Nevada
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Addendum to Revision 1 of the Corrective Action Investigation Plan for Corrective Action Unit 98: Frenchman Flat, Nevada Test Site, Nevada

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**ADDENDUM TO REVISION 1 OF THE
CORRECTIVE ACTION INVESTIGATION PLAN
FOR CORRECTIVE ACTION UNIT 98:
FRENCHMAN FLAT, NEVADA TEST SITE, NEVADA**

U.S. Department of Energy
National Nuclear Security Administration
Nevada Operations Office
Las Vegas, Nevada

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CORRECTIVE ACTION INVESTIGATION PLAN
FOR CORRECTIVE ACTION UNIT 98:
FRENCHMAN FLAT, NEVADA TEST SITE, NEVADA**

Approved by: _____ Signature Approved _____ Date: 6/6/01

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Preface

This document is an addendum to the *Corrective Action Investigation Plan for Corrective Action Unit 98: Frenchman Flat, Nevada Test Site, Nevada*, DOE/NV--478-REV. 1 (DOE/NV, 1999a).

The addendum describes the work activities planned as a result of the U.S. Department of Energy review of the draft Frenchman Flat Corrective Action Unit model of groundwater flow and contaminant transport completed in April 1999. The review included internal and external reviewers. Internal reviewers included the U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office and agencies participating in the Environmental Restoration Program. The external reviewers consisted of a panel of experts in relevant fields of science. The U.S. Department of Energy also solicited comments from the Nevada Division of Environmental Protection during this review.

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List of Acronyms and Abbreviations

$\delta^{13}\text{C}$	Delta Carbon-13
^{14}C	Carbon-14
1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
ALARA	As-low-as-reasonably-achievable
AMEM	Assistant Manager for Environmental Management
amsl	Above mean sea level
bgs	Below ground surface
CADD	Corrective Action Decision Document
CAI	Corrective Action Investigation(s)
CAIP	Corrective Action Investigation Plan
CAU	Corrective Action Unit(s)
CFC	Chlorofluorocarbon(s)
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DRI	Desert Research Institute
FEHM	Finite-Element Heat and Mass-Transfer
FFACO	<i>Federal Facility Agreement and Consent Order</i>
FMP	Fluid Management Plan
ft	Foot (feet)
HASP	Health and Safety Plan
HSU	Hydrostratigraphic unit(s)
IDW	Investigation-Derived Waste
Kd	Distribution coefficient(s)
km	Kilometer(s)

List of Acronyms and Abbreviations (Continued)

LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
m	Meter(s)
mi	Mile(s)
mrem/yr	Millirem(s) per year
NDEP	Nevada Division of Environmental Protection
NNSA/NV	National Nuclear Security Administration Nevada Operations Office
NTS	Nevada Test Site
OSHA	Occupational Safety and Health Administration
PEST	Parameter Estimation
PPE	Personal protective equipment
QAPP	Quality Assurance Project Plan
QC	Quality Control
RadCon	Radiation Control
REOP	Real Estate/Operations Permit
RPP	Radiation Protection Program
RWMS	Radioactive Waste Management Site
SDWA	<i>Safe Drinking Water Act</i>
SEM	Scanning electron microscopy
SLPT	Streamline Particle-Tracking
TD	Total Depth
UGTA	Underground Test Area
USGS	U.S. Geological Survey
WMP	Waste Management Plan
XRD	X-ray diffraction

1.0 Introduction

This document is submitted as an addendum to the *Corrective Action Investigation Plan (CAIP) for Corrective Action Unit (CAU) 98: Frenchman Flat, Nevada Test Site (NTS), Nevada*, DOE/NV--478-REV. 1 (DOE/NV, 1999a). The addendum was prepared to propose work activities in response to comments resulting from the U.S. Department of Energy's (DOE's) review of the draft Frenchman Flat CAU model of groundwater flow and contaminant transport completed in April 1999 (IT, 1999). The reviewers included an external panel of experts (IT, 1999). The U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office also solicited comments from the Nevada Division of Environmental Protection (NDEP) (Liebendorfer, 1999). As a result of the review, additional work scope, including new data-collection and modeling activities, has been identified for the Frenchman Flat CAU. The proposed work scope described in this addendum will be conducted in accordance with the revised Underground Test Area (UGTA) strategy contained in the December 2000 amendment to the *Federal Facility Agreement and Consent Order (FFACO)* (1996). Upon completion of this work, an evaluation will be made to ensure that all issues have been resolved.

The Frenchman Flat CAU model is a group of interdependent models designed to predict the extent of contamination in groundwater due to the underground nuclear tests conducted within this CAU. At the time of the DOE review, the CAU model consisted of a CAU groundwater flow and transport model comprised of two major components: a groundwater flow model and a transport model. The CAU groundwater flow model is supported by a hydrostratigraphic model and a recharge model, whereas the CAU transport model is supported by a source-term model. As part of the modeling activities proposed in this addendum, two new major components may be added to the Frenchman Flat CAU model: a total-system model and two local groundwater flow model and transport models. The local groundwater flow and transport models will have the same types of component and supporting models as the CAU groundwater flow and transport model. For purposes of this document, the term "CAU model" refers to the Frenchman Flat CAU model as a whole, including all component and supporting models. Any single model that is part of the CAU model or any other type of model referred to in this document is explicitly stated. The word "draft" used as a qualifier for the

CAU model, or any of its component or supporting models, refers to the version that was subjected to the DOE review (IT, 1999).

This introduction includes highlights of the revised UGTA strategy and summary descriptions of the draft Frenchman Flat CAU model, the results of the DOE review, and the actions proposed to resume the Frenchman Flat Corrective Action Investigation (CAI). The organization and contents of this addendum are summarized at the end of this introduction.

1.1 Revised UGTA Strategy Highlights

The DOE and NDEP negotiated revisions to the UGTA strategy in 2000. Major revisions to the strategy include new definitions of the contaminant and compliance boundaries, and a revised decision-making process.

In the revised strategy, the contaminant boundary is based on *Safe Drinking Water Act* (SDWA) standards and is derived from radionuclide concentrations simulated by the CAU groundwater flow and transport model. The compliance boundary is negotiated by DOE and NDEP and may or may not match the contaminant boundary. Major revisions to the decision-making process include increased NDEP participation, the addition of a data-collection activity at the initiation of the CAI, and the addition of a data-adequacy decision point. [Section 2.0](#) of this addendum provides information on the revised FFACO UGTA strategy.

1.2 Summary of Draft Frenchman Flat CAU Model

The draft Frenchman Flat CAU groundwater flow and transport model was constructed using SWIFT98 (HSIGeoTrans, 1998), in accordance with the original UGTA strategy as described in the Frenchman Flat CAIP (DOE/NV, 1999a). This draft Frenchman Flat CAU groundwater flow and transport model was designed to simulate groundwater flow and contaminant transport for an area encompassing the Frenchman Flat CAU. Results from the source-term model based on unclassified data from the CAMBRIC test (LLNL, 1999) were used to represent the source term for the modeling of radionuclide transport in the draft CAU groundwater flow and transport model.

Several groundwater flow and transport model simulations were conducted, including a base case corresponding to the conceptual model considered to be most likely, and several other simulations to

explore the uncertainty associated with the base case results. The goal of the simulations was to predict the location of the contaminant boundary as previously defined in the original revision of Appendix VI of the FFACO (1996). As stated in the CAIP (DOE/NV, 1999a), at that time the contaminant boundary was specifically defined as the maximum extent of contamination corresponding to a human dose of 4 millirems per year (mrem/yr) for radionuclides, or a concentration equal to drinking water standards (maximum contaminant levels) for other contaminants, at the 50 percent confidence level within a 1,000-year interval. In the base case simulations, the lateral location of the contaminant boundary (approximated as the particle transport distance) was predicted to be less than 530 meters (m) (1,740 feet [ft]) from the source.

Considering uncertainty in recharge and the role of faults, the maximum lateral particle transport distance was less than 700 m (2,300 ft) from the source. Using a Monte Carlo analysis to assess simultaneous uncertainty in hydraulic conductivity, effective porosity, and recharge, the maximum lateral particle transport distance predicted by the draft CAU groundwater flow and transport model was slightly greater than 1,400 m (4,590 ft). In most of these simulations, the direction of flow was nearly horizontal. Several of the fault uncertainty scenarios included a vertical flow component by increasing the hydraulic conductivity of two or three faults located within the two testing areas of Frenchman Flat. The maximum vertical particle movement was predicted to be less than 80 m (260 ft) from the source.

1.3 Summary of Draft Frenchman Flat CAU Model Review

Following its completion, the draft Frenchman Flat CAU model was reviewed as specified in the UGTA strategy (Section 2.0 of the CAIP [DOE/NV, 1999a] and the FFACO [1996]). To ensure a thorough review of the draft Frenchman Flat CAU model, DOE solicited comments from a panel of external peer reviewers (IT, 1999). NDEP also reviewed the draft Frenchman Flat CAU model (Liebendorfer, 1999).

The reviewers concluded that the completed work has improved the understanding of hydrogeologic issues in this complex and challenging area of investigation. In addition, the reviewers confirmed that mathematical models are appropriate tools to represent chemical and physical properties in the analysis of potential contaminant transport in Frenchman Flat. However, the reviewers also identified several issues relating to insufficiency of data and inadequacy of the modeling process that

should be addressed to provide additional confidence in the modeling results with respect to the potential for contaminant migration to the Lower Carbonate Aquifer. The insufficiency of data prevents adequate constraints on many physical aspects of the Frenchman Flat CAU groundwater flow and transport model, making the conceptual model plausible but non-unique. Modeling inadequacies were identified within the modeling strategy, implementation of the CAU groundwater flow and transport model, and the uncertainty analyses.

The main issues identified by the reviewers may be summarized as follows:

- **Issue 1 - Insufficient Geologic Data:** Available geologic data are inadequate to constrain the hydrostratigraphic framework of Frenchman Flat, particularly with respect to potential vertical pathways between the Alluvial Aquifer and the Lower Carbonate Aquifer. Specific data needed include additional information about the geologic structure including the topography of the Lower Carbonate Aquifer, and stratigraphic data below the Alluvial Aquifer.
- **Issue 2 - Insufficient Hydrologic Data:** Available hydrologic data are inadequate to support the Frenchman Flat CAU groundwater flow model. Specific data needed include: (1) hydraulic head measurements to derive horizontal and vertical hydraulic gradients in the alluvium, (2) hydraulic conductivity measurements to define the variability of hydraulic conductivity in the alluvium, both horizontally and vertically, and (3) groundwater chemistry data for Frenchman Flat and adjacent areas to identify flow patterns and travel times. Again, the emphasis is on specific data that would support or refute pathways for radionuclides to migrate from the Alluvial Aquifer to the Lower Carbonate Aquifer.
- **Issue 3 - Inadequate Modeling Strategy and Implementation:** Inadequacies identified in the modeling strategy and implementation are: (1) the inappropriateness of the CAU groundwater flow and transport model scale which was too large to simulate potentially important small-scale features, (2) the limitations of the finite-difference method to represent the complex geologic structure of the framework, (3) the use of a cumbersome method for estimating the groundwater flow model's boundary conditions, (4) inconsistencies between modeling and measured hydraulic conductivity values, (5) computational errors due to large grid sizes, (6) non-unique groundwater flow model calibration, and (7) lack of consistency in the mass transport data within the model documentation.
- **Issue 4 - Limited Quantification of Uncertainty:** The uncertainty analysis was limited and not inclusive of all actual uncertainties. More specifically, it was determined that the uncertainty analyses related to vertical flow within the two underground testing areas of Frenchman Flat were incomplete and should be expanded.
- **Issue 5 - Contaminant Migration to the Lower Carbonate Aquifer:** The draft CAU groundwater flow and transport model developed using the existing data did not adequately

constrain the possibility of a horizontal or vertical flow path (perhaps along a fault) from the underground nuclear tests to the Lower Carbonate Aquifer. Such a flow path may allow radionuclides to move from the underground tests to the Lower Carbonate Aquifer in less than 1,000 years.

1.4 Proposed Additional CAI Work for Frenchman Flat

Following the review of the draft Frenchman Flat CAU model at a meeting attended by NDEP, DOE, and the Technical Working Group, the issues were discussed and work scopes to address them were proposed. New subcommittees were formed to fully develop work scopes for well drilling and geophysics studies to adequately address the issues relating to insufficiency of geologic and hydrologic information. The existing modeling subcommittee developed additional work scope for the modeling activities.

The proposed additional work scope includes new data-collection activities, development and use of local-scale models of the two underground nuclear testing areas, and potential revisions of the draft CAU groundwater flow and transport model. Brief descriptions of these activities follow. [Table 1-1](#) provides a cross-reference between the issues and the proposed activities.

1.4.1 Data-Collection Activities

Proposed additional data-collection activities are as follows:

- **Hydrogeologic Investigation of the Nuclear Testing Areas:** This activity includes drilling wells in each of the underground nuclear testing subareas to characterize the geology, mineralogy, and hydrology at these locations. These data are intended to address Issues 1, 2, 3 (items 4 and 6), 4, and 5 described in [Section 1.3](#).
- **Aquifer Testing in the Nuclear Testing Areas:** This activity includes conducting two multi-well pump tests in the Alluvial Aquifer to estimate its hydraulic properties. These data will address Issues 2 and 3 (items 4 and 6) described in [Section 1.3](#).
- **Integrated-Geophysical Investigation:** This activity includes seismic surveying and the use of other geophysical methods to better define the geologic structure of Frenchman Flat. These data will address Issues 1, 4, and 5 described in [Section 1.3](#).
- **Isotope- and Geochemistry-Based Investigation:** This activity includes collection and analysis of groundwater samples from existing wells in Frenchman Flat and vicinity, and geochemical analysis to help understand groundwater flow patterns and estimate travel times. These data are intended to help address Issues 2, 3 (item 6), 4, and 5 described in [Section 1.3](#).

Table 1-1
Cross Reference Between Issues Identified During the Model Review
and the Proposed Activities

Issue	Proposed Activities	Location
Issue 1 – Insufficient geologic data	<ul style="list-style-type: none"> - New well drilling and logging - Integrated geophysical investigations 	<ul style="list-style-type: none"> - Section 6.3.1 (pages 44 to 57) - Section 6.3.3 (pages 59 to 63)
Issue 2 – Insufficient hydrologic data	<ul style="list-style-type: none"> - New well testing - Aquifer testing - Isotopic and geochemistry-based investigation 	<ul style="list-style-type: none"> - Section 6.3.1.3.7 and 6.3.1.3.8 (pages 50 to 52) - Section 6.3.2 (pages 57 to 59) - Section 6.3.4 (pages 63 to 68)
Issue 3 – Inadequate modeling strategy and implementation	<ul style="list-style-type: none"> - Total system model to facilitate system understanding and the development of detailed models - Local groundwater flow and transport models with finite-element code and improved boundary condition definition method 	<ul style="list-style-type: none"> - Section 5.4 (pages 14 to 18) - Section 5.6 including Section 5.6.5.3.2 (pages 18 to 39)
Issue 4 – Limited quantification of uncertainty	<ul style="list-style-type: none"> - Preliminary uncertainty analyses using the total system model to identify important features and parameters - More extensive sensitivity and uncertainty analyses using the CAU or local groundwater flow and transport models 	<ul style="list-style-type: none"> Sections 5.6.6 and 5.6.7 (pages 39 to 41)
Issue 5 – Contaminant migration to the Lower Carbonate Aquifer	All proposed activities designed to address Issues 1 through 4.	Section 5.0 and Section 6.0 of CAIP Addendum

The data collected during these activities will be used to address the previously identified issues and to support the local groundwater flow and transport models and potential revisions to the draft CAU groundwater flow and transport model. Detailed descriptions of the proposed data-collection activities are provided in [Section 6.0](#) of this document.

