organic limit [g/m])
- C_p = the peak concentration at the closest waste package ($\cong 0.1$ ppm)
- d = the mass density (grams per m^3)
- ϕ = the porosity ($\cong 0.1$)

⁴ The source of Equation 11-1 is CRWMS M&O (1995b, Attachment II, Equation 17).

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h	=	linear distance to the closest waste package (m)
a_x	=	dispersion in the x direction (1/10 of linear distance) (m)
R	=	ECRB Cross Drift Radius (m)

With a 49-m minimum offset from potential waste expansion areas (over the second testing interval), the organic limit for negligible impacts to waste isolation would be 8.8 g/m of tunnel excavation (see Figure IV-38).

The length of the testing interval is approximately 50 m and occurs over potential expansion areas for WE. It is expected that the organic usage during this interval will exceed the recommended limit of 8.8 g/m. Because of the conservative nature of the analysis, and uncertainties with the exact location of the potential expansion areas, organic use in excess of this limit does not indicate that an adverse impact to waste isolation will occur, only that the potential for impacts to waste isolation may exist. In addition, due to the relatively small interval over which this organic surfactant will be used (approximately 50 m) it is expected that only the expansion areas directly beneath the test interval have the potential to be affected. Due to the relatively small area of the potential expansion zone that could be affected and the large offset of this test interval from the potential repository WE areas (i.e., greater than 540 m), it is expected that the testing of organic surfactants over this interval will have negligible effects on the waste isolation capabilities of the potential repository and may only affect a small portion of the potential expansion area.

11.3.5 Committed Substances in ECRB Cross Drift Phase II

The same approach used above for diesel exhaust constituents was applied to evaluate the limits on DOC , NO_3^- , and SO_4^{2-} from all sources in the North Ramp (CRWMS M&O 1995b), where it was indicated that potential impacts were bounded by an analysis showing that retention of these materials within the North Ramp from all sources will not impact potential radionuclide release and transport over a 10,000 year time period, provided that the local perturbations to the near-field water compositions at the closest waste package were kept at or below a value of 10 percent of ambient concentrations of these dissolved constituents. Because other materials may be used in different distributions (i.e., not necessarily in the proportions assumed for diesel emissions in the Package 2C evaluation), along the North Ramp (and throughout the TS Loop), this additional previous analysis assumed that the major impact for peak concentration perturbation at any point is due to the source density associated with the closest portion of the tunnel.

The analysis given in CRWMS M&O (1995b) is based on advective-dispersive transport from the discharge location to the nearest potential WE Drift (assuming instantaneous and complete dissolution of the organic-bearing, nitrogen-bearing, or sulfur-bearing compound). Other assumptions include matrix-only transport and a saturated matrix. The source configuration for an offset of 37 m (as for segment 4 of the North Ramp) or for the 15 m offset expected in the ECRB Cross Drift is assumed to act as an "infinite plane", with the source density determined by the source mass discharge per unit length of tunnel spread over the surface area of the drift.

We recap here the relevant portions of the analysis from CRWMS M&O (1995b). The infinite plane source allows the calculation of the concentration at the nearest WE Drift using Equation (11-2) for one-dimensional advective-dispersive transport (Bear 1972),

$$C(x, t; m, \phi, v, D_x) = \left[\frac{m}{\phi (4\pi D_x t)^{1/2}} \right] \exp \left\{ -\frac{(x - vt)^2}{4 D_x t} \right\} \quad (\text{Eq. 11-2})$$

where m is the areal source mass density (in mass per unit area), D_x is the longitudinal dispersion coefficient, t is the time, x is the position, v is the flow velocity, and ϕ is the rock matrix porosity. Note that the dispersion coefficient is given by Equation (11-3) (Bear 1972)

$$D_x = a_x v = 0.1 x v \quad (\text{Eq. 11-3})$$

where the scale dependence of the dispersivity, a_x , is taken to be one tenth of the distance traveled (de Marsily 1986). Substituting this expression for D_x and noting that $vt = x$ at the peak concentration leads to Equation (11-4) for the peak concentration C_p ,

$$C_p(x; m, \phi) = \frac{m}{\phi x (0.4\pi)^{1/2}} \quad (\text{Eq. 11-4})$$

which is linear in x . Also note that m may be expressed as Equation (11-5),

$$m = \frac{m_l}{\pi d_t} \quad (\text{Eq. 11-5})$$

where d_t is the diameter of the tunnel and m_l is the linear mass density of the discharged material along the drift.

Substituting for m in the expression for C_p gives Equation (11-6),

$$C_p(x; m_l, \phi, d_t) = \frac{m_l}{\pi^{3/2} (0.4)^{1/2} d_t \phi x} = 0.284 \frac{m_l}{d_t \phi x} \quad (\text{Eq. 11-6})$$

Using limits previously derived (CRWMS M&O 1995b) for C_p at the closest potential WE location, i.e., 0.1 ppm of DOC; 1 ppm for NO_3^- ; and 3.7 ppm for SO_4^{2-} , the distance $x = 15$ m, the drift diameter $d_t = 5.5$ m and the an approximate matrix porosity for the WE zones (CRWMS M&O 1998r) $\phi = 0.1$.

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Therefore, the limits for negligible impacts on committed quantities for these constituents in Phase II of the ECRB Cross Drift are provided in Table 11-2 below:

Table 11-2. Phase II ECRB Cross Drift Recommended Limits (g/m)

DOC	NO ₃ ⁻	SO ₄ ⁼
2.9	29.	107.

11.4 THERMAL/MECHANICAL EVALUATIONS

The previous evaluation of potential impacts to waste isolation caused by TM perturbations resulting from retained TFM and from excavation methods in the TS Loop (CRWMS M&O 1995b and 1999a) indicated that:

1. The potential effects of committed substances on TM characteristics of natural barriers or engineered items in the ESF North Ramp are expected to be negligible if the substances do not interfere with the emplacement and performance of ESF North Ramp seals (at the time when sealing plans for the tunnel are prepared, further analysis of potential impacts to waste isolation should be performed).
2. There is a negligible impact on the overall waste isolation capability of the entire potential repository due to the generation of preferential aqueous pathways through the mechanically disturbed zone.
3. Movement of underground fluids along the sealed ramp (and its surrounding mechanically disturbed zone) should have a negligible impact on the waste isolation capability of the potential repository.
4. To minimize the potential impact of the mechanically disturbed zone induced by the excavation, the TBM method, which results in a smaller disturbed zone compared to the drill-and-blast method, is recommended for the primary excavation method for ECRB Cross Drift construction.
5. Regardless of the excavation method used for the ECRB Cross Drift, no potential impacts to waste isolation resulting from the lack of a specified standoff distance for boreholes were identified, because boreholes will be sealed above and below the potential repository horizon.

Because sealing issues are identical for the TS Loop and the ECRB Cross Drift and the previous evaluation analyzed the potential impacts from excavation methods in a general and spatially independent manner, the recommendations for negligible impact limits from CRWMS M&O (1995b and 1999a), can be applied directly to the ECRB Cross Drift. If these recommendations are followed, then it is expected that there will be negligible impact to waste isolation capabilities of the site due to construction and operations conducted throughout the entire ECRB Cross Drift.

A TM stability analysis was also performed to investigate the potential effects of the presence of the ECRB Cross Drift on WE Drift stability (CRWMS M&O 1998a). Parallel orientation of the ECRB Cross Drift and WE Drifts were assumed for this analysis. This includes the worst case condition in which ECRB Cross Drift is parallel to and directly overlies a WE Drift. Under isothermal conditions, the maximum difference in closure with and without the ECRB Cross Drift is predicted to be within 1 mm, and in all cases predicted that the difference in closure would be less than 10 percent of that expected without the ECRB Cross Drift. The maximum difference in tangential stress nearest the WE Drift wall is predicted to be within 0.5 Mega-Pascals. These differences are less than 10 percent of the tangential stress predicted without the ECRB Cross Drift. Similarly, small changes in closure and tangential stress were found over time with an 85 MTU/acre thermal load included in the analysis. Finally, the effects of seismic loads were also investigated. The presence of the ECRB Cross Drift was found to have a negligible effect on the behavior of the WE Drifts in response to seismic ground motions.

12. IMPACT TO OTHER Q-LIST ITEMS

Potential impacts to other Q-List (YMP 1998a) items (e.g., ground support and underground openings) are bounded by controls applied:

1. In the applicable classification analyses
2. To limit potential adverse impacts to site characterization testing (see Section 10.0 of this DIE)
3. To limit potential impact to the waste isolation capabilities of the site (see Section 11.0 of this DIE).

As such, additional requirements are not necessary.

13. ESTABLISHMENT OF CONTROLS

13.1 SUMMARY OF RESULTS

This evaluation concludes that various activities associated with the ECRB Cross Drift and its auxiliary excavations require QA controls to limit or prevent potential test interference or waste isolation impacts during drift construction and testing activities. Controls for these activities are presented in Section 13.3. This DIE is predicated on these items being temporary. Any incorporation of these items or their constituents into the pre-closure or permanent repository will require a new evaluation as part of the design of permanent items.

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Per CRWMS M&O 1998f, this DIE considered the relevance of applicable requirements from the ESFDR (YMP 1997) pursuant to ensuring that 10CFR60 (Section 15[c][1]) mandates are satisfied. The following ESFDR cites, including their lower-tier subsection requirements, were considered in this evaluation:

ESFDR 3.2.1.1.1, 3.2.1.1.2.4, 3.2.1.1.3.1, 3.2.1.1.3.2, 3.2.1.1.3.4, 3.2.1.1.4, 3.2.1.2.3, 3.4.5.3.1, 3.4.5.6.1, 3.7.1.2, 3.7.2.1.2, 3.7.2.5.1, 3.7.3.1, 3.8.2.6.1, 3.8.2, 3.8.3, and 3.8.4

Based on the following discussions in Section 13.2, DIE-specified QA control requirements are necessary to satisfy every YMP (1997) requirement considered by this evaluation. However, each QA control derived in Section 13.3 cites the specific, applicable requirement from YMP (1997).

Standard engineering tolerances, as specified by the A/E or the TCO, are appropriate for implementation of DIE-generated QA control requirements, unless special tolerances are warranted by the evaluation herein. In such cases, tolerances are specified in the applicable QA control requirement.

13.2 BASIS FOR CONTROLS

13.2.1 Records

It is judged that the record keeping provisions of 10CFR60 (Section 72)—as applied to the ESF through ESFDR Sections 3.2.1.1.1.A, 3.2.1.1.4.C, and 3.7.1.2.B (YMP 1997)—also provide the function of limiting impact in accordance with 10CFR60 (Section 15[c][1]) (e.g., information on locations and descriptions of temporary structural support components that may be needed for the final ground support design). Therefore, these ECRB Cross Drift and associated auxiliary excavation records are required as QA records (Requirement 1). ESFDR Section 3.7.2.1.2.B also requires that planning, design, and construction of permanent ESF items (such as underground openings) be coordinated with repository design. Further, ESFDR Section 3.7.2.1.2.C requires that design, construction, and maintenance records of permanent ESF items be generated as if they were permanent repository items. As applied to ECRB Cross Drift auxiliary excavations, these requirements mandate that accurate information be available for integration into a repository design. As such, it is judged that an additional QA control is required. A QA survey of line and grade for all ECRB Cross Drift auxiliary excavations is required, after their construction, to ensure that accurate information is available for integration into a repository design (Requirement 20).

13.2.2 Water Tracers

Section 10.0 of this DIE indicates that release of untraced water into the tunnel represents a potential test interference. The delivery of properly traced water is the significant consideration to provide assurance of the ability to differentiate such water from naturally occurring sources. The only approved tracer for water is LiBr. Therefore, only nonpotable water that has been traced with LiBr shall be transported into the ECRB Cross Drift (Requirement 2). The

concentration of the LiBr tracer must be controlled (i.e., checked to be 20 ppm $\pm$ 10 ppm) before its introduction into the ECRB Cross Drift by CRWMS M&O (1999a, Requirement 3) (Requirement 2). Tracer is not required in water used outside the underground ESF for mixing concrete, grout, and shotcrete (LANL 1994b). As a measure applied to support appropriate interpretation of potential site characterization results, this requirement is conservatively judged to be a QA requirement.

13.2.3 TBM, Mechanical Excavator, and Support Equipment Maintenance

As discussed in CRWMS M&O (1997e and 1999a), five fluids are used to operate the TBM: hydraulic oil (in onboard reservoirs); lubrication oil (also in onboard reservoirs that are used to lubricate the main bearing, bull gear, and speed reducers); seal grease; lubrication grease (at wear points on the TBM); and water (sufficient for dust control at the conveyor dump points and at the face, bearing purge, and recirculated cooling water [also in onboard reservoirs that are used to cool the main drive motors and hydraulic oil and an onboard reservoir]). TBM fluid systems are closed systems, with the exception of the water spray and seal purge discharges, which are expected to be removed with the excavated muck. CRWMS M&O (1997e and 1999a) also indicate that leak mitigation features are incorporated into the design of a TBM. Similar TFMs and approaches are used for other mechanical excavators and support equipment. Maintenance of such equipment should be conducted similar to that of a TBM.

Such design features are conventional quality features, which should limit potential impacts associated with spills from TBM operations. To minimize the potential for underground TBM equipment spills, the following minimum maintenance practices are also imposed as QA requirements (Requirement 3):

- TBM maintenance procedures shall include provisions to contain loss of hydraulic fluids due to the removal of hydraulic lines or components.
- Periodic maintenance shall be performed on components containing or associated with fluids of concern. The extent (e.g., type of maintenance and components to be maintained) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E.

These requirements, along with other requirements discussed elsewhere in this DIE on spill mitigation and cleanup, are judged adequate to limit potential impact to site characterization testing and waste isolation to the extent practical. The TBM excavation data (CRWMS M&O 1997j) and any other records generated as a result of TBM controls are QA records (Requirement 1). Normal operating practices such as exchange of information on anomalous indications or problems during shift turnover, information on TBM progress, and response to alarms do not require additional QA control, except where this information requires recording as a QA record under 10CFR60 (Section 72) (Requirement 1).

The previous requirement for periodic sampling of hydraulic and lube oils for contaminants, as part of preventative maintenance at a frequency based on manufacturer's recommendations or as approved by the A/E, has been eliminated. Standard maintenance procedures for subsurface

equipment require periodic sampling of these types of fluids. Furthermore, periodic maintenance of components containing or associated with fluids of concern is considered adequate to ensure the detection of any potential spills that were previously addressed by the periodic sampling requirement.

Per Section 6.2.1, the TBM is to be placed in a long-term stand-by condition and temporarily stored at approximately Station 28+23 m. It is conservatively judged that the above requirements are also sufficient to ensure that temporarily storing the TBM within the ECRB Cross Drift at approximately Station 28+23 m (or at some other location before Station 28+23 m) will have negligible potential to impact site characterization testing or waste isolation.

13.2.4 TBM Excavation

Conventional commercial TBM excavation techniques in the ECRB Cross Drift are not expected to compromise the ability to provide either adequate ground support systems or the roadbed for some yet to be determined function in a potential repository. The minimum QA-2 criteria established for Main Access Openings (CRWMS M&O 1997j) sufficiently bound DIE concerns with respect to the TBM excavation of the ECRB Cross Drift such that additional QA requirements are not necessary.

13.2.5 Ground Support and Drift Integrity

As discussed in Section 11.4, the results of the CRWMS M&O (1998a) structural/thermal analyses indicate that potential impacts to a WE Drift due to the excavation of the ECRB Cross Drift are negligible. The CRWMS M&O (1998a) conclusions of negligible structural/thermal/seismic impacts associated with the ECRB Cross Drift being located directly above the proposed repository WE horizon provides partial basis for the removal of Requirement 16 from Revision 01 of this DIE. Per CRWMS M&O (1998e and 1998t), additional testing will be conducted in the TS Main Drift, which will provide confirmation of the conclusions in CRWMS M&O (1998a). While the results of these tests are not required for continued excavation of the ECRB Cross Drift, they do provide significant drift integrity inputs applicable to future repository design. With respect to ground support in ECRB Cross Drift testing-related auxiliary excavations, locating ground support-related boreholes closer than 300 mm to testing-related boreholes could result in potential test interference. Therefore, in ECRB Cross Drift auxiliary excavations, the location of niche-related ground support boreholes shall be coordinated with the TCO (Requirement 16). This requirement is conservatively imposed as a QA control to minimize potential test interference. No further QA controls are required to limit potential waste isolation or test interference impacts.

13.2.6 Damage to Rock from TBM Excavation

Damage to the rock from TBM operation is not expected to be significant enough to create preferential pathways during ECRB Cross Drift construction (CRWMS M&O 1995b). More specifically, TBM excavation is expected to provide relatively low impact to the site and provides confidence that such techniques, as controlled as discussed previously, are consistent with limiting adverse impacts to the extent practical.

13.2.7 Linings, Roadway, and Seals Impact

No seal, lining, nor roadway repository design criteria have yet been established. As such, no evaluation of the likelihood of disturbing a potential seal mount, lining surface, or roadway can be performed at this time. However, it is judged that commercial-grade equipment and standard design and construction practices—such as the controlled use of the TBM for excavation (CRWMS M&O 1997j)—provide sufficient assurance against such an event (i.e., a significant disturbance). Furthermore, future design criteria must consider the as-found ECRB Cross Drift conditions. As discussed in Section 11.1.2.2.6, future quantitative analyses are expected to confirm the qualitative determination herein that the potential for gas-phase conduction within the ECRB Cross Drift is not expected to significantly affect the performance of the proposed repository block. However, pending completion of sufficient quantitative analyses, potential exists for a requirement to seal the ECRB Cross Drift to a level comparable to the bulk rock permeability (i.e., the fracture permeability) to be levied before WE. As discussed in CRWMS M&O (1997j), the ECRB Cross Drift currently has no function in a potential repository, but its future use should not be precluded, should some repository purpose be identified. As such, ground support installed in the ECRB Cross Drift is not subject to QA requirements, but the future installation of a QA-1 classification ground support system should not be precluded. The use of standard, commercially available ground support for stabilization in the ECRB Cross Drift is judged sufficient to limit impacts to the potential repository to the extent practical, and no additional QA requirements are necessary.

13.2.8 Rockbolts and Preferential Pathways

Per CRWMS M&O (1999a), the potential creation of preferential pathways by use of rockbolts is not considered significant. The length and diameter of the hole required for bolt placement are insignificant relative to the size of the ECRB Cross Drift excavation or its associated auxiliary excavations. The majority of the rockbolts are placed in such a way that any preferential path would drain into the ECRB Cross Drift. Further, the rockbolt, along with accompanying materials, act to significantly block the hole that is created. As noted in Section 13.2.7, the design and placement of a rockbolt ground support system in the ECRB Cross Drift and its associated auxiliary excavations are not expected to preclude the installation of permanent ground support in the future. Therefore, it is judged that rockbolt placement has no significant impact to waste isolation, and no QA requirements are necessary.

13.2.9 Boreholes and Standoff Distances

Sections 10.0 and 11.0 of this DIE indicate that in consideration of existing and planned boreholes, no minimum standoff distance requirement has been identified for the ECRB Cross Drift. Further, the evaluation of standoff requirements for future boreholes or associated excavations is allocated to the DIE for Subsurface Testing Activities (CRWMS M&O 1998e) and/or the DIE for Surface-Based Testing Activities (CRWMS M&O 1997f).

13.2.10 Geologic Mapping

As discussed in Section 10.4 of this DIE, test interference in the ECRB Cross Drift and its associated auxiliary excavations can occur if obscuring ground support is installed before the completion of geologic mapping, since the mapping is a photographic and observational activity. As such, the installation of supports that can obscure geologic information should be performed after geologic mapping is complete. As discussed in CRWMS M&O (1999a), the immediate installation of ground support that significantly obscures geologic information before conducting geologic mapping activities only occurs when personnel safety is of concern. Since changes to ground support procedures and materials require A/E review and approval (CRWMS M&O 1996b), it is judged that no specific QA controls to minimize test interference impact are required. The evaluation of other testing-related considerations associated with geologic mapping is allocated to the DIE for Subsurface Testing Activities (CRWMS M&O 1998e).

13.2.11 Schedule and Location of Testing Activities

As discussed in Section 10.8 of this DIE, the schedule and location for conducting testing activities are equally important to the site characterization program as the schedule for construction activities that provide testing access. The instrumentation planned for ECRB Cross Drift and associated auxiliary excavation testing activities will collect data at or near faults or key geologic contacts that may be irretrievable if testing activities were delayed until the entire ECRB Cross Drift was constructed. Further, certain ECRB Cross Drift and associated auxiliary excavation instrumentation is required to collect information significant for the License Application.

To (1) assure that critical testing activities are conducted as required and (2) ensure that the excavation of the ECRB Cross Drift and its associated auxiliary excavations proceeds according to schedule, field-determined locations and schedules for testing activities (including construction support for testing activities) shall be subject to TCO approval. This requirement is conservatively imposed as a QA control to limit potential impact on site characterization activities (Requirement 15). TBM excavation and testing activities may occur concurrently if the TCO and the SOP ascertain that (1) continuing such activities will not endanger the project personnel, the TBM trailing gear, and support systems, and (2) adequate access can be provided to enable the preparation and conduct of testing activities.

The evaluation of specific ECRB Cross Drift and auxiliary excavation site characterization testing activities is not within the scope of this DIE. The evaluation of these activities is allocated to the DIE for Subsurface Testing Activities (CRWMS M&O 1998e) and/or the DIE for Surface-Based Testing Activities (CRWMS M&O 1997f).

13.2.12 Water Controls

As discussed in Section 11.1 of this DIE, unsaturated conditions are considered an important attribute for repository performance, and lower water saturations are expected to provide better performance. The following controls are conservatively judged sufficient to limit to the extent

practical any potential waste isolation impacts associated with the lost of water to the ECRB Cross Drift geologic environment.

Accidental spills of water are to be minimized to the extent practical, and any spills that do occur are to be cleaned up as soon as practical to prevent loss to the environment (Requirement 5). Water loss within the ECRB Cross Drift shall be controlled per optimization of all water application activities, implementation of water collection techniques (in association with each water application activity), and observation/maintenance/repair of all ECRB Cross Drift water-related systems and components (Requirement 5). To ensure an accurate accounting of water use, all hose connections to the ECRB Cross Drift water supply line shall be metered. For the TBM and its trailing gear, the water supply line for each primary activity—such as, TBM spray nozzles, conveyor dust control, rock drilling, wall washing (for geologic mapping), etc.—shall be metered individually (Requirement 5).

Water lost within Phase I of the ECRB Cross Drift shall not exceed an average of 6.25 m^3 per linear meter (or approximately $6.25 \text{ m}^3 \times 264 \text{ gal/m}^3 = 1650 \text{ gal}$ per linear meter) of ECRB Cross Drift excavation (Requirement 5). Water lost within Phase II of the ECRB Cross Drift shall not exceed an average of 2.5 m^3 per linear meter (or approximately 660 gal per linear meter) of ECRB Cross Drift excavation (Requirement 5).

For constant ground conditions (which is a reasonable basis for a given shift), water lost at the front the TBM and water used in the installation of ground support should be relatively uniform over the tunnel excavation for that shift, which is consistent with discussions in Section 11.0 of this DIE. Therefore, the total amount of water lost in a shift shall be averaged over the amount of tunnel excavation in that particular shift (Requirement 5). However, the minimum segment of the ECRB Cross Drift over which the water balance shall average water loss associated with TBM cutterhead and rock drilling operations is 10 m. For water use activities conducted behind the TBM cutterhead and rock drilling operations, the water loss limit shall be applied, as an average, over 10-m segments of the ECRB Cross Drift and shall be checked at the time of its use (Requirement 5). To ensure that conveyor system water loss is negligible, all water spray nozzles associated with the ECRB Cross Drift muck conveyor system shall have an automatic control system, and water spray shall be confined only to the conveyor belt. This control system shall activate water spray when the belt is engaged and shall suspend water spray when belt operation is halted (Requirement 5). If the required automatic water control system for the muck conveyor is temporarily out of service (e.g., for system/component failures or component testing), excavation/conveyor operation may continue. However, continuous manual control of all affected spray nozzles is required during conveyor operations until the automatic water control system is operational. Manual operation of the muck conveyor water spray system requires A/E concurrence and shall not exceed 24 hours without SA Department concurrence (Requirement 5). It is conservatively judged that reporting actual water loss for each 10-segment of the ECRB Cross Drift, or associated auxiliary excavation, at a minimum frequency of once per week is sufficient. Upon the completion of TBM excavation activities, the respective Phase I and Phase II water loss limits shall continue to apply. For water uses where a water loss quantity can be applied as an average water loss over a defined section of tunnel (e.g., dust control), water meter reading and subsequent reporting shall be performed on at least a monthly basis. The total

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quantity of lost water must have been applied evenly throughout the affected 10-m segment of the ECRB Cross Drift. When water is used for other than dust control purposes (or for otherwise exempted water uses), water meter readings and water loss TFM reporting shall continue on a once-per-week basis. These reports shall apply for each week that water is used in the ECRB Cross Drift (Requirement 5). Further, the water meters for water entering and leaving the ECRB Cross Drift shall be read and reported on a once-per-week basis for each week that water is used in the ECRB Cross Drift. These water meter readings shall be checked against expected water usage to ensure that unintentional water loss (i.e., leakage) is not occurring. Should meter readings indicate that there is unintentional water loss, a visual observation of ECRB Cross Drift and auxiliary excavation water lines shall be conducted, and all ECRB Cross Drift water meters shall be read to ensure that leakage is not occurring (Requirement 5).

Water loss reporting shall specify the particular 10-m segment(s) of the ECRB Cross Drift where the water was applied, beginning at Station 0+26 m (Requirement 5). However, the water loss reporting segments shorter than 10 m are permitted in the first water reporting segment of ECRB Cross Drift Phase I and in the last water loss reporting segment of Phase II. These exceptions allow flexibility in the field to establish practical start/end points for other water loss reporting segments along the drift. Another exception within the ECRB Cross Drift where water loss reporting segments may have to be shorter than 10 m is also possible. As noted above, the water loss limit transitions from the Phase I limit to the Phase II limit at the ECRB Cross Drift crossover point with the TS Main Drift (i.e., at approximately Station 7+73 m). As such, water loss must be reported under the Phase I limit until reaching Station 7+73 m and must be reported under the Phase II limit beginning at Station 7+73 m. Water loss reporting segments shorter than 10 m are permitted on either side of the Station 7+73 m water limit transition point to ensure accurate water loss reporting within Phases I and II of the ECRB Cross Drift. As with the ECRB Cross Drift itself, water loss reporting segments shorter than 10 m are also permitted in the first and last water reporting segments of ECRB Cross Drift auxiliary excavations.

The cumulative (i.e., lifetime) total water loss limit for a 10-m Phase I ECRB Cross Drift segment would be: $10 \text{ m} \times 6.25 \text{ m}^3/\text{m} = 62.5 \text{ m}^3$ (or approximately 16,500 gal). The cumulative total water loss limit for a 10-m Phase II ECRB Cross Drift segment would be: $10 \text{ m} \times 2.5 \text{ m}^3/\text{m} = 25 \text{ m}^3$ (or approximately 6,600 gal). For special water loss reporting segments of the ECRB Cross Drift (i.e., segments shorter than 10 m—as described above), the cumulative total water loss limit would be: (the length of the excavated drift segment) $\times$ (the appropriate Phase I or Phase II water loss limit/m). For example, the cumulative total water loss limit for a 3-m water reporting segment in Phase I of the ECRB Cross Drift would be: $3 \text{ m} \times 6.25 \text{ m}^3/\text{m} = 18.8 \text{ m}^3$ (or approximately 4960 gal). These calculated limits are the cumulative total amounts of water that could be lost in a respective Phase I, Phase II, or special water loss reporting segment of the ECRB Cross Drift, before closure of the potential repository. For ECRB Cross Drift water use before closure of the potential repository, the cumulative total water loss in each water loss reporting segment shall not be allowed to exceed the loss limit, without additional SA Department evaluation (Requirement 5).

The $6.25 \text{ m}^3/\text{m}$ (or approximately 1650 gal/m) and $2.5 \text{ m}^3/\text{m}$ (or approximately 660 gal/m) limits include water used in the ECRB Cross Drift for cementitious materials, such as concrete,

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shotcrete or grout⁵, because the entire ECRB Cross Drift is below the lower limit of the PTn member (i.e., below the PTn-TSw1 contact) (Section 9). However, the limit only includes water used for such purposes where the cementitious material is considered to be committed (i.e., to remain post-closure) (Requirement 5). This accounting for water that is used in committed cementitious materials below the lower limit of the PTn member is necessary due to the possibility of thermal dryout, which results from repository heating. Thermal dryout could potentially cause substantial movement of the cementitious water from the location of emplacement to the surrounding rock as discussed in Section 11.2.2.

