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TO: S. Pahle
Models for Palo Duro Basin

A DISCUSSION OF CONCEPTUAL GROUNDWATER FLOW MDOELS,

PALO DURO BASIN, TEXAS

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A DISCUSSION OF CONCEPTUAL GROUNDWATER FLOW MODELS, PALO DURO BASIN, TEXAS

1 INTRODUCTION

This document presents current views of Williams and Associates, Inc., regarding conceptual groundwater flow models for the Palo Duro Basin, in Texas. A general discussion of geology and hydrogeology of the Palo Duro Basin, and of the area near the proposed waste storage site in Deaf Smith County is presented. Based on this discussion conceptual groundwater flow models are presented for the Palo Duro Basin. A discussion of the characteristics of groundwater flow in the vicinity of the Deaf Smith County site is presented also.

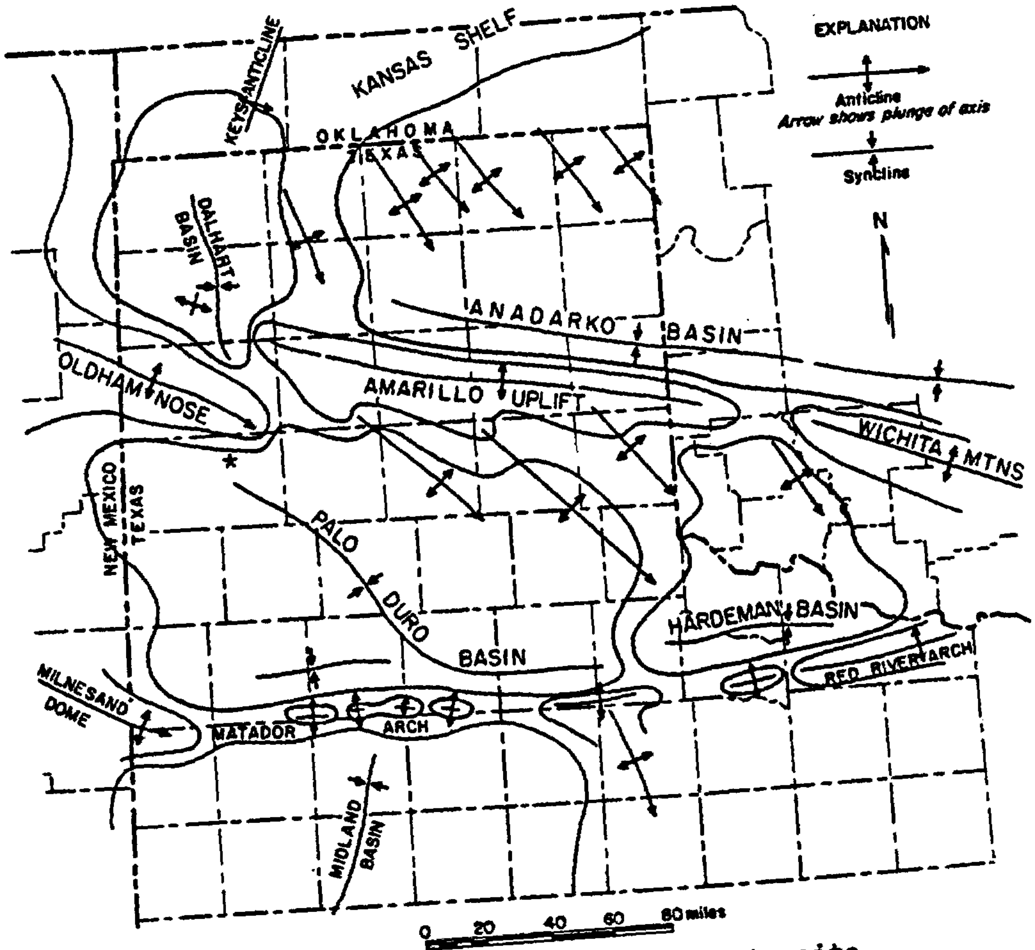
A similar document (Williams and Associates, Inc., 1984) was prepared two years ago which defines much of the basic hydrogeologic framework of the basin. That document presents earlier details of possible conceptual models. Although additional data have been collected in the interim, much of this basic framework remains unchanged. As a result the current report focuses on the impact of recently collected data on conceptual models and on near-site hydrogeologic conditions.

2 GEOLOGY

2.1 Palo Duro Basin

The Palo Duro Basin is a structural basin which occupies a small part of the much larger Permian Basin of Texas, Oklahoma, and Kansas. Basin development in the Texas Panhandle began as early as Late Precambrian, but major structural deformation did not occur until Pennsylvanian time (Stone and Webster Engineering Corp., 1983a). In Pennsylvanian time major tectonic activity produced a series of well-defined structures which began to separate the panhandle area into a series of sharply defined structural basins (fig. 1). Anticlinal structures such as the Amarillo-Wichita Uplift to the north, the Matador Arch to the south, and the Bravo Dome (Oldham Nose) to the northwest, developed during Pennsylvanian time. These structures began to define and separate the Palo Duro Basin from the Anadarko Basin to the northeast, the Midland Basin to the south and the Dalhart Basin to the northwest. Major tectonic activity ended by middle Permian time; this orogeny appears to have been the last major period of tectonic activity in the basin.

The general depositional sequence present in the Palo Duro Basin is illustrated in figure 2 which also reflects the basin's tectonic history. Stratigraphic nomenclature is presented in figure 3. Sedimentary deposition began with the deposition of locally derived clastics during Cambrian time.



* Approximate location of Deaf Smith County site.

Figure 1. Index map of major structural features of Texas Panhandle (after Nicholson, 1960).

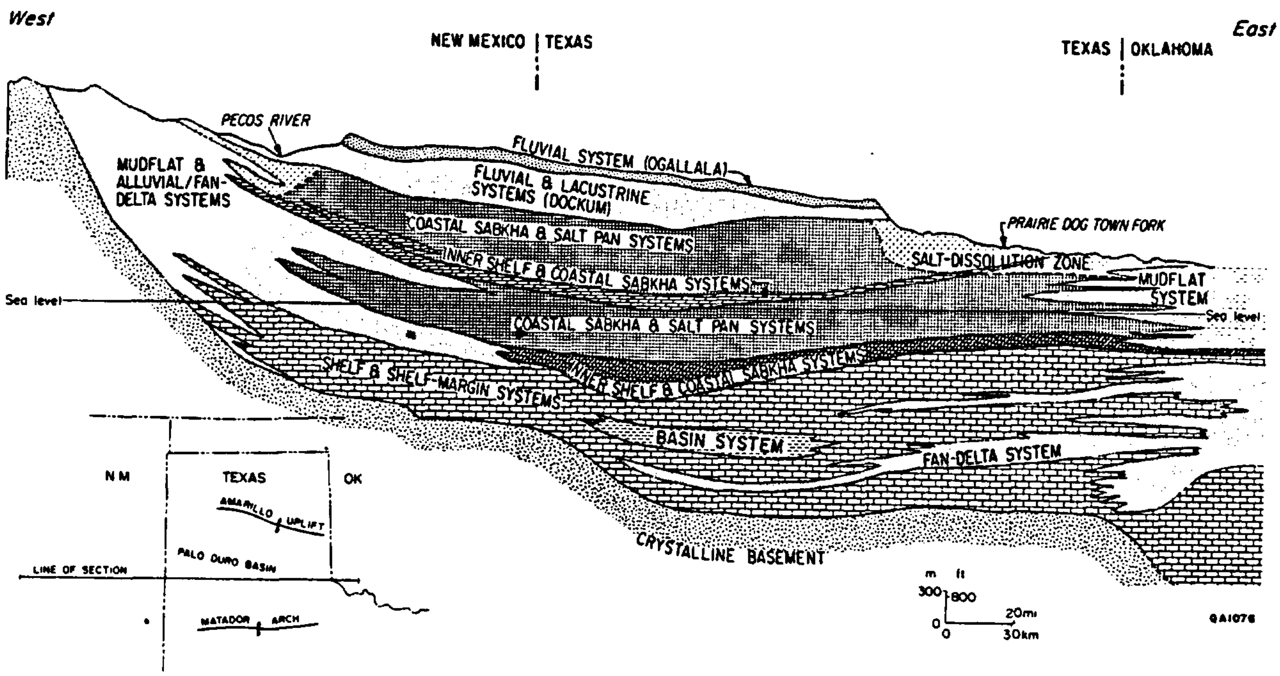


Figure 2. Generalized depositional model along east-west cross-section through the Palo Duro Basin, Texas (after Senger and Fogg, 1983).

ERA	SYSTEM	SERIES	GROUP	FORMATION	HYDROSTRATIGRAPHIC UNIT (HSU)
CENOZOIC	QUATERNARY			RECENT FLUVIAL AND LACUSTRINE DEPOSITS	FRESHWATER FLOW SYSTEM HSU A
	TERTIARY			OGALLALA	
MESOZOIC			DAKOTA		
			FREDRICKSBURG		
			TRINITY		
	JURASSIC			MORRISON	
				EXETER	
	TRIASSIC		DOCKUM	TRUJILLO	
				TECOVAS	
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE	SHALE AND EVAPORITE AQUITARD HSU B
				ALIBATES	
		GUADALUPE	ARTESIA/ WHITEHORSE	SALADO - TANSILL	
				YATES	
				SEVEN RIVERS	
				QUEEN/GRAYBURG	
			PEASE RIVER	SAN ANDRES/BLAINE	
		LEONARD	• • • • • • •	GLORIETA	
			CLEAR FORK	UPPER CLEAR FORK	
				TUBB	
				LOWER CLEAR FORK	
				RED CAVE	
			WICHITA		
		WOLFCAMP			DEEP-BASIN FLOW SYSTEM HSU C
	PENNSYLVANIAN	VIRGIL	CISCO		
		MISSOURI	CANYON		
		DES MOINES	STRAWN		
		ATOKA	BEND		
		MORROW			
	MISSISSIPPIAN	CHESTER			
		MERAMEC			
		OSAGE			
	ORDOVICIAN		ELLENBURGER		
	CAMBRIAN		UNNAMED SANDSTONE		
	PRECAMBRIAN				

Explanation:

— — — Unconformity

• • • • Boundary in Dispute

Figure 3. Stratigraphic nomenclature and division of hydrostratigraphic units of the Palo Duro Basin, Texas (after Bair and others, 1985).

Cambrian and Ordovician age rocks occur only locally within the Palo Duro Basin; mainly in the southern and eastern parts of the basin. Rocks of Silurian and Devonian age are completely absent from the basin; apparently they were removed by erosion from a broad northwest trending structure known as the Texas Arch, which developed during this time (Stone and Webster Engineering Corp., 1983a). Shallow marine carbonates were deposited during Mississippian time, but uplift and erosion at the end of the period removed these rocks from all but the southern half of the Palo Duro Basin. The rocks are primarily limestones and dolomites with some shales deposited in late Mississippian time.

Deposition during Pennsylvanian time reflects the ongoing tectonism of the period. During this time more than 2500 feet of sediments were deposited in the Palo Duro Basin (Nicholson, 1960). The rocks reflect the relative intensity of tectonic activity as they grade from coarse clastics in early Pennsylvanian time, to middle Pennsylvanian shelf carbonate deposits, and to marine shales and limestones near the end of the period. The presence of positive areas along the basin margins resulted in a basin-wide depositional sequence characterized by significant facies variation (fig. 2). Depositional sequences contain a greater amount of coarse clastic material near the uplift areas; arkosic sand (granite wash) dominates these areas. Near the basin center carbonates and fine clastics dominate.

