

TRANSPORT IN SALT BY VERTICAL POROUS MEDIA FLOW  
DEAF SMITH COUNTY SITE, PALO DURO BASIN

Numerical Evaluation of Conceptual Models  
Subtask 3.5  
Mini-Performance Assessment Report #2

July 31, 1986

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## 1.0 INTRODUCTION

### 1.1 General Statement of the Problem

This analysis is a mini-assessment of a particular aspect of the hydrogeology of the Deaf Smith County Salt Site as it pertains to the NRC's licensing criteria, or more specifically, to the requirements outlined in 40CFR191 and 10CFR60. Certain simplifying assumptions have been made in this evaluation that should be considered when comparing the results of this case study to any other.

This case study is aimed at determining the range of permeability values that would be required in the HSU B zone that would make vertical flow through the salt significant with respect to the regulatory criteria. Comparing this result with the estimated range of permeabilities presented in the Environmental Assessment (EA) (DOE, 1986) should allow us to qualitatively evaluate the level of effort needed for additional site characterization. For example, if the limiting permeability of the salt determined from this analysis is much greater than values reported in the EA, then we may conclude that the average travel time of nuclides between the repository and the underlying HSU C zone is in excess of 10,000 years, given the assumptions made herein. Therefore one might conclude that the amount of site characterization work needed to quantify vertical permeabilities in the HSU B zone is limited. However, if the limiting permeabilities determined in this analysis are on the same order



of magnitude as those reported in the EA, then one might conclude that a substantial amount of work was needed to quantify vertical permeabilities to ascertain whether or not the travel path and travel time criteria specified in 10CFR60 is met. Assumptions made in this analysis, such as length of travel path and travel time, are based upon the criteria specified in 10CFR60.

### 1.2 Relevance to the NRC Waste Management Program

DOE General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories, 10CFR960, indicates that in order for the site to qualify for characterization, the pre-placement ground-water travel time to the accessible environment must exceed 1000 years. NRC and EPA regulatory requirements, 10CFR60 and 40CFR191, for license approval list maximum allowable cumulative quantities of radionuclides which could be released to the accessible environment over a 10,000 year period. This mass flux is controlled to a great extent by ground-water travel time. Numerical and analytical models can be used to calculate ground-water travel times. In the analysis presented here we are in effect determining the extent to which vertical flow paths through the sedimentary interbeds below the repository horizon contribute to meeting the 10,000 year criteria.

### 1.3 Relationship to Other Subtasks, Analyses, and Documents

The analysis presented here is very simplified, but nevertheless useful toward guiding, or evaluating, the site character-



ization phase of work that is to come. Identifying the hydrogeologic parameters of prime importance to be used in evaluating the travel time and travel path criteria outlined in 10CFR60 should aid in directing the testing and sampling strategies during site characterization.