The water loss limit for auxiliary excavations off the ECRB Cross Drift (alcoves, niches, etc.) that are wider than 5 m shall be the same as for the corresponding Phase I or Phase II segment of the ECRB Cross Drift where that particular excavation is to be located. Further, no additional water loss is allowed for auxiliary, operational support excavations (e.g., mine power center niches, etc.), which are mined along either rib of the ECRB Cross Drift. Water loss associated with such operational support excavations shall be reported against the limit for appropriate 10-m segment of the ECRB Cross Drift. However, for auxiliary excavations (alcoves, niches, etc.) that are narrower than 5 m, the water loss limit shall be proportional to the projected floor area of the excavation. Specifically, the applicable Phase I or Phase II ECRB Cross Drift water loss limit shall be scaled by a *ratio* of the projected floor width of the auxiliary excavation to the 5-m floor width of the ECRB Cross Drift (Requirement 5). For example, the cumulative total water loss for a 10-m segment in a portion of an auxiliary excavation in Phase II of the ECRB Cross Drift that is 4 m wide would be: $10 \text{ m} \times 2.5 \text{ m}^3/\text{m} \times (4 \text{ m}/5 \text{ m}) = 20 \text{ m}^3$ (or approximately 5,280 gal). This scaled water loss limit would be the cumulative total amount of water loss for that 10-m segment of ECRB Cross Drift auxiliary excavation before closure of the potential repository. Reporting shall be on a once-per-week basis, for each week that water is used in the auxiliary excavation, and the reporting shall specify the particular 10-m segment(s) of the auxiliary excavation where the water was applied. The cumulative total of water lost in each 10-m segment of all auxiliary excavations, before closure of the potential repository shall not exceed the width-based loss limit for that particular 10-m segment without additional SA Department evaluation.

Upon the completion of ECRB Cross Drift auxiliary excavations, the respective auxiliary excavation water loss limits shall continue to apply. For water uses where a water loss quantity can be applied as an average water loss over a defined section of of the auxiliary excavation (e.g., dust control), water meter reading and subsequent reporting shall be performed on at least a monthly basis. The total quantity of lost water must have been applied evenly throughout the affected 10-m segment of the ECRB Cross Drift auxiliary excavation. When water is used for other than dust control purposes (or for otherwise exempted water uses), water meter readings and water loss TFM reporting shall continue on a once-per-week basis, for each week that such water is used in the associated ECRB Cross Drift auxiliary excavation (Requirement 5).

⁵ As used here, grout includes rockbolt grout and grout used for ground consolidation purposes, as well as non-cementitious chemical grouts (if used).

Water lost during the wet drilling of test boreholes emanating (laterally or vertically) from the ECRB Cross Drift shall conservatively be considered to have been lost within the footprint of the ECRB Cross Drift. The quantity of water lost shall be reported as required by YMP (1998b). Any water that is recovered during wet-drilling activities is not counted against the water loss limit (Requirement 5).

As discussed in CRWMS M&O (1999a), the A/E identified the potential capability to remove water from the Swellex-type rockbolts with a Swellex water recovery system. However, further evaluation of this activity, as associated with the TS Loop, concluded that the amount of water either remaining in the Swellex bolts or recovered by such a system was not significant compared to the overall water loss limits. As such, the specific use of the Swellex water recovery system was not warranted as a QA control. The water used for the Swellex-type rockbolts is reported as construction water lost, so any water recovered using a water recovery system can be used to reduce the amount of water lost to the ECRB Cross Drift geologic environment.

Section 10.5.3 addresses the potential for water use associated with the installation of ground support in ECRB Cross Drift alcoves and niches to bias characterization testing results. To minimize potential test interferences, the Alcove #8 Drill Room and Niches #5 and #6 (including both access drift and niche segments) shall conform to the ground support requirements for TS Main Drift niches (CRWMS M&O 1998e and 1999a). The Alcove #8 access drift and all of Alcove #9 shall conform to the ground support requirements for TS Loop alcoves (CRWMS M&O 1999a) (Requirement 5).

ECRB Cross Drift Phase I testing results (LANL 1998a) and actual water loss TFM reports (CRWMS M&O 1998b) have provided additional confirmation that the above requirements, when conservatively applied as QA controls, are adequate to limit potential impacts to waste isolation and test interference. As such, these testing results provide partial basis for removal of the excavation hold point at Station 7+73 m of the ECRB Cross Drift (i.e., the removal of Requirement 16 from Revision 01 of this DIE).

13.2.13 Water TFM Report

Preliminary results of recent moisture studies in the TS Loop indicate that approximately 25 percent of the constructor-applied water, which was reported as lost within the ESF, was actually committed to the site (CRWMS M&O 1998u). These testing results validate an earlier engineering judgement that nearly 100 percent of the water used for dust control is removed with the muck. The previous engineering judgement was applied to dust control associated with TBM excavation, road-header-type, mechanical excavation or drill-and-blast excavation—including the wetting down of muck piles. The previous determination was based, in part, on the use of a dry-head TBM. Per Section 6.2.1, the ECRB Cross Drift TBM cutterhead is equipped with water spray nozzles that are to be originally configured to apply water at a cumulative flow rate of approximately 50 gpm. As with other previously evaluated dust control water sources, most of this water is also expected to be removed with the muck. However, it is conservatively judged that 10 percent of the water applied by the TBM cutterhead is to be considered as lost, as

supported by ECRB Cross Drift Phase I testing results (LANL 1998a). Therefore, water TFM reporting shall exempt the quantities of water associated with dust control activities: (1) 90 percent of the water applied by the nozzles in the cutterhead of the TBM, (2) 100 percent of the water applied directly to the subsurface conveyor muck, and (3) 75 percent of water applied during road-header-type, mechanical excavation and drill-and-blast excavation (Requirement 5). However, the following quantities of water shall be included in TFM reporting and are assumed to be lost to the environment: (1) 10 percent of the water applied by the TBM cutterhead, (2) unrecovered quantities of water used for geologic mapping, other testing or testing-support activities, rock drilling, spraying down the invert (behind the TBM) etc., (3) water that was used in mixing committed cementitious materials below the lower limit of the PTn unit, and (4) 25 percent of the water applied during drill-and-blast or road-header-type, mechanical excavation. Any water not removed shall be reported as a committed quantity as discussed in YMP (1998b). QA controls applied as previously described are judged sufficient to limit impacts to waste isolation to the extent practical (Requirement 5).

It should be noted that the TFM reporting exemption allowances for water, as specified above, are predicated on nearly 100 percent removal of tunnel muck. The cutterhead and conveyor exemption allowances are further predicated on the confinement of liquid-phase water, which has been added to the muck, by the subsurface muck conveyor system as the muck is removed from the ECRB Cross Drift. Therefore, engineering judgement (with A/E concurrence) should be used to estimate a quantity of unrecovered water associated with tunnel muck that is not removed from the ECRB Cross Drift within the complete confinement of the subsurface conveyor system. The resultant estimate of unrecovered water should be subtracted from the specified exemption allowances. For example, such adjustments to the specified TFM reporting exemption allowances for cutterhead and conveyor water are appropriate for ECRB Cross Drift excavation operations conducted before installation of the final configuration of the subsurface conveyor system.

There are similar considerations associated with normal operation of the final configuration of the TBM. If water from the TBM cutterhead—in excess of the 10 percent water loss allowance—is observed to be flowing along the invert of the ECRB Cross Drift, engineering judgement (with A/E concurrence) is appropriate to estimate a quantity of excess unrecovered water. The resultant estimate of unrecovered water should be subtracted from the 90 percent TBM cutterhead TFM reporting exemption allowance. If subsurface conveyor dust control water is not completely confined by the belt, engineering judgement (with A/E concurrence) is also appropriate to estimate any quantity of unrecovered water—until the water is confined by the belt. If any of the excess TFM cutterhead or lost conveyor water is recovered in one of the periodic ECRB Cross Drift invert collection points, it can be subtracted from the cumulative amount of water loss in the appropriate 10-segment of the liquid-phase water balance, as defined in Section 13.2.15.

The water balance shall be used as the source for the YMP (1998b) water loss TFM report. Water reporting, per YMP (1998b), shall be in 10-m segment(s) or other special segment(s)—as described in Section 13.2.12—of the ECRB Cross Drift, beginning at Station 0+26 m. Due to the critical importance of the ECRB Cross Drift water loss report, water loss reporting shall be

completed within one week of performing the daily water balance for a respective water application activity (i.e., no later than nine days after a respective water application activity) (Requirement 5).

ECRB Cross Drift Phase I testing results (LANL 1998a) and actual water loss TFM reports (CRWMS M&O 1998b) have provided additional confirmation that the above requirements, conservatively applied as QA controls, are adequate to limit potential impacts to waste isolation and test interference. It should be specifically noted that the water loss in Phase I of the ECRB Cross Drift, as reported in CRWMS M&O (1998b), is significantly and consistently less than the Phase II water loss limit under both normal tunneling operations and abnormally high water use tunneling operations. As such, these testing results and water loss TFM reports provide partial basis for removal of the excavation hold point at Station 7+73 m of the ECRB Cross Drift (i.e., the removal of Requirement 16 from Revision 01 of this DIE).

13.2.14 Compressed Air

Section 10.6.10 of this DIE indicates that compressed air used for testing may need to be free of condensate. CRWMS M&O (1999a, Section 6.16) discusses the fact that drying, filtering and tracing may be performed with portable units local to such tests. The conduct of testing activities is not evaluated by this DIE, and no QA controls are required for testing activities. Any compressed air testing requirements are evaluated in the applicable FWP and/or its associated DIE.

ESFDR 3.8.2.8.1.D (YMP 1997) indicates that compressed air used underground during construction and operation shall be provided with chemical tracer only upon request by the TCO. As discussed in Section 10.7.1 of this DIE, the TCO may request that traced compressed air be used (e.g., to drill core holes and for field experiments and testing in the ECRB Cross Drift and associated auxiliary excavations). Since the scope of this DIE does not encompass such testing activities, the requests for such tracers are addressed in the applicable FWPs, no additional QA controls are required.

13.2.15 Water Balance

The ESFDR (YMP 1997) requires the maintenance of the capability to keep a water balance (ESFDR 3.4.5.3.1.O, 3.4.5.6.1.D, 3.8.2.6.1.A, and 3.8.2.7.1.E). Although no specific impacts are identified, total water loss due to underground activities is a potentially important TFM input to understanding site performance. The requirement to maintain a liquid-phase water balance is therefore conservatively judged to be a QA requirement to provide an accurate estimate in the event of water loss (Requirement 5). A liquid-phase water balance is defined as the volume (m³ or gal) of water loss per 10-m—or other special (Section 13.2.12)—linear segment of tunnel as derived from water use/recovery data. Water use/recovery data includes supply/discharge water meter readings, discharge/recovery estimates per water use activity, applicable water removal allowances (as specified in Section 13.2.13), and spill estimates, at a minimum. The accuracy required to provide an appropriate estimate, however, is sufficiently broad such that tracking liquid-phase water into and out of the ECRB Cross Drift and reporting such quantities in accordance with the TFM procedure (YMP 1998b) along with a listing of the ECRB Cross Drift

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water uses, including water uses in testing-related auxiliary excavations, is considered adequate to provide the data necessary to fulfill this requirement.

All or most of the water directly associated with the conveyor belt use, TBM cutterhead operations, mechanical excavator (i.e., a road-header-type excavator) operation, and drill-and-blast excavation is assumed to be removed (i.e., not reported as lost water), as discussed in Section 13.2.13. Therefore, the water balance must account for these water uses versus water used for other purposes. Controls applied to minimize and mitigate spills, including spills of muck and/or water, are judged adequate to limit the potential for leakage from the conveyor to significantly impact the accuracy of the TFM reporting.

Conventional quality instruments may be used to obtain the flow values and shall be accurate to ± 10 percent or better for supply water meters and ± 5 percent or better for discharge water meters. Flow meters shall be checked to ensure the continued accuracy. Checking of supply flow meter accuracy shall be performed once every 3 months, and checking of discharge flow meter accuracy shall be performed once every month. Accuracy checking of water meters associated with dedicated fire hoses, which are not regularly operated, shall be performed once every year. Only flow meters appropriate for a respective application shall be used—e.g., only a flow meter for a 2-inch water line is to be used on a 2-inch water line (Requirement 5). It should be noted that, at very high or low flow rates, the amount of error in water meter readings may be very significant. As such, engineering judgement (with A/E concurrence) should be used to estimate quantities of water use/removal associated with very low-flow water applications for use in the water balance. If the appropriate meters are used for individual applications, very high lower rates are not generally expected to occur. Should an ECRB Cross Drift or auxiliary excavation water line experience an unexpected high-flow condition, engineering judgement (with A/E concurrence) should be used to estimate quantities of water use/removal for use in the water balance. However, the appropriateness of the installed water meter for the associated application should also be reevaluated.

Quantities of wastewater discharged from the ECRB Cross Drift will be checked at the intersection of the ECRB Cross Drift and the TS Loop. Reporting the flow values (especially total water not removed from the tunnel) in accordance with the TFM procedure (YMP 1998b) is also sufficient (Requirements 5 and 8). Data generated as a result of planned *in situ* moisture and ventilation tests are judged to be sufficient for providing any additional data to TSPA for modification of total water use or validation of impact assumptions as necessary. (Note: It is not the intent of the water balance requirement to provide information to determine the extent and amount of drying of the rock surrounding the ramps/drifts.)

In summary, the water balance shall include as a minimum: (1) water entering the ECRB Cross Drift; (2) water leaving the ECRB Cross Drift; (3) water used for conveyor, TBM and road-header-type, mechanical excavator dust control operations (including water applied directly on the conveyor belt); (4) water applied by TBM spray nozzles; (5) water used for the general operation of the TBM; (6) water used for wetting of muck piles (if applicable); (7) water applied directly to the invert behind the TBM to control dust; (8) water used to spray down the tunnel walls during geologic mapping activities; (9) water used during the installation of ground

support, including rockbolt drill activities; (10) water used to wash the conveyor belt; (11) water used at fire hose stations (if applicable); and (12) water from any water supply line discharge point that is used for any purpose not already mentioned above (including testing activities. The water balance shall provide an itemized listing of water uses during the recording period. Data obtained from the water balance on recovered water shall be used as the source for water loss reports (Requirement 5). ECRB Cross Drift Phase I testing results (LANL 1998a) and actual water loss TFM reports (CRWMS M&O 1998b) have provided additional confirmation that the above requirements, conservatively applied as QA controls, are adequate to limit potential impacts to waste isolation and test interference. As such, these testing results provide partial basis for removal of the excavation hold point at Station 7+73 m of the ECRB Cross Drift (i.e., the removal of Requirement 16 from Revision 01 of this DIE).

13.2.16 Ponding of Water

Significant ponding of water may lead to further limitation of the amount of water that can be lost within the ECRB Cross Drift and its associated auxiliary excavations. Ponding of water should therefore be prevented. Any ponded water shall be removed to the extent practical with standard pumping equipment (Requirement 5), and any water not removed will be reported as a consumed quantity as required by the TFM procedure (YMP 1998b) (Requirement 8). Constructor spill control procedures must include a requirement to limit unrecovered spills. Any record generated due to the implementation of a spill control procedure, as well as the procedure itself, must be processed as a QA record (Requirements 1 and 8). Use of YMP (1998b) is adequate for the records requirement. Auxiliary ECRB Cross Drift excavations shall have a positive slope relative to the ECRB Cross Drift (Requirement 5). Maintaining positive slope in these excavations will facilitate drainage of construction water out of the excavated opening and into water collection points located along the invert of the ECRB Cross Drift. These controls are conservatively imposed as QA controls to limit impacts to waste isolation.

13.2.17 Thermal Testing Facility Interactions

As discussed in Section 10.2.1 of this DIE, ECRB Cross Drift activities do not present a particular test interference concern to the TTF, provided the ECRB Cross Drift layout meets the 50-m to 100-m offset distance requirement established by the responsible PI. As discussed in CRWMS M&O (1998h), the approved layout of the ECRB Cross Drift indicates that the minimum offset between the TTF and the ECRB Cross Drift is approximately 53 m. Therefore, due to the controls imposed by the ECRB Cross Drift layout design, no additional QA requirements are necessary.

13.2.18 Organics

Section 11.3 of this DIE indicates that if the total retained organic constituents do not exceed specified limits, it is expected that no more than a 10-percent change in the ambient aqueous organics concentration will occur. Therefore, there should be negligible geochemical impact in the ECRB Cross Drift and its associated auxiliary excavations to waste isolation. It is recognized that the negligible-impact DOC limits given in Section 11.3 would be impractical if applied as construction/operation limits. Further, no specific impact from a change in ambient conditions

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has been identified, and there is no indication that the potential impact from exceeding these conservative limits through normal, controlled operation is not mitigable. As such, organic use in the ECRB Cross Drift and its associated auxiliary excavations shall be minimized.

To limit adverse effects on the long-term potential repository to the extent practical, the amount of organic material that is to be permanently retained in these excavations shall be minimized. The following controls are therefore applied to minimize permanently retained organics and thereby limit potential impacts to the extent practical: the use of permanently retained organics during construction and operation of the ECRB Cross Drift and its associated auxiliary excavations shall be avoided when practical alternative materials and methods exist; leakage of organics from construction and/or operational equipment shall be mitigated and repaired as soon as practical; and spills of organics in excess of drips (e.g., ruptured hoses and spills from reservoirs) shall be removed to the extent, and as soon as, practical (Requirement 6). Furthermore, periodic maintenance shall be performed on equipment that contains or minimizes the loss of organic materials. The extent (e.g., type of maintenance, equipment, etc.) and frequency of maintenance shall be based upon manufacturer's recommendations or as approved by the A/E (Requirement 6).

Any organics that are spilled or that are permanently retained in ECRB Cross Drift shall be reported in accordance with the TFM procedure (YMP 1998b) (Requirement 8). QA records shall also identify the types of hydraulic and lube oils in TBMs, mechanical excavators, and support equipment used in the ECRB Cross Drift and its associated auxiliary excavations. These records will better facilitate the identification of any materials potentially spilled from construction/operational equipment. Any possible effects on waste isolation of the total amount of organics retained in the ECRB Cross Drift and its associated auxiliary excavations will be evaluated following construction as described in the TSPA. These controls are determined to be sufficient to limit impacts to waste isolation and minimize potential test interference impacts.

13.2.19 Invert Spills/Invert Accommodations

Unlike the TS Loop, there is no concrete invert to assist in the mitigation of spills in the ECRB Cross Drift nor its auxiliary excavations (i.e., spills should be cleaned up to the extent practical). Liquid spills on the host rock invert of the ECRB Cross Drift and/or auxiliary excavations must be assumed to have penetrated the invert floor, if they are not completely recovered. As such, further visual observations may be necessary to fully assess spills in the ECRB Cross Drift and its auxiliary excavations. Unrecovered quantities of spills must be assumed to be committed to the site. As discussed in Sections 10.0 and 11.0 of this DIE, such committed spills have the potential to cause test interference and to impact waste isolation. Therefore, committed spills must be reported in accordance with YMP (1998b) (Requirement 8). Any potential test interference will be evaluated by the appropriate PI(s). Any possible effects on waste isolation due to spills in the ECRB Cross Drift and/or its associated auxiliary excavations will be evaluated following construction as described in the TSPA. These controls are determined to be sufficient to limit impacts to waste isolation and minimize potential test interference impacts.

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Wooden cross ties treated with the organic fire retardant material FR-40 are to be used on the bare, excavated invert of the ECRB Cross Drift. The wooden cross ties are considered to be temporary ECRB Cross Drift accommodations. As discussed in Section 11.3.3, there is negligible potential for organic materials to impact waste isolation if they are not committed to the site. Similarly, there is negligible potential for organic materials to impact test interference if they are not committed to the site. If the FR-40 treated cross ties are fully cured before use in the ECRB Cross Drift, it is conservatively judged that the potential for committing any of the material to the site is negligible. Therefore, a minimum curing time of 72 hours, after the application of FR-40 fire retardant material, is required before placing treated wooden cross ties in the ECRB Cross Drift (Requirement 6). This control is conservatively imposed as QA control to limit impacts to waste isolation and test interference. Per Section 6.2.2, an alternate to treated wooden cross ties is steel cross ties. Per Sections 10.7 and 11.2, the use of steel, which is listed in Attachment II of this DIE as having no identified restraints, results in negligible potential for test interference or waste isolation impacts, even if the steel cross ties were committed to the site. Therefore, no additional QA requirements are necessary to address the use of steel cross ties in the ECRB Cross Drift.

CRWMS M&O (1998i) also indicates that tunnel muck on the invert of the ECRB Cross Drift will remain between the cross ties up to approximately Station 1+80 m. Due to the potential for unrecovered construction water to collect in and to raise moisture content of this muck, there is an increased potential for the fire retardant material to be leached into the natural environment. Per CRWMS M&O (1998i), the SOP has committed to a visual observation plan, as discussed in Section 6, to address muck already emplaced up to approximate Station 1+80 m. To minimize the potential for waste isolation impacts and test interference, it is conservatively judged that several steps from the SOP plan are to be imposed as QA controls. However, it is further conservatively judged that these QA controls are suitable to limit potential waste isolation impacts and test interference up to approximately Station 7+50 m of the ECRB Cross Drift.

Beyond Station 7+50 m of the ECRB Cross Drift, the invert shall be cleaned of tunnel muck to the extent that water flow to periodic collection points along the invert is not obstructed (i.e., to the extent that water does not pond) (Requirement 5). Muck clean-up shall be completed within 2 working days of the passage of the last car of the TBM trailing gear (Requirement 5). Up to approximately Station 7+50 m, muck emplaced on the ECRB Cross Drift invert may remain subject to the following requirements. An invert water collection point shall be installed on the up-slope side of Station 7+50 m (Requirement 5), and a pump shall be readily available in the vicinity of Station 7+50 m to prevent the introduction and loss of water into the ballast material (Requirement 5). Dust control water applied before approximate Station 7+50 m shall not be allowed to pond in the ballast material (Requirement 5).

For invert segments between approximate Stations 0+26 m and 7+50 m where muck is not removed, 12-inch diameter observation sleeves shall be installed adjacent to cross ties at approximate 25-m intervals (Requirement 5). The observation sleeves facilitate checking of the invert and cross ties for water and/or its effects. The TCO shall check the observation sleeves once every week for standing water and/or its effects and shall notify the SOP and the SA Department if these conditions are observed (Requirement 5). If the TCO and/or the SA

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Department provide formal notification of a persistent standing water problem in the invert observation sleeves, the SOP shall ensure that emplaced muck is removed from the invert (between approximate Stations 0+26 m and 7+50 m), consistent with the above requirement for the remainder ECRB Cross Drift (i.e., beyond Station 7+50 m) (Requirement 5).

For invert segments between Stations 0+26 m and 7+50 m where muck has been removed, invert observation sleeves are not required. The most significant source for water loss after excavation of the drift is expected to be the wetting down of inverts for dust control purposes. In these invert segments, the potential presence of excess water on the invert is readily apparent due to the removal of tunnel muck. As such, control of water ponding, as discussed in Section 13.2.16, is considered to be sufficient to address potential waste isolation and/or test interference concerns. Therefore, no additional QA controls are necessary.

To facilitate excavation of ECRB Cross Drift auxiliary excavations, temporary emplacement of tunnel muck on the drift invert, at the excavation breakout point, may be required to provide stable footing for mechanical excavation equipment. As discussed above, muck on the ECRB Cross Drift invert increases the potential for waste isolation impacts or test interference. Therefore, temporary emplacement of muck on the ECRB Cross Drift invert at the breakout point of an auxiliary excavation is allowed but only immediately before and during the time of the breakout excavation (Requirement 5). An invert water collection point shall be installed on the up-slope side of the auxiliary excavation breakout point breakout, and a pump shall be readily available in the vicinity of the breakout (Requirement 5). Upon completion of auxiliary excavation, the emplaced muck shall be removed from the ECRB Cross Drift invert, consistent with the above muck removal requirement above for approximately Station 7+50 m and beyond (Requirement 5). These requirements are conservatively imposed as QA controls to limit waste isolation impacts or test interference to the extent practical.

Section 6.2.2 indicates that a steel walkway will be attached to the cross ties on the opposite side of the tunnel as the conveyor system. However, this section also considers the potential event that a treated wooden walkway becomes a preferable option to the planned steel walkway. As with the treated cross ties, it is conservatively judged that a treated wooden walkway is expected to result in negligible test interference or waste isolation related impacts if the individual components of a wooden walkway are fully cured before their use in the ECRB Cross Drift. Therefore, a minimum curing time of 72 hours, after the application of FR-40 fire retardant material, is required before placing individual components of a wooden walkway in the ECRB Cross Drift (Requirement 6). This control is conservatively imposed as QA control to limit impacts to waste isolation and test interference.

13.2.20 Perched Water

In accordance with Section 10.0 of this DIE and ESFDR (YMP 1997) requirement B.8.3.A.2, encountering perched water requires TCO notification to give the TCO or PI the opportunity to determine what measures are necessary (Requirement 11). For purposes of TCO notification, whenever seeping water is detected from excavated surfaces, the perched water notification shall

be made. Following tests or collection of water as mandated by the PIs/TCO, remaining perched water is to be removed in accordance with requirements in YMP (1997).

13.2.21 Diesel Usage and Waste Isolation

CRWMS M&O (1994c), an analysis of existing (surplus Nevada Test Site [NTS]) diesel equipment, indicated that the actual emission rates may exceed the negligible impact limits for dissolved organic, nitrate, and sulfur dioxide. This analysis makes very conservative assumptions on the amount of exhaust material that is retained in the ESF. Furthermore, the overall organic limits discussed in Section 11.3 of this DIE are those limits below which negligible impact is expected, not those limits for which an impact is anticipated. Also, opening the mountain to the external environment allows the potential introduction of organic materials to the underground (e.g., rodents, insects, airborne particles, and organic byproducts). As such, as long as diesel emissions are minimized, the amount of diesel emissions actually retained will be bounded by the organic introduction created by the opening itself. Finally, there is no indication that the controlled use of diesel equipment would result in unmitigable impact to the site's ability to isolate waste. Therefore, it was judged that, provided diesel emissions are minimized to the extent practical, diesel equipment is acceptable for use in the TS Loop, subject to checking and reporting as discussed in the following section. This same justification, which was originally prepared for CRWMS M&O (1999a), is equally applicable to the ECRB Cross Drift and its associated auxiliary excavations. As such, no additional QA controls are necessary to address waste isolation considerations.

13.2.22 Diesel Usage and Test Interference

Section 10.6.6 of this DIE also identifies potential test interference impact on *in situ* gas testing activities due to the carbon content of diesel exhaust in the potential repository WE areas. As a result, diesel emissions checking is required to evaluate carbon gaseous discharges before use in the potential repository WE areas (Requirement 7). This requirement is imposed as a QA control to minimize test interference.

13.2.23 Diesel Requirement

As a conservative measure to limit the potential for waste isolation and test interference impacts, the following requirements are indicated: Diesel equipment shall be subject to periodic testing for DPM, sulfur dioxide, oxides of nitrogen, carbon monoxide, and carbon dioxide. To ensure that sulfur oxides constituents in exhaust emissions are minimized, the above-ground 40CFR80 (Section 29) requirement for low sulfur (≤ 0.05 percent) diesel fuel shall be used. In general, detrimental components of diesel exhaust (as identified in previous sections) are to be minimized to the extent practical. Controls for ensuring minimization of these emissions include: (1) minimizing diesel idle time while in the tunnel, (2) conducting regularly scheduled maintenance of diesel equipment, (3) ensuring that diesel emissions are maintained below prescribed guidelines (based on manufacturer's recommendations or as approved by the A/E), and (4) measuring and reporting diesel exhaust emissions. Also, as stated in Section 11.3.2, the use of A-55 clean fuel, as a substitute for diesel fuel, should reduce the amount of detrimental

components of diesel exhaust that are released in the tunnel. A-55 clean fuel is subject to the same controls as diesel fuel. In addition, diesel locomotives used in the ECRB Cross Drift shall have exhaust treatment systems installed on them that are designed to reduce the emissions of DPM into the underground. Diesel use records shall be generated consistent with CRWMS M&O (1999a, Requirement 9e) (Requirement 7). These requirements provide for QA control of diesel emission minimization and are judged to be adequate to limit the potential for adverse impact to the extent practical.

Due to the operation of the subsurface ventilation system, diesel emissions are spread throughout the ESF underground environment. As such, diesel records that identify specific areas do not provide meaningful information. Therefore, the previous QA Control requirement, which specifically identified diesel records for the ECRB Cross Drift, has been eliminated and replaced. This requirement change may be applied retroactively such that no previous diesel records specific to the ECRB Cross Drift are required.

13.2.24 TFM Control

As a conservative measure, it has been determined that the recording of consumed quantities of TFMs as QA records shall be implemented. These reports provide additional bases for the TSPA and allow verification of consumed quantities. Therefore, any TFMs that are permanently emplaced/committed (i.e., are expected to remain after closure of the potential repository) in the ECRB Cross Drift or its auxiliary excavations—including ground support components (such as, rockbolts, steel sets, shotcrete, wire mesh, and steel channel), water, hydraulic fluid, fuel, and wood—must be reported in accordance with the TFM procedure (YMP 1998b), except as specifically exempted in this section or future evaluations. These reports must be controlled as QA records (Requirement 8). This control is conservatively imposed as a QA requirement to limit potential impacts to waste isolation and site characterization activities.

The use of tracer gases SF₆, SUVA-COLD MP[®], noble gases (i.e., He, Ne, Ar, Kr, and Xe), and N in the ECRB Cross Drift and its associated auxiliary excavations is exempted from reporting as TFMs. This exemption is based on the expected (1) negligible impact that these gases present to the waste isolation capabilities of a potential repository at Yucca Mountain (as discussed in Section 11.3.1 of this DIE), and (2) alternate availability of SF₆ usage records (e.g., as part of test documentation records) should such records be required in the future for TSPA activities or to help establish initial conditions for site characterization testing.

Incidental losses of chlorinated, potable water/ice used for drinking and hand washing purposes in the subsurface ESF does not present a significant test interference concern (LANL 1996). Therefore, such losses need not be reported in accordance with YMP (1998b) reporting requirements.

