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PERMIAN BASIN
LOCATION RECOMMENDATION REPORT

TECHNICAL REPORT

SEPTEMBER 1983

OFFICE OF NUCLEAR WASTE ISOLATION

PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
UNDER CONTRACT DE-AC02-83CH10140

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The content of this report was effective as of September 1983. This report was prepared by Battelle Project Management Division, Office of Nuclear Waste Isolation under Contract No. DE-AC02-83CH10140 with the U.S. Department of Energy.

ABSTRACT

Candidate study areas are screened from the Palo Duro and Dalhart Basin areas using data obtained from studies to date and criteria and specifications that consider: rock geometry; rock characteristics; human intrusion potential; surface characteristics; and environmental and socioeconomic conditions. Two preferred locations are recommended from among these areas for additional characterization to identify potential National Waste Terminal Storage (NWTS) salt repository sites.

One location, in northeastern Deaf Smith County and southeastern Oldham County, is underlain by two salt units that meet the adopted screening specifications. The other location, in northcentral Swisher County, is underlain by one salt unit that meets the adopted screening specifications. Both locations have several favorable features, relative to surrounding areas, and no obviously undesirable characteristics. Both lie wholly on the Southern High Plains surface, are in relatively sparsely populated areas, contain no unique land use conflicts, and comprise large enough geographic areas to provide flexibility in site selection. Data gathered to date indicate that these locations contain salt units sufficient in thickness and in depth for the safe construction and operation of the underground facilities under consideration.

FOREWORD

The National Waste Terminal Storage (NWTS) program was established in 1976 by the U.S. Department of Energy's (DOE) predecessor, the Energy Research and Development Administration, to develop technology and provide facilities for the safe, environmentally acceptable, permanent disposal of high-level waste (HLW). HLW includes wastes from both commercial and defense sources, such as spent (used) fuel from nuclear power reactors, accumulations of wastes from production of nuclear weapons, and solidified wastes from fuel reprocessing. The DOE's responsibility for the long-term management of HLW is defined by federal laws, which specify that the DOE must provide facilities for the successful isolation of HLW from the environment in federally licensed and federally owned repositories for as long as the wastes present a significant hazard.

To meet its major objective of isolating HLW, DOE is conducting a technical program that will meet applicable regulatory requirements established by the U.S. Nuclear Regulatory Commission (NRC) and all relevant radiological protection criteria of the U.S. Environmental Protection Agency. The DOE's program emphasizes disposal in mined repositories deep underground in geologically stable formations. Several types of rock are being studied in several states. Rock types include bedded salt deposits, salt domes, basalt (solidified lava), tuff (compacted volcanic ash), and "crystalline" rocks*.

Steps leading to the permanent disposal of HLW are:

- Studying, characterizing, and recommending potential sites for repositories
- Providing waste packaging facilities
- Developing transportation requirements
- Developing the technology to support these steps
- Designing, obtaining licensing for, and operating repositories for commercial waste
- Studying alternative disposal methods as long-range options to the geologic disposal program.

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*Crystalline rock is a general term for igneous and metamorphic rocks, as opposed to sedimentary rocks. Granite is one type of crystalline rock.

Five separate but coordinated projects are involved in the NWTS programs: the Office of Nuclear Waste Isolation (ONWI), the Basalt Waste Isolation Project (BWIP) at DOE's Hanford Site in Washington state, the Nevada Nuclear Waste Storage Investigations (NNWSI) at the federal Nevada Test Site, the Subseabed Disposal Project, and the newly created Office of Crystalline Repository Development (OCRD). ONWI, BWIP, NNWSI, and OCRD focus on different rock types and conduct studies in site evaluation, technology development, facility design, and field testing. These programs share data of general benefit. ONWI and OCRD coordinate site exploration studies on nonfederal lands. The Subseabed Disposal Project is assessing the technical, environmental, engineering, and institutional feasibility of disposing of processed highly radioactive nuclear waste and/or repackaged spent fuel in geologic formations beneath the sediments of the oceans.

Nine sites in the six states, including Texas, have been identified by DOE as being potentially suitable for further study and consideration for the first repository. DOE plans to nominate at least five of the nine sites for site characterization, following issuance of the siting guidelines required by the Nuclear Waste Policy Act of 1982. The basis for the nomination of each site is to be presented in an environmental assessment in which conformity with the final guidelines is analyzed.

DOE is required by the Nuclear Waste Policy Act to recommend three of the nominated sites to the President for site characterization by January 1985. "Site characterization" means the program of exploration to establish the geologic conditions at a potential site and determine suitability for a repository. The studies include borings, surface exploration, exploratory shafts, limited excavations at the base of the shaft, at depth testing, environmental, socioeconomic, and other sutdies. The siting guidelines were finalized through consultation with governors of affected states and were submitted this fall to the NRC for concurrence. According to the Nuclear Waste Policy Act, the President is to recommend one site for the first repository to Congress by 1987. The first repository is scheduled to be in operation in 1998.

A separate process of nominations and recommendations will be conducted for the second repository site, which is to be identified by 1990. DOE is required to apply to the NRC for licenses to construct the repositories.

A federal statute and several documents and statements provide policy and technical guidance in the evolvement and planning of the NWTS program:

(1) U.S. Congress, 1983. Nuclear Waste Policy Act of 1982, Public Law 97-425, Washington, DC, January 7.

(2) Reagan, R., President, U.S., 1981. President's Nuclear Policy Statement, Washington, DC, October 8.

(3) U.S. Department of Energy, 1981. "Program of Research and Development for Management and Disposal of Commercially Generated Wastes; Record of Decision (to adopt a strategy to develop mined geologic repositories ...)", Federal Register, Vol. 46, No. 93, May.

(4) U.S. Department of Energy, 1980. Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste, DOE/EIS-0046F, Washington, DC, October.

(5) U.S. Department of Energy, 1980. Statement of Position of the United States Department of Energy, in the Matter of Proposed Rulemaking on Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), PR-50, 51 (44 FR 61372), DOE/NE-0007, Washington, DC, April.

(6) U.S. Department of Energy 1980. Cross-Statement of the United States Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), PR-50, 51 (44 FR 61372), DOE/NE-0007, Supp. 1, Washington, DC.

(7) Interagency Review Group on Nuclear Waste Management, 1979. Report to the President, TID-29442, Washington, DC, March.

(8) Office of Nuclear Waste Management and U.S. Geological Survey, 1980. Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository, DOE/TIC-11033 (draft), prepared for U.S. Department of Energy and U.S. Department of Interior, Washington, DC.

(9) U.S. Department of Energy, 1981. NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste: Site Performance Criteria, DOE/NWTS-33(2), Office of NWTS Integration, Battelle Memorial Institute, Columbus, OH.

(10) U.S. Nuclear Regulatory Commission, 1981. "Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Waste (10 CFR 60)", Federal Register, Washington, DC, July 8.

(11) U.S. Department of Energy, 1982. National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment, DOE/NWTS-4, Office of NWTS Integration, Battelle Memorial Institute, Columbus, OH, Public Draft.

Throughout the repository siting and construction process, opportunities are provided for public and peer review and comment. DOE maintains an open information program for nuclear waste management activities and is committed to a policy of consultation with state and local officials. The Nuclear Waste Policy Act specifies interactions that must occur between DOE and affected states and Indian tribes and provides for public participation. Information is provided both to technical and nontechnical groups and to governmental officials through review of major reports, briefings, conferences, public meetings, and printed material. Additional opportunities for public participation will occur at public hearings and reviews that are part of the licensing process.

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1 INTRODUCTION

The Permian Basin Location Recommendation Report is a recommendation to focus National Waste Terminal Storage (NWTS) salt site investigations of the Palo Duro and Dalhart Basins in Texas (Figure 1-1) on smaller geographical areas, termed locations. This report describes the site-selection process, the history of salt site investigations to date, the information used, and the decisions made in a transition from area studies to location studies. The evaluations and recommendations made in this report are based on currently available data and are subject to change or modification as more data become available. Conclusions and recommendations are intended for consideration by the U.S. Department of Energy (DOE), the state of Texas, and other interested parties.

Upon acceptance of this recommendation by the DOE, the locations and surrounding areas will undergo more detailed study and screening to identify a specific potential repository site. A potential repository site in the Palo Duro Basin, if identified, will be compared to potential salt sites in the Paradox Basin (Utah) and in the Gulf Coast salt domes region (Louisiana and Mississippi), and eventually to potential repository sites in other rocks (basalt at the Hanford Site, Washington, and tuff at the Nevada Test Site) (Figure 1-2).

A number of organizations participate in the NWTS program studies in Texas. The Project Management Division of Battelle Memorial Institute has responsibility for managing the NWTS program's salt exploration activities for the DOE, through the Office of Nuclear Waste Isolation (ONWI). Stone & Webster Engineering Corporation (S&W), as subcontractor to ONWI, is the Geologic Project Manager responsible for supporting ONWI in planning, administering, and executing geologic investigations. NUS Corporation (NUS), under contract to ONWI, is the Regulatory Project Manager and is responsible for environmental and socioeconomic studies. The Bureau of Economic Geology (BEG) at the University of Texas, under contract with DOE, has been engaged in geologic studies in the Texas Panhandle for the NWTS program since mid-1977. BEG also provides technical review of documents related to Permian Basin studies and assists in planning field activities. A Geologic Review Group, comprising nationally and internationally recognized experts in specialized fields of geology, provides an independent technical review of the program.

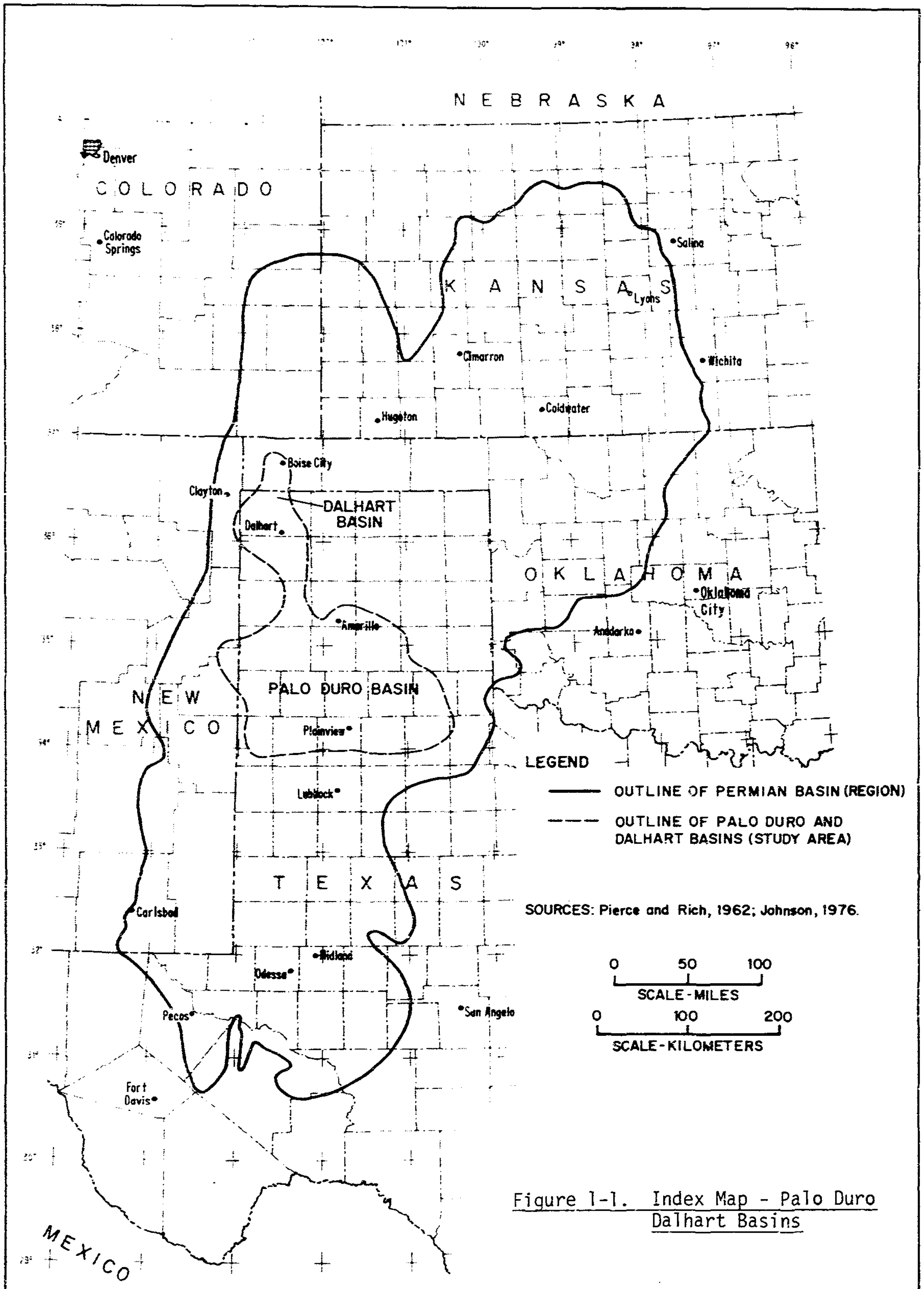

Figure 1-1. Index Map - Palo Duro Dalhart Basins

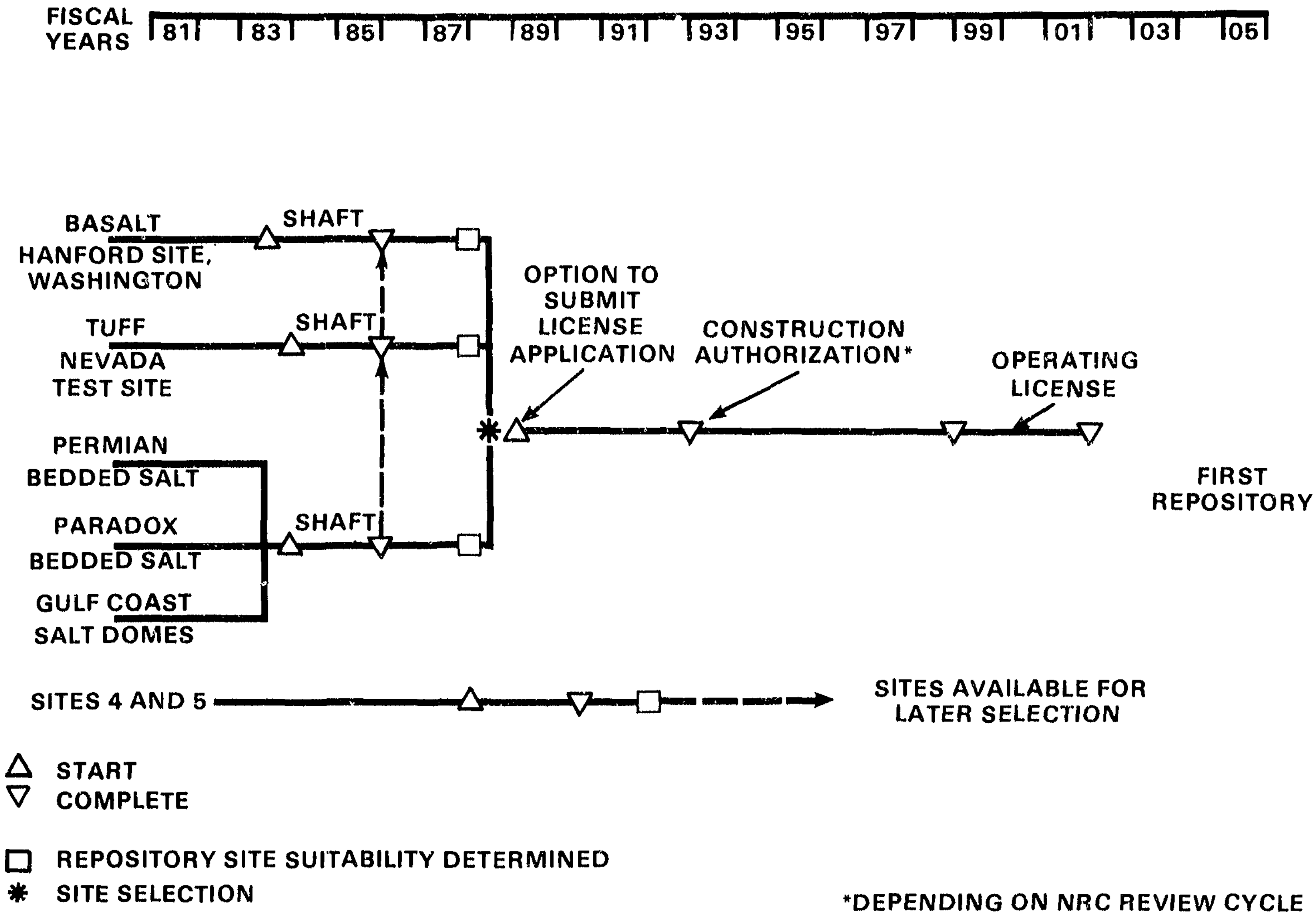

Figure 1-2. NWTS Program Schedule

2 NWTS SITE SELECTION PROCESS

The process the U.S. Department of Energy (DOE) is using for locating sites for a waste repository is described in the public draft National Plan for Siting High-Level Radioactive Waste Repositories (DOE, 1982). This siting process involves a stepwise screening of large portions of the United States, identification and detailed study of potential sites, and selection of one or more of these sites, if suitable, for permanent disposal of high-level waste (HLW), all with state and public involvement.

2.1 DOE SITE PERFORMANCE CRITERIA

The National Waste Terminal Storage (NWTS) program must provide facilities to permanently dispose of HLW in a manner that protects the public health and safety, preserves environmental quality, and maintains institutional acceptability. The U.S. Nuclear Regulatory Commission (NRC), in conjunction with the U.S. Environmental Protection Agency (EPA), defines the requirements for site suitability.

Because the regulatory criteria are still being developed, DOE has developed a set of performance criteria (Table 2-1) (DOE, 1981) to guide NWTS program siting efforts until final regulatory guidelines are available. Some criteria directly address anticipated radiologic and nonradiologic effects that must be limited to acceptable levels. Other criteria address uncertainties that exist in the technology of geologic disposal. Still others address institutional issues such as public involvement in, and understanding of, nuclear waste disposal, its technology options, and licensing. Such criteria will be used to qualify repository sites to regulatory agencies and the public in a technically defendable, timely, economical, and institutionally acceptable manner.

These criteria are expected to be consistent with final NRC and EPA regulatory standards. The applicable draft NRC criteria sections are listed opposite the NWTS criteria in Table 2-1.

Table 2-1. NWTS Site Qualification Criteria*

CRITERION		SUB-CRITERION	NRC CRITERIA
1.0	Site geometry	Minimum depth Thickness Lateral extent	60.122(1)
2.0	Geohydrology	Hydrological Regime Hydrological regime/shaft construction Subsurface rock dissolution	60.112(b,c), 60.122(c,f,g,h) 60.123 (a) (1,2,3,7), (b) (12) 60.123(b) (17) 60.123(b) (5)
3.0	Geochemistry	Geochemical interactions Radionuclide retardation	60.112(b), 60.122(d), 60.123(b) (13, 14, 15) 60.122(g)
4.0	Geologic characteristics	Subsurface setting Host rock characteristics Engineering feasibility	60.122, 60.122, 60.123 60.112, 60.122, 60.123 60.123(b) (16,17)
5.0	Tectonic environment	Tectonics elements Faulting, fracturing, folding Quaternary igneous activity Uplift/subsidence rates Seismicity	60.112(a), 60.122(a,b) 60.123(a) (5), (b) (6,8) 60.123(a) (7), (b) (11) 60.123(a) (7), (b) (8) 60.123(a) (4), (b) (9,10)
6.0	Human intrusion	Resources Exploration history Ownership/control	60.123(b) (1,2,3) 60.123(b) (1,2,3) 60.121(a,b)
7.0	Surface characteristics	Hydrologic system Topographic features Meteorological conditions Nearby hazards	60.123(a) (1,2,3) 60.112(b), 60.122(a) 60.123(a) (6), (b) (4) 60.130
8.0	Demography	Urban areas Transportation risk	60.111(a) (1)
9.0	Environmental protection	Environmental impact Land use conflicts Normal and extreme environmental conditions	
10.0	Socioeconomic impacts	Social impact Access and utility requirements	

(*) For a full statement of each criterion and factors considered, see Site Performance Criteria (DOE, 1981).

2.2 SCREENING PROCESS

The public draft National Plan for Siting High-Level Radioactive Waste Repositories (DOE, 1982) emphasizes a screening process for repository site identification that proceeds sequentially from regions, to areas, to locations, and, finally, to a site(s) (Figure 2-1). The process is intended to provide a rational mechanism by which large, continuous land areas may be reviewed on a technical basis and be expeditiously reduced to smaller areas within which prospects of finding a licensable site are relatively high. The DOE selects the most preferable smaller parcels of land at the end of each phase of study for additional work. To this end, screening specifications, consistent with site performance criteria, are chosen to reduce the scope of the site search, focusing available resources on those places where success is most likely. As studies progress from region to site, specifications for various site characteristics often become more restrictive, although the site performance criteria themselves do not change. The screening specifications are tools for guiding and focusing the siting effort. At each successive phase of site characterization, additional geologic, environmental, and socioeconomic data are obtained. These more detailed, site-specific data are used to evaluate each successively smaller land parcel with respect to site performance criteria.

In some cases, screening specifications used early in the process of evaluating broad geographic areas may no longer be useful during more detailed consideration of smaller areas. For example, basin-wide variations in salt purity are evaluated in this report on the basis of gamma-ray geophysical log response. At the regional and area level, this approach is useful in indicating where the salt-bearing section is relatively free of mudstone, and it was used in screening the Palo Duro and Dalhart Basin areas to identify locations (Section 5.1.2). At the location and site level, specific lithologic variations within the salt-bearing section (already known to be reasonably free of fine-grained clastic material on the basis of earlier screening using the gamma-ray geophysical log response) become more relevant, and are used with other criteria to screen within locations to identify a candidate site.

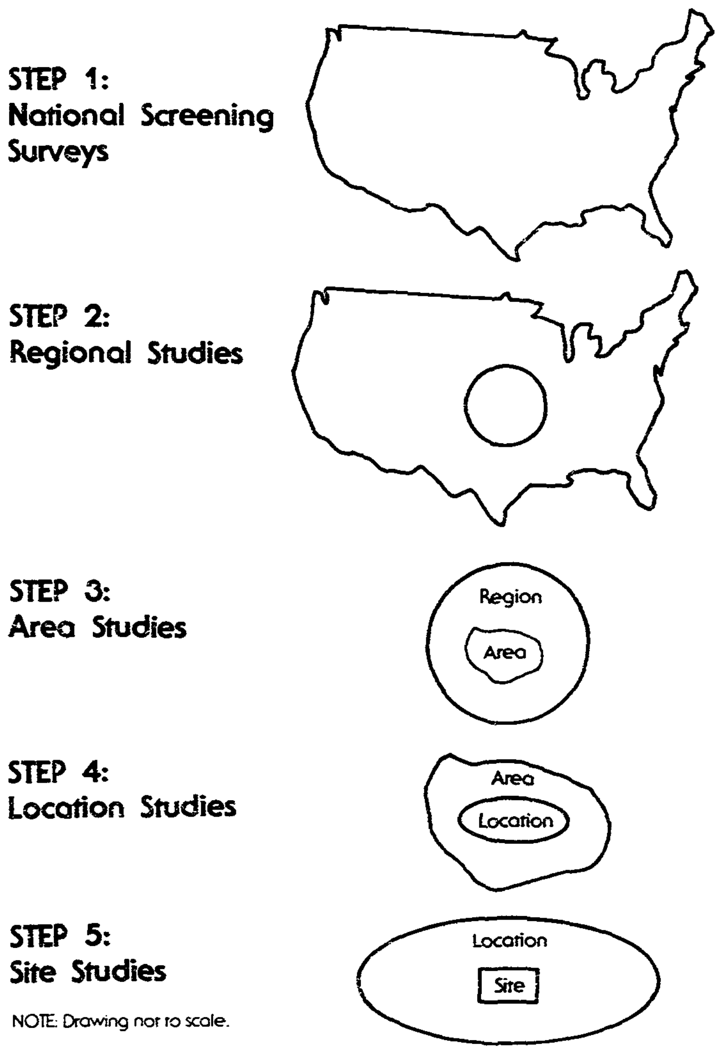

Figure 2-1. The Site Selection Process

3 HISTORY OF SITING INVESTIGATIONS

In 1954, the U.S. Atomic Energy Commission (AEC) asked the National Academy of Sciences - National Research Council (NAS-NRC) to investigate the problem of identifying a suitable geological medium for a nuclear waste repository site. In 1957, the NAS-NRC concluded:

> "The most promising method of disposal of high-level waste at the present time seems to be in salt deposits. The great advantage here is that no water can pass through salt. Fractures are self-sealing. Abandoned salt mines or cavities especially mined to hold waste are, in essence, long-enduring tanks. The possibility of making cavities in salt by pumping in water and removing brine is not favored (except for waste in solid form) unless the size and shape of such a cavity can be accurately controlled. The major element of potential risk in disposal in salt is that the cavity will collapse, structurally, in time. Salt is a weak material and will flow. Hence research is needed on size and shape of openings which can be relied upon to be structurally stable. The cavities should be at relatively shallow depth to avoid high confining pressures." (NAS-NRC, 1957)

This recommendation was reaffirmed in a subsequent report (NAS-NRC, 1970).

In 1962, the U.S. Geological Survey (USGS) published a study for the AEC related to salt deposits in the United States that might contain disposal sites (Pierce and Rich, 1962). This work reported available literature information in the broad regions within the United States underlain by salt deposits. These deposits included salts that underlie parts of Alabama, Colorado, Kansas, Louisiana, Michigan, Mississippi, New Mexico, New York, Ohio, Oklahoma, Pennsylvania, Texas, Utah, and West Virginia.

In 1976, the U.S. Energy Research and Development Administration (ERDA) announced the initiation of the NWTS program. In regional studies (Johnson, 1976; NUS, 1983a), the Permian Basin salt deposits in the Texas Panhandle and western Oklahoma were evaluated from published sources. The Palo Duro and Dalhart Basins of the Texas Panhandle were preferable to the Midland, Delaware, and Anadarko Basins and were recommended for area characterization (NUS, 1983b) (Figure 3-1).

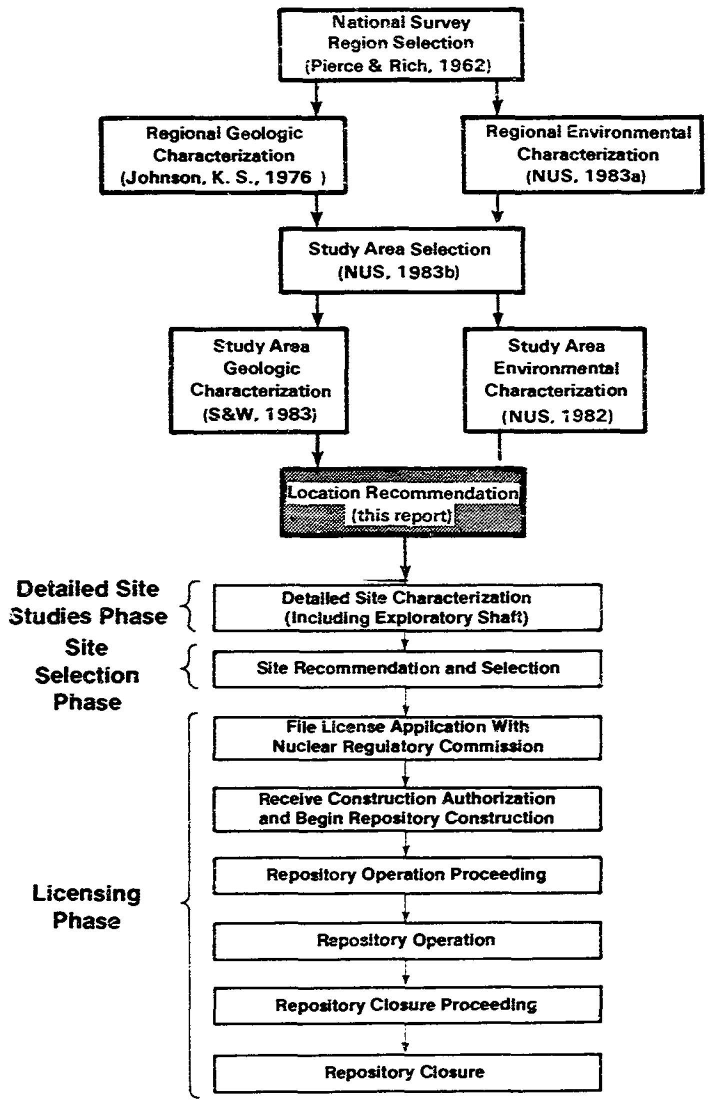

Figure 3-1. Permian Basin Reports and Site Characterization

The bases for these recommendations were:

(1) Numerous salt-bearing units more than 61 m (200 ft) thick between depths of 305 and 915 m (1,000 and 3,000 ft)*

(2) Low levels of historic seismicity

(3) Absence of major, known petroleum reserves

(4) Relatively few exploratory boreholes that penetrate through all of the salt units

(5) Excluding salt, no known significant mineral deposits within or below the salt units

(6) No evidence of ongoing salt dissolution at depths greater than 305 m (1,000 ft)

(7) No recognized geologic, hydrologic, environmental, or socioeconomic factors that preclude further study of the Permian Basin.

Geologic field studies began in 1977 to investigate stratigraphy, structure, ground water, surface hydrology, erosion, tectonics, seismicity, and natural resources. Since 1977, eight boreholes were drilled, selectively cored, and tested. The core samples, geophysical logs, and hydrologic test data are being analyzed to determine lithologic and hydrologic properties of the rocks in the stratigraphic section.

Environmental studies also began in 1977. Environmental factors considered were geography, terrestrial and aquatic ecology, surface hydrology, meteorology, land and water resources, and land use and demography, as well as economic, historical, institutional, and societal factors.

Technical results of studies to date are presented in the geologic and environmental area characterization reports [ONWI-102 (NUS, 1982) and DOE/CH/10140-1 (S&W, 1983)], as well as numerous BEG reports (see Appendix B).

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* Metric conversion factors used in this report are presented in Appendix A. In some cases, where English measurements are approximations, metric equivalents are also approximations.

4 SUMMARY DESCRIPTION OF THE STUDY AREA AND SURROUNDING REGION

The following sections describe the geologic, demographic, socioeconomic, land use, and environmental characteristics of the study area. The information presented is summarized from area characterization reports (S&W, 1983, and NUS, 1982), unless otherwise cited.