1.4.2 Modeling Activities

The modeling approach was revised to address the specific modeling issues identified by the reviewers. Major revisions to the modeling approach include the addition of a total-system model, the potential verification of the CAU groundwater flow and transport model, and the potential addition of local groundwater flow and transport models. The modified modeling approach will have enhanced capabilities for incorporating the uncertainties associated with modeling groundwater flow

and transport within a complex hydrogeologic system. Detailed descriptions of the proposed modeling activities are provided in [Section 5.0](#) of this document. A summary of the proposed additional modeling activities is as follows:

- ***Development of Total-System Model:*** The total-system model provides dynamic, probabilistic simulation of simplified representations of the radionuclide transport system. The total system approach is designed to encompass the full range of uncertainty in a computationally efficient manner. The total-system model will be used to support the detailed CAU- and local-scale groundwater flow and transport models.
- ***Potential CAU Groundwater Flow and Transport Model Verification:*** The new data will be considered for use in the verification process of the draft CAU groundwater flow and transport model. If the new data are found to be in agreement with the draft CAU groundwater flow and transport model, they will be used to verify it. The draft CAU groundwater flow and transport model may then be revised and more extensive sensitivity and uncertainty analyses conducted. If the new data are much different than the existing data, local groundwater flow and transport models will be developed for the two underground nuclear testing areas.
- ***Potential Development of Local Groundwater Flow and Transport Models for the Underground Nuclear Testing Areas:*** This activity will include assessment of existing and new data, the use of a finite-element numerical method and a finer grid, and an improved method of defining boundary conditions. The improvements in the modeling approach address Issue 3 (items 1, 2, 3, 5, and 7) described in [Section 1.3](#).
- ***Sensitivity and Uncertainty Analyses:*** This activity will include the development of several alternative conceptual models of groundwater flow and transport to capture the full range of uncertainty. The total-system model will be used first to investigate the significance of alternative conceptual models of groundwater flow and transport as well as parameter sensitivity and uncertainty. More detailed uncertainty analyses will then be conducted using the detailed numerical models. The improvements to the sensitivity and uncertainty analyses will address Issues 3 (item 6), 4, and 5 described in [Section 1.3](#).
- ***Potential CAU Groundwater Flow and Transport Model Revision:*** The CAU groundwater flow and transport model may be modified if the new data and/or local-scale models lead to significant revisions of the current conceptual model.

Upon completion of the work proposed in this document, an evaluation will be made to decide if any issues still require resolution.

1.5 Document Organization

This addendum was designed to only describe changes that have occurred either in the UGTA strategy or in elements of the CAI since the Frenchman Flat CAIP (DOE/NV, 1999a) was approved by NDEP. The addendum consists of five amended sections, which are as follows:

- [Section 1.0](#), *Introduction*, describes the purpose of this document.
- [Section 2.0](#), *Legal/Regulatory Requirements Addendum*, provides information about the revised FFACO UGTA strategy.
- [Section 5.0](#), *Corrective Action Investigation Addendum*, describes the modeling activities that will be conducted during the second data-collection and analysis phase of the Frenchman Flat CAI.
- [Section 6.0](#), *Field Activity Addendum*, describes the data-collection activities that will be conducted during the second phase of the Frenchman Flat CAI.
- [Section 9.0](#), *Reference Addendum*, contains a list of references cited in this addendum.

2.0 Legal/Regulatory Requirements Addendum

The FFACO was negotiated in 1996 between the U.S. Department of Energy, the U.S. Department of Defense, and the Nevada Division of Environmental Protection. The FFACO is the regulatory driver for environmental restoration activities in Nevada. Appendix VI of the FFACO (1996) contains the environmental restoration strategy for the underground test areas of the NTS. The revised UGTA strategy is described in Section 3.0 of Revision 1 of Appendix VI of the FFACO (1996) issued on December 7, 2000. This CAIP Addendum is in accordance with the revised strategy (FFACO, 1996).

2.2 UGTA Strategy Revisions

Major revisions to the UGTA strategy include new definitions of the contaminant and compliance boundaries, and a revised decision-making process.

2.2.1 CAU Boundaries

In this addendum, the term “CAU boundaries” refers to the contaminant and compliance boundaries for consistency with Revision 1 of Appendix VI of the FFACO (1996). In the revised strategy, these two boundaries may or may not be the same. They are defined as follows:

Contaminant Boundary

The contaminant boundary has been defined in Revision 1 of Appendix VI of the FFACO (1996) as follows:

“A contaminant boundary is the model-predicted perimeter which defines the extent of radionuclide-contaminated groundwater from underground testing above background conditions exceeding the Safe Drinking Water Act (SDWA) standards. The contaminant boundary will be composed of both a perimeter boundary and a lower hydrostratigraphic unit boundary. The computer model predicts the location of this boundary within 1,000 years and must do so at a 95% level of confidence.”

Confidence levels represent uncertainties associated with the location of the contaminant boundary (Figure 3-3 on page VI-3-8 of Revision 1 of Appendix VI of the FFACO (1996). As explained in Appendix VI of the FFACO (1996), “each contour reflects an increased level of confidence that no contaminants exceeding a given regulatory concentration will ever cross that boundary. As

confidence increases, the distance from the CAU increases. The confidence levels could lead to the development of different contaminant boundaries, depending on the degree of certainty decision makers need to select appropriate controls.”

Compliance Boundary

The compliance boundary is negotiated between NDEP and DOE from the contaminant boundary predicted by the CAU groundwater flow and transport model. It is defined on page VI-3-3 of Revision 1 of Appendix IV of the FFACO (1996) as follows:

“The compliance boundary will define the area within which the radiological contaminants above the SDWA standards relative to background are to remain. DOE will be responsible for ensuring compliance with this boundary. The compliance boundary may or may not coincide with the contaminant boundary. If the predicted location of the contaminant boundary cannot be accepted as the compliance boundary, an alternate compliance boundary will be negotiated by both parties (FFACO, 1996).”

2.2.2 Decision Process Description

The revised CAI process used to achieve the UGTA strategy is shown as a flow diagram in Figure 3-2 (page VI-3-6) of the FFACO (1996) in Appendix VI. This decision diagram is provided in [Figure 2-1](#) of this document. A dictionary of the process flow diagram shown in [Figure 2-1](#), which provides detailed descriptions of each step of the process, may be found on pages VI-3-10 through VI-3-16 of Appendix VI of the FFACO (1996).

Figure 2-1
Revised Decision Diagram for the Underground Test Area

5.0 *Corrective Action Investigation Addendum*

The draft Frenchman Flat CAU model was completed and subjected to DOE review. As a result of this review, the DOE proposes additional CAI work including new data acquisition and modeling as described in this addendum to the Frenchman Flat CAIP (DOE/NV, 1999a). The remainder of the Frenchman Flat corrective action will follow the revised UGTA strategy described in the FFACO (1996). This section of the addendum provides an overview of the proposed additional CAI work, followed by descriptions of the proposed modeling activities including the total-system model, the potential verification of the draft CAU groundwater flow and transport model, the local groundwater flow and transport models, the source-term model, and potential revisions to the draft CAU groundwater flow and transport model. The proposed data-collection activities are described in [Section 6.0](#) of this addendum. The preparation of the Corrective Action Decision Document (CADD) will be initiated following completion of the Frenchman Flat CAU model.

5.3 *Overview of Proposed Additional CAI Work*

The additional work proposed for the Frenchman Flat CAU includes new data-collection activities and modeling activities. The results of the CAI activities proposed in this addendum will be presented in the revised CAU model documentation which is described in Section 1.3.1.6 of the CAIP (DOE/NV, 1999a). The objectives and brief descriptions of the proposed work are provided in the following sections.

5.3.1 *Objectives*

The objectives of the CAI, as stated in the CAIP, remain unchanged. A specific objective of the additional CAI activities is to measure parameters governing potential vertical flow from the Alluvial Aquifer to the Lower Carbonate Aquifer. And, if required, local-scale groundwater flow and transport modeling activities will be used, in part, to assess the potential for vertical migration from the contamination sources located in the alluvial and volcanic units to the Lower Carbonate Aquifer.

5.3.2 Proposed Data-Collection Activities

The DOE proposes the following data-collection activities to confirm or improve the current conceptual model of the Frenchman Flat CAU:

- Hydrogeologic investigation of the nuclear testing areas
- Aquifer testing in the nuclear testing areas
- Integrated-geophysical investigation
- Isotope- and geochemistry-based investigation

The hydrogeologic investigation of the nuclear testing areas includes drilling two multi-level wells in each of the underground nuclear testing subareas to characterize the geology, mineralogy, and hydrology at these locations. The aquifer testing activity includes conducting two multi-well pump tests in the Alluvial Aquifer to estimate its hydraulic properties. The geophysics investigation includes seismic surveying and other geophysical methods to better define the geologic structure of Frenchman Flat. The isotope- and geochemistry-based investigation includes collection and analysis of groundwater samples from existing wells in Frenchman Flat and vicinity, and geochemical modeling to help understand flow patterns and estimate groundwater travel times.

The data collected during these activities will be used to support the total-system model, the local groundwater flow and transport models and potential revisions to the draft CAU groundwater flow and transport model. Detailed descriptions of the proposed data-collection activities are provided in [Section 6.0](#) of this document.

5.3.3 Proposed Modeling Activities

As stated in [Section 1.0](#), the modeling activities will be conducted following a modified modeling approach designed to address the specific modeling issues identified by the reviewers. The approach includes the following activities:

- Development of a total-system model
- Potential verification of the draft CAU groundwater flow and transport model
- Potential development of local groundwater flow and transport models

- Sensitivity and uncertainty analyses
- Potential revision of the draft CAU groundwater flow and transport model

A number of modeling options are currently under consideration, with the option choice dependent on the outcome of the data-collection activities.

The total-system model will be developed using the existing data ([Section 5.4](#)). It will be used to facilitate the assessment of uncertainty in governing parameters and processes.

If the new data are in agreement with the draft CAU groundwater flow and transport model, the new data may be used to verify this model. In that case, the draft CAU groundwater flow and transport model may need to be revised but only limited additional modifications may be considered.

Alternatively, if the new data are not in agreement with the draft CAU groundwater flow and transport model, the data will be combined with the data used previously for reassessment. This reassessment will focus on the two underground nuclear test subareas of Frenchman Flat. If the combined data set is deemed adequate at that time, it will be used to develop the local groundwater flow and transport models.

If the new data and local groundwater flow and transport models produce results that do not differ significantly from the results of the draft CAU groundwater flow and transport model (i.e., transport limited to a small distance from the source), then the local groundwater flow and transport models could serve as the CAU groundwater flow and transport model and it may not be necessary to update the draft CAU groundwater flow and transport model.

If the new data and local groundwater flow and transport models lead to significant revisions of the current conceptual model, the draft CAU groundwater flow and transport model will be revised to incorporate the new information and predict the location of the contaminant boundary.

5.4 Total-System Model

The total-system model is a major addition to the Frenchman Flat modeling approach. Descriptions of the total-system model and its implementation are presented in this section.

5.4.1 Total-System Model Description

The total-system model simulates contaminant transport probabilistically using simplified abstractions of the major processes at work. It is built from a series of one-dimensional (1-D) representations of flow paths in which many of the system parameters are treated as uncertain. Although the total-system model provides a more simplified representation of the system than the CAU groundwater flow and transport model, it facilitates a more comprehensive assessment of uncertainty in parameters and processes governing transport because of its superior efficiency. Uncertainty in hydrostratigraphic framework, hydrologic boundary conditions, source term, and parameters can be treated simultaneously in a dynamic probabilistic framework to improve understanding of the transport system.

The total-system model may be used in support of the CAU and local groundwater flow and transport models: (1) to guide the model development process, (2) to investigate the significance of alternative conceptual models of groundwater flow and transport, and (3) to guide the uncertainty analyses. The GoldSim (Golder Associates, 2000) modeling platform is currently being considered to construct a total-system model for the Frenchman Flat CAU. However, other platforms may be considered at a later time. A description of the implementation of the total-system model follows.

5.4.2 Total-System Model Implementation

The total-system model is implemented in a six-step process: (1) define simulation objectives and measures of performance, (2) develop conceptual models, (3) build the mathematical model, (4) quantify total-system model inputs, (5) implement computational total-system model, and (6) evaluate results.

Define Simulation Objectives and Measures of Performance

This first step is used to focus project efforts on the FFACO objectives. As described by Morgan and Henrion (1998), the goal is to “... let the problem drive the analysis.” Objectives need to be clearly identified so total-system models will be developed based only on the specifics of the problem. The objective of groundwater flow and transport modeling for the corrective action strategy is defined in Appendix VI of the FFACO (1996) as determining the maximum extent of the contaminant boundary.

This objective defines the performance measure for evaluating the performance of the system.

Appendix VI of the FFACO (1996) defined the contaminant boundary as “...the model-predicted perimeter which defines the extent of radionuclide-contaminated groundwater from underground nuclear testing above background conditions exceeding the *Safe Drinking Water Act* (SDWA).”

Although a 1-D transport model cannot produce predictions of concentrations along a perimeter, a possible performance measure would be the ratio of the radionuclide concentrations predicted by the total-system model to SDWA standards at a specified distance from the source. Other potential performance measures may be considered during the modeling process.

Develop Conceptual Models

An important aspect of conceptual model development is defining the boundaries of the system. While processes occurring outside the system will influence the system under construction, the total-system model cannot be expected to simulate impacts outside the boundaries of the system. The boundaries of the Frenchman Flat CAU model were discussed in Section 1.2 of the CAIP (DOE/NV, 1999a).

A conceptual model consists of hypotheses describing features such as hydrostratigraphy, structure, water inflow and outflow, and material properties; and hypotheses describing processes controlling the hydrologic source term and transport through the system. The conceptual model provides a view of the total system that includes all interrelationships of features and processes. Given the incomplete data available for Frenchman Flat, multiple conceptual models may be developed based on the same data.

Build the Mathematical Model

In this step, the conceptual model is represented in a mathematical model. The mathematical model includes the assumptions and approximations on which the conceptual model was based. For Frenchman Flat, these processes will include those relevant to the fate and transport of radionuclides in groundwater. The mathematical model may include abstractions from more detailed level process models.

Quantify Model Inputs

Total-system model inputs include geometry of the system, media composing the flow paths, fluid fluxes in the respective media, source species and source fluxes, and physical and chemical properties of the media and contaminant species. Parameter inputs are defined by specifying their values or specifying a probability distribution for uncertain parameters. Multiple alternative conceptual models can be represented in two ways. In some cases, multiple alternative conceptual models can be represented by a single metamodel in which they are represented as special cases determined by the value of one or more parameters (Morgan and Henrion, 1998). Uncertainty about conceptual model form is, thus, translated to uncertainty about parameter values and can be easily evaluated in a total-system model. Alternatively, multiple alternative conceptual models may require investigation of discrete conceptual models. In this case, multiple total-system models, each representing a specific alternative conceptual model, would be developed.

Implement Computational Model

The simulations are conducted by defining the parameter ranges for each uncertain variable, specifying the number of realizations, and specifying run-time parameters such as the number and length of time steps. The total system computational model is run and output is stored for subsequent analysis.

Evaluate Results

In general, transport processes can only be described with 1-D pathways in total-system models. However, such simplifications may be supported and justified with a limited number of fully 3-D groundwater flow and transport model simulations. Comparison of total-system and 3-D groundwater flow and transport model results will be an important step in the evaluation process.

Simulation results will be evaluated to determine the importance of alternative conceptual models and parameters in controlling contaminant transport. The impact of parameter uncertainty and uncertainty due to alternative conceptual models will be evaluated by quantifying the sensitivity of contaminant transport to parameter values and total-system model constructs. Results of total-system model simulations will be used in decisions regarding which alternative conceptual models must be

considered for the CAU groundwater flow and transport model to fully incorporate uncertainty in the results.

The benefit of the total-system model to the FFACO corrective action strategy is that this relatively simpler approach to system simulation allows a much wider range of uncertainty analysis of hydrologic framework, and flow and transport processes to be performed.