13.2.25 Rolling Stock

The areas of concern with rolling stock (exclusive of locomotives) are the potential for incidental spills (both of fluids included in the rolling stock and of fluids being transported to the surface) and accidental explosions. The rolling stock constructor and/or supplier is required to

incorporate in the design and manufacture of rolling stock cars reasonable methods for preventing and mitigating the leakage and spillage of fluids. In addition, the rolling stock constructor and/or supplier is required to describe a program addressing design features, maintenance, operation, and administrative programs for preventing and mitigating leaks and spills (CRWMS M&O 1999a). As discussed in CRWMS M&O (1999a), the following features are incorporated into A/E-specified rail cars: wheel bearings designed to mitigate hydrocarbon releases, fail safe airbrakes, and tie-downs and/or guards to prevent supplies and equipment from shifting during transit. Rail grippers are provided on both the scissor-lift ventilation car and the scissor-lift platform car for stability during lifting operations. A spill board encloses the deck of the maintenance/lube car to contain spilled fluids, and drain plugs will be provided at each end for draining spilled fluids. The maintenance/lube car uses rings welded onto the deck for transporting two grease barrels. Tanks on the maintenance/lube car will be fitted with quick disconnect couplers and caps, sight glasses, and ball type shutoff valves for connections (to prevent overflow). Included in the rolling stock is a tank containing water to be used for storage for subsurface operations. This tank is secured on a standard flat car. The constructor will ensure the operational readiness (with respect to leak prevention/mitigation) of rolling stock before using it in the ECRB Cross Drift. It is also a requirement that maintenance be performed on equipment containing or associated with fluids of concern. The extent (e.g., type of maintenance and components to be maintained) and frequency of maintenance shall be based on recommendations from the manufacturer or as approved by the A/E. As discussed in Sections 6 and 13.2.19, there are no concrete inverts in the ECRB Cross Drift nor its auxiliary excavations. As such, there is no barrier to prevent direct emplacement of leaking fluids from rolling stock. To ensure that such emplacement is minimized, a visual observation of rolling stock, for fluid leaks, no less than once per day is required. Further, any leaks in excess of drips shall be repaired upon discovery. These controls, along with spill controls discussed previously, are sufficient to limit impacts to test interference and waste isolation (Requirement 13).

13.2.26 Underground Storage Vessels

Consistent with CRWMS M&O (1999a), it is conservatively judged that additional storage vessels (i.e., beyond the size of on-board vehicle tanks) for fluids must be placed outside the ECRB Cross Drift and its auxiliary excavations to limit the potential for underground leakage. This does not include the sump storage tanks or on-board tanks, such as those on the rolling stock, TBM, or the TBM trailing gear (Requirement 9).

13.2.27 Conveyor Operation

Conveyor operation introduces a potential for the release of contaminants that may adversely impact site characterization data, or the capability of the site to isolate waste. Operating fluids of concern are lubricating oils, hydraulic fluid, grease, and dust suppression water. As discussed in CRWMS M&O (1999a), the design of the conveyor incorporates several features that will limit spills to the extent practical: use of labyrinth seals on pulley and idler bearings to limit grease from leaking, emergency stop switches operated by pull cords located along the full length of the conveyor, use of fully enclosed chutes with a dust suppression water spray system available for use at most transfer points, a solenoid shutoff valve interlock to prevent water usage when the

conveyor is empty or not running, and a flow meter on each spray header to indicate the amount of water being used. These conventional quality features are adequate when combined with the spill containment/mitigation limits, to limit test interference and waste isolation impacts. No other QA requirements are required. Section 10.5.1 of this DIE discusses the need to clean up muck spills that are excessively wet to the extent practical to limit exposure of *in situ* rock to water or other contaminants. Controls that are in place to limit/mitigate spills of water, hydrocarbons, and other materials, are adequate to provide this control.

13.2.28 Fires

The primary means of extinguishing fires during construction will be a dry chemical fire protection system. As discussed previously, organic materials retained in the ECRB Cross Drift and its associated auxiliary excavations must be limited to prevent effects on a potential repository. It is judged, however, that chemical releases as a result of fires, or the extinguishing of fires, are insignificant relative to this limit (and are therefore not likely to impact waste isolation) since dry chemical residue will be removed following discharge. Section 11.3 of this DIE indicates that dry chemicals and water should not be combined for fire protection unless required for safety reasons. As discussed in CRWMS M&O (1999a), water hose stations are used only as a supplemental system. It is judged that the backup use of water in the amount required to extinguish a fire is not likely to impact waste isolation and that any impact, as a result of this event, can be adequately evaluated when specific details of the event are available. Any actuation of dry chemical fire, protection systems or the backup use of water will be evaluated following removal of the powder and/or water to the extent practical. The requirements associated with mitigation and reporting of spills are adequate to control this activity (Requirements 5 and 6).

13.2.29 Inadvertent Explosions

Inadvertent explosions could occur in the ECRB Cross Drift and its associated auxiliary excavations during construction. However, the potential for such explosions is considered remote enough not to warrant QA controls. Should a significant uncontrolled explosion occur, an evaluation of potential impacts to the surrounding rock mass will have to be conducted at that time based on as-found conditions.

13.2.30 Underground Storage of TFMs

Section 10.7 of this DIE recommends that the storage underground of TFMs that have decomposition and/or combustion products potentially adverse to site characterization be controlled and limited. As discussed previously, conventional practices including compliance with normal industrial hygiene requirements and personnel safety will be used in the construction of the ECRB Cross Drift and its auxiliary excavations. Leak and spill mitigation programs are also required by this DIE, and TFMs are controlled as discussed in YMP (1998b). Through these requirements and practices, the intent of minimizing storage underground is met, because any use or uncontrolled releases of these fluids are reported via the TFM procedure and evaluated appropriately. Therefore, it is conservatively judged that no additional QA controls are required.

13.2.31 Traced Water and Perched Water

Section 10.7.1 of this DIE recommends that grout used in the vicinity of perched water testing be required to contain a tracer. Since the only available supply of nonpotable water in the ECRB Cross Drift and its associated auxiliary excavations is traced water and grout is mixed at or near the use location, it is judged that no additional QA controls are required.

13.2.32 Rock Drills

As discussed in CRWMS M&O (1999a), rock drill hydraulic system features include a system design pressure that is two times the maximum hydraulic system operating pressure, hydraulic fittings and hoses with operating pressures of twice the hydraulic system operating pressure, and the full-flow filtering of pressure lines between components and in return lines. Filters are located to provide for ease of servicing. Maintenance of rock drills and similar equipment (e.g., road-header-type, mechanical excavators; and front end loaders), which involves the use of fluids of concern (as recommended by the manufacturer or as approved by the A/E), will limit potential impacts to waste isolation and site characterization testing (Requirement 13). Pneumatic drills may be necessary, where access with TBM-mounted electro-hydraulic drills or the drill jumbos is restricted, to install ground support for personnel safety. The use of pneumatic drills is bounded by the controls limiting organics and the TFM reporting of fluids lost or consumed such that additional QA controls are not required.

13.2.33 Drinking Water

Drinking water within the ECRB Cross Drift and its associated auxiliary excavations is expected to be provided in small (on the order of a few gallons) temporary coolers or canteens. For health reasons, drinking water (and any associated ice) will not be traced and may be chlorinated. Untraced, chlorinated water may also be provided to hand wash stations. Because of the conservatism associated with hydrological impact evaluations and conclusions, and because of the small quantities involved, incidental spills of drinking water/ice and hand wash station runoff are not considered to require additional QA controls to limit impacts to waste isolation. See Section 13.2.34 for further discussion of drinking water.

13.2.34 Chlorides

The use of chloride-containing chemicals is to be limited to avoid potential test interference impact (see Section 10.7.3) as follows: only non-chloride-based ground enhancing material (e.g., GEM®) is to be used, and the use of chloride-based concrete and grout accelerators is to be limited to the extent practical. TCO concurrence before such use is judged sufficient to provide this control. The amount used shall be recorded in accordance with YMP (1998b) reporting requirements (Requirements 8 and 12) if permanently emplaced/committed. This control is conservatively applied as a QA requirement to limit test interference impacts.

The use of chlorinated water/ice for drinking and hand washing purposes in the subsurface ESF does not present a significant test interference concern (LANL 1996) and therefore does not

warrant additional QA controls. Incidental losses as a result of such uses need not be reported in accordance with YMP (1998b) reporting requirements.

13.2.35 Construction Water and Sampling

Section 10.4 recommends that no water or tracers, except for the traced water used in construction and in the air-mist used to clean the tunnel walls, are to be used in the vicinity of sampling locations within the ECRB Cross Drift and its associated auxiliary excavations. Since nonpotable water piped or transported into the ECRB Cross Drift is required to be traced (Requirement 2) with the only approved tracer (i.e., with LiBr), no additional QA controls are required.

13.2.36 Cement Grouting

Sections 10.5.3 and 10.6.5 of this DIE indicate that cementitious grouting associated with rockbolt installation be limited to the extent practical to limit impacts to the ability to properly characterize the site. Cement grouted rockbolts are not to be used in the ECRB Cross Drift nor its associated auxiliary excavations, except as approved by the TCO. It is conservatively judged that this requirement shall be implemented as a QA control to avoid altering gas sample and air permeability data (Requirement 4).

13.2.37 Shotcrete

As discussed in Section 10.5.3, the constructor must coordinate with the TCO before applying shotcrete in the ECRB Cross Drift and its associated auxiliary excavations, to assure non-interference with testing activities (Requirement 10). As a conservative measure applied to limit potential unidentified test interference impacts, this requirement is imposed as a QA control.

13.2.38 Stabilization of Poor Ground Conditions

Per CRWMS M&O (1998v), alternative excavation/ground support methods (i.e., contingency-based methods outside of specification requirements for stabilizing extremely poor ground) are expected to be invoked occasionally during ECRB Cross Drift other associated excavation activities. (Alternate excavation/ground support methods have been employed in a few instances in the TS Loop, in accordance with CRWMS M&O [1997k, Paragraph 3.01X].) These contingencies are typically expected to consist of the use of lean cement, steel, and/or wood cribbing to stabilize weak ground where the immediate safety of personnel or equipment is at risk. Such methods are applied only until competent ground is reached. Actions taken are documented in accordance with CRWMS M&O (1998w), which requires TCO and SA Department concurrence as soon as practical after the determination of the alternate methods to be used (which may, in some cases, follow implementation). Because these alternate methods are required to protect personnel and equipment, these provisions are judged as adequate to limit potential impacts.

Implementation of such alternate methods typically does not include significant quantities of organic materials, although the use of chemical injection grouting has been considered. Because

of the fact that certain injected chemical grouts violate waste isolation no-impact organic thresholds, a prohibition is placed on its use unless it is the only practical method for continuing excavation. Recognizing the fact that chemical grouting requires a non-trivial equipment deployment, this method shall not be used before conducting an evaluation of potential waste isolation/test interference impacts (Requirement 14). Such evaluations will be based on the as-found ground conditions that require the use of chemical grouting.

13.2.39 ESF TS Loop and Surface ESF Interfaces and Controls

The applicable subsurface or surface DIE (CRWMS M&O 1999a and 1999d, respectively) should be consulted for the controls applicable to the construction and operation of ESF TS Loop and surface ESF equipment that interfaces with the ECRB Cross Drift equipment. Equipment having such interfaces include the subsurface power/grounding distribution system, communication system, lightning protection system, and surface conveyor system. No additional QA controls are required.

One TS North Ramp interface is not specifically evaluated by CRWMS M&O (1999a), as of the approval date of this DIE (i.e., the use of A-55 clean fuel as a substitute for diesel fuel). As discussed in Sections 11.3.2 and 13.2.23 of this DIE, the use of A-55 clean fuel is expected to reduce the amount of detrimental emission constituents. Therefore, it is concluded that the use of A-55 clean fuel in the TS North Ramp (between the ESF North Portal and the ECRB Cross Drift Starter Tunnel) is completely bounded by the CRWMS M&O (1999a) evaluation, conclusions, and QA control requirements. As such, neither further evaluation nor additional QA controls are required.

13.2.40 Electromagnetic Interference

As discussed in Section 10.6.3 of this DIE, transformers, cabling, and other electrical equipment associated with ECRB Cross Drift power distribution and lighting systems could potentially influence test equipment due to EMI. The PIs responsible for individual testing activities will coordinate with the A/E to determine if electromagnetic protection is required. As discussed in Section 10.6.3 of this DIE, EMI shielding or other mitigation measures may be implemented, as required, under the control of the applicable FWP. Therefore, no additional QA controls are required.

13.2.41 Construction Utilities

Temporary construction accommodations could potentially be installed to support construction and operations activities before the installation of the A/E-designed support systems. Such temporary accommodations could include muck handling, electric power, lighting, compressed air, ventilation, water, wastewater, fire protection, communications, and monitoring systems. Any potential construction-supplied monitoring system is evaluated as a part of the system it supports. All temporary, constructor-supplied accommodations are subject to the same applicable DIE requirements as the A/E-designed systems—as verified by the A/E. No additional QA controls are required.

Placement of utility pipes in alcove and niche trenches located in the floors of the alcoves and niches is subject to the following stipulations:

- a. The utility trenches would be lined with concrete material
 - 1) The amount of concrete utilized in lining the trenches would need to be quantified and reported to the TFM Database.
 - 2) Removal of the concrete before HLW emplacement occurs shall occur to the extent practical. Any concrete not removed shall be reported to the TFM Database as permanently emplaced.
- b. Disturbance of actively utilized convergence pins, which have been placed strategically at the entrances into alcoves and niches, shall be avoided to the extent practical. The Test Coordination Office (TCO) shall evaluate possible testing interference should any convergence pin be identified as subject to disturbance by these planned trenching activities. The TCO shall formally notify Design/SOP of the critical convergence pin locations that cannot be disturbed.

13.2.42 Surfactant Material and Binding Agent Use

Section 11.3.4.3 of this DIE derives a special organics loss limit of 8.8 g/m of excavation that is applied in the second ECRB Cross Drift testing interval (i.e., between approximate Stations 2+88 m and 3+38 m). This limit was derived based on the unique offset distance between the testing interval and the closest potential waste package. Section 6.4.1 of this DIE describes testing activities designed to verify the amount of the surfactant material that has been committed to the site (i.e., remains after excavation and recovery activities have been completed). To ensure that the surfactant test was not compromised and to ensure that the bounding conditions of the Section 11.3.4.3 of this DIE surfactant use limit were not exceeded, surfactant material use was restricted to only the approved testing zones—approximately Station 2+88 m to 3+38 m. An absolute cessation of surfactant material use was required by Station 3+75 m, pending further evaluation by the SA Department (Requirement 6).

As with the general organics evaluation in Section 13.2.18 of this DIE, it was recognized that the negligible-impact DOC limit given in Section 11.3.2.4 of this DIE (i.e., 8.8 g/m of excavation) were impractical if applied as construction/operation limit. Further, no specific impact from a change in ambient conditions had been identified, and there was no indication that the potential impact from exceeding this conservative limit through normal, controlled operation was not mitigable. As such, surfactant use in the approved testing zone of the ECRB Cross Drift was permitted on the basis of minimizing its use to the extent practical. It should also be emphasized that the surfactant limit was a loss limit, not a use limit. Therefore, efforts to recover as much of the surfactant material as practical were expected to result in the actual quantity of committed surfactant being below the 8.8-g/m limit.

Per Section 11.3 of this DIE, organic materials committed to Phase II of the ECRB Cross Drift have greater potential to impact performance of the potential repository WE areas, due to the

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reduced minimum stand off distance of 15 m. Therefore, surfactant material use in Phase II of the ECRB Cross Drift was prohibited pending an SA Department evaluation of Phase I surfactant test data, which was reflected in Requirement 6 of Revision 01 to this evaluation.

Per LANL (1998a), surfactant material data collection was conducted at approximately Station 3+00 m of the ECRB Cross Drift. LANL (1998a) also provides preliminary results of the ECRB Cross Drift Phase I and laboratory surfactant material tests. These testing results are supplemented by moisture studies in the TS Loop. Preliminary results of ECRB Cross Drift dust sampling, which was conducted by LANL personnel, are included in LANL (1998a) to supplement the surfactant material evaluation.

Laboratory testing and analyses of water/surfactant material mixture samples concluded that only about 25 percent of the mixture that is originally reported as lost, on the water loss TFM reports, is actually lost to the underground environment (LANL 1998a). However, preliminary data from ECRB Cross Drift Phase I testing, as of the date of approval for Revision 02 of this DIE, could not substantiate an actual amount of residual surfactant in the drift. The laboratory results, actual water loss records, application rate of the surfactant material, and relative organic content of the surfactant material (at the specified application rate) can be used to approximate the amount of committed organics due to surfactant use. The average water loss reported by CRWMS M&O (1998b) for Stations 2+90 through 3+40 m (or the approximate location of the surfactant testing zone) is about 630 gal per 10-m segment of drift (or about 63 gal/m). (It should be noted that the 63 gal/m water loss is the total water loss as averaged over the entire surfactant testing zone of the Phase I ECRB Cross Drift. Only the water used at the TBM cutterhead contained surfactant material. However, using the full 63 gal/m in the following calculation will ensure that conservatism is maintained.) The surfactant material application ratio was approximately 4000:1 (i.e., water to surfactant) (CRWMS M&O 1998x). Using this specific mix ratio, CRWMS M&O (1998y) calculated the relative organic content of the surfactant material to be 0.2413 grams/gal. Therefore, a very conservative estimate of organic material committed to the site as a result of surfactant material use is calculated to be: $(63 \text{ gal/m}) \times (0.2413 \text{ liters/gal}) \times (0.25 \text{ [percentage of actual surfactant loss]}) = 3.8 \text{ g/m}$ of organic material emplacement. This figure is clearly below the 8.8 g/m limit for surfactant material in the Phase I testing zone. The actual testing results are expected to provide significantly lower organic loss amounts.

As noted above, dust sampling was also conducted in the ECRB Cross Drift (LANL 1998a). Air samples were taken during dry TBM cutterhead, wet TBM cutterhead, and wet TBM cutterhead with surfactant modes tunneling operation. While analysis of the data is not yet complete, it should be noted that a dry TBM cutterhead generates 3 to 4 times the dust of a wet TBM cutterhead. However, a wet TBM cutterhead with surfactant generates twice as much dust as a wet TBM cutterhead. While further evaluation of this data is recommended, an initial observation is that surfactant use may not be the most desirable solution for controlling tunnel dust.

With specific regard to potential surfactant use in Phase II of the ECRB Cross Drift, Section 11.3.5 establishes a negligible-impact limit of 2.9 g/m of excavation for DOC. This limit applies to all organic materials used in Phase II of the ECRB Cross Drift—including the surfactant

material. As noted above, surfactant testing results (LANL 1998a) suggest that, on average, approximately 3.8 g/m of organic material are expected to be lost. The quantity of organic material loss associated with the surfactant material alone would exceed the negligible-impact DOC limit for Phase II. As noted in the Phase I surfactant material discussion above, no specific impact from a change in ambient conditions has been identified to date. There are also no indications that potential impacts from exceeding this conservative limit through normal, controlled tunneling operations, are not mitigable. However, an overall evaluation of potential waste isolation impacts, due to surfactant and other organic TFM loss in Phase II of the ECRB Cross Drift, is recommended before using surfactant material in the Phase II portion of the drift. Therefore, surfactant material shall not be used in Phase II of the ECRB Cross Drift pending further evaluation by the SA Department (Requirement 6). As a conservative measure applied to limit potential waste isolation impacts, this requirement is imposed as a QA control.

Section 10.6.2 discusses the test interference associated with surfactant material use and concludes the quantity of surfactant material used within the ECRB Cross Drift should be documented. The implementation of Requirement 8 is judged to be sufficient to satisfy the potential test interference concern, and no additional QA requirements are necessary.

Nearly 100 percent of a binding agent, if used, is expected to be removed with the muck, as long as it is only applied to the muck within the confines of the conveyor belt. Thus, if binding agent application is confined to the conveyor, no test interference or waste isolation impact is anticipated, based on discussions in Sections 10.6.2 and 11.3. A QA control is warranted to ensure a binding agent, if used, is restricted to application on the conveyor belt (Requirement 6).

13.2.43 Alternative Excavation Techniques

CRWMS M&O (1999a) describes the use of road-header-type, mechanical excavators and drill-and-blast excavations techniques to construct auxiliary excavations (e.g., testing alcoves and niches, or operational support excavations). These excavation techniques will be required within the ECRB Cross Drift for similar purposes. Road-header-type, mechanical excavators are bounded by requirements discussed elsewhere in this DIE on use of equipment containing fluids of concern (Requirement 13). Per Section 10.5.2, drill-and-blast excavation techniques are acceptable for operational support excavations, testing alcove and niche access drifts, and the first 5-m segment of the actual niches provided they are controlled. However, to limit the amount of test interference due to the addition of drill-and-blast-related construction water, Section 10.5.2 has restricted excavation of approximately the last 3-m of the Alcove #8 access drift, the entire Alcove #8 Drill Room and the last 10-m segment of testing-related alcoves and Niches #5 and #6 to the use of mechanical excavation techniques (Requirement 5). Section 10.5.2 also indicates that dust control water associated with the excavation of access drifts for ECRB Cross Drift niches must be restricted to minimize the potential for test interference. Therefore, during the excavation of the last 15-m of ECRB Cross Drift Niches #5 and #6, dust control water shall be restricted to only drill water for blast holes, misted water sprays on the mechanical excavator cutterhead, and water sprays on its conveyor (Requirement 5). Spray head type, flow rate, and the procedures for maintaining spray units shall be submitted to the A/E for review and approval before use in the access drifts (Requirement 5). Neither road-header-type or

drill-and-blast excavation techniques is expected to compromise the ability to provide adequate ground support systems.

Section 10.5.2 also addresses potential test interference considerations, other than water use, which are associated with drill-and-blast excavation techniques. To provide evidence of the application of appropriate controls on drill-and-blast techniques, work must be performed by trained personnel as approved by the A/E with selected witnessing. Further, constructor blast plans and blast patterns are to be approved by the A/E with TCO concurrence. Documentation of A/E-required inspections is also required. Explosives are to be procured from a qualified supplier per 27CFR55. Provisions also include training and qualification documentation, receipt verification of materials, and processing of construction records and changes. A/E approval of blasting materials, with TCO concurrence, is considered adequate to ensure that explosives are procured from a qualified supplier per 27CFR55. Furthermore, receipt inspection and verification are satisfied by the constructor's standard material-receipt-inspection process and by A/E-required inspections. These provisions are judged sufficient for these purposes. Training records, procedures, and inspection records associated with drill-and-blast operations must be retained as QA records. To ensure that sufficient information is available to address potential discrepancies that could potentially result in site characterization data due to blasting activities, records shall be generated to document each blast. At a minimum, the time, location, type of explosive, and size (i.e., pounds explosive per delay) of each blast shall be reported. To provide assurance that appropriate practices have been employed and are in conformance with 10CFR60 (Section 72), use and retention of blast records and blast plans as QA records are required (Requirements 17 and 18).

13.2.44 Moisture Studies Testing Boreholes

The ECRB Cross Drift Phase I testing activities, and potentially at other locations within the drift, involve the drilling of downward (i.e., nearly vertical) boreholes in the invert of the drift. These boreholes are located in the bottom of the invert, by design, to be the lowest possible point in the drift. Per Section 10.2.2, the quantity of fluids introduced into testing boreholes, located at the bottom of the ECRB Cross Drift invert, shall be minimized to the extent practical (e.g., by using berms, collars, grouted pipes, or seals) (Requirement 19). This requirement is conservatively imposed as a QA control to limit test interference.

13.2.45 Water Loss Limits for Core Drilling and Slot Cuts in the ECRB for Geomechanical Information

Water use in association with construction of these cored boreholes and the construction of the slot cuts (which are cut in the Cross Drift using a rock saw) will be kept within the maximum water loss limits for the ECRB (every 10 m segment)(Weaver 2001).

13.2.46 Installation of Refuge Areas and Refuge Chamber(s)

Installation and maintenance of a refuge area behind the bulkhead at STA 17+63, and a refuge chamber in Alcove #8 shall be subject to the following test interference concerns in the

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installation of the fireproofing on the bulkheads at STA 17+63 and in Alcove #8 due to current ongoing hydrologic and other testing.

- a). This testing requires maintaining, to the extent possible, stable relative humidity levels behind the respective bulkheads. In addition, the bulkhead at STA 17+63 is to be closed and sealed for a period of several months. The Alcove #8 bulkhead will also be closed with very limited access. Test interference concerns want to minimize opening bulkhead doors for access and egress.
- b). There is concern in Alcove #8 that in-place panels of instruments, traced water holding tanks, and testing beds may be disturbed by dust generated during installation activities, physical jostling of sensitive recording instruments, and/or, disturbance of electrical and hydrologic connections between these instruments and hardware and the test beds. The TCO needs to be notified and concurrence received should there be a need to disturb existing equipment and instruments in Test Exclusion Area #1 (Attachment VI).
- c). There is an observation window in the bulkhead in Alcove #8 to allow observation of personnel operating behind the bulkhead which shall be maintained.
- d). The invert in Alcove #8 has been cleaned of dust and foreign material to avoid possible contamination of the testing beds. All installation processes needed for establishing the Refuge Chamber in Alcove #8 shall avoid the introduction of dust or foreign materials on the invert in Alcove #8.
- e). Construction, operations, and maintenance activities are to not enter Test Exclusion Area #2 (Attachment VI) unless approved by the TCO. All planned entrances through the testing bulkheads in the ECRB require coordination and concurrence with the TCO.

ESF Design has calculated the maximum number of people who can physically occupy the Alcove #8 Refuge Chamber (Keifer 2001). This calculation is consistent with the Guidelines for Refuge Chamber Design derived from Mine Safety and Health Agency (MSHA) regulations. This calculation is as follows:

Area of Alcove #8 - CAD area calculation from DWG 40361.	92135397 mm ²
convert to sq. m & round to 3 sig. Figures	92.1 m ²
Assume 20% of alcove is taken by equipment and 80% of area is available for personnel.	X 80.0%
Net space for personnel.	73.7 m ²
Convert to sq. ft.	X 10.763910 sq. ft. /m ²
Net space for personnel.	793 sq. ft.
Given: Recommend space requirement per person. (Development of Guidelines for Refuge Chamber Design §3.0)	+ 15.0 sq. ft. / person.
Capacity.	53 persons.

13.2.47 Reversal of Ventilation System Fans

There is test interference concern from dust generation resulting from the need for the SOP to test one fan by reversing its operation. The following considerations apply to the planned reversal of the fan/ventilation system test: 1) The TCO shall also be notified two days in advance of any changes to the planned fan reversal activity or schedule to ensure proper test-interference controls are maintained, and 2) The TCO shall provide concurrence that all testing areas have been adequately protected before start of the fan reversal activity. The following proposed solutions to the TCO concern are:

- 1) At each breakout location for each alcove and niche throughout the entire ESF and ECRB a non-permeable cloth be used to prevent dust from entering the testing area(s).
- 2) At each test area location throughout the entire ESF and ECRB not housed within an alcove or niche, a non-permeable cloth be installed to protect the non-heat generating instrumentation from dust.
- 3) For all testing locations that have electronic instrumentation (i.e., balances, computers, video equipment, etc.) which generate heat and cannot be powered down, there should be a semi-permeable cloth installed over the instrumentation.

The TCO or affected PIs should be allowed to be on location during the fan reversal activity. Personnel Limitations for the Refuge Chamber located in Alcove #8

13.3 QA CONTROLS

The following QA requirements have been identified as a result of this evaluation. These requirements are to be applied in addition to other conventional design practices. Standard engineering tolerances, as specified by design drawings, design specifications, and/or FWP's, shall apply to the implementation of the following QA requirements, except for those QA requirements where tolerances are specifically noted.

Requirement 1: Records required for 10CFR60 (Section 72) shall be maintained as QA records.

[ESFDR 3.2.1.1.1.A, 3.2.1.1.4.C, 3.7.1.2.B]

Requirement 2: Nonpotable water transported into the ECRB Cross Drift shall be traced (except for water used outside the tunnel for mixing concrete, grout, and shotcrete that is then used in the ECRB Cross Drift). LiBr concentration is to be controlled by CRWMS M&O (1999a, Requirement 3).

[ESFDR 3.2.1.2.3.B, 3.4.5.3.1.G, 3.4.5.3.1.P, 3.7.2.5.1, 3.8.2.6.1.E]

Requirement 3: The following minimum requirements apply to mechanical excavator and other support equipment maintenance to minimize the potential for underground spills of fluids of concern:

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- (3a) Maintenance procedures shall include provisions to contain loss of hydraulic fluids due to the removal of hydraulic lines or components.
- (3b) Periodic maintenance shall be performed on components containing or associated with fluids of concern. The extent (e.g., type of maintenance and components to be maintained) and frequency of maintenance shall be based on manufacturer's recommendations or as approved by the A/E.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D]

Requirement 4: Cement grout in the ECRB Cross Drift and its associated auxiliary excavations is prohibited without TCO concurrence.