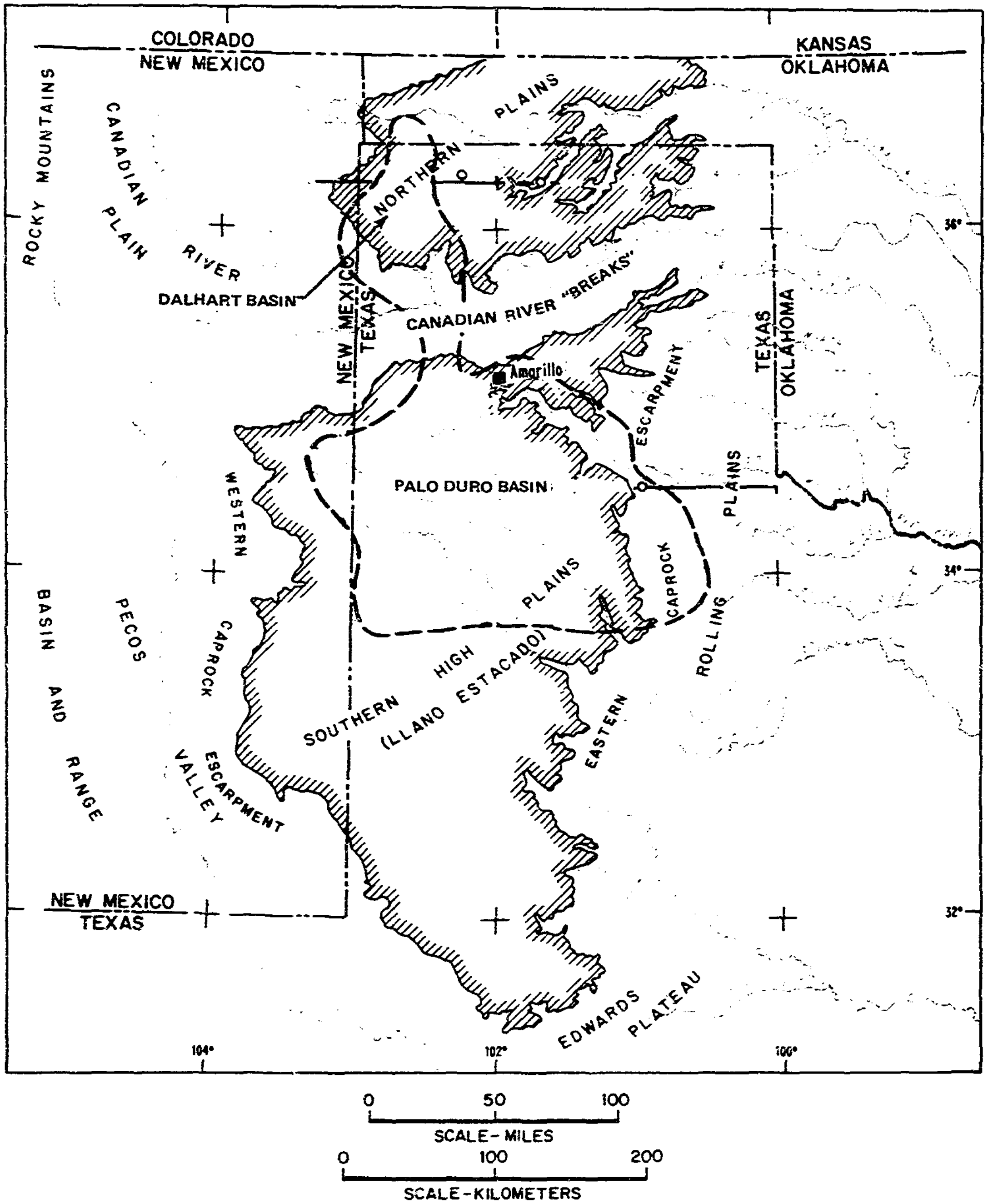
4.1 GEOLOGY

The Palo Duro and Dalhart Basins, along with several other small structural basins, lie within the larger Permian Basin (Figure 1-1). The Permian Basin is defined as that area underlain by bedded salt deposits of Permian age. This definition is consistent with that of Johnson and Gonzales (1978).

4.1.1 Physiography/Topography

The physiographic divisions of the Texas Panhandle and adjacent areas are shown in Figure 4-1. The areas of primary interest lie beneath the High Plains. The Canadian River "Breaks" separates the Northern High Plains element from the Southern High Plains element. The High Plains are bounded on the east and west by caprock escarpments. The Southern High Plains element is a relatively flat-lying surface sloping to the southeast. The low-relief topographic features which characterize the Southern High Plains surface include numerous internally drained basins (playas), narrow draws (stream valleys), and stabilized relict dune fields. Gustavson et al (1981) have estimated the rate of retreat at between 109 and 183 m (360 to 600 ft) per thousand years.* The average rate of local slope erosion at sites along the escarpment ranged from 457 to 787 cm (180 to 310 in.) per thousand years (Simplins et al, 1982. Gustavson et al (1981) also report denudation rates in 17 basins in the Rolling Plains near (and including) the Eastern Caprock Escarpment. The normalized rates range from 10 cm to 108 m (4 in. to 354 ft) per thousand years. The geomorphic processes relevant to assessing

* Data from Gustavson et al (1981) are stated in centimeters per year. These rates have been normalized to inches per year, a more commonly used rate.



LEGEND

— — — OUTLINE PALO DURO AND DALHART BASINS

BOUNDARY OF HIGH PLAINS SURFACE

SOURCE: MODIFIED FROM S&W, 1983

Figure 4-1. Major Physiographic Elements of the Texas Panhandle Region the suitability of this area are discussed in more detail in the area characterization report (S&W, 1983) and numerous Bureau of Economic Geology (BEG) reports (Appendix B).

4.1.2 Stratigraphy

The major stratigraphic units of the study area are shown in Figure 4-2. A summary description of the potential host rock and surrounding strata is provided below. Numerous BEG reports (Appendix B) and the area geologic characterization report, DOE/CH/10140-1, (S&W, 1983) provide detailed discussions of the stratigraphy of the Texas Panhandle.

The Precambrian basement consists of igneous and metamorphic rocks. Above the Precambrian rocks are Cambrian (?) and Ordovician sandstones and carbonates. These units are thin and porous, and of limited lateral extent.

Overlying these are Mississippian rocks that typically consist of several hundred feet of limestone and dolomite locally interbedded with shale and sandstone. The Mississippian rocks are covered by up to 762 m (2,500 ft) of Pennsylvanian deposits. The oldest Pennsylvanian rocks in the Palo Duro Basin are predominantly arkosic sandstones and shales that are interbedded with progressively more limestone toward the top. Thick clastic wedges developed on the flanks of major uplifted areas (the Amarillo Uplift and, to a lesser extent, the Matador Uplift) during Early Pennsylvanian time, and limestones or terrigenous muds were deposited in the basins. Limestone reefs first developed at shelf incipient margins during this period. The Mississippian and Pennsylvanian strata contain saline water-bearing zones and potential petroleum-producing horizons.

The overlying Permian-aged Wolfcamp Series consists of up to 610 m (2,000 ft) of limestone, shale, dolomite, and arkosic sands (near the Amarillo Uplift). The lower Wolfcamp exhibits rapid vertical and horizontal facies changes. Carbonate shelves developed on the flanks of the basins. As these basins filled, the carbonates extended across the topographic highs. Fine-grained clastic materials accumulated in the deeper, central portions of the basins. Late Wolfcamp deposits are mostly dolomitic, indicating the development of a more restricted marine depositional environment (Nicholson, 1960). This type of restricted, shallow marine environment lasted throughout Permian time (Hartman and Woodard, 1971). The Wolfcamp Series is a major saline aquifer of concern in evaluating the Palo Duro Basin.

ERA	SYSTEM	SERIES	GROUP	FORMATION	GENERAL LITHOLOGY AND DEPOSITIONAL SETTING
CENOZOIC	QUATERNARY				FLUVIAL AND LACUSTRINE CLASTICS
	TERTIARY			OGALLALA	
	CRETACEOUS		DAKOTA		NEARSHORE MARINE CLASTICS
MESOZOIC				FREDRICKSBURG	
				TRINITY	
	JURASSIC			MORRISON	
				EXETER	
	TRIASSIC		DOCKUM	TRUJILLO	FLUVIAL DELTAIC AND LACUSTRINE CLASTICS AND LIMESTONES
				TECOVAS	
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE	SALT, ANHYDRITE, REDBEDS, AND PERITIDAL DOLOMITES
				ALIBATES	
		GUADALUPE	ARTESIA/ WHITEHORSE	**SALADO-TANSILL**	
				YATES	
				SEVEN RIVERS	
				QUEEN/GRAYBURG	
				SAN ANDRES/BLAINE	
		LEONARD	CLEAR FORK	**GLORIETA**	
				UPPER CLEAR FORK	
				TUBB	
				LOWER CLEAR FORK	
				RED CAVE	
			WICHITA		
		WOLFCAMP			SHELF AND PLATFORM CARBONATES, BASIN SHALE, AND DELTAIC SANDSTONES
	PENNSYLVANIAN	CISCO			
		CANYON			
		STRAWN			
		ATOKA/BEND			
		MORROW			
	MISSISSIPPIAN	CHESTER			SHELF LIMESTONE AND CHERT
		MERAMEC			
		OSAGE			
	ORDOVICIAN		ELLENBURGER		SHELF DOLOMITE
	CAMBRIAN		UNNAMED SANDSTONES		SANDSTONES
	PRECAMBRIAN				IGNEOUS AND METAMORPHIC

Contains Major Salt Beds (shaded)

Erosional unconformity (wavy line)

SOURCE: Handford and Dutton, 1980, Presley, 1980, Nicholson, 1960; Tait et al, 1962, Totten, 1956, Kelley and Trauger, 1972. Bassett and Bentley, 1983

Figure 4-2. Stratigraphic Column of the Palo Duro and Dalhart Basins

The Leonard Series, made up of the Wichita Group, Red Cave, Lower Clear Fork, Tubb, Upper Clear Fork, and Glorieta Formations, lies above the Wolfcamp Series. The Leonard Series is approximately 610 m (2,000 ft) thick and typically contains carbonates, evaporites, shales, and fine sandstones. Lowermost Leonard Series rocks are low-porosity dolomites, shales, and anhydrites of the Wichita Group. These are overlain by shales, anhydrites, and thin siltstones of the Red Cave Formation. The Lower Clear Fork Formation is typically over 122 m (400 ft) thick and consists of dolomite, anhydrite, shale, and salt (primarily in the upper portions). The Tubb Formation, which overlies the Lower Clear Fork, consists of siltstones, fine-grain sandstones, and shale layers, with an occasional salt-bearing shale or anhydrite layer. The siltstone and sandstone layers are locally porous and may contain brine. The Upper Clear Fork Formation, directly above the Tubb Formation, contains about 305 m (1,000 ft) of anhydrite, salty mudstone, and salt with interbeds of shale and dolomite. Upper Clear Fork rocks are usually impermeable, although the dolomite layers may be locally porous. The Glorieta Formation is predominantly shale and sandstone in the Dalhart Basin and mudstone and evaporites in the Palo Duro Basin. Major salt beds occur within the Glorieta in the western Palo Duro Basin and the Dalhart Basin.

The Guadalupe Series, above the Leonard, comprises the San Andres/Blaine, Queen/Grayburg, Seven Rivers, Yates, and part of the Salado-Tansill Formations. The stratigraphy of the Guadalupe Series is similar to that of the upper Leonard Series rocks. The main difference between the rocks of the two series is that the Guadalupe Series contains thicker and more extensive salt beds. There are few porous rocks within the Guadalupe Series, particularly in the lower portion. An exception may be the lower San Andres unit 4 dolomite.

The Middle and Upper Permian salt-bearing rocks have been subdivided into major lithogenetic units by Presley (1981b) (Table 4-1).

The San Andres Formation was deposited in a range of environments: open marine shelf (burrowed and fossiliferous carbonates); algal flats and carbonate sabkhas (laminated dolomite and nodular anhydrite); and hypersaline intertidal and supratidal brine pans (massive salt, laminated anhydrite). Presley (1981a) concludes that, "In the northern Palo Duro Basin, deposition of lower San Andres salt strata occurred in inner brine pan environments. Lateral persistence of salt beds of relatively uniform composition may be expected in this area. Massive salt beds intertongue progressively to the south with

Table 4-1. Principal Lithogenetic Units in Upper Permian Salt-Bearing Strata in the Texas Panhandle

SERIES	LITHOGENETIC UNIT (THIS REPORT)	FORMATIONS AND INFORMAL SUBDIVISIONS	DEFINITIVE CHARACTERISTICS	GEOLOGIC HISTORY	REGIONAL PALEOGEOGRAPHIC SETTING
Ochoan	SALADO-DEWEY LAKE (POST-SAN ANDRES UNITS)	Dewey Lake Red Beds Alibates Fm Salado (-Tansill) Salt	Post-San Andres rocks are predominantly red beds and salt deposited in salt- and mud-flat depositional systems. Salt beds intertongue with clastic beds composed predominantly of mudstone. However, the proportion of sandstone in these clastic beds is greater than that observed in older Permian red-bed units.	Mud-flat and salt-flat facies early in post-San Andres time shifted progressively landward, such that Queen-Grayburg rocks are predominantly red beds and upper Seven Rivers rocks are predominantly salt. The remainder of the post-San Andres was a time of periodic, abrupt basin-wide shifts in mud-flat, salt-flat, and brine pan depositional systems. Alibates time was unique in that a broad brine pan in which gypsum and carbonates were deposited spread across much of the Texas Panhandle. This was the final Permian carbonate depositional event in this area.	Much of the post-San Andres is equivalent to carbonate shelf margin facies of the Goat Seep and Guadalupe reef tracts in the Delaware and southern Midland Basins. Post-San Andres rocks in the Texas Panhandle formed in a large marine-influenced embayment landward of these reefs in the Delaware Basin. Salado salt was deposited over older carbonates and evaporites. This relationship records a major seaward shift in environments. However, in the Texas Panhandle deposition of these units was far updip, and the shift between Yates red beds and Tansill-Salado salt was only one of several shifts from mud-flat to salt environments in the Panhandle area.
Guadalupian	SEVEN RIVERS-YATES (POST-SAN ANDRES UNITS)	Yates Red Beds Seven Rivers Fm: upper salt; lower red beds			
	? QUEEN-GRAYBURG (POST-SAN ANDRES UNITS)	Queen-Grayburg Red Beds			
	SAN ANDRES	San Andres Formation: upper; lower (unit 5, unit 4, unit 3, unit 2, unit 1)	In comparison with other Permian depositional sequences, San Andres rocks contain only minor amounts of red clastic sediments. The exception to this is in the eastern Panhandle where there was an interplay of terrestrial and marine systems in San Andres time. The lower part of the San Andres contains relatively mud-free salt beds that alternate cyclically with dolomite and anhydrite. The upper part of the San Andres is composed of relatively mud-free salt interbedded predominantly with anhydrite.	San Andres depositional systems shifted gradually to the south. During early San Andres time, there were cyclic alternations of carbonate shelf, inner-shelf, and brine pan depositional systems. In later San Andres time, carbonate shelf systems shifted to the south. Cyclic alternation of environments continued in the Texas Panhandle, although the cycles were of sulfate-dominant and halite-dominant brine pan deposition.	Early in San Andres time in the southeastern Texas Panhandle, San Angelo deltas prograded into San Andres brine pans and marine-shelf systems. Flowerpot mud flats formed laterally to the deltas (Smith, 1974). Across the basin in the northwestern Texas Panhandle, eolian deposits of the Glorieta Sandstone formed the northwestern margin of the San Andres evaporite basin (Presley, 1981). Glorieta sands in central New Mexico were deposited in coastal barrier systems landward of marine-shelf environments (Milner, 1978). San Andres shelf margin and deep basin systems were present in the southern Midland and Delaware Basins. In late San Andres time, terrestrial environments shifted landward, and brine pan and shelf systems shifted gradually to the south.
Leonardian	UPPER CLEAR FORK-GLORIETA	Glorieta Red Beds: unit 3, unit C, unit 2, unit B, unit 1, unit A Upper Clear Fork Salt: unit 2, unit 1	Both upper Clear Fork-Glorieta and lower Clear Fork-Tubb rocks exhibit an overall regressive shift in the same types of depositional systems. Within each of these two major depositional sequences, carbonate shelf facies at the base of each sequence grade upward and landward progressively into brine pan, salt-flat, and mud-flat facies. Lower and upper Clear Fork rocks are composed of carbonates overlain by evaporites. The basal carbonates record early-stage transgression of marine-shelf depositional systems. In both the lower Clear Fork-Tubb and upper Clear Fork-Glorieta there is a gradual upsection increase in red mudstone and siltstone, such that Tubb and Glorieta rocks are predominantly red beds deposited in broad tidal mud flats. These Tubb and Glorieta mud flats extended across much of the Texas Panhandle and record late-stage maximum regression in the respective depositional sequences.	In the southern Palo Duro Basin in upper Clear Fork time there was a cyclic alternation of inner-shelf and brine pan depositional systems. In the northeastern Texas Panhandle, deposition was in mud and salt flats. In Glorieta time, supply of clastics increased, and broad mud flats extended across much of the Texas Panhandle and graded to the south into barrier-island and nearshore depositional systems. In addition, there was a cyclicity of mud-flat and salt-flat depositional systems in Glorieta time, such that Glorieta red-bed- and salt-dominant units intertongue over large areas.	During upper Clear Fork time evaporite depositional systems in the Texas Panhandle graded to the east and northwest into arid terrestrial environments. Carbonate shelf margin and deeper basin environments were present in the northern Midland Basin, just to the south of the Matador Arch, and also in the Delaware Basin to the southwest. In Glorieta time, terrestrial eolian systems of the Glorieta Sandstone in the northwestern Panhandle migrated progressively to the southeast. This eolian deposition continued into San Andres time. Throughout Glorieta time carbonate shelf margin environments in the northern Midland Basin migrated progressively to the south.
	LOWER CLEAR FORK-TUBB	Tubb Red Beds: upper unit, lower unit upper cycle lower cycle		Early in lower Clear Fork time inner-shelf depositional systems occupied the southern Palo Duro Basin. Lower Clear Fork brine pans extended over much of the northern Palo Duro Basin and into the Anadarko Basin. Late in lower Clear Fork time and Tubb time, supply of clastics increased from eastern and northwestern source areas, and Tubb mud flats extended across much of the Texas Panhandle and graded to the south into barrier-island and nearshore depositional systems.	During lower Clear Fork time evaporite depositional systems graded to the east and northwest into arid terrestrial environments, including wadi plain fluvial systems (Handford, 1980). Lower Clear Fork shelf margin systems were present in the northern Midland Basin as far north as the Matador Arch.

SOURCE: Presley, 1981b.

anhydrite. Impurities in the salt are predictable and may be expected to vary in a systematic manner."

The upper San Andres salt beds underlie most of the Palo Duro Basin; the thickest beds, at depths between 305 and 915 m (1,000 and 3,000 ft) are principally in Deaf Smith, Randall, Parmer, and Castro Counties (Figures 4-3 and 4-4). These salt beds are commonly interbedded with anhydrite and mudstone and individual beds may thicken or thin rapidly across the basin.

The lower San Andres unit 5 contains salt beds that are persistent throughout much of the central and northern Palo Duro Basin. Salt more than 38 m (125 ft) thick exists at depths between 300 and 900 m (1,000 and 3,000 ft) in parts of Deaf Smith, Randall, Parmer, Oldham, and Castro Counties (Figures 4-5 and 4-6).

The lower San Andres unit 4 salt beds are continuous across the central and northern Palo Duro Basin (Figure 4-7). They are more than 38 m (125 ft) thick between a depth of 305 and 915 m (1,000 and 3,000 ft) throughout most of the central portion of the basin (Figure 4-8).*

The Queen/Grayburg Formation, overlying the San Andres/Blaine, is predominantly sandstone, siltstone, mudstone, and some anhydrite and dolomite. This formation thickens southward across the Palo Duro Basin. The lower portion of the Seven Rivers Formation is mostly terrigeneous clastics interbedded with salt and anhydrite. The upper part of the Seven Rivers Formation is predominantly salt throughout most of the Palo Duro Basin. The Yates Formation is a relatively thin, fine sandstone and shale deposit between the Seven Rivers and Salado-Tansill Formations. The Salado-Tansill Formation is comprised of anhydrite, dolomite, and shale in the northern Palo Duro Basin, and contains thick salt units in the southern Palo Duro Basin.

The Ochoa Series consists of the Salado-Tansill (upper portion), Alibates, and Dewey Lake Formations. The Alibates Formation consists of thin anhydrite or dolomite and shale layers. The Dewey Lake is very similar to the lower part of the Triassic Dockum Group, and, in some areas, the contact appears to be gradational.

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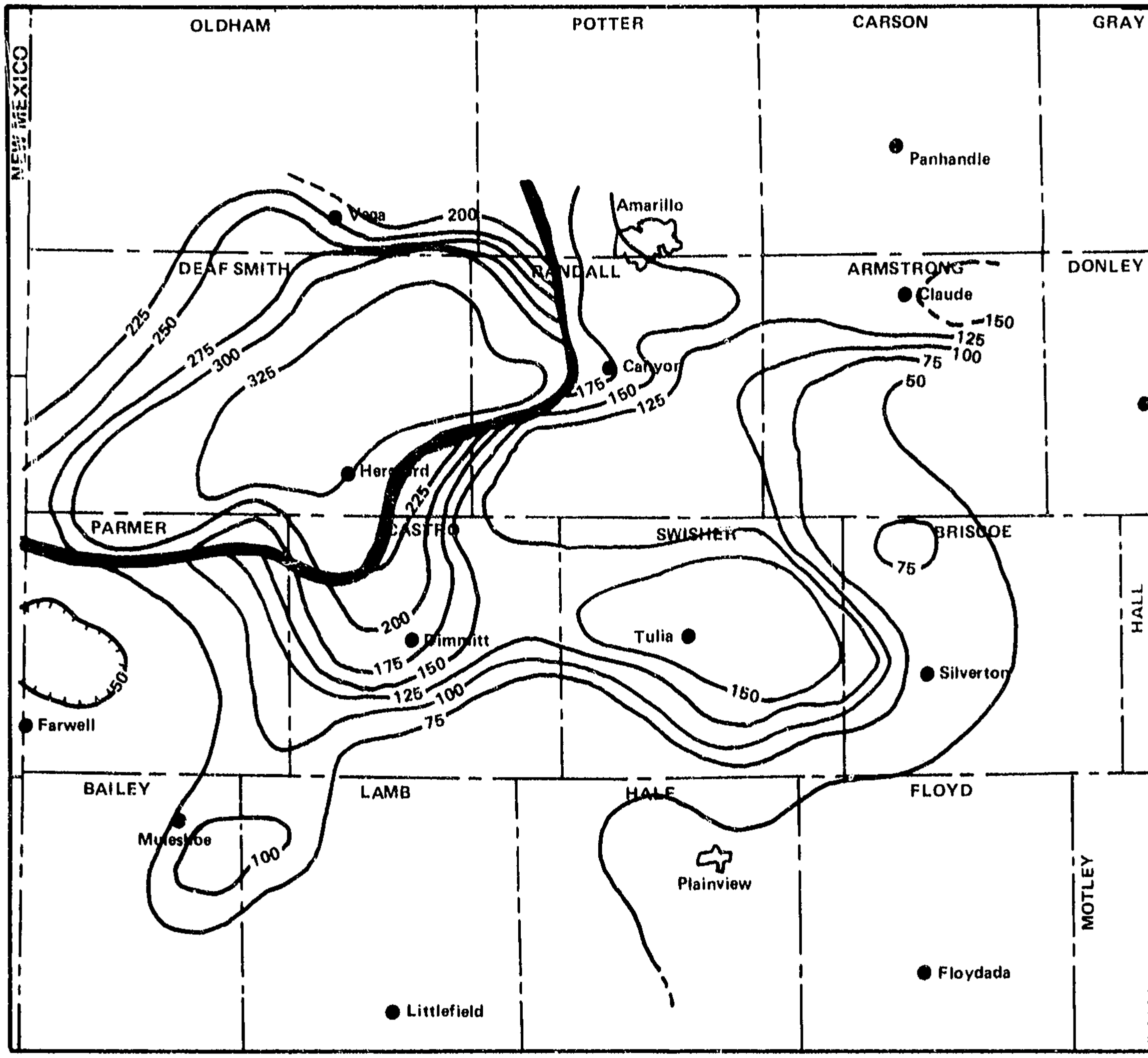
* Although other salt units exist, only the upper San Andres and the lower San Andres unit 5 and unit 4 salt have been discussed here because they are the only salt units which have characteristics which meet initial screening specifications (See Section 5.1.2).



Note: Northwest of the boundary, the Upper San Andres salt is present as a single unit.

Southeast of the boundary, the Upper San Andres salt splits into two units and only the thickness of the uppermost bed is contoured.

Contour interval: 25 ft

Salt thicknesses mapped include non-halite interbeds.

Figure 4-3.

Isopach Map, Salt, Upper San Andres Formation

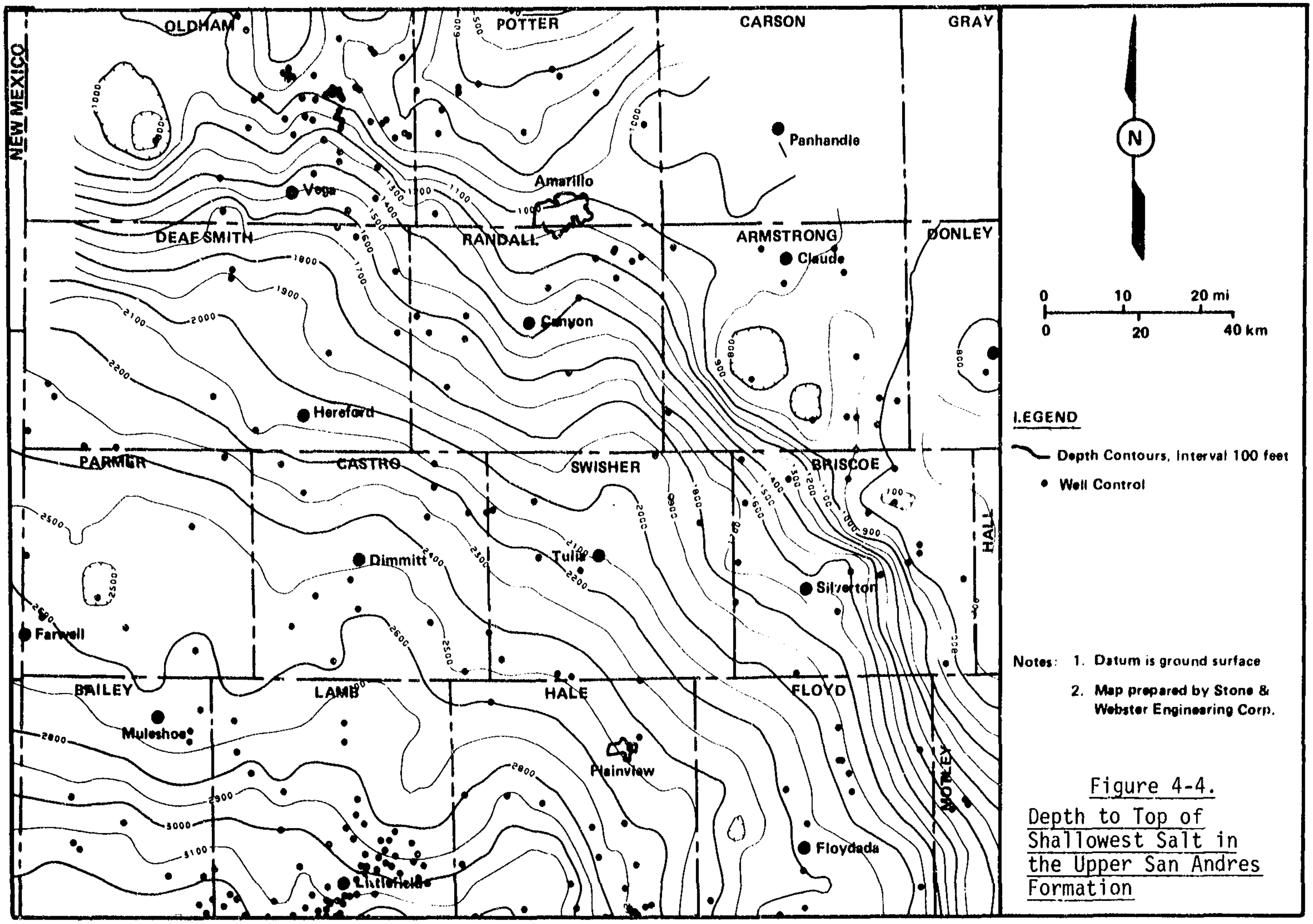


Figure 4-4.
Depth to Top of Shallowest Salt in the Upper San Andres Formation

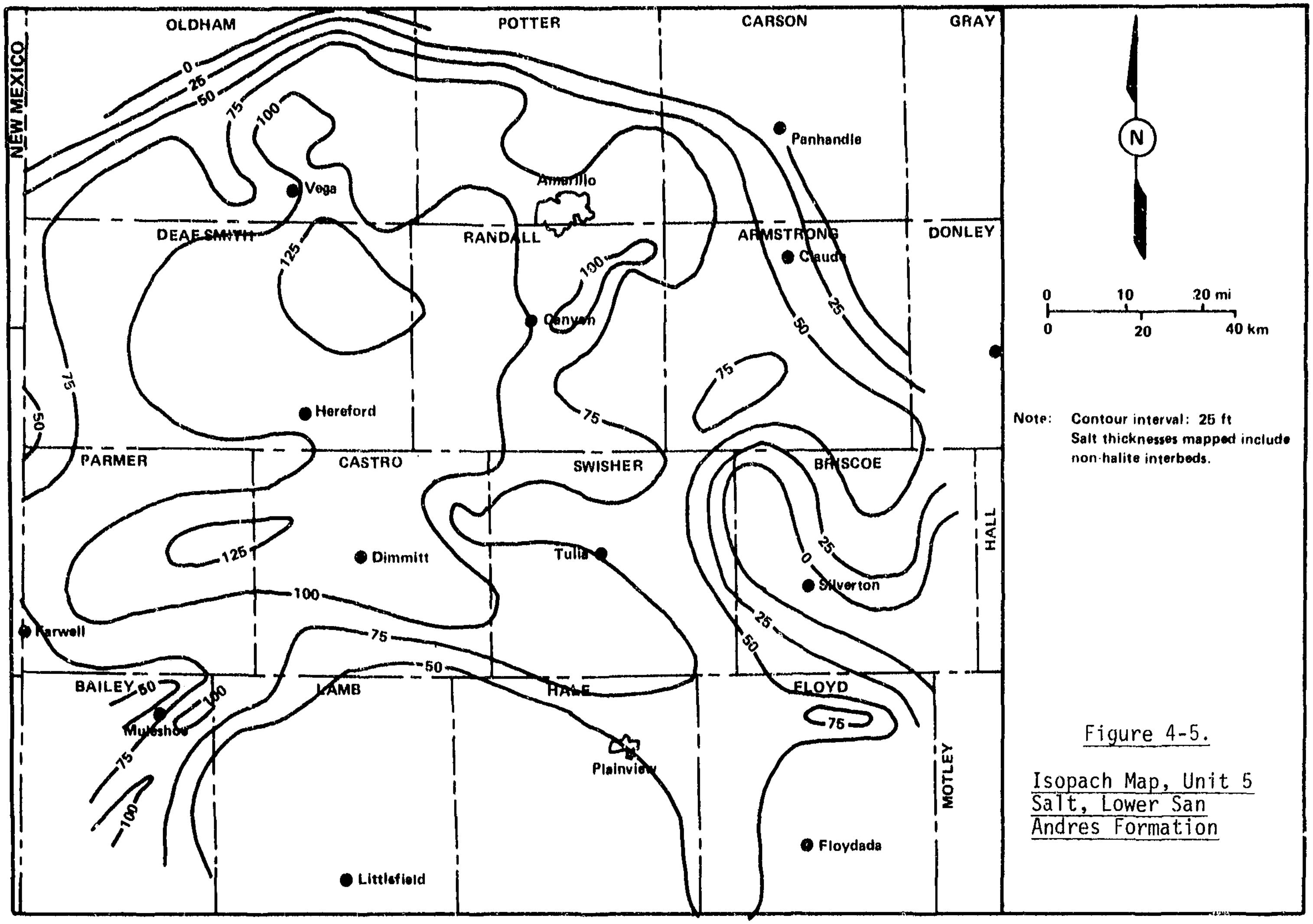


Figure 4-5.

