TRANSPORT IN THE INTERBEDS OF THE HSU B ZONE BY HORIZONTAL POROUS MEDIA FLOW DEAF SMITH COUNTY SITE, PALO DURO BASIN

Numerical Evaluation of Conceptual Models
Subtask 3.5
Mini-Performance Assessment Report #3

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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 an interbed of the HSU B zone that would make horizontal 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 sedimentary interbeds 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 accessible environment 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 horizontal 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 horizontal 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-emplacement 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 horizontal 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 never-

theless useful toward guiding, or evaluating, the site characterization 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 horizontal hydraulic conductivity values would be necessary in an interbed of the HSU B zone, beneath the repository, to allow the release of nuclides to the accessible environment 5 km down-gradient from the repository and over a 10,000 year period to meet the EPA limit for the subject case of horizontal 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

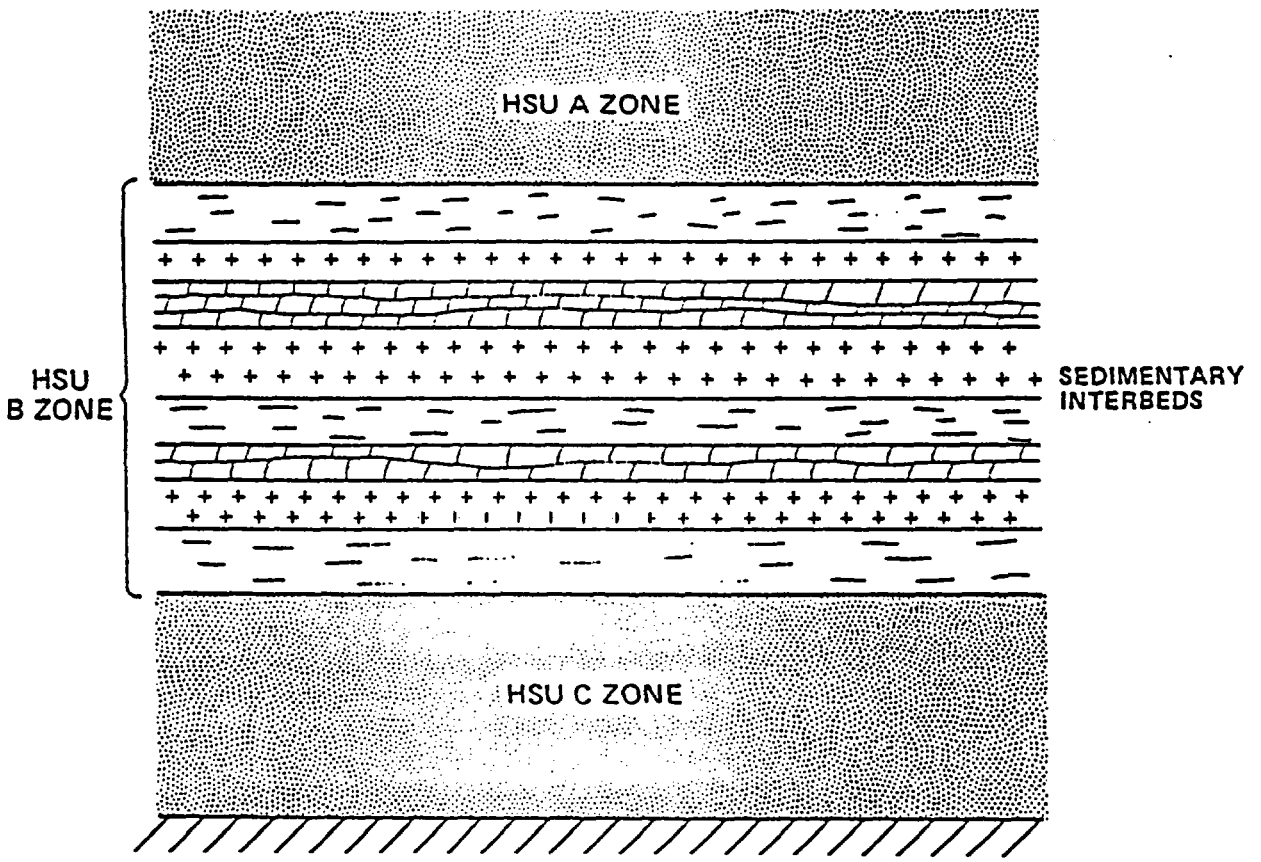

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Figure 1. Idealized cross-section of the Palo Duro basin stratigraphic units.

bedrock.

3.2 Concepts Used for Analysis

In this analysis, we will assume that horizontal porous media flow can occur through an interbed of the HSU B zone, and that vertical flow within these sedimentary interbeds is negligible. Nuclides emanating from the repository will therefore travel vertically downward to the interbed instantaneously. Upon contacting the interbed, it is assumed that the nuclides are transported 5 km horizontally 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 sedimentary interbeds, some of which act as aquitards between layers of higher permeability, in which the upper aquifer has a higher head potential than the lower aquifer, we can assume that water moving through the HSU B zone has a potential to move horizontally away from the repository