[ESFDR 3.2.1.2.3.B, 3.2.1.2.3.D, 3.7.3.1.B, 3.7.3.1.K]

Requirement 5: Water use and purposeful or accidental loss of water to the environment in the ECRB Cross Drift and its associated auxiliary excavations shall be minimized to the extent practical by imposing the following controls:

- (5a) Water loss within the ECRB Cross Drift and its associated auxiliary excavations shall be controlled by optimization of all water application activities, implementation of water collection techniques (in association with each water application activity), and observation/maintenance/repair of all ECRB Cross Drift and associated auxiliary excavation water-related systems and components. The extent and frequency of observation/maintenance of water-related systems and components shall be approved by the A/E. Such controls shall also address the minimization and removal, to the extent practical, of any spilled or ponded water from the ECRB Cross Drift and its associated auxiliary excavations.

Beyond Station 7+50 m of the ECRB Cross Drift, the invert shall be cleaned of tunnel muck to the extent that water flow to periodic collection points along the invert is not obstructed (i.e., to the extent that water does not pond). Muck clean-up shall be completed within 2 working days of the passage of the last car of the TBM trailing gear. To ensure stable footing for mechanical excavation equipment, the temporary emplacement of muck on the ECRB Cross Drift invert at the breakout point of an auxiliary excavation is allowed, but only immediately before and during the time of breakout excavation. An invert water collection point shall be installed on the up-slope side of the auxiliary excavation breakout, and a pump shall be readily available in the vicinity of the auxiliary excavation breakout. Upon completion of the auxiliary excavation, the emplaced muck shall be removed from the ECRB Cross Drift invert, consistent with the above muck removal requirement for approximately Station 7+50 m and beyond. Should the TCO and/or the SA Department conclude that persistent standing water is creating significant potential for the fire retardant material on the cross ties to leach into the invert, the muck shall be removed pending a recommendation from the TCO and/or the SA Department.

Muck emplaced on the ECRB Cross Drift invert before Station 7+50 m may remain, subject to the following requirements. An invert water collection point shall be installed on the up-slope side of Station 7+50 m, and a pump shall be readily available in the vicinity of Station 7+50 m. Dust control water applied before approximate Station 7+50 m shall not be allowed to pond in the ballast material. Between approximate Stations 0+26 m and 7+50 m, 12-inch diameter observation sleeves shall be installed adjacent to cross ties at approximate 25-m intervals in drift segments where muck has not been removed. If the TCO and/or SA Department provide formal notification of a persistent standing water problem, the SOP shall ensure that emplaced muck is removed from the invert (between approximate Stations 0+26 m and 7+50 m), consistent with the above requirement (i.e., the requirement for approximately Station 7+50 m and beyond of the ECRB Cross Drift).

- (5b) Any water not removed shall be reported as an unrecovered quantity as required by the TFM procedure (YMP 1998b).
- (5c) All hose connections to the ECRB Cross Drift and its associated auxiliary excavation water supply lines shall be metered.
- (5d) A liquid-phase water balance shall be maintained and reported in accordance with the TFM procedure (YMP 1998b). The water balance may be used to adjust reports of use against limits. The water balance shall include as a minimum: (1) water entering the ECRB Cross Drift; (2) water leaving the ECRB Cross Drift; (3) water used for dust control operations associated with the conveyor, TBM, and other mechanical excavators (including water applied directly on the conveyor belt); (4) water applied by TBM spray nozzles; (5) water used for the general operation of the TBM; (6) water used for wetting of muck piles (if applicable); (7) water applied directly to the excavated invert, behind the TBM, to control dust; (8) water used to spray down the tunnel walls during geologic mapping activities; (9) water used during the installation of ground support, including rockbolt drill activities; (10) water used to wash the conveyor belt; (11) water used at fire hose stations (if applicable); and (12) water from any water supply line discharge point that is used for any purpose not already mentioned above (including testing activities). The water balance shall provide an itemized listing of water uses during the recording period.

NOTE: It is not the intent of this requirement to provide information to determine the extent and amount of drying of the rock surrounding ECRB Cross Drift and its associated auxiliary excavations.

Conventional quality instruments may be used to obtain this data and shall be accurate to ± 10 percent or better for supply water meters and ± 5 percent or better for discharge water meters. Water meters shall be flow checked to ensure continued

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accuracy. Checking of supply flow meter accuracy shall be performed once every 3 months, and checking of discharge flow meter accuracy shall be performed once every month. Accuracy checking of water meters associated with dedicated fire hoses shall be performed once every year. Only water line sizes and flow meters appropriate for a respective application shall be used.

NOTE: At very high or low flow rates, the amount of error in water meter readings may tend to increase significantly. As such, engineering judgement (with A/E concurrence) should be used to estimate quantities of water use/removal in the water balance that is associated with very low-flow water applications. If water meters are appropriately sized for their respective applications, very high-flow conditions are not generally expected. Should an ECRB Cross Drift or associated auxiliary excavation water line experience an unexpected high-flow condition, engineering judgement (with A/E concurrence) should be applied to estimate quantities of water use/removal in the water balance, but the appropriateness of the meter for its application should be reevaluated.

- (5e) The amount of construction water lost in Phase I of the ECRB Cross Drift excavation (not including the ECRB Cross Drift Starter Tunnel) shall not exceed an average of 6.25 m³/m (or approximately 1650 gal per linear meter) of tunnel excavated. The amount of construction water lost in Phase II of the ECRB Cross Drift shall not exceed an average of 2.5 m³ per linear meter (approximately 660 gal/m) of tunnel excavated. No additional construction water loss (per linear m of an applicable Phase I or Phase II ECRB Cross Drift segment) shall be allowed for auxiliary, operational support excavations (e.g., mine power center niches, etc.), which are mined along either rib of the drift. The amount of construction water lost in auxiliary excavations off the ECRB Cross Drift (alcoves, niches, etc.) shall not exceed the applicable Phase I or Phase II water loss limit per linear m of excavation (based on the respective location of the excavation) as scaled by the following ratios:

$$\frac{\text{Phase I auxiliary excavation water loss limit}}{(\text{m}^3/\text{m})} = \frac{\text{Projected floor width (m)}}{\text{ECRB Cross Drift width (5 m)}} \times 6.25 \text{ m}^3/\text{m}$$

$$\frac{\text{Phase II auxiliary excavation water loss limit}}{(\text{m}^3/\text{m})} = \frac{\text{Projected floor width (m)}}{\text{ECRB Cross Drift width (5 m)}} \times 2.5 \text{ m}^3/\text{m}$$

However, the above water loss limits shall not exceed the maximum limit as determined using a 5 m excavation width. Any ECRB Cross Drift auxiliary excavation wider than 5 m shall use a 5 m floor width for determination of the applicable water loss limit.

For water use associated with the TBM cutterhead and rock drilling operations, water loss shall be checked and recorded for the water balance at a minimum

frequency of at least once per shift, for each shift that water is used. The water balance shall reflect an average of the total amount of unrecovered water during a respective shift over the total distance of TBM advance during that shift. The minimum segment of the ECRB Cross Drift or associated auxiliary excavation over which the water balance shall average the water loss associated with TBM cutterhead and rock drilling operations is 10 m.

NOTE: Water loss reporting segments shorter than 10 m are permitted in the first water reporting segment of the Phase I of the ECRB Cross Drift and in the last water reporting segment of Phase II. Shorter water reporting segments may be required on both sides of the ECRB Cross Drift Phase I/Phase II transition point at Station 7+73 m to ensure water loss is accurately reported within Phase I and Phase II, respectively. As with the ECRB Cross Drift itself, water loss reporting segments shorter than 10 m are also permitted in the first and last water reporting segments of ECRB Cross Drift auxiliary excavations, as appropriate.

For all other ECRB Cross Drift water use activities, water loss shall be checked and documented for the water balance at the time of water use. Water loss shall not exceed the respective Phase I or Phase II limit, as applied over 10-m segments of the ECRB Cross Drift or associated auxiliary excavation. The water balance shall specify water loss within the individual 10-m segment of the ECRB Cross Drift or associated auxiliary excavation that it was applied.

Upon the completion of excavation activities, the respective ECRB Cross Drift Phase I, Phase II, and auxiliary excavation water loss limits shall continue to apply. For water uses where a water loss quantity can be applied as an average water loss over a defined section of tunnel (e.g., dust control), water meter reading and subsequent reporting shall be performed on at least a monthly basis. The total quantity of lost water must have been applied evenly throughout the affected 10-m segment of the ECRB Cross Drift or associated auxiliary excavation. When water is used for other than dust control purposes (or for otherwise exempted water uses), water meter readings and water loss TFM reporting shall continue on a once-per-week basis, for each week that such water is used in the ECRB Cross Drift and/or its associated auxiliary excavations. Further, the water meters for water entering and leaving the ECRB Cross Drift shall be read and reported on a once-per-week basis, for each week that water is used. These water meter readings shall be checked against expected water usage to ensure that unintentional water loss (i.e., leakage) is not occurring. Should meter readings indicate unintentional water loss, a visual observation of ECRB Cross Drift and its auxiliary excavation water lines shall be conducted, and all ECRB Cross Drift water meters shall be read to ensure that leakage is not occurring.

The water balance shall be checked against the respective Phase I, Phase II, or auxiliary excavation water limit at a minimum frequency of at least once per week, for each week that water is used. The water balance shall also be used as the source

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for the YMP (1998b) water loss TFM report. Water reporting, per YMP (1998b), shall be in 10-m segment(s) of the ECRB Cross Drift, beginning at Station 0+26 m, and in 10-m segments of the appropriate auxiliary excavation. Due to the critical importance of the ECRB Cross Drift water loss report, water loss TFM reporting shall be completed within one month of performing the weekly water balance for a respective water application activity (i.e., no later than thirty- days after a respective water application activity). The cumulative total of water lost in each TFM water loss reporting segment associated with the ECRB Cross Drift, before closure of the potential repository, shall not be allowed to exceed the loss limit, without additional SA Department evaluation.

The following allowances should not be counted against water loss limit: (1) 90 percent of the water applied by TBM cutterhead, (2) 100 percent of the water applied directly to the subsurface conveyor muck, nor (3) 75 percent of the water applied during road-header-type, mechanical and drill-and-blast excavation. The designated percentage of the amount of water used in these applications is to be reported as used and recovered in the water balance because this water is considered to be removed with the muck. Any water recovered that is metered or otherwise measured is also not counted against the respective ECRB Cross Drift Phase I, Phase II, or associated auxiliary excavation water limit.

NOTE: The TFM reporting exemption allowances above are predicated on normal, optimized operation of the TBM cutterhead and subsurface conveyor system. In some instances, some amount of the exempted water may be observed to not be removed as discussed in Section 13.2.13 of this DIE. In such cases, engineering judgement (with A/E concurrence) should be used to estimate quantities of unrecovered water associated with TBM cutterhead and conveyor operations. The resultant estimate of unrecovered water should be subtracted from the specified TFM reporting exemption allowances and reported as lost within the appropriate section(s) of the drift or associated auxiliary excavation. Any quantity of the excess TBM cutterhead or conveyor water that is ultimately recovered in one of the periodic ECRB Cross Drift invert collection points may be subtracted from the cumulative amount of water loss in the liquid-phase water balance within the respective section(s) of the drift or associated auxiliary excavation in which the water was applied.

The ECRB Cross Drift Phase I 6.25 m³/m (or approximately 1650 gal/m) limit, Phase II 2.5 m³/m (or approximately 660 gal/m) limit, and any applicable auxiliary excavation water loss limits include water used in the ECRB Cross Drift for cementitious materials, such as concrete, shotcrete, or grout, where the cementitious material is considered to be committed (i.e., to remain during post-closure).

- (5f) All water spray nozzles associated with the ECRB Cross Drift muck conveyor system shall have an automatic control system, and water spray shall be confined only to the conveyor belt. This control system shall activate water spray when the

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belt is engaged and shall suspend water spray when belt operation is halted. If the automatic water control system is temporarily out of service (e.g., for system/component failures or component testing), excavation/conveyor operation may continue. However, continuous manual control of all affected spray nozzles is required during conveyor operations until the automatic water control system is operational. Manual operation of the muck conveyor water spray system requires A/E concurrence and shall not exceed 24 hours without SA Department concurrence.

- (5g) The inverts of ECRB Cross Drift auxiliary excavations shall have a positive slope relative to the ECRB Cross Drift to facilitate drainage of water out of the excavated opening. However, the slope of the ECRB Cross Over Alcove #8 is restricted to approximately 0.5 percent. To limit the amount of test interference due to the addition of construction water, the excavation of approximately the final 3-m segment of the Alcove #8 access drift, the entire Alcove #8 Drill Room, and the final 10-m segment of Niches #5 and #6 is restricted to the use of mechanical excavation techniques. To minimize potential test interferences, the Alcove #8 Drill Room and Niches #5 and #6 (including both the access drift and niche segments) shall conform to the ground support requirements for TS Main Drift niches (CRWMS M&O 1998e and 1999a). The Alcove #8 access drift and all of Alcove #9 shall conform to ground support requirements for TS Loop alcoves (CRWMS M&O 1999a). Dust control water for the final 15-m of ECRB Cross Drift Niches #5 and #6 excavations is restricted to only drill water for blast holes, misted water sprays on the mechanical excavator cutterhead and water sprays on its conveyor during the excavation of the niches. Spray head type, flow rate, and procedures for maintaining spray units shall be submitted to the A/E for review and approval before use in the niche access drifts.

[ESFDR 3.2.1.1.2.4.H, 3.2.1.1.3.1, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D, 3.2.1.2.3.E, 3.4.5.3.1.O, 3.4.5.6.1.C, 3.4.5.6.1.D, 3.7.1.2.C, 3.7.2.1.2.E, 3.8.2.6.1.A, 3.8.2.6.1.H, 3.8.2.7.1.E, 3.8.2.7.1.F, 3.8.2.7.1.G]

Requirement 6: The amount of organic material that is to be permanently retained in these excavations shall be minimized to the extent practical as follows:

- (6a) The use of permanently-retained organics during construction and operation of the ECRB Cross Drift and its associated auxiliary excavations shall be avoided when practical alternative materials and methods exist.
- (6b) Leakage of organics from construction/operational equipment shall be mitigated and repaired as soon as practicable (e.g., the installation of drip pans, catchments, etc.).
- (6c) Spills or releases of organics, powders, solvents, etc., in excess of drips (e.g., from ruptured hoses and spills from reservoirs) shall be removed to the extent, and as soon as, practical.

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- (6d) Any materials that are spilled or permanently retained in the ECRB Cross Drift or its associated auxiliary excavations shall be reported in accordance with the TFM procedure (YMP 1998b).
- (6e) Surfactant material use is restricted to only a 50-m testing zone in Phase I of the ECRB Cross Drift. Surfactant material shall not be used in Phase I of the ECRB Cross Drift beyond Station 3+75 m, which includes the full 50-m testing zone, without further evaluation by the SA Department. Surfactant material shall not be used in Phase II of the ECRB Cross Drift pending further evaluation by the SA Department.
- (6f) Should a binding agent be used to control dust associated with ECRB Cross Drift conveyor system operation, application of the binding agent is restricted to only muck that is on the conveyor belt.
- (6g) A minimum curing time of 72 hours, after the application of FR-40 fire retardant material, is required before placing treated wooden cross ties and treated wooden walkway components, if used, in the ECRB Cross Drift.
- (6h) Periodic maintenance shall be performed on equipment that contains or minimizes the loss of organic materials. The extent (type of maintenance, equipment, etc.) and frequency of maintenance shall be based upon manufacturer's recommendations or as approved by the A/E.

NOTE: There is no concrete invert to collect/absorb spills in the ECRB Cross Drift nor its associated auxiliary excavations—unlike the ESF TS Loop. Therefore, some quantity of spilled materials must be assumed to have been consumed if the entire spill amount is not recovered.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.E]

Requirement 7: The following minimum requirements apply to the use of diesel equipment in the ECRB Cross Drift and its associated auxiliary excavations:

- (7a) Diesel equipment shall be subject to testing for diesel particulate matter, sulfur dioxide, oxides of nitrogen, carbon monoxide, and carbon dioxide. Diesel equipment shall be tested before initial use in the ECRB Cross Drift, and at a frequency accepted by the A/E thereafter. The checks shall ensure that diesel emission constituents of concern are within manufacturer's recommendations (or within standards developed on site in a manner acceptable by the A/E).
- (7b) Diesel exhaust shall be minimized to the extent practical. Controls to minimize diesel emissions shall include minimization of diesel idle time in the tunnel and regularly scheduled maintenance (including maintenance of emissions-related systems).

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- (7c) Diesel locomotives without exhaust treatment systems that are designed to reduce emissions of diesel particulate matter shall not be used in the ECRB Cross Drift.
- (7d) Low sulfur (≤ 0.05 percent) diesel fuel shall be used.
- (7e) Diesel use records shall be generated consistent with the DIE for the Subsurface ESF (CRMWS M&O 1999a, Requirement 9e).

NOTE: Due to the operation of the subsurface ventilation system, diesel emissions are spread throughout the ESF underground environment. As such, diesel records that identify specific areas do not provide meaningful information. Therefore, the previous requirement, which specifically identified diesel records for the ECRB Cross Drift, has been eliminated and replaced. This requirement change may be applied retroactively such that no previous diesel records specific to the ECRB Cross Drift are required.

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

Requirement 8: QA records shall be made and provided in accordance with the TFM procedure (YMP 1998b) for all TFMs that are permanently emplaced/committed (i.e., to remain after closure of the potential repository) to the ECRB Cross Drift and its associated auxiliary excavations, including water and wood, and unrecovered spills, except as specifically exempted in a DIE (e.g., see Section 13.2.24 of this DIE). QA records shall also identify the types of hydraulic and lube oils in TBMs, mechanical excavators, and support equipment used in the ECRB Cross Drift and its associated auxiliary excavations.

NOTE: TFM use and reporting in the TS Loop and the ECRB Cross Drift Starter Tunnel, as associated with the ECRB Cross Drift, are controlled by the requirements of CRWMS M&O (1999a).

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E]

Requirement 9: Large fluid storage systems shall not be located underground. Large systems are defined as storage tanks or vessels that exceed the volume of normal on-board vehicle fluid reservoirs, not including the sump storage tank, or those volumes within tanks or systems mounted on the TBM, TBM trailing gear, conveyor drives and belt storage units, or rolling stock.

[ESFDR 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E]

Requirement 10: The application of shotcrete in the ECRB Cross Drift and its associated auxiliary excavations shall be coordinated with the TCO before its application to minimize the potential for interference with testing activities.

[ESFDR 3.2.1.2.3.B, 3.7.3.1.K]

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Requirement 11: Provisions shall be made for immediate TCO notification if perched water is encountered, as indicated by water seeping from excavated surfaces.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.D]

Requirement 12: The use of chloride shall be limited as follows:

(12a) Only non-chloride-based electrical ground enhancing material shall be used.

(12b) Use of chlorides (including chloride-based concrete and grout accelerators) shall be limited to the extent practical. Their use (other than to chlorinate water/ice used for drinking and hand wash purposes) shall require TCO concurrence, and shall be recorded as a TFM if permanently emplaced/committed.

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B]:

Requirement 13: Minimize the potential of leaks from equipment (e.g., rolling stock; road-header-type, mechanical excavators; and diesel and/or electric locomotives) containing fluids of concern in the ECRB Cross Drift and its associated auxiliary excavations (such as hydraulic fluid and oil) by the following minimum requirements:

(13a) Maintenance shall be performed on equipment containing or associated with fluids of concern. The extent (e.g., type of maintenance and components to be maintained) and frequency of maintenance shall be based on recommendations from the manufacturer or as approved by the A/E.

(13b) The constructor shall ensure the operational readiness of equipment containing fluids of concern before its use in the ECRB Cross Drift or associated auxiliary excavation by performing visual observation of rolling stock/equipment, for fluid leaks, no less than once per day. Any leaks in excess of drips shall be repaired upon discovery.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E]

Requirement 14: Evaluation of the use of chemical grout injection to stabilize weak ground (including re-evaluation of potential waste isolation and test interference impact) requires SA Department approval before its implementation.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D, 3.7.3.1.B, 3.7.3.1.K]

Requirement 15: The field-determined location and timing for preparation and conduct of ECRB Cross Drift and associated auxiliary excavation testing activities shall be subject to TCO approval.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.F]

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Requirement 16: The location of niche-related ground support boreholes in ECRB Cross Drift testing-related auxiliary excavations shall be coordinated with the TCO.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.F]

Requirement 17: Controlled drilling-and-blasting within the ECRB Cross Drift, and its associated auxiliary excavations, shall be performed in accordance with the following minimum QA requirements.

(17a) qualification of those performing the operations

(17b) performance to required tolerances (post-blast)

(17c) A/E approval of blasting plans with TCO concurrence

(17d) A/E approval of blasting patterns with TCO concurrence

(17e) A/E approval of blasting materials with TCO concurrence.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.G, 3.2.1.2.3.H, 3.7.2.1.2.F]

Requirement 18: Drill-and-blast work in the ECRB Cross Drift, and its associated auxiliary excavations, shall be documented in accordance with the applicable A/E specifications. Drill-and-blast records shall document work processes in conformance with 10CFR60 (Section 72). Records associated with documentation of training and qualifications for drill-and-blast operations shall be treated as QA records. Blast records, blast plans, and blast patterns shall also to be treated as QA records. As a minimum, the type of explosive, size (i.e., pounds explosive per delay), time, and location of the blast shall be reported as QA records.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.G, 3.2.1.2.3.H]

Requirement 19: The quantity of fluids introduced into testing boreholes, located at the bottom of the ECRB Cross Drift and associated auxiliary excavation inverts, shall be minimized to the extent practical (e.g., by using berms, collars, grouted pipes, or seals).

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.D, 3.8.2.6.1.H, 3.8.2.7.1.F]

Requirement 20: The line and grade of all ECRB Cross Drift auxiliary excavations shall be verified by QA survey after their construction to ensure that accurate information is available for integration into a repository design.

[ESFDR 3.2.1.2.3.A, 3.7.2.1.2.B, 3.7.2.1.2.C]

Requirement 21: Activities which produce significant dust and/or water (i.e., sawing, sweeping, welding, drilling, etc.) are prohibited inside the Alcove #8 bulkhead during installation and maintenance of the Refuge Chamber setup nor shall there be dust-

generating activities within Alcove #8 when the bulkhead door is open such that dust can pass behind the bulkhead door). The bulkhead doors in Alcove #8, as well as behind the bulkhead at STA 17+63 are to be kept closed as much as possible. Planned activities, which require access and egress through these bulkhead doors need to have concurrence by, and coordination with the TCO. In addition, the installation of refuge area equipment and supplies behind the bulkhead in Alcove #8 shall be approved by the TCO prior to installation.

[ESFDR 3.2.8.1, 3.2.9.A, 3.7.2.4.1, 3.7.2.4.1.A, 3.2.1.2.3.F].

Requirement 22: Protection against contamination by airborne dust shall be provided to ESF and ECRB testing areas and all testing instrumentation and equipment during any construction, operations or maintenance activities within the ESF and/or the ECRB which generates substantial quantities of airborne dust. In addition, the TCO shall provide concurrence that all testing areas have been adequately protected before the fan reversal activity is started.

[ESFDR 3.2.1.2.3.F]

Requirement 23: The TCO must be notified of, and approve of any work within designated Test Exclusion Areas.

[ESFDR 3.2.1.1.4.A]

13.4 REMOVAL REQUIREMENTS

Non-permanent items shall be removed to the extent practical, before the licensed operation phase of a potential repository. Any incorporation of these items or their constituents into the permanent repository will require a new evaluation as part of the design of permanent items.

13.5 RECOMMENDED CHANGES TO REQUIREMENTS DOCUMENTS

Although not directly associated with this DIE, a request to change Section 3.7.2.3 of the ESFDR (YMP 1997) has been submitted. Specifically, the ECRB Cross Drift should be added to the list of Main Access Openings. This ESFDR change was requested to ensure that the ECRB Cross Drift is designed and constructed consistent with the orientation, depth, and layout of the repository design. As a direct result of this change, requirements will be mandated that preserve the potential use of the ECRB Cross Drift for some yet to be determined function (such as performance confirmation activities) in a potential repository. Based on adding the ECRB Cross Drift to the list of Main Access Openings, a further request was made to acknowledge that all Main Access Openings are not excavated to a 7.62-m diameter opening. The ECRB Cross Drift is only 5 m in diameter.

14. LIST OF REFERENCES

14.1 DOCUMENTS

Bear, J. 1972. *Dynamics of Fluids in a Porous Media*. New York, New York: American Elsevier. (ISBN 0-444-00114-X) TIC: 217568.

Bodvarsson, G.S.; Bandurraga, T.M.; and Wu, Y.S., eds. 1997. *The Site-Scale Unsaturated Zone Model of Yucca Mountain, Nevada, for the Viability Assessment*. LBNL-40376. Berkeley, California: LBNL. ACC: MOL.19971014.0232.

Buscheck, T.A. and Nitao, J.J. 1993. "The Analysis of Repository-Heat-Driven Hydrothermal Flow at Yucca Mountain." *High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada, April 26 – 30, 1993, Vol. 1*, pp. 847 – 867. La Grange Park, Illinois: American Nuclear Society. TIC: 235542.

Cunningham, R. 2001. *"Lightsticks for ECRB Refuge Stations"*. [Las Vegas, Nevada] Bechtel SAIC. ACC. MOL.20011211.0287.

de Marsily, G. 1986. *Quantitative Hydrogeology Groundwater Hydrology for Engineers*. Orlando, Florida: Academic Press, Inc. (ISBN 0-12-208916-2) TIC: 208450.

Dunlap, B.; Francis, N.D.; Ho, C.K.; and Wilson, M.L. 1997. "Provide Input to XPA07, PA204, PA208, PA210 Models." *UZ-Thermohydrology Drift-Scale Analyses*. Level 4 Milestone SLX09F7. TR543FB3. Sandia, New Mexico: SNL. ACC: MOL.19980205.0251.

Eaton, R.R. 1994. "Effect of Fractures on Repository Dryout." *High Level Radioactive Waste Management, Proceedings of the Fifth Annual International Conference, Las Vegas, Nevada, May 22 – 26, 1994, Vol. 4*, pp. 2442 – 2449. La Grange Park, Illinois: American Nuclear Society. TIC: 212015.

Ervin, E.M.; Luckey, R.R.; and Burkhardt, D.J. 1993. "Summary of Revised Potentiometric-Surface Map of Yucca Mountain and Vicinity, Nevada." *High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada April 26-30, 1993, Vol. 2*, pp.1554 – 1558. La Grange Park, Illinois: American Nuclear Society. TIC: 235056.

Fischer, H.B.; List, E.J.; Koh, R.C.Y.; Imberger, J.; and Brooks, N.H. 1979. *Mixing in Inland and Coastal Waters*. San Diego, California: Academic Press. (ISBN 0-12-258150-4) TIC: 239312.

Keifer, J. 2001. *Maximum Capacity of Alcove #8 Refuge Chamber*. Las Vegas, Nevada. Bechtel SAIC Company. ACC: MOL.20011217.0099.

Marshall, T.J. and Holmes, J.W. 1979. *Soil Physics*. Melbourne, Australia: Cambridge University Press. (ISBN 0-521-22622-8) TIC: 240992.

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Matties, J. 2001a. *"Request for TFM Approval: E-5 MATS, T-49 TAPE, Graphite Intumescent Seal"*. [Las Vegas, Nevada] Bechtel SAIC Company. ACC: MOL.200111211.0288.

Matties, J. 2001b. *"Re: Addition of 'Activated Lightstick' to the TFM list of items being considered in terms of ECRB Refuge Chambers setup"*. [Las Vegas, Nevada] Bechtel SAIC Company. ACC: MOL.200111217.0098.

Mitchell, A.2001a. *"Re: Request for TFM Approval Addition"*. [Las Vegas, Nevada] Bechtel SAIC Company. ACC: MOL.20011211.0289.

Mitchell, A.2001b. *"Recommended Test Interference Controls Prior to Reversing the ESF Fan"*. [Las Vegas, Nevada] Bechtel SAIC Company. ACC: MOL.20011211.0290.

Philip, J.R. 1969. "Theory of Infiltration." *Advances in Hydrosience, Vol. 5*, pp. 215-296. New York, New York: Academic Press. TIC: 224852.

Robison, J.H.; Stephens, D.M.; Luckey, R.R.; and Baldwin, D.A. 1988. *Water Levels in Periodically Measured Wells in the Yucca Mountain Area, Nevada, 1981-87*. USGS Open-File Report OFR-88-468. Denver, Colorado: USGS. TIC: 205995.

Robinson, B.A.; Wolfsberg, A.V.; Viswanathan, H.S.; Bussod, G.Y.; Gable, C.W.; and Meijer, A. 1997. *The Site-Scale Unsaturated Zone Transport Model of Yucca Mountain*. LANL Milestone SP25BM3. Los Alamos, New Mexico: LANL. ACC: MOL.19980203.0570.

van Genuchten, M.Th. 1980. "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils." *Soil Science Society American Journal, Vol. 44*, pp. 892 – 898. Madison, Wisconsin: Soil Science Society of America. (ISBN 0361-5995) TIC: 217327.

Weaver, D. 2001. *"DIE Additional Info-Geotech Coring/Sampling/Slots"*. [Las Vegas, Nevada] Bechtel SAIC Company. ACC: MOL.20011217.0009.

Whitham, G.B. 1974. *Linear and Nonlinear Waves*. New York, New York: John Wiley and Sons, Inc. (ISBN 0-471-94090-9) TIC: 239310.

Yang, I.C.; Turner, A.K.; Sayre, T.M.; and Montazer, P. 1988. *Triaxial-Compression Extraction of Pore Water from Unsaturated Tuff, Yucca Mountain, Nevada*. USGS Water-Resources Investigations Report 88-4189. Denver, Colorado: USGS. ACC: NNA.19890309.0161.

