Rec'd w/cd letter dtd 7/8/94

Study Plan for
Study 8.3.1.15.2.2

Characterization of the Site Ambient Thermal Conditions

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

1028

YMP-021-R3
06/06/94

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT
STUDY PLAN APPROVAL FORM

Study Plan Number 8.3.1.15.2.2

Study Plan Title Characterization of the Site Ambient Thermal Conditions

Revision Number 0

Prepared by: U. S. Geological Survey

Date: June 1994

Approved:

6/23/94
Assistant Manager for Scientific Programs / Date

6/19/94
Director, Quality Assurance Division / Date

Effective Date: 7/7/94

STUDY PLAN

FOR

STUDY 8.3.1.15.2.2

CHARACTERIZATION OF THE SITE AMBIENT THERMAL CONDITIONS

Rev. 0

June 9, 1994

U. S. GEOLOGICAL SURVEY

ABSTRACT

Study 8.3.1.15.2.2 involves an analysis of heat-flow and thermal conductivity measurements obtained as part of Activity 8.3.1.8.5.2.3 (Heat flow at Yucca Mountain and evaluation of regional ambient heat flow anomalies) that will be used to determine in situ temperatures, capabilities of the repository host rock and surrounding rock units to conduct heat, and heat flux. These data are required to establish the ambient (pre-repository) thermal conditions for (1) analyzing the host rock thermomechanical response to waste storage, (2) providing essential information for constructing thermomechanical and hydrothermal models used in design and performance assessment of the potential repository, and (3) determining ventilation needs during repository construction and operation.

TABLE OF CONTENTS

FIGURES

FIGURES

STUDY 8.3.1.15.2.2
CHARACTERIZATION OF THE SITE AMBIENT THERMAL CONDITIONS

This study, consisting of Activity 8.3.1.15.2.2.1, Evaluation of site ambient thermal conditions, is part of Investigation 8.3.1.15.2 (Studies to provide the required information for spatial distribution of ambient stress and thermal conditions). It is included in the thermal and rock properties program (fig. 1-1), and is one of a series of studies needed to characterize preclosure rock properties in support of design and performance assessment calculations of the potential repository underground facilities (fig. 1-2).

1. PURPOSE AND OBJECTIVE OF THE STUDY

The objective of this study is to evaluate available thermal data to determine the ambient (pre-repository) temperature and thermal conductivity of the Yucca Mountain host rock and surrounding units for use as initial conditions in thermomechanical models used in the design and performance assessment of the potential repository underground facilities.

1.1 Information to be obtained and how that information will be used

The study will characterize in-situ thermal conditions (temperature and thermal conductivity) of the potential repository horizon and surrounding units at Yucca Mountain based on information acquired in Activity 8.3.1.8.5.2.3 (Heat flow at Yucca Mountain and evaluation of regional heat flow anomalies). The information will be used to: (1) provide baseline temperatures and thermal conductivities within the repository host rock and surrounding units; and (2) determine heat-flow, both vertically and laterally, in the immediate vicinity of Yucca Mountain by a combination of one- and two-dimensional analyses.

Specific uses of the information for measuring repository performance against goals for performance measures are discussed in section 1.2 below. Uses of the information for supporting other studies are discussed in section 4.

1.2 Rationale and justification for the information to be obtained: why the information is needed.

The information to be obtained in this study is needed for design of the potential repository in accordance with tentative design goals and to predict the performance of the repository and measure the predicted performance against tentative goals associated with performance measures. Specifically, information from the study is needed to establish the geothermal regime at Yucca Mountain because it is the framework for analysis of host-rock

thermomechanical and hydrothermal response to waste storage. Temperature within the host rock must also be known to determine ventilation needs during repository construction and operation. Data on temperature, thermal conductivity, and heat flux will be used to establish the initial conditions for thermomechanical models used in design and performance assessment of the repository underground facilities. The issues specifically requiring information from this study are discussed below.