Isopach Map, Unit 5 Salt, Lower San Andres Formation

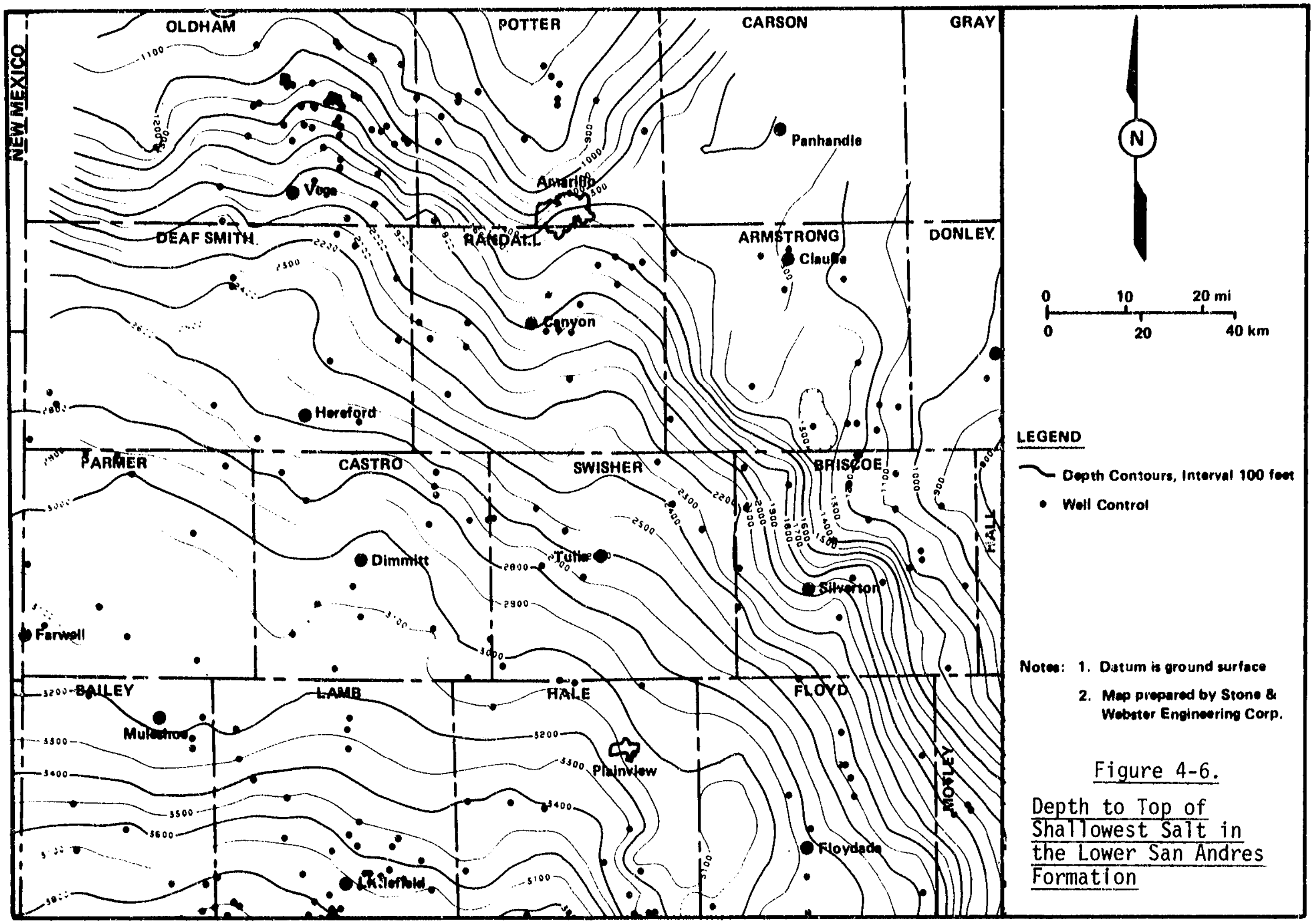
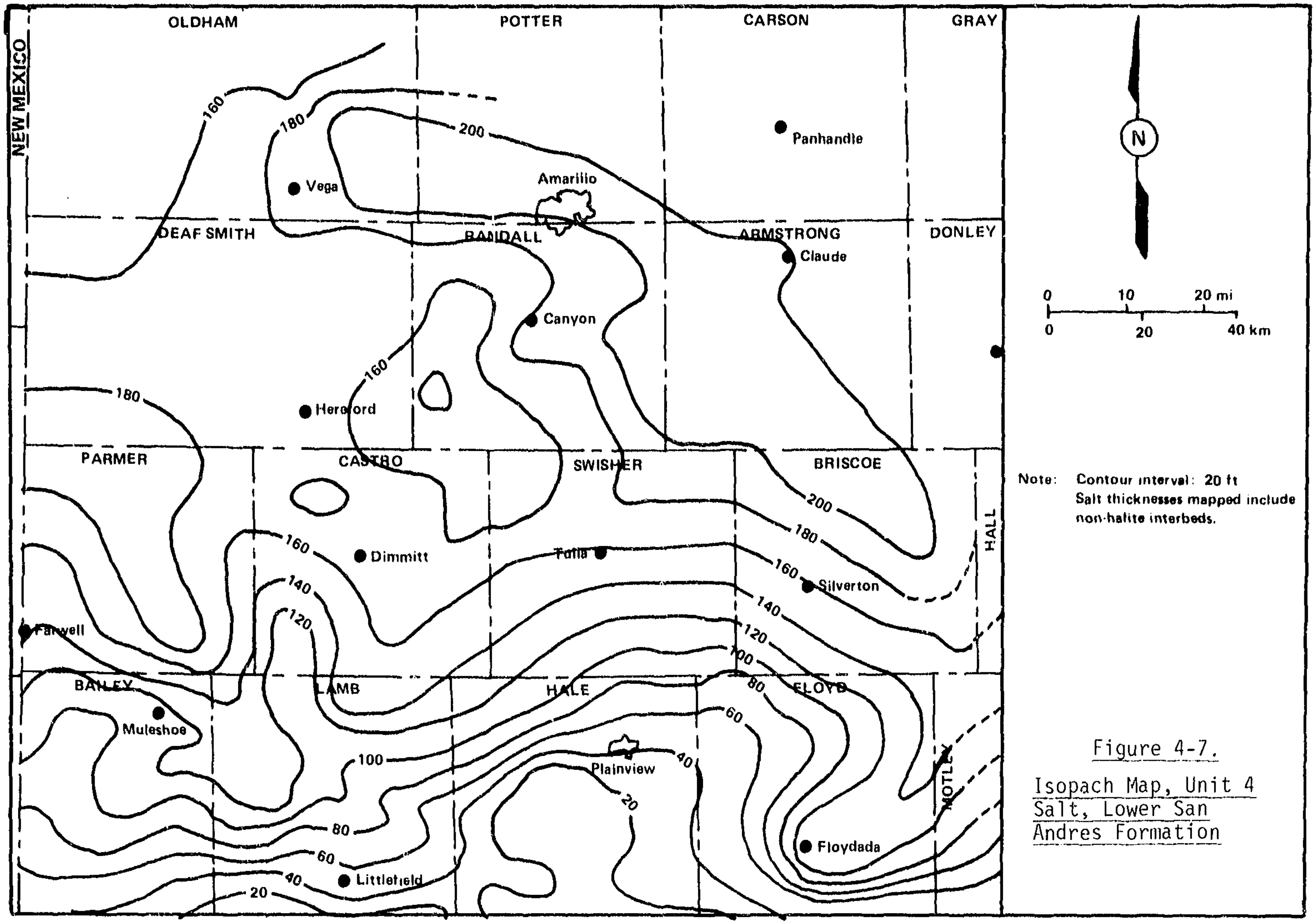


Figure 4-6.

Depth to Top of Shallowest Salt in the Lower San Andres Formation



Note: Contour interval: 20 ft
Salt thicknesses mapped include non-halite interbeds.

Figure 4-7.

Isopach Map, Unit 4 Salt, Lower San Andres Formation

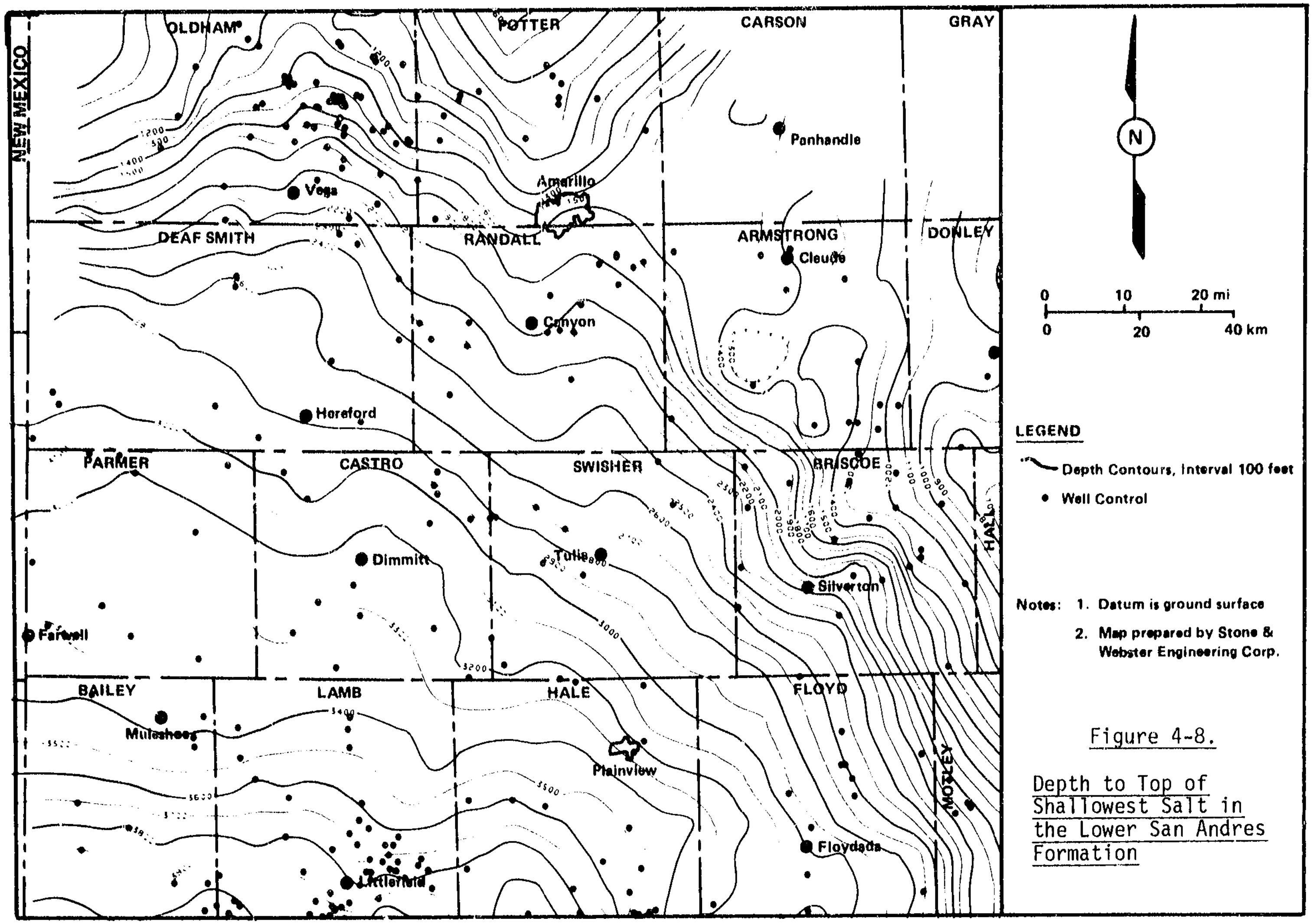


Figure 4-8.

Depth to Top of Shallowest Salt in the Lower San Andres Formation

The major post-Permian-age sediments are those of the Dockum Group and the Ogallala Formation. The Triassic Dockum Group, up to 244 m (800 ft) thick in the northwestern Palo Duro Basin, is a series of red to gray fluvial sandstones, siltstones, and mudstones. The Dockum fluvial system contains complex channel systems. It is a saline aquifer in some areas and secondary source of fresh water in others.

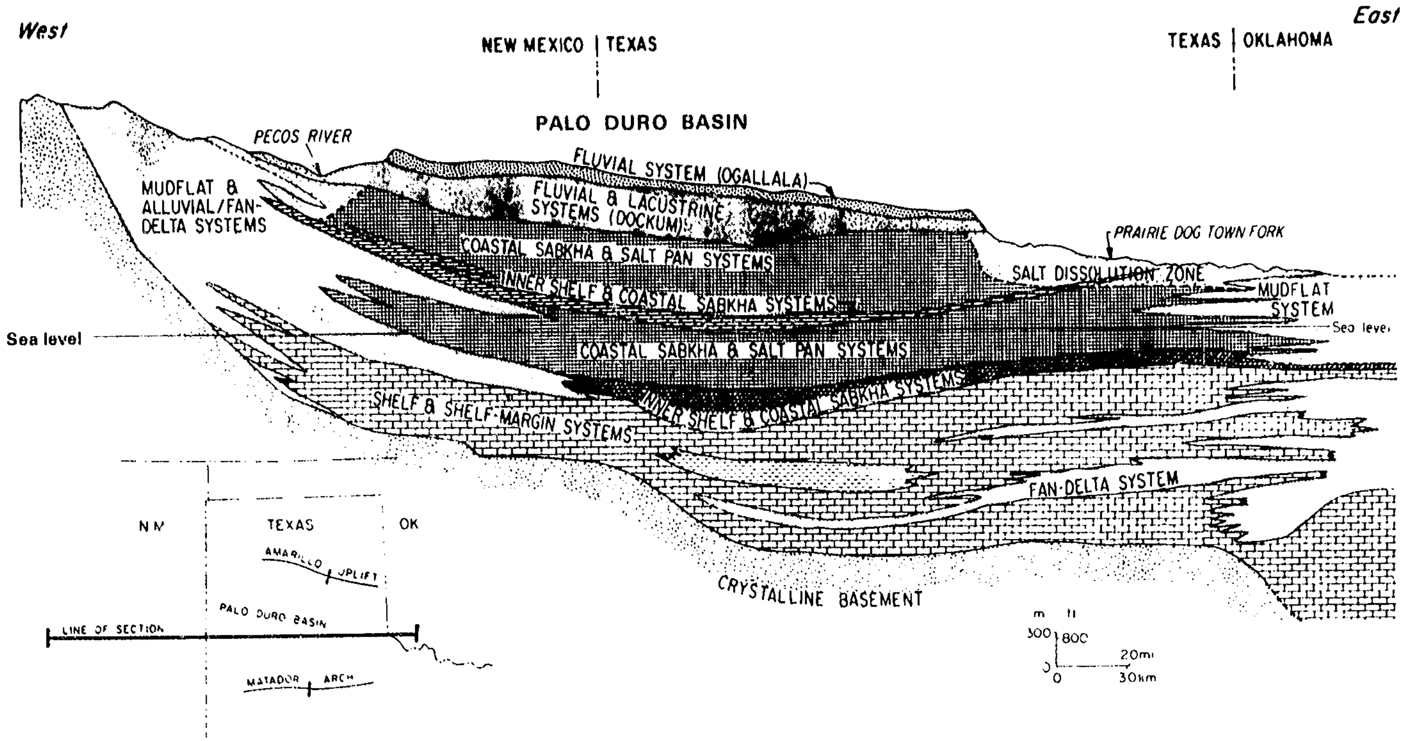
The Oqallala Formation (Tertiary) contains the major aquifer of the region. It consists of poorly cemented, fluvial, coarse to fine-grained sand with some gravel layers. Local zones of caliche up to 3 m (10 ft) thick occur near the surface of the Ogallala. Local eolian erosion and deposition have occurred throughout the area since deposition of the Ogallala.

4.1.3 Geohydrology

The study area can be divided into three hydrostratigraphic units. The uppermost unit consists of the Ogallala and Dockum Formations; the middle unit consists of the Permiam evaporites interbedded with shales, anhydrites, and carbonates. The lower unit is made up of the Wolfcamp carbonates, Pennsylvanian carbonates, and "granite wash" arkosic sandstone. The major hydrologic units and corresponding depositional systems of the Palo Duro Basin are illustrated in Figures 4-9 and 4-10.

The Ogallala aquifer is the major fresh-water aquifer in the Texas Panhandle; its characteristics are known and are described in detail by the Texas Department of Water Resources (Knowles et al, 1982). The Ogallala aquifer consists of very permeable sands and gravels intermixed with clays and caliche (Cronin, 1961) and has a saturated thickness of up to 91 m (300 ft) in the study area. The average hydraulic conductivity of the Ogallala is about 8 m/day (INTERA, 1984). On a regional basis, flow appears to be west to east-southeast (Simpkins, 1980), but on a local scale, flow can be completely reversed by heavy pumping due to irrigation, municipal, or industrial use.

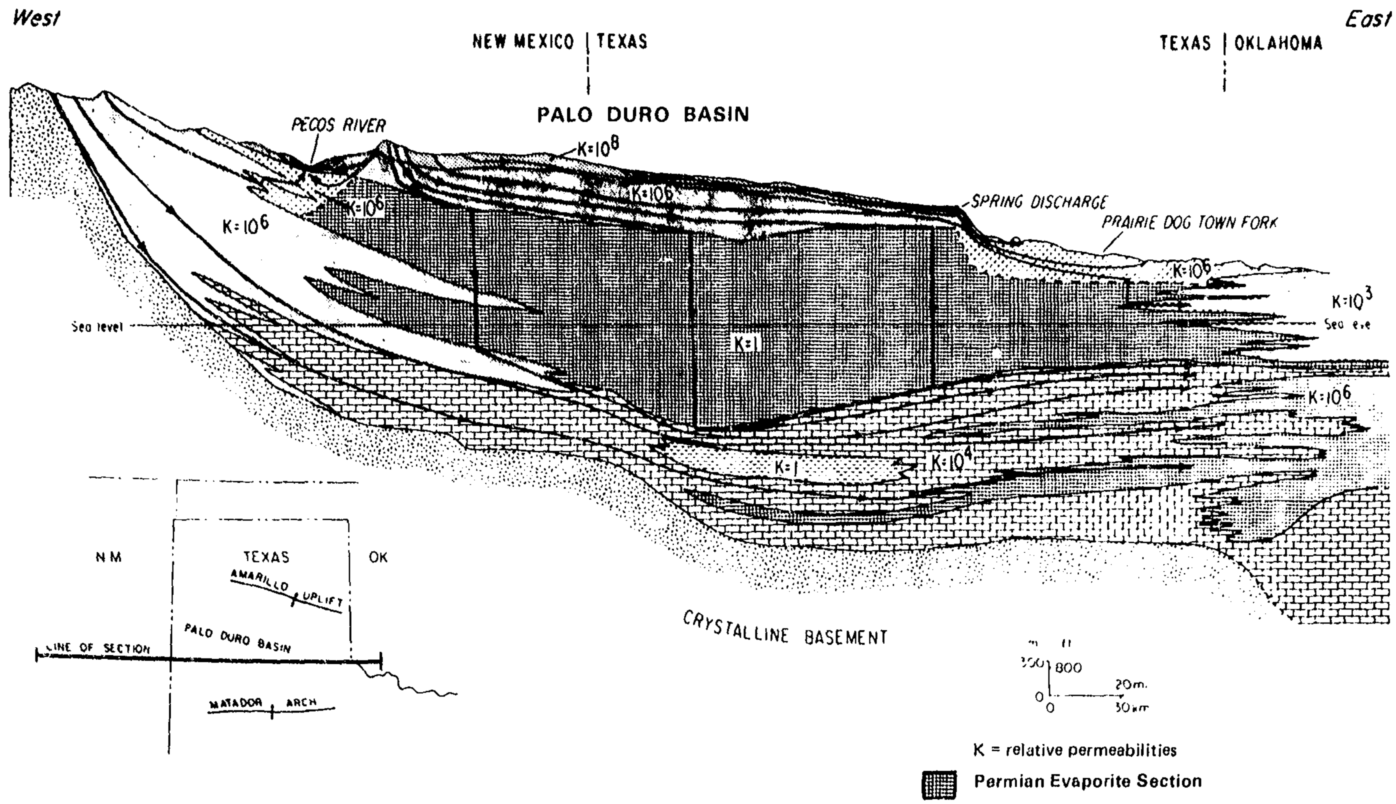
The Dockum consists mainly of siltstones, mudstones, and sandstones. Current evidence suggest the Dockum is hydraulically interconnected with the Ogallala, although, locally, siltstones may act as confining units. Thicknesses of up to 214 m (700 ft) exist in the study area. Poor transmitting capacity (average hydraulic conductivity 0.4 m/day (INTERA, 1984)) over much of the area has precluded its use as a water source. Where it is used, yields



Note: The coastal Sabkha and salt pan systems contain the salt beds being considered as potential host rock.

SOURCE: Bentley (1981)

Figure 4-9. Generalized East-West Cross Section of the Major Depositional Systems in the Palo Duro Basin



SOURCE: Bassett et al (1981)

Figure 4-10. Conceptualized Flow Lines Through the Major Hydrologic Units are much lower than from the overlying Ogallala and water becomes brackish with depth.

The Permian evaporite section consists of salt, anhydrite, dolomite, and shales totaling approximately 1,373 m (4,500 ft). This section acts as an aquitard throughout the basin and effectively separates the upper and lower hydrostratigraphic units. Interbedded dolomites may have the capability to transmit fluid, although drill stem tests to date have indicated that permeability is generally less than 0.3 mD; visual inspection of core also suggests that permeabilities are low.

The Wolfcamp Series consists of carbonates and shales with a total thickness of up to 610 m (2,000 ft) in the basin. Drill stem test data indicate an average permeability of about 1 mD (Bassett and Bentley, 1983). The fluid is a brine (150,000 ppm). Flow within the Wolfcamp appears to be to the east-northeast (Bentley, 1981), possibly to the Amarillo Uplift, although data are too sparse to predict exact flow paths. Velocity ranges from 3.4 to 32 cm/yr (∿1.2 to 13 in/yr) have been calculated using permeabilities and porosity data from Bentley (1981). The Wolfcamp is very heterogeneous and flow paths and rates can vary widely.

Interbedded Pennsylvanian carbonates and shales as much a 610 m (2,000 ft) thick underlie the Wolfcamp. Very little data are available on these units, but hydraulic properties of the Pennsylvanian carbonates maybe similar to those of the Wolfcamp carbonates.

Granite wash (arkosic) sandstones are thickest near the Amarillo Uplift and Oldham Nose, which are the source areas for the material. The sandstone units thin toward the center of the basin, and may or may not be continuous basinwide. Hydraulic conductivity varies greatly throughout the basin but generally falls within a range of 0.08 to 0.008 m (0.26 to 0.026 ft) per day (INTERA, 1984).

Pressure measurements taken from drill stem test data suggest a general downward potential gradient from the Ogallala to the Wolfcamp, and continued downward potential through the Pennsylvanian carbonates to the granite wash. Locally, the potential gradient between the granite wash and Wolfcamp may be reversed, but in all cases a downward potential gradient exists through the Permian salt strata (S&W, 1983).

Table 4-2. Rates of Horizontal and Vertical Salt Dissolution

Basin	Mean annual solute load $\times 10^5 ft^3$	Annual rates of horizontal dissolution: Mean ft/yr	Mean cm/yr	Max ft/yr	Min ft/yr	Annual rates of vertical dissolution: Mean $\times 10^{-5}$ ft/yr	Mean $\times 10^{-3}$ cm/yr	Max $\times 10^{-5}$ ft/yr	Min $\times 10^{-5}$ ft/yr
1A Canadian River (Tascosa)	(5 years)** 4.460	0.00189	0.0576	0.00246	0.00132	1.0499	3.2001	1.367	0.735
1B Canadian River (Amarillo)	(5 years) 6.9542	0.00188	0.0575	0.00239	0.00081	1.0312	3.1431	1.306	0.452
1C Canadian River (Canadian)	(3 years) 7.9221	0.00186	0.0568	0.00251	0.00118	0.7665	2.3362	1.072	0.484
3 Salt Fork of the Red River (Wellington)	(9 years) 2.119	0.00621	0.1893	0.01265	0.00154	0.7405	2.2571	1.509	0.183
4A Prairie Dog Town Fork of the Red River (Lakeview)	(9 years) 24.1188	0.00963	0.2935	0.02337	0.00376	5.6674	17.2742	11.926	2.637
4C Little Red River (Turkey)	(9 years) 12.851	0.25353	7.7276	0.47850	0.13238	27.1130	82.6404	51.172	14.157
4D Prairie Dog Town Fork of the Red River (Childress)	(9 years) 119.5366	0.08485	2.5862	0.01925	0.00564	17.7560	54.1203	29.142	11.816
5A North Pease River (Childress)	(5 years) 4.3677	0.01077	0.3283	0.01607	0.00758	1.7911	5.4593	2.672	1.261
5B Middle Pease River (Paducah)	(5 years) 0.5515	0.00100	0.0305	0.00248	0.00018	0.2027	0.6177	0.500	0.037
5C Pease River (Childress)	(8 years) 32.5842	0.02408	0.7339	0.03318	0.01737	5.8465	17.8200	8.056	4.216
6-10 Area includes basins 6-10	(5-9 years) 115.5136	0.1249	3.8070	0.1735	0.0846	30.8860	94.1405	42.910	20.926
6 North Fork Wichita River (Paducah)	(8 years) 19.8165	2.6808	81.7108	3.2283	2.1093				
8A South Fork Wichita River (Guthrie)	(6 years) 13.6156	0.2686	8.1870	0.3115	0.2229				
10B Salt Fork Brazos River (Peacock)	(9 years) 25.0487	0.0327	0.9967	0.0672	0.0087				
10C Croton Creek (Jayton)	(9 years) 6.3678	0.0635	1.9355	0.1352	0.0218				
10D Salt Fork Brazos River (Aspermont)	(9 years) 70.1657	0.07216	2.1994	0.1061	0.0447				

**Number of years of data.

SOURCE: From Gustavson Finley and McGillis, 1980.

4.1.4 Salt Dissolution

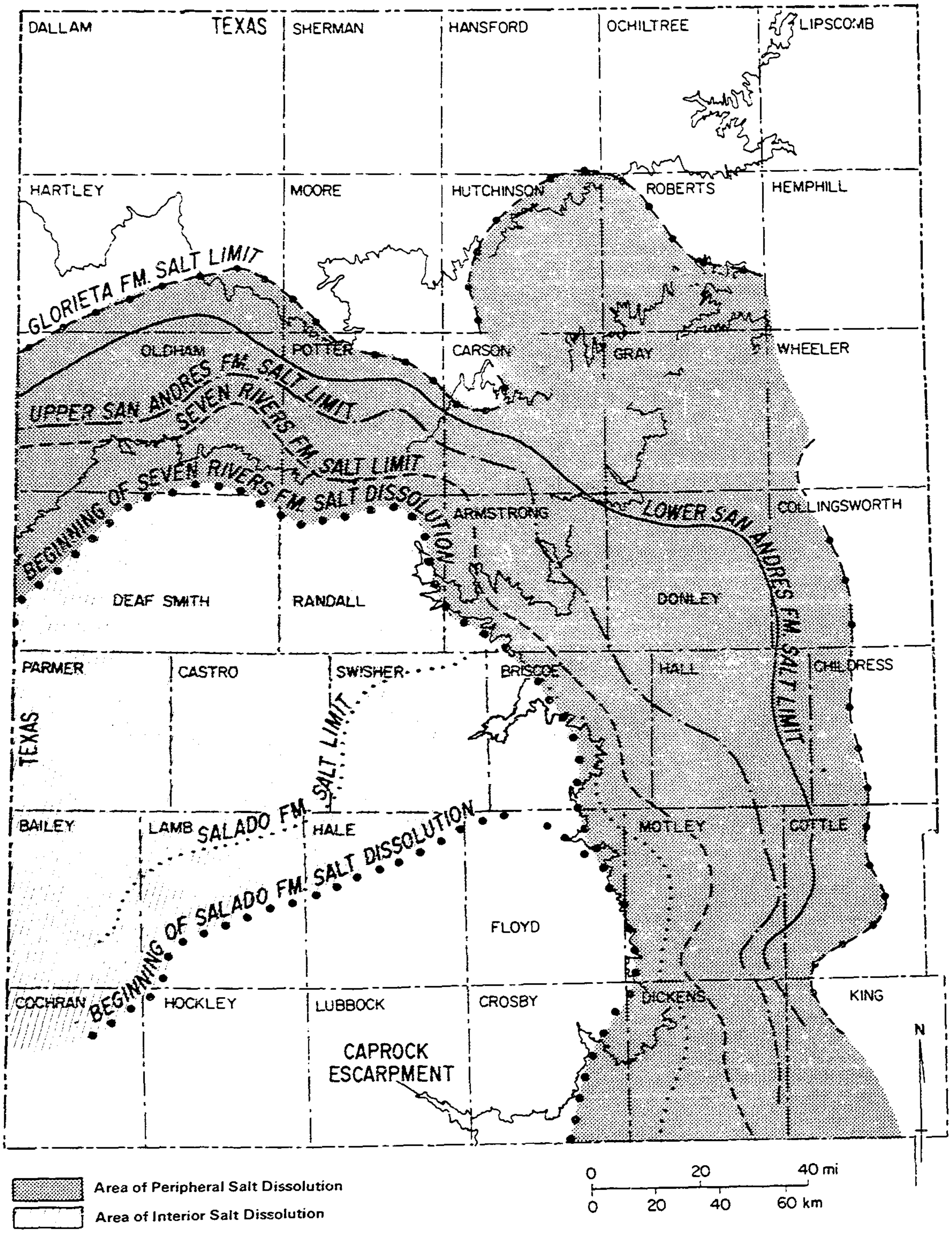
Salt dissolution phenomena in the Panhandle region can be divided into two categories: peripheral and interior. Peripheral dissolution occurs adjacent to the caprock escarpments, where salt is exposed to shallow hydrologic and geomorphic processes. Interior dissolution occurs or has occurred basinward, beneath the Southern High Plains surface.

Gustavson et al (1980) estimated peripheral salt dissolution rates based on the solute load of streams draining the dissolution zones along the northern and eastern edges of the southern High Plains. A maximum mean annual rate of lateral dissolution of 82 cm/yr (2.68 ft/yr) was calculated from water quality measurements at the North Fork of the Wichita River at Paducah, Texas. A summary of similar estimates is presented in Table 4-2.

The estimated extent of dissolution along the northeastern flank of the Palo Duro Basin was interpreted by the BEG (Gustavson, 1980) and is summarized in Figure 4-11. A revised interpretation (Gustavson and Finley, in press) and recent core examination (Well Completion Reports for G. Friemel #1 and Detten #1 Boreholes: S&W, 1983) suggest that salt dissolution in the Seven Rivers Formation may have occurred farther south than suggested in Figure 4-11. The age, extent, and significance of interior dissolution are the subjects of ongoing investigations.

4.1.5 Seismicity/Tectonics

The study area is characterized by generally low levels of seismicity. However, the historical earthquake record is short and based mostly on intensity reports; the greatest intensities reported within the Texas Panhandle are Modified Mercalli intensity VI. Most faults and folds of the region (Figure 4-12) are associated with uplift of Precambrian basement rock which occurred at the basins' margins during the Pennsylvanian, prior to salt deposition. A recently identified fault or fault zone trending from Swisher County northwestward through Castro County and into central Deaf Smith County is the subject of continuing structural and stratigraphic investigations. There appears to have been little tectonic activity since the end of Permian deposition, other than periods of regional uplift and downwarping, and faulting of Triassic age in the vicinity of the Amarillo Uplift. The area is



SOURCE: Modified from Gustavson, et al, 1980; and Gustavson and Finley, in preparation.