Yang, I.C.; Davis, G.S.; and Sayre, T.M. 1990. "Comparison of Pore-Water Extraction by Triaxial Compression and High-Speed Centrifugation Methods." *Proceedings, Conference on Minimizing Risk to the Hydrologic Environment, American Institute of Hydrology*, pp. 250 – 259. Dubuque, Iowa: American Institute of Hydrology. (ISBN 0-8403-6182-3) TIC: 224435.

14.2 STANDARDS AND REGULATIONS

10CFR60. Energy: *Disposal of High Level Radioactive Waste in Geologic Repositories*. Washington, D.C.: United States Government Printing Office. TIC: 238445.

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

27CFR55. Alcohol, Tobacco Products, and Firearms: *Commerce in Explosives*. Washington, D.C.: United States Government Printing Office. TIC: 241903.

40CFR80. Protection of Environmental Area: *Controls and Prohibitions on Diesel Fuel Quality*. Washington, D.C.: United States Government Printing Office. TIC: 1656.

CRWMS M&O 1998f. Determination of Importance Evaluations. Procedure NLP-2-0, Rev. 5. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981116.0120.

YMP 1998b. *Tracers, Fluids, and Materials Data Reporting and Management*. YMP Procedure AP-2.17Q. Las Vegas, Nevada: Yucca Mountain Site Characterization Office (YMSCO). ACC: MOL.19981218.0216.

14.3 WORKS CONSULTED

BLR 1996a. *Geology of the North Ramp - Stations 0+60 to 4+00, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada*. 305654. U.S. Department of the Interior, BLR and USGS. Washington D.C.: U.S. Government Printing Office. ACC: MOL.19970106.0449.

BLR 1996b. *Geology of the North Ramp - Stations 4+00 to 28+00, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada*. 305655. U.S. Department of the Interior, BLR and USGS. Washington D.C.: U.S. Government Printing Office. ACC: MOL.19970106.0496.

BLR 1997a. *Geology of the Main Drift - Stations 28+00 to 55+00, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada*. SPG42AM3. U.S. Department of the Interior, BLR and USGS. Washington D.C.: U.S. Government Printing Office. ACC: MOL.19970625.0096.

BLR 1997b. *Geology of the South Ramp - Station 55+00 to 78+77, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada*. SPG42CM3. U.S. Department of the Interior, BLR and USGS. Washington D.C.: U.S. Government Printing Office. ACC: MOL.19980127.0396.

CRWMS M&O 1994a. *Waste Isolation Evaluation for Use of Non-Committed Fluids and Materials at the Site Surface*. B00000000-01717-2200-00098 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: NNA.19940413.0033.

CRWMS M&O 1994b. *Waste Isolation Evaluation, Tracers, Fluids, and Materials for Exploratory Studies Facility (ESF) Phase 1A Construction*. BAB000000-01717-2200-00062 REV 03. Las Vegas, Nevada: CRWMS M&O. ACC: NNA.19940224.0046.

CRWMS M&O 1994c. *Use of NTS Surplus Diesel Locomotives in the Excavation and Operation of the North Ramp of the ESF*. BAB000000-01717-1700-00001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971023.0259.

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

CRWMS M&O 1995a. *Total System Performance Assessment-1995: An Evaluation of the Potential Yucca Mountain Repository*. B00000000-01717-2200-00136 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960724.0188.

CRWMS M&O 1995b. *Waste Isolation Evaluation: Tracers, Fluids, and Materials and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction*. BABE00000-01717-2200-00007 REV 04. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19950721.0172.

CRWMS M&O 1996a. *The Hydrologic Properties of the Unsaturated Zone at Yucca Mountain, Nevada, Based on the USGS Lithologic Model Units*. BA0000000-01717-2200-00007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960808.0071.

CRWMS M&O 1996b. *QA Classification Analysis of Ground Support Systems*. BABEE0000-01717-2200-00001 REV 05. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19970508.0371.

CRWMS M&O 1997f. *Determination of Importance Evaluation for Surface-Based Testing Activities*. BAA000000-01717-2200-00101 REV 00/ICN 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980202.0314, MOL.19980722.0259, MOL.19981124.0286, and MOL.19990329.0260.

CRWMS M&O 1997g. *Determination of Available Volume for Repository Siting*. BCA000000-01717-0200-00007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971009.0699.

CRWMS M&O 1997i. "Provide VA T/H Sensitivity Analysis to Design." *Level 4 Milestone SLX09J2*. WP12541215M1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980213.0394.

CRWMS M&O 1997j. *QA Classification Analysis of Main Access Openings*. BABEAD000-01717-2200-00002 REV 04. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980210.0154.

CRWMS M&O 1997k. *Subsurface General Construction*. BAB000000-01717-6300-01501 REV 05 (including Engineering Change Requests [ECRs] E98-0038, E98-0064, and E98-0074). Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980127.0685, MOL.19980721.0296, MOL.19980923.0003, and MOL.19981123.0619.

CRWMS M&O 1998a. *Thermomechanical Analysis for ECRB/Emplacement Drift Interactions*. BCAA00000-01717-0200-00009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980518.0104.

CRWMS M&O 1998e. *Determination of Importance Evaluation for Exploratory Studies Facility (ESF) Subsurface Testing Activities*. BAB000000-01717-2200-00011 REV 01/ICN 02.

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981124.0065, MOL.19990317.0468, and MOL.19990323.0164.

CRWMS M&O 1998g. *Enhanced Characterization of the Repository Block Requirements Document (ECRB-RD)*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980512.0819.

CRWMS M&O 1998h. *East-West Cross Drift Starter Tunnel Layout Analysis*. BABEAF000-01717-0200-00008 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980216.0530.

CRWMS M&O 1998i. *Summary of Work – East-West Cross Drift*. BAB000000-01717-6300-01019 REV 01 (including ECRs E98-0025 and E99-0002). Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980410.0185, MOL.19980504.0236, and MOL.19981123.0455.

CRWMS M&O 1998n. *Geology of the Exploratory Studies Facility TS Loop*. BAB000000-01717-0200-00002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980415.0283.

CRWMS M&O 1998o. *Total System Performance Assessment—Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. Chapter 5, “Waste Package Degradation Modeling and Abstraction.” B00000000-01717-4301-00005 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0005.

CRWMS M&O 1998p. *Total System Performance Assessment—Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. Chapter 6, “Waste Form Degradation, Radionuclide Mobilization, and Transport through the Engineered Barrier System.” B00000000-01717-4301-00006 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0006.

CRWMS M&O 1998q. *Repository Subsurface Waste Emplacement and Thermal Management Strategy*. B00000000-01717-0200-00173 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980918.0084.

CRWMS M&O 1998r. *Total System Performance Assessment—Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. Chapter 2, “Unsaturated Zone Hydrology Model.” B00000000-01717-4301-00002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0002.

CRWMS M&O 1998s. *Total System Performance Assessment—Viability Assessment (TSPA-VA) Analyses Technical Basis Document*. Chapter 7, “Unsaturated Zone Radionuclide Transport.” B00000000-01717-4301-00007 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0007.

CRWMS M&O 1998v. *Cross Drift Subsurface General Construction*. BABEAF000-01717-6300-01502 REV 00 (including ECRs E98-0022, E98-0033, E98-0037, E98-0040, E98-0047, and E98-0052). Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980409.0679,

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

MOL.19980414.0302, MOL.19980625.0360, MOL.19980716.0202, MOL.19980716.0206, MOL.19980728.0023, and MOL.19980824.0005.

CRWMS M&O 1998w. *Technical Document Preparation Plan for Plans for Continuing TBM Advance*. BAB000000-01717-4600-00024 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980410.0591.

CRWMS M&O 1999a. *Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility*. BAB000000-01717-2200-00005 REV 07/ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990211.0800, MOL.19990215.0260, and MOL.19990317.0092.

CRWMS M&O 1999d. *Determination of Importance Evaluation for the Surface Exploratory Studies Facility*. BAB000000-01717-2200-00106 REV 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990329.0272.

CRWMS M&O 2000. *Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift*. BABEAF000-01717-2200-00011 REV 04 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000223.0875.

DOE 1997a. *Geologic Mapping of the Exploratory Studies Facility*. Field Work Package FWP-ESF-96-010, Rev. 0. Las Vegas, Nevada: YMSCO. ACC: MOL.19971007.0574.

DOE 1997b. *Perched-Water Testing in the Exploratory Studies Facility*. Field Work Package FWP-ESF-96-011, Rev. 0. Las Vegas, Nevada: YMSCO. ACC: MOL.19971007.0581.

DOE 1997c. *Consolidated Sampling in the ESF*. Field Work Package FWP-ESF-96-009, Rev. 0. Las Vegas, Nevada: YMSCO. ACC: MOL.19971007.0567.

DOE 1997d. *Construction Monitoring in the Exploratory Studies Facility*. Field Work Package FWP-ESF-96-002, Rev. 2. Las Vegas, Nevada: YMSCO. ACC: MOL.19971028.0317.

DOE 1998. *Moisture Studies in the Exploratory Studies Facility*. Field Work Package FWP-ESF-96-004, Rev. 3. Las Vegas, Nevada: YMSCO. ACC: MOL.19981123.0208.

DOE 2000. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 10. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000427.0422.

Liu, H. H. 2001. *Pre-Test Prediction of Alcove 8-Niche 3 Cross-Over Test*. [Las Vegas, Nevada]: Bechtel SAIC Company. ACC: MOL.20010904.0433.

YMP 1997. *Exploratory Studies Facility Design Requirements*. YMP/CM-0019, Rev. 2, ICN 1. Las Vegas, Nevada: YMSCO. ACC: MOL.19960926.0065 and MOL.19980107.0544.

YMP 1998a. *Q-List*. YMP/90-55Q, Rev. 5. Las Vegas, Nevada: YMSCO. ACC: MOL.19980513.0132.

14.4 CORRESPONDENCE

CRWMS M&O 1997a. *Figure 7-1 Subsurface Repository Layout for VA Design (Relative to the ECRB Drift)*. Procedure QAP-3-12 Design Input Transmittal dated September 4, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990305.0192.

CRWMS M&O 1997b. *ECRB TBM*. Lotus Notes Documentation dated November 19, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980209.0537.

CRWMS M&O 1997c. *Dust Suppression Meeting*. Lotus Notes Documentation dated November 12, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980209.0538.

CRWMS M&O 1997d. *Reference for ECRB Utilities*. Lotus Notes Documentation dated November 19, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980209.0541.

CRWMS M&O 1997e. *Determination of Importance Evaluation Testing Requirements and Constraints for ECRB Testing Associated with Cross-Drift Construction*. Interoffice Correspondence LV.SPO.TEST.AJM.10/97-186 dated October 15, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980211.0702.

CRWMS M&O 1997h. *Repository Subsurface Layout Configuration Drawings*. Technical Document Review Transmittal DR.06/97-379 dated June 30, 1997. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971210.0267.

CRWMS M&O 1998b. *SA Evaluation of Actual Use TFM Reports*. Interoffice Correspondence LV.SA.DMJ.06/98-068 dated June 18, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980729.0611.

CRWMS M&O 1998c. *ECRB TBM Tunneling*. Lotus Notes Documentation dated May 5, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990304.0117.

CRWMS M&O 1998d. *ECRB Water Testing Zones*. Lotus Notes Documentation dated May 18, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990304.0112.

CRWMS M&O 1998i. *Revised "Response to Request for Design Input, CMO-13, 1-15-98," tracking no. CMO-19*. QAP-3-12 Design Input Transmittal dated June 15, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980728.0276 and MOL.19990218.0201.

CRWMS M&O 1998j. *Cross Drift TBM - disposition*. Lotus Notes Documentation dated July 20, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990120.0156.

CRWMS M&O 1998k. *ECRB Revised D&TRI for Alcoves and Niches*. Lotus Notes Documentation dated August 7, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981124.0076 and MOL.19990120.0157.

CRWMS M&O 1998m. *Water minimization*. Lotus Notes Documentation dated June 23, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990218.0206.

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

CRWMS M&O 1998t. *ECRB Cross-Over*. Lotus Notes Documentation dated May 18, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990218.0203.

CRWMS M&O 1998u. *Water Data*. Lotus Notes Documentation dated February 23, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990305.0201.

CRWMS M&O 1998x. *CW-10 Application Rate*. Lotus Notes Documentation dated May 29, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990218.0204.

CRWMS M&O 1998y. *ECRB Cross Drift DIE – Section 13 Discussion on Phase II Use of Surfactant*. Lotus Notes Documentation dated June 15, 1998. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990218.0205.

CRWMS M&O 1999b. *Correction – ECRB Change Request/Bulkheads, etc.* Lotus Notes Documentation dated February 23, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990330.0553

CRWMS M&O 1999c. *Revised Transmittal of Design and Test-Related Information for Design and Construction of the Enhanced Characterization of the Repository Block Cross Over Alcove 8, and Niches #5 and #6*. Interoffice Correspondence LV.NEPO.TEST.JLH.03/99-235 dated March 2, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990330.0431.

Fogger Systems International 1997. *YMP Dust Suppression Scope of Work*. Fogger Systems International Facsimile Transmittal dated November 12, 1997, including attached MSDS. Centralia, Washington: Fogger Systems International. ACC: MOL.19980209.0539.

LANL 1994a. *Transmittal of Design and Test-Related Information for Design and Construction of Exploratory Studies Facility North Ramp (Design Package 2C) (SCPb: N/A)*. LANL Memorandum LA-EES-13-LV-03-94-026 dated March 23, 1994. Los Alamos, New Mexico: LANL. ACC: MOL.19951002.0366.

LANL 1994b. *Support for Exemption from Use of Tracers for Certain Elements of the Exploratory Studies Facility Underground Construction*. LANL Memorandum LA-EES-13-LV-02-94-054 dated February 22, 1994. Los Alamos, New Mexico: LANL. ACC: NNA.19940325.0030.

LANL 1996. *Select Use of Chlorinated Water in the Exploratory Studies Facility*. LANL Memorandum LA-EES-13-LV-07-96-005 dated July 2, 1996. Los Alamos, New Mexico: LANL. ACC: MOL.19971001.0688.

LANL 1997. *Revised Transmittal of Design and Test-Related Information on the East-West Cross Drift*. LANL Memorandum LA-EES-13-LV-06-97-014 dated June 25, 1997. Los Alamos, New Mexico: LANL. ACC: MOL.19990305.0195.

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LANL 1998a. *Transmittal of Preliminary Water Use in the East-West Cross-Drift Information.* LANL Memorandum LA-EES-7-06-98-019 dated June 22, 1998. Los Alamos, New Mexico: LANL. ACC: MOL.19990218.0202.

LANL 1998b. *Transmittal of Design and Test-Related Information for Design and Construction of the Enhanced Characterization of the Repository Block Cross Over Alcove 8, Niches #5 and #6, F/M Test Beds #2 and #3, and Crest Alcove 9.* LANL Memorandum LA-EES-7-06-98-006 dated June 5, 1998. Los Alamos, New Mexico: LANL. ACC: MOL.19981030.0232.

LLNL 1998a. *Shipment of Certified Software Package for NUFT 2.0h.* LLNL letter LLYMP9805013 dated May 4, 1998. Livermore, California: LLNL. ACC: MOL.19980810.0394.

LLNL 1998b. *Shipment of Certified Software Package for XTOOL 7.15.* LLNL letter LLYMP9805014 dated May 4, 1998. Livermore, California: LLNL. ACC: MOL.19980810.0257.

SNL 1997a. *The Base-Case Thermal Properties for TSPA-VA Modeling.* SNL Memo dated April 16, 1997 with corrections dated August 7, 1997. Sandia, New Mexico: SNL. ACC: MOL.19990305.0196.

SNL 1997b. *Evaluation of Varying Permeabilities and van Genuchten α and β Parameters for Both the Fractures and Matrix on UZ Flow in a 1D Column.* SNL Memo dated June 17, 1997. Sandia, New Mexico: SNL. ACC: MOL.19980213.0385.

YMP (Yucca Mountain Site Characterization Project) 2001. *Cross Drift Thermal Testing.* Field Work Package FWP-ESF-01-002. Rev 0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20010628.0247.

14.5 DRAWINGS AND SPECIFICATIONS

BSC (Bechtel SAIC Company) 2001. *ECRB Refuge Station Elev., Sections and Details.* BABEAF000-01717-2100-40360 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. URN-0999.

BSC (Bechtel SAIC Company) 2001. *ECRB Refuge Station General Arrangement and Details.* BABEAF000-01717-2100-40361 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. URN-0998.

15. ATTACHMENTS

Attachment	Title
I	List of Acronyms
II	TFMs Approved for Use in the ECRB Cross Drift
III	Section 11.1.2.3 Supplemental Calculations
IV	Figures for Section 11
V	Section 11.1.2.4 Supplemental Calculations
VI	Alcove #8 Sketch of Test Exclusion Areas #1 & #2

ATTACHMENT I

*Determination of Importance Evaluation for the ESF Enhanced Characterization of the
Repository Block Cross Drift*

ATTACHMENT I LIST OF ACRONYMS

*Determination of Importance Evaluation for the ESF Enhanced Characterization of the
Repository Block Cross Drift*

LIST OF ACRONYMS

10CFR60	Title 10, Code of Federal Regulations, Part 60
27CFR55	Title 27, Code of Federal Regulations, Part 55
40CFR80	Title 40, Code of Federal Regulations, Part 80
A/E	Architect/Engineer
Ar	Argon
BLR	Bureau of Land Reclamation
CHn	Calico Hills Nonwelded Hydrogeologic Unit
ch1v	Calico Hills Nonwelded Vitric Modeling Unit 1
ch3z	Calico Hills Nonwelded Zeolitic Modeling Unit 3
ch4z	Calico Hills Nonwelded Zeolitic Modeling Unit 4
cm	Centimeter(s)
CPVC	Chlorinated Polyvinyl Chloride
CRWMS	Civilian Radioactive Waste Management System
CSCI	Computer Software Configuration Identification
CSNF	Commercial Spent Nuclear Fuel
DIE	Determination of Importance Evaluation
DOC	Dissolved Organic Carbon
DOE	United States Department of Energy
DPM	Diesel Particulate Matter
EBS	Engineered Barrier System
ECR	Engineering Change Request
ECRB	Enhanced Characterization of the Repository Block
EMI	Electromagnetic Interference

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ESF	Exploratory Studies Facility
ESFDR	Exploratory Studies Facility Design Requirements
FWP	Field Work Package
gal	Gallons
gal/m	Gallons per Meter
g/m	Grams per Meter
gpm	Gallons per Minute
He	Helium
H ₂ PO ₄ ⁻	Phosphate(s)
ICN	Interim Change Notice
kg	Kilogram(s)
Kr	Krypton
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratories
LiBr	Lithium Bromide
LLNL	Lawrence Livermore National Laboratory
m	Meter(s)
m ⁻¹	Per Meter
m ²	Square Meters
m ³	Cubic Meters
M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
mm	Millimeters
mm/yr	Millimeters per Year

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m/yr	Meters per Year
MSDS	Material Safety Data Sheet
MTU	Metric Tons of Uranium
N	Nitrogen Gas
Ne	Neon
NLP	Nevada Line Procedure
NO ₃ ⁻	Nitrate(s)
NTS	Nevada Test Site
NUFT	Nonisothermal Unsaturated-Saturated Flow and Transport Model
PI	Principal Investigator
ppm	Parts per Million
PTn	Paintbrush Nonwelded Hydrogeologic Unit
PVC	Polyvinyl Chloride
PWR	Pressurized-Water Reactor
QA	Quality Assurance
SA	Safety Assurance
SBT	Surface-Based Testing
SF ₆	Sulfur Hexafluoride
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratories
SO ₄ ⁼	Sulfate(s)
SOP	Site Operations Projects
TBM	Tunnel Boring Machine
TBV	To Be Verified

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TCO	Test Coordination Office
TCw	Tiva Canyon Welded Hydrogeologic Unit
TFM	Tracers, Fluids, and Materials
TM	Thermal/Mechanical
Tptpll	Topopah Spring Crystal-Poor, Lower Lithophysal Lithostratigraphic Unit
Tptpln	Topopah Spring Crystal-Poor, Lower Nonlithophysal Lithostratigraphic Unit
Tptpmn	Topopah Spring Crystal-Poor, Middle Lithophysal Lithostratigraphic Unit
Tptpul	Topopah Spring Crystal-Poor, Upper Lithophysal Lithostratigraphic Unit
Tptrv	Topopah Spring Crystal-Rich, Vitric, Non- to Moderately-Welded Lithostratigraphic Unit
TS	Topopah Spring
TSPA	Total System Performance Assessment
TSPA-VA	Total System Performance Assessment – Viability Assessment
TSw	Topopah Spring Welded Hydrogeologic Unit
TSw1	Topopah Spring Welded Lithophysae-Rich Thermal/Mechanical Unit
TSw2	Topopah Spring Welded Lithophysae-Poor Thermal/Mechanical Unit
TSw3	Topopah Spring Welded Vitrophyre Thermal/Mechanical Unit
tsw4	Topopah Spring Welded Middle Nonlithophysal Modeling Unit 4
tsw5	Topopah Spring Welded Lower Lithophysal Modeling Unit 5
tsw6	Topopah Spring Welded Lower Nonlithophysal Modeling Unit 6
tsw7	Topopah Spring Welded Basal Vitrophyre Modeling Unit 7
TTF	Thermal Testing Facility
USGS	United States Geologic Survey
UTFM	Unsaturated, Transient Flow Model

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Repository Block Cross Drift*

WE	Waste Emplacement
Xe	Xenon
YAP	Yucca Mountain Administrative Procedure
YMP	Yucca Mountain Site Characterization Project
YMSCO	Yucca Mountain Site Characterization Office

ATTACHMENT II

*Determination of Importance Evaluation for the ESF Enhanced Characterization of the
Repository Block Cross Drift*

ATTACHMENT II

TFMS APPROVED FOR USE IN THE ECRB CROSS DRIFT

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

TFMs APPROVED FOR USE IN THE ECRB CROSS DRIFT

General Notes: Any TFM's containing organics that will be permanently retained are subject to DIE Requirement 6. See Page II-5 of II-5 for other applicable notes, as indicated on individual items in the following lists.

Group 1: Approved for use in accordance with the manufacturer's directions and precautions relative to application, storage, disposal, etc.

Tracers, Fluids and Materials

Note

007 - Chemical Sharpener (torch tip cleaner)
 Activitated Lightstick-all colors, all types
 Aervoe-Pacific Marking Paint
 American Polywater SpliceMaster Cable Cleaner Type GX
 Argon (Noble Gas)
 Austin Powder Company – Detonating Cord
 Austin Powder Company – Dynamites Series
 Austin Powder Company – Emulex 500 and 700 Series
 Austin Powder Company – Gelatin and Semi-Gelatin Dynamites
 Austin Powder Company – Shock*Star Tubing
 Blastoff (for improvement of traction on rails)
 Brazaloy (welding flux)
 Burke/EDOCO Acrylic Bondcrete CM-0170
 Carlon Standard Clear PVC Solvent Cement
 Citra Scrub Cleaner
 Clor-D-Tect 1000 (for analysis of chlorinated compounds used in oil)
 Clor-D-Tect 4000 (for analysis of chlorinated compounds used in oil)
 Concrete
 CRC Extreme Duty Silicon
 Crosslinked Polyethylene Backer Rod
 DB-Series Oils
 Delvo Stabilizer, set retarder admixture for concrete
 Detacord – 18 grain Detonating Cord

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Detonation Cord – 200 Grain	
DYNO-Nobel Explosive - K622A	
DYNO-Nobel Explosive - K622B	
DYNO-Nobel IRESPLIT Semi-Gelatin Dynamite	
DYNO-Nobel UNIGEL Semi-Gelatin Dynamite	
E-5 Mats by Interam	1,7
Ensign-Bickford PRIMADET Non-Electric Delay Detonator Noiseless Lead-In-Line (NLIL)	
Ensign-Bickford PRIMADET Non-Electric Delay Detonators (LP) Series	
Ensign-Bickford PRIMADET Non-Electric Delay Detonators (MS) Series	
Ensign-Bickford Shock Tube	
Federal Cartridge Company Small Arms Primers	
Firedam 150 Caulk	
FX-250 rapid-setting mortar (powder & liquid)	
Graphite Intumescent Seal (GIS) by Interam	1,2
Helium (Noble Gas)	
ICI Explosives CORDTEX Detonating Cord	
ICI Explosives EXEL Flexible Plastic Shock Tubes	
ICI Explosives EXEL Lead-In Line instantaneous detonator	
ICI Explosives EXEL LP Long Delay Detonator	
ICI Explosives EXEL MS Short Delay detonator	
ICI Explosives GELDYN Semi-Gelatin Dynamite (cartridges)	
ICI Explosives USA, Inc., "Magnum 65" Detonator Sensitive Emulsion Explosive	
ICI Explosives USA, Inc., PRIMACORD Detonating Cords	
ICI Explosives XACTEX Semi-Gelatin Dynamite (cartridges)	
Iresplit D&D1	
ITP Standard Backer Rod	
Kit 82-A1 (Scotchcast 4)	
Kit 82-A2 (Scotchcast 4)	
Krypton (Noble Gas)	
LAMTEC Corporation Brand 3035 Facing Material	

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LAMTEC Corporation Brand WMP-30 Facing Material
LAMTEC Corporation Brand WMP-F Facing Material
Lithium Bromide (LiBr)
M28R metal magnetic particle weld-testing powder (iron)
MARKAL Paintstik "B" and "B 3/8" markers
Midwest Fasteners, Inc., Product Code IHSP spindle fastener
Monobath 50-50 (a photographic developer/fixer)
Neon (Noble Gas)
Nitrogen Gas
Nonel Super LP Series Detonator
Owens-Corning Fiberglass Duct Wrap
Polyheed, cement dispersing agent
POWERCORD 60-, 100-, 150-, 200-grain Detonating cords
R-12 (Forane), Food Freezant 12
Rheobuild 1000, cement dispersing agent
Rheobuild 2500, cement dispersing agent
Rockbolts
Rolled channel arches (steel)
Sanford "Mean Streak" Waterproof Marking Sticks
Sherwin-Williams Co. KRYLON Interior/Exterior Spray Paint
Sikacrete 950, silica-fume admixture for concrete
Sikacrete 950DP, densified dry powder microsilica admixture for concrete
Sikament 300, water-reducing liquid admixture for concrete
SikaTard 902/908/914, set retarder admixture for concrete
Silica Flour
Stay-Silv 400023 brazing flux
Steel
Steel lagging
Steel sets
Sulfur Hexafluoride (SF6)

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Super Filter Coat No. 412

SUVA-COLD MP® (tetra fluoroethane)

T-49 Tape by Interam

7

TD 210 rubber insulating compound

Tremproof waterproofing

Unigel

Weld-Aid Tip Dip - 006 Nozzle Gel

White & Wib Hi Perf. Acry. Paint

Wil-X Cement

Windex glass cleaner - blue

Wire mesh

Xenon (Noble Gas)

Group 2: Approved for use subject to special requirements and in accordance with the manufacturer's directions and precautions relative to application, storage, disposal, etc.

