SPATIAL DISTRIBUTION OF POTENTIAL NEAR SURFACE MOISTURE FLUX AT YUCCA MOUNTAIN

Alan L. Flint
U.S. Geological Survey
Hydrologic Research Facility
P.O. Box 327, M/S 721
Mercury, NV 89023
(702) 295-5970

Lorraine E. Flint
U.S. Geological Survey
Hydrologic Research Facility
P.O. Box 327, M/S 721
Mercury, NV 89023
(702) 295-6002

ABSTRACT

An estimate of the areal distribution of present-day surface liquid moisture flux at Yucca Mountain was made using field measured water contents and laboratory measured rock properties. Using available data for physical and hydrologic properties (porosity, saturated hydraulic conductivity, moisture retention functions) of the volcanic rocks, surface lithologic units that are hydrologically similar were delineated. Moisture retention and relative permeability functions were assigned to each surface unit based on the similarity of the mean porosity and saturated hydraulic conductivity of the surface unit to laboratory samples of the same lithology. The potential flux into the mountain was estimated for each surface hydrologic unit using the mean saturated hydraulic conductivity for each unit and assuming all matrix flow. Using measured moisture profiles for each of the surface units, estimates were made of the depth at which seasonal fluctuations diminish and steady state downward flux conditions are likely to exist. The hydrologic properties at that depth were used with the current relative saturation of the tuff, to estimate flux as the unsaturated hydraulic conductivity. This method assumes a unit gradient. The range in estimated flux was 0.02 mm/yr for the welded Tiva Canyon to 13.4 mm/yr for the nonwelded Paintbrush Tuff. The areally averaged flux was 1.4 mm/yr. The major zones of high flux occur to the north of the potential repository boundary where the nonwelded tuffs are exposed in the major drainages.

INTRODUCTION

Yucca Mountain, Nevada (Fig. 1), is currently being evaluated as a potential site for a geologic repository for high-level radioactive waste. Unsaturated groundwater flow may be a potential source of radionuclide transport to the accessible environment[1]. Shallow infiltration of natural precipitation is a potential source of water for deeper percolation of groundwater through the thick unsaturated zone which includes the potential repository horizon. Characterization of flux in the near surface volcanic tuffs is important for defining the upper surface boundary conditions for site-scale groundwater flow models. These models will be used to estimate moisture flux through the deep unsaturated zone at Yucca Mountain. A series of 1-D[2], 2-D[3], and 3-D[4] models are being developed to estimate moisture conditions and flux rates under present day saturations

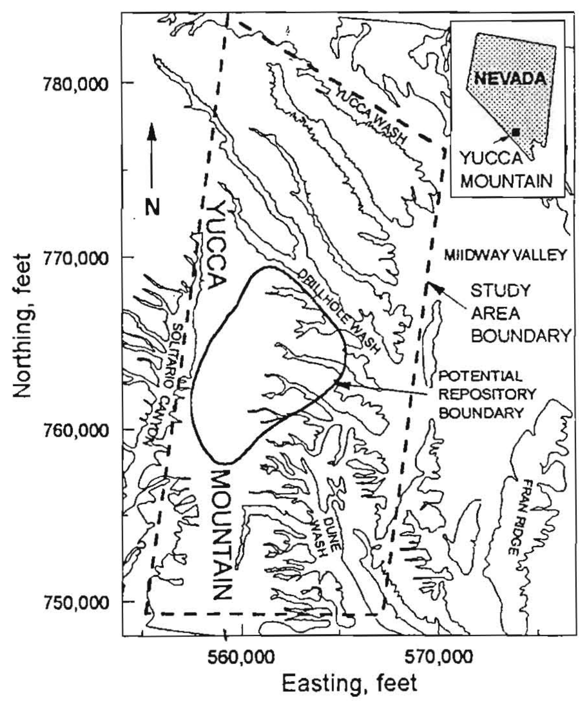

Figure 1. Location of site area in southern Nevada.

and climatic conditions. The spatial and seasonal variability of flux at the upper boundary needs to be determined to evaluate the appropriateness of 1-D or 2-D flow models or the necessity of a 3-D model. These models will be used to predict the behavior of the site under varying climatic and thermal conditions and to ascertain if Yucca Mountain is a suitable location to isolate radioactive waste from the accessible environment. Although the more complex 3-D models are more difficult to run, they may provide more realistic results. The model development and its dimensionality will require an understanding of the large scale surface heterogeneities and properties of the surface features that will control the near surface flux conditions under varying climatic scenarios.