5.5 Potential Draft CAU Groundwater Flow and Transport Model Verification

The data collection activities proposed in this document ([Section 6.0](#)) are designed to fill gaps in the data sets used to construct the Frenchman Flat CAU groundwater flow and transport model. After the data are collected and analyzed, they will be evaluated with respect to the draft CAU groundwater flow and transport model. One possible outcome of this evaluation is that the newly acquired data could be completely consistent with the assumptions and predictions of the draft CAU groundwater flow and transport model. In that case, the new data will be used to verify the draft CAU groundwater flow and transport model. The local groundwater flow and transport models may then be unnecessary, and revisions to the draft CAU groundwater flow and transport model will be limited to reducing its size and refining the grid spacing in the testing areas.

5.6 Local Groundwater Flow and Contaminant Transport Models

If the new data are not deemed appropriate for use in the verification of the draft CAU groundwater flow and transport model, local-scale groundwater flow and transport models will be developed. The local-scale groundwater flow and contaminant transport modeling proposed in this addendum is designed to expand the uncertainty analyses, while honoring the new data to be collected. In particular, the local groundwater flow and transport models will be used to assess horizontal and vertical flow pathways along which radionuclides may potentially be released to the Lower Carbonate Aquifer. These local-scale models will be focused on the two underground nuclear test areas of Frenchman Flat, and will be designed to provide a greater level of detail and allow a wider range of uncertainty analyses. The vertical pathway uncertainty analyses will be enhanced by including hydrostratigraphic framework model uncertainty, greater model resolution, and new hydraulic head and geologic data from hydrostratigraphic units beneath the alluvium, and hydraulic conductivity data obtained from aquifer tests in the alluvium.

5.6.1 Local Groundwater Flow and Transport Modeling Process

The process for modeling groundwater flow and transport at the local-scale modeling generally follows, and must be consistent with, the modeling process at the CAU scale, described in Section 5.1.1 of the *Frenchman Flat Corrective Action Investigation Plan* (DOE/NV, 1999a). Details specific to the local-scale modeling process are presented and discussed in this section. Modeling steps that are relevant to the local groundwater flow and transport models are as follows:

- Objectives
- Data assessment
- Code selection
- Flow model development
- Transport model development
- Sensitivity and Uncertainty Analysis

The first step in the modeling process is the establishment of modeling objectives. The work proposed in this CAIP Addendum will enhance the ability of the draft CAU groundwater flow and transport model to meet the objectives presented in the Frenchman CAIP (DOE/NV, 1999a). Although these overall modeling objectives are still valid and remain unchanged, the local groundwater flow and transport models have one specific additional objective: to assess potential horizontal and vertical flow pathways between the underground nuclear tests and the Lower Carbonate Aquifer. If the new data demonstrate that the vertical pathway is not viable, then the value of the local groundwater flow and transport models is greatly reduced.

If the new data demonstrate that the vertical pathway is potentially viable, the objectives will be achieved by creating and using local-scale groundwater flow and transport models of the two underground nuclear testing areas of Frenchman Flat. These local-scale models will have a finite-element formulation to provide greater flexibility and accuracy in resolving complex geometric features associated with stratigraphic units and structural features present.

The second modeling process step, data assessment, will be enhanced by the new data to be collected as explained in [Section 6.0](#). In this step, the existing and newly collected groundwater flow and contaminant transport data will be interpreted and used to refine the current conceptual model of

groundwater flow and radionuclide transport in Frenchman Flat. Conceptual models of the local groundwater flow systems encompassing the two underground nuclear testing areas will then be extracted from this improved conceptual model of the CAU.

The code selection step is next. The use of a finite-element code in the local groundwater flow and transport models was recommended by the reviewers during the DOE review of the draft Frenchman Flat CAU model (IT, 1999). During the Frenchman Flat code evaluation (DOE/NV, 1999a), the finite-difference code SWIFT98 (HSIGeoTrans, 1998) ranked first and was selected as the code for the CAU groundwater flow and transport model. At that time, the Finite-Element Heat and Mass-Transfer (FEHM) code (Zyvoloski et al., 1997) ranked second solely because of unfamiliarity with the code and computer memory constraints. These concerns have been removed because of recent enhancements to FEHM to make it more memory efficient. FEHM is being proposed as the code to simulate the local-scale groundwater flow and contaminant transport in the Frenchman Flat CAU, as described in this addendum.

The fourth step in the modeling process is the simulation of groundwater flow. The local groundwater flow and transport models will be at a smaller scale than the draft CAU groundwater flow and transport model. This reduction in scale is due in large part to DOE concerns that the draft CAU groundwater flow and transport model was too coarse and was unable to represent the possible vertical flow pathways that may impact radionuclide migration, especially near local features such as faults. The draft CAU groundwater flow and transport model included most of the Frenchman Flat basin, all of the underground tests, and many of the mapped or geophysically inferred faults in the basin. The modeling in the underground testing areas will be refined to include two smaller-scale groundwater flow and transport models, one centered around the northern underground tests, and the other centered around the southern underground tests. These two local models will have much finer grid resolution than the draft CAU groundwater flow and transport model.

The transport simulations, also part of the fourth step, will be performed to assess the migration of radionuclides. The transport simulations form the basis for the contaminant boundary calculations. The local-scale contaminant transport modeling will be performed with a small nodal spacing designed to prevent initial dilution and limit artificial dispersion. The majority of the local-scale contaminant transport simulations will be performed with a 3-D streamline particle-tracking (SLPT)

technique. Particle tracking is the most efficient way to investigate factors and variables that directly influence the velocity of a contaminant. The particle-tracking method includes a number of important processes of interest in Frenchman Flat including advection, solute reactions with aquifer material, dispersion, radioactive decay, particle sources and sinks, dual porosity, and matrix diffusion. A limited number of fully 3-D advection-dispersion transport simulations may be performed to supplement the particle-tracking technique.

The fifth and sixth steps, the sensitivity and uncertainty analyses, will be expanded as compared to similar analyses conducted during the development of the draft Frenchman Flat CAU groundwater flow and transport model. Specifically, alternative hydrostratigraphic models will be developed and tested to determine their impact on radionuclide transport. Other enhancements will include a broader range of parameter values and the inclusion of transport parameters in the uncertainty analyses. As recommended by the DOE review, the uncertainty analyses need to more fully explore the possibility of vertical migration while expanding the parameter ranges for the other parameters which were thought to be too narrow.

5.6.2 Data Assessment for Groundwater Flow Model

The existing and newly acquired data will be assessed to facilitate meeting the objective of the local-scale groundwater flow models. Particular emphasis will be placed on the geologic data to identify alternative hydrostratigraphic models. Additionally, the range of uncertainty of parameters such as hydraulic conductivity will be reexamined following the addition of the new data ([Section 6.0](#)) to the existing data set.

5.6.2.1 Geologic Data

A concern identified during the DOE review was the limited number and poor resolution of CAU groundwater flow and transport model simulations using alternative interpretations of the hydrostratigraphic framework model (Hydrostratigraphic Unit [HSU] model), particularly as it pertains to the assessment of potential vertical migration pathways. A three-step process is proposed: (1) transfer the base model to the EarthVision platform; (2) compare the base model with the new geologic data and modify the HSU model, if necessary; and (3) identify and create alternative HSU models for uncertainty analyses.

The existing base HSU model will be transferred to an EarthVision platform to enhance visualization and facilitate the creation of alternative HSU models. The base HSU model was the result of a collaboration of a large number of expert geologists who carefully examined and interpreted the existing data.

The new geologic data collected during the activities described in [Section 6.0](#) will be evaluated with respect to the base HSU model. If the new geologic data are not consistent with the base HSU model, this model will be modified to honor the new data. If the new data are consistent with the base HSU model, it will be left unchanged (or perhaps with only minor adjustments). In either case, the new data will help to bound the range of alternative HSU interpretations.

During the development of the draft CAU groundwater flow and transport model for Frenchman Flat, a number of alternative HSU interpretations were considered, but only one alternative HSU model was constructed. Other alternative HSU models were assessed via modified parameter distributions in the draft CAU groundwater flow and transport model, but the DOE review considered the latter approach inadequate for some alternatives. Under this proposed work, the alternative HSU models will be created in the EarthVision platform in consultation with expert geologists to provide a range of permissible alternatives consistent with the observed data. These alternative HSU models will be tested by simulating groundwater flow and particle tracking to quantify the impact of geologic uncertainty on the migration of radionuclides in groundwater. It is expected that a small number (less than 10) of alternative HSU models will be selected for full simulation with the local groundwater flow and transport models as part of the uncertainty analyses.

5.6.2.2 Hydraulic Heads

Existing and newly collected hydraulic head data will be used to constrain the local groundwater flow model realizations. The new hydraulic head data described in [Section 6.0](#) will provide additional data points with which to determine the horizontal hydraulic gradient. More importantly, the new hydraulic head data will be measured in both the Alluvial Aquifer and the Lower Carbonate Aquifer and will provide vertical hydraulic head information. The vertical hydraulic head information is expected to provide vertical hydraulic gradient estimates through the Alluvial Aquifer and across the confining units that separate the Alluvial Aquifer and the Lower Carbonate Aquifer. Observed horizontal and vertical hydraulic head data will serve as calibration targets for the local groundwater

flow and transport models. In addition, during the uncertainty analyses, the observed hydraulic head data will be used to determine if a realization is permissible. The criteria for permissible realizations will be established following calibration of the base local groundwater flow model.

5.6.2.3 Recharge

As stated in Section 5.1.3.1 of the Frenchman Flat CAIP (DOE/NV, 1999a), there are two sources of groundwater recharge to the Frenchman Flat groundwater flow system. The first source is subsurface inflow, and the second is areal recharge from local precipitation. The external peer review panel (IT, 1999) acknowledged on page 23 that: *“There is very little that can be done to accurately quantify recharge over extensive areas in arid and semiarid settings where recharge amounts may be only a small fraction of precipitation.”* The reviewers also believed that there are large uncertainties associated with the Maxey and Eakin (1949) approach used to estimate recharge for the draft Frenchman Flat CAU groundwater flow model despite the fact that the recharge used in this model was in a plausible range based on measurements at Yucca Mountain. The recharge uncertainty included in the draft CAU groundwater flow model produced at most a 30 percent increase in travel distance, but did not consider large local variations in recharge.

Large-scale recharge estimates are being developed by Desert Research Institute (DRI) and the U.S. Geological Survey (USGS). The DRI has been conducting a regional study of recharge over an area including the NTS. The results of this study will be estimates of steady-state recharge for each grid cell of the study domain. Grid cell dimensions for the DRI recharge model are 2 by 2 kilometers (km) (1.2 by 1.2 miles [mi]). These recharge estimates are intended to guide input for the Frenchman Flat CAU groundwater flow model. Additional recharge estimates will come from work being conducted by the USGS in support of regional-scale groundwater flow modeling for the Yucca Mountain Project. These new recharge estimate techniques, combined with historical methods (Maxey and Eakin, 1949), will provide a range of recharge estimates for groundwater flow simulations at the CAU scale. It is expected that uncertainty analyses with the recharge models will help to place bounds on the CAU-scale recharge.

At the local scale within Frenchman Flat, recharge is expected to be spatially variable. Recharge is very small in areas away from washes as demonstrated by measurements at the Radioactive Waste Management Site (RWMS) (Tyler et al., 1996). In washes, measurement of chloride profiles indicate

that washes and similar topographic features may be contributing recharge under the modern climatic conditions in Frenchman Flat (Tyler et al., 1996). Recent observations of rainfall runoff events (French and Curtis, 1999) clearly demonstrate that channel infiltration occurs during precipitation events. At the RWMS site in Area 5, French and Curtis (1999) observed that channel flow at the site was much less than predicted with rainfall runoff models that did not account for infiltration. At the northern end of Yucca Flat, French and Curtis reported that over 75 percent of the water flowing in an alluvial channel was lost to infiltration over a reach of about 2.9 kilometers (1.8 miles). They simulated the runoff event with a technique that accounts for channel infiltration and were able to match the observed runoff into the U-10i crater. How much of this infiltration eventually becomes groundwater recharge is unknown.

The primary uncertainty with respect to local recharge is the amount of infiltration through washes and other depressions that eventually become groundwater recharge. For the local-scale groundwater flow models, a greater effort will be applied to defining the locations of channels and depressions that may allow infiltration and these will be defined as aquifer recharge locations. The work of Tyler et al. (1996) suggests that if recharge is occurring via channel infiltration, it must be limited to the near vicinity of the channels; otherwise, recent recharge would have been observed in their soil borings away from washes. One approach to better define the upper bound percentage will be to use the groundwater chemistry data proposed in [Section 6.0](#), combined with existing soil water chemistry data (Tyler et al., 1996) to place upper bounds on modern recharge. Another approach is to treat recharge as an adjustable parameter determined during the calibration of the local groundwater flow model. These different approaches to defining recharge will be considered during the modeling process.

5.6.2.4 Hydraulic Properties

The hydraulic conductivity data available for Frenchman Flat were obtained from single well tests, slug tests, and grain size analyses. In some cases, no data are available for a specific HSU, and ranges of values are taken from data outside of Frenchman Flat. During the DOE review of the draft Frenchman Flat CAU model, a concern was expressed that, in some cases, the calibrated hydraulic conductivity values tend to fall below the available measured data for the volcanic units (summarized for areas outside Frenchman Flat) and the alluvium near CAMBRIC (from core and slug tests).

However, the calibrated hydraulic conductivity values derived from the draft CAU groundwater flow model are generally consistent with observed single-well test data.

New hydraulic conductivity data are planned to be collected via two aquifer tests ([Section 6.0](#)).

These aquifer tests, one in the northern testing area and the other in the southern testing area of Frenchman Flat, will have a pumping well and at least one observation well. The wells for these tests are screened in the Alluvial Aquifer. It is expected that the aquifer tests will provide information on the horizontal hydraulic conductivity of the Alluvial Aquifer over scales of 30 to 200 meters (100 to 700 ft). Some of the observation wells will be screened in different vertical positions and may provide data that can be interpreted to provide the vertical hydraulic conductivity of the Alluvial Aquifer. The success of these anisotropy interpretations depends on the aquifer properties which are not yet known. Therefore, it is not certain that the anisotropy interpretation will be successful. In addition to observation points in the Alluvial Aquifer, hydraulic heads will be measured in wells screened in the volcanic units and the Lower Carbonate Aquifer, if possible. It is not expected that observable drawdown will be measured in observation wells completed in HSUs other than the Alluvial Aquifer during the aquifer test. Therefore, the aquifer tests are not expected to provide hydraulic conductivity data on HSUs other than the Alluvial Aquifer.

The hydraulic conductivity data from the aquifer tests will be used to constrain the calibration of the local groundwater flow models. In addition, the new data will be included with the existing data from the Alluvial Aquifer of Frenchman Flat to assess the appropriate range of values to use in the uncertainty analyses.

5.6.3 Data Assessment for Contaminant Transport Model

Contaminant transport data such as effective porosity, dispersivity, and adsorption will be reassessed to gain a better understanding of the range of values to be included in the Monte Carlo analyses. Additional data will be collected to assess the distribution of reactive minerals in the Alluvial Aquifer from samples collected during drilling. These new data will provide key information for the classified source-term modeling which will be performed after the revisions to the CAU groundwater flow and transport model. In addition, measurements of melt glass surface area will be used to better define this important parameter in the classified source-term simulations. Many of the other parameters such as effective porosity, dispersivity, and adsorption used in the contaminant transport

and source-term modeling have defensible ranges that were not well documented in the modeling reports. The documentation will be improved to better justify the data used in the CAU model. In addition, the new contaminant transport data will be included in the sensitivity and uncertainty analyses.

5.6.4 Code Selection

The finite-element code FEHM is proposed to build the local groundwater flow and transport models of Frenchman Flat. The finite element formulation of FEHM will provide greater flexibility to simulate complex geometries. Although this flexibility comes at the cost of increased complexity in mesh generation, some very refined mesh generation tools are available to simplify the process.

FEHM is proposed for additional modeling of groundwater flow and contaminant transport in Frenchman Flat without any further testing because it had been recognized as one of the best candidate codes for the Frenchman Flat CAU earlier on. It was one of the three codes selected for testing during the code selection process. The primary reasons FEHM was not chosen at the time were large memory requirements and a lack of familiarity with the code on the part of the modeling group. Since that time, the FEHM code has been made more memory-efficient and the members of the modeling team have become familiar with the code while testing it for use in the Pahute Mesa CAU groundwater flow and transport model. Additionally, the continued refinement and expansion of the capabilities of FEHM by scientists at Los Alamos National Laboratory (LANL) make this code well suited for present and future work.