Performance Issue 1.6 (Pre-waste-emplacement groundwater travel time, Section 8.3.5.12): Information from this study is needed to determine and define the disturbed zone. The disturbed zone has been defined qualitatively in 10 CFR 60.2 as

> "that portion of the controlled area the physical or chemical properties of which have been changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository ... "

Temperature data from this study will be used to support the performance measure which addresses the initial temperature conditions (before waste emplacement) within that portion of the Topopah Spring Member that is considered to be the potential repository horizon (see SCP table 8.3.1.15-1). Because the pre-existing temperature field will be disturbed as a result of construction and operation of the repository, including emplacement of heat-producing waste, it is necessary to establish initial temperature conditions to predict the thermal and thermomechanical response of the host rock, surrounding strata, and groundwater system. Performance Issue 1-6 requires that the mean of the initial temperatures in the repository level be determined with a medium confidence level (SCP Table 8.3.5.12-3).

Design Issue 1.11 (Configuration of underground facilities (postclosure), Section 8.3.2.2): Information from the study is needed to measure the predicted performance of the repository against one performance goal in order to demonstrate that the potential repository and its engineered barriers would comply with 10 CFR 60.133 (see SCP table 8.3.1.15-1). The study will provide baseline measurements on the ambient thermal properties of the potential repository host rock (thermal/mechanical unit TSw2, a subdivision of the Topopah Spring Member) and surrounding units. This information will be used to establish initial temperature conditions of the repository horizon and surrounding units needed in thermomechanical modeling as it bears upon repository design (i.e., configuration of the underground facilities and repository engineered barriers) and performance (see SCP table 8.3.1.15-1). The performance goal specified for thermal/mechanical unit TSw2 is ± 3 °C. A medium confidence is needed to meet the performance measure. Specifically, initial temperature conditions are needed to: design the layout and engineered barriers to contribute

to performance (Part 60.133(a)(1); accommodate site specific conditions (Part 60.133(b); reduce deleterious rock movement (Part 133(e)(2)); select excavation methods that limit preferential pathways (Part 60.133(f)); and predict thermal and thermomechanical response of the rock mass (Part 60.133(i)).

Design Issue 1.10 (Characteristics and configurations of the waste packages, Section 8.3.4.2): Thermal properties of the host rock and surrounding units will be used in analyses needed to characterize the near-field environment of the waste packages. Characterization of the waste package environment will depend on establishing the ambient thermal conditions at the repository level and determining how those conditions are altered by repository construction and waste emplacement. Specifically, information from this study will be used to evaluate the thermal loading constraints of TSw2 (and surrounding units) that may influence the integrity of the waste package (see SCP table 8.3.4.2-4). The performance goal specified for thermal/mechanical unit TSw2 is ± 3 °C. A medium confidence is needed to meet the performance measure.

Design Issue 4.4 (Preclosure design and technical feasibility (Section 8.3.2.5): Information from the study is needed to predict the performance of the potential repository in terms of the performance goal that the mean temperature of the waste package not exceed 350 °C (see SCP table 8.3.2-5). The licensing strategy calls for that goal to be attained with high confidence. Data from this study will be used to establish the initial temperature of the repository horizon and provide data on the thermal conductivity of the repository host rock.

Whereas this study will provide much of the baseline data on the spatial distribution of ambient temperature and heat flow, it will supplement and spatially extend only the thermal conductivity data base developed under Study 8.3.1.15.1.1, Laboratory thermal properties, for the host rock and near-field units. Volumetric heat capacity will be provided for design and performance analyses by Activity 8.3.1.15.1.1.2.

2. RATIONALE FOR THE SELECTED STUDY

Characterization of the ambient temperature of the Yucca Mountain repository host rock and surrounding units is required both for operational design considerations and for the resolution of certain performance issues, as discussed in section 1.2.