During Permian time most major tectonic activity had ceased and the stratigraphic sequence reflects the decreasing significance of previous tectonically positive areas. Deposits of the Wolfcamp Series resemble those of the underlying Pennsylvanian sequence. Carbonates were deposited along the basin flanks while arkosic sands were still being deposited along the Amarillo Uplift. Shales and other fine-grained sediments characterize the Wolfcamp sequence in the central part of the basin.

Throughout Permian time depositional conditions became much more restrictive. Leonard Series deposits consist of 2000 feet of interbedded carbonates, evaporites, and terrigenous clastics. Significant facies changes occur, with a general trend "from terrigenous clastic material to evaporite (halite and anhydrite), and then to carbonates in a north-to-south facies sequence" (Stone and Webster Engineering Corp., 1983a, p. 64). The overlying San Andres Formation reflects a similar depositional environment containing principally salt beds with thin interbeds of dolomite, anhydrite and mudstones. The Permian sequence above the San Andres exhibits similar depositional conditions. The late Permian sequence consists primarily of terrigenous clastic deposits and some thin carbonates with relatively minor amounts of evaporitic deposits. At the end of Permian time the Palo Duro Basin underwent a minor amount of uplift and a transition from marine to non-marine deposition. The Triassic Dockum Group, consisting of fluvial and lacustrine terrigenous clastics and non-marine dolomites, was deposited.

Little Mesozoic deposition apparently occurred. No Jurassic or Cretaceous rocks have been found in the Palo Duro Basin. Insufficient data exist to determine if the absence of these rocks is due to erosion or nondeposition

(Budnik, 1985). Tertiary deposits consist primarily of the Ogallala Formation; sequence of alluvial gravels, sands, and silts. This sequence is 200 to 400 feet thick in the Palo Duro Basin but it reaches thicknesses of greater than 500 feet in depressed areas in the pre-Ogallala surface (Seni, 1980).

Stratigraphic studies of Palo Duro Basin geology produce a conceptualization of a structural basin that developed in Pennsylvanian time and gradually filled with a thick clastic and evaporitic sequence. A major transition in facies occurred in early Permian time from a sequence dominated by carbonates to one dominated by clastics and evaporites. Ultimately this latter sequence was capped by clastics of the Dockum Group and later the Ogallala Formation. The middle and upper Permian sequence is characterized by great facies variation with units alternating among fine-grained clastics, thin carbonate units and evaporite deposits.

Evidence for faulting and other major structural deformation is restricted largely to pre-Permian strata. Structure contour maps prepared for various Paleozoic surfaces (Budnik, 1984) reveal considerable faulting of Precambrian basement and of Paleozoic units up to and including the Pennsylvanian sequence. Structure contour and isopach maps produced on post-Permian sequences reveal significantly less faulting; however substantial evidence exists that indicates that deformation continued into Cenozoic time as well.

Budnik (1984, p. 12) believes that deposition of the Dockum Group was "influenced by some of the same structures that affected Permian and earlier deposition." He also presents evidence to indicate that substantial deformation within the Palo Duro Basin occurred in Tertiary time and that it has continued since the deposition of the Ogallala Formation. Direct evidence of Cenozoic faulting is difficult to find within the Palo Duro Basin. Budnik (1984), however, reports that north of the Palo Duro Basin the lower part of the Ogallala may be faulted based on abrupt thickening of this unit at some locations. Much of the later deformation is believed to have occurred as a result of reactivation of Paleozoic structures. Regional seismicity and the presence of Quaternary faulting in Oklahoma, has led Budnik (1985, p. 24) to conclude that the "entire region has remained tectonically active until the present."

2.2 Deaf Smith County

Little subsurface geologic information has been obtained from the proposed site in Deaf Smith County; however, it is possible to draw some conclusions concerning geology in the vicinity of the site based on the extrapolation of stratigraphic trends and on nearby well data. The location closest to the site for which detail subsurface data are available is that of the J. Friemel #1 well drilled as part of the area characterization studies (fig. 4). In general terms the stratigraphy of Deaf Smith County reflects that described above for the Palo Duro Basin. Unlike other areas in the basin,

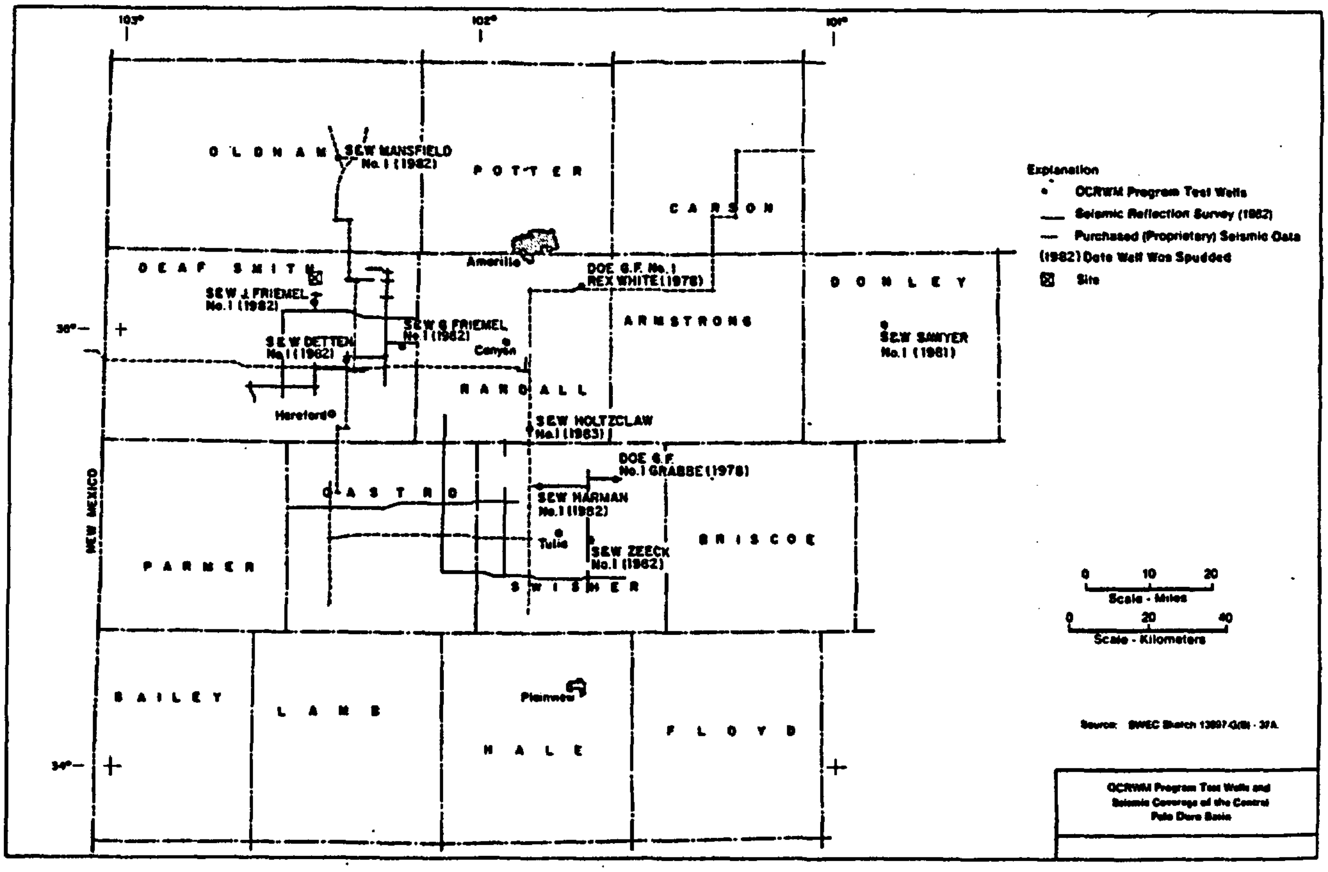


Figure 4. Location map of Department of Energy stratigraphic and hydrologic test wells, Palo Duro Basin, Texas (after U.S. Dept. of Energy, 1984).

however, none of the sequence between Precambrian age rocks and Pennsylvanian age rocks is present in the Deaf Smith County area; this hiatus apparently is a result of the fact that the axis of the Texas Arch passes through the county. Erosion or non-deposition associated with this positive feature apparently accounts for the absence of these units (Budnik, 1985).

Analysis of the log of the J. Friemel #1 well reveals that arkosic sands predominate in the lower half of the Pennsylvanian sequence penetrated by the well, whereas limestone and shale are present in the upper half. Rocks of the Wolfcamp Series penetrated in the well consist of about 550 feet of calcareous shales overlain by 600 feet of limestones and dolomites. We have commented previously (Williams and Associates, Inc, 1986a) on the presence of so much shale in a unit (Wolfcamp) that has been modeled as a single aquifer. The dolomite continues upward into the overlying Wichita Formation and constitutes most of this 300-foot thick unit. About 4000 feet of interbedded shales, mudstones and evaporites overly the Wichita Formation. Some carbonate units occur interbedded with the evaporite units of the lower San Andres Formation. Cycle-4 of the lower San Andres Formation is currently the favored stratigraphic horizon for a waste storage facility. Above the San Andres, the fine-grained marine clastics and evaporites continue to dominate although the thickness and number of evaporite units decreases upward.

The contemplated repository site appears to be located in a rather narrow north-south trending trough which connected the Palo Duro Basin with the Dalhart Basin to the north during Pennsylvanian and early Permian time. As a result, stratigraphic sequences of these time periods deposited in the vicinity of the site are presumed to have significantly less coarse clastic material than correlative units to either the east or west. The trough apparently was still present into middle Permian time; isopach maps of the upper Clear Fork and Glorieta Formations reflect its presence in the vicinity of the site (Stone and Webster Engineering Corp., 1983a). By the time of deposition of the San Andres Formation the effect of this trough had diminished; the San Andres tends to thin evenly to the north. Despite this thinning, total net salt content of the lower San Andres is highest in northern Deaf Smith and southern Oldham counties. Consequently the site appears to be located in an area where Permian and Pennsylvanian stratigraphic units are thick as a result of deep quiet-water deposition. Stratigraphic studies indicate that both thickness and composition of the Pennsylvanian and Permian sequences vary significantly to the west and to the northeast.

Knowledge of the amount and nature of structural deformation within the vicinity of Deaf Smith County is limited. Current subsurface data indicate little evidence of major post-Pennsylvanian structural discontinuities; however, evidence does suggest that some faulting may be present in the vicinity of the Deaf Smith site. Discussion presented by R. Budnik (Williams and Associates, Inc., 1985) indicates that structures within the central Palo Duro Basin generally consist of isolated topographic highs and poorly defined topographic lows. Examples of such features which may have influenced recent structural development in Deaf Smith County include the Castro Trough located in Castro County and the Oldham-Harman and Arney positives located to the northwest in Randall County. Each of these features has a northwest trend and the features themselves and/or the boundaries between them may be fault controlled. Discussion presented at data evaluation meetings (Williams and Associates, Inc., 1985) indicate that while faults may not be traceable vertically from Paleozoic units to younger units, or to the surface, a disturbed zone or flexure associated with the fault may extend to the surface. Within Deaf Smith County both northwest and northeast trending faults appear to be present.

3 HYDROGEOLOGY

The depositional and structural history coupled with the results of hydrogeologic testing of some of the units within the Palo Duro Basin leads to some conclusions regarding the hydrogeologic properties of these units and the nature of groundwater flow within the basin. The post-Precambrian sequence in the Palo Duro Basin has been divided into three hydrostratigraphic units (HSUs) by some investigators. Division of the geologic section into HSUs is illustrated in figure 3. Discussion of a basis for this division is presented in Bassett and others (1981) and in Bair and others (1985).