## 2.0 OBJECTIVE

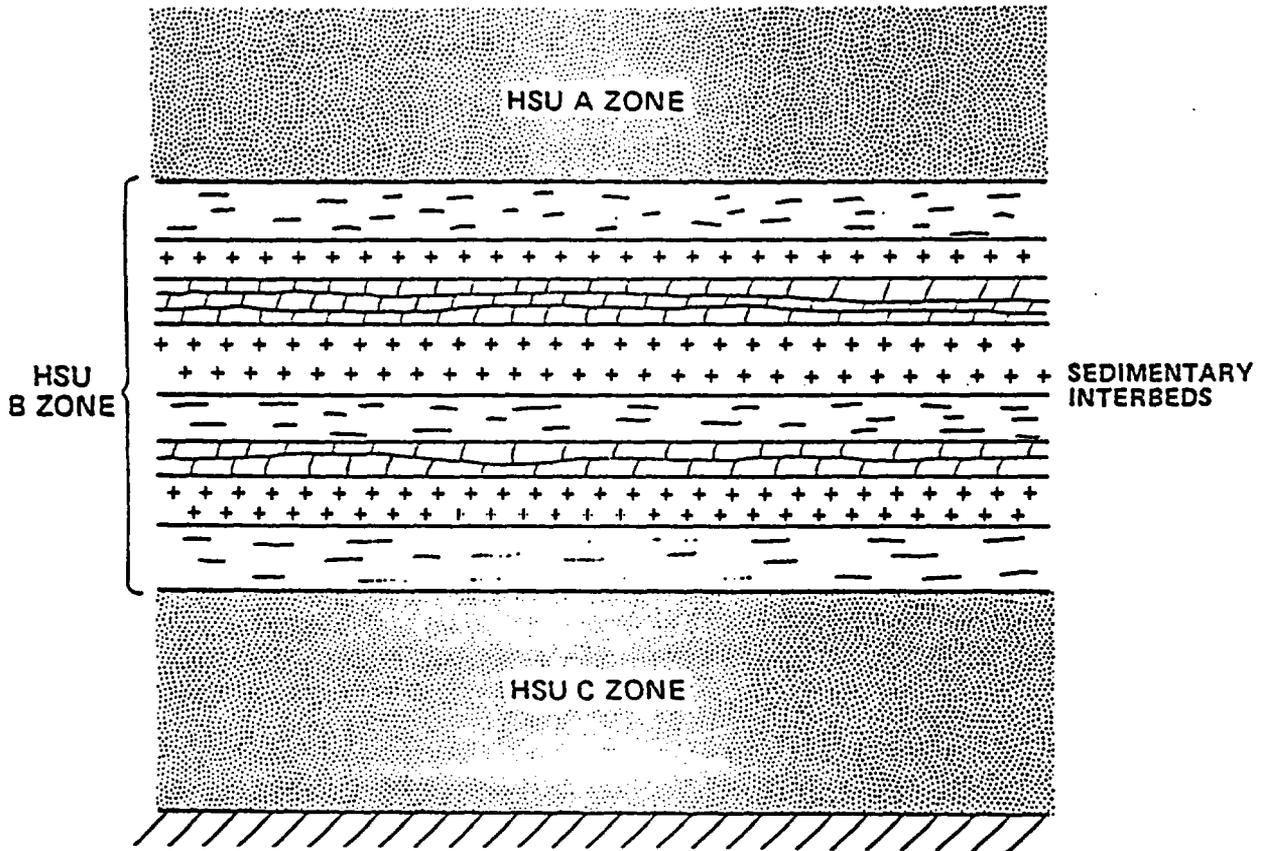
This analysis is intended to address what range of vertical hydraulic conductivity values would be necessary in the HSU B zone, beneath the repository, to allow the release of nuclides to the underlying Wolfcamp aquifer within a 10,000 year period to meet the EPA limit for the subject case of vertical flow alone, given our current understanding of the porosity and potential head gradients.

## 3.0 GENERAL APPROACH

### 3.1 Hydrologic Setting

The Palo Duro Basin is comprised of three zones of hydrostratigraphic units (HSU). Figure 1 depicts a generalized cross-section in the area of the proposed repository. The HSU A zone is a fresh-water aquifer. The HSU B zone is comprised of a series of sedimentary interbeds, with the proposed repository located in the San Andres Formation Unit 4 salt bed. The HSU C zone is chiefly considered a brine aquifer, which is underlain by bedrock.





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Figure 1. Idealized cross-section of the Palo Duro basin stratigraphic units.