2.1 Activity 8.3.1.15.2.2.1 Evaluation of site ambient thermal conditions

2.1.1 Rationale for the selected analyses

The natural distribution of subsurface temperatures and thermal conductivity must be known to calculate perturbed temperatures for various disposal configurations. In this activity, ambient thermal conditions at the potential repository site will be determined based on (1) the variation of temperature with depth in existing and proposed drill holes, and (2) the thermal conductivity of cores, drill cuttings, or outcrop samples. These basic data will be provided by Activity 8.3.1.8.5.2.3 and will be analyzed and applied in this activity to determine the near-surface heat flow and its variations, both vertically and laterally, within and around the potential repository. The study will be coordinated with Activity 8.3.1.15.1.1.3 (Thermal conductivity characterization), and data shared as appropriate.

2.1.2 Rationale for selecting the number and location of data sites and for the timing of analyses

The number and location of the sites chosen for temperature and thermal-conductivity measurements will be determined by Activity 8.3.1.8.5.2.3. Accordingly, the timing of the present activity will depend upon the availability of those measurements. Figures 2-1 and 2-2 are index maps taken from the study plan for Activity 8.3.1.8.5.2.3 to indicate the scope of the investigation planned for that activity.

2.1.3 Constraints: factors affecting selection of analyses

The choice of the analyses for this activity was unaffected by the following factors: impacts on the repository site, simulation of repository conditions, timing, and interference with other tests or with exploratory shaft facility design and construction. With regard to accuracy and precision, limits and capability of analytical methods, and scale of the phenomenon to be measured, the thermal data (from Activity 8.3.1.8.5.2.3) being used to characterize the ambient thermal conditions at Yucca Mountain are well within the limits of accuracy designated in the SCP (Table 8.2.1.15-1). The requirement is for measurements of the ambient temperatures of the rocks penetrated in drill holes to be within $\pm$2-3°C with medium confidence levels. The planned tests for Activity 8.3.1.8.5.2.3 will record rock temperatures within accuracies of $\pm$1°C. The recovery of a borehole from temperature

disturbances introduced by drilling is variable, and is most easily tracked by performing a time-series of temperature logs.

3. DESCRIPTION OF ANALYSES

The objectives of Activity 8.3.1.15.2.2.1 (the only activity in Study 8.3.1.15.2.2) are to: (1) to provide baseline temperatures and thermal conductivities within the repository host rock and surrounding units; and (2) to determine heat-flow and its variations, both vertically and laterally, in the immediate vicinity of Yucca Mountain.

3.1 General approach

Digital temperature logs (temperature vs. depth) and thermal-conductivity measurements from drillhole cores and cuttings at Yucca Mountain and the surrounding area will be available from Activity 8.3.1.8.5.2.3. The thermal conductivity data for the appropriate stratigraphic units will be tabulated for use in this study and will also be provided to Activity 8.3.1.15.1.1.3.

As a first step in the interpretation, least-squares analyses of nearly linear segments of temperature profiles will provide thermal gradients which, when combined with the thermal conductivity data, will be used to calculate ambient conductive, one-dimensional heat flow. Further evaluations are intended to determine the degree to which ambient temperatures and, therefore, apparent heat flows may be influenced by drilling or by the continued presence of the borehole, which provides a pathway for the movement of fluids, whether water or gases. Factors in these evaluations include: (a) the overall shape of the temperature profile which, in many cases, can reveal fluid movement and heat transport within or across the borehole; (b) the consistency of repeated, time-series profiles that reveal recovery from drilling-induced perturbations; and (c) the consistency of heat flows calculated for various depth segments in the borehole.

Contour maps of temperature will be prepared for a range of elevations or quasi-horizontal surfaces (e.g., the host-rock "horizon") that are pertinent to considerations of repository design and performance. Temperature contours will be prepared on cross sections at various positions and azimuths intersecting the potential repository. The areal distribution of one-dimensional heat flow and the patterns of isotherms on the contour maps and cross sections will provide the basis for judgment as to whether the ambient heat flux is adequately represented by the one-dimensional determinations of conductive heat flow. Estimates of horizontal temperature gradients and resultant total conductive heat flux will be made based on cross-section data.

3.2 Methods and procedures

This activity involves the analysis of data to be collected in Activity 8.3.1.8.5.2.3, the methods for which are described in technical procedures pertinent to that study.