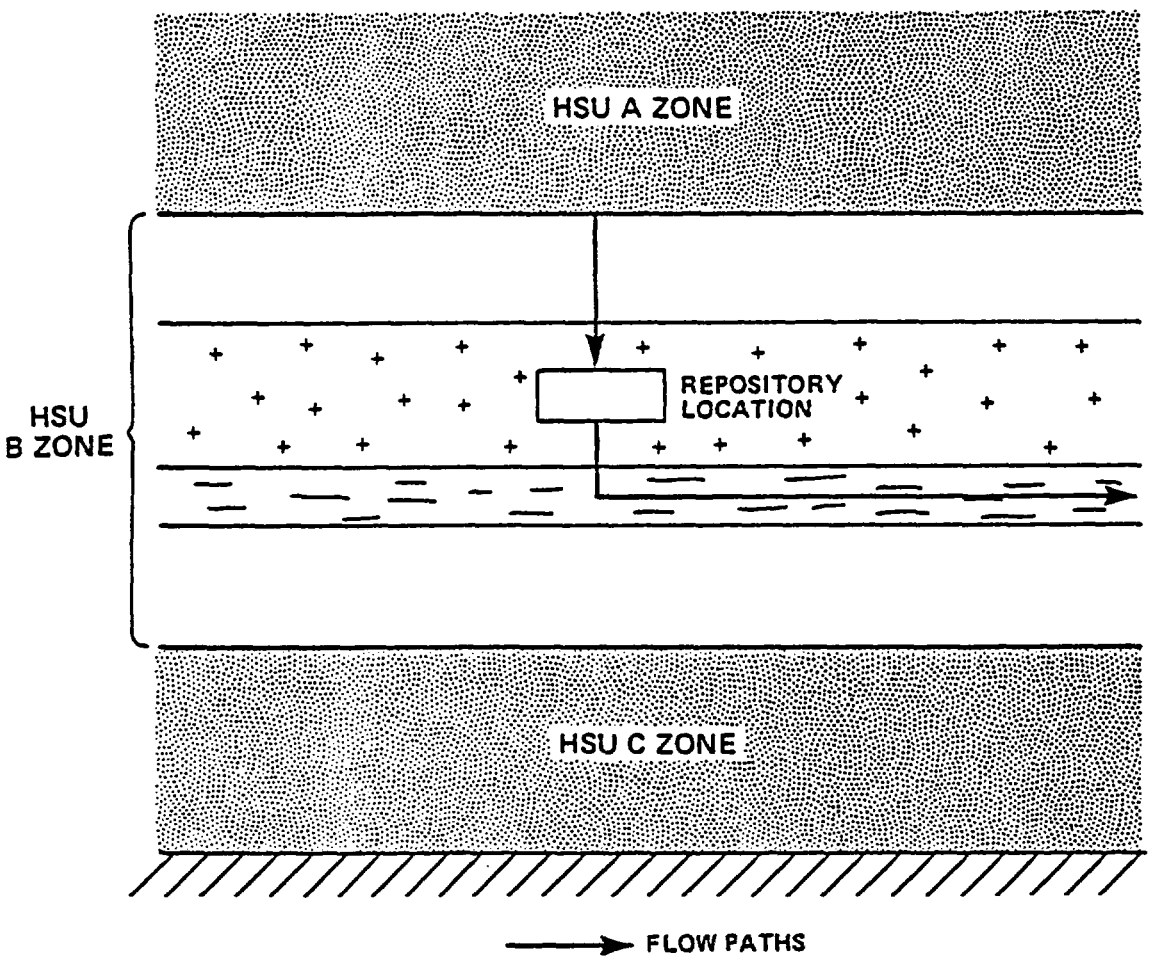

Figure 2. Idealized flow paths for horizontal porous media flow through sedimentary interbeds.

through one or more of the higher permeability interbeds. A darcian approach to estimating the horizontal flux of water through one of these interbeds can then be applied. Given the current knowledge of porosity and head gradients across the HSU B zone, combined with the limiting travel path and 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 horizontal darcian flow occurs within a sedimentary interbed. 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 horizontal flow
- isothermal conditions
- constant fluid density
- homogeneous and isotropic medium
- no fracture permeability, strictly porous media flow
- radionuclides emanating vertically downward out of the repository horizon instantaneously arrive at the higher permeability interbed under study

4.4 Application of Solution

The travel time assumed for nuclides to move from the repository to the accessible environment 5 km away is 10,000 years. 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 accessible environment 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 effective porosity and the horizontal hydraulic gradient through the HSU B zone.

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%.

No potential head estimates have been made within the HSU B zone. To be conservative, we would want to assume the largest gradient practical. If we assumed no head loss between the Dockum Group and the interbed at the site, and no head loss between the interbed and the underlying Wolfcamp 5 km down-gradient of the site, then this should yield a conservative estimate of the gradient for this case. Figure 3-58 in the EA depicts the estimated potentiometric surface for the Dockum. The head at the site is approximately 3350 feet. Figure 3-61 depicts the Wolfcamp potentiometric surface, from which we estimate the head 5 km down-gradient of the site to be about 2000 feet. Therefore, the gradient through a flow path in one of the sedimentary interbeds might be about 0.082.

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

TABLE 1 - ESTIMATED HYDRAULIC PARAMETERS FOR MODEL #3 INPUT

PARAMETER	VALUES
Length of Travel Path	16,400 feet
Travel Time	10,000 years
Horizontal Head Gradient	0.082 feet/feet
Effective Porosity	1% to 10%

6.0 RESULTS

Based upon a travel time of 10,000 years and a travel path of 5 km, the average pore velocity of nuclides in the interbed would be about 1.64 feet/year. Using the low estimate of effective porosity, the estimated maximum acceptable value of K would be 0.20 feet/year (0.20 md). With a porosity of 10%, the estimated K would be 2.0 feet/year (2.0 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 0.20 to 2.0 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. Therefore it cannot be shown that horizontal flow in the HSU B zone alone would allow a demonstration that the site meets the EPA release limits required by 10CFR60, based upon 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 conductivity range and that which was obtained through testing or calculations and presented in the EA, it would appear that additional site characterization with reqard to quantifying the horizontal 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 horizontal gradient used in this analysis was probably conservatively high, based upon the fact that no head data has been collected in the HSU B zone. Additional testing of the potential head gradient through these interbeds might therefore be warranted.

9.0 REFERENCES

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