5.6.5 Model Construction

The process of creating the two local groundwater flow and transport models will be presented in this section. These local-scale models are intended to assess specific concerns or processes that are more difficult to adequately treat with the larger-scale CAU groundwater flow and transport model. Specifically, these local-scale groundwater flow and transport models will be used to assess the uncertainty with respect to possible vertical flow and the possibility that radionuclides may move vertically from the underground tests to the Lower Carbonate Aquifer in less than 1,000 years. The construction of the local groundwater flow and transport models includes three major steps:

- (1) selection of the model areas, (2) development of the groundwater flow model and
- (3) development of the transport model.

5.6.5.1 Model Area Selection

The size of the local groundwater flow and transport models will be only as large as necessary to capture the aspects of the flow system that would impact vertical flow scenarios. The local groundwater flow models will be 3-D to capture the complexity of the geologic and hydrologic systems. However, during the modeling process, it may be determined that a vertical cross-section simulation may be needed to further refine the modeling. That decision will not be made until after the 3-D groundwater flow and transport models are built.

The potential model area for the northern local groundwater flow and transport model is shown in [Figure 5-1](#). In addition, [Figure 5-1](#) shows the location of the seven underground tests, the geologically and geophysically inferred faults, the surficial geology, the surface topography, and the location of two cross sections through the proposed site of Well ER-5-3. More information about Well ER-5-3 is presented in [Section 6.0](#) of this document. The two geologic cross sections, A-A' and B-B,' are presented in [Figure 5-2](#) and [Figure 5-3](#), respectively. The potential local groundwater flow and transport model area shown in [Figure 5-1](#) is subject to change based on the data collected from Well ER-5-3. Reasons for choosing this model area are explained in the next paragraph.

The primary goal of the local groundwater flow and transport model is to assess possible alternative flow paths, especially vertical flow along fault planes. As seen in [Figure 5-2](#) and [Figure 5-3](#), the proposed groundwater flow and transport model area includes the geologically and geophysically inferred faults in the vicinity of the underground tests, and extends as far east as the fault along Scarp Canyon, considered to be a major basin-bounding fault in the Frenchman Flat hydrostratigraphic framework model. To the north, this local groundwater flow and transport model area extends beyond the B-B' cross section to the point where the water table is projected to intersect the Lower Carbonate Aquifer (shown as Pre-Tertiary Units, Undivided in [Figure 5-2](#) and [Figure 5-3](#)). This proposed local groundwater flow and transport model area for the northern testing area is expected to be sufficient to allow assessment of fault influences on the local flow system, while accounting for lateral flow to the north and northeast in the Alluvial Aquifer.

Figure 5-1
Potential Local Groundwater Flow and Transport Model Area
for the Northern Testing Area of Frenchman Flat

Figure 5-2
West-East Geologic Cross Section through
the Northern Testing Area of Frenchman Flat

Figure 5-3
North-South Geologic Cross Section through
the Northern Testing Area of Frenchman Flat

In the central portion of Frenchman Flat, where the southern testing area is located, the potential local groundwater flow and transport model area is presented in [Figure 5-4](#). [Figure 5-5](#) is the west-east geologic cross section through the proposed location of Well ER-5-4. More information about Well ER-5-4 is presented in [Section 6.0](#) of this document. The local groundwater flow and transport model area shown in [Figure 5-4](#) includes the three underground tests in the southern testing area and three of the geophysically inferred faults. The expected direction of groundwater flow in the Alluvial Aquifer is to the east-southeast, so the proposed local groundwater flow and transport model area has been extended to the east and south.

The overall size of the local groundwater flow and transport model areas shown in [Figure 5-1](#) and [Figure 5-4](#) will be as large as a few kilometers on a side and extend vertically just into the Lower Carbonate Aquifer to provide a fixed hydraulic head lower boundary to this local model. Both local groundwater flow and transport model areas are subject to change per the outcome of the proposed new data to be collected as described in [Section 6.0](#). The size and shape of the local groundwater flow and transport model areas could change to reflect the new information. Nonetheless, the goals of the two local groundwater flow and transport models remain the same; to assess the possibility of a vertical (or near vertical) pathway from the underground test cavities to the Lower Carbonate Aquifer.

The boundaries of the local groundwater flow and transport models will not necessarily be rectangular (as shown in [Figure 5-1](#) and [Figure 5-4](#)) because they may correspond to a hydrostratigraphic boundary. Final decisions about these boundaries will be made during the modeling process.

5.6.5.2 Groundwater Flow Model

This section describes the groundwater flow model construction process. The construction process includes model setup and model calibration.

Figure 5-4
Potential Local Groundwater Flow and Transport Model Area
for the Southern Testing Area of Frenchman Flat

Figure 5-5
West-East Geologic Cross Section through
the Southern Testing Area of Frenchman Flat

5.6.5.2.1 Model Setup

Several tasks must be completed to set up the local groundwater flow models. These tasks include: definition of the model grid, assignment of initial parameter values, definition of boundary conditions, and assignment of target head and flux values.

Model Grid

The local groundwater flow and transport model areas shown in [Figure 5-1](#) and [Figure 5-4](#) will be discretized using finite-element grids. These grids will have greater resolution in the vicinity of underground tests and faults. The finite-element mesh will follow the hydrostratigraphic framework contours and the fault contacts.

Two finite-element gridding options are available, structured and unstructured. Structured grids are logically rectangular with a well-defined and regular relationship between each point and its neighbor. Structured finite-element grids are more versatile than finite-difference grids, which are also structured but with the additional constraint that the cell boundaries meet at right angles. Unstructured grids are constructed from a variety of element shapes such as triangles, quadrilaterals, and tetrahedra, and offer greater flexibility in representing complex geometries.

This greater flexibility comes at a higher cost because the relationship of one element to another must be explicitly stated. The gridding option is not yet defined, but could include a combination of structured and unstructured grids. Final grid decisions will be made after the new data collection is finished.

Initial Parameter Estimates

Initial distributions of hydraulic conductivity and surficial recharge will be assigned to the groundwater flow model grids following completion of the data assessment activities described in [Section 5.6.2.4](#) and [Section 5.6.2.3](#).

Boundary Conditions

The boundary conditions for the local groundwater flow models are difficult to specify with certainty because the boundaries do not correspond to physical features. Therefore, other approaches must be used to assign boundary conditions. Specified boundary fluxes obtained from the regional groundwater flow model were used in the draft CAU groundwater flow model. This approach is rigorous, but the DOE review intimated the direct link to the regional groundwater flow model limited the range of uncertainty analyses. Alternative approaches to defining boundary conditions for the local groundwater flow models are being considered.

The alternative approaches for specifying boundary conditions for the local groundwater flow models can be placed into two groups, those that specify fluxes and those that specify heads. In both cases, the values specified on the boundary may be determined from measured data (hydraulic head and hydraulic conductivity) or from a larger-scale groundwater flow model. In the specified flux approach, the flux of water across the model boundary is specified for each node of the boundary. To make the numerical solution unique, a small number of the local groundwater flow model grid nodes, either internal or on the boundary, must have hydraulic head values specified. The local groundwater flow model then predicts the hydraulic head distribution in the model domain which is compared with measured hydraulic heads. This approach guarantees that the total flux of water through the local groundwater flow model is consistent with expectations based on a larger-scale groundwater flow model or measured values.

In the specified-head approach, hydraulic head values are assigned to each node on the groundwater flow model boundary. The specified hydraulic heads may be obtained from a larger-scale groundwater flow model or from measured hydraulic head data, or they may be extrapolated to the local groundwater flow model boundary and assigned. This allows the groundwater flow model to calculate the amount of water flowing through the system. For the constant-head boundary approach to be realistic, constraints must be placed on the total flux through the flow system. Constraints on the total flux can be estimated from uncertainty analyses using local hydraulic head and aquifer parameter data or from uncertainty analyses with the larger-scale groundwater flow models.

Under many conditions, the specified-head and specified-flux approaches are equally valid, so the choice of which method to use may be based on operational factors. Both approaches can be

calibrated to observed water levels within the local groundwater flow and transport model area and to total flux through the system. In general, the hydraulic head values predicted by the groundwater flow model are more sensitive to hydraulic conductivity adjustments when boundary flux is specified than when constant-head boundaries are assigned. With specified-head boundaries, changes in hydraulic conductivity modify the flux through the system, causing groundwater velocities to be more variable than with specified-flux boundaries.

Ideally, a groundwater flow model is calibrated with both types of boundary conditions. When calibrating to hydraulic head measurements, the groundwater flow model will be much more sensitive to hydraulic conductivity adjustments in specific HSUs, or zones, if specified-flux boundaries are assigned. The groundwater flow model can then be switched to specified head conditions to adjust the mean hydraulic conductivity to calibrate to total fluxes.

Whether the local groundwater flow models use specified-flux or specified-head, the values along the boundary must be provided. If local data are available, the boundary heads and fluxes (hydraulic conductivity times hydraulic gradient [Darcy's Law]) can be derived from local data. Alternative conceptual models are more easily included in the simulations when using local data because the range of values, heads, gradients, and hydraulic conductivities can be used to constrain the values.

Target Hydraulic Heads

Calibration target hydraulic heads will be selected following the completion of the data assessment activities described in [Section 5.6.2.2](#). Observed horizontal and vertical hydraulic heads will serve as calibration targets for the local groundwater flow models.

5.6.5.2.2 Groundwater Flow Model Calibration

The calibration of the steady-state local groundwater flow models will focus on matching new and existing predevelopment hydraulic head data, especially newly-collected data with depth. These new data will provide vertical head data in the Alluvial Aquifer in selected volcanic units, and in the Lower Carbonate Aquifer. In addition, the groundwater flux across the local groundwater flow model boundaries also may be a calibration target if specified head boundaries are used. These

boundary flux targets will not be fixed values, but rather ranges of values based on uncertainty in the local data.

During the calibration, a number of features and parameters will be adjusted to match observed heads and estimate boundary fluxes. Hydraulic conductivity of the different HSUs and the fault zones will be adjusted during calibration. The new hydraulic conductivity data on the Alluvial Aquifer will help constrain the calibration of the local groundwater flow models. As noted previously, recharge may be used as a calibration parameter. More difficult adjustments, such as modifications to the hydrostratigraphic framework model may be required during calibration. These may lead to multiple calibrations which will become part of the uncertainty analyses.

Both the manual (trial and error) or automated (inverse method) calibration approaches may be used to calibrate the local groundwater flow models. The manual calibration is the same approach used for the draft Frenchman Flat CAU groundwater flow model and depends on the modeler's skill and judgement to adjust the various parameters so that predictions match the calibration targets. The automated approach uses an optimization approach such as the parameter estimation (PEST) code (Westmark Computing, 1998) to adjust parameters to provide the best match to observed data. The PEST approach has been applied successfully with MODFLOW and FEHM. Both calibration approaches will be considered for the local groundwater flow models.

5.6.5.3 Contaminant Transport Model

The local transport model will be used to simulate the migration of contaminants in groundwater from the underground test cavities. This involves setting up the transport model and performing simulations.

5.6.5.3.1 Model Setup

Set up of a contaminant transport model includes refining the grid (if necessary), defining the sources of contamination, and assigning transport parameters to the grid.

Model Grid

The transport simulations build upon the flow paths generated by the local steady-state groundwater flow models. Thus, the local transport model may use the same grid as the local groundwater flow model. However, grid refinements may be necessary under certain conditions. As stated in the previous section, it is not expected that the local-scale model grids will require additional refinements for transport simulations.

Source Term

The hydrologic source term is the only boundary of concern for the transport simulations. The source mass fluxes for Frenchman Flat are determined using the Lawrence Livermore National Laboratory (LLNL) source term model (LLNL, 1999). The LLNL source-term model provides the mass flux of radionuclides from the cavity exchange volume and the melt glass into the groundwater. These fluxes will be placed into the corresponding nodes of the local groundwater flow and transport models. The local transport model grids will be of sufficient resolution to ensure that initial dilution of the source concentrations does not occur.

The source-term model will be used to calculate two versions of the hydrologic source term. The first one is based on unclassified data and the second one on classified data. Each of the hydrologic source terms will be used to simulate the sources of contamination in the local groundwater flow and transport models. Detailed source-term and groundwater flow and transport simulation results based on classified data will be documented in classified reports. Descriptions of the source-term model are provided in [Section 5.7](#).

Transport Parameters

Transport parameter values such as those for dispersivity, matrix porosity, matrix diffusion, and effective porosity will be determined on a HSU basis. Initially, mean parameter values will be determined for each HSU. Later, during the uncertainty analyses, the variability in parameter values will be included in the calculations.

5.6.5.3.2 Transport Model Simulations

Following the completion of the data assessment activities discussed in [Section 5.6.3](#), initial local contaminant transport simulations will be performed using averaged data or declassified data from selected nuclear tests. Later on, simulations may be performed using classified source information for individual tests. Descriptions of the techniques that may be used to perform the contaminant transport simulations are provided.

One of several techniques may be used to simulate the migration of radionuclides in the local transport models. A SLPT method developed in FEHM is well suited for these simulations. The SLPT method solves for particle residence time along a one-dimensional path and accounts for effects from advection, dispersion, equilibrium sorption retardation, radioactive decay, and matrix diffusion. A second approach utilizes a three-dimensional solution to the advection-dispersion equation to solve for radionuclide concentrations within the flow system. The SLPT method is preferred for the local transport models for several reasons. First, the SLPT method does not require additional refinement to the flow grid. Second, it is computationally efficient, even with many thousands of particles. Third, it incorporates the important processes of interest in Frenchman Flat. The SLPT method is expected to be sufficient to assess the vertical flow scenarios. However, as a check on the SLPT method, a limited number of 3-D transport simulations with the local transport models will be performed to check the results of the SLPT simulations.

5.6.6 Sensitivity Analyses

Extensive sensitivity analyses will be performed with the local groundwater flow and transport models to assess the importance of the different parameters. The parameters of interest include the hydraulic conductivity, recharge, porosity, dispersivity, adsorption, source term concentration, and source term release rate. Additionally, the sensitivity of the local groundwater flow and transport models to specific assumptions such as the decrease of the hydraulic conductivity with depth needs to be fully tested. These sensitivity analyses are intended to identify the most important parameters to be used in the later uncertainty analyses.

5.6.7 Uncertainty Analyses

Uncertainty analyses will be conducted with the local groundwater flow and transport models proposed in this addendum. The purpose of the uncertainty analyses is to assess the range of possible outcomes (radionuclide migration distances) from uncertainty in the input parameters and assumptions used in the local groundwater flow and transport models.

The uncertainty analyses conducted using the draft CAU groundwater flow and transport model were criticized during the DOE review as not being extensive enough. The uncertainty analyses will be expanded to include alternative hydrostratigraphic models, boundary flux uncertainty, and parameter uncertainty for both flow and transport parameters. The primary goal of the alternative hydrostratigraphic models is to assess the impact of the geologic uncertainty on the predicted contaminant transport distances with particular emphasis on potential vertical pathways of flow. These pathways may include juxtaposition of transmissive units across faults, or flow along the fault plane itself. Boundary flux uncertainty embodies a wide variety of sources including flow and recharge external to the groundwater flow models and local hydraulic parameter uncertainty. In general, boundary flux uncertainty is maximized by using specified-head boundaries for the groundwater flow model and allowing the hydraulic conductivity and recharge to vary over the likely range of values. Groundwater flow and transport parameter uncertainty will be reassessed to better document the range of uncertainty and, if necessary, modify the uncertainty ranges of those parameters. Groundwater flow and transport model simulations with the range of parameter values will yield an assessment of the prediction uncertainty due to parameter uncertainty. In addition, the list of uncertain parameters will be expanded to include more of the transport parameters.