### 3.2 Concepts Used for Analysis

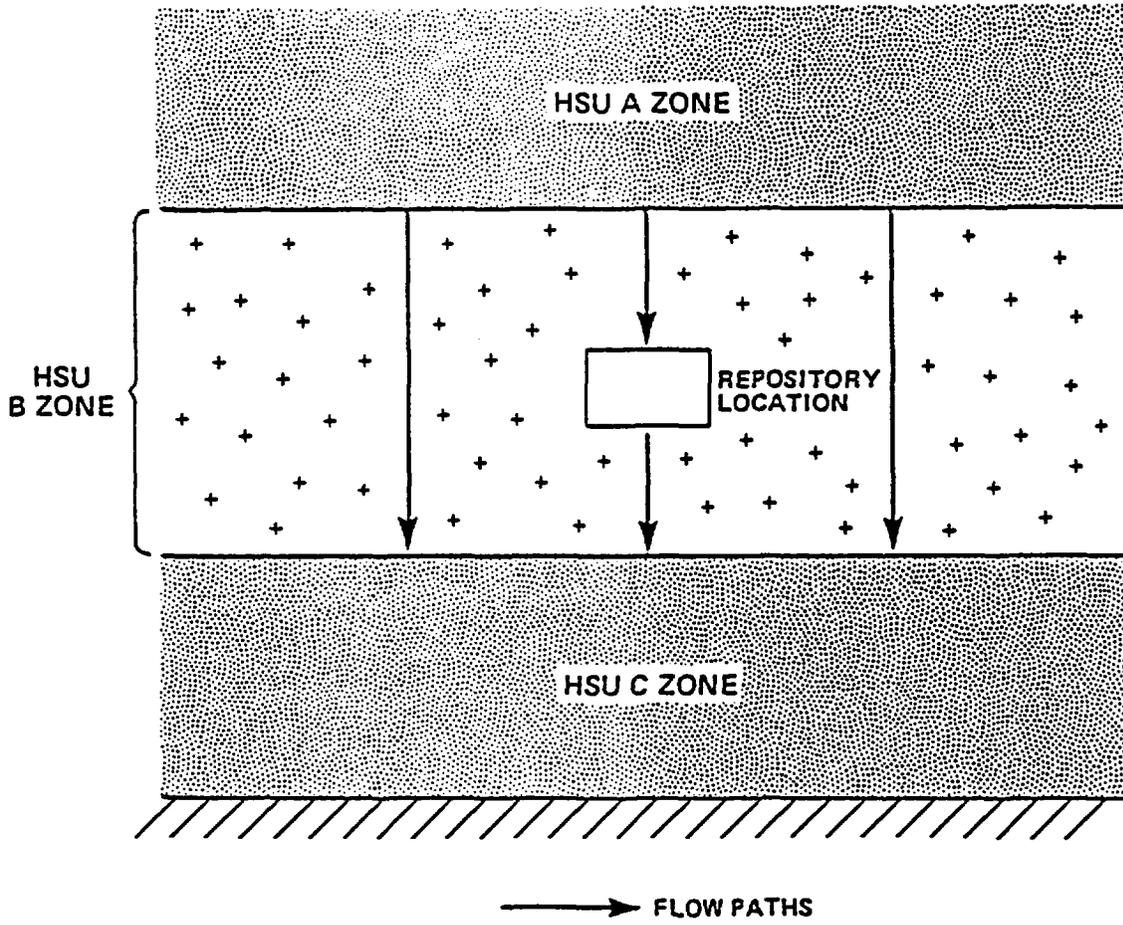
In this analysis, we will assume that vertical porous media flow can occur through the HSU B zone, and that horizontal flow within these sedimentary interbeds is negligible. Nuclides emanating from the repository will therefore travel vertically downward to the Wolfcamp aquifer, in the HSU C zone. Upon contacting the Wolfcamp, it is assumed that the nuclides are instantaneously transported to the accessible environment. Figure 2 represents the generalized cross-section for this transport mechanism. The acceptable travel time under these criteria would be 10,000 years. Applying a darcian approach to this ground-water flow problem would allow us to use existing porosity and hydraulic gradient data to estimate the range of hydraulic conductivity values necessary to meet the requirements of 10CFR60.

## 4.0 TECHNICAL APPROACH

### 4.1 Statement of Problem

Given the three layer system described above, where the middle zone is comprised of less permeable material which acts as an aquitard between two aquifers, in which the upper aquifer has a higher head potential than the lower aquifer, we can assume that water moving through the aquitard is moving vertically downward. A darcian approach to estimating the flux of water through this aquitard can then be applied. Given the current





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Figure 2. Idealized flow paths for vertical porous media flow through salt.



knowledge of porosity and head gradients across the aquitard, combined with the limiting travel time criteria from 10CFR60, will allow us to solve for the limiting hydraulic conductivity values that would classify this site as favorable.

#### 4.2 Solution Technique

We have assumed that vertical darcian flow occurs between the repository and the underlying Wolfcamp. The governing equation describing the pore velocity is:

$$V = q/n = Ki/n = L/t$$

where:      V = pore velocity [L/T]  
              q = darcy flux [L/T]  
              n = effective porosity  
              i = hydraulic gradient [L/L]  
              K = hydraulic conductivity [L/T]  
              L = length of travel path [L]  
              t = travel time [T]

This equation can then be rearranged to solve for K, and estimates made for the remaining parameters based upon data presented in the EA and the regulatory criteria of 10CFR60.