1275 Almaplex Industrial Lubricants¹

1607 Contact Cleaner^{1, 2}

2001 Monolec Wire Rope Lubricant¹

3752 Almagard Vari-purpose Lubricant¹

3M 1606 Cable Cleaner and Degreaser¹

3M SCOTCH-WELD DP-190 Grey Epoxy Adhesive⁷

3M Super 77 Spray Adhesive¹

605 Almasol Vari-purpose Gear Lubricant¹

607 Almasol Vari-purpose Gear Lubricant¹

A-55 Clean Fuel⁸

Air Kontrol Filter Spray¹

Ansul "Foray" dry chemical fire suppression agent⁴

Aqua Resin Clear with and without dye¹

ATF Dextron (automatic transmission fluid)¹

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Bortz Paint Thinner¹
Burke Non-Ferrous, Non-Shrink Grout⁶
Burrell Fibercrete³
Burrell Shotcrete³
Butyl rubber adhesive⁷
CC-2 Preparation Kit (Cable Cleaner)¹
Chevron Soluble Oil HD (Machining oil used during vent line fabrication)¹
Chevron Special LS Diesel Fuel⁸
Chlorides⁵
Citgo C-500 Motor Oil, SAE 30¹
Citra Spray Paint Numbers 2124, 2125, 2133, 2137, 2143, 2148, 2155, 2156, 2163, 2169,
2171, 2175, 2178, 2182, 2183, 2187, 2190, and 2192¹
CITRIKLEEN (parts cleaner/degreaser)¹
Copper Sulfate (must be retained within reference electrodes)
Cotronics epoxy resin w/ hardeners⁷
Cotronics two component ceramic adhesive w/ thinners and hardeners⁷
CRC Moly Lube¹
CRC Quick Clean¹
Cresset Crete-Lease 727 release agent⁷
CW-10 (Surfactant for TBM cutterhead use)⁴
DB-Series Oil¹
Devcon Sure Shot Super Epoxy Resin and Hardener⁷
Diesel Fuel⁸
Dow Corning 4 electrical insulating compound⁷
Dow Corning plastic adhesive 739⁷
Drive Train Fluid HD SAE 30¹
Drive Train Fluid HD SAE 50¹
Dura-Lith Grease EP NLGI 2¹
Ensign-Bickford PRIMADET non-electric detonators and lead-in lines⁵
Epple 28 sealant¹
EPY500 Part A and EPY500 Part B - two part epoxy⁷

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EZ Mud Shale Stabilizer and Viscosifier (used inside SEAMIST liner)⁷
FE-36 fire suppressant agent⁴
Fiske Brothers Refining Co. Fiske No. 35 Soluble Oil (cutting oil)¹
Flowcable, powder admixture for cement grout⁶
Foster 36-10, Weatherite Mastic (roof sealant)¹
FR-40 Fire Retardant Material (cross tie treatment)⁴
GE Silocones Silicone Rubber Compounds SILOGLAZE 2800/2900, SILGLAZE-II⁷
Gear Compound EP ISO 220¹
Gear Compound EP ISO 320¹
GEM®⁴
Greenlee-Textron Blue Gel Cable Pulling Compound¹
HILTI (CF 128) Filler Foam⁷
HPS Shotcrete Accelerator³
Hydraulic Oil AW ISO 46¹
ICI Explosives POWERsplit Detonator Sensitive Slurry Explosive (cartridges)⁵
ITW-Philadelphia Resins Corp. Ramset EPCON System Hardener Ceramic 6 formula¹
ITW-Philadelphia Resins Corp. Ramset EPCON System Resin Ceramic 6 formula¹
John Deere & Company Hy-Gard Transmission and Hydraulic Oil¹
Litton/Kester flux-cored solder wire¹
Lubrication Engineers 9200 Almasol Dry Film Lubricant¹
Lubrication Engineers, Inc., 608 Almagard Vari-Purpose Gear Lubricant¹
Macklanburg-Duncan POLYCEL Expanding Foam⁷
Master Builder MicroAir - air entraining agent⁷
Matheson Gas Products POLY-ETCH Active Sodium Solution⁷
MB-QSL 100, liquid shotcrete accelerator³
MB-SF, accelerator, silica-fume mineral admixture for concrete, shotcrete³
Meyco Rockbolt and Anchor Grout, cement grout⁶
Mollub-Alloy 777-2 (grease used in lubrication of locomotives, pickup and utility trucks)¹
Monoammonium phosphate dry chemical fire suppression agent⁴
National Floor Sweep⁷

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Non-Ferrous Shrink Grout No. CM-0010⁶
Option 1 (Relton) (water based metal working fluid)¹
Para-Chem Southern, Inc. Kraloy PVC Pipe Cement¹
Pot-Pouri solution, in portable toilet units¹
Rawplug Co. Chem-stud Anchor Capsules¹
Rectorseal Corp. HURRICANE HOMER PVC Solvent Cement^{5, 7}
Resbond 907GF-6 Adhesive⁷
RPM Heavy Duty Motor Oil SAE 15W-40¹
RPM Universal Gear Lube SAE 80W-90¹
RPM Universal Gear Lube SAE 85W-140¹
Rust-Oleum paint, aerosol¹
S5Z Wil-X Cement Grout (B)⁶
SAE 90, Chevron RPM Gear Oil (transmission oil for Tractor Trucks)¹
Safety-Kleen Corp. Safety-Kleen #6638 Premium Gold Solvent¹
Scotch Brand 1602 Insulating Sealer (red)¹
Scotchcast Brand Flame Retardant Compound¹
Scotchkote Brand Electrical Coating¹
Seymore Marking Paint, 16-657¹
Shellzone (R) All Season Antifreeze (ethylene and diethylene glycol)¹
Sigunit L20, liquid shotcrete set accelerator³
Sigunit NC Liquid, shotcrete set accelerator³
Sigunit Powder, shotcrete set accelerator³
SikaTell 100, liquid shotcrete admixture³
SikaTell 200, liquid shotcrete admixture³
Silli-Soda-Crete Grout (including Type I/II cement, sodium silicate, and Pozzolith 100-
XR dispersing agent)⁶
Sodium Silicate, sealant for ECRB Cross Drift bulkheads^{6, 7}
Stay-Clean 40028 (Lead Free) soldering flux^{1, 2}
SUNISO 3GS, viscosity=150 (specially refined oil for air conditioning compressors)¹
Tactoo GPA-72 hi-temp construction adhesive⁷
Thermo Trap⁷

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Type HP Cleaner/Degreaser¹

United Duct Sealer¹

Water (Non-potable and Chlorinated)⁹

WELD-ON P-70 Primer for PVC and CPVC Plastic Pipe⁷

NOTES:

1. These materials have decomposition or combustion products that have the potential to interfere with site characterization testing (i.e., chlorine and carbon). Limiting storage underground or storing in fireproof cabinets are conventional practices that can be used to address this concern. Refer to DIE Requirement 6 for QA controls.
2. These materials react with water to form products such as hydrochloric acid and acetic acid. Hydrochloric acid could bias Chlorine-36 measurements. Limiting storage underground or storing in such a way as to limit contact with water are conventional practices that can be used to address this concern. Refer to DIE Requirement 6 for QA controls.
3. Refer to CRWMS M&O (1999a, DIE Requirement 12) for limits or constraints.
4. Refer to DIE Requirement 6 for limits or constraints.
5. The use of any materials containing chloride in the TS Loop shall require TCO concurrence, with the exception of chlorinated water/ice used for drinking and hand wash purposes (see DIE Requirement 12).
6. Refer to DIE Requirement 4 for limits or constraints.
7. Remove these materials to the extent practical upon completion of testing.
8. Refer to DIE Requirements 6, 7, 8, and 9 for limits or constraints.
9. Refer to DIE Requirements 2, 5, and 8 for limits or constraints.

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ATTACHMENT III

SECTION 11.1.2.3 SUPPLEMENTAL CALCULATIONS

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

SECTION 11.1.2.3 SUPPLEMENTAL CALCULATIONS

Drainage of Added Water from the Fracture Continuum

The drainage time for water in the fracture continuum is computed using the one-dimensional mass balance equation:

$$\phi_f \frac{\partial S_f}{\partial t} + \frac{\partial q_f}{\partial z} = 0 \quad (\text{Eq. III-1})$$

where S_f is the fracture water saturation, ϕ_f is the fracture porosity, and q_f is the volumetric flow rate per unit area. The larger apertures characteristic of fractures result in small values of capillary pressure. In this case, the fracture water is expected to be at values close to atmospheric pressure and the flow is dominated by gravitational effects.

Therefore, an approximate statement of Darcy's law for fractures is

$$q_f = K_f (S_f) \quad (\text{Eq. III-2})$$

where K_f is the effective hydraulic conductivity of the fractures. Given this approximation, Equation (III-1) becomes

$$\phi_f \frac{\partial S_f}{\partial t} + \frac{dK_f}{dS_f} \frac{\partial S_f}{\partial z} = 0 \quad (\text{Eq. III-3})$$

Equation (III-3) is a first-order, hyperbolic differential equation that may be written in the following form (Whitham 1974):

$$\frac{dS_f}{dt} = 0 \quad (\text{Eq. III-4})$$

along the trajectory

$$\frac{dz}{dt} = \frac{1}{\phi_f} \frac{dK_f}{dS_f} \quad (\text{Eq. III-5})$$

In Equations (III-4) and (III-5), the time variable t is also the parameter that defines progress along the characteristic curve defined by Equation (III-5). The characteristic curve is found to be a straight line because the fracture water saturation (S_f) is constant along the characteristic, according to Equation (III-4). The initial condition assumes that fractures between the ECRB Cross Drift and the water table are initially saturated and that the undisturbed fracture saturations above the disturbed zone are much lower. Drainage of the fracture system follows an expansion

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wave solution to Equations (III-4) and (III-5) because the propagation velocity given by Equation (III-5) is lower at smaller values of z (Whitham 1974). Therefore, a continuous solution to the problem is immediately available.

The elapsed time for any particular saturation level to move a given distance, z , through the fracture system may be calculated from the integral of Equation (III-5),

$$t = z \left(\frac{1}{\phi_f} \frac{dK_f}{dS_f} \right)^{-1} \quad (\text{Eq. III-6})$$

The relationship that is commonly used for the effective hydraulic conductivity, K_f , is the van Genuchten relationship (van Genuchten 1980):

$$K_f(S_f) = K_{fs} S_f^{1/2} \left[1 - (1 - S_f^{\beta/(\beta-1)})^{1-(1/\beta)} \right]^2 \quad (\text{Eq. III-7})$$

As a bounding calculation, we use the smallest value of K_{fs} , 3.09 meters/year (m/yr), for zones between the ECRB Cross Drift and the water table, and the largest value ϕ_f , 5.0×10^{-4} . The value for β is constant, given as

$$\beta = \frac{1}{1-m} \quad (\text{Eq. III-8})$$

where $m = 0.492$ (Bodvarsson et al. 1997), or $\beta = 1.9685$. Clearly, the most impact would occur to the system if the natural water flux is low. The lowest average infiltration rate currently anticipated is 0.0014 m/yr. The natural variation in flux is expected to be about 50 percent therefore we expect the changes in flux locally below the ECRB Cross Drift to be negligible if they are within 150 percent of the undisturbed value. Therefore, the limiting flux is: $1.5 \times 0.0014 \text{ m/yr} = 0.0021 \text{ m/yr}$. To achieve a flux that is less than this value, the fracture water saturation needs to be 0.2739 or less, based on Equations (III-2) and (III-7). If the distance from the ECRB Cross Drift to the water table is taken to be approximately 300 m, then from Equation (III-6), the time required for the fracture system to drain to a saturation of 0.2739 is 4.2 years.

Drainage of Added Water from the ch1v Matrix

Description of the Analysis Approach

The stratigraphy for the calculations used here are shown in SNL (1997b, Figure III-1). In this DIE, the TSw hydrogeologic unit is subdivided into several model units, which exhibit similar flow characteristics. The TSw model units specifically applicable to this analysis are annotated as tsw4, tsw5, tsw6, and tsw7 throughout this Attachment. Similarly, the CHn hydrogeologic unit is subdivided into several model units of similar flow characteristics. The CHn model units specifically applicable to this analysis are annotated as ch1v, ch3z, and ch4z throughout this Attachment. The ECRB Cross Drift is planned to penetrate the tsw4 in the vicinity of the TS

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Main Drift cross-over (SNL 1997b, Figure III-1). The ECRB Cross Drift will proceed down through the strata as it progress south west across the potential repository block, following the slope of potential WE drifts in the current repository design. However, the ECRB Cross Drift will remain in the TS hydrogeologic unit, and in fact will not penetrate the tsw7 (basal vitrophyre). As stated in the main text, the flow of construction water is expected to be primarily through fractures in the various TSw model units due to the low matrix permeability in these units. This assumption is examined more closely in the next section. The much larger matrix saturated hydraulic conductivity, larger matrix porosity, lower matrix water saturations, and lower fracture saturated hydraulic conductivity in the Calico Hills nonwelded vitric (chl_v model unit) leads to much greater potential for matrix imbibition of any water flowing in the fractures. The imbibed water will then drain more slowly than through the fractures (see discussion above on fracture drainage). The slower drainage in the matrix is primarily due to the much greater storage capacity of the matrix as compared with the fractures. The fractures do not have sufficient porosity to hold very much water (roughly 0.03 m between the ECRB Cross Drift and the water table), and will drain very quickly at high water saturations due to the high effective hydraulic conductivity. Water introduced to the matrix will result in much smaller changes in water saturation and effective hydraulic conductivity, leading to slower drainage.

The method used to compute drainage from chl_v is based on a quasi-steady flow approximation. One-dimensional, steady flow fields are determined for flow rates corresponding to the saturated hydraulic conductivity of the underlying Calico Hills zeolitic unit (0.00328 m/yr), and for the limiting flux identified in the main text, 0.0021 m/yr. Steady flow saturation distributions through the Calico Hills zeolitic (ch_{3z} and ch_{4z}) model units are computed for these flow rates. Results from these calculations are used to establish the capillary pressure at the lower boundary of the chl_v. Then, steady-flow saturation distributions for the chl_v are computed for 0.0021 m/yr and 0.00328 m/yr flow rates. From these calculations, the average saturation in the chl_v is derived for these flux values. Due to its high permeability, the flux through the chl_v can easily exceed the saturated conductivity of the underlying ch_{3z} unit. However, the drainage from the chl_v is conservatively assumed to be limited to a flux of 0.00328 for average saturation conditions in excess of those required to maintain a steady flow of 0.00328 m/yr. Similarly, the drainage is assumed to be a value of 0.0021 m/yr for average saturations in the chl_v that lie between the average saturations established for flow rates of 0.0021 m/yr and 0.00328 m/yr. In this way, we obtain a conservative time estimate for water to drain from the chl_v unit. As shown in the following section, excess water remaining in the CH_{3z} and CH_{4z} units are very small (due to the high saturations under natural conditions). The CH_{3z} and CH_{4z} units will quickly drain to an average saturation required for a flux of 0.0021 m/yr.

Steady Flow Analysis

From the model layer definition diagram in SNL (1997b, Figure III-1), we see that most of the zeolitic rock is in the ch_{3z}. Using properties from Table 2-20 of CRWMS M&O (1998r) for present-day climate, we find that properties for the ch_{3z} and ch_{4z} are very similar as given in Table III-1 below:

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Table III-1. Properties of CHn Model Units ch3z and ch4z

Model Layer	Saturated Hydraulic Conductivity (m/yr)	Porosity	van Genuchten α (per meter [m ⁻¹])	β	S_r
ch3z	0.00328	0.240	0.0191	1.28	0.20
ch4z	0.00558	0.169	0.00759	1.91	0.33

The ch4z is found to be slightly more permeable and less porous with offsetting variations in α and β . These characteristics would lead to slightly faster drainage in the ch4z than in the ch3z. Therefore, to simplify the problem, we conservatively assume that the entire zeolitized region (ch3z and ch4z) may be characterized by ch3z properties.

Note that we are using the property set calibrated to the present-day, expected value infiltration (I), which is 0.007 m/yr over the potential repository block (CRWMS M&O 1998r). Calibration was also conducted for I/5, or 0.0014 m/yr. In the I/5 case, the ch3z was found to have a saturated hydraulic conductivity of 0.000676 m/yr. This lower saturated hydraulic conductivity means that water flow rates at the critical level of 0.0021 m/yr (and above) would have to be carried by fracture flow in the zeolitic model units. The alternative, i.e., the drainage of the chl_v into fractures in the ch3z, would lead to faster drainage of excess water in the chl_v because the fractures in the ch3z are much less restrictive to flow than the matrix, for either property set. Furthermore, differences between the chl_v properties for these two calibrations are very small. Therefore, use of the property set calibrated to the expected-value infiltration (0.007 m/yr) is a conservative choice for this analysis.

The steady flow saturation profile is obtained by direct integration of Darcy's law (Bear 1972)

$$q_s = K(S) + K(S)\Psi'(S)\frac{dS}{dz} \quad (\text{Eq. III-9})$$

where q_s is the water flow rate (m/yr), S is the normalized matrix saturation, Ψ is the capillary pressure, and

$$\Psi'(S) \equiv \frac{d\Psi}{dS} \equiv \text{slope of the capillary pressure function (m}^{-1}\text{)}$$

The normalized water saturation, S , is related to the physical water saturation (fraction of the pore volume occupied by water) through the following:

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$$S = \frac{S_p - S_r}{1 - S_r} \quad (\text{Eq. III-10})$$

where S_p is the physical water saturation and S_r is the residual water saturation.

The functional relationship for $K(S)$ is the same as given in Equation (III-7), except that the subscript f is dropped for describing matrix flow and the shape factor, β , is the corresponding factor for the matrix instead of the fractures. The capillary pressure function, $\Psi(S)$, is given by (van Genuchten 1980):

$$\Psi(S) = \frac{1}{\alpha} [S^{\beta/(1-\beta)} - 1]^{1/\beta} \quad (\text{Eq. III-11})$$

where α is the van Genuchten capillary pressure scaling factor (m^{-1}) for the matrix.

Equation (III-9) may be rearranged to give:

$$dz = \frac{K(S)\Psi'(S)}{q_s - K(S)} dS \quad (\text{Eq. III-12})$$

From Equation (III-12), we find

$$z = z_b - \int_{S_i}^{S_b} \frac{K\Psi'}{q_s - K} dS \quad (\text{Eq. III-13})$$

where z_b is the coordinate for the bottom of the unit, S_b is the water saturation at the bottom of the unit, and S_i is the saturation at position z . The average normalized water saturation, S_a , is given by

$$S_a = \frac{1}{T} \int_{z_i}^{z_b} S dz = \frac{1}{T} \int_{S_i}^{S_b} \frac{SK\Psi'}{q_s - K} dS \quad (\text{Eq. III-14})$$

where S_i is the normalized water saturation at the top of the unit, z_i is the coordinate at the top of the unit, and $T = z_b - z_i$, is the thickness of the unit.

The calculation procedure for the drainage time is as follows:

1. Using Equation (III-7) solve for the singularity in Equation (III-13) for flow rates, q_s , of 0.0014 m/yr and 0.0021 m/yr. For the ch3z unit, we have found that this singularity is sufficiently close to the saturation that would be obtained using Equation (III-13) to match the layer depth. In fact, this method has been found to be preferable numerically to Equation (III-13) because the depth is sensitive to very small changes in saturation using Equation (III-13), and these small variations in saturation are not significant for subsequent computations. The saturation of the singularity is taken as the saturation at the top of the unit, which may then be evaluated for capillary pressure using Equation (III-11). Given continuity of pressure across the unit interfaces, this

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establishes the capillary pressure at the bottom of the chl_v. Using Equation (III-11), derive the water saturation at the lower contact of the chl_v for both flow rates. (Note that the flow rate 0.00328 m/yr is equal to the saturated hydraulic conductivity of the ch3z. Therefore, at this flow rate, the unit is saturated and the capillary pressure is zero at all positions.)

2. Integrate Equation (III-14) across the chl_v to find the average normalized water saturation for the flow rate of 0.0014 m/yr. Using Equation (III-10), compute the average physical water saturation from the average normalized water saturation. Assume some volume of ECRB Cross Drift construction water, V , is imbibed into the chl_v matrix. (Note that for a one-dimensional system, the volume, V , is expressed in units of length.) Convert this volume of water into a change in saturation by dividing by the thickness and porosity, and add to the average physical water saturation. This is the disturbed, average physical water saturation, S_{pad} .

$$S_{pad} = S_{pa} + \frac{V}{\phi T} \quad (\text{Eq. III-15})$$

Note that if Equation (III-15) results in a value greater than 1, then the disturbed saturation is simply set to 1. Use Equation (III-10) to compute the disturbed, normalized, average water saturation, S_{ad} .

3. Integrate Equation (III-14) across the chl_v to find the average normalized water saturation for a flow rate of 0.0021 m/yr using the boundary saturation computed in step 1. At the higher flow rate of 0.00328 m/yr, the lower boundary of the chl_v is saturated (as discussed in 1. above). Integrate Equation (III-14) across the chl_v to find the average normalized water saturation for a flow rate of 0.00328 m/yr.
4. Let the highest flow rate (0.00328 m/yr) be q_h , the limiting flow rate (0.0021 m/yr) be q_l , and the natural flow rate (0.0014 m/yr) be q_n . Let the average normalized water saturations in the chl_v at the highest and limiting flow rates be S_{ah} and S_{al} , respectively. The drainage time, t_D , is then given by:

$$t_D = T \phi (1 - S_r) \left[\left(\frac{S_{adv} - S_{ahv}}{q_h - q_n} \right) + \left(\frac{S_{ahv} - S_{alv}}{q_l - q_n} \right) \right] \quad (\text{Eq. III-16})$$

The drainage time is defined to be the time for the average water saturation to drop to the value for which the steady flow rate equals the limiting flow rate of 0.0021 m/yr. This equation for the drainage time is simply the sum of the drainage times over the two saturation ranges S_{adv} to S_{ahv} and S_{ahv} to S_{alv} . The volume of water associated with each range is the porosity (ϕ) times the unit thickness T times the normalized saturation difference times the residual saturation factor ($1 - S_r$; to convert from normalized to physical saturation). Each volume is divided by the difference between the outflow rates for the two different saturation ranges, q_h and q_l and the natural inflow rate q_n .

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Finally, the integrals in Equations (III-13) and (III-14) are numerically evaluated using a trapezoidal rule integration routine, "traprule," available in the commercial software package Macsyma Pro (2.2), version 2.6.1c.

Drainage Time Calculations for the ch1v

The ch1v has a thickness of about 19 m (SNL 1997b, Figure III-1). However, the ch1v varies in thickness within the potential repository block. Therefore, additional calculations are carried out for a thickness of 4 m and a thickness of 40 m. To maintain the same total thickness, the ch3z is adjusted such that the total thickness of the combined ch1v and ch3z is always 140 m. The cases investigated are identified in Table III-2, and the calculation results for each case are identified in Tables III-3 through III-6 below.

Table III-2. ch1v and ch3z Thickness Combinations Evaluated

Case	ch1v Thickness (m)	ch3z Thickness (m)
1	4	136
2	19	121
3	40	100

* Total thickness of ch1v and ch3z is 140.

Table III-3. ch1v Drainage Time Calculations Step 1

ch3z T (m)	Flow rate (m/yr)	ch3z S_{tz} - eq (7)	ch3z $\Psi(z_{tz})$ (m) - eq (11)	ch1v S_{bv} - eq (11)
100	0.0014	0.99827	1.1981	0.9025
121	0.0014	0.99827	1.1981	0.9025
136	0.0014	0.99827	1.1981	0.9025
100	0.0021	0.99986	0.1675	0.9883
121	0.0021	0.99986	0.1675	0.9883
136	0.0021	0.99986	0.1675	0.9883

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Table III-4. ch1v Drainage Time Calculations** Step 2

ch1v T (m)	Flow Rate (m/yr)	ch1v S_{iv} - eq (13)	ch1v S_{av} - eq (14)	ch1v S_{pav} - eq (10)	ch1v S_{padv} - eq (15)	ch1v S_{adv} - eq (10)
4	0.0014	0.7285 (1000) [*]	0.8006 (1000) [*]	0.8086	1.0	1.0000
19	0.0014	0.5517 (1000) [*]	0.6567 (1000) [*]	0.6704	0.7697	0.7601
40	0.0014	0.4795 (1000) [*]	0.5792 (1000) [*]	0.5960	0.6432	0.6283

* Number of intervals used in the trapezoidal integration.

** With V (water volume input per unit area) = 0.5 m

Table III-5. ch1v Drainage Time Calculations Step 3

ch1v T (m)	Flow Rate (m/yr)	ch1v S_{ilv} - eq (13)	ch1v S_{alv} - eq (14)
4	0.0021	0.7585 (1000) [*]	0.8526 (1000) [*]
19	0.0021	0.5588 (1000) [*]	0.6782 (1000) [*]
40	0.0021	0.4862 (1000) [*]	0.5929 (1000) [*]
ch1v T (m)	Flow Rate (m/yr)	ch1v S_{ilv} - eq (13)	ch1v S_{alv} - eq (14)
4	0.00328	0.7645 (1000) [*]	0.8634 (1000) [*]
19	0.00328	0.5616 (1000) [*]	0.6831 (1000) [*]
40	0.00328	0.4936 (1000) [*]	0.5977 (1000) [*]

* Number of intervals used in the trapezoidal integration.

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Table III-6. ch1v Drainage Time Calculations Step 4

ch1v T (m)	ch1v t_D (yr) - eq (16)
4	90
19	232
40	235

The maximum drainage time is found for the intermediate thickness of the ch1v, a value of 235 years for a 40-m thickness.

Drainage of Added Water from the ch3z Matrix

The maximum drainage time for the ch3z matrix (which also includes the ch4z, see discussion under steady flow analysis heading) is easily found using the same strategy as used for the ch1v. However, we can just consider the worst case, i.e., that the unit is saturated and must drain to a saturation at which the steady flow rate is 0.0021 m/yr. We assume that the unit drains at the limiting rate of 0.0021 m/yr, which is conservative because we know that the drainage starts out at 0.00328 m/yr and decreases to 0.0021 m/yr. The average normalized saturation for the ch3z at a flow rate of 0.0021 m/yr was established in the previous section to be 0.99986 for a thickness of 121 m. Porosity of the ch3z matrix is 0.24 and the residual saturation is 0.2. A simple "single-step" drainage approximation similar to Equation (III-16) may be given as:

$$t_D = T \phi (1 - S_r) \left(\frac{S_{ad} - S_{ah}}{q_h - q_n} \right) \quad (\text{Eq. III-17})$$

where S_{ad} is 1, S_{ah} is 0.99986, q_h is 0.0021 m/yr, and q_n is 0.0014 m/yr. Using these numbers the drainage time is 0.465 years. Similar, small drainage times are found for thicknesses of 100 m and 136 m.

Drainage of Added Water from the TSw Matrix

Previously, we assumed that a pulse of water introduced to fractures in the TSw hydrogeologic unit from ECRB Cross Drift construction and testing activities would stay primarily in the fracture continuum until reaching the ch1v unit. Here we examine the implications of this assumption and the consequences if water is imbibed by different model units in the TSw hydrogeologic unit. Model calculations that have addressed episodic transient infiltration from the surface indicate that the transient pulse quickly penetrates the densely welded, highly fractured TCw hydrogeologic unit. However, the transient flows are found to imbibe into rock matrix in the nonwelded PTn hydrogeologic unit. The effect of the PTn hydrogeologic unit is to smooth out the short, but intense, transient flow over a longer time period with lower flow rates (CRWMS M&O 1998r). The TSw is similar to the TCw in terms of fracture and matrix

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properties. We base our assumption that water released from the ECRB Cross Drift will travel through fractures in the TSw.

Calculations similar to those for the CHn may be performed to investigate the drainage time for construction water imbibed by the TSw model units. A starting point is to find the average saturations for these units at the undisturbed flow rate of 0.0014 m/yr.

Steady Flow in the TSw

The steady flow profile through the tsw5 is calculated here using the formulation introduced for the ch1v. (Note that Phase II of the ECRB Cross Drift will start in the tsw4 at its easternmost point, and move down in the stratigraphic structure going southwest.) Starting with Equation (III-13), we compute the water saturation at the top of the ch3z, then use Equation (III-11) to compute the capillary pressure at the top of the unit. (Note: Properties for each unit needed in these calculations are given in Table III-8 below). The average saturation may then be obtained using Equation (III-14). For the next unit up in the column, we use Equation (III-11) again to find the water saturation at the bottom of this next unit so that the capillary pressure is the same as found at the top of the unit immediately below. We can repeat this process unit by unit up through the column to obtain the saturation profile in the TSw. The resultant saturation profile is identified in Table III-7 below.

Table III-7. TSw Hydrogeologic Unit Saturation Profile

Model Unit	S_b - eq (11)	S_t - eq (13)	S_a - eq (14)	Ψ_t (m) - eq (11)
ch3z	0.9999**	0.9983 (from Equation [III-7] - see Table III-3)	0.9985 (1000)	1.1981
ch1v	0.9025	0.5517 (1000)	0.6567 (1000)	19.82
tsw7	0.9501	0.95056 (1000)	0.9511 (10000)	19.7
tsw6	0.9855	0.8827 (1000)	0.9365 (1000)	74.7
tsw5	0.7199	0.9885544 (1000)	0.9810 (1000)	-----

* Number of intervals used in the trapezoidal integration.

** The value of water saturation at the base of the ch3z is taken to be essentially saturated because this is the saturated zone boundary. A value of 0.99999999 was used instead of 1.0 because $d\Psi/dS$ becomes infinite at 1.0.

As shown in Table III-7, the water saturations in the TSw model units are high, ranging from about 94 to 97 percent. The saturations are higher than measurements reported in Bodvarsson et

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al. (1997), suggesting that water flow rates through the matrix are less than 0.0014 m/yr. Therefore, we do expect fracture flow to carry a portion of the natural percolation flux through the TSw model units. This lends further justification to the assumption that a short, intense pulse of introduced water to the TSw will primarily flow through the fractures.

Drainage Time Estimates for the TSw

The tsw7 matrix has a low porosity (0.02). Using Equation (III-10), the average physical saturation is found to be 0.9756 and the total volume that could be stored in the matrix is only about 0.0093 m of water. Therefore, a limiting drainage time for the tsw7 may be computed using Equation (III-17) to be 7 years.

The tsw6 has a much larger storage capacity than the tsw7. Using Equation (III-10), the average physical saturation of the tsw6 is 0.9479. The total volume that could be stored is 0.31 m, less than the test value of 0.5 m. Using Equation (III-13), and assuming the same boundary condition at the tsw6/tsw7 interface, we compute the S_i of the tsw6 for a flow rate of 0.0021 m/yr to be 0.8921. Using Equation (III-14), the average saturation is found to be 0.9403, corresponding to an average physical saturation (using Equation [III-10]) of 0.9510. Using the simple one-step drainage approximation, Equation (III-17), we find a drainage time of 418 years. Although this is somewhat longer than the 300 year period we have selected for limiting flow, the single-step drainage approximation used is very conservative. For example, the initial drainage rate would proceed at a flow rate equal to the saturated hydraulic conductivity, 0.0321 m/yr. This is 15 times higher than the conservatively assumed rate. Given this conservatism and the fact that water is not expected to be strongly imbibed into the tsw6, drainage of construction water from the tsw6 matrix is not expected to significantly prolong the time for flow rates to fall below the threshold flow rate.