The uncertainty analyses defined above will be computationally burdensome for 3-D distributed parameter models such as the local and CAU groundwater flow and transport models. To maximize the efficiency of the uncertainty analyses, the total-system model will be used first. The total system approach is designed to encompass the full range of uncertainty in a computationally efficient manner. The total-system model, as presented in [Section 5.4](#), combines source, conceptual model, hydrostratigraphic model, and parameter uncertainty using simplified approximations to the complex 3-D processes. The total-system model can assess the interaction of the different sources of uncertainty and will help to guide the 3-D local and CAU groundwater flow and transport model uncertainty analyses by eliminating factors of secondary importance.

The uncertainty analyses in the local groundwater flow and transport models will be focused primarily on the possible modes to transport radionuclides from the underground test cavities to the Lower Carbonate Aquifer. This uncertainty will include alternative hydrostratigraphic models, alternative conceptual models such as whether the hydraulic conductivity decreases with depth within a single HSU, and variation in physical and chemical properties of the material. The range of transport distances within 1,000 years using the particle-tracking analyses will be the measure of transport uncertainty. Uncertainty analyses of the local groundwater flow and transport models will also include source term uncertainty analyses presented in the source-term model (LLNL, 1999). Processes and parameters shown to be unimportant during the total-system modeling will be eliminated from the 3-D uncertainty analyses.

5.7 Source-Term Model

The source-term model developed by LLNL will be used to calculate two hydrologic source terms for input into the CAU and local groundwater flow and transport models, one based on unclassified data and the other based on classified data.

The source-term model based on unclassified data is limited to unclassified data from the CAMBRIC experiment. The restriction to unclassified data limits the number of radionuclides that can be considered. Nonetheless, it does include a number of mobile and sorbed radionuclides such as tritium, cesium, strontium, europium, plutonium, and americium. The details of the source-term model using unclassified data have been documented in a report published by LLNL (1999).

The source-term model based on classified data will be refined after the local groundwater flow and transport models are complete and after revisions to the Frenchman Flat CAU groundwater flow and transport model, if necessary, are made. Refinements to this source-term model will include uncertainty analyses with respect to melt glass surface area, exchange volume hydraulic conductivity, effective distribution coefficients (K_d s), and the distribution of reactive minerals based on new measurements.

The results of the source-term modeling will be used to simulate the sources of contamination in the local groundwater flow and transport models. The radionuclides and associated parameters used in the source-term model and CAU and local groundwater flow and transport models will be carefully

coordinated to ensure consistency. As stated before, the details of all source-term and groundwater flow and transport modeling using classified data will be documented in classified reports.

5.8 *Potential CAU Groundwater Flow and Transport Model Revisions*

Potential revisions to the Frenchman Flat CAU groundwater flow and transport model will be evaluated based on the findings of the new data collection described in [Section 6.0](#) and, if required, the simulations with the local groundwater flow and transport models proposed in this section.

If the new data and modeling of local groundwater flow and transport support the present conceptual model (i.e., horizontal flow through the Alluvial Aquifer toward Lower Carbonate Aquifer), some revisions to the CAU groundwater flow and transport model may be necessary. These revisions may include reducing the size of the model area, refining the model grid, and expanding the uncertainty analyses pertinent to horizontal flow. This may involve changing the CAU groundwater flow model boundary conditions from specified flux to specified head to expand boundary flux uncertainty.

If the new data and modeling of local groundwater flow and transport identify a vertical flow pathway that is probable, the revisions to the Frenchman Flat CAU groundwater flow and transport model may be more extensive. The exact nature of revisions cannot be determined at this time.

The regional groundwater flow model (DOE/NV, 1997) will continue to provide boundary conditions to the CAU groundwater flow model, but the connection between the two models may be less direct than in the draft CAU groundwater flow model. As described earlier, several different approaches are available to incorporate regional-scale boundary influences into the CAU- and smaller-scale groundwater flow models. Each of these approaches will be evaluated during the modeling process.

5.9 *Summary*

Following its completion, the draft Frenchman Flat CAU model was subjected to a DOE review. Major issues identified during the DOE review include the inability of the draft CAU groundwater flow and transport model to accurately simulate groundwater flow and contaminant transport at the local scale in the vicinity of the testing areas, and data insufficiency at the same area. To resolve these issues, DOE proposes additional data-collection and modeling activities to assess the potential for vertical contamination migration from the alluvial and volcanic units to the Lower Carbonate

Aquifer. Data proposed for collection include water levels, solid samples, and hydraulic property data from two locations in Frenchman Flat. The proposed modeling activities include the development of a total-system model and the potential development and use of two local groundwater flow and transport models. These local-scale models have been described earlier in this section and will be supported by the new information gathered during the data-collection activities described in [Section 6.0](#) of this addendum. The need to revise the Frenchman Flat CAU groundwater flow and transport model will depend, in part, on the outcome of the data collection. If the new data verify the draft CAU groundwater flow and transport model with respect to vertical flow, there may not be much need for the local groundwater flow and transport models. This in turn may lead to a reduction in the size of the CAU groundwater flow and transport model and the refinement in the vicinity of the testing areas.

6.0 Field Investigation Addendum

6.3 Proposed Characterization Activities

This portion of the addendum was prepared to describe the data-collection activities that have been proposed by DOE following their review of the draft Frenchman Flat CAU model. These activities will follow the revised UGTA strategy described in the FFACO (1996) and referenced in [Section 2.0](#) of this document. As stated in [Section 5.3.2](#), the four activities are as follows:

- Hydrogeologic investigation of the nuclear testing areas
- Aquifer testing in the nuclear testing areas
- Integrated-geophysical investigation
- Isotope- and geochemistry-based investigation

The newly acquired information collected during these activities will be used to supplement the existing information, which was used to develop the draft Frenchman Flat CAU model. The existing and newly acquired information will then be used in the modeling activities described in [Section 5.0](#) of this document, as appropriate. Descriptions of the proposed activities are provided in this addendum to Section 6.0 of the CAIP (DOE/NV, 1999a).

6.3.1 Hydrogeologic Investigation of the Underground Testing Areas

The Frenchman Flat CAI includes the drilling and completion of hydrogeologic investigation wells at two locations in the Frenchman Flat basin. These wells were proposed to gather site-specific data within the two underground nuclear test subareas: the northern testing area and the southern testing area, where contamination originates. These new wells are intended to provide information on the geology, hydrogeology, and water chemistry in the vicinity of nuclear testing areas, which are considered to be not fully characterized. Previous drilling in these areas penetrated only the alluvium, or just into the underlying volcanic units in a few boreholes. The new wells are planned to penetrate significant depths below the Alluvial Aquifer. The information will help improve the conceptual model of groundwater flow and transport in the vicinity of the underground testing areas, which in turn will help with building better hydrologic models.

6.3.1.1 Scientific Objectives

The purpose of the proposed wells is to collect data to test and/or improve the current hydrostratigraphic and hydrologic models of the Frenchman Flat CAU. The proposed well locations are intended to provide the maximum amount of hydrogeologic information, particularly with respect to potential vertical migration pathways from the underground tests to the Lower Carbonate Aquifer. The scientific objectives for the proposed wells are listed in a sequential order that follows the well installation activities:

- 1) Characterize the geology of the area located in the vicinity of the wells at depth or to the Lower Carbonate Aquifer, if practical. Characterization includes identification of the stratigraphic unit present, determination of their physical nature, thicknesses, structure, and hydrogeologic and mineralogic properties.
- 2) Provide borehole geologic and geophysics information in support of the integrated geophysical investigations described in [Section 6.3.3](#).
- 3) Improve the understanding of vertical hydraulic gradients within the alluvial aquifer and between the various HSUs in the vicinity of the underground testing areas of Frenchman Flat.
- 4) Serve as pumping or observation wells in the aquifer tests proposed to determine horizontal and perhaps vertical hydraulic conductivity within the Alluvial Aquifer described in [Section 6.3.2](#).
- 5) Characterize groundwater geochemistry at the water table, near the base of the alluvium, and at depth or to the Lower Carbonate Aquifer, if practical.

An additional future objective for these two wells is to serve as potential long-term monitoring point(s) for water levels and groundwater chemistry, and possibly contaminants originating from the Frenchman Flat underground nuclear tests. The evaluation of the suitability of these wells to serve as monitoring wells will not be addressed in this document.

6.3.1.2 Description of Proposed Wells

A brief description of the proposed wells is provided (e.g., location, depth, and estimates of depth to water and land surface elevation). [Table 6-1](#) summarizes pertinent information for the two wells, including: well names, general well location descriptions, well location coordinates, proposed maximum depths, expected depths to groundwater, and well surface elevations. More detailed well descriptions are provided in [Section 6.3.1.4](#).

The proposed well locations are in the northern testing area and the southern testing area. The location in the northern testing area is designated Well ER-5-3, and the location in the southern testing area is designated Well ER-5-4. The proposed locations of Well ER-5-3 and Well ER-5-4 are shown in [Plate 1](#). Well ER-5-3 will have a satellite well for aquifer testing purposes. Both of these proposed locations are close to the locations of underground nuclear tests. Well ER-5-3 is located in the vicinity of two underground nuclear test locations: NEW POINT and MILK SHAKE. Well ER-5-4 is located in the vicinity of three underground nuclear test locations: CAMBRIC, WISHBONE, and DILUTED WATERS.

The wells are proposed to be drilled to depths ranging from 1,158 to 1,329 m (3,800 to 4,000 ft) below ground surface (bgs). Groundwater is expected to be encountered between 220 and 287 m (720 and 943 ft) bgs. The wells will provide hydrogeologic information for the various HSUs, starting with the Alluvial Aquifer and at depth, or down to the Lower Carbonate Aquifer, if practical.

Table 6-1
Information Summary for Proposed Wells ER-5-3 and ER-5-4

Well Name	General Location	Approximate Coordinates UTM ^a (m)	Approximate Coordinates NSP ^b (ft)	Proposed Total Depth (m/ft bgs)	Expected Depth-to-Water (m/ft bgs)	Expected Static Waste-Level Elevation (m/ft amsl) ^c	Surface Elevation (m/ft amsl)
ER-5-3	Northern Frenchman Flat	E ^d 594,657 N ^e 4,081,123	N 773,594 E 713,147	1,158 3,800	287 943	735 2,410	1,022 3,353
ER-5-4	Central Frenchman Flat	E 592,484 N 4,075,665	N 755,710 E 705,950	1,329 4,000	220 720	734 2,407	953 3,127

^a Universal Transverse Mercator, Zone 11, NAD 27

^b Nevada (Central) State Planar Coordinates, NAD 27

^c Above mean sea level

^d Northing

^e Easting

6.3.1.3 Field Activities

Installation of the proposed wells for the Frenchman Flat hydrogeologic investigation program will involve several field activities. These activities include borehole drilling, cuttings and core sample collection and description, geophysical logging, well completion, well development, and groundwater sample collection. Each field activity is discussed in the subsections that follow.

6.3.1.3.1 Drilling

The drilling depths proposed for the two locations are based on the scientific objectives presented in [Section 6.3.1.1](#). The proposed depths are estimated based on available information and assumptions regarding subsurface hydrogeology. Because of uncertainty in subsurface hydrogeology and drilling conditions, every objective listed may not be achieved for each well. Boreholes will be drilled using either mud rotary or air-foam rotary techniques.

Drill cuttings and cores will be collected during drilling to sample the geologic units penetrated by the boreholes. Drill cuttings will be collected at specified intervals, while conventional and/or sidewall cores may also be collected to provide supplemental geologic information of a specific borehole interval. The cuttings will be evaluated to determine the characteristics of the geologic units penetrated during drilling. Drill cutting samples and cores will be collected following the current standard procedures to ensure consistency.

6.3.1.3.2 Drill Cuttings and Core Sample Collection

Drill cuttings and cores will be collected during the drilling of the two wells. Composite drill cutting samples will be collected for geologic analysis at regular 3-m (10-ft) intervals, if possible, during the drilling process from the base of the conductor casing to the total depth of each borehole.

Conventional and/or sidewall cores may also be collected to provide supplemental geologic information of a specific borehole interval. The collection and management of geologic cuttings and core for the UGTA Project will be conducted in accordance with standard procedures. Sample handling, packaging, storage, and chain-of-custody maintenance will be conducted in accordance with applicable standard operating procedures.

6.3.1.3.3 Drill Cuttings and Core Sample Description

Drill cuttings and core descriptions will be performed in compliance with the same standard operating procedures. Additional subsamples of the cuttings or core may also be subjected to petrographic or chemical analysis. The results will be recorded on a lithologic log, which will serve as the basis for defining the geology of the area penetrated by the wells, in support of the first objective of this characterization activity ([Section 6.3.1.1](#)).

Samples will be analyzed for identification of the geologic formations penetrated by the borehole and for factors that might be expected to affect contaminant transport such as presence of reactive minerals, lithology, and geological structures. Samples may also be selected for analysis of bulk elemental concentrations of radionuclides or other properties relevant to the Frenchman Flat CAI. Description methods may be modified to accommodate cuttings containing radionuclides. The core samples will provide additional information such as lithology (e.g., color, grain size, and texture), percentage of the minerals within the rock, and degradation or alteration of primary minerals. Subsequent interpretations of the descriptions of the cuttings enables geologists to derive geologic information about tops of formations, unit thicknesses, lithologic composition, qualitative permeability estimate, presence or absence of fractures, and borehole stability.

Petrographic or chemical analysis of subsamples of cuttings or core will emphasize the characteristics pertinent to the hydraulic properties of the rocks or the potential transport of constituents of concern. These include fractures, degree of alteration, matrix clay content, porosity, and permeability. In addition, samples of cuttings will be selected for chemical analysis of bulk elemental and mineralogic constituents and possibly radionuclides. These additional analyses will be used to characterize the distribution of the elemental constituents, and possibly radionuclides, in the rock matrices and on fracture surfaces. These analyses may include determination of bulk elemental concentrations by atomic absorption and inductively coupled plasma spectroscopy. Radionuclide concentrations and distributions may be determined by mass spectroscopy. The distribution of the elements of interest, such as their occurrence in the rock matrices and/or on fracture faces, may be determined by electron microprobe or scanning electron microscope techniques.

6.3.1.3.4 Geophysical Logging

The proposed geophysical logging suite will support the first two scientific objectives stated in [Section 6.3.1.1](#). The logs will help define the geologic, hydrologic, and physical characteristics of rock units within the two boreholes in support of the first scientific objective. The logs will also provide discrete control points for the 3-D gravity model discussed in [Section 6.3.3.2](#) in support of the second scientific objective. In addition, the geophysical logs may be used to help determine and assure appropriate completion of the borehole.

Geophysical data will be collected from each borehole using wireline techniques. In most cases, wireline geophysical logs will be collected within the uncased borehole. Geophysical logging will be conducted throughout the saturated and unsaturated portions of each borehole from the well total depth to the bottom of the surface casing. The recommended suite of saturated-zone geophysical logs includes the following:

- Caliper
- Spectral gamma ray
- Temperature/differential temperature
- Compensated density
- Neutron porosity
- Resistivity
- Sonic
- Borehole deviation (gyroscopic)
- Sidewall cores (percussion/rotary)
- Downhole chemistry
- Thermal flow
- High performance spinner

In addition, several other optional geophysical logs may be required through both the unsaturated and saturated portions of the borehole, if unexpected or unusual borehole conditions are encountered.

6.3.1.3.5 Well Development

The wells will be developed to minimize the effects of drilling on the formation around the borehole and to restore the water quality in the rock matrix to near that of the natural formation water prior to drilling.

The objectives of well development are: (1) to remove residual cuttings and drilling fluids that may have invaded the formation during drill advancement, (2) to improve the hydraulic efficiency of the formation immediately around the borehole by minimizing the effects of drilling on the formation, and (3) to restore the water quality of the natural formation. Well development also helps ensure that water levels measured in the well represent the formation conditions prior to disturbance as closely as possible.

Development will take place in two phases. The initial phase (open-borehole development) will take place in the open borehole prior to well completion, provided the borehole is stable, after the total depth is reached, and drilling is completed. The final phase (completion-zone development) will take place in the completion zone or zones after well installation is complete.