Figure 4-11. Extent of Salt Dissolution

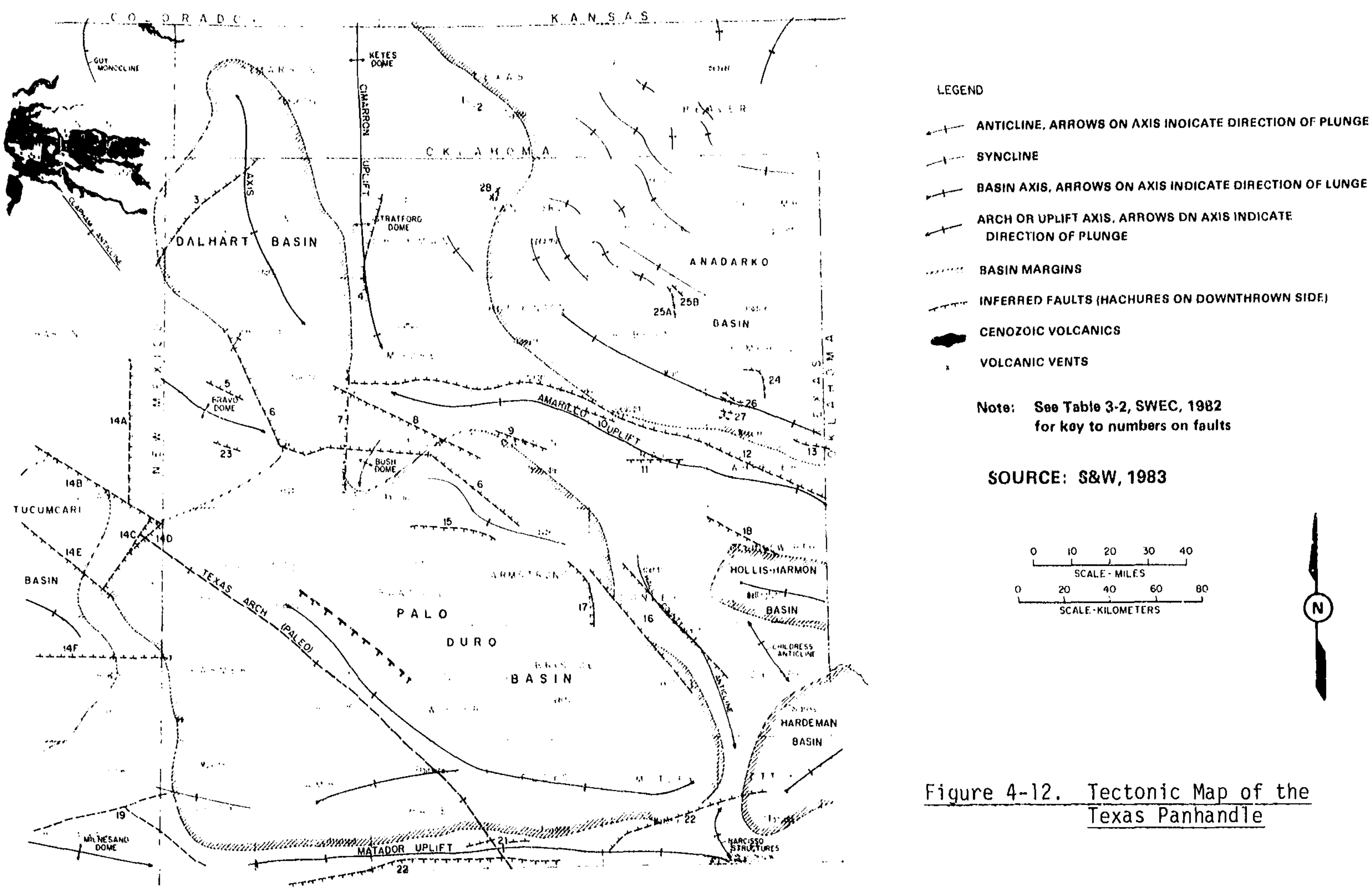


Figure 4-12. Tectonic Map of the Texas Panhandle

located in a zone where there is a horizontal acceleration in rock expected to be less than 4 percent of gravity; there is a 90 percent chance that no greater acceleration will be experienced in 50 years (Figure 4-13; Algermissen and Perkins, 1976).

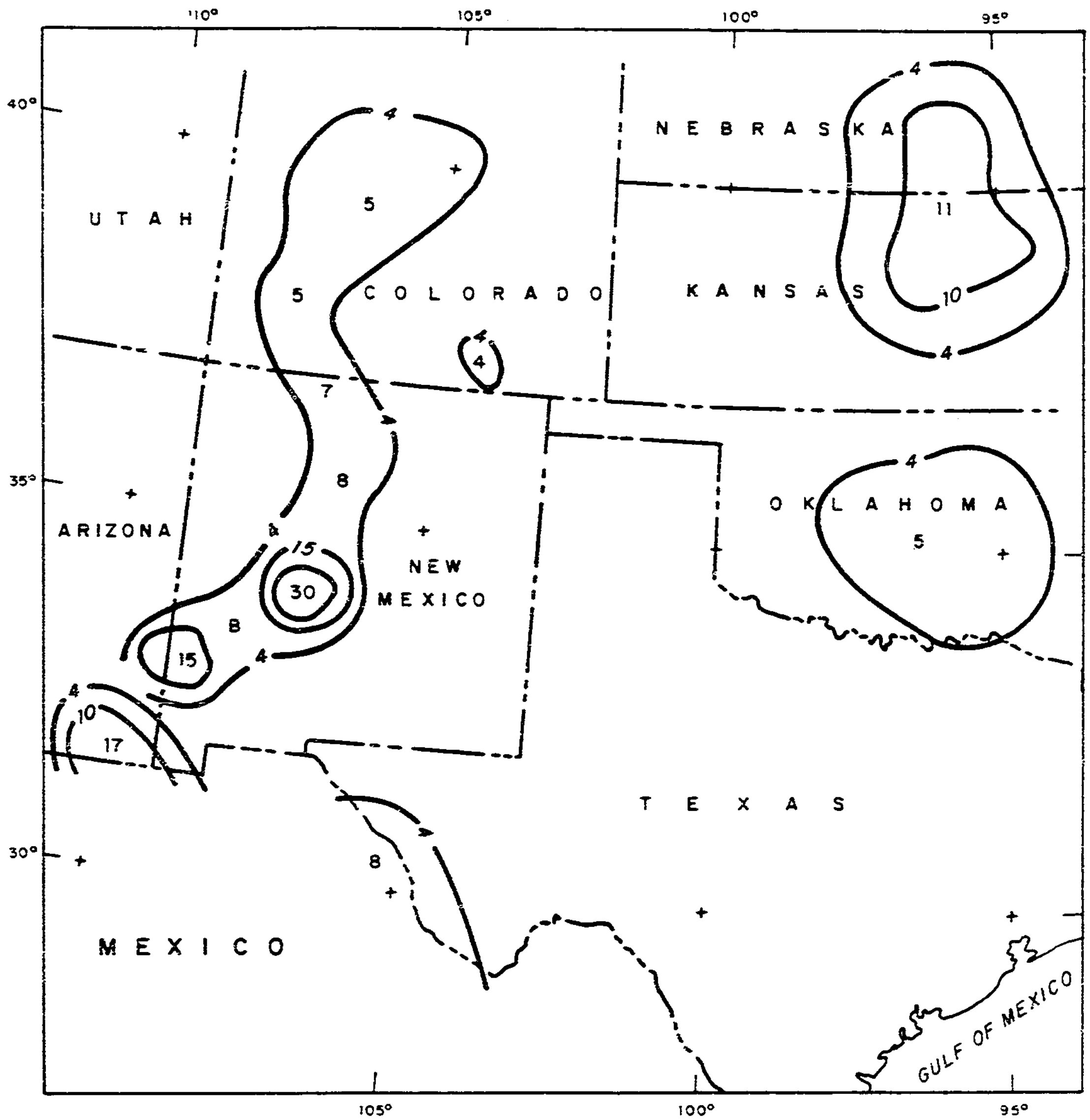
4.1.6 Resources

Three categories of the study area's natural resources are discussed below: oil and gas (including helium and carbon dioxide), mineral resources currently mined, and potential mineral resources.

4.1.6.1 Oil and Gas Resources

The Texas Railroad Commission (TRC) Annual Report for 1979 (TRC, 1980) lists about 600 gas fields and about 400 oil fields in the Texas Panhandle. Nearly all the gas and oil fields are in the northeastern part of the Panhandle region and are associated with the Anadarko Basin, the Amarillo Uplift, and the Cimarron Uplift; most fields are in the Anadarko Basin (Figure 4-14). Gas and oil fields in other parts of the region are widely scattered, most being along the basin's margins or on its surrounding uplifts. The only oil and gas fields in the central portions of the Palo Duro and Dalhart Basins are a cluster of fields in Oldham County and southwest Potter County, and the inactive Rehm field in Hartley County. The Marathon #1 Mayfield discovery (1982) produced oil in westcentral Briscoe County.

Although the Palo Duro and Dalhart Basins apparently meet most of the requirements for generating and entrapping hydrocarbons (Hartman and Woodard, 1971), very little oil or gas has been found in them despite numerous, widespread wildcat wells. BEG has analyzed stratigraphic-depositional systems and shelf margin evolution in the Palo Duro and Dalhart Basins. The studies show that potential reservoirs are present in fan delta sandstone, shelf margin dolomite, and high constructive delta sandstone (Dutton, 1980; Handford and Dutton, 1980). Dutton (1980) has also studied potential source rocks of Pennsylvanian and Permian age in the Palo Duro Basin to determine whether they contain sufficient organic matter for generating commercial quantities of hydrocarbon and whether the disseminated organic matter was ever sufficiently heated during burial to generate hydrocarbon from kerogen. Dutton et al



NOTES:

1. CONTOURS ENCLOSE AREAS WITH HORIZONTAL ACCELERATION IN ROCK EQUAL TO OR GREATER THAN NUMBER ON THE CONTOUR.
2. EXPRESSED AS PER CENT OF GRAVITY WITH 90% PROBABILITY OF NOT BEING EXCEEDED IN 50 YEARS.

Figure 4-13. Seismic Hazard Map

SOURCE: Algermissen and Perkins, 1976

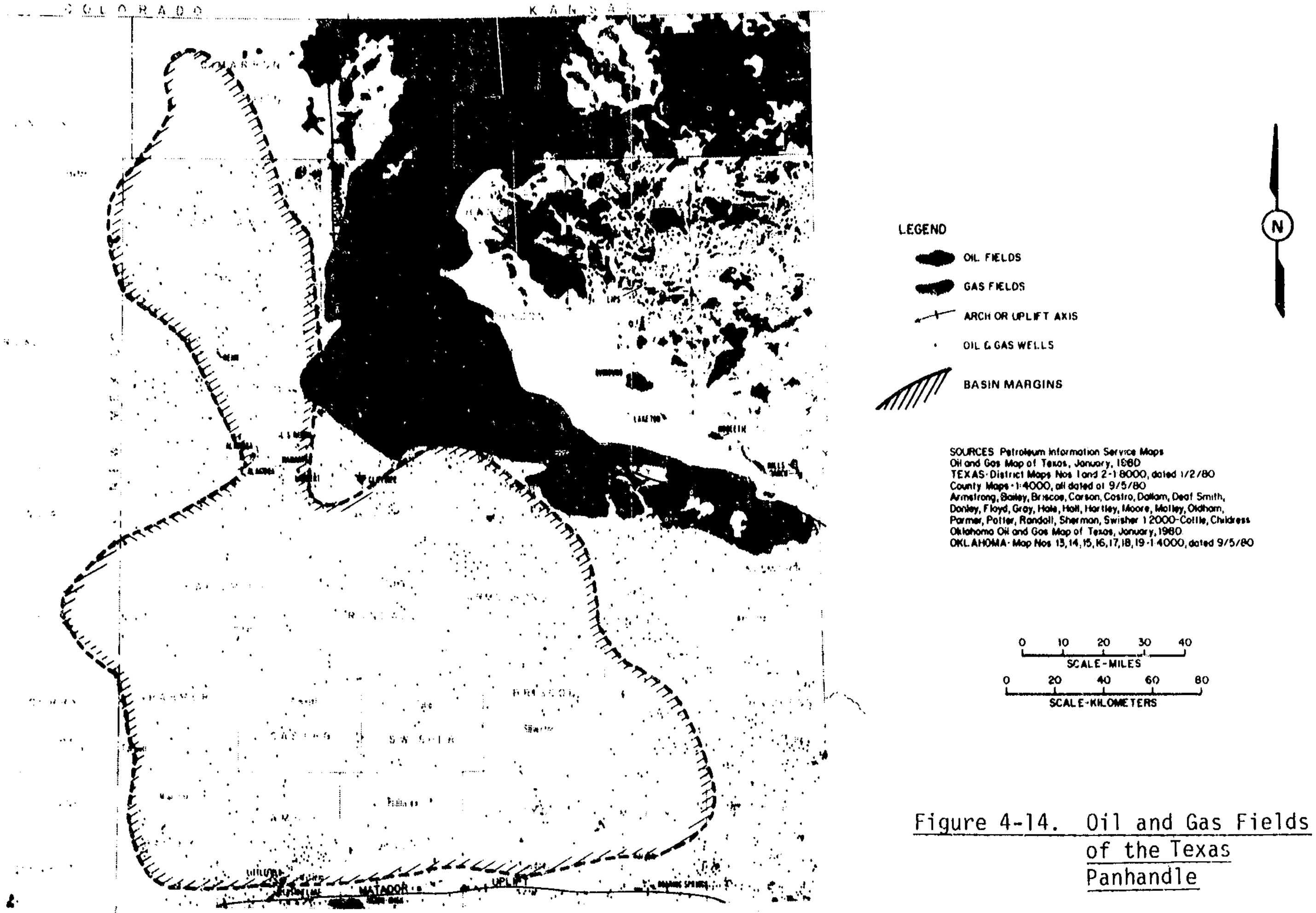


Figure 4-14. Oil and Gas Fields of the Texas Panhandle

(1982) present an optimistic evaluation of the oil and gas resource potential of the Palo Duro Basin.

4.1.6.2 Mineral Resources Currently Mined

Bulk materials are being extracted at numerous, widely scattered open pits and quarries in the Panhandle region. These materials include sand and gravel, caliche, dolomite, and limestone. Figure 4-15 shows the locations of active and inactive mining operations as well as mineral occurrences and prospects which have no history of significant production. Solution-mining operations, such as a previously operating salt-brining operation in Deaf Smith County near Hereford, will be avoided during site screening.

A computer-generated list of Texas mineral producers (Garner et al, 1980) indicates that only the following 11 counties, of the 32 in the Texas Panhandle, now have active production of the above materials: Armstrong, Cottle, Gray, Hansford, Hutchinson, Lamb, Moore, Motley, Oldham, Potter, and Swisher. The data in the list are preliminary.

4.1.6.3 Potential Mineral Resources

Potential mineral resources in the Panhandle area include copper, uranium, coal, potash, gypsum, and salt. The locations of the mineral occurrences are shown in Figure 4-15.

Copper. No copper mineralization has been found in the Palo Duro Basin (Handford, 1979), although there are some similarities between the Permian depositional systems in the Palo Duro Basin and depositional systems elsewhere that contain copper mineralization. Handford (1979) suggests that the failure to find copper mineralization in the Palo Duro Basin might be due to depth of potential deposits, lack of outcrops, and insufficient mineral exploration.

Uranium. More than 50 uranium occurrences have been reported in the Panhandle region in strata that range in age from Pleistocene to Permian. Most uranium occurrences are in strata of the Dockum Group of Triassic age, where mineralization is in terrestrial sandstone, siltstone, and shale beds. Uranium resources have not been developed in the Panhandle region. Neither the Mineral Map of Oklahoma, 1969, nor the Mineral Resources of Texas Map (BEG, 1979) shows any active or inactive uranium mines in the Panhandle region.

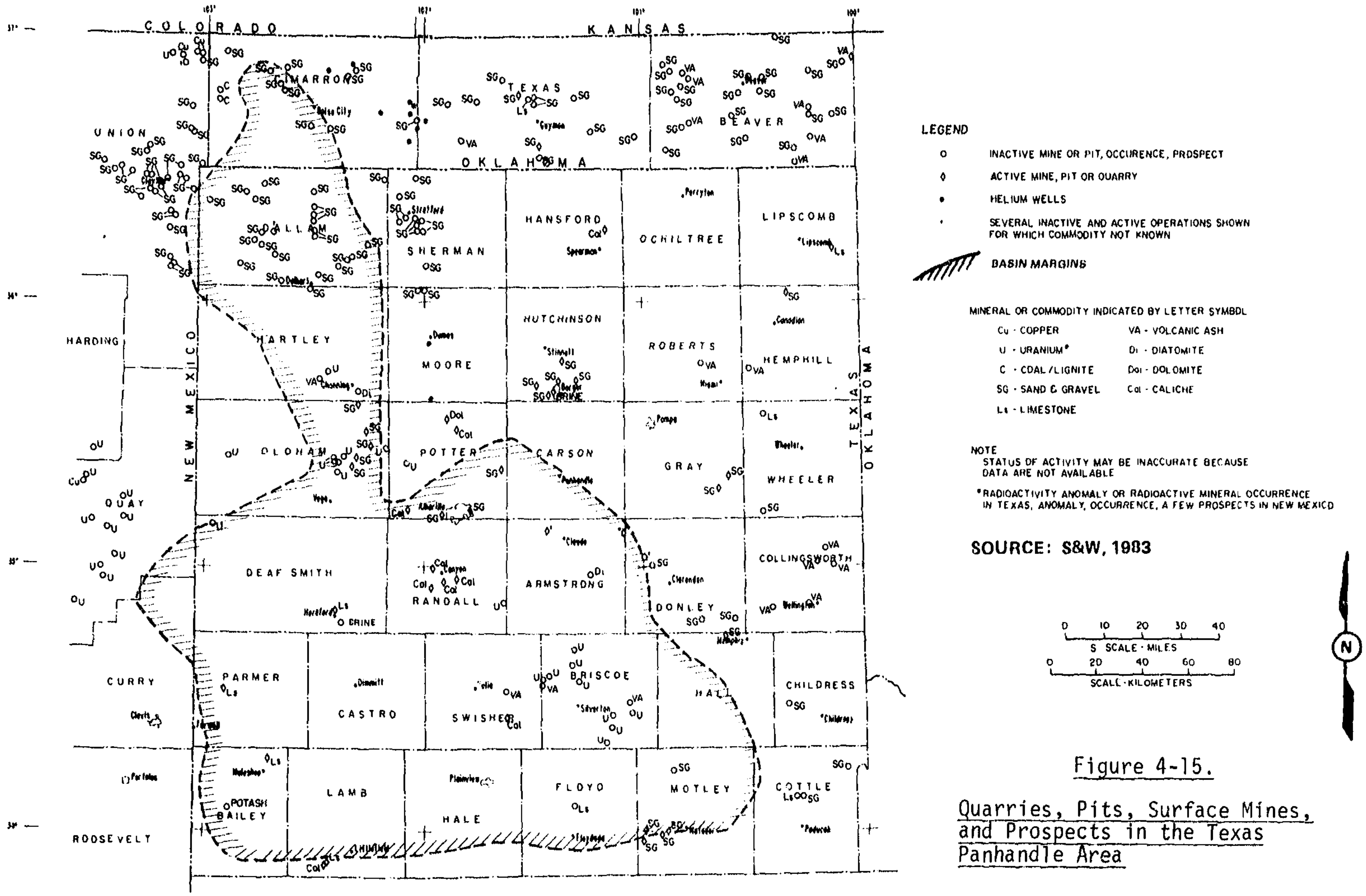


Figure 4-15.

Quarries, Pits, Surface Mines, and Prospects in the Texas Panhandle Area

Potash. Potash was reported in wells drilled in Potter, Randall, and Oldham Counties (Cunningham, 1934). Subsurface correlation and mapping of the Permian evaporites have not identified potash deposits in the Palo Duro Basin (Handford, 1979).

Coal. Coal occurs in the Panhandle region, but there is no history of production or indication that the beds are of any commercial value. The coal beds are thin and occur at depths of up to several thousand feet.

Salt and Gypsum. Although data as to the quanitity of salt in the Panhandle region are not available, the resources are known to be substantial. Despite its abundance, the only salt production in the Panhandle region is from brine wells of the Phillips Petroleum Company at Borger in Hutchinson County, Texas, and from a currently inactive brine well located near Hereford in Deaf Smith County (Figure 4-15).

Gypsum resources in the Panhandle area are also great but have not been developed. The nearest production is just east of the study region in Oklahoma and in Hardeman County, Texas, where the Georgia Pacific Corporation operates a surface mine. The greatest potential for future production of gypsum is from the southeast part of the Panhandle area where the Permian formations crop out in Childress, Hall, Collingsworth, Briscoe, Donley, and Wheeler Counties (BEG, 1979).

4.2 ENVIRONMENT

4.2.1 Demography and Socioeconomics

The Dalhart Basin area, in the northwest corner of the Texas Panhandle, is mostly rural and sparsely populated. The largest population center, the town of Dalhart, had a 1980 population of 6,854. The 1980 populations of the other incorporated communities in the basin were Texline, 477, and Channing, 304 (USDC, 1980). Projections by the U.S. Water Resources Council (1974) indicate that the population of the region is expected to decline in the future.

The Palo Duro Basin area, in the north-central section of the Texas Panhandle, is also sparsely populated. Its largest population centers are Hereford (15,853), Plainview (22,187), and Canyon (10,724). Portions of the urban area surrounding Amarillo also extend into the basin. The city of Amarillo had a 1980 population of 149,230. The city of Lubbock (1980 population 173,979) is located just south of the basin. Amarillo and Lubbock are both classified as Standard Metropolitan Statistical Areas (SMSA) as defined by the U.S. Census Bureau.* The respective SMSA populations are 173,699 and 211,651.

Other communities located in the Palo Duro and Dalhart Basins are shown in Figure 4-16. Population centers of 2,500 or more range in density from 1,235.0 (Littlefield, Lamb County) to 3,934.0 persons per square mile (Dumas, Moore County). This compares with a county-wide density range of 1.6 persons per square mile in Oldham County to 107.4 persons per square mile in Potter County. In general, however, county densities in this area are less than 19.0 persons per square mile (See Table 4-3).

The economic base of the Dalhart Basin area is limited because of the small population. Manufacturing is the largest employment sector, accounting for about 22 percent of total employment. Per capita income for the five counties wholly or partly included in the basin averaged $4,836 in 1975. Projections by the U.S. Water Resources Council (1974) indicate that per capita income should increase 73 percent from 1980 to 2000 and remain approximately 94 percent of the United States average.

The Palo Duro Basin area has a more diverse economic base. The civilian labor force for the 18-county study area was 148,778 in 1978, with over 25 percent of the workers in the manufacturing sector (USDC, 1979d). There is a wide range in per capita income between the urban areas adjacent to Amarillo and the more rural counties. In 1975 the estimated average per capita income was $4,384 for all counties in the Basin (USDC, 1979d). Between 1980 and 2000 the per capita income is forecast to increase approximately 70 percent (U.S. Water Resources Council, 1974).

4.2.2 Land Use

Agriculture is the most important land-use activity within the Dalhart Basin area. Irrigation cropland comprises 46 percent of the area, whereas 3 percent is nonirrigated or dry. Approximately 50 percent of the Dalhart

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* An SMSA is one or more contiguous counties containing at least one city of 50,000 inhabitants or more. Additional counties have to meet various criteria for metropolitan character and of social and economic integration with the central city in order to be included within an SMSA.

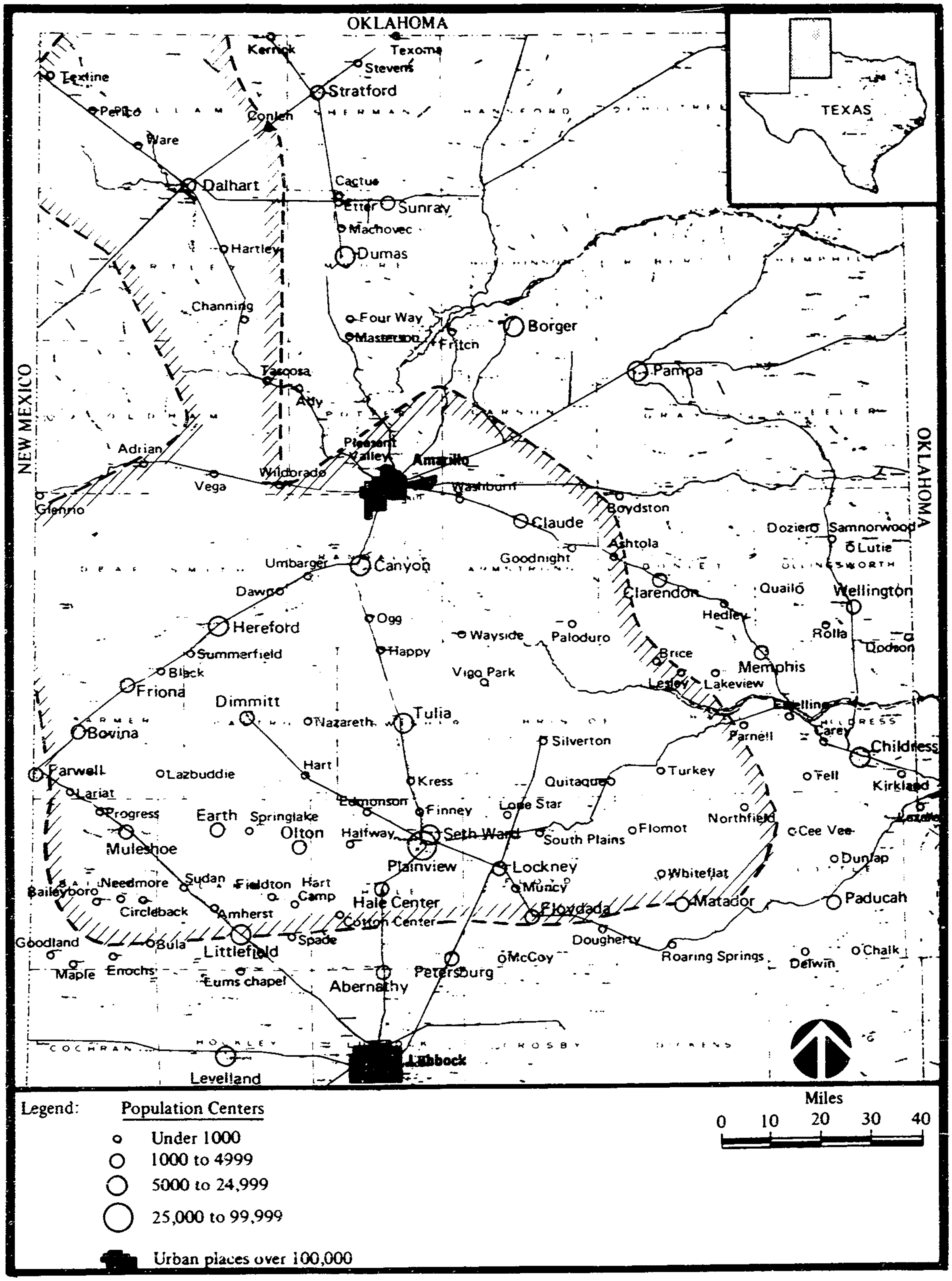


Figure 4-16. Population Centers and Urban Places

Table 4-3. 1980 Population Density of Counties and Communities of 2,500 or More in the Palo Duro and Dalhart Basin Study Areas*

Dalhart Basin		Palo Duro Basin	
County/ Communities	Population Density (persons per square mi)	County/ Communities	Population Density (persons per square mi)
Dallam Co.	4.3	Armstrong Co.	2.2
Dalhart	2016.0	Bailey Co.	9.9
Hartley Co.	2.7	Muleshoe	1937.0
Moore Co.	18.3	Briscoe Co.	2.9
Dumas	3934.0	Castro Co.	12.1
Oldham Co.	1.6	Dimmitt	2510.0
Sherman Co.	3.4	Childress Co.	9.8
		Childress	1293.0
		Collingsworth Co.	5.1
		Wellington	2174.0
		Cottle Co.	3.3
		Deaf Smith Co.	14.0
		Hereford	2831.0
		Donley Co.	4.2
		Floyd Co.	9.9
		Floydada	2621.0
		Hale Co.	38.4
		Abernathy	2640.0
		Plainview	2673.0
		Hall Co.	6.4
		Memphis	1862.0
		Lamb Co.	18.2
		Littlefield	1235.0
		Motley Co.	2.0
		Parmer Co.	12.8
		Friona	2721.1
		Potter Co.	107.4
		Randall Co.	81.5
		Amarillo	2144.0
		Canyon	2681.0
		Swisher Co.	10.8
		Tulia	2036.0

Source: U.S. Department of Commerce, 1982

* Community densities were calculated by using 1980 population data and 1970 land area information. Land area data are not available for population centers under 2,500 people.

Basin area is rangeland (NUS, 1982). Areas of special interest include the 37,229-hectare (92,000-acre) Rita Blanca National Grassland, Rita Blanca Lake Park [506 hectares (1,250 acres)], Cal Farley's Boys Ranch [1,010 hectares (4,100 acres)], and the ~12-hectare (30-acre) XIT Springs (Buffalo Springs) (Texas Parks and Wildlife Department, 1979). Additional potentially sensitive or conflicting land uses within the basin include five historic structures, numerous small airports or landing strips, and two military air-training routes.

Agriculture is also the most important land-use activity in the Palo Duro Basin area. Irrigated cropland constitutes 60 percent of the basin, only 3 percent is nonirrigated or dry. Approximately 35 percent of the Palo Duro Basin is rangeland (NUS, 1982). Areas of land use of special interest include Palo Duro Canyon State Park [6,499 hectares (16,046 acres)]; the Buffalo Lake National Wildlife Refuge [3,104 hectares (7,664 acres)]; Muleshoe National Wildlife Refuge [2,353 hectares (5,809 acres)]; Caprock Canyon State Park [5,489 hectares (13,554 acres)]; Los Largos Canyon [9,070 hectares (22,400 acres)]; and the Matador Wildlife Management Area [11,414 hectares (28,183 acres)] (Texas Parks and Wildlife Department, 1979). Additional potentially sensitive or conflicting land uses include eight sites listed in the National Register of Historic Places; 15 sites designated by the Texas Historical Commission; more than 30 airports, including one tower-controlled facility; and two military air-training routes (NUS, 1982).

Extensive portions of the Palo Duro and Dalhart Basin area are classified as prime farmland if irrigated. The Ogallala aquifer is the source of nearly all irrigation water. This aquifer is being depleted rapidly, and within 50 years may be producing on the order of 50 percent less water (Knowles et al, 1982).

4.2.3 Atmosphere

The climate of the study area is generally semiarid; the area is located between the dry desert climate to the west and wet humid climate to the east and southeast. The Rolling Plains area exhibits the characteristics of a semiarid climate, but receives more precipitation, on the average, than the remainder of the area. Precipitation, evaporation, and temperature gradients do not coincide with the eastern escarpment; it is not a climatic boundary.

Normal yearly precipitation ranges from about 41 cm (16 in.) in the western part of the Palo Duro Basin area to 58 cm (23 in.) in the eastern portion. Precipitation in the Dalhart Basin area averages 52 cm (20.3 in.) per year; however, large variations in the annual precipitation are common. For example, annual precipitation in the Dalhart Basin area has ranged from a low of 24 cm (9.56 in.) to a high of 101 cm (39.75 in.). In the Palo Duro Basin area, annual precipitation has ranged from 22 to 103 cm (8.73 to 40.55 in.) (USDC, 1974, 1978).

Most of the precipitation occurs May through October and is attributed to warm moist air moving northward from the Gulf of Mexico. The maximum 24-hour rainfall associated with a 100-year recurrence interval averages about 15.2 cm (6.0 in.) across the Dalhart Basin area and about 17 cm (6.5 in.) across the Palo Duro Basin area; the monthly maximum snowfall, recorded at Lubbock, Texas, is 43 cm (16.8 in.) (Baldwin, 1973; USDC, 1974, 1978, 1979a,b)

In the western portion of the study area, monthly average temperatures range from 2.2 C (36.0 F) in January to 26.5 C (79.7 F) in July. Prolonged occurrences of extreme cold (below -17.8 C or 0 F) and extreme heat (higher than 37.8 C or 100 F) are rare. Average relative humidities are normally low, typically in the range of 54 to 60 percent (USDC 1974, 1978).

On the average, wind speeds are high; when combined with low precipitation and sparse vegetation, there is a high potential for wind erosion and dust storms (Chepil et al, 1962). The basins are located west and south of the area of the United States which experiences relatively frequent tornadoes. An average of 3.5 and 8.7 tornadoes per year occur in the Dalhart and Palo Duro Basin areas, respectively. The 100-year-recurrence extreme wind in the Texas Panhandle is estimated to be 38.0 m/s (85 mph). This value is typical of most areas of the mid-western United States (Simiu et al, 1979).