3.3 QA Requirements

Quality Assurance (QA) requirements for this study/activity will be specified in a Yucca Mountain Project QA Grading Report, which will be issued as a separate controlled document. All procedures applicable to this study/activity will be identified on the basis of the findings in the Grading Report and will be prepared in accordance with applicable QA requirements.

3.4 Required tolerance, accuracy, and precision

Based on the accuracy of temperature and thermal conductivity measurements ($\pm 1°C$) expected to be obtained from Activity 8.3.1.8.5.2.3 (Heat flow at Yucca Mountain and evaluation of regional ambient heat flow anomalies), estimates of the near-surface ambient heat flow is expected to be within ± 10 percent, an accuracy dictated primarily by the uncertainty in determining the average vertical thermal conductivity for the borehole interval under study. The higher uncertainties arise from the difficulties in maintaining or recreating in situ moisture content in samples from the unsaturated zone.

Factors other than instrumental measurements can affect the significance of calculated heat flows, as discussed in part in Section 3.1. Spatial variations of conductive heat flow can result from a variety of processes including convection (natural or induced by the presence of the borehole) of water in the saturated zone or gases and water (perched) in the unsaturated zone, as well as by vaporization or condensation in the unsaturated zone. For some performance-assessment uses of the information produced by this study, evidence of such processes will be of interest and will be specified to data users.

3.5 Range of expected results

Previous studies (e.g., Sass et al., 1988) show measured subsurface temperatures to be in the range of 15 to 60°C. Thermal conductivities range from 0.4 to 6 watts per meter-Kelvin ($W\ m^{-1}\ K^{-1}$); and heat-flow determinations range from 25 to 150 milliwatts per square meter ($mW\ m^{-2}$).

3.6 Required equipment

Required equipment is standard, and listed in pertinent technical procedures for Study 8.3.1.8.5.2 (Characterization of igneous intrusive features).

3.7 Data-reduction techniques

No special data-reduction techniques are required. See Section 3.1.

3.8 Representativeness of results

The areal distribution and number of drill holes for which data are provided to this activity are expected to be representative of ambient temperatures and thermal conductivities of various stratigraphic units in the Yucca Mountain area. In the unsaturated zone where natural or induced fractures are oriented perpendicular to the direction of heat flow, the effective conductivity of the rocks may be significantly different from that measured in the laboratory.

3.9 Relations to performance goals and confidence levels

See sections 1.2 and 4.

4. APPLICATIONS OF RESULTS

Data collected in this study will contribute to an understanding of the ambient thermal conditions of the repository horizon and surrounding units at Yucca Mountain. Specifically, results from this study will be used as initial boundary conditions for constructing thermomechanical and hydrothermal models used in the development of the geologic framework of the Yucca Mountain site (Investigation 8.3.1.4.2) and three-dimensional rock characteristics models (Study 8.3.1.4.3.2). For further discussion, see section 1.2.

5. SCHEDULE AND MILESTONES

Based on the scheduling and expected input of heat-flow and rock conductivity measurements from Activity 8.3.1.8.5.2.3 (Heat flow at Yucca Mountain and evaluation of regional ambient heat flow anomalies), a preliminary report on site ambient thermal conductivity is scheduled for the end of FY 1997, and a final report is scheduled for the end of FY 1998.

REFERENCE

Sass, J.H., Lachenbruch, A.H., Dudley, W.W., Jr., Priest, S.S., and Munroe, R.J., 1988, Temperature, thermal conductivity, and heat flow near Yucca Mountain, Nevada: some tectonic and hydrologic implications: U.S. Geological Survey Open-File Report OF 87-649, 118p.