The rate of water production during development will be monitored with a flowmeter or by direct measurement to collect information on the production capacity of the formation. Produced water will be monitored both visually and with water quality monitoring instrumentation to observe changes occurring during development. Produced fluids will also be monitored for fluid management purposes, as required in the *Fluid Management Plan (FMP) for the Underground Test Area Project* (DOE/NV, 1999b).

Samples taken for fluid management purposes along with samples collected for laboratory analysis will be handled in accordance with applicable standard operating procedures to ensure that the samples are properly packaged and shipped, if necessary, and that chain of custody is maintained.

6.3.1.3.6 Well Completion

Following initial well development and geophysical logging, each well will be completed. Well completion consists of final well construction, including setting and cementing of casings, placement of screened intervals, and installation of other well hardware. Each well will potentially have completions in the Alluvial Aquifer, volcanic units, and at depth, or to the Lower Carbonate Aquifer, if practical, to achieve the first, third, and fifth scientific objectives listed in [Section 6.3.1.1](#). Well completion strategies will vary from well to well, depending upon the specific conditions prevailing at the well site. The final well designs will be part of the drilling criteria of each well.

6.3.1.3.7 Depth-to-Water and Pressure Head Measurements

Depth-to-water and pressure head measurements are used to derive hydraulic heads, which can be used to define groundwater flow patterns and calculate vertical and horizontal hydraulic gradients in support of the third scientific objective listed in [Section 6.3.1.1](#). Hydraulic heads also serve as calibration targets during the calibration of the groundwater flow models, and may be used to define the boundary conditions as described in [Section 5.0](#).

During the well installation process, depths-to-water will be measured after drilling and after well completion. Depths-to-water measured after drilling and after well completion within the borehole provide composite measurements of all the intervals open to the well. Pressure heads will be measured after well completion within discrete completion zones and will be representative of specific aquifer units. Of particular interest are pressure heads in the Alluvial Aquifer and lower aquifer completion zones. Such measurements will help estimate vertical hydraulic gradients. All depth-to-water and pressure head measurements will be made using the same applicable standard operating procedures to assure accuracy and consistency.

6.3.1.3.8 Groundwater Sampling and Analysis

Two sets of groundwater samples will be collected from each well. The initial set of groundwater samples will be collected following the construction of the wells to provide preliminary baseline chemistry to ensure that the water discharged from the pump meets discharge standards. The second set of groundwater samples will be collected following final development of the wells to characterize the groundwater chemistry of each well in support of the fifth scientific objective listed in [Section 6.3.1.1](#).

The first set of groundwater samples will be collected after well construction activities have been completed. The groundwater samples will represent a composite of all water-bearing units within the screened intervals. The samples will then be sent to the laboratory for analysis. A complete description of the analytical suite is provided in Table 5-1 of the *Underground Test Area Quality Assurance Project Plan - Nevada Test Site, Nevada* (DOE/NV, 2000b). The list will include the following constituents:

- Dissolved and total metals
- Major anionic constituents (e.g., carbonate/bicarbonate)
- pH
- Total dissolved solids
- Dissolved and total organic carbon
- Tritium
- Gamma scan, gross alpha, and gross beta
- Gamma-emitting radionuclides, if radioactive contamination is detected from the screening analyses

It is recognized that the wells may not be fully developed at the time of this initial sample collection, and the groundwater sampled may not be fully representative of natural formation waters. However, the approximated chemistry of the groundwater produced will be established through the analysis of these samples. The results of these analyses will serve as a preliminary reference groundwater chemistry for the parameters listed above, to which subsequent samples may be compared.

The second set of groundwater samples will be collected after final well development. These groundwater characterization samples will be collected to establish groundwater chemistry for individual well locations and specific zones to satisfy the scientific objectives. The samples will be analyzed for the same constituents as the first set of groundwater samples. The results of the analyses will serve as the final baseline groundwater chemistry for these parameters at the well locations.

6.3.1.4 Specific Well Information

General information about drilling at the two well locations proposed for the Frenchman Flat CAU has been summarized in [Table 6-2](#). An overview of information specific to each of the two locations is presented in the following subsections.

6.3.1.4.3 Well ER-5-3 Location

The following overview of information specific to Well ER-5-3 includes the well description, location, physiography, geologic setting, and predictive geology and hydrology. The scientific objectives of this well are as described in [Section 6.3.1.1](#).

Drilling at the Well ER-5-3 location ([Plate 1](#)) is proposed to a depth of 1,173 m (3,850 ft) bgs. The borehole is anticipated to penetrate saturated alluvium, the Volcanic Aquifer, the Tuff Confining Unit, and possibly terminate within the Lower Carbonate Aquifer. Specific zones of interest at the Well ER-5-3 location include the water table, the base of the Alluvial Aquifer, the middle of the Tuff Confining Unit/Volcanic Confining Unit, and the Lower Carbonate Aquifer. Information from this well will help improve the existing 3-D hydrostratigraphic model for the Frenchman Flat area. Features specific to the well are described in the following text.

The proposed Well ER-5-3 location is in the northeastern corner of Area 5 of the NTS, Nye County, Nevada ([Plate 1](#)). The location of Well ER-5-3 was selected to be within a part of the northern

Table 6-2
Underground Nuclear Tests in the Northern Testing Area of Frenchman Flat

Test Name	Hole Name	CAS Number	Date	Nevada State Plane Coordinates	Yield Range (kt)	Working Point Depth (m/ft)	Working Point Stratigraphy	Working Point HSU	Depth-to-Water (m/ft)
DERRINGER	U-5i	05-57-004	09/12/1966	N 775,216 E 709,282	7.8	255 837	QTA	AA	298 977
DIAGONAL LINE	U-11g	11-57-005	11/24/1971	N 775,819 E 714,079	<20	264 866	QTA	AA	301 987
DIANA MOON	U-11e	11-57-003	08/27/1968	N 775,094 E 715,147	<20	242 794	QTA	AA	295 968
MILK SHAKE	U-5k	05-57-005	03/25/1968	N 773,094 E 715,146	<20	265 869	QTA	AA	282 925
NEW POINT	U-11c	11-57-002	12/13/1966	N 775,094 E 713,147	<20	239 784	QTA	AA	292 958
MINUTE STEAK	U-11f	11-57-004	09/12/1969	N 775,100 E 715,900	<20	265 869	QTA	AA	298 977
PIN STRIPE	U-11b	11-57-001	04/25/1966	N 778,800 E 712,275	<20	296 971	TX	VA	358 1,174

Sources: DOE/NV, 2000b; FFAO, 1996; IT, 1996

AA = Alluvial Aquifer
VA = Volcanic Aquifer
QTA = Quaternary Alluvium
TX = Volcanic units
kt = Kiloton
amsl = Above mean sea level

testing area where the alluvium is saturated. It was also selected to be near the location of an inferred fault located roughly 366 m (1,200 ft) to the east. The drilling site is on a south-sloping Quaternary alluvial surface at an elevation of approximately 1,022 m (3,353 ft) above mean sea level (amsl) (Plate 1). The southern end of the Halfpint Range is 1,750 m (5,750 ft) to the north of Well ER-5-3 and Massachusetts Mountain is about 2,740 m (9,000 ft) to the northwest. Surface drainage in the vicinity of the well site is generally to the south toward the Frenchman Flat playa.

The nearest underground nuclear tests to Well ER-5-3 are NEW POINT, conducted 457 m (1,500 ft) due north in Emplacement Hole U-11c and MILK SHAKE, conducted about 914 m (3,000 ft) to the southeast in Emplacement Hole U-5k (Plate 1). Other underground nuclear tests in the northern Frenchman Flat testing area were conducted at U-5i (DERRINGER), U-11b (PIN STRIPE), U-11e

(DIANA MOON), U-11f (MINUTE STEAK), and U-11g (DIAGONAL LINE) (Plate 1). Specific information on the underground nuclear tests conducted within the northern testing area of the Frenchman Flat CAU is provided in Table 6-2.

The geology of the well is predicted based on the draft Frenchman Flat hydrostratigraphic model which was constructed using all relevant data available at the time (Figures 5-2 and 5-3). Quaternary and Tertiary alluvial sediments are estimated to extend to a depth of approximately 564 m (1,850 ft) bgs. Basalt flow(s) were encountered in two nearby boreholes. Based on these two data points, a related basalt flow could be penetrated at the Well ER-5-3 location at a depth of about 274 to 297 m (900 to 975 ft) bgs. Beneath the alluvium, up to approximately 137 m (450 ft) of Ammonia Tanks and Rainier Mesa ash-flow tuffs are expected. Although these units thin rapidly to the south and east, significant welded intervals are anticipated. Underlying the Rainier Mesa Tuff approximately 305 m (1,000 ft) of zeolitic, nonwelded, and bedded tuffs are anticipated. Older Tertiary sedimentary rocks of the Rocks of Pavits Spring and Rocks of Winapi Wash may or may not be present. This lithologically diverse assemblage of tuffs, mudstones, siltstones, minor gravels, and rare limestones is quite thick in southern Frenchman Flat, but is not believed to have been deposited in extreme northern Frenchman Flat. If present, these units would be encountered at about 1,006 to 1,097 m (3,300 to 3,600 ft) bgs. Depth to Paleozoic carbonate rocks, based on gravity data (Grauch and Hudson, 1995) is estimated to be about 1,097 m (3,600 ft) bgs. The presence of Pogonip Group rocks in outcrops to the east and northeast suggest that rocks of similar age, perhaps Antelope Valley limestone, might be present at Well ER-5-3.

The proposed Well ER-5-3 location is situated within the northern half of the basin where fault blocks are generally tilted towards the east along north-south striking, west-dipping normal faults. A north-south striking fault has been inferred near the well site from gravity data and geologic data from two boreholes: Wells U-11c and U-11g#1. This fault location is estimated to be 366 m (1,200 ft) east of Well ER-5-3 (at the tuff/alluvium contact). Actual depths to formations at the Well ER-5-3 location will depend, in part, on the proximity of this inferred fault. Local hydrology could also be affected by this fault.

Plate 1 shows the groundwater level contours within the Cenozoic geologic units in the immediate vicinity of the proposed well location. The contours are based on average predevelopment levels.

Groundwater data points are sparse in the area, although some well data exist in the vicinity. Most notably, the three UE-5 PW wells, drilled in support of the Area 5 RWMS, indicate a slight gradient to the north. Groundwater is expected to be encountered in Well ER-5-3 at a depth of approximately 287 m (943 ft) bgs, at an elevation of roughly 735 m (2,410 ft) amsl.

Water-level elevation in five wells completed in the shallow, saturated units in northern Frenchman Flat (i.e., PW-1, PW-2, PW-3, UE-11a, and UE-5f) is about 734 ± 0.5 m ($2,407 \pm 1.5$ ft) amsl. These data indicate that at least on the western half of the northern group of underground tests, the water table in the Alluvial Aquifer and Timber Mountain Aquifer is at a similar elevation. There are no water-level data from the Lower Carbonate Aquifer in the immediate vicinity of the northern group of underground tests. However, if the water levels in WW-C and WW-C-1 to the northwest, and TW-3 to the southeast, are extrapolated through the area of ER-5-3, the potentiometric surface elevation in the Lower Carbonate Aquifer beneath the ER-5-3 location may be between 725 and 726 m (2,377 and 2,380 ft) amsl. This information indicates a vertical hydraulic head difference between the Alluvial Aquifer to the Lower Carbonate Aquifer of 8 to 9 m (26 to 30 ft).

6.3.1.4.4 Well ER-5-4 Location

An overview of information specific to Well ER-5-4 is provided. The information includes well description, location, physiography, geologic setting, and predictive geology and hydrology. The scientific objectives of this well are as described in [Section 6.3.1.1](#).

Drilling at the Well ER-5-4 location ([Plate 1](#)) is proposed to a depth of 1,219 to 1,524 m (4,000 to 5,000 ft) bgs. The borehole is planned to penetrate saturated alluvium, Tuff Confining Unit, Volcaniclastic Confining Unit, and ultimately reach total depth (TD), if practical, within the Lower Carbonate Aquifer. This well is intended to provide information which will help validate the current hydrostratigraphic model, and provide new information about the hydrogeology of the testing area in central Frenchman Flat.

The proposed Well ER-5-4 location is in the central portion of Area 5 of the NTS, Nye County, Nevada. The location of Well ER-5-4 was selected to be in the southern testing area in the close proximity of existing wells for aquifer testing purposes. It also was selected to be near the location of an inferred fault located at depth. This drilling site is located approximately 1.6 km (1 mi) northwest

of the Frenchman playa on a Quaternary alluvial surface at an elevation of approximately 953 m (3,127 ft). Surface drainage in the vicinity is generally to the southeast toward the playa lake.

The Well ER-5-4 location is in the vicinity of three underground nuclear tests: WISHBONE (U-5a), DILUTED WATERS (U-5b), and CAMBRIC (U-5e). The nearest test (CAMBRIC) was conducted 81 m (267 ft) below the water table, 352 m (1,156 ft) southwest of Well ER-5-4. The other two nuclear tests were conducted above the water table, both located over 915 m (3,000 ft) to the southeast. Specific information on the underground nuclear tests conducted within the southern underground test area of Frenchman Flat CAU is provided in [Table 6-3](#).

Table 6-3
Underground Nuclear Tests in the Southern Testing Area of Frenchman Flat

Test Name	Hole Name	CAS Number	Date	Nevada State Plane Coordinates	Yield Range (kt)	Working Point Depth (m/ft)	Working Point Stratigraphy	Working Point HSU	Depth-to-Water (m/ft)
CAMBRIC	U-5e	05-57-003	05/14/1965	N 755,419 E 704,831	0.75	295 968	QTA	AA	218 715
DILUTED WATERS	U-5b	05-57-002	06/16/1965	N 753,500 E 707,999	<20	193 633	QTA	AA	208 682
WISHBONE	U-5a	05-57-001	02/18/1965	N 753,500 E 709,999	<20	175 574	QTA	AA	206 676

Sources: DOE/NV, 2000b; FFAO, 1996; IT, 1996

AA = Alluvial Aquifer
QTA = Quaternary Alluvium
kt = Kiloton

The geology at the well location is expected to include Quaternary and Tertiary alluvial deposits, Tertiary volcanic units, and possibly Paleozoic carbonate rocks ([Figure 5-5](#)). Quaternary and Tertiary alluvial deposits are expected to be approximately 853 m (2,800 ft) thick at this location. Below the surficial deposits, up to 305 m (1,000 ft) of pre-Rainier Mesa volcanic units may be encountered, consisting of mostly zeolitized tuffs. Older Tertiary sedimentary rocks such as the Rocks of Pavits Spring and the Rocks of Winapi Wash are believed to overlie the Paleozoic carbonate rocks in this part of Frenchman Flat (Prothro and Drellack, 1997), but they may be faulted out at this location.

The proposed Well ER-5-4 location is situated within the central part of Frenchman Flat where movement along major north-striking faults created a series of relatively narrow, east-dipping, half-graben subbasins elongated in a northerly direction ([Figure 5-5](#)). Well ER-5-4 is to be drilled into one of these structural blocks and is predicted to encounter one of the basin-forming faults at a depth of approximately 1,508 m (3,800 ft).

[Plate 1](#) shows the groundwater level contours within the Cenozoic units, in the immediate vicinity of the well. Groundwater data points are clustered to the east and south of the Well ER-5-4 location. The closest existing wells (RNM-1 and RNM-2) are located approximately 295 m (970 ft) away, to the west-southwest. Groundwater is expected to be encountered at the Well ER-5-4 location at a depth of approximately 220 m (720 ft) bgs, at an elevation of roughly 734 m (2,407 ft) amsl.

6.3.2 Aquifer Testing

Aquifer testing is proposed to be conducted in the two underground testing subareas of Frenchman Flat. Aquifer testing provides a direct method for estimating the hydraulic properties of the hydrostratigraphic units tested. Hydraulic properties include hydraulic conductivity and storage coefficient. These are two parameters that are essential to understanding and simulating groundwater flow systems. The scientific objectives, proposed aquifer tests, and data analysis activities are described in this section.