It is recognized that definition of three hydrostratigraphic units in an area as hydrogeologically complex as the Palo Duro Basin constitutes an oversimplification of the basin hydrogeology. Currently, insufficient data exist to permit a more detailed subdivision of hydrostratigraphic units and related aquifers. Consequently discussion herein will be based on these three conceptualized hydrostratigraphic units. It must be emphasized that each HSU may very well contain several aquifers and aquitards and that at some point in time additional hydrostratigraphic units should be defined. We have commented on this problem in several reviews. We have pointed out also that different DOE sponsored studies have treated these units in different ways (Williams and Associates, Inc., 1986a).

HSU A includes units of the Triassic Dockum Group up to and including the Ogallala Formation and any overlying saturated sequence. HSU A contains fresh-water aquifers that constitute a primary source for irrigation and drinking water supplies. Most water is obtained from the Ogallala but in some areas permeable clastics of the Dockum Group are significant sources of water. Potentiometric data presented by Dutton and Simpkins (1985) indicate that the potentiometric surface of the Dockum aquifer is several hundred feet below the water table in the Ogallala Formation in Deaf Smith County. This relationship suggests that groundwater movement may be downward from the Ogallala Formation to the Dockum aquifer. Dockum potentiometric data indicate that the dominant flow direction is to the east, although the direction becomes northerly in Oldham County just north of the proposed disposal site. Water-level contours of the Ogallala aquifer indicate a southeasterly flow direction (fig. 5). Horizontal hydraulic conductivity values of 8.15 m/day have been reported for the Ogallala and 0.82 m/day for the Dockum (table 1).

HSU B consists of the thick sequence of middle and upper Permian shales, mudstones and evaporites. Very low permeability appears to predominate this unit. It is considered primarily to be an aquitard or perhaps an aquiclude at some locations. Bassett and others (1981) report a value of 8×10^{-8} m/day for the hydraulic conductivity of the main aquitard sequence (table 1). Considerable study has been done of the cycle-4 unit of the lower San Andres Formation because of interest in it as a disposal horizon. Values of permeability of the cycle-4 unit determined from Department of Energy hydrologic test wells are presented in table 2. However these studies have not included adequate field-scale measurements of hydrogeologic properties.

A potentiometric surface map has been generated for the San Andres Formation (fig. 6). It suggests that flow in the vicinity of the Deaf Smith site may be south to southeast. It also seems probable that because of head differences between aquifers of HSU A and brine aquifers of HSU C below HSU B that flow in HSU B has a strong downward component. Such a conclusion is supported by work of the Texas Bureau of Economic Geology (1982, p. 12) which reports that hydraulic head in the San Andres is greater than that in the underlying so-called Deep-Basin Brine Aquifer in Deaf Smith County.

One important characteristic of HSU B is the extensive facies variation which occurs both vertically and horizontally in many of the geologic units. Such facies changes produce corresponding changes in porosity and permeability and make prediction of hydrogeologic behavior of HSU B difficult.

The carbonate facies which immediately underlie the evaporite sequence of cycle-4 in the lower San Andres Formation is of particular hydrogeologic interest. Data presented in tables 1 and 2 indicate that the few tests performed on this dolomite have produced a range of horizontal hydraulic conductivity values. This unit is significant not only because of its stratigraphic position, but also because it appears to display consistent thickness and it is laterally extensive. Work presented by Texas Bureau of Economic Geology (1982) indicates that this carbonate unit extends further to the north than most other interbedded carbonates in the evaporite sequence. Ramondetta (1982) reports that these carbonate units do not pinch out but tend to combine into a single thick, porous, limestone in the Midland and Delaware basins to the south. Data presented by the Texas Bureau of Economic Geology (1982, p. 3) indicate that the effective porosity "tends to be greater and more widespread in the cycle-4 than in other cycles of the San Andres." Based on hydrologic tests on six hydrostratigraphic test wells, Dutton (1985, p. 136) reports the following conclusions regarding the cycle-4 carbonate unit:

> (1) fluid pressure ranges from about 975 to 1,362 psi (6.72 to 9.39 MPa), (2) fluid movement and discharge to a well can be

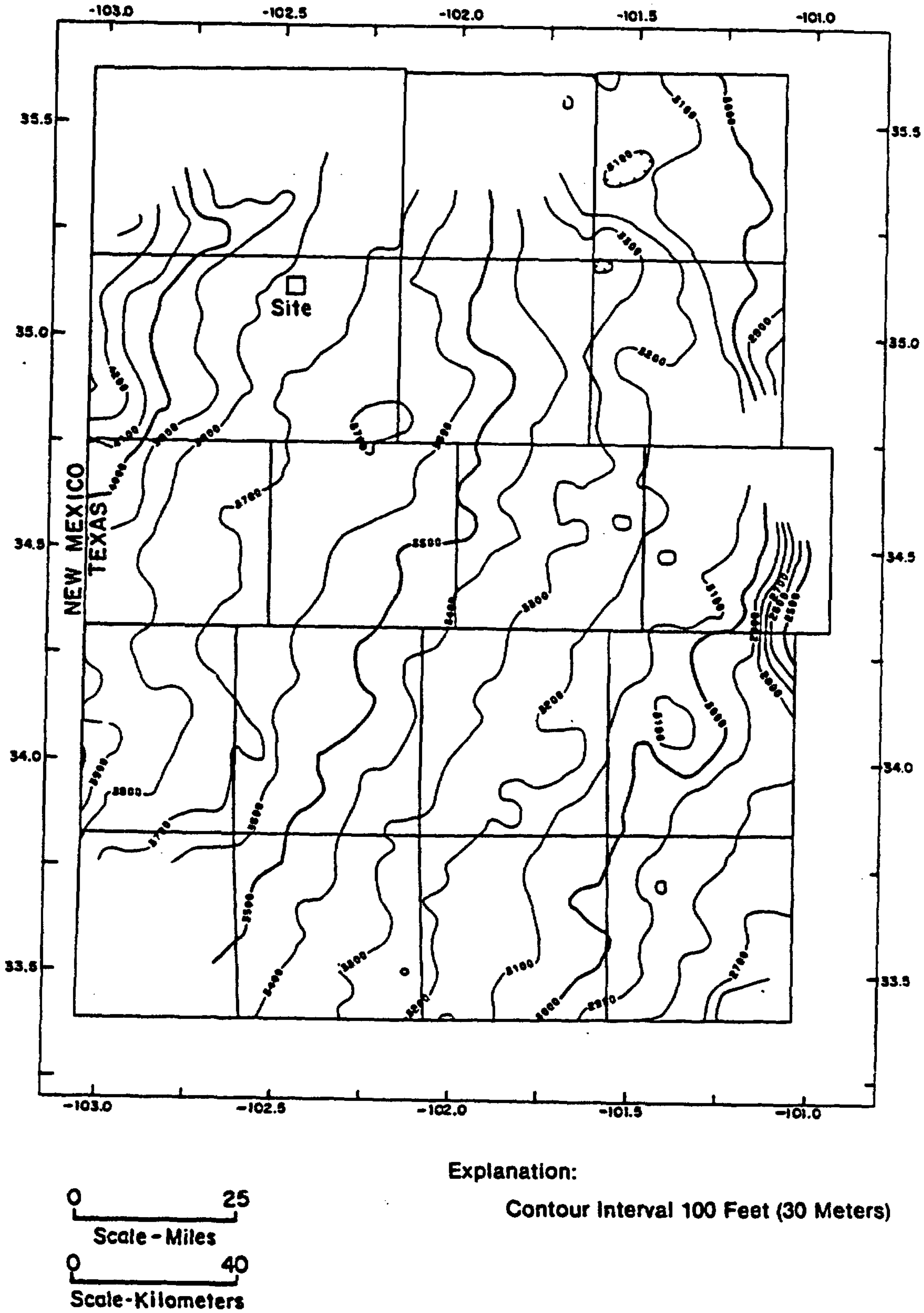


Figure 5. Water-level contour map of the Ogallala aquifer (1981), Palo Duro Basin, Texas (after Stone and Webster Engineering Corp., 1984).

Table 1. Hydraulic conductivity values of selected units, Palo Duro Basin, Texas.

Unit	Hydraulic Conductivity (m/day)	Remarks	Source
Ogallala	8.15		Simpkins and Fogg, 1982
Dockum	0.82		Simpkins and Fogg, 1982
Blaine	3.05		Simpkins and Fogg, 1982
San Andres Unit #4	3.05		Simpkins and Fogg, 1982
Flowerpot and Quartermaster	823		Simpkins and Fogg, 1982
Whitehorse	0.92		Simpkins and Fogg, 1982
Main Aquitard Sequence	8.15×10^{-8}		Bassett and others, 1981
San Andres Unit #4	0.4-0.5	Solution Zone in Sawyer #2	Dutton and others, 1985
Seven Rivers	0.16-0.3	Solution Zone in Mansfield #2	Dutton and others, 1985
Granite Wash	4×10^{-4} - 3×10^{-3}*	J. Friemel #1	Senger and others, 1984
Pennsylvanian Limestone	1×10^{-3}*	J. Friemel #1	Senger and others, 1984
Wolfcamp Limestone	1×10^{-5}*	J. Friemel #1	Senger and others, 1984
Wolfcamp Dolomite	2×10^{-7} - 2×10^{-4}*	Sawyer #1	Conti and others, 1985
	2×10^{-5}*	Mansfield #1	Conti and others, 1985
	8×10^{-7} - 2×10^{-2}*	Zeeck #1	Conti and others, 1985
Wolfcamp Limestone	1×10^{-7} - 3×10^{-5}*	Sawyer #1	Conti and others, 1985
	9×10^{-6} - 1×10^{-3}*	Mansfield #1	Conti and others, 1985
	5×10^{-7} - 6×10^{-5}*	Zeeck #1	Conti and others, 1985
Wolfcamp Sandstone	2×10^{-6} - 2×10^{-3}*	Sawyer #1	Conti and others, 1985
	7×10^{-7} - 9×10^{-6}*	Zeeck #1	Conti and others, 1985

* Values were converted from permeabilities using conversion of 1 md = a.2×10^{-5} m/day as described by Wirojanagud and others (1984).

Table 2. Permeability values obtained from tests in Department of Energy hydrologic test wells, Palo Duro Basin, Texas. (See figure 4 for well location.) (After U.S. Dept. of Energy, 1984).