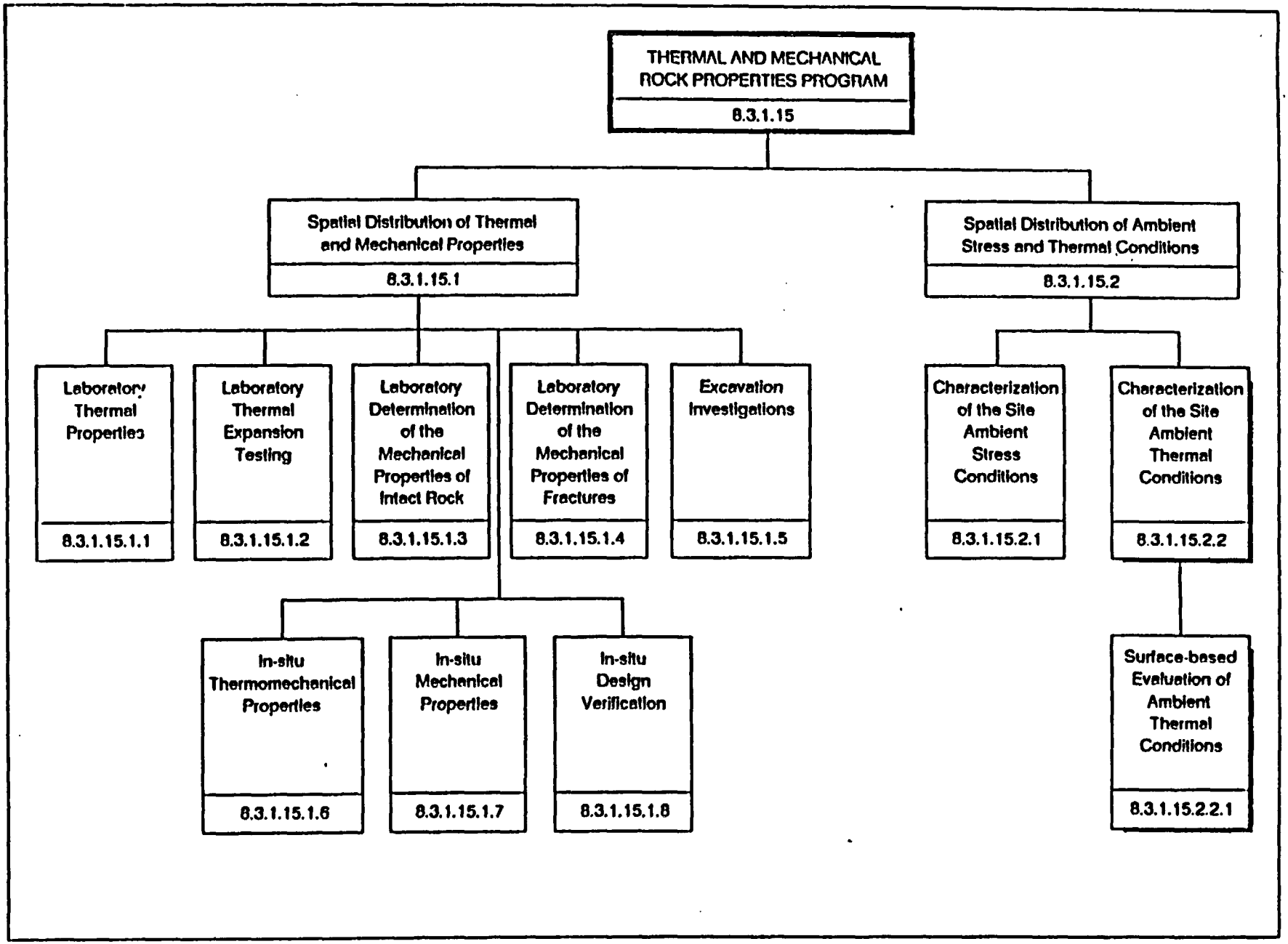

Figure 1-1. Postion of Study 8.3.1.15.2.2 (highlighted) within the thermal and mechanical rock properties program (Program 8.3.1.15).