6.3.2.1 Scientific Objectives

The purpose of the aquifer testing of the Frenchman Flat underground testing areas is to obtain estimates of the hydraulic properties of the aquifer systems located in the vicinity of the wells used during aquifer testing. The specific scientific objectives are as follows:

- 1) Estimate horizontal hydraulic conductivities in the Alluvial Aquifer.
- 2) Estimate storage coefficients for the Alluvial Aquifer.
- 3) Estimate vertical hydraulic conductivities within the Alluvial Aquifer, if possible.

The hydraulic conductivity values will be used during the calibration of the local groundwater flow models. The measured storage coefficients will be used in the verification of the CAU or local

groundwater flow and transport models, as described in Section 5.0 of the Frenchman Flat CAIP (DOE/NV, 1999a).

6.3.2.2 *Proposed Aquifer Tests*

Two aquifer tests are planned at this time: one within the northern underground test area in the vicinity of Well ER-5-3; and the second one within the southern underground testing area in the vicinity of Well ER-5-4.

The aquifer test proposed to be conducted in the northern underground testing area will include Well ER-5-3 and a satellite well. During this aquifer test, one of the two wells will serve as the pumping well. Groundwater will be pumped from a zone completed in the Alluvial Aquifer, and the hydraulic response will be observed in another Alluvial Aquifer completion zone located within the same well. The hydraulic response of the Alluvial Aquifer will also be observed in the second well. Both the drawdown and recovery responses will be recorded.

The aquifer test to be conducted in the southern underground testing area will include Well RNM-2S, Well ER-5-4, and Well UE-5n. Wells RNM-2S and UE-5n are screened in the Alluvial Aquifer, Well ER-5-4 is planned to be screened in different vertical positions and may provide data that can be interpreted to provide the vertical hydraulic conductivity of the alluvium. During this aquifer test, Well RNM-2S will be pumped and water levels will be observed in the other wells. Time-drawdown and time-recovery data may be recorded in more than one Alluvial Aquifer completion zone in Well ER-5-4.

The aquifer tests are expected to provide information on the horizontal hydraulic conductivity of the alluvium over scales of 30 to 200 m (98 to 656 ft). An attempt will also be made to measure drawdowns in well intervals screened in the volcanic units and at depth (Well ER-5-3 and Well ER-5-4). However, it is not expected that a measurable response will be observed in these intervals during the aquifer tests.

As currently planned, aquifer testing may be initiated when the proposed wells, ER-5-3 and ER-5-4, are fully constructed and initial development has been completed. Further details on the designs of the aquifer tests will be specified in the criteria that are specific to this activity.

6.3.2.3 Aquifer Test Data Analysis

The hydraulic response data collected during the two aquifer tests will be analyzed using appropriate methods that will be selected at the time of the analysis. Products of the data analysis will be estimates of horizontal hydraulic conductivity and storage coefficient for the Alluvial Aquifer in the northern and southern underground testing areas. An attempt will also be made to estimate vertical hydraulic conductivities within the Alluvial Aquifer from the time-drawdown response data obtained from Alluvial Aquifer completion zones vertically separated from the pumping intervals. The estimates of horizontal hydraulic conductivities will be divided by the estimates of vertical hydraulic conductivities (if obtainable) to calculate anisotropy ratios. The success of the anisotropy interpretations will, therefore, depend on the estimation of the hydraulic conductivities values. The observed response data between the Alluvial Aquifer and the aquifer units at depth, if measurable, will be used to estimate vertical hydraulic conductivities between the HSUs present.

6.3.3 Integrated Geophysical Investigations

The integrated geophysical investigations include seismic surveying, collection and/or analysis of gravity data, and analysis of aeromagnetic and/or ground magnetic data. The investigations will help better define the basin structure, structures within the basin, and the distribution of the Tertiary rocks present in Frenchman Flat. The integrated geophysical investigations are proposed to better determine the subsurface geologic conditions of the area, primarily structure. This information will help identify the faults and other structural features that exist in the area. It will not show whether such structural features form conduits or barriers to groundwater flow. The different geophysical analyses will be compared with each other for consistency and mutual support to improve the interpretations. The information will then be used to update the current hydrostratigraphic model and develop alternative hydrostratigraphic models as described in [Section 5.6.2.1](#).

6.3.3.1 Scientific Objectives

The purpose of this activity is to investigate specific geologic structural features in the Frenchman Flat area to refine the geologic framework of the current conceptual model of groundwater flow. Radionuclides from nuclear tests may migrate laterally within the basin or vertically to the regional aquifer (Lower Carbonate Aquifer). Because of the implications for transport of radionuclides from

Frenchman Flat in regional flow beneath the basin, it is important to determine the stratigraphy and structure of the Tertiary rocks within the basin controlling migration to the Lower Carbonate Aquifer. The configuration (depth and structures) of the Lower Carbonate Aquifer beneath the basin also affects the distance that radionuclides must travel within the alluvial and volcanic HSUs before entering the Lower Carbonate Aquifer.

Specific objectives of the geophysical investigations are as follows:

- 1) Determine the depths to the underlying regional aquifer (Lower Carbonate Aquifer) in the vicinity of the two testing areas.
- 2) Determine the generalized topography of the Lower Carbonate Aquifer surface beneath the basin, locate major structures, and obtain a better estimate of the thickness of the Tertiary/Quaternary units across the basin.
- 3) Delineate structures in the vicinity of the underground testing areas that might provide vertical pathways from the alluvial and volcanic units in which testing was conducted to the Lower Carbonate Aquifer. Structures such as faults or shear zones may provide such vertical pathways themselves or do so by juxtaposing the Alluvial Aquifer or Volcanic Aquifer with the Lower Carbonate Aquifer.
- 4) To the extent possible, delineate stratigraphic units within the alluvial and volcanic sections, particularly in the vicinity of the testing areas.

6.3.3.2 Proposed Integrated Geophysical Investigations

Proposed geophysical investigations include collection of additional geophysical data and analysis of existing and newly acquired data. The investigations include the following activities:

- Collection and analysis of seismic data in conjunction with borehole information to image the Paleozoic subcrop surface (Lower Carbonate Aquifer) beneath the basin as well as stratigraphic and structural detail within the basin in conjunction with borehole information
- Analysis of gravity data using 3-D inversion methodology to derive a topographic representation of the Paleozoic subcrop surface (Lower Carbonate Aquifer) beneath Frenchman Flat; this activity may include additional gravity data collection to fill in data gaps
- Analysis of existing aeromagnetic data to delineate faults

6.3.3.2.1 Field Activities

Field activities associated with the geophysical investigations include conducting seismic surveys and possibly collecting gravity data. Descriptions of these activities follow.

Seismic Survey

Seismic methodology may be used to image the depth to the Pre-Tertiary basement beneath the Frenchman Flat basin. Two methods are available: the seismic refraction and the seismic reflection methods. In addition, seismic surveys may be conducted in two-dimensional (2-D) or 3-D profiles.

In the seismic refraction method, the times of arrival of the initial ground movement generated by seismic sources, typically explosives in shallow drill holes, are recorded at various distances from the sources using receivers (geophones). In the reflection method, the times of arrival of ground movement that has been reflected off of subsurface interfaces after the initial ground motion are recorded at various distances from the sources.

In 2-D seismic surveys, sources and receivers are placed together along a single straight line. As each explosive is detonated, the geophone receivers record the seismic energy refracted or reflected from layers of rock beneath the surface. The resulting seismic data produce a 2-D profile similar to a vertical cross section. In 3-D seismic surveys, the sources and geophone receivers are positioned along numerous separate, criss-crossing lines forming a geometric pattern. Thus, when vibrations are produced at each source point location, the refracted or reflected waves are recorded by geophones located at various distances and directions from the source location. The survey results in a 3-D volume of seismic data which can offer considerable advantages in detail and resolution over 2-D seismic data.

A 3-D seismic survey using the reflection method is proposed for Frenchman Flat. The potential survey area is a rectangle 2.5 by 5.5 miles, elongated in a northeast direction, covering an area of 13.8 square miles ([Plate 1](#)). This area includes the new well locations (Well ER-5-3 and Well ER-5-4). The details of the survey, such as the extent of the area and the specific locations of the seismic lines, will depend on final evaluations and access requirements.

Gravity Survey

Additional gravity data may be needed to fill data gaps identified in the existing gravity data set for Frenchman Flat (Ponce, 1997). The areas where data are sparse are located along the margins of the Frenchman Flat basin, where gravity changes most rapidly. Previously unsurveyed, Pre-Tertiary outcrops surrounding Frenchman Flat would be particularly targeted for surveying because of the importance of such data in the modeling methodology. The decision to collect new gravity data will be made following completion of the data analysis using the existing data as described under *Gravity Data Analysis* in [Section 6.3.3.2.2](#).

6.3.3.2.2 Data Analysis Activities

The data analysis activities associated with the integrated geophysical investigations include three stages: (1) analysis of the seismic data to provide structural information about the top of the Lower Carbonate Aquifer, (2) analysis of the gravity data to build a 3-D gravity model supported by the seismic data, and (3) analysis of aeromagnetic data to delineate faults within the basin for comparison to those depicted in the gravity model.

Seismic Data Analysis

In support of the first scientific objective, the seismic method is expected to provide reliable depth estimates for northern and central Frenchman Flat within the seismic survey area and show structure on the surface of the Lower Carbonate Aquifer. Analysis of the seismic data in conjunction with borehole information from the new proposed wells may allow delineation of some stratigraphic detail within the alluvial and volcanic units. Information obtained from the seismic survey will be integrated with the 3-D gravity inversion analysis to develop a 3-D representation of the topography of the Lower Carbonate Aquifer, as described in the following text.

Gravity Data Analysis

A 3-D inversion technique developed for Yucca Flat (Phelps et al., 1999) will probably be used to analyze the Frenchman Flat gravity data (Ponce, 1997). The analysis is expected to yield a 3-D

gravity model representative of the topography of the top surface of the Lower Carbonate Aquifer in Frenchman Flat in support of the second scientific objective.

In addition to gravity data, this method of analysis also requires the compilation and use of density log data and stratigraphic information from existing boreholes. Density data are used to estimate the density of the Pre-Tertiary rocks and the density contrast between the Pre-Tertiary rocks and the overlying rocks (Quaternary and Tertiary). Stratigraphic information from existing wells and the proposed wells helps reduce the uncertainty of this analysis. Seismic data are not required but they may be used as constraining data to guide the interpretation of the gravity data, which will help reduce uncertainty.

The 3-D gravity model will first be constructed using the existing gravity data set for Frenchman Flat (Ponce, 1997). The importance of the data gaps will then be evaluated. If it is determined that selected or all data gaps need to be filled, then the gravity data-collection activity described in [Section 6.3.3.2.1](#) will be conducted, and the 3-D gravity model will be updated. No further analysis would be required otherwise.

Aeromagnetic Data Analysis

Aeromagnetic data flown at a 400-meter line spacing and at 122 meters above ground level are currently available for Frenchman Flat (McCafferty and Grauch, 1997). This existing data set will be analyzed to delineate faults in the subsurface of Frenchman Flat in support of the third scientific objective of this activity. The method is more likely to be effective in delineating faults located in areas where shallow alluvial cover occurs, such as in the northern testing area of Frenchman Flat. However, the existing data may not provide the desired level of detail, and the success of this analysis is highly dependent on the consistency of the magnetic signature of the volcanic rocks, which is subject to the thermal history of the rocks. Faults inferred from the aeromagnetic data may be compared with those inferred from the 3-D gravity model, and with faults mapped at basin margins.

6.3.4 Isotopic and Geochemistry-Based Investigation

The isotopic and geochemistry-based investigation for Frenchman Flat includes the collection and analysis of groundwater, the integration of new and existing data, and data interpretation. This

activity is designed to provide additional data in support of the hydrologic model(s) because the interpretations derived from the existing data used in the draft Frenchman Flat CAU model were inconclusive.

6.3.4.1 Scientific Objectives

The isotopic and geochemistry-based investigation for Frenchman Flat has two scientific objectives. One objective of this investigation is to provide independent information on the origin and flow paths of groundwater through the Frenchman Flat groundwater flow system, including vertical groundwater flux from overlying units to the Lower Carbonate Aquifer. Another objective is to provide estimates of groundwater age and travel times using measured concentrations of natural tracer in groundwater.

6.3.4.2 Field and Laboratory Activities

Field and laboratory activities related to the isotopic and geochemistry investigation include groundwater sampling, and mineralogical characterization of non-fractured alluvial materials. Each of these tasks has the potential to produce new data that can be incorporated into geochemical-based modeling efforts to provide independent estimates of flow paths, travel times, and vertical groundwater fluxes for the Frenchman Flat groundwater flow system. Additional information on each of these activities is presented in the subsections that follow.

Groundwater Sampling

Groundwater samples are proposed to be collected from seven existing wells within Frenchman Flat. The existing well locations are listed in [Table 6-4](#) and shown in [Plate 1](#). At each of these sites, a variety of field parameters will be measured including water temperature, pH, specific conductance, dissolved oxygen, and alkalinity. The groundwater samples will be analyzed for the following constituents:

- Major anions and cations
- Delta carbon-13 ($\delta^{13}\text{C}$) and carbon-14 (^{14}C) activity for organic carbon and inorganic carbon
- Radioisotopes, including chlorine-36 and tritium
- Strontium and uranium isotopic ratios
- Dissolved noble gases, including helium-3
- Stable isotopes of hydrogen and oxygen

Table 6-4
List of Groundwater Sampling Locations in Frenchman Flat

Well Name	Rationale for Sampling	UTM ^a Coordinates (m)
RNM-2S	Satellite well for the Cambrian radionuclide migration experiment	E ^b 592,138/N ^c 4,075,480
UE-5c WW	Deepest well in Frenchman Flat; provides confirmation of groundwater age	E 590,982/N 4,077,000
WW-4a	Along modeled flow path of groundwater entering Frenchman Flat from northwest; currently only one general chemistry sample and no C-14 or stable isotope data exist for the well	E 586,646/N 4,084,390
WW-5A	Screened near water table for comparison with data from WW-5C (which is screened deeper); currently no C-14 or stable isotope data exist for the well	E 592,986/N 4,070,370
WW-5B	Screened near water table, for comparison with data from WW-5C (which is screened deeper); currently no stable isotope data exist for the well	E 591,990/N 4,073,130
WW-5C	Screened deeper than WW-5A or WW-5B for comparison to those wells	E 592,476/N 4,071,750
UE-5 PW-3	Screened near the water table to provide data for groundwater at/near the water table	E 591,713/N 4,080,400

^a Universal Transverse Mercator, Zone 11, NAD 27

^b Easting

^c Northing

In addition, the samples will be analyzed for Chlorofluorocarbons (CFCs) to determine if any young (<60 year old) groundwater is present in any of these well waters. Although tritium also can be used to identify the presence of young groundwater, its concentration can only indicate a presence; whereas, if CFCs are present, then they can be used to determine the age of this young groundwater.

Groundwater samples will be collected either from a discrete-interval sampler or at the ground surface from a discharge port if a well contains a dedicated pump. The discrete-interval sampler will be used in conjunction with flow logging to identify and sample groundwater from intervals where vertical flow occurs within the well bore. This will ensure that samples are not collected from stagnant sections of the borehole, such as the portion above the screened interval. For wells that

contain pumps, groundwater will be pumped from each well prior to sampling, until field parameters stabilize, to ensure that representative groundwater samples will be collected. Groundwater conductivity and pH will be monitored during pumping, and stabilization of these parameters will indicate that purging is complete. Flow logging will be performed to identify flow zones in wells without dedicated pumps.

The groundwater sample analysis results for all geochemical parameters measured will constitute the most consistent and complete set of groundwater chemistry data available to date for the Frenchman Flat area and vicinity. This data set will be consistent with regards to analytical methods and time of collection (i.e., because all data will be collected over a relatively short time frame).

Mineralogical and Isotopic Characterization of Solids from Boreholes

A number of alluvial material samples will be selected for characterization and analysis based on their geochemical significance and hydrostratigraphic setting. The selected samples will undergo micrographic, isotopic, and trace element analysis. Specifically, splits will be collected from the two proposed wells and archived core samples located at the USGS core library in Mercury, Nevada. From these splits, mounts will be prepared for scanning electron microscopy (SEM). X-ray diffraction (XRD) analysis will also be performed on selected carbonate, clay, oxyhydroxide, or zeolite phases that cannot be adequately characterized using SEM or microprobe.