Well/County	Test Type	Depth (ft)	Formation/Lithology	Permeability (md)
Mansfield/Oldham	DST	4800-4996	Wolfcamp/limestone (HSU C)	26.6
	DST	4812-4840	Wolfcamp/limestone (HSU C)	11.6
	DST	6612-6640	Pennsylvanian/- (HSU C)	8.8
	Pump Test	4514-4638	Wolfcamp/limestone (HSU C)	0.5
	Pump Test	4818-4890	Wolfcamp/limestone (HSU C)	4.3
Sawyer/Donley	DST	2950-3123	Wolfcamp/dolomite (HSU C)	0.2
	Pump Test	3172-3189	Wolfcamp/- (HSU C)	6.1
	Pump Test	4250-4342	Pennsylvanian/granite wash (HSU C)	2.7
	Pump Test	4450-4535	Mississippian/limestone (HSU C)	5.4
	Pump Test	4604-4640	Ellenberger/- (HSU C)	0.3
J. Friemel/Deaf Smith	DST	5630-5909	Wolfcamp/dolomite (HSU C)	1.0
	Pump Test	5809-5926	Wolfcamp/carbonate (HSU C)	1.0
	Pump Test	7300-7329	Pennsylvanian/carbonate (HSU C)	100.0
	Pump Test	7707-7734	Pennsylvanian/granite wash (HSU C)	500.0
	Pump Test	7590-7904	Pennsylvanian/granite wash (HSU C)	10.0
	Pump Test	8040-8050	Pennsylvanian/granite wash (HSU C)	150.0
	Pump Test	8122-8137	Pennsylvanian/granite wash (HSU C)	150.0
	Pump Test	8168-8204	Pennsylvanian/granite wash (HSU C)	50.0
Zeeck/Swisher	DST	1927-2972	Lower San Andres 4/carbonate (HSU B)	0.3
	DST	5365-5542	Wolfcamp/carbonate (HSU C)	6.8
	DST	7146-7225	Pennsylvanian/limestone (HSU C)	2.8
	Pump Test	5470-5550	Wolfcamp/limestone (HSU C)	7.0, 8.0
	Pump Test	603-5640	Wolfcamp/limestone (HSU C)	0.1, 0.03
	Pump Test	7140-7230	Wolfcamp/carbonate (HSU C)	8.8, 8.9
Detten/Deaf Smith	DST	2749-2839	Lower San Andres 4/carbonate (HSU B)	0.2
G. Friemel/Deaf Smith	DST	2600-2710	Lower San Andres 4/carbonate (HSU B)	0.1
Harmon/Swisher	DST	2840-2906	Lower San Andres 4/limestone (HSU B)	0.01
	DST	2830-3050	Lower San Andres 4/carbonate (HSU B)	0.2
Holtzclaw/Randall	DST	1718-1764	Queen-Grayburg/siltstone (HSU B)	1.56

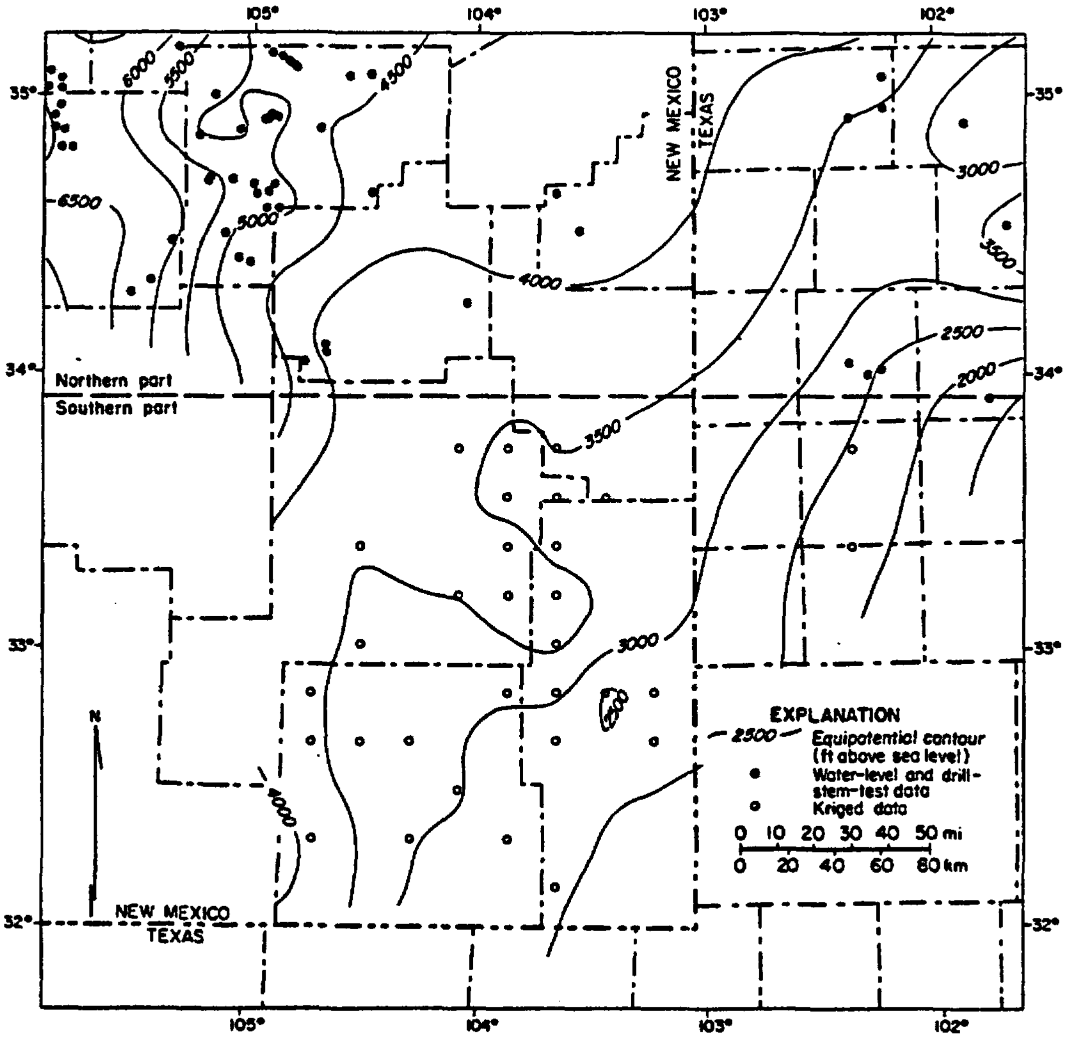


Figure 6. Potentiometric surface map of the San Andres Formation, Palo Duro Basin, Texas (after Orr, 1983).

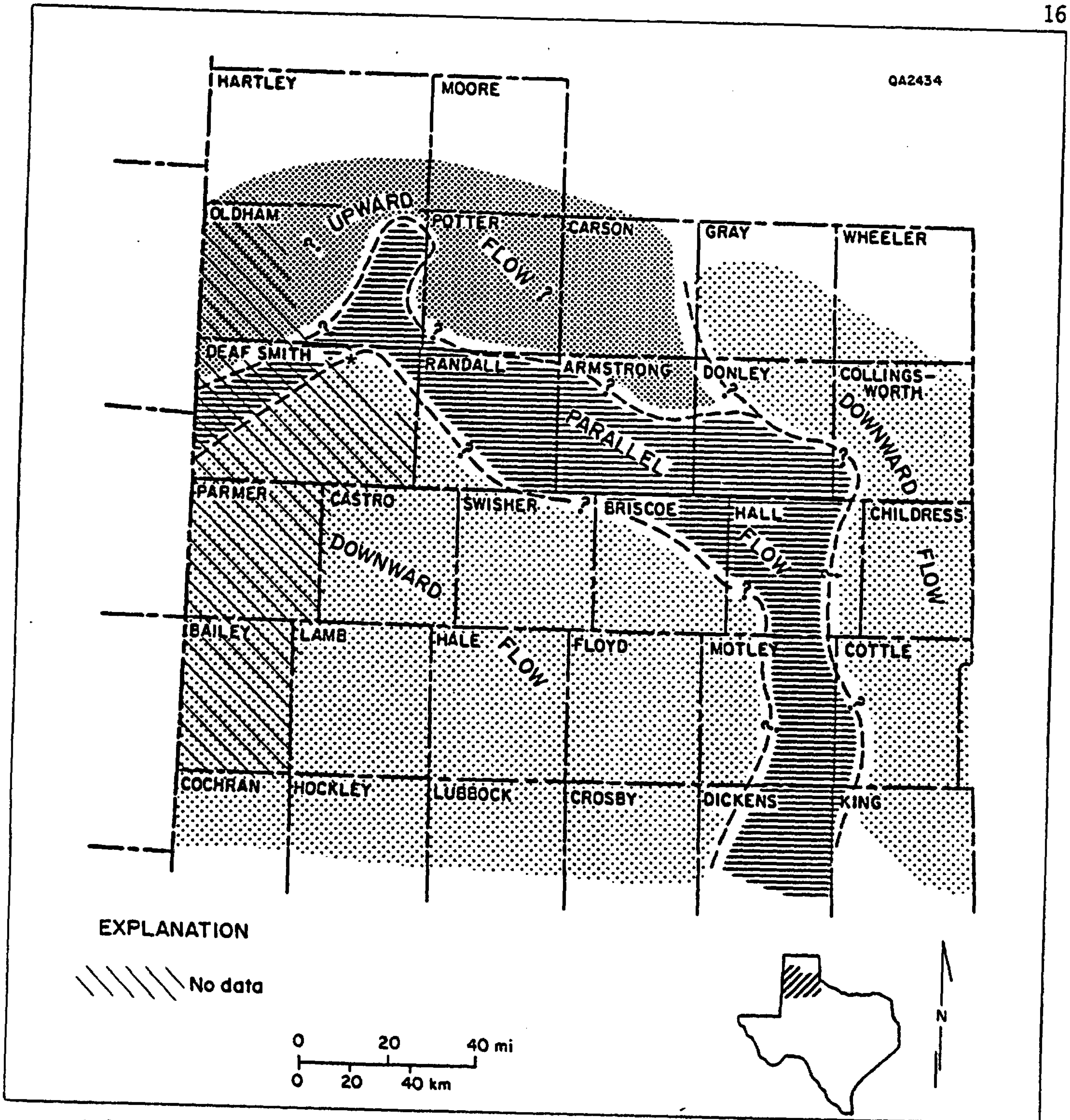
induced by pressure drawdown, (3) fluid movement and discharge can be sustained at low rates for at least a year and probably longer, and (4) the cycle-4 carbonate is hydraulically extensive and, once fluid production is stopped, fluid pressure can return to initial conditions.

All of this information indicates that zones with high enough hydraulic conductivity to be considered aquifers do exist within HSU B and even within the lower San Andres Formation.

HSU C includes the Pennsylvanian and lower Permian (Wolfcamp) sequence. This sequence is portrayed by some investigators to consist primarily of carbonates and arkosic sands; it is believed to be much more permeable than most of HSU B. But as noted earlier shale also is a major component at some locations. Evaluation of hydraulic conductivity values presented in table 1 produces several questions. Permeability values presented in table 2 clearly indicate higher values for HSU C than for most of HSU B. A tendency has evolved to describe a single brine aquifer known as the Deep-Basin Brine Aquifer in HSU C because of hypothesized geologic and hydrogeologic similarities among the stratigraphic units of the Pennsylvanian and lower Permian. While this "lumping" is convenient, it is also somewhat inconsistent with the data base because at least one brine aquifer is associated with each of the lower and upper Pennsylvanian sequences and with the lower Permian sequence.

Considerable investigation of pressure conditions within HSU C has been attempted. Evaluations of pressure vs depth relationships presented by Bair and others (1985), Orr and others (1985), and Orr and Kreitler (1985) indicate that "underpressured" conditions exist within HSU C throughout most of the Palo Duro Basin. Reviews and discussions of these papers are presented in Williams and Associates, Inc., 1985b, 1986a, and 1986b. Work presented by Orr and others (1985) indicates that within the Deep-Basin Brine Aquifer an area of hydrostatic pressure conditions is present beneath the zone of known salt dissolution within the basin. Overpressured conditions in the Deep-Basin Brine Aquifer may exist in the northwest part of the basin (fig. 7). Potentiometric data indicate that everywhere within the basin equivalent fresh-water heads of HSU C are lower than those of HSU A although this head difference decreases to the southeast. Richter (1985) reports that to the east in the Hardeman Basin (fig. 1) equivalent fresh-water heads of the Deep-Basin Brine Aquifer are higher than land surface and that in some areas salt water heads may also be above land surface.

In the vicinity of Deaf Smith County underpressured conditions appear to exist in HSU C although, according to Orr and others (1985), the proposed site appears to be very close to the zone of transition between the area of underpressured conditions and that of hydrostatic pressure conditions to the north (fig. 7). Potentiometric surface maps prepared of HSU C (fig. 8) indicate that flow in brine aquifers of the Wolfcamp Series, in the vicinity of the Deaf Smith County site, is northeasterly. Potentiometric surfaces



* Approximate location of Deaf Smith County site.

Figure 7. Zones of inferred flow direction within the Deep-Basin Brine aquifer, Palo Duro Basin, Texas (after Orr and others, 1985).