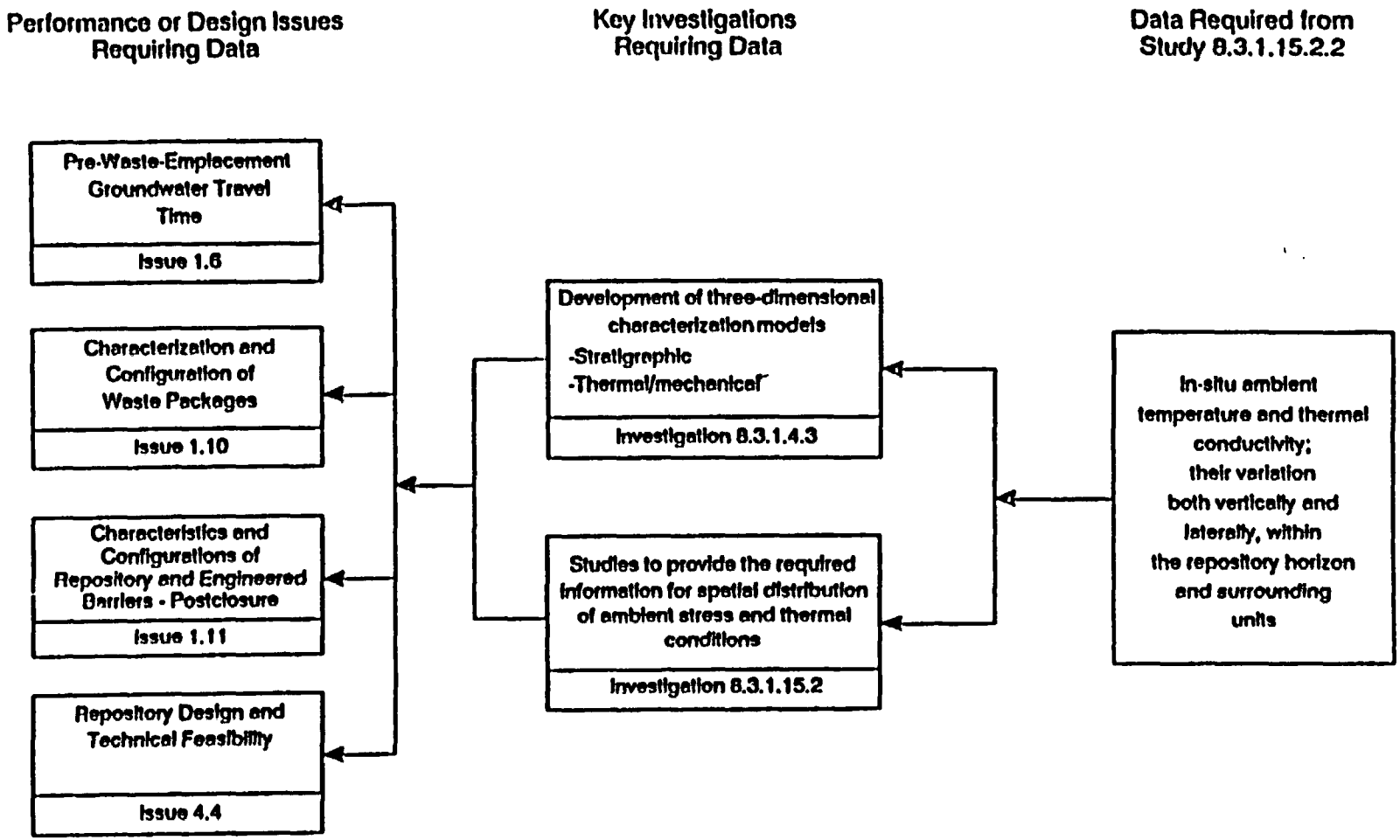

Figure 1-2. Information required from Study 8.3.1.15.2.2 for issue resolution.