Table 4-4 provides a summary of severe meteorological events that could influence repository development in this area.

Fundamental changes in the climate of the area have occurred over the last 2 million years (the Pleistocene Epoch). During this period there were four recognized glacial stages, the most recent of which ended about 10,000 years ago. Although glaciers did not extend to the basins, the climate was probably cooler, wetter, and stormier than at present (Schwarzbach, 1963). The current epoch (Holocene) is considered to be interglacial (Sellers, 1965).

Air quality data indicate that suspended particulate concentrations in the study area have exceeded the national secondary ambient air-quality standards. Portions of the Palo Duro Basin area have exceeded the primary ambient air quality standards for particulates. Since particulate concentrations in the Texas Panhandle can be attributed largely to fugitive dust, and because the area is largely rural, the Palo Duro and Dalhart Basin areas meet air quality standards for suspended particulates set by the EPA (EPA, 1978).

Table 4-4. Severe Meteorological Events

Weather Event	Area	
	Dalhart	Palo Duro
Extreme winds*	38.0 m/s (85 mph)	38.0 m/s (85 mph)
Maximum precipitation*	14.0 to 16.5 cm (5.5 to 6.5 in.)	15.2 to 16.5 cm (6.0 to 6.5 in.)
Tornadoes:		
(number/yr/km^2)	0.000280	0.000338
(number/yr/mi^2)	0.000725	0.000875

*100-year recurrence.

The Clean Air Act Amendments of 1977 (U.S. Congress, 1977) specify increments over which the particulate concentrations in Class I areas may not be increased. There are no Class I air quality areas within 160 km (100 mi) of the Dalhart Basin area; however, the Capulin Mountain National Monument in New Mexico [about 80 km (50 mi) west-northwest of the Dalhart Basin area] has been recommended for designation as a Class I area (USDI, 1979a). Class I areas in the vicinity of the Palo Duro Basin area are the Wichita Mountains Wilderness Area in Oklahoma [about 137 km (85 mi) east of the basin] and the Salt Creek Wilderness Area in New Mexico [120 km (75 mi) southwest] (EPA, 1977). These two areas have been designated as areas in which visibility is to be protected (EPA, 1979).

The term "mixing levels" is defined as the height above the surface below which relatively vigorous vertical atmospheric mixing occurs. Therefore, the mixing level indicates the practical vertical limit of dispersion of pollutants.

The annual afternoon mixing level for the Palo Duro Basin area ranges from 1,800 m (5,900 ft) in the eastern section to 2,200 m (7,215 ft) in the western section. The annual average mixing level for the Dalhart Basin area is approximately 2,200 m (7,215 ft) (Holzworth, 1972). In general, mixing height in the study area can be characterized as somewhat higher, and generally indicative of better dispersion, than typical conditions through the contiguous United States.

Restrictive dispersion conditions are defined as the occurrence of a mixing height of less than 1,524 m (5,000 ft) two or more consecutive days with wind speeds of less than 4 m/s (8.95 mph) and no significant precipitation. The average atmospheric dispersion conditions in the Dalhart Basin are relatively good year-around and in the Palo Duro Basin only two episodes of restrictive dispersion were recorded in a 5-year period (Holzworth, 1972).

4.2.4 Background Radiation

The limited data available for the study area reveal no anomalous external dose rates from background radiation. Dose rates in the Dalhart Basin area range from 111 to 119 mrem/yr, with a mean of 114. Dose rates for the Palo Duro Basin area range from 100 to 118 mrem/yr, with a mean of 109 (NUS, 1982).

4.2.5 Surface Hydrology and Flooding

The Southern High Plains is a nearly level, practically undissected, high table land with slow to moderate surface drainage and small shallow lakes (playas). The Palo Duro Basin is drained by the headwaters of the Red and Brazos Rivers, which rise in eastern New Mexico (Figure 4-1) and flow southeastward across Texas. The Southern High Plains area has a low mean annual precipitation, high rate of evaporation, and low mean annual runoff (NUS, 1982). The Southern High Plains area generally does not contribute to streamflow east of the Caprock Escarpment except during periods of heavy rainfall. Runoff collects in the numerous playas to form temporary ponds or lakes that generally do not drain into streams except during unusual precipitation events. Long, shallow valleys with poorly defined intermittent tributaries follow the general slope of the land at widely spaced intervals. These valleys form the headwater reaches of the Red and Brazos Rivers. Runoff accumulating in the streams ordinarily flows for only a short distance before being lost by seepage or evaporation (Cronin, 1969).

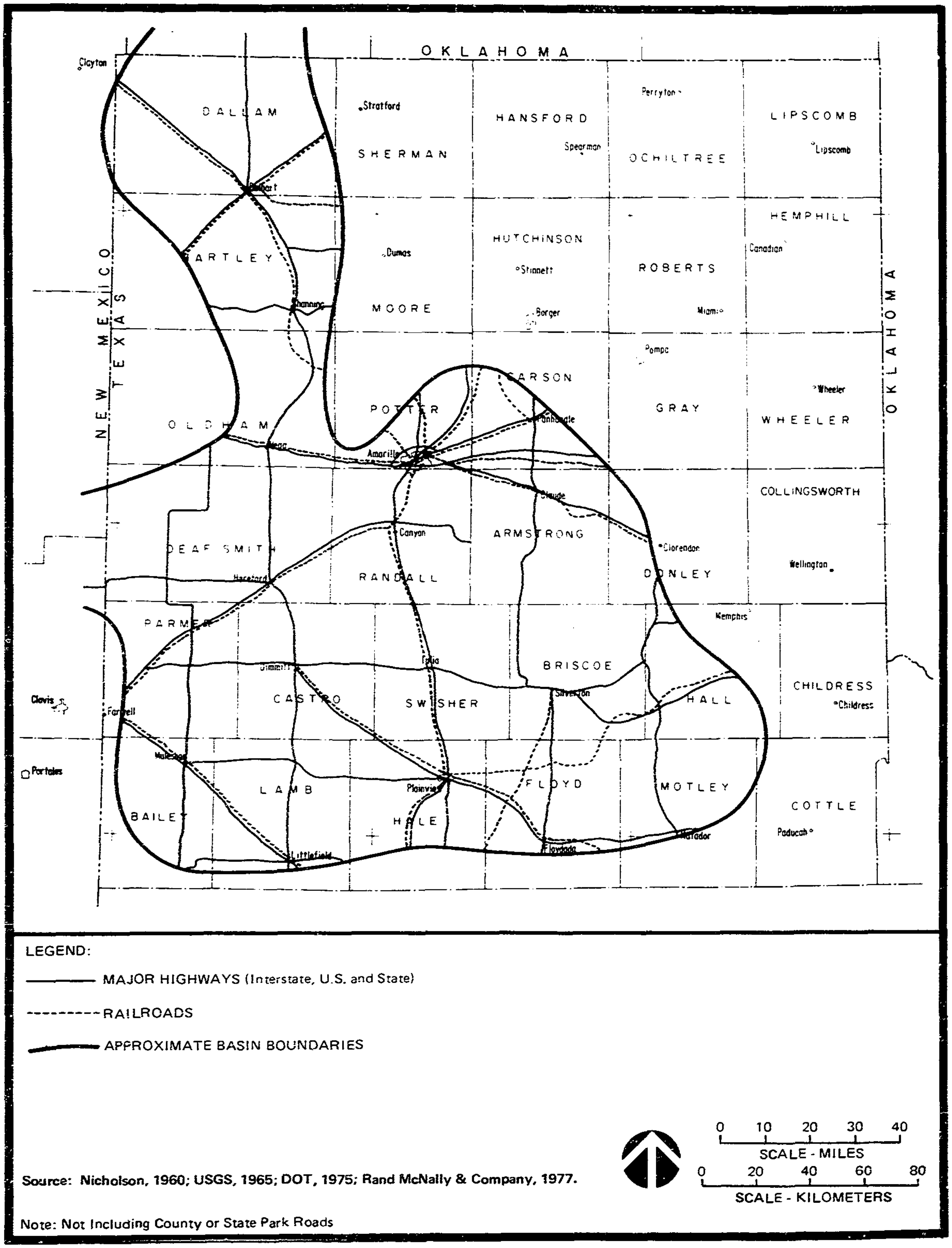
Major flooding occurs infrequently in the upper branches and tributaries of the Red and the Brazos Rivers. However, intense thunderstorms can produce localized flooding, with rapidly rising and falling discharge and high flow velocities (TWDB, 1977). The heavy rains that fell in the Palo Duro and the Tierra Blanca Creeks in Randall County on May 26, 1978, are typical of the local intense thunderstorms in the Texas Panhandle (Finley, 1979). The storm produced 13.0 cm (5.1 in.) of precipitation at Canyon and 7.1 cm (2.8 in.) at Buffalo Lake, 16 km (10 mi) to the southwest. This heavy precipitation produced a flash flood along the Prairie Dog Town Fork of the Red River. The peak flow at Lakeview in Hall County was about 1,608 m^3/s (56,800 ft^3/s). The peak water height within the Palo Duro Canyon State Park was 4.1 m (13.7 ft), as indicated by flood debris surveys.

The U.S. Geological Survey (1979) has prepared maps of floodprone areas for portions of the Texas Panhandle. These maps show the areas that are subject to flooding by the 100-year storm. As expected, most of the playa lakes are flooded under these conditions.

4.2.6 Transportation

Most of the Dalhart Basin study area is generally accessible by major highways and secondary roads (see Figure 4-16). There are no major rail hubs within the basin (the closest one is Amarillo). The Palo Duro Basin area has a highly developed transportation network with both interstate highways and extensive single-track rail lines. Within or adjacent to the basin are rail hubs of Amarillo, Lubbock, and Plainview. In addition to the active railroads shown in Figure 4-17, there is a rail line west of Amarillo that is currently not in regular service. Information from the Texas Railroad Commission (1980) indicates that part of this railroad (Amarillo to Vega) may be rehabilitated with assistance from the state of Texas.

The Dalhart Basin study area has three airfields. None are tower-controlled facilities (Figure 4-18). There are numerous airfields in the Palo Duro Basin area. Plainview and Amarillo have tower-controlled airports (USDC 1979e).



Source: Nicholson, 1960; USGS, 1965; DOT, 1975; Rand McNally & Company, 1977.

Note: Not Including County or State Park Roads

Figure 4-17. Major Roads and Railroads

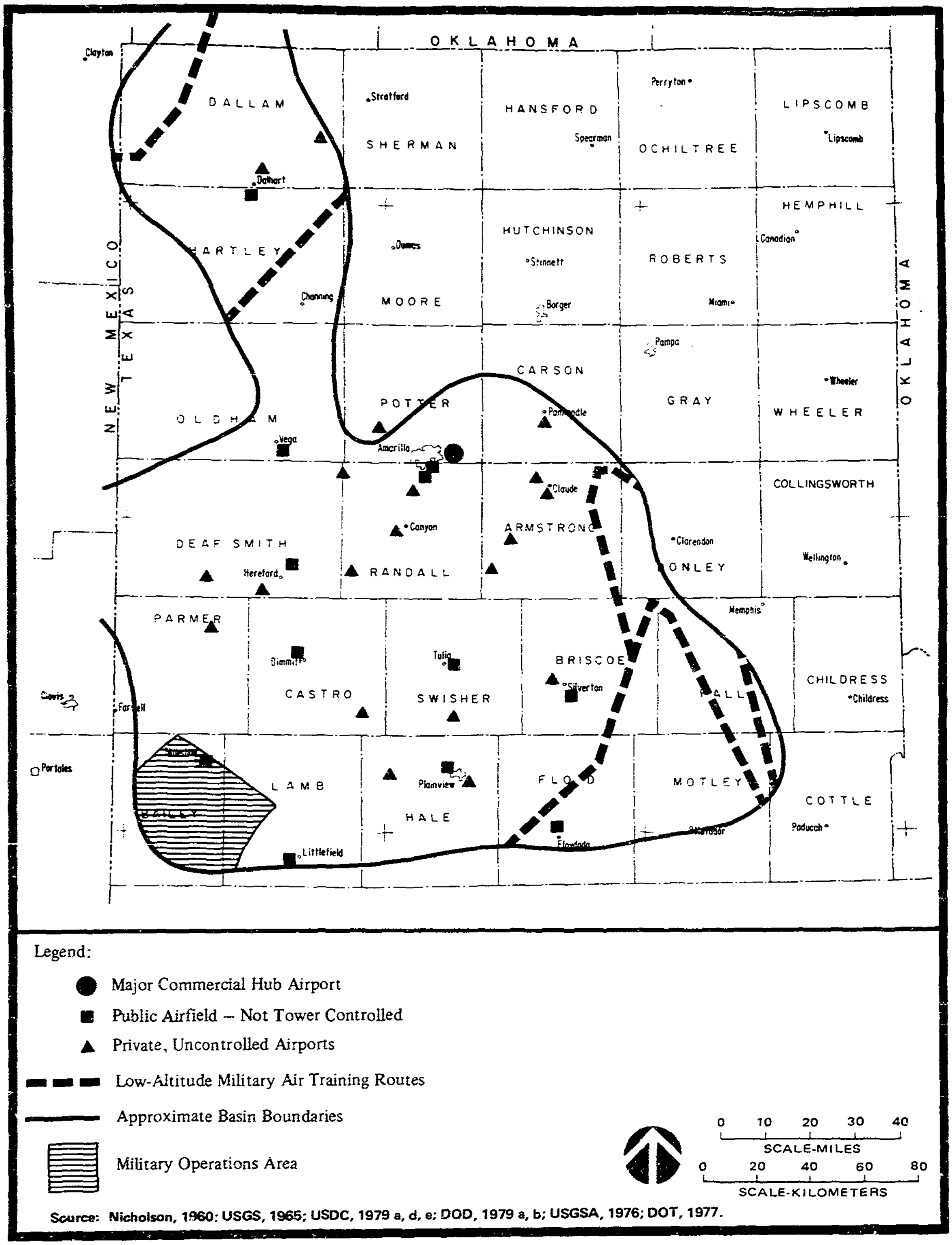


Figure 4-18. Airports and Military Training Routes

4.2.7 Ecosystems

Areas overlying the Dalhart and Palo Duro Basins consist primarily of grasslands, rangelands, and agricultural areas. Since most areas are cultivated or grazed, natural areas are scarce. Wildlife habitats are limited to playa lakes, canyons, or ravines formed by permanent or intermittent streams or rivers, cedar breaks, remnant prairie areas, and shrublands that are lightly to moderately grazed. Wetlands are scarce, occurring principally along rivers. Playas become temporary wetlands during the wetter part of the year and provide important habitat to migrating water fowl and shorebirds.

The aquatic resources of the Texas Panhandle are limited. Most streams in the Palo Duro Basin area are intermittent and limited in supporting recreational fishing. The Prairie Dog Town Fork of the Red River has been classified by the U.S. Fish and Wildlife Service as a high-priority fishery resource, primarily because of its aesthetic qualities. The Palo Duro Creek and Tierra Blanca Creek both support a limited recreational fishery (USDI, 1978). Other streams in the Palo Duro Basin area are intermittent and too shallow to support viable recreational fisheries (Crabtree, 1969; Lewis, 1957). In the Dalhart Basin, the Canadian River above Lake Meredith has been classified by the U.S. Fish and Wildlife Service (USDI, 1978) as a "highest valued fishery resource" that supports self-sustaining populations of native fish species. This river also has unique aesthetic qualities. The Punta de Agua Creek and the Beaver River are classified as "high-priority fishery resources" (Crabtree, 1969). A few other permanent or semipermanent streams contain limited sport fishery in deeper pools, but most support only minnows. Many of the streams are highly mineralized or brackish and contain only salt-tolerant species of the minnow family (Cyprinodon sp.) (Crabtree, 1969).

Baylor Lake, Buffalo Lake, Greenbelt Reservoir, and Lake Mackenzie support (or have supported) sport fisheries in the Palo Duro Basin area. A few other reservoirs support a seasonal put-and-take fishery. Most playas in this basin contain water only seasonally and lack fisheries.

There are no known threatened or endangered aquatic species in the study area. Recreationally important species include members of the sunfish family (e.g., bass and crappie) and several catfish species. These species are heavily dependent on the largely managed aquatic ecosystems of the area's reservoirs or the flow of the few permanent streams in the basin.

The aquatic habitats of the basin are heavily controlled by the scarcity of water or its intermittent availability and the high salt content of many water bodies. Feedlots and organic pollutants resulting from runoff and leaching of farmland have further strained the aquatic ecosystems.

The Dalhart Basin area contains three recreational and natural areas that are larger than 405 hectares (1,000 acres). The largest of these, the Rita Blanca National Grassland, has more than 31,200 hectares (77,000 acres) within the basin. Within the Palo Duro Basin there are six recreational and natural areas larger than 405 hectares (1,000 acres). These areas include national wildlife refuges, two state parks, and two recreational areas operated by water authorities. Collectively these areas cover approximately 37,958 hectares (93,756 acres) of the Palo Duro Basin area (Riley and Riley, 1979).

Three endangered species of birds, the southern bald eagle, peregrine falcon, and the least tern, occur on federal and/or state lists of endangered species (USDI, 1979b; Potter 1979). The southern bald eagle formerly nested in Potter County (Oberholser, 1974) of the Palo Duro Basin area but it is now considered a nonbreeding migrant or winter resident (Brownlee, 1977). The peregrine falcon may occur in the basin during migration, but this is considered unlikely. Although the least tern is occasionally sighted in the Texas Panhandle, its breeding habitat does not occur in the Dalhart and Palo Duro Basin area (NUS, 1982).

The black-footed ferret is the only federally protected mammal potentially occuring in the study area. The only documented records of the black-footed ferret in the Palo Duro Basin area are from Potter, Bailey, Hale and Childress Counties. No records are available since 1964 (Oberholser, 1974). The only known black-footed ferret records for the Dalhart Basin area were from Dallam County in 1953 and 1971. No ferrets have been reported from the area in recent years.

Two species, the Texas kangaroo rat and the Palo Duro mouse, are considered threatened according to the Texas Parks and Wildlife Department (TPWD). The Texas kangaroo rat, which generally occurs in mesquite brushland with clay and loamy soils, is known to occur in the Palo Duro Basin area from a single specimen collected from Motley County (Roberts, 1969). The Palo Duro mouse (Peromyscus comarche) has a very narrow habitat preference and is unlikely to occur anywhere in the Palo Duro Basin area except in rocky, cedar-covered slopes along the escarpment. (TPWD, 1979 and Texas Organization for Endangered Species, 1979.)

5 EVALUATION OF STUDY AREA

The Palo Duro and Dalhart Basin areas in the Texas Panhandle have been screened in order to identify smaller locations where site exploration efforts will be focused. Current knowledge of the characteristics of this area, as reflected in the National Waste Terminal Storage (NWTS) program's data base for the Texas Panhandle, has been considered in relation to NWTS Site Performance Criteria (Table 2-1; DOE, 1981). Screening specifications (Table 5-1) have been developed for each site performance criterion that has an adequate data base and can meaningfully be used to define smaller locations with favorable characteristics.

Table 5-1. Site Performance Criteria and Specifications Applied to Screen from Areas to Locations

DOE/NWTS-33(2) Criterion (DOE, 1981)	Subcriterion	Screening Specification
I. Site geometry (host rock)	1. Minimum 2. Maximum depth 3. Thickness	305 m (1,000 ft) 915 m (3,000 ft) 38 m (125 ft)
IV. Geologic characteristics	Host rock characteristics	Gamma-ray geophysical log response of 15 API units or less (indicative of "massive salt")
VI. Human intrusion	Oil or gas resources	Avoid existing/abandoned fields
VII. Surface characteristics	Flooding	Defer 1.6 km (1 mi) on either side of perennial streams
VIII. Demography	Urban areas	Exclude standard metropolitan statistical areas (SMSA)
IX. Environmental protection	Conflicting land use	Avoid wildlife refuges, reservoirs

5.1 NWTS CRITERIA USED FOR SCREENING

5.1.1 Site Geometry

Three factors are included in the site geometry criterion: depth to host rock, thickness of host rock, and lateral extent of host rock.

5.1.1.1 Depth to Host Rock

Proposed rule 10 CFR 60.122 (i) (NRC, 1981) specifies that a favorable condition for meeting performance objectives is the emplacement of waste at a minimum depth of 305 m (1,000 ft) below the ground surface. This minimum depth specification has been adopted for screening purposes. No surface geomorphic process is expected to pose a threat to a repository sited deeper than 305 m (1,000 ft). Total erosion of the Southern High Plains by continued backwasting of its margins would leave more than 305 m (1,000 ft) of cover in the central Palo Duro Basin above the salt units of the lower San Andres Formation. It appears that there would be no direct threat to repository integrity under a continuation of Quaternary erosional conditions (S&W, 1983).

The maximum depth at which a repository can be sited is a function of the host rock strength and the mass of overlying rock; when the force exerted by of the weight of overlying rock approaches the strength of the host rock, maintaining a mined opening is difficult. A maximum repository depth of 915 m (3,000 ft) has been proposed based on mining exprience and the mechanical behavior of salt under lithostatic pressure (Brunton et al, 1978). This maximum depth of 915 m (3,000 ft) has been adopted for screening the study area. Interpretation of laboratory data on salt properties in the Palo Duro Basin suggests that the maximum depth be less than 915 m (3,000 ft) so that maintaining a mined opening will not be difficult. The facility's actual depth will be determined from the results of later, additional rock testing if detailed site characterization proceeds in the Palo Duro Basin.

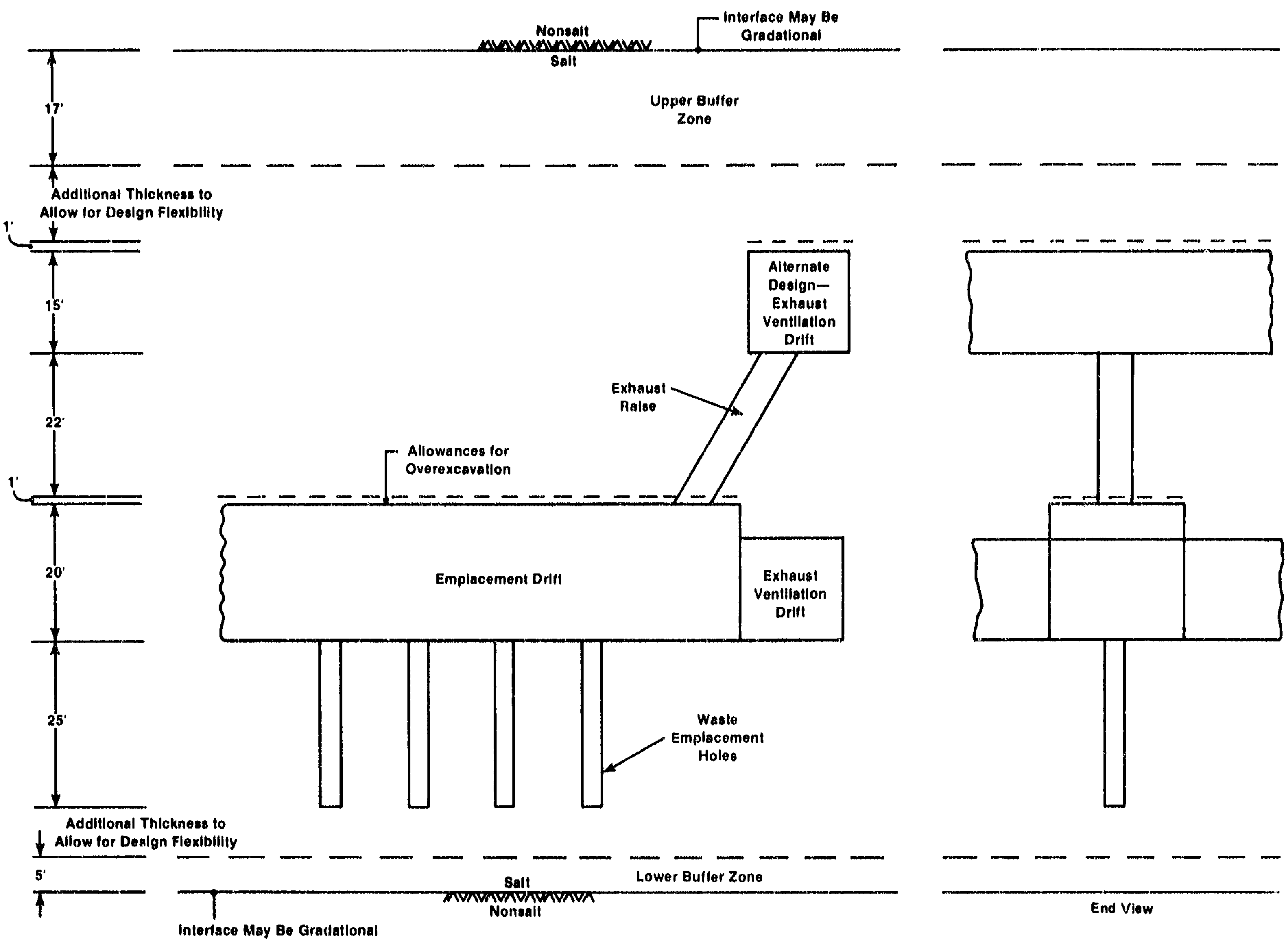
5.1.1.2 Thickness of Host Rock

Several salt unit thicknesses between 21 and 61 m (70 and 200 ft) have been suggested for use in screening potential bedded-salt host rocks. The salt thickness specification for screening the Palo Duro and Dalhart Basins [38 m (125 ft)] has been determined as the thickness necessary to accommodate repository workings (emplacement, ventilation, and access drifts), with upper and lower salt "buffer" zones, and to allow additional thickness for local rock variations in the salt unit.

Figure 5-1 shows the anticipated dimensions for two conceptual designs. Emplacement canisters holding uncut spent fuel rods, approximately 4.9 to 5.5 m (16 to 18 ft) long, require 6.1-m- (20-ft)-high rooms and 7.6-m- (25-ft)-deep boreholes to accommodate emplacement and shielding. The vertical separation required between emplacement and ventilation exhaust drifts is conservatively estimated based on assumed rock stresses.

Summing the dimensions illustrated in Figure 5-1 yields a 25-m (82-ft) thickness requirement for the repository workings. An upper buffer zone of an additional 5.2 m (17 ft) thickness is required if the exhaust ventilation drift were placed above the emplacement drift. A lower buffer zone, not less than 1.5 m (5 ft) thick, is allowed to protect the lower host rock interface from excessive thermal loading and to limit the canister centerline temperature. Where nonsalt stringers (e.g., mudstone, siltstone, anhydrite, dolomite) are present, as in the Palo Duro and Dalhart Basins, additional thickness in the repository unit may be required to accommodate these rock fabric variations. The thicker the salt unit is, the better the mine designer and developer can position drifts, pillars, roof, and waste emplacement holes to avoid rock characteristics. An additional 6.1 m (20 ft) of thickness is assumed to be sufficient to provide reasonable flexibility in repository design and development. Thus, for this study area, a salt thickness specification of approximately 38 m (125 ft) is used conservatively as a screening parameter. The salt thickness for a final repository design may be less than 38 m (125 ft), and will depend on site-specific stratigraphy and rock properties that will be evaluated in site characterization.

Figures 4-3 through 4-8 are isopach and depth contour maps respectively for the upper San Andres salt and the lower San Andres unit 5 and unit 4 salts. These are the only salt beds that meet the thickness and purity (see Section 5.1.2.1) specifications.



Source: Derived from Kaiser Engineers, 1978.

Figure 5-1. Conceptual Repository Designs in Bedded Salt

Figure 5-2 is a summary map which illustrates the geographic area beneath which at least one salt unit is greater than 38 m (125 ft) thick between the depths of 305 and 915 m (1,000 and 3,000 ft) below ground surface. The Dalhart Basin does not contain a salt unit meeting these initial specifications and is, therefore, eliminated from further consideration and discussion.

5.1.1.3 Lateral Extent of Host Rock

The lateral extent of host rock is not used for screening the study area because all of the major salt beds have lateral dimensions many times larger than the repository working area.

5.1.2 Geologic Characteristics

5.1.2.1 Host Rock

Salt bed purity and thickness varies both laterally and vertically within individual salt units. Salt purity, as a host rock characteristic, defined below, has been used for screening. Other host rock characteristics, such as fracture orientation, position of interbeds, the potential for thermally induced fractures, water content, the potential for hydration and dehydration of mineral components, brine migration, and other phenomena are details which generally can only be ascertained from site-specific investigations. For this reason they have not been used as factors in screening the study area.

Two basic types of salt have been identified in core samples from the Randall and Swisher County boreholes (DOE/Gruy Federal No. 1 Rex White, and No. 1 Grabbe); i.e., massive salt, and chaotic mudstone-salt. The massive salt is predominantly clear or milky to gray-colored halite crystals with minor mudstone (shale) or organic impurities. The chaotic mudstone-salt is predominantly clear halite crystals set in a matrix of mudstone or claystone; the relative percentages of halite and mudstone vary. These two types of salt have been differentiated using geophysical logs (Handford, 1980).

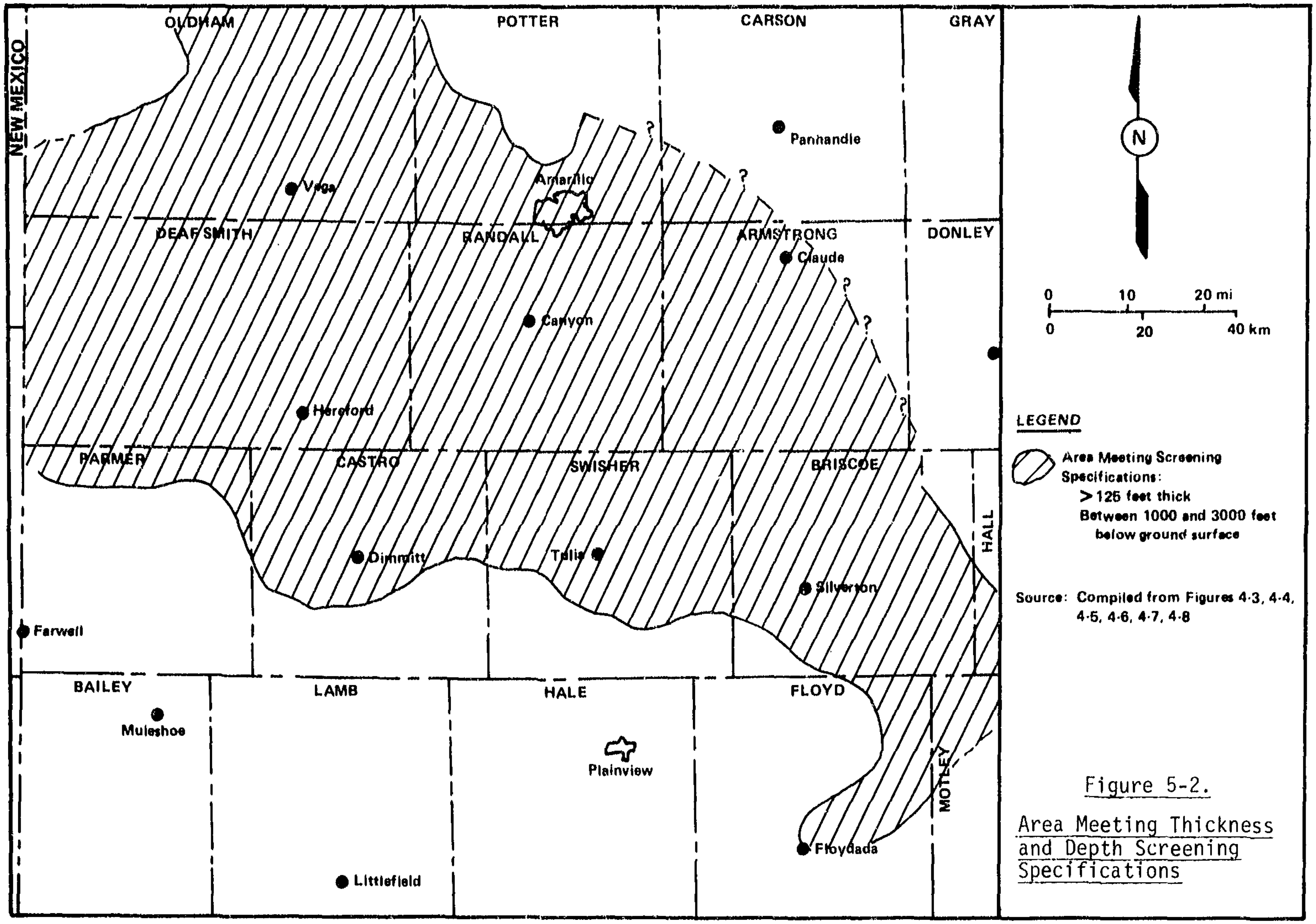


Figure 5-2.