Surface infiltration is a function of the properties of the surficial materials and the availability of water as a result of climatic conditions. The properties define the maximum or potential flux, while the climatic conditions (i.e. precipitation amount, rate, seasonality), determine the input into the system and, therefore, the estimated flux rate. To identify the potential flux, the hydraulic properties of the surface materials must be estimated. The alluvial cover over the site is a mechanism that stores, concentrates, and evaporates water, thus influencing the timing and volume of the input into the bedrock. The influence of the alluvium is accounted for by evaluating the water content at the alluvium bedrock interface. Deeper alluvium results in smaller water content changes and hence is closer to a steady state flux rate. Shallow alluvium allows for a greater change in water content and makes estimating flux more difficult unless surface features can be incorporated[5]. Important surface features include welded and nonwelded volcanic tuff penetrated by varying concentrations of fractures. Most of the surface fractures are filled with calcium carbonate or other surficial materials (i.e. silts and clays). Although fractures may be important mechanisms in the near surface,[5] they are being excluded in this exercise. The small surface area of the exposed fracture under the alluvium and the small number of fractures in the nonwelded tuffs allow for a reasonable preliminary analysis.

The intent of this exercise is to test a method that combines an understanding of the factors controlling the flux at the near surface, and the hydrologic properties of the surface rocks, to produce a surface map of potential moisture flux into the mountain over a 6 square km area. This map provides insight as to the regions of the site that have the potential to produce the highest surface flux. It also helps to identify locations where additional information may be needed. In addition, it will provide preliminary input of surface flux for each grid block in the 3-D site-scale model currently being developed[4]. Fracture networks and fracture properties may be included in a similar analysis when more fracture information becomes available.

SITE DESCRIPTION

Yucca Mountain is located in the Mojave Desert, 160 km northwest of Las Vegas, Nevada (Fig. 1). It is an uplifted, tilted, and faulted ridge that is composed of layers of volcanic ash-flow and ash-fall tuffs with widely varying physical and hydrologic properties largely due to differences in welding. The surface of the mountain has been eroded to expose different units in different locations with varying hydrologic properties. The climate at Yucca Mountain is represented by average annual precipitation of 170 mm/yr with a range of 165 mm/yr at the south end of the mountain to 230 mm/yr at the north end of the mountain[6].

The extent of the study site for this exercise is represented by the boundaries selected for the site-scale model being produced cooperatively by the U.S. Geological Survey and Lawrence Berkeley Labs[4]. The boundaries on the east, west, and north coincide with locations of major faults and all boundaries were selected to represent no-flow boundary conditions for 3-dimensional numerical modeling of unsaturated zone flow (Fig. 2). Grid blocks for modeling were developed for the site-scale model to correspond roughly with major faults, known boreholes and topographic features and are presented in this exercise with the flux estimates to represent spatial distribution.

METHODOLOGY

Physical and Hydrologic Properties of Rocks

Samples were collected from surface outcrops in a series of 8 transects that produced 685 core samples which were used to obtain measurements of various physical and hydrologic properties. Properties which were used in this study included porosity for 467 samples using water saturation and Archimedes' displacement, saturated hydraulic conductivity for 287 samples using a steady state permeameter, and moisture retention characteristics for 45 samples representing all lithologic units using a chilled-mirror psychrometer. Van Genuchten functions[7] were fit to the moisture retention data. Saturated hydraulic

Canyon Member that have porosities greater than 16 percent.

Potential Surface Flux

The TCw is the unit with the lowest porosity and conductivity, but is fairly similar to the TSw. The TCmw and the RM have intermediate conductivities and the PTn has a relatively large mean porosity and high conductivity. These surface hydrologic units were outlined on the geologic map within the site-scale model boundaries (Fig. 3).

Table 3. Calculated potential and present-day flux (mm/yr) for surface units.