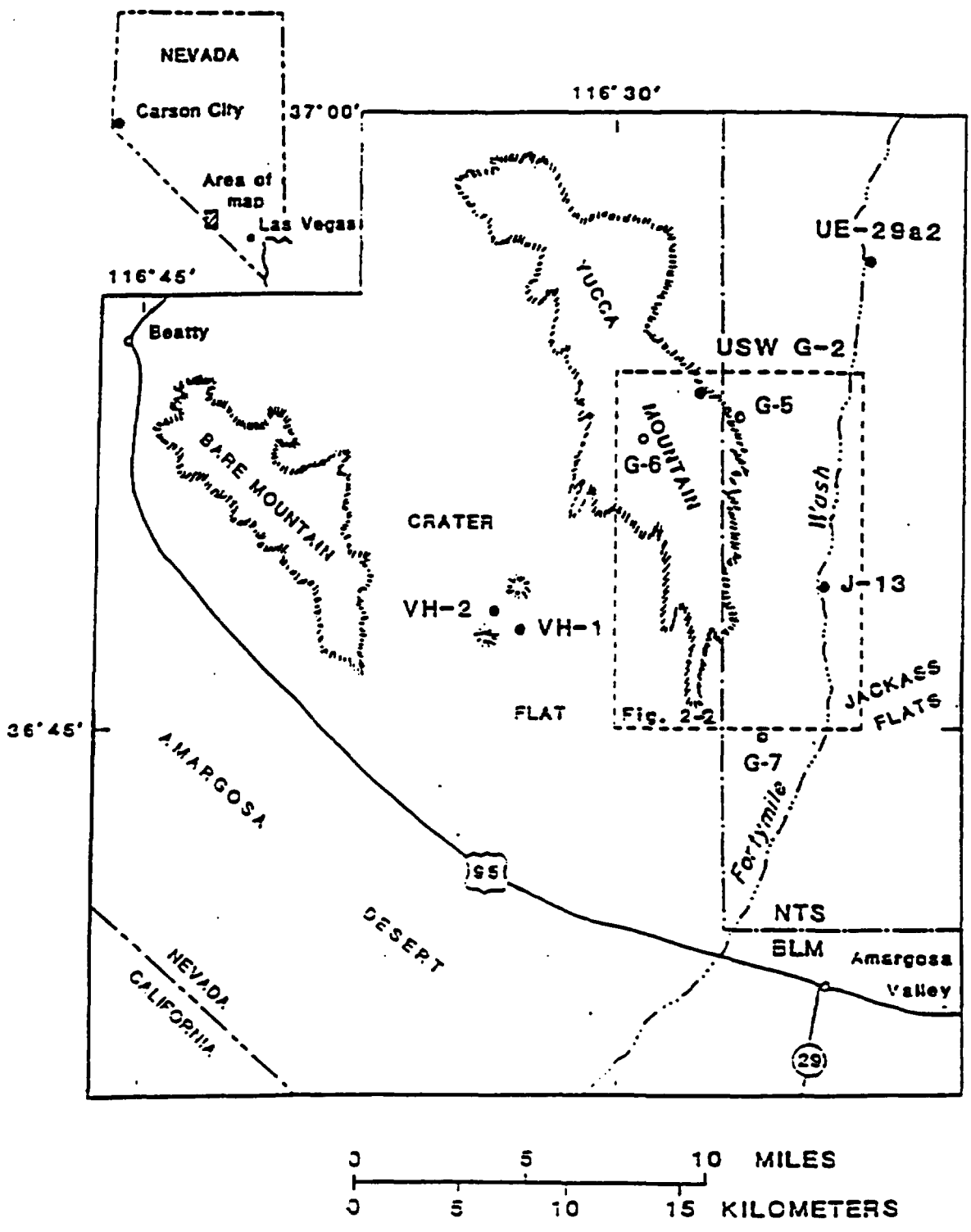

Figure 2-1. Map of Yucca Mountain and vicinity. Map is taken from study plan for Study 8.3.1.8.5.2, Characterization of igneous intrusive features; locations of selected boreholes shown by solid dots (existing) and open circles (proposed), and by well numbers.