6.3.4.3 Data Analysis Activities

Data analysis activities related to the isotopic- and geochemistry-based investigation include the integration of new data with the existing data for Frenchman Flat and subsequent data interpretation. These activities will further define and explain the geochemical evolution of groundwaters within the Frenchman Flat flow system.

6.3.4.3.1 Data Integration

The integration of new data into the existing groundwater geochemistry data set for Frenchman Flat is a necessary first step in conducting geochemistry-based evaluations. These evaluations will support the definition of flow paths, travel times, and vertical groundwater fluxes for the groundwater flow models developed for the Frenchman Flat CAU.

6.3.4.3.2 Data Interpretation

Data obtained from the field and laboratory activities conducted under this activity, along with new data collected from the new wells discussed in [Section 6.3.1](#), will be used to the extent possible to identify groundwater flow paths, estimate groundwater ages, and evaluate vertical groundwater fluxes from overlying units to the Lower Carbonate Aquifer.

Identification of Groundwater Flow and Reaction Paths

Existing geochemical data were previously compiled and interpreted in support of the draft Frenchman Flat CAU groundwater flow model. This existing geochemical data set will be combined with the results from the groundwater sampling program discussed in this section. The combined data set will be used to update the geochemical interpretations and provide verification, to the extent possible, of flow paths and groundwater travel times determined by the groundwater flow models.

Data that will be used during this activity will include major-ion chemistry, stable isotope results, and selected radioisotope data. Geochemical models that simulate reaction paths, such as NETPATH (Plummer et al., 1994) or PHREEQC (Parkhurst, 1995), may be used in the updated interpretation.

NETPATH is an interactive FORTRAN program used to interpret net geochemical mass-balance reactions between initial and final waters along a hydrologic flow path. It can also be used to compute the mixing proportions of two to five initial waters and the net geochemical reactions that can account for the observed composition of a final water. The geochemical modeling will allow for the interpretation of geochemical reactions, mixing proportions, evaporation and/or dilution of waters, and mineral mass transfer in the chemical and isotopic evolution of natural and environmental waters. The results of the geochemical modeling may be utilized to evaluate the potential for vertical flux of groundwater into the Lower Carbonate Aquifer from overlying units.

Calculation of Groundwater Ages and Evaluation of Flow Velocities

Data permitting, calculated groundwater flow velocities based on geochemical tracers will be compared to velocities calculated from hydraulic measurements and from groundwater flow

modeling. The results will provide verification of interpretations made using the groundwater flow model results.

Dissolved inorganic and organic ^{14}C will be used to estimate groundwater ages and flow velocities. Dating groundwater with ^{14}C requires knowledge of groundwater flow paths and geochemical reactions along the flow path because dissolved carbon is typically involved in reactions in the groundwater environment. Important chemical reactions that could affect ^{14}C transport are dissolution and precipitation of carbonate minerals along fracture surfaces and isotopic exchange with carbonates or soil gas reservoirs. Groundwater ^{14}C ages will be corrected to account for these reactions. To perform corrections, data obtained during this investigation (e.g., carbon-13 data from groundwater and calcite and ^{14}C data for calcite) will be used. It is anticipated that a correction model that integrates hydrogeology and geochemistry will be developed. This correction model will incorporate more carbon sources than those allowed in published correction models. Results of the reaction-path modeling discussed above will be used to support correction of ^{14}C ages.

6.4 Field Support Activities

Field support includes those activities associated with waste management, health and safety, and sampling and analysis. These support activities, along with the current versions of the documents that set forth the corresponding policies and practices to be followed, are discussed in the following subsections.

6.4.1 Waste Management

Waste management is one element of a comprehensive on-site compliance program to be implemented at Frenchman Flat investigation sites. The development of this program is tailored to anticipated site conditions; however, it includes contingencies in the event field operating conditions change. Periodic field evaluations are conducted to ensure proper implementation of this program and on-site compliance. The program also includes waste minimization which is discussed below and fluid management which is discussed in the sampling portion of this section. The details of the comprehensive compliance program may be found in the *Underground Test Area Project Waste Management Plan* (WMP) (DOE/NV, 1996), the UGTA FMP (DOE/NV, 1999b), and site-specific planning and field documents.

Waste management covers the segregation, tracking, characterization, and disposal of wastes generated during field activities. Frenchman Flat CAI activities that will generate waste include drill site construction, well drilling, well completion, well development, and sampling operations (herein termed well installation activities). Other investigation activities that may generate hazardous waste include aquifer testing and the periodic groundwater sampling of newly installed wells and existing wells.

The largest volume of waste generated during drilling and sampling activities is effluent (fluids) and groundwater. The management of fluids and groundwater produced at the proposed Frenchman Flat wells is addressed in the UGTA FMP (DOE/NV, 1999b) discussed later in this section. Other wastes, such as sanitary and hydrocarbon waste, are generated as a result of the operation and maintenance of heavy equipment as well as other support functions on the drill site.

6.4.1.1 Investigation-Derived Waste Management

Management of Investigation-Derived Waste (IDW) is described in the UGTA WMP (DOE/NV, 1996), which provides a general framework for waste management at Frenchman Flat investigation sites. Details regarding the characterization, storage, treatment, and disposal of wastes generated at Frenchman Flat investigation sites will be addressed in site-specific field instructions or similar working-level documents. All wastes generated as a result of Frenchman Flat investigation activities will be managed and disposed of in compliance with applicable federal, state, and local laws and regulations.

Based on an evaluation of available data and technical input from scientists supporting the UGTA program, the Frenchman Flat wells will be drilled and constructed under far-field conditions. This indicates that the potential for generating radioactive waste is remote. In the event that the wells are found to be contaminated, they will be converted to near-field wells. The presence of tritium in excess of the fluid management criteria listed in the UGTA FMP (DOE/NV, 1999b) will require the well to be reclassified as a near-field well. The designation of near- and far-field is important since the waste management strategies for the near- and far-field wells differ in one aspect. Near-field activities require establishment of a controlled area where radioactive contamination would be closely monitored and managed; far-field activities do not.

Process knowledge regarding the presence of hazardous materials or radioactive contaminants and/or data from sampling and analysis, combined with monitoring results, will be used to define the waste management strategy for each well location. The potential for generating hazardous, radioactive, and mixed waste streams will be assessed separately for each drilling location. Operations conducted under this CAI will emphasize prevention of hazardous waste generation. When required, personnel will be trained and procedures implemented to address management of radioactive and hazardous waste streams.

Waste characterization will be based on the results of process knowledge, fluid management monitoring and sampling, and groundwater characterization sampling. This information will be used to assign the appropriate waste type (i.e., sanitary, hydrocarbon, hazardous, radioactive, or mixed) to the IDW. Direct sampling of waste may be necessary if process knowledge is inadequate for characterization.

6.4.1.2 Waste Minimization

The generation of IDW is minimized through the implementation of the comprehensive compliance program. Waste minimization is achieved through the control of hazardous materials, materials substitution, and waste segregation. Hazardous materials shall be controlled, managed, and tracked in accordance with Occupational Safety and Health Administration (OSHA) requirements and applicable procedures and protocols. Material substitution is implemented wherever possible to prevent or minimize the generation of a hazardous waste. Waste such as effluent and personal protective equipment (PPE) will be segregated to the greatest extent possible to minimize the generation of hazardous, radioactive, and/or mixed waste.

6.4.2 Health and Safety

The health and safety of workers and the public and protection of the environment will have the highest priority during the Frenchman Flat CAI in accordance with the DOE Integrated Safety Management System. Worker protection will be achieved through compliance with DOE Orders, OSHA regulations, and the primary Real Estate/Operations Permit (REOP) holder's Health and Safety Plan (HASP). Requirements specified in these documents are subject to change, and the work performed for this CAI will be conducted in accordance with the most current published versions of

these documents. Bechtel Nevada currently holds the primary REOP for UGTA activities conducted on the NTS; therefore, compliance with the Bechtel Nevada HASP (BN, 2001) is required from all participating agencies.

When radiological constituents are present in groundwater at levels of occupational health concern or are anticipated due to the proximity of the well to an underground nuclear test, additional documents apply. Work controls will be guided by the NTS Radiation Protection Program (RPP) (DOE, 1990), *NV/YMP Radiation Control (RadCon) Manual* (DOE/NV, 2000a), and 10 CFR 835, "Occupational Radiation Protection" (CFR, 2000a). The NTS RPP establishes the policy by which radiological doses are maintained within acceptable limits and radiation exposures are maintained as-low-as-reasonably-achievable (ALARA) concept below these limits. The *NV/YMP Radiological Control Manual* represents DOE-accepted guidelines and best practices for implementing NTS radiation protection programs in accordance with 10 CFR 835 regulations (CFR, 2000a).

The HASP (BN, 2001) is the "governing" document under which all on-site UGTA environmental restoration operations are conducted. The HASP (BN, 2001) prescribes the minimum procedures that will be followed while performing field operations and describes the roles and responsibilities of key project personnel. Its requirements are written to comply with DOE Orders and federal regulations such as 29 CFR 1910 (CFR, 2000b) and 29 CFR 1926 (CFR, 2000c).

The principal hazards associated with activities at Frenchman Flat sites are those associated with industrial operations, environmental conditions, site location, and the presence of dangerous animals. Industrial operation activities involve heavy equipment operation, potential for falling objects, and rotating and moving machinery. Environmental conditions such as the weather and terrain may increase the potential for accidents. The remoteness of some of these sites and the terrain may delay the response time for medical and fire services. During the spring, summer, and fall months, personnel may encounter snakes, spiders, and scorpions. Some deer mice in Nevada have been found to carry the hantavirus. Although the possibility of encountering deer mice in Frenchman Flat is low, the risk still exists and needs to be accounted for during planning of field activities.

Hazardous chemicals, including lead, at levels of occupational health concern are not anticipated in the groundwater. The only anticipated source of chemical hazards to workers is from the materials brought on site. These materials may include fuel for the drill rig and generators; small volumes of

nitric, hydrochloric, or sulfuric acid to be used as sample preservatives; and testing standards and reagents used for groundwater analysis. Proper storage and handling of these materials, will reduce the potential for accidents involving chemical hazards.

Groundwater from the wells installed as part of the Frenchman Flat CAI is not anticipated to contain radionuclide concentrations above levels considered safe to drink. The only radionuclide that may be encountered at elevated levels is tritium in the form of tritiated groundwater. Due to the distance of the planned wells from underground nuclear tests, mixed fission products are not expected to be encountered. As a precautionary measure, operations will be conducted to ensure that personnel exposure to water vapor, splashes of groundwater, and drilling fluids are minimized and that access to the site is restricted to personnel involved in the operation.

6.4.3 Sampling and Analysis

Sampling and analysis of solids and fluids will be performed during this investigation. The activities will include sample collection, screening for potential contamination, and off-site laboratory analysis. Laboratory data shall be used to ensure compliance with program requirements and for characterization of process material and the groundwater.

6.4.3.1 Solid Sampling and Analysis

Solid samples of interest include surface and subsurface soils, and rock cuttings and cores collected from the boreholes during drilling.

If contamination is suspected at a site, surface and subsurface soil samples may be collected prior to the disturbance of soil for construction activities. At drilling pad sites, nonintrusive surface radiological surveys will be conducted with portable survey instruments. If warranted, surface and shallow subsurface soil samples will be collected for field and laboratory chemical and radiochemical analysis.

Rock cutting samples shall be collected from the drilling fluid discharge line as the borehole is advanced. Core samples shall be collected using percussion sidewall, rotary sidewall, vertical rotary, or similar techniques. The sampling frequency and intervals for collection of rock cuttings and core samples shall be performed in accordance with task-specific plans and the appropriate procedures.

Field analysis of rock cuttings and core samples will be performed by on-site and off-site geologists to describe and identify the rocks penetrated during drilling operations. Laboratory testing to determine hydrologic, physical, and chemical properties may be performed on selected cuttings and core samples.

The activities associated with the collection, processing, and description of cuttings and core samples will be performed as directed in task-specific plans and in accordance with approved procedures.

6.4.3.2 Fluid Sampling and Analysis

Fluid samples of interest include process fluids and groundwater. Process fluids are those fluids produced during the drilling, well construction, development, and purging activities that occur prior to the collection of a representative groundwater sample. They include drilling compound formulations, water produced during well completion, well development activities, and water purged prior to sampling. Groundwater is defined as water that is considered representative of the aquifer and is suitable for sampling and aquifer characterization purposes.

Fluids generated during all phases of the operation will be managed in accordance with the requirements contained in the UGTA FMP (DOE/NV, 1999b), work plans, field instructions, and as discussed in [Section 6.3.1](#). Fluids produced during drilling, well completion, and well development and testing will be collected for analysis. Fluids that do not meet the fluid management criteria for release to an unlined infiltration basin will be contained in lined sumps.

In addition, fluids produced during well purging or development will be monitored for pH, conductivity, and temperature to determine stabilization prior to the collection of groundwater characterization samples. These activities shall be conducted in accordance with the work plans, field instructions, and the appropriate procedures. Additional parameters may be included as prescribed in the work plans and instructions.

Groundwater samples will include characterization samples from the newly installed wells and samples from wells considered for use as makeup water-supply wells for drilling and well construction. Groundwater characterization samples will be collected from the newly installed wells at the completion of well development, and periodically thereafter until the well is taken

out-of-service or until monitoring is no longer required. Water-supply wells will be sampled prior to their use. Sampling and analysis of the water supply wells will ensure that the groundwater is free of target constituents. It will also establish background water chemistry and radiochemistry levels for constituents of concern, and provide baseline data for wells not previously sampled.

Process fluid and groundwater samples shall be collected, processed, and transported in accordance with state and federal regulations, and applicable standard procedures. If on-site monitoring or other knowledge indicates the potential for environmental samples to meet the definition of hazardous material under U.S. Department of Transportation (DOT) regulations, internal contractor procedures for the transport of hazardous materials shall be followed. These contractor procedures mandate compliance with applicable DOT shipping regulations. Specific guidance for this type of sampling will be provided in site-specific plans and instructions, and in accordance with appropriate procedures. Process fluid samples collected for fluid management purposes will be analyzed for selected metals, tritium, gross alpha, and gross beta parameters as specified in the UGTA FMP (DOE/NV, 1999b). All groundwater samples shall be sent to an analytical laboratory to be analyzed for the parameters listed in Table 5-1 of the *UGTA Quality Assurance Project Plan (QAPP)* (DOE/NV, 2000b). The analyses listed in this table include metals, major ions, general chemistry, age and migration parameters, radiological indicator parameters, nuclear fuel products, and other radionuclides.

6.4.3.3 Quality Assurance

All sampling and analysis tasks shall be conducted in accordance with the requirements of the UGTA QAPP (DOE/NV, 2000b). Section 7.0 of the CAIP (DOE/NV, 1999a) provides a summary of the QA program.

6.4.3.4 Field Quality Control

Project participants shall ensure that field quality control (QC) samples are collected and submitted to a selected analytical laboratory in a manner consistent with the UGTA QAPP (DOE/NV, 2000b). The frequency, number, and type of QC samples collected during drilling activities will be specified in site-specific plans, project plans, the UGTA QAPP (DOE/NV, 2000b), and appropriate procedures. The types of QC samples may include field duplicates, equipment rinsate blanks, and, if necessary,

rinsate source blanks. Collection and documentation of field QC samples will be conducted in accordance with approved plans and procedures that meet the requirements of the UGTA QAPP (DOE/NV, 2000b).

6.4.3.5 Waste Management

Waste in the form of PPE, sampling equipment, and drilling materials will be generated as a result of this investigation. Specific requirements for characterization sampling of these wastes are contained in [Section 6.4.1](#) of this document and also in the UGTA WMP (DOE/NV, 1996).

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Plate 1

**Locations of Proposed Wells,
Seismic Survey Area, and Groundwater
Sampling Points in Frenchman Flat**