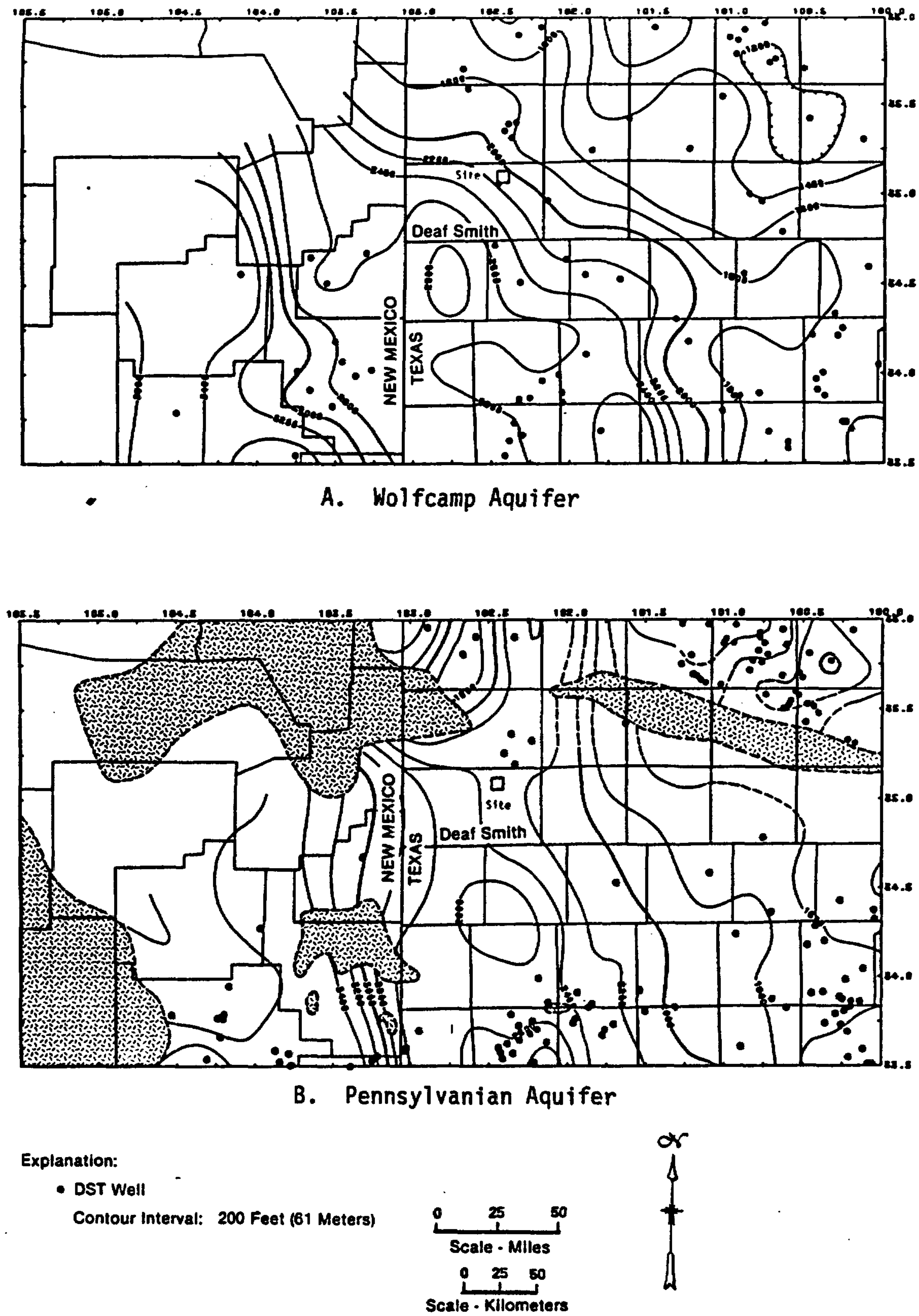


Figure 8. Potentiometric surface maps of Wolfcamp and Pennsylvanian aquifers, Palo Duro Basin, Texas and New Mexico (after Bair and others, 1985).

presented in figure 8 indicate that considerable difference exists between the lower Permian brine aquifer and brine aquifers associated with the Pennsylvanian sequence. Flow in the deeper portions of HSU C appears to be more easterly than flow in the Wolfcamp Series.

4 CONCEPTUAL MODELS

Insufficient data exist to characterize groundwater flow reliably in any rocks other than the Ogallala Formation within the Palo Duro Basin. However some generalizations regarding regional groundwater flow for the Palo Duro Basin and related flow conditions in the area of the Deaf Smith County site can be made. These generalizations are based on current knowledge of geology and hydrogeologic parameters; they represent a reasonable set of possibilities based on this existing information.

4.1 Basin-Wide Models

In earlier work Williams and Associates, Inc. (1984) described a generalized three-layer system as a basis for proposed conceptual models. The three-layer conceptualization is maintained in this report despite several factors which indicate this is an oversimplification of actual hydrogeologic conditions. First, ample evidence exists to indicate that the rocks below the salt sequence do not constitute a single aquifer. Second, previous discussion of the cycle-4 dolomite sequence suggests that it can not be considered an aquitard. Finally, water bearing units associated with the Ogallala Formation and Dockum Group are at least two separate and distinct aquifers within HSU A. The three-layer system is maintained in this report because, as yet, adequate data do not exist basin-wide to permit further subdivision.

Potentiometric maps of HSUs A, B, and C suggest that flow is generally west to east or northeast. Work by Richter (1985) indicates that major discharge from HSU C may take place in the Hardeman Basin east of the Palo Duro Basin. Data presented by Bassett and Bentley (1983) and Bair and others (1985) indicate that significant recharge to HSU C may occur on the western edge of the basin in the vicinity of the Pecos River in New Mexico. Flow in HSU C is presumed to be generally downward and lateral toward the area of discharge where flow becomes vertically upward. Upward flow within the unit may occur in the northwest part of the basin also (fig. 7).

Recharge to and discharge from HSU A is more localized with natural recharge occurring from precipitation and natural discharge from springs along the Caprock Escarpment. Most discharge from the Ogallala Formation is through pumpage. Water table contours presented in figure 5 indicate a flow direction from west to east with flow being directed to the southeast in the vicinity of the Deaf Smith County site.

Conditions in HSU B remain largely unknown. HSU B is saturated and some units such as the carbonate at the base of cycle-4 of the lower San Andres could be considered aquifers. Natural recharge and discharge must be occurring; however, the mechanism for and location of recharge and discharge for this HSU are understood poorly. Discussion by Texas Bureau of Economic Geology (1982) suggests that some recharge is occurring to HSU B in the west in the vicinity of the Pecos River Valley. Leakage from overlying and/or underlying units probably provides additional recharge. Discharge for HSU B also is defined poorly, but it does appear that some discharge occurs east of the Caprock Escarpment (Texas Bureau of Economic Geology, 1982). Leakage into surrounding hydrostratigraphic units may occur also.

Considerable discussion was presented concerning regional conceptual models in an earlier report by Williams and Associates, Inc. (1984). In this report four basic conceptual model variations were proposed. During the time since that report was prepared little additional information has been collected that would indicate that any one of the variations is no longer applicable, nor to require the development of other conceptualizations. For this reason only a brief review of the regional conceptual models is presented here.

Figure 9 presents schematic drawings that illustrate each of the four possible conceptual models. They are:

1. A three-layer model in which HSU B is an aquiclude. In this model recharge to HSU C occurs in the western highlands and flow is roughly parallel to unit boundaries. No leakage occurs into or out of HSU B.

2. A three-layer model in which virtually all recharge to HSU C arrives via leakage through HSU B. This conceptualization is similar to a model described by Bassett and Bentley (1983) and, as discussed by Williams and Associates, Inc. (1984), is suggested by recent studies by Bredehoeft and others (1983). This work suggests that actual vertical conductivity of a confining unit may be significantly higher than small scale hydrologic tests indicate.

3. A three-layer model in which recharge to HSU C occurs both at the western edge of the basin and from leakage through HSU B. In addition, the possibility of dissolution of the evaporite sequence and flow returning to HSU A is included. Such dissolution seems a possibility in view of locally anomalous water quality values present in aquifers of the Dockum Group (Stone and Webster Engineering Corp., 1983b).

4. A three-layer model in which recharge to HSU C occurs both by leakage through HSU B and directly at the western basin margin. This model also reflects the heterogeneity of HSU B and the fact that continuous zones of sufficient permeability to transmit flow laterally exist within HSU B. An example of such a unit is the cycle-4 carbonate of the lower San Andres Formation.

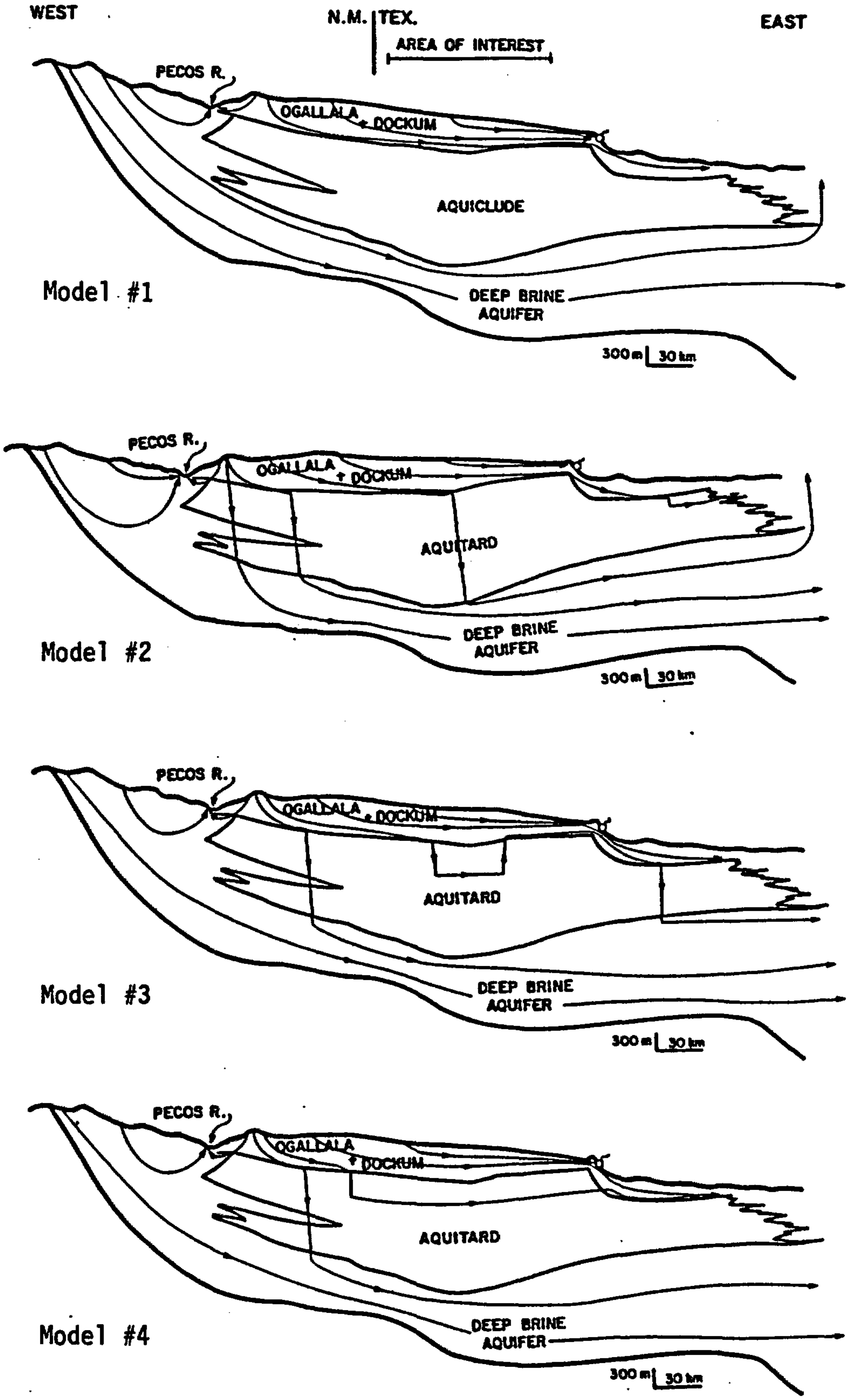


Figure 9. Generalized conceptual models of groundwater flow, Palo Duro Basin, Texas and New Mexico (after Williams and Associates, Inc., 1984).