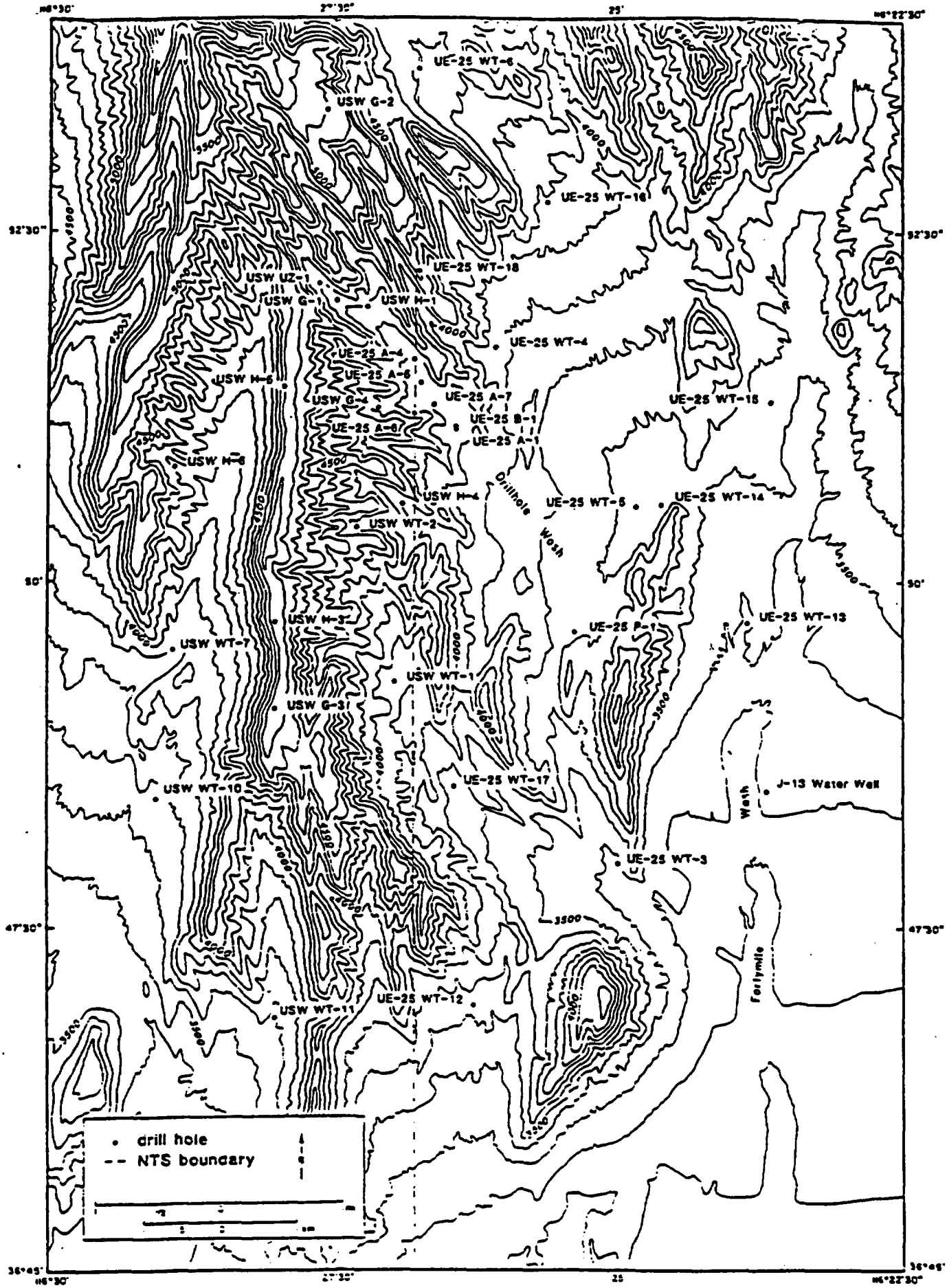

Figure 2-2. Map showing locations of wells in and adjacent to Yucca Mountain that are available for heat-flow and rock conductivity measurements to be obtained as part of Study 8.3.1.8.5.2, and analyzed in the present study.

The following is for the Office of Civilian Radioactive Waste Management Records management purposes only and should not be used when ordering this document:

Accession number: NNA.940609.0005