The tsw5 is found to have a relatively high average saturation under the natural flow rate. Using Equation (III-13), and assuming the same boundary condition at the tsw5/tsw6 interface, we compute the S_i of the tsw6 for a flow rate of 0.0021 m/yr to be 0.9962. Using Equation (III-14), the average saturation is found to be 0.9903, corresponding to an average physical saturation (using Equation [III-10]) of 0.9911. For a simple one-step drainage approximation (drainage proceeds at a rate of 0.0021 m/yr, with incoming flow rate of 0.0014 m/yr) we use Equation (III-17) to find a drainage time of 139 years. The limited available storage capacity and lower saturated hydraulic conductivity of this unit leads to the lower drainage times, despite being thicker than the other TSw model units.

The tsw4 has a saturated hydraulic conductivity of 0.00146 m/yr, and therefore, could not release water at rates above the limiting flow rate of 0.0021 m/yr.

Overall Bound for Drainage Time

The drainage times considered so far have relied on the specific properties of the different units. However, a simple bound on the drainage time may be computed that is independent of the specific properties of the units. If we assume that we drain the entire quantity of added water,

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0.5 m, and that we do so at the limiting flow rate of 0.0021 m/yr, with natural influx of 0.0014 m/yr, then the drainage time is 714 years.

Table III-8. Properties for the Model Units (from CRWMS M&O 1998r)

ch3z:			
	Permeability	$9.12 \times 10^{-18} \text{ m}^2$	$(3.28 \times 10^{-3} \text{ m/yr})$
	Porosity	0.240	
	van Genuchten α	$1.95 \times 10^{-6} \text{ Pa}^{-1}$	(0.0191 m^{-1})
	van Genuchten m	0.220	$(\beta = 1/(1-m) = 1.28)$
	Residual Saturation	0.20	
	Thickness (including ch4z)	121.0 m	
ch1v:			
	Permeability	$1.32 \times 10^{-12} \text{ m}^2$	$(475. \text{ m/yr})$
	Porosity	0.265	
	van Genuchten α	$6.61 \times 10^{-5} \text{ Pa}^{-1}$	(0.647 m^{-1})
	van Genuchten m	0.190	$(\beta = 1/(1-m) = 1.23)$
	Residual Saturation	0.040	
	Thickness	19.0 m	
tsw7:			
	Permeability	$1.29 \times 10^{-17} \text{ m}^2$	$(4.64 \times 10^{-3} \text{ m/yr})$
	Porosity	0.020	
	van Genuchten α	$1.55 \times 10^{-6} \text{ Pa}^{-1}$	(0.0152 m^{-1})
	van Genuchten m	0.387	$(\beta = 1/(1-m) = 1.63)$
	Residual Saturation	0.50	
	Thickness	19.0 m	
tsw6:			
	Permeability	$8.91 \times 10^{-17} \text{ m}^2$	$(3.21 \times 10^{-2} \text{ m/yr})$
	Porosity	0.092	
	van Genuchten α	$7.41 \times 10^{-7} \text{ Pa}^{-1}$	(0.00725 m^{-1})
	van Genuchten m	0.414	$(\beta = 1/(1-m) = 1.71)$
	Residual Saturation	0.18	

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Table III-8. Properties for the Model Units (from CRWMS M&O 1998r) (Continued)

	Thickness	65.0 m	
tsw5:			
	Permeability	$1.55 \times 10^{-17} \text{ m}^2$	$(5.58 \times 10^{-3} \text{ m/yr})$
	Porosity	0.115	
	van Genuchten α	$3.31 \times 10^{-6} \text{ Pa}^{-1}$	(0.0324 m^{-1})
	van Genuchten m	0.229	$(\beta = 1/(1-m) = 1.30)$
	Residual Saturation	0.080	
	Thickness	95.0 m	
tsw4:			
	Permeability	$4.07 \times 10^{-18} \text{ m}^2$	$(1.46 \times 10^{-3} \text{ m/yr})$
	Porosity	0.089	
	van Genuchten α	$1.02 \times 10^{-6} \text{ Pa}^{-1}$	(0.00998 m^{-1})
	van Genuchten m	0.322	$(\beta = 1/(1-m) = 1.47)$
	Residual Saturation	0.180	
	Thickness	41.0 m	
Conditions:			
	Temperature	27 C	
	Kinematic Viscosity	$0.0086 \text{ cm}^2/\text{s}$	
	Density	0.997 gm/cm^3	(997 kg/m^3)

ATTACHMENT IV

*Determination of Importance Evaluation for the ESF Enhanced Characterization of the
Repository Block Cross Drift*

ATTACHMENT IV FIGURES FOR SECTION 11

Figure IV-1. Base case "Point Load" Design Layout (Dunlap et al. 1997)

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Figure IV-2. Schematic of the Y-Z Grid (partial) Parallel to Waste Emplacement Drift

nz	Material	nx = 1 Thickness (m)	ny	1	2	3	4	5	6	7	8	9	10	11	12	13
				cf1	drift	drift	cf2	cf2	drift	drift	cf3	cf3	drift	dfl	dfl	drift
				2.935	3.011	3.011	2.650	2.650	4.638	4.638	2.650	2.650	2.949	2.685	2.685	2.254
18	TSw3	13.116														
19	TSw3	7.116														
20	TSw4	6.000														
21	TSw4	7.454														
22	TSw4	5.000														
23	TSw4	3.000														
24	TSw4	3.000														
25	TSw4	3.000														
26	TSw4	1.500														
27	TSw5	2.500														
28	TSw5	3.640														
29	TSw5	2.000														
30	TSw5	1.000														
31	TSw5	0.570														
32	TSw5	0.290														
33	liner	0.177														
34	drift	0.354														
35	drift	0.936														
36	drift	1.445														
37	WP	0.723														
38	WP	0.723														
39	invert	0.340														
40	liner	0.177														
41	TSw5	0.265														

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nz	Material	ny = 1 Thickness (m)	nx	1	2	3	4	5	6	7	8	9	10	11
				WP	drift	drift	liner	rock	rock	rock	rock	rock	rock	rock
				0.723	1.184	0.354	0.177	0.300	0.600	1.000	1.600	2.200	2.732	3.132
18	TSw3	13.116												
19	TSw3	7.116												
20	TSw4	6.000												
21	TSw4	7.454												
22	TSw4	5.000												
23	TSw4	3.000												
24	TSw4	3.000												
25	TSw4	3.000												
26	TSw4	1.500												
27	TSw5	2.500												
28	TSw5	3.640												
29	TSw5	2.000												
30	TSw5	1.000												
31	TSw5	0.570												
32	TSw5	0.290												
33	liner	0.177												
34	drift	0.354												
35	drift	0.936												
36	drift	1.445												
37	WP	0.723												
38	WP	0.723												
39	invert	0.340												
40	liner	0.177												
41	TSw5	0.265												

Figure IV-3. Schematic of the X-Z Grid (partial) Perpendicular to Waste Emplacement Drift

ATTACHMENT IV

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-4. Schematic of the Y-Z Grid (partial) Parallel to Waste Emplacement Drift Showing the Location of the CF3 and CF4 ECRB Drifts

nz	Material	nx = 1 Thickness (m)	ny	1	2	3	4	5	6	7	8	9	10	11	12	13	14
				cfl	drift	drift	cf2	cf2	drift	drift	cf3	cf3	drift	df1	df1	drift	cf4
				2.935	3.011	3.011	2.650	2.650	4.638	4.638	2.650	2.650	2.949	2.685	2.685	2.254	2.650
18	TSw3	13.116															
19	TSw3	7.116															
20	TSw4	6.000															
21	TSw4	7.454															
22	TSw4	5.000															
23	TSw4	3.000															
24	TSw4	3.000															
25	TSw4	3.000									tsw4						tsw4
26	TSw4	1.500															
27	TSw5	2.500															
28	TSw5	3.640															
29	TSw5	2.000									tsw5			tsw5			tsw5
30	TSw5	1.000															
31	TSw5	0.570															
32	TSw5	0.290															
33	liner	0.177															
34	drift	0.354															
35	drift	0.936									cf3						cf4
36	drift	1.445															
37	WP	0.723															
38	WP	0.723															
39	invert	0.340															
40	liner	0.177															
41	TSw5	0.265															

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-5. Schematic of the X-Z Grid (partial) Perpendicular to Waste Emplacement Drift
Showing the Location of the CF3 and CF4 ECRB Drifts

nz	Material	ny = 8 & 14 Thickness (m)	nx	1	2	3	4	5	6	7	8	9	10	11
				WP	drift	drift	liner	rock	rock	rock	rock	rock	rock	rock
				0.723	1.184	0.354	0.177	0.300	0.600	1.000	1.600	2.200	2.732	3.132
18	TSw3	13.116												
19	TSw3	7.116												
20	TSw4	6.000												
21	TSw4	7.454												
22	TSw4	5.000												
23	TSw4	3.000												
24	TSw4	3.000												
25	TSw4	3.000												
26	TSw4	1.500												
27	TSw5	2.500												
28	TSw5	3.640												
29	TSw5	2.000												
30	TSw5	1.000												
31	TSw5	0.570												
32	TSw5	0.290												
33	liner	0.177												
34	drift	0.354												
35	drift	0.936												
36	drift	1.445												
37	WP	0.723												
38	WP	0.723												
39	invert	0.340												
40	liner	0.177												
41	TSw5	0.265												

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-6. Schematic of the Y-Z Grid (partial) Parallel to Waste Emplacement Drift Showing the Location of the WE ECRB Drifts

nz	Material	nx = 1 Thickness (m)	ny	1	2	3	4	5	6	7	8	9	10	11	12	13	14
				cf1	drift	drift	cf2	cf2	drift	drift	cf3	cf3	drift	df1	df1	drift	cf4
				2.935	3.011	3.011	2.650	2.650	4.638	4.638	2.650	2.650	2.949	2.685	2.685	2.254	2.650
18	TSw3	13.116															
19	TSw3	7.116															
20	TSw4	6.000															
21	TSw4	7.454															
22	TSw4	5.000															
23	TSw4	3.000															
24	TSw4	3.000															
25	TSw4	3.000															
26	TSw4	1.500															
27	TSw5	2.500															
28	TSw5	3.640															
29	TSw5	2.000															
30	TSw5	1.000															
31	TSw5	0.570															
32	TSw5	0.290															
33	liner	0.177															
34	drift	0.354															
35	drift	0.936															
36	drift	1.445															
37	WP	0.723															
38	WP	0.723															
39	invert	0.340															
40	liner	0.177															
41	TSw5	0.265															

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-7. Schematic of the X-Z Grid (partial) Perpendicular to Waste Emplacement Drift Showing the Location of the WE ECRB Drift

nz	Material	ny = 8 & 14 Thickness (m)	nx	1	2	3	4	5	6	7	8	9	10	11
				WP	drift	drift	liner	rock	rock	rock	rock	rock	rock	rock
				0.723	1.184	0.354	0.177	0.300	0.600	1.000	1.600	2.200	2.732	3.132
18	TSw3	13.116												
19	TSw3	7.116												
20	TSw4	6.000												
21	TSw4	7.454												
22	TSw4	5.000												
23	TSw4	3.000												
24	TSw4	3.000												
25	TSw4	3.000												
26	TSw4	1.500												
27	TSw5	2.500												
28	TSw5	3.640												
29	TSw5	2.000												
30	TSw5	1.000												
31	TSw5	0.570												
32	TSw5	0.290												
33	liner	0.177												
34	drift	0.354												
35	drift	0.936												
36	drift	1.445												
37	WP	0.723												
38	WP	0.723												
39	invert	0.340												
40	liner	0.177												
41	TSw5	0.265												

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-8. Temperature History Plots for Specific WE Drift Locations for the 11.5 mm/yr Base, CF3, CF4, and WE Cases

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Figure IV-9. Relative Humidity History Plots For Specific WE Drift Locations for the 11.5 mm/yr Base, CF3, CF4, and WE Cases

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Figure IV-10. Temperature History Plots for the tsw5 Grid Block Located Above the CF3 Waste Package for the 11.5 mm/yr Base, CF3, CF4, and WE Cases

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-11. Temperature History Plots for the tsw5 Grid Block Located Above the CF4 Waste Package for the 11.5 mm/yr Base, CF3, CF4, and WE Cases

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-12. Temperature History Plots for the Grid Blocks Located Above the CF3 and CF4 Waste Packages that Contain TSW4 or ECRB Properties for the 11.5 mm/yr Base, CF3, CF4, and WE Cases

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Figure IV-13. Temperature History Plots for Specific WE Drift Locations for the 6.5 and 11.5 mm/yr Base Cases

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Figure IV-14. Relative Humidity History Plots for Specific WE Drift Locations for the 6.5 and 11.5 mm/yr Base Cases

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Figure IV-15. Temperature History Plots for Specific tsw4 and tsw5 Grid Blocks Located Above the CF3 and CF4 Waste Packages for the 6.5 and 11.5 mm/yr Base Cases

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Figure IV-16. Temperature History Plots for Specific WE Drift Locations for the 6.5 mm/yr Base, CF4, and WE Cases

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Figure IV-17. Relative Humidity History Plots for Specific WE Drift Locations for the 6.5 mm/yr Base, CF4, and WE Cases

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Figure IV-18. Temperature History Plots for the tsw5 Grid Block Located Above the CF3 Waste Package for the 6.5 mm/yr Base, CF4, and WE Cases

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Figure IV-19. Temperature History Plots for the tsw5 Grid Block Located Above the CF4 Waste Package for the 6.5 mm/yr Base, CF4, and WE Cases

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-20. Temperature History Plots for Specific WE Drift Locations for the 11.5 mm/yr Base Case and the 11.5 mm/yr CF4 and WE Cases with Increased Initial Liquid Saturation in the TSw5 Grid Blocks between the ECRB and WE Drifts

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-21. Relative Humidity History Plots for Specific WE Drift Locations for the 11.5 mm/yr Base Case and the 11.5 mm/yr CF4 and WE Cases with Increased Initial Liquid Saturation in the TSw5 Grid Blocks between the ECRB and WE Drifts

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Figure IV-22. Temperature History Plots for the tsw5 Grid Block Located Above the CF3 Waste Package for the 11.5 mm/yr Base Case and the 11.5 mm/yr CF4 and WE Cases with Increase initial Liquid Saturation of 0.99 in the TSW5 Grid Blocks between the ECRB and WE Drifts

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-23. Temperature History Plots for the tsw5 Grid Block Located Above the CF4 Waste Package for the 11.5 mm/yr Base Case and the 11.5 mm/yr CF4 and WE Cases with Increase Initial Liquid Saturation of 0.99 in the TSw5 Grid Blocks between the ECRB and WE Drifts

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-24. Profile, Parallel to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 11.5 mm/yr Base Case

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-25. Profile, Perpendicular to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 11.5 mm/yr Base Case

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-26. Profiles, Parallel to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 11.5 mm/yr Base and CF4 Cases

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Figure IV-27. Profile, Perpendicular to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 11.5 mm/yr Base and CF4 Cases

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Figure IV-28. Profiles, Parallel to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 6.5 and 11.5 mm/yr CF4 Cases

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-29. Profile, Perpendicular to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 6.5 and 11.5 mm/yr CF4 Cases

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Figure IV-30. Profiles, Parallel to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 1, 10, 30, and 300 years for the 11.5 mm/yr CF4 Cases with Initial Ambient Liquid Saturations and with Increased Initial Liquid Saturation in the TSw5 Grid Blocks between the ECRB and WE Drifts

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Figure IV-31. Profile, Perpendicular to the WE Drift, of the Vertical Liquid Flux through the tsw5 grid layer at 1, 10, and 30 years for the 11.5 mm/yr CF4 Cases with Initial Ambient Liquid Saturations and with Increased Initial Liquid Saturation in the TSw5 Grid Blocks between the ECRB and WE Drifts

*Determination of Importance Evaluation for the ESF Enhanced Characterization of the
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Figure IV-32. Percolation Flux Frequency Plot for Repository Emplacement Area LBNL Parameter Set #1

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Figure IV-33. Percolation Flux Frequency Plot for Repository Emplacement Area LBNL Parameter Set #2

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Figure IV-34. Percolation Flux Frequency Plot for Repository Emplacement Area LBNL Parameter Set #3

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Figure IV-35. Flux Response at the Water Table ECRB Input: 1 m over 5 days at time 0, steady flow of 0.00724 m/yr

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Figure IV-36. Flux Response at the Water Table ECRB Input: 1 m over 5 days at time 0, steady flow of 0.001448 m/yr

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Figure IV-37. Flux Response at the Water Table ECRB Input: 0.5 m over 5 days at time 0, steady flow of 0.001448 m/yr

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-38. Organic Limit per Distance from Closest Waste Emplacement Area

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Figure IV-39. Profiles, Parallel to the WE Drift, of the Vertical Liquid Flux through the tsw5 Grid Layer at 30, 300, 5,000, 40,000, and 100,000 years for the 59.21 mm/yr with ECRB Drift Above CF4

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ATTACHMENT V

SECTION 11.1.2.4 SUPPLEMENTAL CALCULATIONS

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

SECTION 11.1.2.4 SUPPLEMENTAL CALCULATIONS

Model Abstraction for Episodic Transient Flow in a Fracture/Matrix System; Model Assumptions, Formulation and Solution Methods

Transient Fracture Flow Model with Matrix Absorption

To begin the model derivation, we assume the following:

1. One-dimensional flow
2. Dual porosity; vertical flow in fractures, horizontal absorption in matrix
3. Gravity dominated flow in fractures
4. Capillary dominated flow in matrix

Using these assumptions, we construct a mathematical representation of the flow process using differential material balance equations for the fractures and matrix, respectively,

$$\phi_f \frac{\partial S_f}{\partial t} + \phi_m \frac{\partial \bar{S}_m}{\partial t} + \frac{\partial V_f}{\partial z} = 0 \quad (\text{Eq. V-1})$$

and

$$\phi_m \frac{\partial S_m}{\partial t} + \frac{\partial V_m}{\partial x} = 0 \quad (\text{Eq. V-2})$$

where z is the vertical coordinate; x is the horizontal coordinate describing distance into the matrix from the fractures; t is the time; $\phi_f(z)$ is the fracture porosity; $\phi_m(z)$ is the matrix porosity; $V_f(z, t)$ and $V_m(x, t; z)$ are the fracture and matrix Darcy velocities in the z and x directions, respectively; $S_f(z, t)$ and $S_m(x, t, z)$ are the fracture and matrix water saturations, respectively; and $\bar{S}_m$ is the average matrix saturation defined by:

$$\bar{S}_m(t; z) = \frac{1}{L_f} \int_0^{L_f} S_m(x, t; z) dx \quad (\text{Eq. V-3})$$

where $L_f(z)$ is the fracture half-spacing. Assuming gravity driven flow in the fractures (ignoring pressure gradients in the fractures) and capillary driven flow in the matrix (i.e., no gravity), the Darcy flow rates are given by:

$$V_f(S_f, z) = K_{fs}(z) k_{rf}(S_f) \quad (\text{Eq. V-4})$$

$$V_m(S_m; z) = K_m(S_m; z) \frac{d\Psi_m(S_m; z)}{dS_m} \frac{\partial S_m}{\partial x} \quad (\text{Eq. V-5})$$

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

where $K_{fs}(z)$ is the saturated hydraulic conductivity of the fractures, k_{rf} is the fracture relative permeability, $K_m(S_m; z)$ is the effective conductivity of the matrix, and $\Psi_m(S_m; z)$ is the capillary pressure.

Matrix Imbibition Model

Substituting Equation (V-5) into Equation (V-2) gives:

$$\frac{\partial S_m}{\partial t} = \frac{\partial}{\partial x} \left\{ D_s \frac{\partial S_m}{\partial x} \right\} \quad (\text{Eq. V-6})$$

where

$$D_s = - \frac{1}{\phi_m} K_m \frac{d \Psi_m}{d S_m} \quad (\text{Eq. V-7})$$

The expression for D_s is a function of S_m and z . Philip (1969) has shown that integral properties (such as $\overline{S_m}$) for a step change boundary condition and a semi-infinite medium may be modeled *exactly* using a constant value of $D_s = D_s^*$, where

$$D_s^* = \frac{\pi F_s^2}{4 \phi_m^2 (S_{m0} - S_{mi})^2} \quad (\text{Eq. V-8})$$

S_{m0} is the boundary matrix saturation at the fracture/matrix interface, S_{mi} is the initial (uniform) matrix saturation, and F_s is the “sorptivity function” for one-dimensional imbibition defined by

$$F_s = \phi_m \int_{S_{mi}}^{S_m} \Phi(S_m) d S_m \quad (\text{Eq. V-9})$$

$$D_s(S_m) = - \frac{1}{2} \frac{d \Phi}{d S_m} \int_{S_{mi}}^{S_m} \Phi(\sigma) d \sigma \quad (\text{Eq. V-10})$$

Therefore, let

$$D_s(S_m, z) = D_s^*(z) \quad (\text{Eq. V-11})$$

The general form of $K_m(S_m; z)$ and $\Psi_m(S_m; z)$ (and its derivative with respect to S_m) show opposite trends, i.e., as saturation decreases $K_m(S_m; z)$ decreases and the derivative of $\Psi_m(S_m; z)$ increases.

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Both of these functions can be separated into a product of a dimensional scaling factor and a dimensionless factor that contains the saturation dependence,

$$K_m(S_m, z) = K_{ms}(z) k_{rm}(S_m, z)$$

$$\Psi(S_m, z) = \frac{1}{\alpha_m(z)} \psi_m(S_m, z)$$

where α_m is the van Genuchten capillary pressure scale factor (Van Genuchten 1980), and K_{ms} is the matrix saturated hydraulic conductivity. Therefore, Equation (V-7) may be written as,

$$D_s = - \frac{K_{ms}}{\phi_m \alpha_m} k_{rm} \frac{d \psi_m}{d S_m}$$

This suggests that the value of D_s^* may be reasonably approximated by the following:

$$D_s^* = \frac{K_{ms}}{\phi_m \alpha_m} \quad (\text{Eq. V-12})$$

Substituting Equation (V-11) into Equation (V-6) gives:

$$\frac{\partial S_m}{\partial t} = D_s^* \frac{\partial^2 S_m}{\partial x^2} \quad (\text{Eq. V-13})$$

The boundary and initial conditions for a step input are:

$$S_m(x, 0; z) = S_{mi} \quad L_f > x > 0 \quad (\text{Eq. V-14})$$

$$S_m(0, t; z) = S_{m0} \quad t > 0 \quad (\text{Eq. V-15})$$

$$\frac{\partial S_m}{\partial x}(L_f, t; z) = 0 \quad t > 0 \quad (\text{Eq. V-16})$$

As indicated by Equation (V-1), the average matrix saturation is needed. Take the spatial average of Equation (V-13) over x to give

$$\frac{\partial \overline{S_m}}{\partial t} = - \frac{D_s^*}{L_f} \frac{\partial S_m}{\partial x} \Big|_{x=0} \quad (\text{Eq. V-17})$$

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

The spatial derivative of S_m at $x = 0$ may be approximated by the difference in the boundary saturation, S_{m0} and the initial saturation, S_{mi} , divided by the matrix imbibition length scale, L_p . This gives:

$$\left. \frac{\partial S_m}{\partial x} \right|_{x=0} = \frac{S_{mi} - S_{m0}}{L_p} \quad (\text{Eq. V-18})$$

This approximation assumes that the change in matrix saturation during a given transient flow event through the fractures is small. Using Equation (V-18), Equation (V-17) becomes:

$$\frac{\partial \overline{S_m}}{\partial t} = - \frac{D_s^*}{L_f L_p} (S_{mi} - S_{m0}) \quad (\text{Eq. V-19})$$

Now, S_{m0} is set by capillary equilibrium between the water in the fractures and the matrix, i.e.,

$$\psi_m(S_{m0}) = \psi_f(S_f) \text{ or} \quad (\text{Eq. V-20})$$

$$S_{m0} = \psi_m^{-1}(\psi_f(S_f)) \quad (\text{Eq. V-21})$$

The contact area between the fractures and matrix is postulated to be proportional to the fracture relative permeability. Therefore, Equation (V-19) is modified to be:

$$\frac{\partial \overline{S_m}}{\partial t} = - \frac{D_s^* k_{rf}(S_f)}{L_f L_p} (S_{mi} - \psi_m^{-1}(\psi_f(S_f))) \quad (\text{Eq. V-22})$$

where $k_{rf}(S_f)$ is the fracture relative permeability function. The capillary equilibrium function is assumed to be nearly unity (or the maximum saturation in the matrix) until S_f becomes very small. Therefore, Equation (V-22) becomes,

$$\frac{\partial \overline{S_m}}{\partial t} = \frac{D_s^* k_{rf}}{L_f L_p} (1 - S_{mi}) \quad (\text{Eq. V-23})$$

Transient Fracture Flow with Matrix Imbibition

Substituting Equations (V-23) and (V-4) into Equation (V-1) gives

$$\frac{\partial S_f}{\partial t} + \frac{K_{fs}}{\phi_f} \frac{d k_{rf}}{d S_f} \frac{\partial S_f}{\partial z} + \frac{\phi_m}{\phi_f} \frac{D_s^*}{L_f L_p} (1 - S_{mi}) k_{rf} + \frac{k_{rf}}{\phi_f} \frac{d K_{fs}}{d z} = 0 \quad (\text{Eq. V-24})$$

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

Define the following dimensionless variables:

$$t_D = \frac{\overline{K_{fs}} t}{L_{wt}} \quad (\text{Eq. V-25})$$

$$z_D = \frac{\overline{K_{fs}}}{L_{wt}} \int_0^z \frac{\phi_f(\xi)}{K_{fs}(\xi)} d\xi \quad (\text{Eq. V-26})$$

$$\gamma(z) = \frac{\phi_m(z)}{\phi_f(z)} \frac{L_{wt}}{\overline{K_{fs}}} \frac{D_s^*(z)}{L_f(z) L_p(z)} (1 - S_{mi}(z)) + \frac{1}{\phi_f(z)} \frac{L_{wt}}{\overline{K_{fs}}} \frac{dK_{fs}(z)}{dz} \quad (\text{Eq. V-27})$$

or, in terms of z_D ,

$$\gamma(z_D) = \frac{\phi_m(z_D)}{\phi_f(z_D)} \frac{L_{wt}}{\overline{K_{fs}}} \frac{D_s^*(z_D)}{L_f(z_D) L_p(z_D)} (1 - S_{mi}(z_D)) + \frac{d \ln\{K_{fs}(z_D)\}}{dz_D} \quad (\text{Eq. V-28})$$

where L_{wt} is the distance from the ground surface to water table, γ is the matrix sorptivity, and $\overline{K_{fs}}$ is an average saturated fracture hydraulic conductivity (e.g., the harmonic mean, geometric mean, etc.). Using these dimensionless variables, Equation (V-24) becomes

$$\frac{\partial S_f}{\partial t_D} + \frac{d k_{rf}}{d S_f} \frac{\partial S_f}{\partial z_D} + \gamma k_{rf} = 0 \quad (\text{Eq. V-29})$$

Iterative Improvement

The above flow model (Equation [V-29]) may be initially solved using the approximation that spatial gradients of water saturation in the matrix, L_p , are scaled by the fracture spacing, L_f . This approximation is reasonable if the matrix imbibition “source” term, i.e., the transient fracture water saturation, is present for a long time compared with the imbibition time scale, L_f^2/D_s^* . For shorter exposures to water, the matrix imbibition will be stronger due to larger water saturation gradients in the matrix that are dominated by shorter length scales associated with the imbibition process itself (rather than the fracture spacing). This feedback scenario can only be approximately included in the flow model as developed here. One way to include this effect in an approximate manner is to define an “exposure” time. This time is weighted by the fracture flux because fracture/matrix interactions during higher-flux conditions are more important to the overall transient flow problem. The flux-weighted exposure time, σ_D , is given by the following:

Determination of Importance Evaluation for the ESF Enhanced Characterization of the Repository Block Cross Drift

For the case

$$z_D < p_{Dlb} \quad \text{and} \quad t_{Dpl} + T_D > t_{DBC} \quad (\text{Eq. V-30})$$

$$\sigma_D(z_D) = \frac{\left\{ \int_{t_{Dpl}}^{t_{DBC}} (t_D - t_{Dpl}) S_f^n dt_D + \int_{t_{DBC}}^{t_{Dpl} + T_D} (t_D - t_{Dpl}) S_f^n dt_D + \int_{t_{Dpl} + T_D}^{\infty} T_D S_f^n dt_D \right\}}{\left\{ \int_{t_{Dpl}}^{t_{DBC}} S_f^n dt_D + \int_{t_{DBC}}^{\infty} S_f^n dt_D \right\}} \quad (\text{Eq. V-31})$$

where T_D is the matrix imbibition time scale over the fracture spacing, defined by the following:

$$T_D = \frac{L_f^2}{D_s^*} \frac{\overline{K_{fs}}}{L_{wt}} \quad (\text{Eq. V-32})$$

For the case

$$z_D < p_{Dlb} \quad \text{and} \quad t_{DBC} > t_{Dpl} + T_D \quad (\text{Eq. V-33})$$

$$\sigma_D(z_D) = \frac{\left\{ \int_{t_{Dpl}}^{t_{Dpl} + T_D} (t_D - t_{Dpl}) S_f^n dt_D + \int_{t_{Dpl} + T_D}^{t_{DBC}} T_D S_f^n dt_D + \int_{t_{DBC}}^{\infty} T_D S_f^n dt_D \right\}}{\left\{ \int_{t_{Dpl}}^{t_{DBC}} S_f^n dt_D + \int_{t_{DBC}}^{\infty} S_f^n dt_D \right\}} \quad (\text{Eq. V-34})$$

Finally, for the case

$$z_D > p_{Dlb} \quad (\text{Eq. V-35})$$

$$\sigma_D(z_D) = \frac{\left\{ \int_{t_{Dpl}}^{t_{Dpl} + T_D} (t_D - t_{Dpl}) S_f^n dt_D + \int_{t_{Dpl} + T_D}^{\infty} T_D S_f^n dt_D \right\}}{\left\{ \int_{t_{Dpl}}^{\infty} S_f^n dt_D \right\}} \quad (\text{Eq. V-36})$$

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The penetration length for matrix imbibition derived from these average exposure times (σ_D) is given by:

$$L_p(z_D) = \sqrt{D_s^* \sigma_D(z_D)} \quad (\text{Eq. V-37})$$

However, this is based on an initial estimate from the transient flow calculation that σ_D underestimates the exposure time due to an initial guess of the matrix imbibition length scale of L_f , which is too large (and allows quicker penetration of the transient pulse through the fractures due to reduced matrix interaction). The initial underestimate of exposure time will result in an underestimate of L_p in Equation (V-37) and, therefore, an overestimate of matrix imbibition with the iterative improvement. A better approximation to L_p could be argued to be somewhere between the value given by Equation (V-37) and the fracture spacing, L_f . This qualitative argument leads to the following geometric average length as a better approximation:

$$L_p(z_D) = \left\{ \sqrt{D_s^* \sigma_D(z_D)} L_p^*(z_D) \right\}^{\frac{1}{2}} \quad (\text{Eq. V-38})$$

where L_p^* is the penetration depth from the previous iteration. To start the iteration, let $L_p^* = L_f$. The use of Equation (V-38) requires the solution first be calculated using a fixed length scale, L_f . Improved estimates for L_p may be derived using revised values for σ_D from the appropriate relationships given above and Equation (V-38). Upon each calculation for a revised value of L_p , as a function of position, the flow field is recalculated. The iterative process can be continued until a satisfactory assignment of $L_p(z_D)$ is obtained.