#### 4.3 Assumptions

The following assumptions were made for this analysis, and should be considered when comparing the results of this study to any other:

- one-dimensional, steady flow occurs vertically downward
- isothermal conditions
- constant fluid density
- homogeneous and isotropic medium



- no fracture permeability, strictly porous media flow
- when radionuclides reach the Wolfcamp formation they are instantaneously transported to the accessible environment

#### 4.4 Application of Solution

The travel time assumed for nuclides to move from the repository to the Wolfcamp is 10,000 years, based upon criteria specified in 10CFR60. The resulting estimates of hydraulic conductivity can then be compared to the measured or calculated values reported in the EA. If the predicted range of hydraulic conductivity values from this analysis is much greater than the values reported in the EA, and those values reported in the EA are considered statistically representative, then it might be concluded that only minimal assessment of the hydraulic conductivity of the HSU B units is necessary in the future. In other words, if the values of permeability reported in the EA are considerably less than the limiting values calculated in this analysis, then the darcian flux through the HSU B zone should be of such a magnitude that the average travel time from the repository to the Wolfcamp is in excess of 10,000 years. On the other hand, considering the simplicity of this analysis, or the sparcity of field data, it may be advisable to put together a more detailed site characterization plan.

#### 5.0 ANALYSES



Based upon the preceding assumptions and governing flow equation we need to obtain estimates of the length of travel path, the effective porosity, and the vertical hydraulic gradient through the HSU B zone.

The length of the travel path is estimated conservatively from the data presented in Table 3-3 in the EA. The distance between the repository horizon and the top of the Wolfcamp is approximately 2270 feet.

According to the EA, effective porosity values for the sedimentary interbeds in the HSU B zone range from less than 1% to greater than 10%. For this analysis we will assume values of 1% and 10% to bracket the range of expected results.

No potential head estimates have been made within the HSU B zone. Under a saturated regime, we might assume that the HSU B zone acts as an aquitard between the HSU A and HSU C zones, and that the head loss across the HSU B zone is linear. Therefore, the gradient between the Dockum and Wolfcamp aquifers is considered the same as that within the HSU B zone. Figure 3-60 in the EA shows the vertical gradient in the vicinity of the proposed site to be about 0.65.

Table 1 presents a summary of the input data to this model.

## 6.0 RESULTS

Based upon a travel path of 2270 feet and a travel time of 10,000 years, the estimated maximum pore velocity of nuclides in the HSU B zone, under the preceding assumptions, is 0.23 feet-



TABLE 1 - ESTIMATED HYDRAULIC PARAMETERS FOR MODEL #2 INPUT

<u>PARAMETER</u>	<u>VALUES</u>
Length of Travel Path	2270 feet
Travel Time	10,000 years
Vertical Head Gradient	0.65 feet/feet
Effective Porosity	1% to 10%



/year. Using the low estimate of effective porosity, the estimated maximum acceptable value of K would be 0.0035 feet/year (0.0035 md). With a porosity of 10%, the estimated K would be 0.035 feet/year (0.035 md).

### 7.0 CONCLUSIONS

The results just presented show that given our current understanding of the gradient across the HSU B zone, and a possible range of effective porosity values between 1% and 10%, the effective hydraulic conductivity which would allow the EPA release standard to be met could range from 0.0035 to 0.035 md, respectively. The limited amount of permeability testing that has been done in the HSU B zone suggests that the permeability of these interbeds ranges anywhere from 0.0007 to 3.05 md. The effective vertical permeability would be weighted heavily by the less permeable units when flow is dominantly vertically downward in a horizontally stratified medium. Therefore at this time one cannot unequivocally conclude that the vertical downward movement of nuclides through the HSU B zone to the Wolfcamp would present a problem in terms of satisfying the criteria in 10CFR60 with the data currently available, given the assumptions applied in this analysis.

### 8.0 DISCUSSION

Because the preceding analysis did not appear to yield a definitive difference between the predicted hydraulic conductivi-



ty range and that which was obtained through testing or calculations and presented in the EA, it would appear that additional site characterization with regard to quantifying the vertical permeability of the HSU B interbeds might be needed if the assumptions used in this analysis are warranted. Also, the hydraulic data used in this analysis, as reported in the EA, was not obtained from the near field, but taken from wells off-site or from generic values in the scientific literature. On this basis it might be appropriate to consider additional site characterization of the permeability of the HSU B units, as well as additional porosity and head data.

It should be noted, also, that the assumption of instantaneous travel time of nuclides from directly below the repository at the HSU B/Wolfcamp boundary to the accessible environment is conservative. Another mini-performance assessment coupling vertical flow through the HSU B zone and horizontal flow through the Wolfcamp to the accessible environment might not conclude that additional data is needed to characterize the permeability of the interbeds.

## 9.0 REFERENCES

U.S. Department of Energy, 1986, Environmental Assessment, Deaf Smith County Site, Texas, DOE/RW-0069, Vol. 1.