Each of these four conceptual models is viable because sufficient data do not yet exist to eliminate one or more of them. Several lines of existing evidence do suggest that model #1 may be the least probable. First, data presented by Hovorka (1985) indicate that although some of the evaporite units are laterally extensive, they are thin and are interbedded with a variety of clastic and non-clastic deposits. The variability of the middle and upper Permian sequence suggests that it may not be an effective aquiclude. Second, data presented by Fisher and Kreitler (1985) reveal that water samples from HSU C tend not to be in isotopic equilibrium with respect to oxygen and hydrogen. This disequilibrium led Fisher and Kreitler (1985, p. 172) to conclude that the sampled brine is a mixture "of older fluid which has traveled along a regional flow path from the principal recharge zone and a younger water recharged from a more local source." These hydrochemical data suggest that leakage through the evaporite sequence is a significant source of recharge to HSU C. Finally, discussions regarding structural deformation and faulting presented earlier suggest that faulting and related disruption probably exist in HSU B. Vertical discontinuities associated with this faulting probably permit vertical movement of groundwater through HSU B even if the depositional sequence proved to be completely impermeable.

Currently the most reasonable conceptualization of basin-wide groundwater flow is one in which local to intermediate flow systems are operating in HSU A with recharge to these local systems occurring from precipitation. Recharge is most significant in upland areas near the western margin of the basin. Flow direction is predominantly to the east and southeast. Discharge from HSU A occurs naturally along the Caprock Escarpment and at other locations at which the aquifers are dissected by erosion. Significant discharge from HSU A also occurs in the form of pumpage throughout the entire Palo Duro Basin area. Discharge also occurs in the form of leakage into HSU B.

The flow system associated with HSUs B and C is more regional with substantial recharge occurring in the western highlands in the vicinity of the Pecos River. Recharge also occurs in the form of leakage from HSU A into HSU B and in many areas from HSU B into HSU C. Flow direction is to the east and northeast. Discharge from the system in the central and southern parts of the basin is in the east where fluid potential gradients indicate that upward flow is possible. In the northern part of the Palo Duro Basin regional flow may move into the arkosic sands (granite wash) associated with the Amarillo Uplift; the nature of discharge from this part of the system is unknown.

4.2 Deaf Smith County

Currently, the understanding of groundwater flow within the Palo Duro Basin is limited by lack of data and by the complex nature of the large flow system. It is possible to define, in very general terms, probable recharge and discharge areas and related flow directions on a basin-wide scale;

however, doing so for specific areas within the basin is much more tenuous. Nevertheless, data do exist which permit making some general observations regarding groundwater flow in the vicinity of the contemplated Deaf Smith County site. Most of these data come from either the extrapolation from regional trends or from hydrogeologic test wells drilled in the vicinity of the site. To date ten such wells have been drilled within the Palo Duro Basin; their locations are shown in figure 4. Perhaps the J. Friemel #1 well is the most significant of these wells with respect to the Deaf Smith County site because of its close proximity to the site. This well is located approximately three miles to the south of the contemplated site area.

Potentiometric data for the Ogallala aquifer (Stone and Webster Engineering Corp., 1984) and for the Dockum Group (Dutton and Simpkins, 1985) indicate that flow in HSU A is east-southeast near the contemplated site. Relatively little is known about aquifers associated with the Dockum Group although, as stated earlier, hydraulic heads are believed to be lower in Dockum aquifers than in the Ogallala aquifer. Thus if flow occurs between these two units it is presumed to be downward.

Data from HSU B in the vicinity of the contemplated site are sparse but hydrogeologic tests run in the J. Friemel #1 well provide some information. These tests indicate that pressures are less than hydrostatic in the unit which implies that vertical flow in the vicinity of the site probably is downward. These data must be viewed with caution because of the short period of time allowed for pressure-water level equilibration in the test intervals. The assumed static pressures or water levels may differ significantly from the true values which are still unknown. Measured values of vertical permeability of HSU B are nonexistent; however, values of 2.0×10^{-4} md were used by Kreitler and others (19884) and Senger and Fogg (1984) in computer simulations of the system.

Hydrochemical data presented by Kreitler and others (1984) also support the idea of downward vertical flow through HSU B. The absence of isotopic equilibrium of water samples collected from HSU C suggests that a relatively recent source of meteoric water has mixed with older water in HSU C. Calculations presented by Fisher and Kreitler (1985, p. 172) indicate that assuming

> the basinal fluid had reached isotopic equilibrium with dolomite, the zone 6 [Pennsylvanian carbonate] J. Friemel brine consists of approximately 50% younger, isotopically unequilibrated water. If some enrichment of the younger water occurred prior to mixing with deep basinal fluids, the estimated contribution of younger fluid to the deep-basin brine aquifer would be greater. Vertical recharge through the overlying Evaporite Aquitard should leave a chemical signature on the waters in the uppermost permeable zone of the Deep-Basin Brine Aquifer; this signature is seen in the high Na:Cl ratios of Wolfcamp fluids. The depleted oxygen isotopic compositions indicate that although the J. Friemel and

> Mansfield well sites are not major recharge areas, an important fraction of the fluid now present at depths as great as 8,100 ft (2470 m) and temperatures as high as 55 C has a significant meteoric water signature, and has not experienced in situ conditions long enough for isotopic equilibration to have occurred.

Models presented by Kreitler and others (1984, p. 8) support this conclusion; computed fluxes indicate that "leakage through the Evaporite Aquitard accounts for 50 percent of the ground water flowing through the Wolfcamp aquifer and 33 percent of the flow through the whole Deep-Basin Brine aquifer."

Kreitler and others (1984, p. 16) also report that brines sampled from the Mansfield well have the largest component of meteoric water; those from the J. Friemel #1 well have the second largest. As can be seen on figure 4, these two wells are on either side of the proposed site area. These isotopic data suggest that water in HSU C underlying the contemplated site area has a significant content of meteoric water and that substantial downward vertical leakage through he aquitard may occur in the area.

Comparison of these data with results of pressure vs depth evaluations of Orr and others (1985) illustrated in figure 7 reveal some potential interpretational inconsistencies. Isotopic data from the Mansfield #1 well apparently have the the highest content of meteoric water of all test wells sampled. Following the explanation proposed by Kreitler and others (1984) greater amounts of downward vertical leakage are taking place at or near the location of this well as evidenced by this high meteoric water content. Examination of figure 7 indicates that the Mansfield #1 well is located in or near the proposed zone of upward flow within the Deep-Basin Brine Aquifer. If upward flow is indeed occurring in this aquifer in the vicinity of the Mansfield #1 well it seems possible that water moving upward in the brine aquifer would tend to influence the isotopic concentrations in favor of older water.

Knauth and Hubbard (1984) have proposed an alternative explanation for the apparent isotopic disequilibrium of the brines. They suggest that meteoric water may be reaching HSU C by moving vertically through the permeable arkosic sand (granite wash) deposits associated with the Bravo Dome (Oldham Nose) and Amarillo Uplift and moving laterally into the carbonate aquifers of HSUs B and C. This idea may explain why the Mansfield #1 well has the high meteoric water content as it is located more closely to the coarse-grained deposits than any of the other hydrologic test wells. This hypothesis implies a potentially more rapid flow path for recharge to the Deep-Basin Brine Aquifer and permeable zones within HSU B than does direct leakage through fine-grained units of HSU B. Kreitler and others (1984) suggest that increased fracturing may be the cause of high meteoric water content in the Mansfield #1 well. This hypothesis also suggests a more direct flow path through HSU B.

In addition to vertical flow in HSU B existing evidence also indicates that horizontal flow also may occur. Permeabilities of carbonate rocks in HSU B are high enough to permit continued pumping over long periods of time; therefore, the units must be capable of transmitting water over significant lateral distances. In some cases these rocks extend over large areal distances. Consequently they constitute pathways for lateral flow of groundwater over long distances.

HSU C contains at least two separate aquifers; one is associated with lower Permian (Wolfcamp Series) units and another is associated with the Pennsylvanian sequence. As mentioned previously herein, these units often are combined and referred to as the Deep-Basin Brine Aquifer. Considerable study has been directed toward measuring pressure conditions of the Deep-Basin Brine Aquifer. Drill stem test (DST) data have been evaluated by a number of workers including Orr and Senger (1984), Bair and others (1985), Orr and others (1985), and Orr and Kreitler (1985). These efforts have produced some limited information regarding pressure conditions and groundwater flow in the aquifer. Data presented by Orr and others (1985) (fig. 7) indicate that downward flow within the Deep-Basin Brine Aquifer occurs in a large part of the southwest and central parts of the Palo Duro Basin, but becomes horizontal along an arcuate band roughly coincident with the zone of known salt dissolution in the basin. The transition between downward and horizontal flow appears to occur in the vicinity of the Deaf Smith County site; horizontal flow conditions apparently exist downgradient from the contemplated site with flow toward the northeast.

Analysis of table 2 reveals that Pennsylvanian carbonate and granite wash rocks tested in the J. Friemel #1 well have the highest permeabilities of all test results presented. These data suggest that flow in HSU C has a greater lateral component than flow in HSU B. It seems quite probable that downgradient toward the Amarillo Uplift permeabilities of equivalent zones may be significantly higher as facies become more coarse grained.

On the basis of these observations a few general conclusions about groundwater flow in the vicinity of the contemplated Deaf Smith County site can be drawn. It seems probable that leakage through HSU B is occurring and that either the amount of leakage or proximity to an area of leakage increases north of the site. Water that reaches the lower San Andres sequence may either continue downward or move laterally through zones of higher permeability associated with carbonate interbeds. Actual points of recharge of this water are unknown but some recharge in close proximity to the site area may occur. The presence of faults or related tectonic disturbed zones may enhance vertical movement through HSU B.

Modeling results presented by Senger (1985) indicate that fracture zones in HSU B either in the central Palo Duro Basin or in the vicinity of the Caprock Escarpment could have significant effect on basin hydrodynamics. Senger (p. 30) concludes that the effects of fracture zones through HSU B in the center of the basin may produce head changes in HSU C that may go undetected because of the limited amount of head data currently available.

Senger (1985, p. 5) also reports that fractures in the salt units "occur almost always in thin mudstone, siltstone, and anhydrite layers." These fractures are most often filled with fibrous halite. The presence of halite filled fractures suggests the possibility of temporal variations in hydraulic conductivity in the aquitard. Periods of time may exist when vertical hydraulic conductivity is significantly increased if fractures are suddenly generated by tectonic or solution activity. Characterization of the hydrologic properties of HSU B may have to involve consideration of such temporal variation in hydrologic parameters (Williams and Associates, Inc., 1986c).

Evidence suggests that movement of water both laterally and vertically through HSU B is reasonable. The amount of the water is unknown but it is possible that leakage through HSU B is widespread and may account for a significant part of recharge to HSU C. Areas of discharge also are unknown but they presumably are to the northeast where both HSUs B and C grade into coarser, more permeable arkosic sand-granite wash deposits.