An "exposure time" for the analogous process, matrix diffusion, can be derived using the same method as discussed above by substituting the relevant molecular diffusion coefficient for the hydraulic diffusivity to define a molecular diffusion time scale T_{dm} .

Solution to the Transient Fracture Flow Model

The equation describing the evolution of water saturation in the fractures under transient conditions is given by Equation (V-29), restated here:

$$\frac{\partial S_f}{\partial t_D} + \frac{d k_{rf}}{d S_f} \frac{\partial S_f}{\partial z_D} + \gamma k_{rf} = 0 \quad (\text{Eq. V-39})$$

A general solution for this problem is developed using the following relationships for fracture relative permeability:

$$k_{rf}(S_f) = S_f^n \quad (\text{Eq. V-40})$$

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Equation (V-39) is a first-order, nonlinear, hyperbolic equation for S_f . The solution may be developed using the method of characteristics. The time-evolution of S_f along a characteristic curve is given by Whitham (1974):

$$\frac{d S_f}{d t_D} = -\gamma S_f^n \quad (\text{Eq. V-41})$$

where the characteristics curve is a solution to:

$$\frac{d z_D}{d t_D} = n S_f^{n-1} \quad (\text{Eq. V-42})$$

Now, γ is a function of z_D , therefore, to obtain a form of Equation (V-41) that can be independently integrated, divide Equation (V-41) by Equation (V-42) to give:

$$\frac{d S_f}{d z_D} = \frac{\gamma}{n} S_f \quad (\text{Eq. V-43})$$

This may be integrated from $z_D = z_{Ds}$ (the ground surface if $z_s = 0$) to some depth z_D . At $z_D = z_{Ds}$, the water saturation, $S_{f0}(\tau)$, varies as a function of time. Integrating Equation (V-43) gives:

$$\int_{S_{f0}(\tau)}^{S_f} \frac{d \sigma}{\sigma} = -\frac{1}{n} \int_{z_{Ds}}^{z_D} \gamma(\xi) d \xi \quad (\text{Eq. V-44})$$

Let the integral of γ be defined by:

$$\Gamma(z_D) = \frac{1}{n} \int_{z_{Ds}}^{z_D} \gamma(\xi) d \xi \quad (\text{Eq. V-45})$$

Solving Equation (V-44) for S_f gives:

$$S_f(z_D, \tau) = S_{f0}(\tau) \exp\{-\Gamma(z_D)\} \quad (\text{Eq. V-46})$$

This expression may be used to integrate the characteristic paths in Equation (V-42). Substituting Equation (V-46) for S_f into Equation (V-42) gives:

$$\frac{d z_D}{d t_D} = n S_{f0}^{n-1} \exp\{-(n-1)\Gamma\} \quad (\text{Eq. V-47})$$

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Integrating Equation (V-47) from $z_D = z_{Ds}$ to z_D and $t_D = \tau$ to t_D gives:

$$S_f O^{n-1}(t_D - \tau) = \frac{1}{n} \int_{z_{Ds}}^{z_D} \exp \{ (n-1) \Gamma(\xi) \} d\xi \quad (\text{Eq. V-48})$$

Define the integral in Equation (V-48) to be:

$$\Omega(z_D; z_{Ds}) = \frac{1}{n} \int_{z_{Ds}}^{z_D} \exp \{ (n-1) \Gamma(\xi) \} d\xi \quad (\text{Eq. V-49})$$

Solving Equation (V-48) for τ , using Equation (V-49) gives:

$$\tau = t_D - \frac{\Omega}{S_f O^{n-1}} \quad (\text{Eq. V-50})$$

Consider a “square wave” initial condition defined by:

$$S_f O(\tau) = S_{f0c} \quad \tau^* > \tau > 0 \quad (\text{Eq. V-51})$$

$$S_f O(\tau) = 0 \quad \tau > \tau^* \quad (\text{Eq. V-52})$$

For $\tau^* > \tau > 0$, Equation (V-50) becomes:

$$\tau = t_D - \frac{\Omega}{S_{f0c}^{n-1}} \quad (\text{Eq. V-53})$$

where S_{f0c} is the source saturation level. For $\tau > \tau^*$, Equation (V-50) can be solved for S_{fp} to give:

$$S_f O(\tau^*) = \left\{ \frac{\Omega}{t_D - \tau^*} \right\}^{\frac{1}{n-1}} \quad (\text{Eq. V-54})$$

Shock Front Trajectory

The trajectory of the saturation discontinuity (i.e., a shock) that leads the propagation of the initial square wave is described by the following (Whitham 1974):

$$\frac{d p_D}{d t_D} = S_{fp}^{n-1} \quad (\text{Eq. V-55})$$

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where p_D is the (dimensionless) position of the shock and S_{fp} is the water saturation at the shock. The derivation of the shock trajectory is divided into two parts, based on the origin of the characteristic either being in the saturated zone ($S_{fp} = 1$; $\tau^* > \tau > 0$) or in the expansion fan ($S_{fp} < 1$; $\tau = \tau^*$).

For $\tau^* > \tau > 0$, let the shock position be denoted by p_{DI} , and Equation (V-55) becomes:

$$\frac{d p_{DI}}{d t_D} = S_{fp}^{n-1} \quad (\text{Eq. V-56})$$

Substituting for S_{fp} using Equation (V-46) gives:

$$\frac{d p_{DI}}{d t_D} = S_{foc}^{n-1} \exp \{ -(n-1) \Gamma(p_{DI}) \} \quad (\text{Eq. V-57})$$

Rearranging Equation (V-57) and integrating from $t_D = 0$ (because the shock wave begins at $t_D = 0$) to t_D , and from $p_{DI} = p_{DI_s}$ to p_{DI} gives:

$$\int_0^{t_D} d\sigma = S_{foc}^{1-n} \int_{p_{DI_s}}^{p_{DI}} \exp \{ (n-1) \Gamma(\xi) \} d\xi \quad (\text{Eq. V-58})$$

From Equation (V-49), the integral in Equation (V-58) over ξ is $\Omega(p_{DI})$. Therefore, Equation (V-58) becomes:

$$t_D = \frac{n \Omega(p_{DI})}{S_{foc}^{n-1}} \quad (\text{Eq. V-59})$$

This shock trajectory is followed until the shock passes out of the zone where the characteristics originate from an initially saturated condition. The "boundary" characteristic between the initially saturated zone and the expansion fan is defined by the characteristic trajectory, Equation (V-50), with $\tau = \tau^*$, or

$$t_D = \tau^* + \frac{\Omega(p_{DI_b})}{S_{foc}^{n-1}} \quad (\text{Eq. V-60})$$

To solve for the position of the intersection of the shock and the boundary characteristic, p_{DI_b} , equate the expressions for t_D in Equations (V-59) and (V-60) to obtain:

$$\Omega(p_{DI_b}) = S_{foc}^{n-1} \frac{\tau^*}{n-1} \quad (\text{Eq. V-61})$$

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Equation (V-61) gives the position p_{Dlb} implicitly in terms of known parameters. Substituting $\Omega(p_{Dlb})$ in Equation (V-61), for $\Omega(p_{DI})$ Equation (V-60) gives the time of the intersection of the shock and the boundary characteristic to be:

$$t_{Db} = \frac{n \tau^*}{n-1} \quad (\text{Eq. V-62})$$

For the expansion fan, $\tau = \tau^*$, let the shock position be denoted by p_{DII} . The shock trajectory is derived using Equation (V-55),

$$\frac{d p_{DII}}{d t_D} = S_{fp}^{n-1} \quad (\text{Eq. V-63})$$

Substituting for S_{fp} using Equations (V-46) and (V-54) gives:

$$\frac{d p_{DII}}{d t_D} = \frac{\Omega(p_{DII})}{t_D - \tau^*} \exp \{ -(n-1)\Gamma(p_{DII}) \} \quad (\text{Eq. V-64})$$

Rearranging Equation (V-64) to integrate the trajectory from $t_D = t_{Db}$ to t_D and $p_{DII} = p_{Dlb}$ to p_{DII} gives:

$$\int_{t_{Db}}^{t_D} \frac{d \sigma}{\sigma - \tau^*} = \int_{p_{Dlb}}^{p_{DII}} \frac{\exp \{ (n-1)\Gamma(\xi) \}}{\Omega(\xi)} d \xi \quad (\text{Eq. V-65})$$

The integral over ξ in Equation (V-65) may be evaluated by noting, from Equation (V-49), that

$$\frac{d \Omega(z_D)}{d z_D} = \frac{1}{n} \exp \{ (n-1)\Gamma(z_D) \} \quad (\text{Eq. V-66})$$

Therefore, Equation (V-65) may be written as

$$\int_{t_{Db}}^{t_D} \frac{d \sigma}{\sigma - \tau^*} = n \int_{\Omega(p_{Dlb})}^{\Omega(p_{DII})} \frac{d \omega}{\omega} \quad (\text{Eq. V-67})$$

The integral over σ can be evaluated,

$$\int_{t_{Db}}^{t_D} \frac{d \sigma}{\sigma - \tau^*} = \ln \left\{ \frac{t_D - \tau^*}{t_{Db} - \tau^*} \right\} \quad (\text{Eq. V-68})$$

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Substituting for t_{Db} using Equation (V-62) gives,

$$\int_{t_{Db}}^{t_D} \frac{d\sigma}{\sigma - \tau^*} = \ln \left\{ (n-1) \left\{ \frac{t_D - \tau^*}{\tau^*} \right\} \right\} \quad (\text{Eq. V-69})$$

The integral over ω gives

$$\int_{\Omega(p_{DIb})}^{\Omega(p_{DII})} n \frac{d\omega}{\omega} = n \ln \left\{ \frac{\Omega(p_{DII})}{\Omega(p_{DIb})} \right\} \quad (\text{Eq. V-70})$$

Using Equations (V-67), (V-69), and (V-70) to solve for t_D gives,

$$t_D = \tau^* + \frac{\tau^*}{n-1} \left\{ \frac{\Omega(p_{DII})}{\Omega(p_{DIb})} \right\}^n \quad (\text{Eq. V-71})$$

Solution Summary

The boundaries of the derived solution are defined by the p_{DI} and p_{DII} shock waves and the boundary characteristics as shown in Figure V-1. These boundaries are given by the following expressions:

The p_{DI} shock, from Equation (V-59):

$$t_D = \frac{n \Omega(p_{DI})}{S_{f0c}^{n-1}} \quad (\text{Eq. V-72})$$

where Ω is defined by Equation (V-49).

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**Schematic Characteristics Diagram
For Transient Flow in a Fracture/Matrix System**

Figure V-1. Boundary Characteristics Diagram

The p_{DII} shock, from Equation (V-71), with Equation (V-61) for $\Omega(p_{DII})$ gives

$$t_D = \tau^* + \left\{ \frac{n-1}{\tau^*} \right\}^{n-1} \left\{ \frac{\Omega(p_{DII})}{S_{f0c}^{n-1}} \right\}^n \quad (\text{Eq. V-73})$$

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The boundary characteristic, from Equation (V-50) with $S_{f0} = 1$ and $\tau = \tau^*$ gives:

$$t_D = \tau^* + \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \quad (\text{Eq. V-74})$$

The zones defined by these boundaries have the following solutions:

Zone I: Lies above the p_{DI} shock, below the boundary characteristic and to the right of the time axis.

Using Equation (V-46) with $S_{f0} = S_{f0c}$ gives:

$$S_f(z_D) = S_{f0c} \exp\{-\Gamma(z_D)\} \quad (\text{Eq. V-75})$$

where $\Gamma(z_D)$ is defined by Equation (V-45).

Zone II: Lies above the p_{DII} shock, above the boundary characteristic, and to the right of the time axis.

Using Equations (V-46) and (V-54) gives for S_f :

$$S_f(z_D, t_D) = \left\{ \frac{\Omega(z_D)}{t_D - \tau^*} \right\}^{\frac{1}{n-1}} \exp\{-\Gamma(z_D)\} \quad (\text{Eq. V-76})$$

Zone III: Lies to the right of the p_{DI} and p_{DII} shocks (the undisturbed zone) where $S_f = 0$.

Step Function Model for the Fracture/Matrix Sorptivity, $\gamma(z_D)$

The spatial distribution of the fracture/matrix sorptivity function, γ , may be approximated, starting from Equation (V-28), by the following step function form:

$$\gamma(z_D) = \sum_{i=1}^N H(z_{i+1} - z_D) H(z_D - z_i) \gamma_{di} + \frac{d \ln \{K_{fs}(z_D)\}}{dz_D} \quad (\text{Eq. V-77})$$

where $H(\xi)$ is a step function defined by:

$$H(\xi) = 0 \quad \xi < 0 \quad (\text{Eq. V-78})$$

$$H(\xi) = \frac{1}{2} \quad \xi = 0 \quad (\text{Eq. V-79})$$

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$$H(\xi) = 1 \quad \xi > 0 \gamma_d \quad (\text{Eq. V-80})$$

is the portion of γ due to matrix absorption of water from the fractures and γ_{di} is the value of γ_d in the i^{th} layer. Note that $z_{Ds} = z_l$ and is 0 at the ground surface. The value for the integral function, Γ , defined by Equation (V-45) may be evaluated using Equation (V-27) for γ and using $L_p = L_f$.

$$\Gamma(z_D) = \frac{1}{n} \int_{z_{Ds}}^{z_D} \sum_{i=1}^N H(z_{i+1} - \xi) H(\xi - z_i) \gamma_{di} d\xi + \frac{1}{n} \ln \left\{ \frac{K_{fs}(z_{Di})}{K_{fs}(z_{D1})} \right\} \quad (\text{Eq. V-81})$$

This integral may be reduced to a series expression:

$$\Gamma(z_D) = \frac{1}{n} \sum_{i=1}^N \left\{ H(z_D - z_{i+1})(z_{i+1} - z_i) \gamma_{di} + H(z_{i+1} - z_D) H(z_D - z_i)(z_D - z_i) \gamma_{di} \right\} + \frac{1}{n} \ln \left\{ \frac{K_{fsi}}{K_{fs1}} \right\} \quad (\text{Eq. V-82})$$

The function $\Omega(z_D)$ is defined by Equation (V-49). This function may be evaluated using Equation (V-45) for Γ and is given by the following:

$$\Omega(z_D) = \frac{1}{n} \int_{z_{Ds}}^{z_D} \exp \left\{ \frac{(n-1)}{n} \left\{ \sum_{i=1}^N \left\{ H(\xi - z_{i+1})(z_{i+1} - z_i) \gamma_{di} + H(z_{i+1} - \xi) H(\xi - z_i)(\xi - z_i) \gamma_{di} \right\} + \ln \left\{ \frac{K_{fsi}}{K_{fs1}} \right\} \right\} \right\} d\xi \quad (\text{Eq. V-83})$$

This integral may also be reduced to the following series expression:

$$\begin{aligned} \Omega(z_D) = & \sum_{i=1}^N \frac{H(z_D - z_{i+1})}{(n-1) \gamma_{di}} \left\{ \frac{K_{fsi}}{K_{fs1}} \right\}^{\frac{n-1}{n}} \\ & \exp \left\{ \sum_{j=1}^{i-1} \frac{1}{n} H(z_D - z_{j+1})(n-1) \gamma_{dj}(z_{j+1} - z_j) \right\} \left\{ \exp \left\{ \frac{1}{n} (n-1) \gamma_{di}(z_{i+1} - z_i) \right\} - 1 \right\} \\ & + \frac{H(z_{i+1} - z_D) H(z_D - z_i)}{(n-1) \gamma_{di}} \left\{ \frac{K_{fsi}}{K_{fs1}} \right\}^{\frac{n-1}{n}} \\ & \exp \left\{ \sum_{j=1}^{i-1} \frac{1}{n} H(z_D - z_{j+1})(n-1) \gamma_{dj}(z_{j+1} - z_j) \right\} \left\{ \exp \left\{ \frac{1}{n} (n-1) \gamma_{di}(z_D - z_i) \right\} - 1 \right\} \end{aligned} \quad (\text{Eq. V-84})$$

Iterative Improvement to Matrix Imbibition Length Scale and Calculation of γ_a

A first solution to the flow problem is obtained by using the approximation that $L_p = L_f$. This solution is then substituted into Equations (V-30) through (V-38) to provide an improved

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approximation to the matrix imbibition length scale, L_p . The new length scale is then incorporated into the expression for γ_d . To accomplish this, first calculate the imbibition time scale, T_D , for each step in the spatial discretization and the time for intersection of the boundary characteristic with the leading shock, t_{DBC} . Also calculate the position of the shock intersection point, p_{Dib} . With these values, the case required to calculate the exposure time can be determined using Equations (V-31), (V-34), and (V-36).

For the case

$$z_D < p_{Dib} \quad \text{and} \quad t_{DPI} + T_D > t_{DBC} \quad (\text{Eq. V-85})$$

Using Equation (V-31) and the expressions for saturation and time boundaries presented in the solution summary, gives the following result for the exposure time, σ_D :

$$\begin{aligned} \sigma_D(z_D) = & \frac{S_{f0c}^n}{2} \Omega^{\frac{-n}{n-1}}(z_D) F \left\{ \left\{ t^* + \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^2 - \frac{n^2 \Omega^2(z_D)}{S_{f0c}^{2n-2}} \right\} \\ & + F \left\{ \frac{n-1}{n-2} \right\} \left\{ \frac{n\Omega(z_D)}{S_{f0c}^{n-1}} - T_D + \tau^* \right\}^{\frac{n-2}{n-1}} \\ & - F(n-1) \{T_D - t^*\} \left\{ \frac{n\Omega(z_D)}{S_{f0c}^{n-1}} + T_D + \tau^* \right\}^{\frac{-2}{n-1}} \\ & - F \left\{ \frac{n-1}{n-2} \right\} \left\{ \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^{\frac{n-2}{n-1}} \\ & + F \{ (n-1)t^* \} \left\{ \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^{\frac{-1}{n-1}} \end{aligned} \quad (\text{Eq. V-86})$$

where

$$F = \frac{\Omega^{\frac{n}{n-1}}(z_D)}{S_{f0c}^n \tau^*} \quad (\text{Eq. V-87})$$

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For the case

$$z_D < p_{Dlb} \quad \text{and} \quad t_{DBC} > t_{DPI} + T_D \quad (\text{Eq. V-88})$$

Using Equation (V-34) and the expressions for saturation and time boundaries given in the solution summary, gives the following result for the exposure time, σ_D :

$$\begin{aligned} \sigma_D(z_D) = & \frac{S_{f0c}^n}{2} G \left\{ \left\{ T_D + \frac{n \Omega(z_D)}{S_{f0c}^{n-1}} \right\}^2 - \frac{n^2 \Omega^2(z_D)}{S_{f0c}^{2n-2}} \right\} \\ & + G T_D S_{f0c}^n \left\{ \frac{(n-1) \Omega(z_D)}{S_{f0c}^{n-1}} - T_D + \tau^* \right\} \\ & + G(n-1) T_D S_{f0c} \Omega(z_D) \end{aligned} \quad (\text{Eq. V-89})$$

where

$$G = \frac{1}{S_{f0c}^n \tau^*} \quad (\text{Eq. V-90})$$

For the case

$$z_D > p_{Dlb} \quad (\text{Eq. V-91})$$

Using Equation (V-36) and the expressions for saturation and time boundaries given in the solution summary, gives the following result for the exposure time, σ_D :

$$\begin{aligned} \sigma_D(z_D) = & F \left\{ \frac{n-1}{n-2} \right\} \left\{ \left\{ \frac{n-1}{\tau^*} \right\}^{n-1} \left\{ \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^n - T_D \right\}^{\frac{n-2}{n-1}} \\ & + F(n-1) \{ T_D - \tau^* \} \left\{ \left\{ \frac{n-1}{\tau^*} \right\}^{n-1} \left\{ \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^n - T_D \right\}^{\frac{n-1}{n-1}} \\ & - F \left\{ \frac{n-1}{n-2} \right\} \left\{ \frac{n-1}{\tau^*} \right\}^{n-2} \left\{ \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^{\frac{n(n-2)}{n-1}} \\ & + F \tau^{*2} \left\{ \frac{\Omega(z_D)}{S_{f0c}^{n-1}} \right\}^{\frac{-n}{n-1}} \end{aligned} \quad (\text{Eq. V-92})$$

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where

$$F = \frac{\Omega_{n-1}^n (z_D)}{S_{fvc}^n \tau^*} \quad (\text{Eq. V-93})$$

Model Abstraction for Matrix Water Redistribution and Matrix Water Return Flow to the Fractures

Redistribution of Matrix Water Following a Fracture Flow Event

We formulate the redistribution of matrix water during the inter-episodic time periods using a simple finite-difference approximation for exchange of water between the layers. This model uses the following

$$V_{mi} = K_{hi} (1 + P_{cgi}) \quad (\text{Eq. V-94})$$

where V_{mi} is the Darcy flow velocity between matrix layer $I - 1$ and I , K_{hi} is the harmonic effective hydraulic conductivity between the two given grid blocks, and P_{cgi} is a first-order difference approximation to the capillary pressure gradient. Effective hydraulic conductivity and capillary pressure models proposed by van Genuchten (1980) are used to describe the variation of these properties as functions of water saturation,

$$K_m(S_{mn}) = K_{ms} S_{mn}^{\frac{1}{\beta_m}} \left\{ 1 - \left\{ 1 - S_{mn}^{\frac{\beta_m}{\beta_m-1}} \right\}^{1-\frac{1}{\beta_m}} \right\}^2 \quad (\text{Eq. V-95})$$

$$P_{cm}(S_{mn}) = \frac{1}{\alpha_m} \left\{ S_{mn}^{\frac{\beta_m}{1-\beta_m}} - 1 \right\}^{\frac{1}{\beta_m}} \quad (\text{Eq. V-96})$$

where the normalized matrix water saturation, S_{mn} , is defined by,

$$S_{mn} = \frac{S_m - S_{mr}}{1 - S_{mr}} \quad (\text{Eq. V-97})$$

and S_{mr} is the residual matrix water saturation.

The matrix to fracture flow during the redistribution period is computed from a balance of capillary driven flow from the matrix to the fractures and the gravity driven (unit gradient) fracture flux from the resulting water entering fractures. This balance is computed from,

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$$K_m(S_{mn}) \left\{ \frac{P_{cf}(S_f) - P_{cm}(S_{mn})}{L_f} \right\} = K_f(S_f) \quad (\text{Eq. V-98})$$

where L_f is the fracture spacing. We computed the effective conductivity and capillary pressure of the fractures using expressions analogous to those for the matrix given by Equations (V-95) and (V-96). In the case of the fracture saturation, the residual water saturation is taken to be zero, therefore the fracture normalized fracture saturation equals the physical saturation. The matrix saturations are fixed during the redistribution period; therefore, Equation (V-98) is solved for S_f to give the fracture flux.

The fracture flow and transport during the redistribution period uses the results for the cumulative primary fracture flow (see Equation [V-99]) and computes the expected cumulative flow across each unit and adds the flux to the contribution of each successive flow from matrix to fracture.

Cumulative Flux from Primary Fracture Flow Events

Cumulative Primary Fracture Flux

We compute the cumulative flux of primary fracture flow at the water table by integrating the fracture flux at the water table over time. The fracture flux is given by Equation (V-4) and relationships between saturation, position, and time are given by Equations (V-75) or (V-76), depending on the duration of the episodic event. First, we will consider a short pulse and use Equation (V-76) to describe the evolution of the primary fracture flow at the water table, as a function of time. Integrating the flux from the (dimensionless) time the shock (p_{DII}) arrives at the water table, given by Equation (V-73), to a subsequent dimensionless time, t_D gives,

$$F_{cpf}(t_D) = \frac{K_{fs}}{K_{fs}} L_{wt} (n-1) \Omega \frac{n}{n-1} \exp(-n \Gamma) \left\{ \frac{\tau^* S_{f0c}^n}{(n-1)} \Omega \frac{-n}{n-1} - (t_D - \tau^*) \frac{-1}{n-1} \right\} \quad (\text{Eq. V-99})$$

where F_{cpf} is the cumulative water volume from primary fracture flow, Γ and Ω are functions of position defined by Equations (V-82) and (V-84), respectively, K_{fs} is the saturated fracture hydraulic conductivity at the water table, $\overline{K_{fs}}$ is the harmonic mean of K_{fs} , L_{wt} is the distance to the water table, n is the saturation exponent (see Equation [V-4]), τ^* is the (dimensionless) duration of the episodic pulse, and S_{f0c} is the fracture saturation of the pulse. The value of t_D is restricted to a value greater than the value of t_D for the boundary characteristic given by Equation (V-74) of the flow solution.

The limit of Equation (V-99) as $t_D \rightarrow \infty$ gives,

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$$F_{cpf} (t_D \rightarrow \infty) = K_{fs} S_{f0c}^n \left\{ \frac{L_{wt} \tau^*}{K_{fs}} \right\} \exp(-n \Gamma) \quad (\text{Eq. V-100})$$

The term $K_{fs} S_{f0c}^n \left\{ \frac{L_{wt} \tau^*}{K_{fs}} \right\}$ is equal to the volume of water entering the system at the surface during the episodic pulse. Therefore, the total cumulative water production due to primary fracture flow is equal to the volume of water introduced times the exponential factor. For short pulses, the factor Γ , which is a function of position, will also be modified under the scheme discussed in the fracture flow model concerning iterative improvement. However, this factor can only become *larger* for shorter duration pulses, if affected at all.

For long pulses, the cumulative flux is computed using Equation (V-75) for the water saturation and Equation (V-72) for the time of arrival of the shock front. In this case F_{cpf} is,

$$F_{cpf} (t_D \rightarrow \infty) = K_{fs} S_{f0c}^n \left\{ \frac{L_{wt} \tau^*}{K_{fs}} \right\} \exp(-n \Gamma) \quad (\text{Eq. V-101})$$

In this case, as $t_D \rightarrow \infty$, $\tau^* \rightarrow \infty$ and $S_{f0c} \rightarrow 0$ for a finite volume of input. Therefore, at large times let $t_D = \tau^*$ and Equation (V-101) becomes,

$$F_{cpf} (t_D \rightarrow \infty) = K_{fs} S_{f0c}^n \left\{ \frac{L_{wt} \tau^*}{K_{fs}} \right\} \exp(-n \Gamma) \quad (\text{Eq. V-102})$$

Equation (V-102) is the same as Equation (V-100) and (V-101). From this result, we see that the cumulative flux of primary fracture flow at the water table, due to a short-duration transient pulse at the surface, should be either equal to or less than that for a longer-duration pulse. Therefore, in the limit of very long pulses, i.e., approaching steady flow, the total cumulative primary fracture flux at the water table should be equal or larger than that resulting from a short duration pulse of equal total volume.

The time distributions for short and long pulses are not equivalent, however. The flux profile in time given by Equation (V-99) goes like

$$F_{cpf} (t_D) = F_{cpf}^\infty - A (t_D - \tau^*)^{\frac{-1}{n-1}} \quad (\text{Eq. V-103})$$

and for Equations (V-100) and (V-102),

$$F_{cpf} (t_D) = F_{cpf}^\infty \frac{t_D}{\tau^*} - \frac{B}{\tau^{\frac{1}{n}}} \quad (\text{Eq. V-104})$$

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where A and B are constants. For a fixed value of τ^* , Equation (V-104) indicates a linear approach of the cumulative flux to the final value, whereas Equation (V-103) “front-loads” the arrival of flux, with the flux rate dropping off at long times.

ATTACHMENT VI

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ATTACHMENT VI

SKETCH OF ALCOVE #8 SHOWING TEST EXCLUSION AREAS #1 & #2

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SKETCH OF ALCOVE #8 SHOWING TEST EXCLUSION AREAS