Area Meeting Thickness and Depth Screening Specifications

Because gamma-ray geophysical logs are available from most of the previously drilled holes in the study area, they provide a means of delineating, on a basin-wide scale, areas of more pure (lower API values) and muddier (higher API values) salt beds. The Bureau of Economic Geology (BEG) (Ruppel and Ramondetta, 1982) has used gamma-ray logs to approximate variations in mud (terrigenous clay) content of the San Andres Formation salt beds across the Palo Duro Basin (Figures 5-3, 5-4, and 5-5). In practice, an average gamma-ray value of 15 API units appears to define the boundary between massive salt and chaotic mixmixtures of mudstone-salt as determined from core samples (Fisher, 1982). The gamma-ray geophysical tool alone, although useful in determining the presence of fine-grained clastic material, does not distinguish anhydrite from salt.

Figures 5-3, 5-4, and 5-5 have been used herein to aid in screening from a large, potentially qualifying area (Figure 5-2) to smaller locations. To do this, it was first assumed that banded to massive salt is more desirable as a potential host rock than chaotic mudstone-salt because:

- The massive salt bed is generally thicker and more uniform in composition over the expanse of a site; therefore, characterization and modeling are easier.
- The massive salt bed more closely resembles salt in which mining has been done; therefore, mine design and development are more certain.
- The thermal and mechanical properties of the massive salt bed are better understood; therefore, performance assessment and mine design are facilitated.

Secondly, the areas mapped by BEG as salt with an average API value of 15 or less are assumed to represent areas dominated by banded to massive salt and they are, therefore, more desirable than areas mapped at greater than 15 API units. The areas outlined in Figures 5-6, 5-7, and 5-8 are those that contain salt beds greater than 38 m (125 ft) thick between depths of 305 and 915 m (1,000 and 3,000 ft) and are mapped with an average API value of 15 or less*.

* The boundaries identified in Figures 5-6, 5-7, and 5-8 are the exact product of a map overlaying process. The boundaries should not be considered absolute; suitable locations outside these boundaries may be identified as the result of further study or refined analysis.

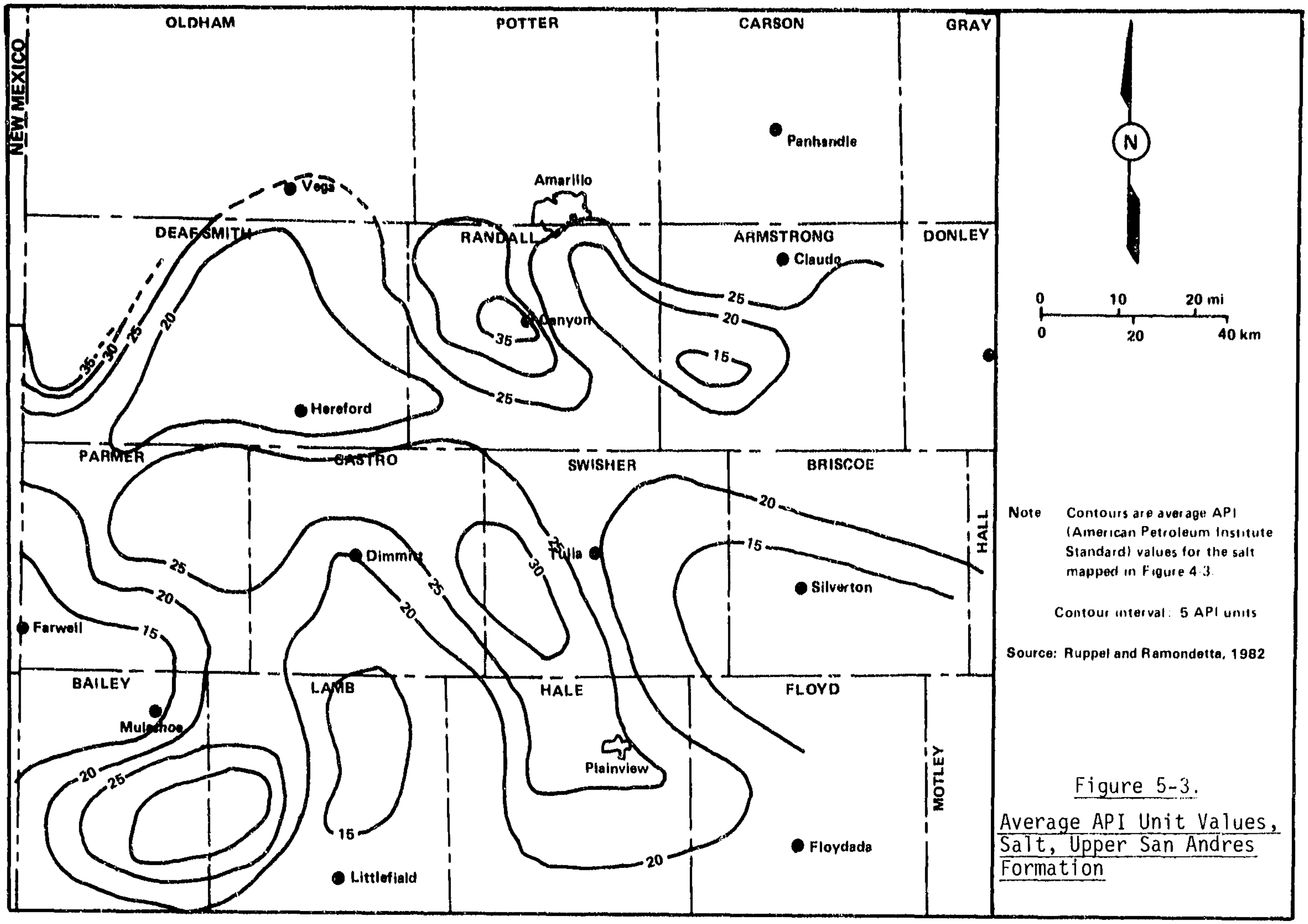


Figure 5-3.

Average API Unit Values, Salt, Upper San Andres Formation

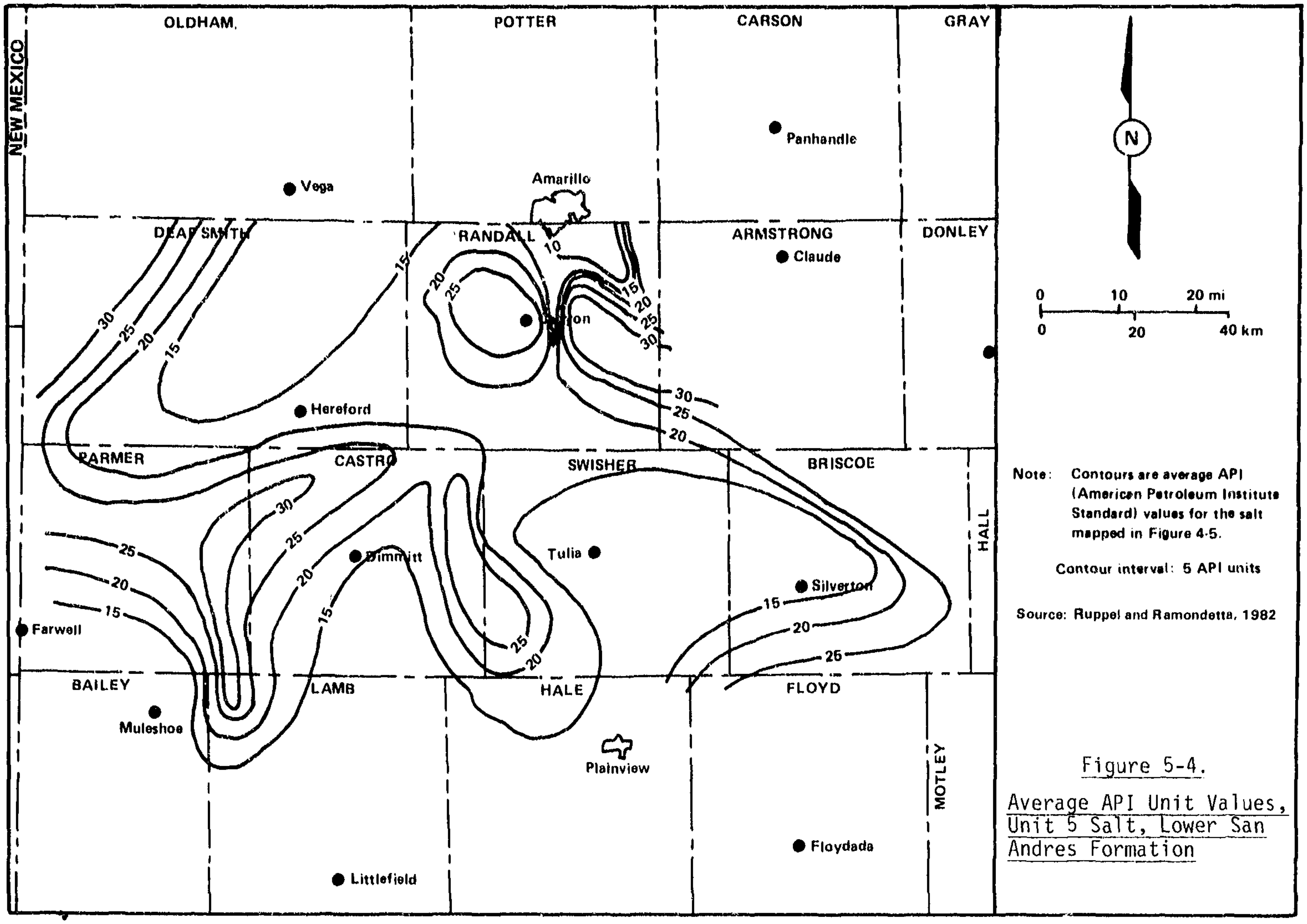
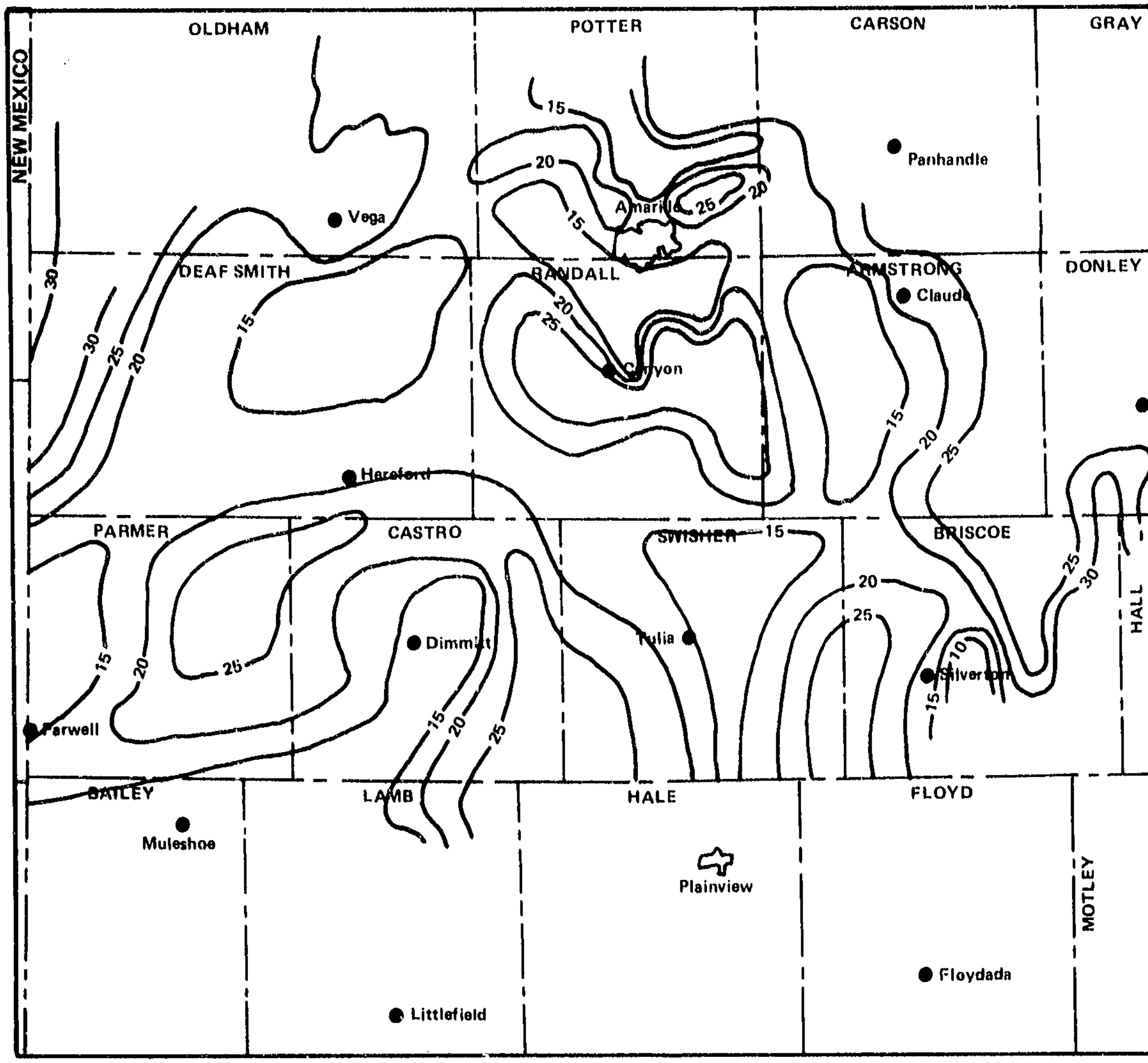


Figure 5-4.

Average API Unit Values, Unit 5 Salt, Lower San Andres Formation



0 10 20 mi

0 20 40 km

Note Contours are average API (American Petroleum Institute Standard) values for the salt mapped in Figure 4 7

Contour interval 5 API units

Source: Ruppel and Ramondetta, 1982

Figure 5-5.

Average API Unit Values, Unit 4 Salt, Lower San Andres Formation

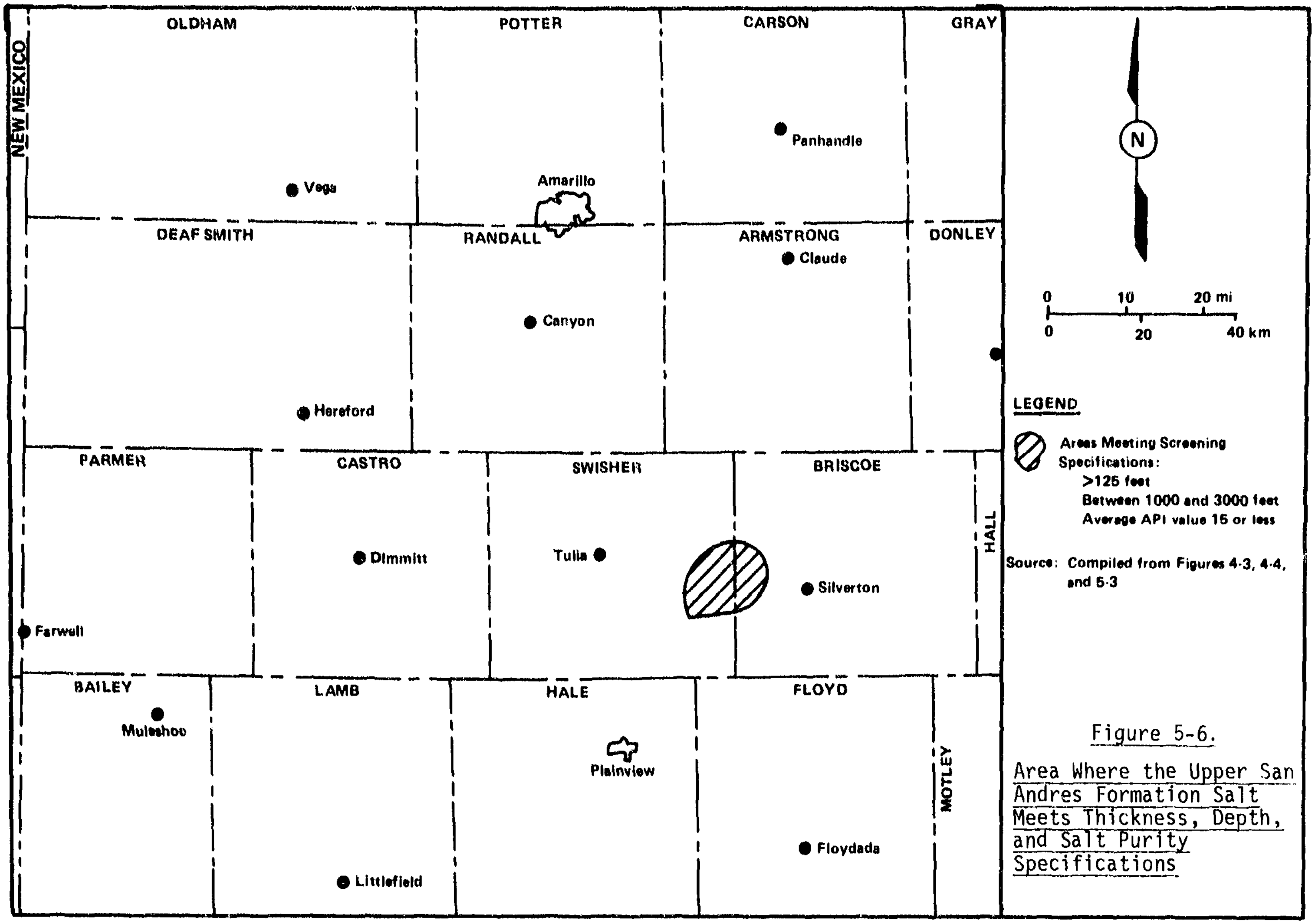


Figure 5-6.

Area Where the Upper San Andres Formation Salt Meets Thickness, Depth, and Salt Purity Specifications

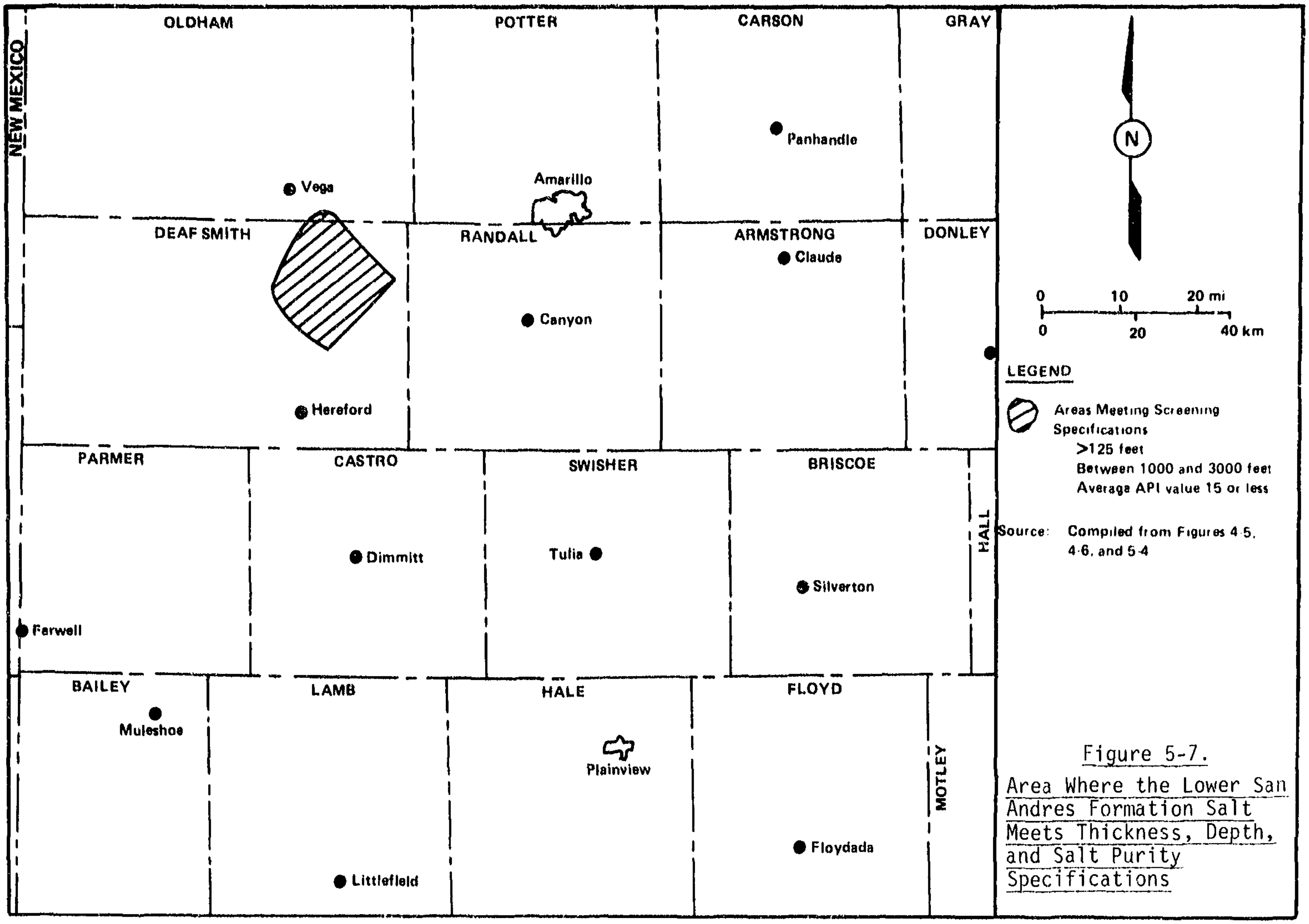


Figure 5-7.
Area Where the Lower San Andres Formation Salt Meets Thickness, Depth, and Salt Purity Specifications

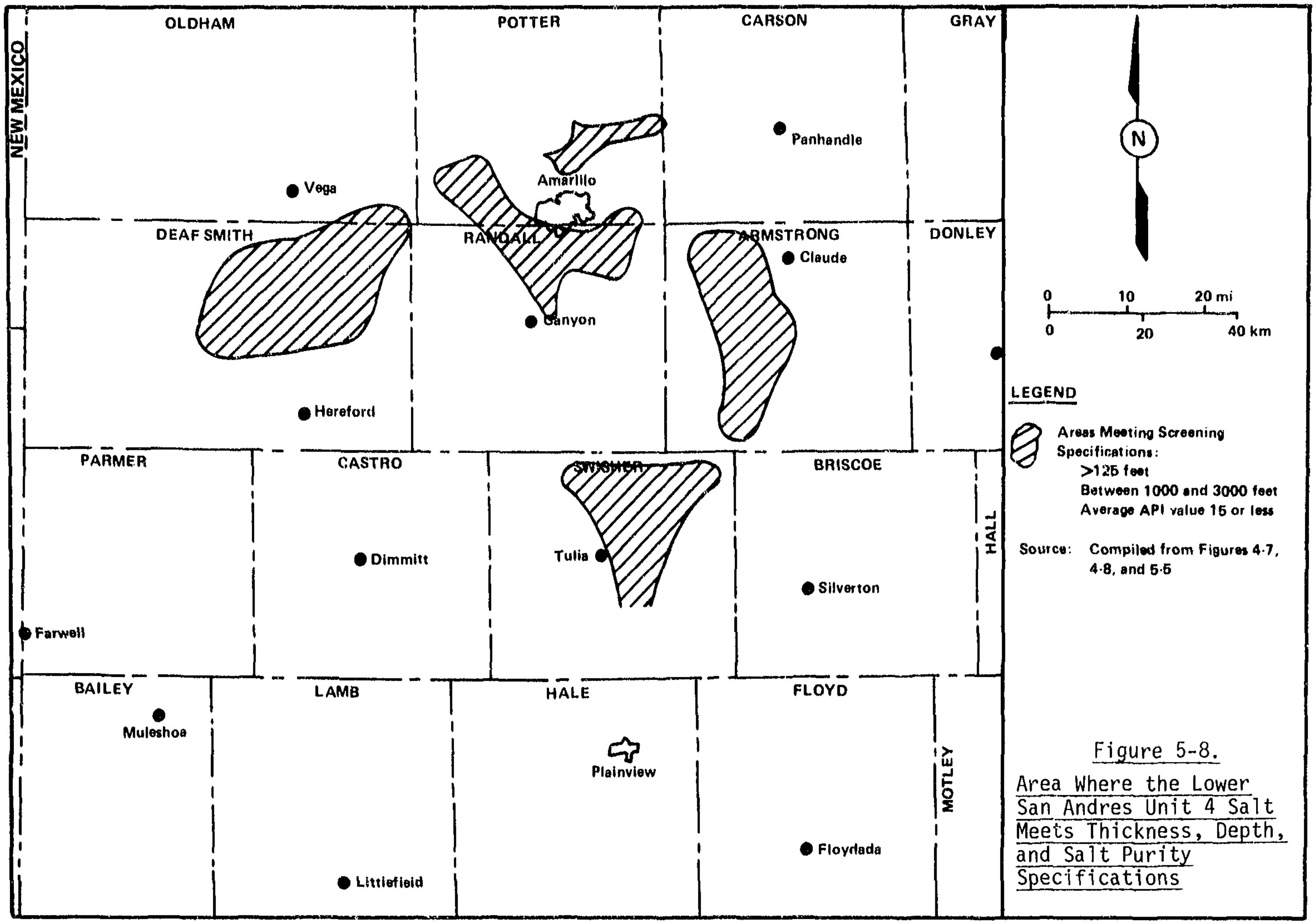


Figure 5-8.

Area Where the Lower San Andres Unit 4 Salt Meets Thickness, Depth, and Salt Purity Specifications

5.1.3 Human Intrusion

5.1.3.1 Exploitable Oil or Gas Resources

Virtually all the oil and gas produced in the study region comes from reservoirs beneath the Permian evaporite section being considered for repository siting. Human intrusion into a repository would most likely be a result of a search for these reservoirs.

Although the search for hydrocarbons in the Palo Duro Basin has been unsuccessful on the whole, optimism still exists as to the potential of the area. BEG is evaluating existing oil and gas fields and mapping trends which may represent areas of future hydrocarbon exploration. Areas with producing or abandoned oil fields (Figure 4-14) will undoubtedly be further explored and exploited first, and for this reason a screening specification has been adopted to eliminate these locations from siting consideration.

No screening specification has been adopted to defer specific exploration trends or locations around boreholes; the former are not well enough understood, and the latter are site-specific considerations.

5.1.4 Surface Characteristics

Factors such as surficial hydrology, topography, meteorology, and industrial, transportation, and military installations are considered under this criterion.

5.1.4.1 Surficial Hydrological Systems

The USGS (1979) has identified areas along perennial and some intermittent streams that would be inundated by a 100-year or less frequent flood. To avoid siting in these flood-prone regions, a 1.6-km (1-mi) zone on each side of these streams will be deferred from siting consideration (Figure 5-9). The existence of playa lakes is considered to be of minor importance; their flood zones will be delineated during location phase studies and they will be avoided during siting, if feasible. Intermittent stream valleys and draws, and areas subject to 100-year or less frequent flooding will be avoided in siting. Probable-maximum-flood (PMF) calculations will be made during location characterization.

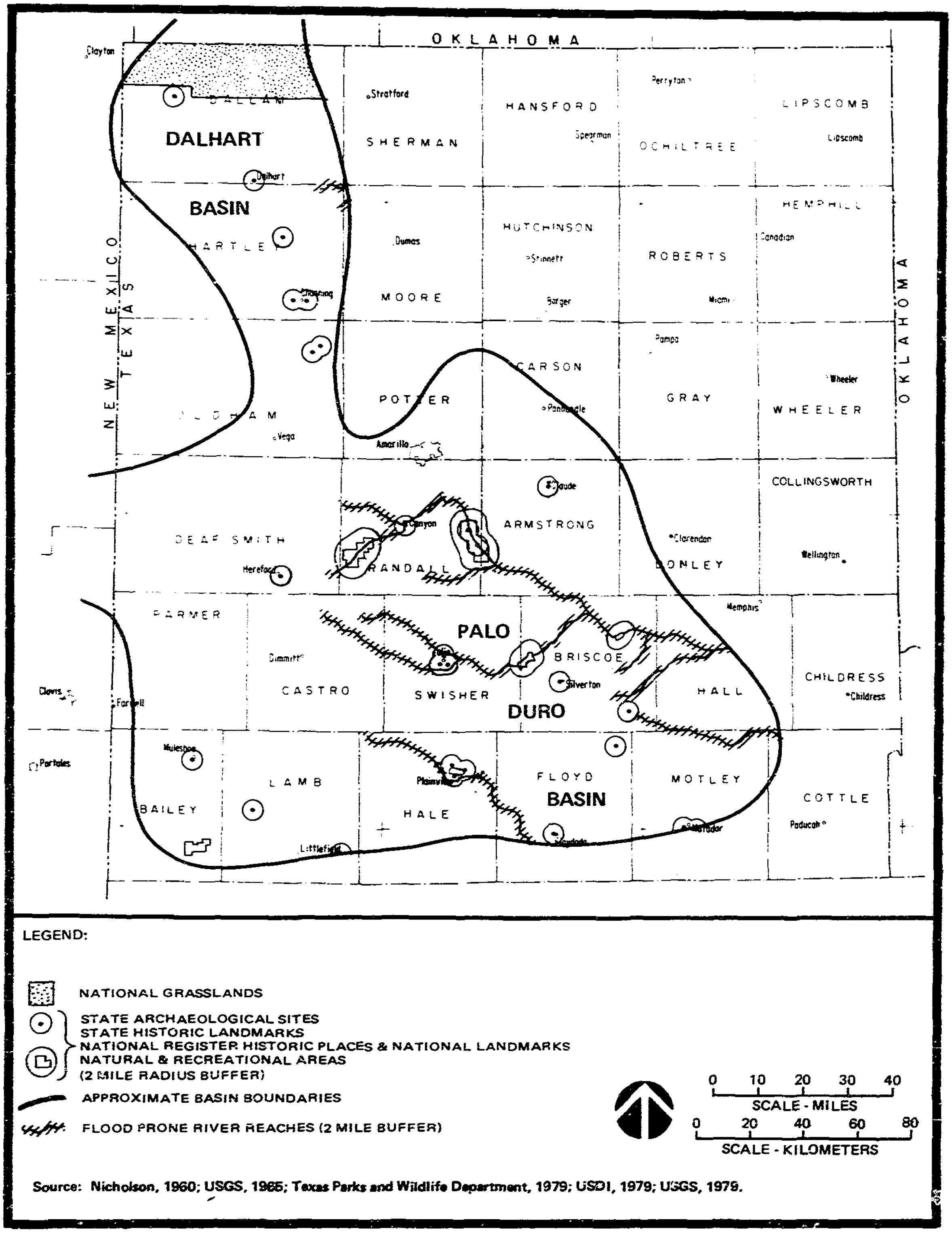


Figure 5-9. Dedicated Lands and Flood Prone River Reaches

5.1.4.2 Surface Topographic Features

The Palo Duro Basin lies beneath two physiographic sections: the Southern High Plains area, a nearly level, practically undissected, high table land, and the Osage Plains (Rolling Plains) area, a broad, nearly-level-to-rolling plain with rivers in broad, shallow channels. The Southern High Plains is separated from the Osage Plains by the Caprock Escarpment, a belt of rugged and broken land that slopes abruptly down to the Osage Plains (Baker et al, 1963; Rawson, 1967).