5 LIMITATIONS AND DATA NEEDS

Major uncertainties exist despite progress which has been made toward defining the groundwater flow system in the Palo Duro Basin. Most of these uncertainties involve either the amount of or reliability of hydrogeologic data necessary for accurate definition of conceptual models. In initial attempts to define a general basin-wide conceptual model, these limitations are perhaps less critical because the overall effect of a data gap or an inaccurate value may be minor. As greater detail becomes desirable, however, the importance of each parameter value becomes greater.

Problems still exist with respect to potentiometric data and with potentiometric surfaces produced for HSU C (Williams and Associates, Inc., 1986a, 1986b). Data available for generation of piezometric surfaces consist almost entirely of DST values from oil exploration wells. These data are highly variable in quality and questions exist regarding their accuracy and validity. Numerous attempts have been made to improve the data base through various culling procedures and to generate potentiometric surface maps for the Wolfcamp Series aquifer, the Pennsylvanian aquifer and for the Deep-Basin Brine Aquifer. Some of these culling procedures appear to be quite subjective.

Two potentiometric surface maps of the Wolfcamp Series brine aquifers are presented in this report. Figure 8A is a map produced by Bair and others (1985); figure 10 is a similar map produced by Smith and others (1983). Both of these maps were prepared using statistical procedures to generate control points. As might be expected these maps are considerably different than earlier maps produced by Bentley (1981). However, comparison of these two figures also illustrates that considerable variation exists between

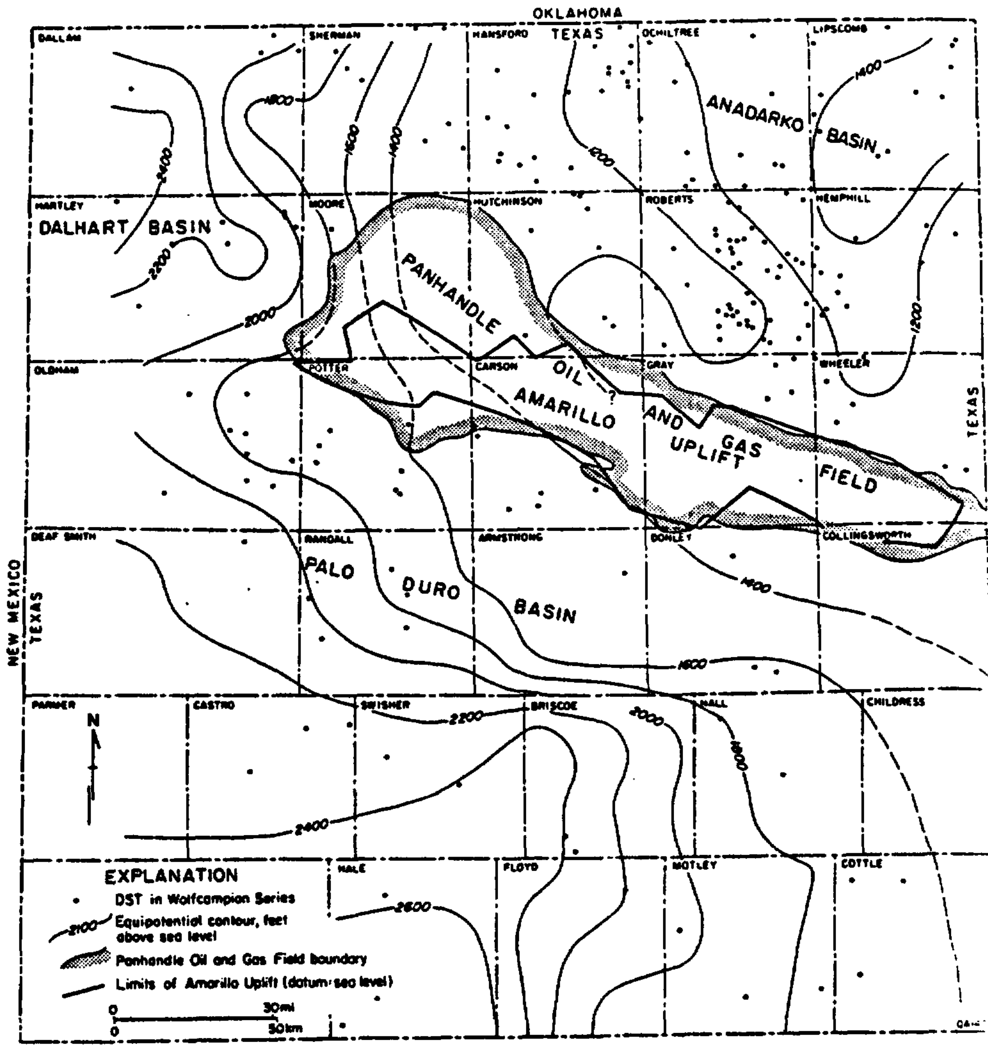


Figure 10. Potentiometric surface map of Wolfcamp brine aquifer, Palo Duro Basin, Texas (after Smith and others, 1983).

these two later versions as well. As long as significant uncertainty regarding fluid potential distribution exists, refinement of conceptual models will not be possible.

The problems with potentiometric surfaces are complicated by the combining of data from discrete aquifers in the Pennsylvanian and lower Permian sequence into the single Deep-Basin Brine Aquifer. The potentiometric surface defined by Smith (1985) for the lower Pennsylvanian aquifer is considerably different from that constructed for the entire Pennsylvanian by Bair and others (1985). It is also different from potentiometric surface maps constructed for the Wolfcamp aquifer by either Bair and others (1985) or Smith and others (1983). The tendency to treat these as a single aquifer and to develop a conceptual model based on this assumption may represent a trade of accuracy for simplicity and ultimately produce problems in later characterization phases.

Williams and Associates, Inc. (1984, p. 18) has indicated four areas of specific data needs. These needs include 1) additional potentiometric data from northwest New Mexico and for near-site areas, 2) better areal and vertical distribution of high-quality potentiometric data, 3) additional hydraulic conductivity data and 4) additional hydrochemical data. Each of these needs still exists despite efforts over the last two years to meet some of these needs. As attempts are made to produce more refined and detailed conceptual models, the importance of these data needs increases.

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Hanford

(Continued from page 1)

A Berkeley scientist who has followed the national site-selection process closely said Hanford had the edge in political acceptance, but that may have changed.

"Six months ago, Hanford was No. 1, Nevada was second and Deaf Smith County in Texas was third," he said. "The general feeling now is that Hanford is not a shoo-in any more.

"A lot of (Basalt Waste Isolation) Project managers at Hanford are starting to look for other jobs."

The Hanford radiation releases that contaminated parts of Eastern Washington and Eastern Oregon from the 1940s through the '60s were kept secret until February, when 19,000 pages of previously classified government documents were released.

They revealed 1.1 million curies of radioactive iodine and hundreds of thousands of curies of other radioactive elements were released into the air, water and soil.

At a Nuclear Waste Board workshop Wednesday in Seattle, where Eschels heard comments on the effects of a Hanford repository, people said they couldn't trust Energy Department reassurances that the project wouldn't further contaminate the Northwest.

A similar workshop will be at 7 p.m. Tuesday at Spokane City Hall.

If the Energy Department follows results of its own studies, Hanford will not make the finalist list on technical grounds, Eschels said.

"There are too many questions about ground-water travel and other safety issues," he said. "But we recognize that there are other non-technical reasons which USDOE might use to put Hanford in the top three."

The federal agency still might include Hanford because it owns the land and considers the Tri-Cities a friendly community, Eschels said.

The repository, scheduled to open in 1998, will hold at least half of the nation's most deadly wastes from nuclear reactors — wastes that must be isolated from the environment for more than 10,000 years.

In addition to Hanford's basalts, other top contenders include volcanic rock at the Nevada Test Site and a salt bed in Texas.

Salt domes in Louisiana and Mississippi also are under consideration. In all, USDOE has nine sites to choose from.

A specific date in May has not been set for announcement of the three repository finalists. On the day, top Energy Department officials will telephone governors in the affected states, hold a congressional briefing and call a national news conference to reveal the choices.

As the selection date nears, rumors are rampant about which three sites will be finalists, said Rep. Nelson, a former plutonium fuels researcher with Battelle's Pacific Northwest Laboratories.

He said the latest rumored scenario is that the Energy Department, because of technical problems with the site and growing political opposition, might drop Hanford and substitute a salt dome in Louisiana or Mississippi.

"If Hanford were to drop out, they could justify the salt sites as another diverse geological environment because they are salt domes instead of salt beds," Nelson said.

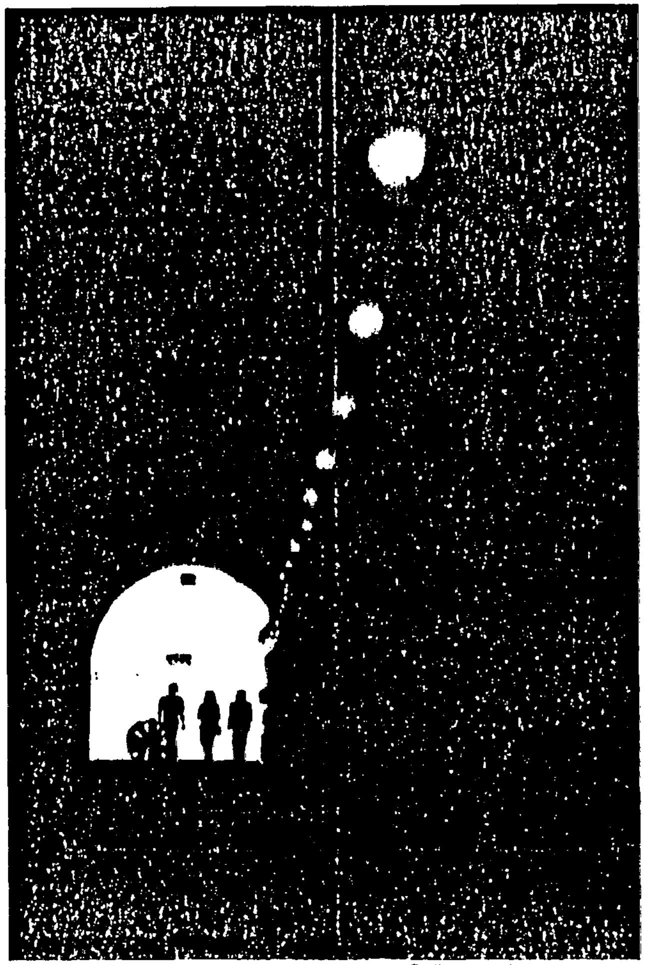
The Nuclear Waste Policy Act of 1982 requires the Energy Department to study potential sites in three kinds of rock. The three sites will be studied intensively for five years before a final choice is made.

The Berkeley scientist said the rumored new lineup is Nevada, the Texas site (which he said will be studied but not picked because of political opposition) and a salt dome site, probably in Mississippi.

Energy Department officials are keeping their decision a closely guarded secret, said Don Provost, performance assessment manager for the state Office of High-Level Nuclear Waste Management.

"What they are doing is known to very few people," Provost said. "They are keeping it within the family of key headquarters personnel."

He said a National Academy of Sciences critique of the Energy Department's methods of site selection, requested by Gardner last fall and released April 10, may change the rankings enough so that Hanford drops out.



Staff photo by STEVE THOMPSON

Rockwell Hanford is testing basalt rock in Gable Mountain.

In comments in March 1985 on the Hanford draft environment assessment, Washington's Nuclear Waste Board said the Energy Department had a "prematurely optimistic" view of Hanford's suitability.

The board suggested that Hanford would drop in the ranking process if the Energy Department honestly evaluated its technical flaws.

But the reports of radiation contamination from past Hanford plutonium production have hurt Hanford's prospects, Provost said.

"I think the recent bad publicity on Hanford has had a huge effect," he said. "It has generated a lot of discussion in Washington, D.C."