Surface Unit	Percent of Area	Potential Flux (mm/yr)	Present-day Flux (mm/yr)
TCcr	6	3.4	0.04
TCmw	6	122.0	0.22
TCw	68	0.9	0.02
PTn	12	16398.7	13.40
RM	1	133.7	0.60
TSw	6	1.9	0.08

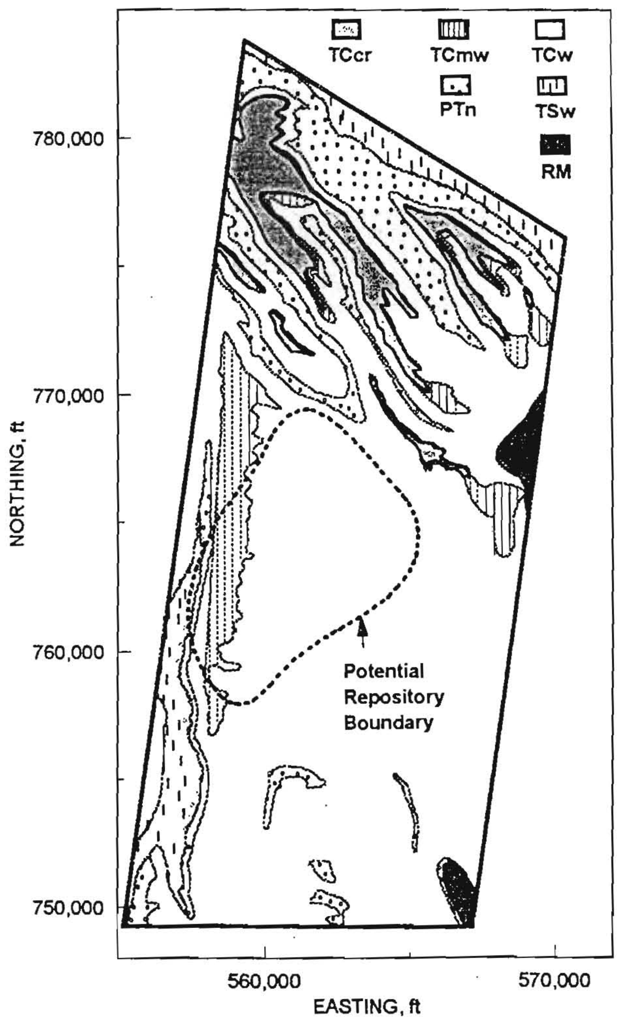

Figure 3. Geologic units at the surface of Yucca Mountain or directly under the alluvium.

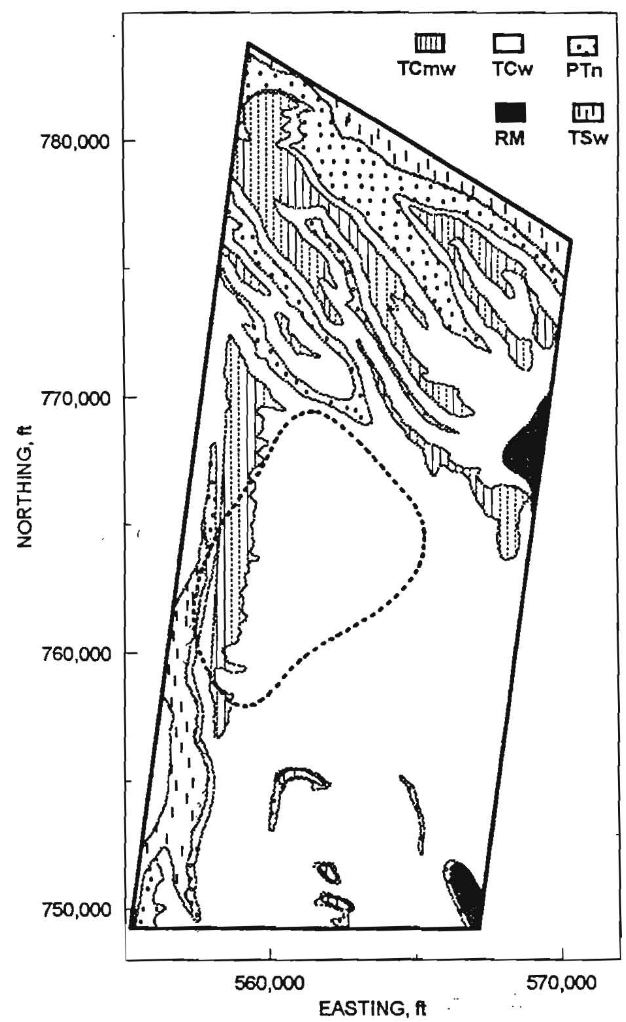

Figure 4. Geologic units at steady state over the surface of Yucca Mountain.