The terrain west of the escarpment (the High Plains) has uniform topographic relief. The low-relief terrain does not represent any hazards in site access and development. The gently eastward-sloping Osage Plains to the east of the Caprock Escarpment is less uniform, with wide valleys bounded by abrupt escarpments (Baker et al, 1963; Rawson, 1967), and is consequently considered less favorable than the High Plains.

The Eastern Caprock Escarpment is characterized by deeply incised canyons and near-vertical cliffs. The escarpment and its vicinity are considered less favorable than the High Plains due to potential hazards associated with siting and access, and they are consequently deferred.

5.1.4.3 Meteorological Phenomena

Meteorological and severe meteorological events that could influence siting and design are described in Table 4-4. Meteorological phenomena in the study areas do not vary significantly enough to indicate a preference for any location within the study area.

5.1.4.4 Industrial, Transportation, and Military Installations

This subcriterion addresses activities that could conflict with the construction and operation of a repository. Within the study area, these include airfields, low-altitude military training routes, and industries in the chemical and nuclear sector.

Neither of the basin areas can be judged superior to the other on the basis of conflicting uses. However, some locations within the study area may eventually be judged less favorable than others because of conflicting industrial, transportation, or military facilities and activities.

5.1.5 Demography

This criterion includes consideration of urban areas and tranportation.

5.1.5.1 Urban Areas

Within or adjacent to the study area are the region's two standard metropolitan statistical areas (SMSA): Amarillo (1980 population 173,699) and Lubbock (1980 population 211,651) (USDC, 1982).

These SMSA were excluded from consideration because of their high population densities. Similarly, communities were less favored than outlying areas in the counties. Community densities in this region range from 1235.0 to 3934.0 persons per square mile, and county densities generally are less than 19.0 persons per square mile. However, population centers in the vicinity could be drawn upon to provide some of the repository work force, thus minimizing in-migration and its related socioeconomic impacts.

5.1.5.2 Transportation, Access, and Utilities

Most parts of the study area are accessible to major highways or secondary roads and to rail transportation. No locations within the study area are sufficiently different in terms of access or potential access to rail and highway transportation to justify a screening specification for this factor. Figure 4-16 shows the major components of the area's transportation network. Utility systems were not evaluated during area characterization activities; they will be evaluated during location studies and considered in site selection.

5.1.6 Air, Water, and Environmental Protection

5.1.6.1 Environmental Impacts

Wherever possible, natural and recreational areas, as well as important wildlife habitat, will be avoided. Since these areas represent only a fraction of the total basin areas, they do not significantly restrict the options available for identifying locations for future study.

Since few rare or endangered species breed or reside permanently within the study area, it is unlikely that they will be affected.

5.1.6.2 Air, Water, and Land-Use Conflicts

Air quality and atmospheric dispersion are not useful factors for discriminating within the Palo Duro Basin; air quality problems are local, related to point or area pollution sources typically associated with urban areas. Possible land-use conflicts are associated with distinct dedicated land uses, such as parks or wildlife refuges (see Figure 5-9). Much of the agricultural land in the Palo Duro Basin area is classified as prime agricultural land. This land classification will be evaluated during location phase studies and will be considered during the site-selection phase.

5.1.6.3 Normal and Extreme Environmental Conditions

Information on normal and extreme environmental conditions is given in Section 4.2.2. This factor has not been used in screening because there are no significant differences within the Palo Duro Basin study area.

5.2 NWTS CRITERIA FOR WHICH SCREENING SPECIFICATIONS WERE NOT ADOPTED

5.2.1 Geohydrology

Screening specifications relative to the geohydrology of the study area have not been adopted because the characteristics of the major hydrologic units are considered to be relatively uniform and always favorable at the scale (hundreds of miles) being considered. Local variations in hydrologic properties or setting cannot be distinguished with the data available for the central Palo Duro Basin area. Important aspects of the hydrologic suitability of the study area remain to be investigated: e.g., properties of deep basin shelf margin carbonates; possible old boreholes, or open, vertically oriented fracture systems; possible permeable carbonate beds within the Permian evaporite section.

Dissolution of the bedded salts is a process that is active today and that has probably been taking place since salt deposition more than 230 million years ago (Bachman and Johnson, 1973). Its past occurrence and future potential throughout much of the study area require that this phenomenon be further investigated and considered a potentially adverse condition to siting within the Palo Duro Basin. There is no evidence, however, to indicate that a mechanism exists in the central Palo Duro Basin, or a situation is likely to develop within 10,000 years, for dissolving salt at the depths being considered for potential repository development. Because of this, there is no basis for a screening specification relative to salt dissolution within the Palo Duro Basin. However, because salt dissolution is occurring near the periphery of the Southern High Plains, distances further from the Canadian River Breaks and Eastern and Western Caprock Escarpments will likely be considered more favorable than those nearer to these topographic features.

5.2.2 Geochemistry

An understanding of geochemical characteristics and processes is important in assessing the suitability of a candidate site. Potential chemical interactions and radionuclide retardation affect waste package material design and assessment of long-term performance of the repository. Many of the mineralogical and chemical data of interest require site-specific investigations; such data are not available and, therefore, no screening specification has been developed for this factor.

5.2.3 Tectonic Environment

The existing data base shows no tectonic elements or features in the central part of the study area which provide a basis for differentiating one area from another. No Quaternary faults (aside from those related to salt dissolution and collaspe) have been identified. Quaternary igneous activity is well beyond the boundaries of the study area. Ground-surface acceleration data have not yet been obtained.

5.2.4 Socioeconomic Impacts

Towns within the vicinity of a nuclear waste repository would experience social, economic, and land-use impacts similar to those associated with any major energy development. These impacts include changes such as population growth resulting from an influx of workers, local economic growth and development, additional burdens on housing and community services, changing land-use patterns, and changes in local revenues and expenditures. Some of these impacts may be reduced by choice of repository site. Others can be managed through community planning and impact mitigation funding. Factors which influence the magnitude of socioeconomic effects include the population size, the number of in-migrant workers and families, the availability of housing and community services, and the economic diversity of the region. Potentially conflicting land uses were described in Section 4.2. The existence and impact of comprehensive land-use plans will be determined during location investigations.

6 RECOMENDATION OF LOCATIONS

This chapter summarizes evaluations of the Palo Duro and Dalhart Basins and provides a recommendation for location studies. The site performance criteria and screening specifications applied to identify potential study locations are repeated below.

DOW/NWTS-33(2) Criterion (DOE, 1981)	Subcriterion	Screening Specification
I. Site geometry (host rock)	1. Minimum depth 2. Maximum depth 3. Thickness	305 m (1,000 ft) 915 m (3,000 ft) 38 m (125 ft)
IV. Geologic characteristics	Host rock characteristics	Gamma-ray geophysical log response of 15 API units or less (indicative of "massive salt")
VI. Human intrusion	Oil or gas resources	Avoid existing/abandoned fields
VII. Surface characteristics	Flooding	Defer 1.6 km (1 mi) on either side of perennial streams
VIII. Demography	Urban areas	Exclude standard metropolitan statistical areas (SMSA)
IX. Environmental protection	Conflicting land use	Avoid wildlife refuges, reservoirs

6.1 CANDIDATE LOCATIONS

The areas that meet the screening specifications adopted for Criterion I and IV are illustrated in Figures 5-6, 5-7, and 5-8 (Section 5.1.2). The geographic areas that meet the depth, thickness, and salt purity screening specifications are shown in Figure 6-1. The locations of producing and abandoned oil/gas fields are also shown on this figure.

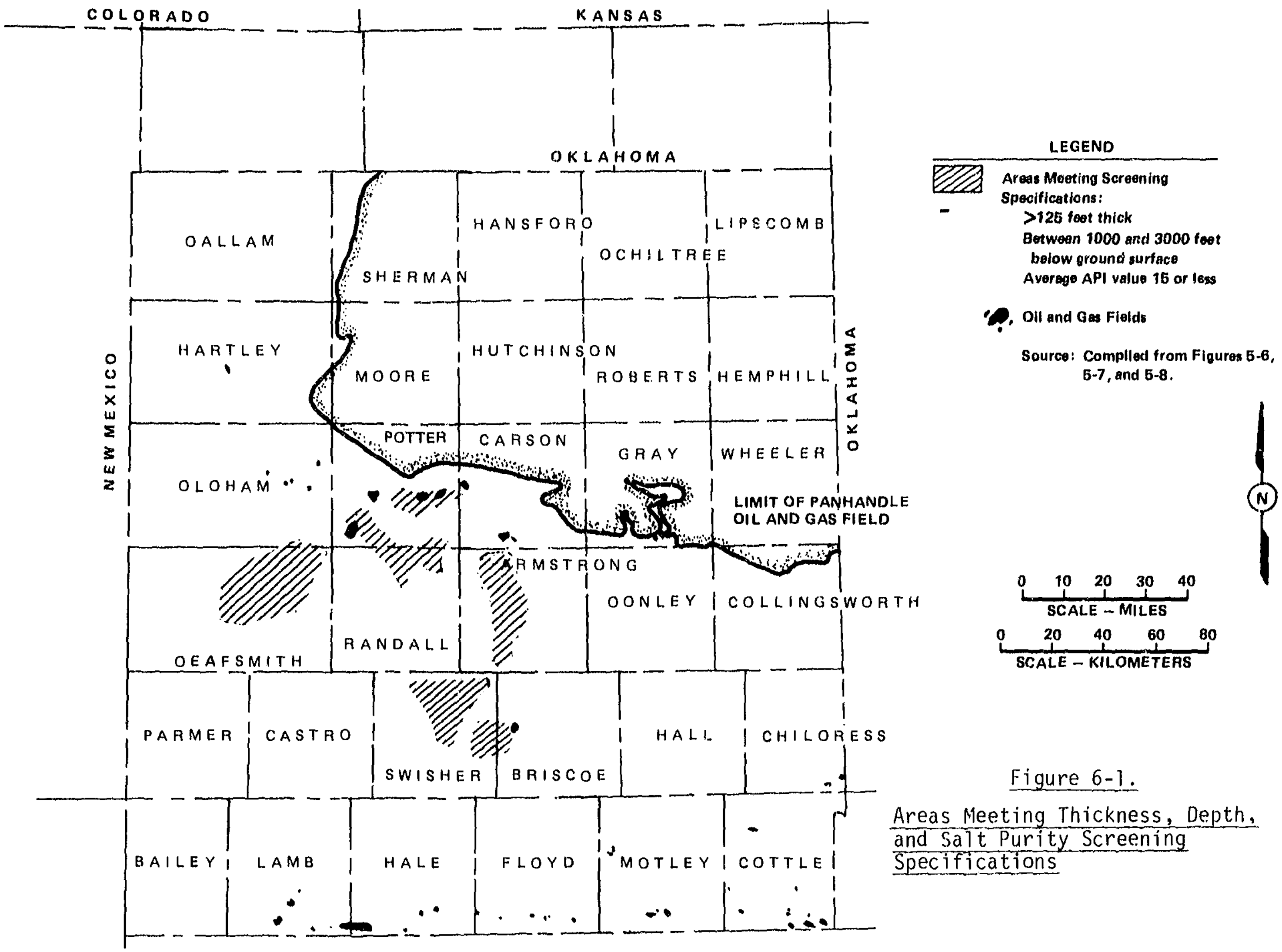


Figure 6-1.

Areas Meeting Thickness, Depth, and Salt Purity Screening Specifications

The geographic areas which pass the initial screens (Figure 6-1) have been further screened by applying the specifications adopted for Criteria VII, VIII, and IX (Figure 6-2). These areas have been labeled A through F for ease of discussion.

Area A. Area A is located in northeastern Deaf Smith County and southeastern Oldham County; its southern boundary is approximately 16 km (10 mi) north of Hereford (population 15,853). It is situated wholly on the Southern High Plains and is essentially flat lying. Area A is predominantly cultivated, irrigated, agricultural land. Major highway and rail systems are nearby.

The area is underlain by two thick salt units: the lower San Andres unit 5 and unit 4. Unit 5 salt is as shallow as 549 m (1,800 ft) and unit 4 salt is as deep as 915 m (3,000 ft) beneath the area.

Area B. Area B is located in northcentral Swisher County; the southern portion of the area is adjacent to Tulia (population 5,486). It is situated wholly on the Southern High Plains, and is essentially flat lying. Area B is predominantly cultivated, agricultural land. A major highway and railroad flanks the area.

Thick salt of the lower San Andres unit 4 underlies the area. Depth to the top of salt ranges from 732 to 915 m (2,400 to 3,000 ft).

Area C. Area C is located in southern Potter County and northern Randall County. The area lies between the cities of Amarillo (population 149,230) and Canyon (population 10,724). The northwestern portion of the area is within the Canadian River "Breaks"; the rest of the area is essentially flat lying. The area is bisected by the region's major highway and railroad system. The area is also close to known oil and gas fields.

The lower San Andres unit 4 salt is thick and shallower than 610 m (2,000 ft) beneath this area.

Area D. Area D is in eastern Swisher County and western Briscoe County. This area straddles the Caprock Escarpment with the Southern High Plains to the west and the Rolling Plains to the east. Area D contains both cultivated land and rangeland. Lake Mackenzie Reservoir is situated within the area. The area is close to a recent petroleum discovery in Briscoe County.

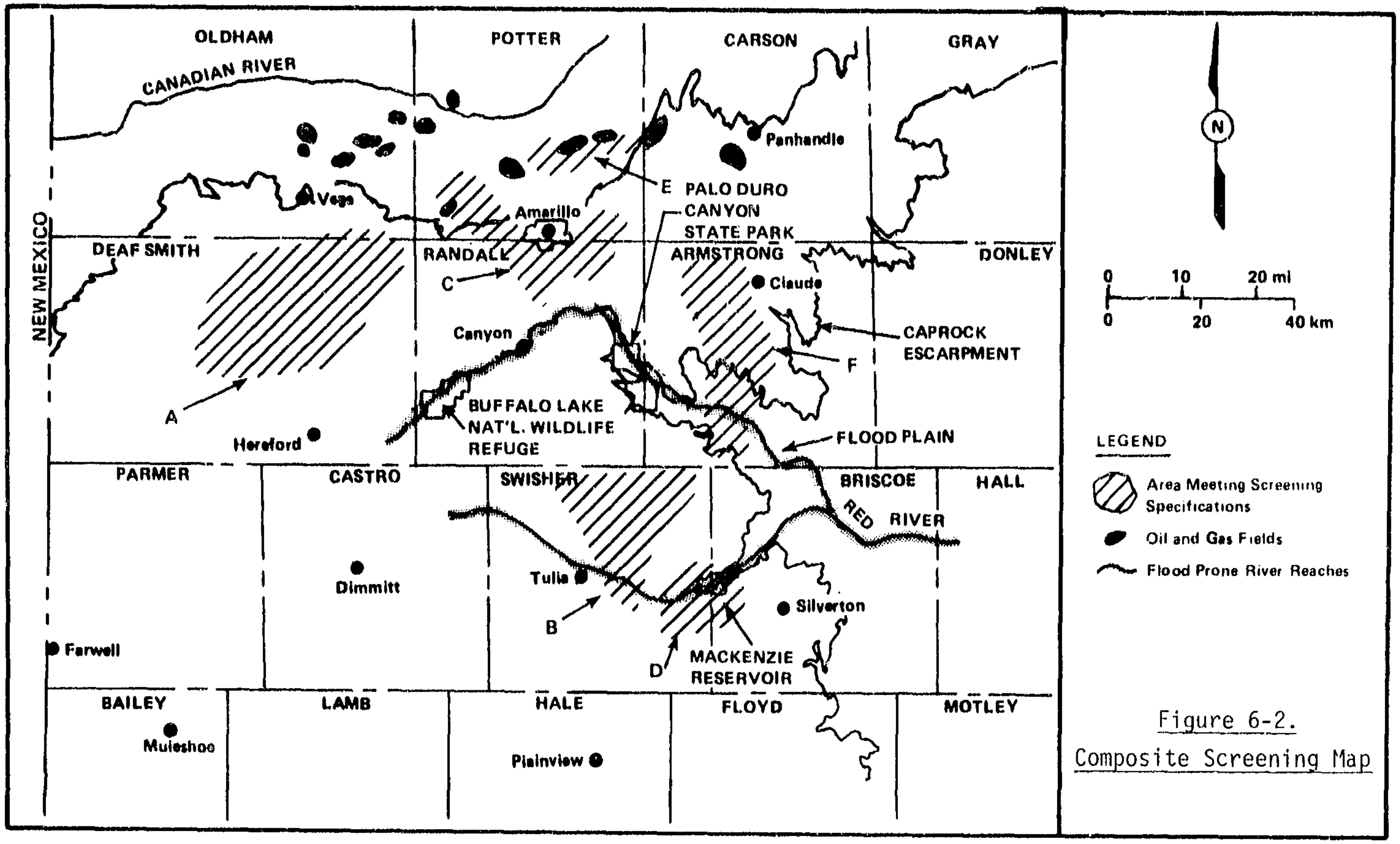


Figure 6-2.
Composite Screening Map

This area is underlain by thick salt of the upper San Andres Formation. The depth to the top of the upper San Andres salt ranges from 457 to 701 m (1,500 to 2,300 ft).

Area E. Area E is in central Potter County, north of Amarillo. This area lies wholly within the Canadian River "Breaks", off the Southern High Plains surface. The area is predominantly rangeland and is bisected by major highway and rail systems. This area is adjacent to known oil and gas fields.

The lower San Andres unit 4 salt is thick and shallower than 427 m (1,400 ft) beneath this area.

Area F. Area F is in western Armstrong County. This area is quite diverse in character. Parts of the area lie off the Caprock Escarpment and are in the flood plain of the Prairie Dog Town Fork of the Red River. This area contains both cultivated land and rangeland. The northern portion of the area is adjacent to a highway and railroad.

This area is underlain by thick salt of the lower San Andres unit 4. Depth to the top of this salt ranges from 305 m (1,000 ft) (off the Caprock Escarpment) to 549 m (1,800 ft) (beneath the Southern High Plains surface).

6.2 RECOMMENDATION OF PREFERRED LOCATIONS

Because each of Areas A, B, C, D, E, and F (Figure 6-2) meets the adopted screening specifications (Table 5-1), each area is potentially adequate for repository siting and could be considered for more detailed investigation. There are, however, differences among the potential areas which make certain areas preferable. The more preferable areas are those which have the greatest likelihood of proving suitable for repository siting and of meeting U.S. Nuclear Regulatory Commission licensing requirements. They have fewer features or phenomena which are likely to become issues or concerns during facility licensing. The areas can be discriminated, based on the extent to which they:

- Are away from the margins of the Southern High Plains where topography is irregular, erosion rates are high, and salt dissolution may occur in the potential repository unit
- Are away from known oil and gas fields

- Have more than one potential repository horizon
- Have salt at depths as shallow as possible while maintaining a thick rock section between the potential repository horizon and the surface
- Have relatively few boreholes which penetrate the potential repository horizon
- Comprise a large continuous geographic area to provide flexibility in siting
- Have low population densities
- Have no unique land use conflicts.

Areas A and B have most of these favorable characteristics and no obviously unfavorable characteristics. Relative to Areas C, D, E, and F, they are the preferred locations for additional study.

Each of Areas C, D, E, and F has several less desirable characteristics. Area C, being very close to Amarillo and Canyon, is not as desirable as Areas A and B because there are greater population densities and land use conflicts; e.g., highway and railway systems, airports. In addition, Area C is near known oil and gas fields (increased potential for human intrusion) and the Canadian River "Breaks".

Area D is not as desirable as Areas A and B because it straddles the Caprock Escarpment, an area of rugged terrain and high erosion rates, and is close to areas where salt dissolution may occur in the potential repository horizon. It is also near an area of recently increased petroleum exploration and development. Also, the Lake MacKenzie Reservoir or water supply and recreational facility lies in the area.

Area E is not a favored location because of its proximity to Amarillo, to other population centers, and to oil and gas fields. This location is within the Canadian River "Breaks", has more topographic relief than Areas A and B, and is near areas where salt dissolution has occurred in the potential repository horizon. In addition, because the salt of interest is quite shallow [between 305 and 427 m (1,000 and 1,400 ft)], a relatively thinner rock section exists between the potential repository horizon and surface.

Area F is also less favored than Areas A and B. Parts of this area are unfavorable because they lie off the Southern High Plains. The remainder of the area is less desirable because of its proximity to the Caprock Escarpment and areas of salt dissolution. In addition, the northern part of this area has been more densely drilled than other areas and, as a result, is potentially less suitable from a licensing standpoint.

6.3 SUMMARY OF RECOMMENDATION

Future repository siting and characterization efforts should focus on Areas A and B, northeastern Deaf Smith and southeastern Oldham, and north-central Swisher Counties, respectively (Figure 6-3) because these areas have the greatest likelihood of containing a suitable site with relatively fewer licensing issues or concerns. All other areas in the Palo Duro and Dalhart Basins should be deferred from further consideration at this time.

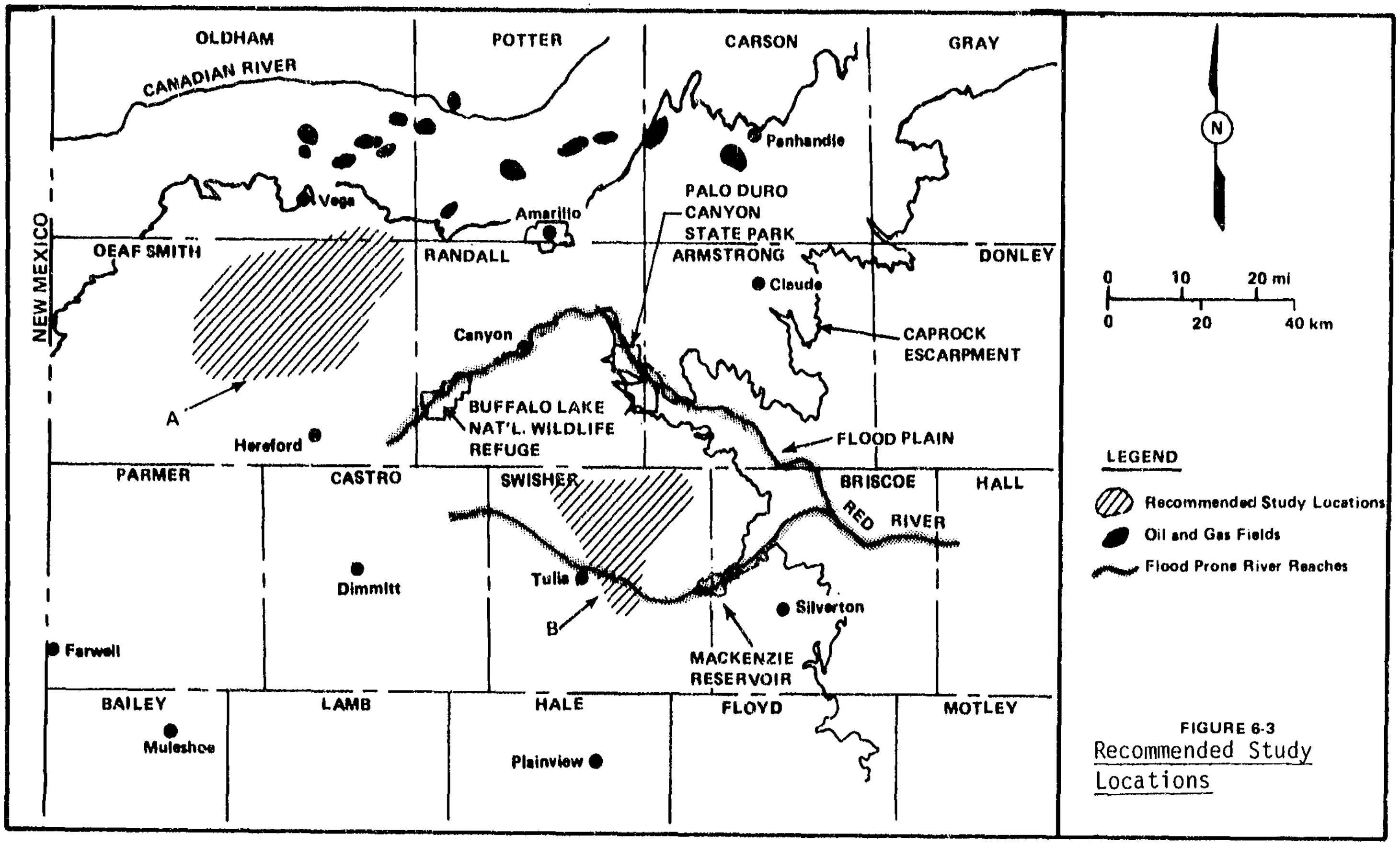


FIGURE 6-3
Recommended Study Locations

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APPENDIX A

CONVERSION FACTORS USED

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CONVERSION FACTORS USED

1 foot = 0.305 meter

1 inch = 2.54 centimeters

1 mile = 1.6 kilometers

1 acre = 0.4047 hectare

1 cubic foot = 0.028317 cubic meter

1 mile per hour = 0.44704 meter per second

APPENDIX B
TEXAS BUREAU OF ECONOMIC GEOLOGY
PUBLICATIONS RESULTING FROM
WEST TEXAS WASTE ISOLATION RESEARCH

PUBLICATIONS ASSOCIATED WITH RESEARCH IN THE PALO DURO AND DALHART BASINS

I. Bureau Publications

1979

Dutton, S. P., Finley, R. J., Galloway, W. E., Gustavson, T. C., Handford, C. R., and Presley, M. W., 1979, Geology and geohydrology of the Palo Duro Basin, Texas Panhandle: a report on the progress of nuclear waste isolation feasibility studies (1978): The University of Texas at Austin, Bureau of Economic Geology Geological Circular 79-1, 99 p.

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PUBLICATIONS ASSOCIATED WITH RESEARCH IN THE PALO DURO AND DALHART BASINS

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APPENDIX C
GLOSSARY

GLOSSARY

Alluvium--Materials deposited by a stream or other running water.

ALO--DOE Albuquerque Operations Office

Alternative Design Concept--Any disposal concept other than geologic disposal in a mined repository.

Anhydrite--Mineral of composition $CaSO_4$; loosely applied to a bedded rock (or caprock) composed of that mineral. Commonly found in association with gypsum and rock salt.

Aquifer--A layer of permeable rock through which water flows.

Area--A geographical unit of approximately 1000 square miles (or about 2600 square kilometers). An area is part of a region. There are one or more locations within an area.

Backfilling--Placement of originally removed or new materials into evacuated areas of a mine, including holes drilled for waste canisters, drifts, accessways, and shafts.

Background Radiation--Radiation occurring naturally in the environment, including cosmic rays, the naturally radioactive elements of the earth, and radiation from the human body itself.

Banking--Identifying candidate repository lands and reserving them from any use which would compromise their qualifications as candidate sites.

Barrier--Any medium or mechanism that separates radioactive material from adjacent material, such as: a container, waste form, overpack, backfill material, or a geologic medium.

Basalt--A fine-grained, dark-colored, extrusive igneous rock, rich in iron magnesium minerals in a fine-grained groundmass.

Basin--1. (Topographic): the area drained by a stream or lake, bordered by a drainage divide. 2. (Sedimentary): a large, downwarped area which, over a long period of geologic time receives an accumulation of sediments.

Bedded--Arranged in layers.

Bedrock--Rock that is an integral part of the earth's crust (as opposed to a boulder, for example).

Biosphere--(1) Zone at and adjacent to the earth's surface where all life exists. (2) All living organisms of the earth.

Borehole--A hole drilled into the earth, often to a great depth, as a prospective oil well or for exploratory purposes. A borehole is generally of small diameter, such that workers cannot work inside it, and is drilled mostly vertically, or possibly on a slant or horizontally. A borehole could be near the surface, or could penetrate into the repository formation or through it.

Bounding Calculation--Calculation based on an envelope of parametric values to indicate the limits of results that can be obtained.

Breach--Loss of integrity of containment or isolation. In the case of a repository, a channel created for ingress and egress of ground water.

Breccia--Fragmental rock whose components are angular and, therefore, as distinguished from conglomorates, are not waterworn.

Breccia Pipe--A roughly cylindrical occurrence of breccia, usually of volcanic origin.

Brine--Water containing dissolved salts in greater concentration than ordinary seawater. In salt deposits, brine may be present as fluid inclusions and would be in equilibrium with the surrounding crystalline salt.

Buffer Zone--A portion of the site that surrounds the repository facility and is composed of essentially undisturbed geologic and surficial environment.

Burnup--A measure of reactor fuel consumption, normally expressed as the amount of thermal energy produced per unit weight of uranium placed in the reactor.

Canister--A container for waste, spent fuel, and high-level waste. The waste will remain in this canister during and after burial in the repository. A canister affords physical containment but not radiation shielding.

Caprock--A heterogeneous, relatively impervious, rock that immediately overlies a salt dome, typically anhydrite, limestone, or gypsum, possibly all three arranged in layers.

CFR--Code of Federal Regulations

Characterization--The collecting of information necessary to evaluate suitability.

Closure--Filling an underground excavation through deformation, subsidence, or backfilling.

Cold--With reference to radioactive waste, no radioactive nuclides are present.

Conservative--Providing large margins of safety against undesirable outcomes without overestimating adverse consequences and underestimating mitigating factors.

Containment--Confining radioactive wastes within prescribed boundaries.

Cretaceous--The last period in the Mesozoic Era, extending from 136 to 65 million years ago.

Criterion--A standard, rule, or test by which a decision or judgment may be based.

Decay (Radioactive)-- The spontaneous transmutation of a radionuclide into another nuclide by the emission of a charged particle or electromagnetic radiation.

Decommissioning--Activities associated with removing a repository from service, i.e., backfilling, shaft sealing, and the end of surface-facility use (including demolition, dismantling, etc.).

Decrepitation--The process of cracking or spalling, possibly due to thermal stress.

Dehydrate--To remove bound water or oxygen and hydrogen in the proportion in which they form water.

Denudation--The process of wearing away or removing overlying matter from underlying rocks.

Diagenesis--Process involving physical and chemical changes in sediment after deposition that converts it to consolidated rock.

Diapir--A piercement through geological strata in which a mobile core, such as rock salt, has injected into the more brittle overlying rock, generally forming geological folds or anticlines.

Dissolution--Dissolving of minerals such as salt by fluids, typically water.

DOE--U.S. Department of Energy

Domed--Pertaining to salt domes.

Drift--A horizontal or nearly horizontal mined passageway.

Earth Sciences--In the context of NWTS, earth sciences refers to the geological, geophysicals, geohydrological, and geochemical processes about which fundamental understanding is considered important to the establishment of a mined geological repository.

Ecosystem--The complex of a biological community and its environment functioning as a unit.

Embayment--An indentation in a shoreline forming an open bay.

Emplacement--Placing the waste in its location for storage or disposal.

EPA--Environmental Protection Agency

Erosion--The general natural process which materials at the surface of the Earth are loosened, worn down, and transported from their original locations.

Exclusion Area--Area surrounding repository site over which DOE has authority to determine all actives.

Factor--A characteristic that is evaluated to determine whether a criterion is fulfilled.

Fault--A fracture or fracture zone along which there has been displacement of the sides relative to each other parallel to the fracture. Such a break in the continuity of a rock formation is accompanied by vertical or lateral displacement on one side or the other. What were once continuous rock strata or veins are separated or displaced vertically and/or horizontally during faulting.

Flood Basin--Flat areas between the sloping low plains on one side and the river lands on the other side, occupied by heavy soils and commonly having either no vegetation or a strictly swampy vegetation.

Folding--Bending or undulating in layers of rocks, usually caused by compression.

Fractures--This general term includes any break in a rock caused by mechanical failure resulting from stress, whether or not it causes displacement. Fractures may include joints, cracks, and faults.

Fuel Cycle--All of the steps involved in supplying and using fuel materials for nuclear power reactors, including related waste management operations.