In the Tri-Cities, where new nuclear projects generally are lobbied for and greeted with enthusiasm, there is ambivalence about the repository.

Although site characterization could bring up to $1 billion to the Tri-Cities for additional Hanford studies, Richland Mayor John Poynor said the jobs issue is secondary in this case.

"If this isn't the right site to characterize, then the people here aren't going to support it just for the jobs," Poynor said.

At state hearings last year, the Tri-Cities Industrial Development Council said it would neither endorse nor oppose the project, but would wait for release of a final environmental assessment this spring.

The environmental documents will be released when the three site finalists are announced.

"If it's not safe, we're not going to be for it," TRIDEC executive director Sam Volpentest said.

Volpentest, who has lobbied for most of Hanford's nuclear projects, said recent newspaper stories about the large radiation releases have hurt the Tri-Cities' image, and that upcoming congressional hearings on the secret Hanford emissions may have the same effect.

"Due to the WPPSS (Washington Public Power Supply System) disaster, it's never been tops, and we've been trying to build a better image for our area," he said.

Volpentest said the big radiation releases are "history" and shouldn't be linked to the repository issue.

Public interest groups, including the Washington, D.C.-based Environmental Policy Institute, aren't sure the Energy Department will let go of Hanford even if it is not geologically suitable.

They noted that Hanford is the site the department favored, and studied for seven years, before Congress passed the Nuclear Waste Policy Act. But they also say the recent Hanford revelations could have hurt Hanford's prospects.

"The Nuclear Waste Policy Act is perceived by the Energy Department as a gauntlet which they must run through," said Bob Alvarez, director of EPI's radiation information program.

"The object is to go through the gauntlet while being ambushed by states and citizens, while trying to hold on to as many balls as they can," Alvarez said. "The balls politically easiest to hold on to will be the sites they pick, regardless of their scientific merits.

"Given the steady erosion of public confidence in the Energy Department in Washington and Oregon, the Hanford ball could slip out of USDOE's hands. But it's still too early to say whether that's going to happen."

Alvarez concurs with Washington state officials that the technical information on Hanford "clearly puts it at the bottom of the list."

Factors working in Hanford's favor include the fact that the Energy Department already owns the site and has "irretrievably contaminated it to such an extent that they believe they can build a repository there," Alvarez said.

"The joker in the deck is whether the people of Washington will accept this," he said. "I think USDOE has miscalculated the degree of opposition to this project in Eastern Washington."

Eschels said that even if Hanford becomes a finalist, the emerging public record of past radiation contamination will play an important role in a state decision on issuing a notice of disapproval.

That move would come in 1991, when site characterization is finished and the president chooses a site. Under terms of the Nuclear Waste Policy Act, if the state files such a notice, it takes a majority vote of Congress to overrule the disapproval.

"The past Hanford contamination could serve as a major argument for Washington to reject the repository project," Nelson said.

Mistrust may kill Hanford as N-repository

By Karen Dorn Steele
Staff writer

Recent revelations of major radiation releases and soil contamination at the Hanford Nuclear Reservation could eliminate Hanford as a finalist for the nation's first burial tomb for radioactive wastes.

That's the speculation from state officials as they await a mid-May decision by the U.S. Department of Energy on which three sites will be chosen for detailed, billion-dollar "site characterization" studies.

Publicity about the radiation releases has triggered a growing mistrust in the Northwest of federal government pronouncements that nuclear projects at Hanford — including the proposed repository — won't harm the economy or public health, said Curt Eschels, assistant to Gov. Booth Gardner for energy and environmental affairs.

"The revelations about what the federal government has already done at Hanford certainly don't enhance a sense of trust," Eschels said.

"In the past, we didn't have a choice about the secret releases," he said. "Now, our eyes are open."

State Rep. Dick Nelson, D-Seattle, a member of the state Nuclear Waste Board, says Hanford should be dropped from the list.

"The revelations of the early releases from the defense facilities at Hanford serve to point out that we've done more than our share in storing and accepting the impacts of nuclear waste and weapons production," Nelson said.

"I'm a believer in the collective conscience of the country," he said. "It's unfair to unload all the waste and all the risk on one state."

The Nuclear Waste Policy Act of 1982, passed by Congress to govern the site-selection process, allows the Energy Department to consider two major factors — geological suitability and political acceptance.

An Energy Department report a few years ago said Hanford's strongest attributes were "sociopolitical" — the site was on federally owned land in a pro-nuclear community.

(See Hanford on page 8)

4-27-86
Spokesman-Review

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(See Hanford on page 8)

4-21-86
Spokesman-Review

Tribe will ask DOE for pact on waste concerns

By Johnny Johnson
of the Tribune

LAPWAI – The Nez Perce Tribal Executive Committee will call on the U.S. Department of Energy for a consultation and cooperation agreement recognizing the tribe's concerns about the possibility of the Hanford Nuclear Reservation being chosen as the nation's first repository for high-level nuclear waste.

A resolution to that effect was passed by NPTEC, governing body of the tribe, at this week's session here, commission secretary Allen P. Slickpoo said Thursday. NPTEC wants the agreement to "relate to the concerns for the rights, privileges and responsibility of the tribe in the repository siting process," he said. Hanford is believed to be one of three top candidates for the dump.

The agreement sought by NPTEC would not in any way suggest that "the tribe approves or supports a decison to locate a repository at Hanford," Slickpoo, the NPTEC contact person under the Nuclear Waste Policy Act of 1982, said.

At a meeting at Albuquerque, N.M., last week, Slickpoo said, Nez Perce and other officials were told by DOE that it would announce about mid-May the names of the three top candidates for the nuclear waste dump. The Hanford reservation in Washington and sites in Texas and Nevada are believed to be the top contenders.

At the Albuquerque meeting, attended by representatives of the Nez Perce, Yakima and Umatilla tribes as well as several states where sites are being considered, DOE officials promised orally to provide draft reports on the environmental evaluations of the sites under consideration before announcing the top three, Slickpoo said.

"We are very anxious to receive the draft reports," he said. When the site recommendations are received, he said, the three tribes and representatives of the Council of Energy Resource Tribes "will get together and have a strategy session to review the recommendations. If it is Hanford, we will plan strategy for whatever course of action that is necessary."

The three Pacific Northwest tribes were designated by DOE as affected tribes under the Nuclear Waste Policy Act because they have treaty fishing rights on the Columbia River. The Hanford site under study is four miles from the Columbia.

The Nez Perce tribe has contracted with the Denver-based CERT organization to study the potential dangers of using the Hanford site for the dump.

Friday, April 25, 1986

Sierra Club vows suit to halt dump

By DAVID FISHER
Of our staff

The Sierra Club would file suit to keep the federal government from using Hanford as a primary dump for high-level nuclear wastes, a club official said at Washington State University Thursday night.

The federal Department of Energy is expected to announce a list of two or three preferred dump sites for high-level wastes within the next few weeks, Sierra Club Regional Vice Presidents Chairperson Ann Bringloe told a small crowd in the Compton Union Building.

Hanford is on the department's selection list because it is a federally-owned site already used for low-level waste dumping, Bringloe said.

But the Richland site's questionable geology, its proximity to the Columbia River, its inadequate transporation facilities and poor safety record should make it one of the least favored sites on the list, Bringloe said.

"We really want them to find a geologic repository," Bringloe said. "Wherever we build, there will be problems ... but some sites have greater deficiencies than others. We would likely go to court if Hanford is on the list, because we believe we have uncovered serious technical difficiencies there."

According to Bringloe, the problems at Hanford include:

- Basalt rock under the site is fractured, and under high pressure. Drilling could cause "rock bursts," and stored waste could seep through cracks into surrounding ground water.
- The area is prone to earthquake swarms that could collapse the type of underground

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SUIT

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storage proposed by the DOE.

- And transportation lines into the Richland area are unsafe. Barges on the Columbia River system are accident-prone, and rail lines into the site are old and poorly maintained. Highways pass through congested urban areas.

Bringloe noted that Hanford has been a storage site for low-level wastes for years — but its safety record is poor. Documents obtained recently by the Sierra Club and other groups have revealed serious historical leaks at the site, Bringloe said, and the National Academy of Sciences predicts contaminated groundwater could reach the Columbia River in 10 to 20 years.

Along with Hanford, the DOE is considering undergound sites in Nevada and Utah, Bringloe said. The sites contain various rock forms, including tuft — a volcanic rock — and salt.

After a primary site is selected, the department will look for secondary dump sites in eastern granite formations, she said.

Lawmakers of 7 states try to trash N-dump studies

Associated Press

WASHINGTON – Legislators from seven states under scrutiny for sites to store nuclear waste introduced Senate and House bills Tuesday to terminate the process.

The bills, spearheaded by Sen. George Mitchell, D-Maine, and Rep. Olympia Snowe, R-Maine, would eliminate the volume cap on a disposal site planned for the western United States and stop the Department of Energy search for a second site in a crystalline rock formation.

The sponsors said a second repository for high-level waste and spent reactor fuel will not be needed if a 70,000-metric ton cap is removed from the first repository.

"This is an artificial cap, having no basis in scientific requirements," said Snowe. She and Mitchell also cited DOE statistics indicating the volume of high-level nuclear waste is not expected to increase as quickly as was originally projected.

"Does it make sense to spend tens of billions of taxpayers' dollars for the siting and characterization of crystalline sites when it is not necessary to do so? The answer is clearly no," said Mitchell.

The first respository is expected to be built in Nevada, Texas or Washington state and is scheduled to be operational in 1998. DOE is selecting possibilities for a second site from among crystalline rock formations in Maine, New Hampshire, Virginia, North Carolina, Georgia, Wisconsin and Minnesota.

The companion House and Senate bills would, among other things, end the crystalline repository search; remove the volume limitation on the first site; and set up a scientific commission to report to Congress on deep geologic disposal and available alternatives.

Many of the states involved in the second site search have complained that DOE is choosing inappropriate areas. Snowe said sites selected in Maine are in areas that contain "the state's single largest water supply, Indian lands protected by federal law, serious geologic faults, insufficiently thick granite, and runs the risk of violating at least one treaty with Canada."

Rep. James Broyhill, R-N.C., has asked Energy Secretary John Herrington to halt the search for a second site, arguing it is unnecessary.

Wednesday, April 23, 1986

Foley fears Hanford will be nuke dump

Associated Press

SPOKANE – Despite what he called its unsuitability, the Hanford nuclear reservation will be chosen as one of three finalists for the nation's first high-level commercial nuclear waste repository, U.S. Rep. Thomas Foley predicted Monday.

Foley, D-Wash., emphasized that he had no specific information on which sites the Department of Energy will recommend when the three choices are revealed, probably next month.

"I oppose it," he said. "I'd be delighted if I am wrong."

The DOE has been studying the Hanford site for a number of years.

"I do not want to raise expectations at the last moment that it won't (be picked)," he said.

The Northwest congressional delegation will insist that if the central Washington site is chosen for further study, that it be judged solely on technical grounds.

He noted that the mood of Pacific Northwest residents has changed regarding Hanford.

"The Department of Energy used to think the project was politically acceptable," he said. "That's not so now."

Foley also discussed international terrorism and Libya, and work on the federal budget at a news conference Monday.

He said the rise in terrorism across the world in the wake of the U.S. raids on Libya was expected, and that was a risk the administration took when Libya was bombed.

No amount of retaliation can eliminate state-supported terrorism, he said. "It's like a criminal act; no single act can eliminate it."

Continued operations by five U.S. oil companies in Libya will be the subject of congressional review. The United States may find it difficult to get other countries to impose economic sanctions against Libya, if U.S. oil companies continue in business there, the Fifth District representative said.

"The best reaction would be to eliminate the sale of Libyan oil entirely," Foley said.

Tuesday, April 29, 1986