Geohydrologic--Pertaining to ground water and its movements through geologic environment.

Geologic Isolation--Placement of nuclear waste in a deep stable geologic formation.

Geomorphology-Physiography--The branch of science that deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of landforms.

Geophysics--The science of the earth with respect to its structure, composition, development, and dynamic processes.

Geophysical Survey--A survey which involves probing the earth from measurement recorded at the surface. Among the rock properties which are commonly measured are electrical resistivity, self-potential, gamma radiation (both natural and induced), density. acoustic velocity, and magnetic and gravimetric fields.

Geosphere--The solid portion of the earth synonymous with the lithosphere.

Gneiss--A coarse-grained rock in which bands rich in granular minerals alternate with bands in which materials predominate.

Gradient--Slope, particularly of a stream and land surface. In mathematical terms, a change in value of one variable with respect to another variable.

Gravity Survey--The systematic measurement of the gravity field of a specified area; useful for determining the distribution of rocks in the subsurface, based on density variations.

Ground Acceleration--Vibration of the earth's crust caused by earthquakes. It has both horizontal and vertical components.

Ground Water--Subsurface water existing in the zone of saturation, a subsurface zone in which all the interstices are filled with water under pressure greater than that of the atmosphere. Even if the zone contains gas-filled interstices or interstices filled with fluids other than water, it is still considered saturated.

Gypsum--A mineral, $CaSO_4$ $2.H_2O$. A possible caprock material.

Half-Life--The time required for the disintegration of half the atoms of some specific radioactive element.

High-Level (Radioactive) Wastes--Nuclear wastes resulting from reprocessing of spent fuel. They are characterized by intense, penetrating radiation and by high heat generation rates. Unless in protective canisters, such as shipping casks, high-level wastes must be handled remotely.

HLW--High-level waste

Host Medium--The geologic material, such as rock salt or granite, in which the waste is emplaced.

Hydraulic Head--The force exerted by a static fluid at a given level owing to the height of fluid above that level; ground water tends to flow from areas of high head to areas of low head.

Hydrocarbon--A compound consisting predominately of two elements, carbon and hydrogen, such as petroleum.

Hydrology--The science of the occurrence, distribution, and movement of the waters of the earth.

Igneous--Refers to rocks formed by cooling and solidification of molten material from earth's crust or below.

Impoundments--Bodies of water, such as ponds, confined by a dam, dike, floodgate, or other barrier.

Inner Control Zone--Area around the repository (about 1-mile radius) which would have some restrictions on surface and subsurface use.

In Situ--In its natural position or place within the selected site.

Intrusion--(1) The process by which molten igneous material penetrates surrounding rock; (2) the entrance into an area or space by humans or their artifacts.

Isolation--Segregating wastes from the biosphere to the extent required to meet applicable radiological performance objectives.

Jurassic--The second period in the Mesozoic Era, extending from 195 to 136 million years ago.

Karst--A type of typography that is formed over limestone, dolomite, or gypsum by dissolving or solution, and that is characterized by haystack shaped hills adjacent to closed depressions or sinkholes, caves, and underground drainage.

LETCO--Law Engineering Testing Company, Atlanta, GA.

Licensing--The process of obtaining the permits and authorizations from responsible federal, state, and local regulatory agencies required to site, construct, operate, and decommission a repository. Includes preparing required documentation, submitting it to the appropriate agencies, responding to agency requests for additional information, and testifying as necessary at public hearings. Within the licensing framework, as defined in statutory requirements, approved permits or licenses must be available prior to the commencement of the activity involved.

Lithology--The physical characteristics of rocks as determined by microscopic study.

Location--Land contained within 30 square miles (or about 78 square kilometers) surrounding a repository site.

Migration--The movement of fluids through porous and permeable rock in geologic formations.

Model--In applied mathematics, the analytical or mathematical representative or quantification of a real system and the ways that phenomena occur within that system. Individual or sub-system models can be combined to give system models. Deterministic and probabilistic models are two types of mathematical models.

MSA--Major Systems Acquisition

MSC--Material Steering Committee

MTU--Metric tons of uranium dioxide in nuclear fuel.

NEPA--National Environmental Policy Act (1969)

NRC--U.S. Nuclear Regulatory Commission

Offset--Displacement of formerly contiguous bodies due to faulting.

ONWI--Office of Nuclear Waste Isolation

Operational Period--The period during which a nuclear installation is being used for its intended purpose until it is shut down and decommissioned.

Outer Control Zone--Area around the repository (a 2- to 3-mile radius) which would have restrictions on surface and subsurface activities, including drilling or mining.

Paleohydrologic--Pertaining to ancient ground water, that is, water that has existed within a formation since its formation.

Permeability--In hydrology, the capacity of a rock, sediment, or soil for transmitting fluids. Permeability depends on the size and the shape of the pores, the size and shape of their interconnections, and the extent of the latter. It is measured by the rate at which a fluid of standard viscosity can move a given distance through a given interval of time. The unit of permeability is the darcy.

Piezometric Level--The level to which the water from a given aquifer will rise under its full head. (See Hydraulic Head)

Plasticity--The property of a material, e.g. rock salt, that enables it to undergo permanent deformation without appreciable volume change or elastic rebound, and without rupture.

Porosity--The ratio of the total aggregate volume of voids or interstices in a rock or soil to its total volume, usually expressed as a percentage.

Porous--Containing voids, pores, interstices, or other openings which may or may not interconnect.

Quaternary--The most recent geologic period, extending from 3 million years ago to the present.

Radioactive Waste--Any material containing or contaminated with radionuclides at concentrations or activities greater than exempt quantities established by the competent authorities and for which there is no foreseen use.

Region--Severals thousand square miles of land within the U.S. that may include all or parts of several states.

Remote Sensing--The acquisition of information about the earth by the use of aircraft or satellites, such as high altitude photography or side-looking radar.

Repository--A place in a geologic formation in which to store radioactive wastes so that they are contained and isolated from the biosphere.

Reprocessing--The process by which spent fuel from a reactor is separated into waste material and material to be reused as nuclear fuel.

Retardation Factor (Rd)--A component of the hydrological or geochemical regime which slows the migration or transport of a radionuclide.

Retrievability--Capability of removing waste from its place of isolation using planned engineering procedures.

Rock Mechanics--The branch of mechanics concerned with the response of rock to the force fields (thermal, mechancial, hydrological) of its physical environment.

Salinity--A measure of the total dissolved solids in a saline water.

Salt Dome--A salt structure resulting from the upward movement of a salt mass, generally due to diapirism.

Seal--A device, mechanism, or material utilized or emplaced to retard the flow of liquid or gas.

Seismic--Of or related to natural or artificially generated vibratory ground motion.

Seismic Reflection Method--A seismic exploration technique which produces a graphic cross-sectional representation of the disposition of rock units in the subsurface; based on the reflection of artificially generated seismic waves by subsurface formations.

Seismic Refraction Method--A seismic exploration technique used for determining the depths to various rock formations; based on variations in the velocity at which artificially generated seismic waves travel through the subsurface.

Shaft--An excavation of small cross-sectional area, compared with its depth, made for finding or mining ore or coal; raising water, ore, rock, or coal; hoisting and lowering men and material; or ventilating underground workings. Often specifically applied to approximately vertical shafts as distinguished from an incline or inclined shaft. A shaft in a repository will be large enough to permit workers to have access and do work related to the placing of seals.

Shale--Laminated consolidated rock consisting predominantly of fine-grained clay minerals, quartz, and other mineral and rock fragments.

Short-Term--The 50-year period after closing a repository.

Site--Any potential or actual repository land nominally 10 square miles (about 26 square kilometers) including the underground repository itself and about 240 acres (about 97 hectares) of controlled surface area where radioactive wastes are handled or stored. There can be one or more sites at a location.

Sorption--A broad term referring to reactions taking place within pores or on the surfaces of a solid. Its use avoids the problem of technical distinction between absorption and adsorption reactions. ABSORPTION is generally used to refer to reactions taking place largely within the pores of solids, in which case the capacity of the solid is proportional to its volume. ADSORPTION refers to reaction taking place on solid surfaces so that the capacity of a solid is proportional to its surface area. An example of the latter is ION EXCHANGE, whereby ions occupying charged sites on the surface of the solid are displaced by ions from solution

Spent Fuel--Nuclear fuel that has been irradiated and subsequently removed from the reactor. It contains uranium, plutonium and other actinides, radioactive fission products, and other nuclides.

Stratigraphy--(1) That branch of geology which treats of the formation, composition, sequence, and correlation of the stratified rocks as parts of the earth's crust. (2) By extension, the arrangement of strata as to geographic position and chronologic order of sequence.

Subsidence--A local movement downward as in settling or sinking of an area of the earth's surface with little or no horizontal motion.

Syncline--A fold in rocks in which the strata dip inward from both sides toward the axis.

Tectonic--Of, pertaining to, or designating the rock structure and external forms resulting from the deformation of the earth's crust. Frequently associated with earthquakes and volcanic activity. As applied to earthquakes, it is used to describe shocks not caused by volcanic action or by the collapse of caverns or landslides. Refers to those processes by which rocks of the earth's crust and upper mantle are deformed (faulted, fractured, folded, etc.).

Tertiary--The first of two periods in the Cenozoic era, extending from 65 to 3 million years ago.

Thermal Loading--The quantity of heat-generating materials placed in a given area or volume (e.g., kilowatts per hectare).

Transport Time--Time required for migration or hydrologic transport of a radionuclide from the repository to the accessible biosphere, taking into account sorption characteristics of the geosphere.

Transuranic Waste--Radioactive waste containing alpha emitting transuranic elements with half-lives greater than one year, in excess of 10 nanocuries per gram. Transuranic elements include 233U and the nuclides of all elements above uranium in the periodic table.

Triassic--The first period in the Mesozoic Era, extending from 225 to 195 million years ago.

TRU--Transuranic Waste

Tuff--A medium-grained rock formed of small compacted fragments of volcanic glass, mineral grains, and rock particles.

Uplift--A lifting up of the earth's crust by the movement of stratified or other rock.

USGS--U.S. Geological Survey of the Department of the Interior

Waste Form--Radioactive waste, in either treated or untreated condition, including any inerts, binder, or stabilizer. (Waste can be specially formed to serve special purposes, e.g., high-level waste can be fixed in a vitrified matrix to inhibit leaching waste.)

Waste Inventory--Quantity of waste in a repository at any given time.

Waste Package--A system of engineered components designed to contain nuclear waste within the region of initial placement for an extended period of time. It must preserve the ability to retrieve the wastes through the required retrieval period, and must act as a barrier to radionuclide mobilization and release into the geologic system over long periods of time.

Well Log--Record of a well, generally a lithologic record of the strata penetrated.

Whipstock--The use of a long wedge-shaped steel device with a concave groove along its inclined face, placed in an oil well and used during drilling to deflect and guide the drill bit toward the direction in which the inclined grooved surface is facing. To use a whipstock to drill a directional well.

APPENDIX D

COMMENTS AND RESPONSES

127

REC'D MAY 17 1983

TEXAS ENERGY AND NATURAL RESOURCES ADVISORY COUNCIL
200 EAST 18TH STREET AUSTIN, TEXAS 78701 512 475-0414

May 16, 1983

Mr. J. O. Neff, Program Manager
National Waste Terminal Storage
Program Office
U. S. Department of Energy
505 King Avenue
Columbus, Ohio 43201

Dear Mr. Neff:

Formal review by the State of Texas of "Permian Basin Location Recommendation Report" (DOE/CH/10140-2; November, 1982) has been completed under the coordination of the staff of the Office of High-Level Nuclear Waste Affairs of the Texas Energy and Natural Resources Advisory Council. The attached list indicates individuals to whom the Location Recommendation Report (LRR) was sent and their respective affiliations. In most cases, additional agency staff were designated to participate in the review. Staff of TENRAC who reviewed the document include Steve Frishman, Danny Smith, and L. Edwin Garner (geology consultant to TENRAC). A notice was published in the Texas Register soliciting comment from the public and announcing the availability of the report at specified locations in Hereford, Tulia, and Austin, Texas. Finally, the prospective members of the High-Level Waste Subcommittee of the TENRAC Advisory Committee on Nuclear Power were sent copies of the LRR and convened on April 4, 1983, for a detailed discussion of that document as well as the Department of Energy Siting Guidelines. A list of those prospective members is also attached.

In the letter to the reviewers we (1) noted that the recommendations in the LRR are based largely on the information appearing in the "Area Geologic Characterization Report for the Palo Duro and Dalhart Basins, Texas" (AGCR) and (2) called attention to the table on page 75 (LRR) of criteria and screening specifications used and the discussion on page 53 (LRR) of the site performance criteria not used. Most of the reviewers were familiar with the AGCR by having participated in its review.

The reviewers were also advised that at that time a supplement to the LRR was being prepared which would reduce the proposed locations to a single site. Concurrent review of the LRR and the supplement was suggested as an option. When the supplement phase was postponed, the reviewers were requested to complete and forward their LRR comments.

In some cases, the responses from the State reviewers include a section of comments on the Department of Energy Repository Siting Guidelines (10 CFR 960) because of the similar review periods and the relation between the documents. Rather than deleting these sections and leaving perhaps mysterious gaps, these responses have simply been left intact. The comments on the guidelines were used in the earlier State response to that document and need not be addressed in the context of the LRR review process.

The comments presented below are designated as (1) general comments on the overall purpose and content of the LRR or (2) specific technical comments which reference particular parts of the report. Some of these general and specific remarks reiterate those presented by individual reviewers. Copies of the full text of all individual reviews are also attached and merit your careful attention, as our comments in this letter are not intended to fully summarize or evaluate all points raised by individual reviewers.

General Comments:

1. A total of ten site qualification criteria with a total of thirty subcriteria appear in Table 2-1, but only eight of those subcriteria are used to identify the potential locations and only four of the eight pertain to geologic conditions. The Nuclear Waste Policy Act (NWPA) and the Proposed Repository Siting Guidelines (10 CFR 960) both clearly reflect the central role that geologic characteristics are to play in the screening process, yet critical geologic characteristics including geohydrology, geochemistry, and tectonics have not been considered, primarily because of lack of data. Specific remarks on the purported reasons for deferring consideration of these and other criteria appear in the specific comments. The publication of primary decision documents should be keyed to the availability of sufficient data and analysis to sufficiently and substantively support the decisions and legitimize the process.

2. At this screening stage and earlier ones, decisions have been made based on insufficient or preliminary information which has since been re-evaluated and updated. In many cases, as in this one, data collection and evaluation have continued as decision documents are prepared and the conclusions reached do not reflect all of the available data. At some points, such as the selection of locations and sites, the parameters necessary for arriving at an informed decision should be determined, fully analyzed, and then applied in the decision process.

3. The screening specifications that quantify the corresponding subcriteria used in the LRR were selected with little or no published substantiation or justification. The acceptable quantitative limits of these parameters should be clearly derived from site performance criteria for high-level waste disposal. Ideally those site performance criteria should be available in

final form prior to finalizing and using the derived screening specifications. Because the Environmental Protection Agency (EPA) Standard (40 CFR 191) and the Nuclear Regulatory Commission (NRC) Rules (10 CFR 60) could be finalized as late as 1984 and still comply with NWPA; the screening criteria can, at this point, only be derived from draft performance criteria. However, to establish at least minimal legitimacy of the screening specifications, they should be analytically derived from the existing draft criteria available.

Specific Comments:

4. Geohydrology, Section 4.1.3--The raw data used to derive the values presented in the geohydrology section are the same numbers presented in the AGCR and are still inadequate. The Intera, 1982 reference appears to provide some new data but it is, upon further examination, only a statistical manipulation of earlier BEG data.

Although the TDWR, 1982 report "Evaluation of Groundwater Resources of the High Plains of Texas" is acknowledged in the LRR, there is little indication that data from this publication are considered. There are considerable data in the TDWR report that could provide an additional basis for screening locations.

5. Salt Dissolution, Section 4.1.4--How much lowering of the ground surface has resulted from salt dissolution? Is there a relationship between seismic activity and loci of dissolution? Is any active faulting associated with dissolution?

6. Seismicity/Tectonics, Section 4.1.5--A seismic monitoring program in the area will provide valuable data relating to some of the questions asked in the previous section. Since salt dissolution is active within the region, it should be investigated as a source of seismic activity. Will the planned microseismic network be sensitive to this possible source?

The probability of horizontal acceleration in rock should be calculated for 10,000 years. The probabilities may be unacceptable. Also, up-to-date ground acceleration data should be included here. It could be very important for screening.

7. Land Use, Section 4.2.2--No mention is made of the Pantex facility in Amarillo. This is an important nuclear facility and should be considered during the screening process.

Depletion figures for the Ogallala in the last paragraph of this section do not agree with figures given in TDWR, 1982.

8. Evaluation of Study Area, Section 5 - The omission of geohydrology, geochemistry, and tectonic environment from the screening process makes this document totally inadequate for the screening for locations. At this point,

the criteria that have been omitted are as important as the criteria that have been used.

In Figure 5-2, the boundary of "Area Meeting Screening Specifications" is incorrect in the southwest corner of the map. The source data listed indicates that the boundary should be moved northward in Parmer, Castro, and western Swisher Counties.

9. Geohydrology, Section 5.2.1--The incomplete nature of the geohydrologic studies as stated in sentence 3 of paragraph 1 makes it impossible to say that conditions are relatively uniform and always favorable. In fact, the data now available indicate that the hydrology is not uniform and perhaps should be utilized as a screening criterion.

10. Geochemistry, Section 5.2.2--No information is given to show the relationship of geochemical conditions to dissolution or potential rock/waste interactions. Samples are available from the salt intervals, yet there is no mention of studies underway to determine these critical factors for the High Plains area. Geochemistry is certainly relevant to waste package design, but its implications for basin-wide geohydrology and its impacts must be recognized and evaluated.

11. Tectonic Environment, Section 5.2.3--A seismic monitoring network is essential. No adequate data can be obtained without such a system. Ground-surface acceleration data should be an important factor in screening. Studies should also be initiated to determine stress conditions within the basin. Preliminary interpretations indicate that this criterion is not insignificant for screening to the location level.

Have any studies been initiated to determine the effect of reactivation of volcanic activity in adjacent areas? It seems likely that ash falls could have a negative impact on the area.

The fault that extends from Swisher County, through Castro County, to Deaf Smith County is still under investigation. This fault should be an important factor in screening considerations. Faulting associated with salt dissolution and collapse could have a negative impact on maintaining stable shaft and repository conditions and should be considered during screening.

12. Socioeconomic Impacts, Section 5.2.4--The socioeconomic analysis is far from the level of development necessary for impact analysis, but some predictive work could be performed. The economic mainstays of the Panhandle could be fully described at this point and screening relative to current and future land use could have been performed.

The primary deficiencies of this report are the subset of siting subcriteria used and the deferral of the investigation of the other criteria. The only geologic criteria for which sufficient data were available include site geometry and host rock quality. Clearly, other geologic criteria are equally or more important and should also be addressed at this screening stage. Basing location selection on these few criteria can eliminate areas that could, in fact, be more suitable overall. The rationale that criteria were deferred to reduce the area for which detailed studies are to be performed is not consistently applicable because of the areal or regional nature of some of those deferred criteria, such as tectonics and geohydrology.

Another major concern is the apparent lack of basis for the quantitative screening specifications. It is essential that the acceptable limits for screening specifications be explicitly justified and consistent with available site performance criteria promulgated by EPA and NRC. The limited discussion of rationale for screening specifications in the LRR deals almost entirely with engineering considerations, with very little attention given to the relation between the minimum specifications and long-term integrity of the site.

Thank you for the opportunity to review the LRR. We look forward to your responses to our comments as well as those of other State reviewers. We appreciate your acquiescence in allowing additional time to complete this review. As the press of initial activity precipitated by enactment of the Nuclear Waste Policy Act begins to abate, these review activities are expected to be completed more quickly.

If you have questions or comments regarding this letter, please contact me or Steve Frishman, Manager, TENRAC Office of High-Level Nuclear Waste Affairs.

Sincerely,

Bill Carter

Bill Carter
Acting Executive Director

BC/jb

Attachments

cc: Myra McDaniel
Jimmy Mathews
Bill Fisher
Steve Frishman
Danny Smith
Reviewing Parties

STATE AGENCY REVIEWERS

Ms. Denise Darcy
Air Control Board
Control Strategy Division
6330 Highway 290 East
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Dr. Tommy Knowles
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Data Collection Section
Stephen F. Austin Bldg., Room 469
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Ms. Arlene Wilson
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PROSPECTIVE MEMBERS OF THE
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The Honorable Glen Nelson, County Judge
Deaf Smith County Courthouse, Room 201
Hereford, TX 79045

The Honorable Charles Staniswalis
Texas House of Representatives
State Capitol, Room 108B
Austin, TX 78701

MAR 31 1983

TEXAS AIR CONTROL BOARD

6330 HWY. 290 EAST
AUSTIN, TEXAS 78723
512/451-5711

3/31/83

Steve, FYI Attach MLH

March 30, 1983

Milton L. Holloway, Ph.D.
Executive Director
Texas Energy and Natural
Resources Advisory Council
200 East 18th Street
Austin, Texas 78701

Subject: Permian Basin Location Recommendation Report
(DOE/CH/10140-2)

Dear Dr. Holloway:

In addition to reviewing the above cited document, our staff has had numerous contacts with representatives of the Department of Energy involved with this project. The principal issue discussed was the procedure necessary to acquire a permit related to the handling/storage of mine wastes extracted from the boring of a shaft. The Texas Air Control Board's concerns are centered around the creation of a particulate problem at the site and also in the atmosphere of the surrounding areas. No application for a permit has been filed and all discussions are preliminary. Prior to initiating this project, application will have to be made for either a permit or an exemption, and at that time air emission data will be reviewed in more detail.

We have no comments regarding potential radioactive emissions at this time. In the past, all matters related to radioactive materials which have come to the attention of this agency have been deferred to the lead jurisdiction of the Texas Department of Health. Within the year, it is hoped this process will be formalized in a memorandum of understanding between the two agencies.

Milton L. Holloway, Ph.D. March 30, 1983

Thank you for providing us the opportunity to review the document. If we can assist further, please contact me.

Sincerely,

Roger R. Wallis, Deputy Director
Standards and Regulations Program

cc: Mr. Gerald W. Hudson, P.E., Regional Supervisor, Lubbock

TEXAS DEPARTMENT OF WATER RESOURCES
1700 N. Congress Avenue
Austin, Texas

April 1, 1983

Mr. Danny Smith, Assistant Manager
Office of High Level Nuclear Waste Affairs
Texas Energy and Natural Resources
Advisory Council
200 East 18th Street
Austin, Texas 78701

Dear Mr. Smith:

Re: Technical Report DOE/CH/10140-2: Permian Basin Location Recommendation Report

This is in response to Dr. Milton Holloway's March 8, 1983, letter to Dr. Tommy Knowles requesting our review of the referenced report. Our comments on the report and biographical sketches of the reviewers are enclosed. We note that the areas recommended in the referenced report are very similar to those recommended in an earlier version of the report (ONWI-288) that we reviewed last year.

Dr. Holloway also asked for our review and comment on proposed guidelines for recommending sites for repositories. Such comments are also enclosed.

If you have any questions, please do not hesitate to contact us.

Sincerely,

C. R. Baskin, P.E.
Director
Data and Engineering Services Division

Enclosure (3)

[illegible] • Austin, Texas 78711 • Area Code 512 475 3187

Texas Department of Water Resources
Comments on
Permian Basin Location Recommendation
Report, Review Copy for TENRAC
DOE ICH/10140-2

1. On page 17, paragraph 2, the formations of the Guadalupe Series are listed; however, the Salado-Tansill Formation is not listed but is shown in Figure 4-2 to be at least partly a member of the Guadalupe Series.

2. On page 19, paragraphs 5 and 6, are the references to the Salado-Formation referring to the formation shown as Salado-Tansill in Figure 4-2?

3. On page 21, Figure 4-4, the word 'Andres' is mispelled in the title block.

4. On page 26, paragraph 4, the reference at the end of the first sentence should be (Knowles and others, 1982).

5. On page 43, paragraph 3, it is stated that the Ogallala will, in 50 years, be producing between 50 and 75 percent less water. Our recent planning work shows that in the Palo Duro Basin, the 2030 production rate will be at least 50 percent of current. The 75 percent reduction value listed in the report is too great a reduction.

6. On page 46, paragraph 4, sentence 2, Figure 4-1 does not show the Red and Brazos Rivers as stated in the report.

7. On page 56, paragraph 3, summary of the dimensions illustrated in Figure 5-1 yields 25.6 meters, not the 25 meters shown in the text.

8. On page 59, Figure 5-2 is in error. The map is purported to show the area containing at least one salt unit that is at least 125 feet thick and is between 1,000 and 3,000 feet below land surface. Three units were considered: Upper San Andres Formation (Figures 4-3 and 4-4), Unit 5 Salt-Lower San Andres Formation (Figures 4-5 and 4-6), and Unit 4 Salt-Lower San Andres Formation (Figures 4-7 and 4-8).

   The southern boundary line running from New Mexico to central Swisher County appears to be the most significant error. This line apparently is the 125-foot thickness line for Unit 4 (from Figure 4-7), but Figure 4-8 shows that Unit 4 in that area is more than 3,000 feet deep.

Also, we were unable to identify the source of the lines showing the north and east boundaries of the area shown in Figure 5-2. One place we disagree with the northern boundary is in central Potter County where all three units appear to be within 1,000 feet of the surface.

Attached is a copy of Figure 5-2 on which we have indicated areas of disagreement.

9. On page 67, paragraph 3, it is stated that specific exploration trends are not well enough understood to be used as a screening specification. It appears inappropriate to make this decision because Figures 39a and 39b of the 1979 progress report by the Bureau of Economic Geology (Geological Circular 79-1) show trends that could easily invite exploratory drilling. Exploration trends appear to be better understood than is implied in the subject report.

10. On page 70, paragraph 3, Figure 5-10 is referenced but is not included in the report.

11. Page 78, Figure 6-2, the westernmost portion of Area E apparently should be excluded because the salt is within 1,000 feet of the land surface as shown in Figure 4-8.

12. The lack of dissolution of massive salt beds is a criterion for site selection and storage of nuclear wastes. Present saturation and slow movement of deep ground water prevents dissolution. Should dewatering of the facility be necessary during construction and operation, it is possible that ground-water flow would be accelerated resulting in dissolution processes not now significantly active.

13. Development of a storage site will involve excavation of large volumes of material. Tailings will be stored near the site at the surface. Improper storage will impact surface - (runoff) and ground-water (leaching and infiltration beneath tailings) quality.

14. The Lower San Andres Cycle 4 dolomite may be porous. Although Ramondetta (Bureau of Economic Geology, Geological Circular 81-3, pp. 52-53) reports that the resource potential is poor due to a regional porosity pinchout just north of the Matador Arch, it is believed that this dolomite might be porous, and it should be evaluated in future tests.

15. We agree in principle with the recommendation that Areas A and B (portions of Deaf Smith and Swisher Counties, respectively) as shown on Figure 6-3 be considered for additional site characterization studies and surveys. This agreement is based on the assumption that presently unresolved hydrological and geochemical issues will be adequately addressed.

16. Reference is made to Section 5.2.1, pages 71 and 72 of the subject report. We believe this report retains the weakness exhibited in previous reports in either minimizing the importance of, or postponing to the indefinite future, a proper comprehensive characterization and analysis of groundwater resources in the selected project areas. We emphasized our concerns regarding this persistent weakness in comment 6.c. of our review of an earlier version of this report (comments transmitted to TENRAC by March 18, 1982, letter addressed to T. J. Taylor). We believe that the subject report should provide a specific, definitive reply to this previously-stated concern, which we now reiterate. Our continued emphasis of this point is reinforced by our perception of the emphasis also given in the Department of Energy's currently-proposed new regulations, 10 CFR Part 960. This regulation places equal emphasis on geohydrologic characterization and evaluation, and host-rock geologic characterization and evaluation.

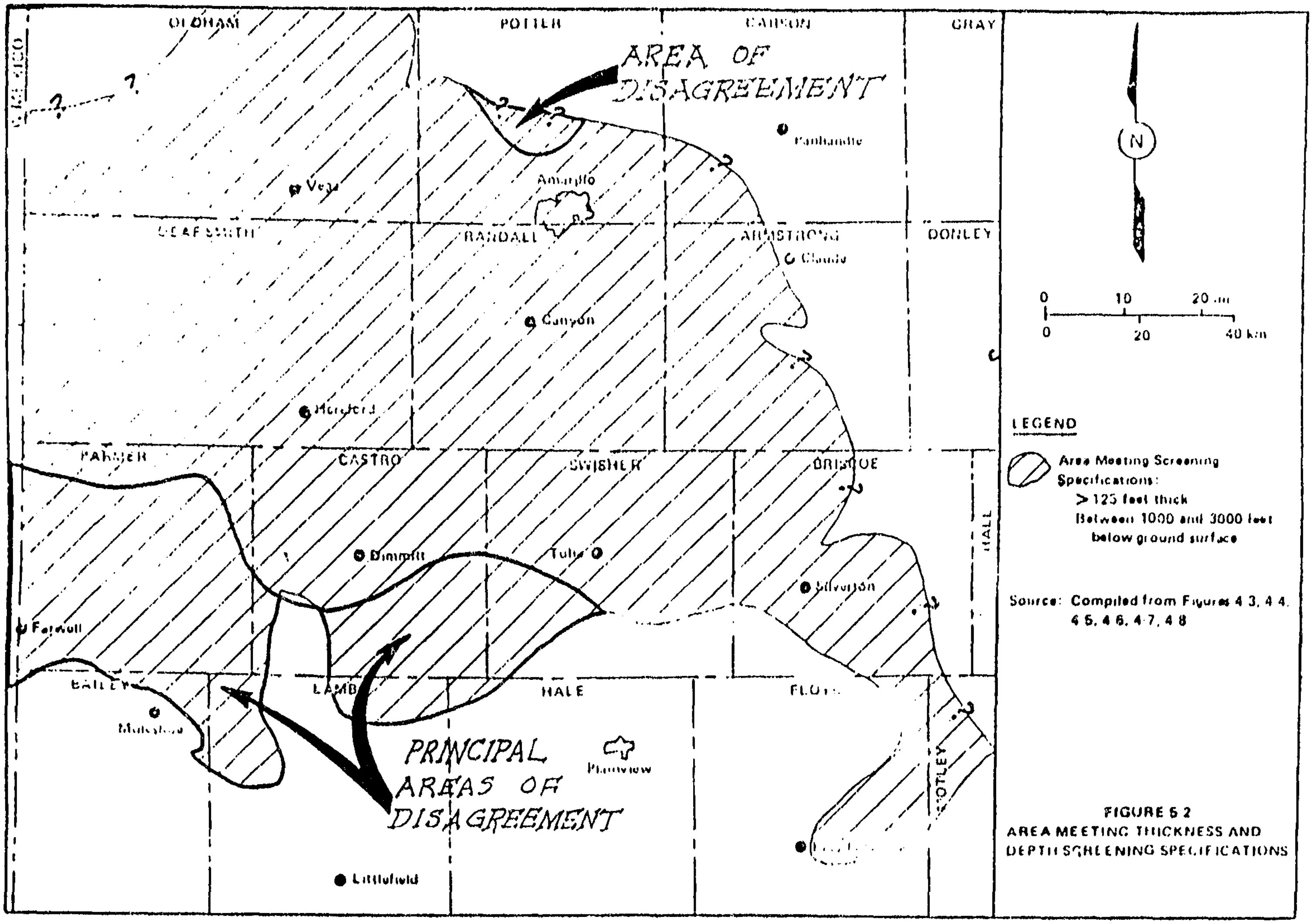

FIGURE 5.2
AREA MEETING THICKNESS AND DEPTH SCREENING SPECIFICATIONS

Texas Department of Water Resources
Comments on
Department of Energy Proposed General Guidelines
for Recommendation of
Nuclear Waste Repositories 10 CFR Part 960

1. We concur in the review comments and recommendations of the State Working Group relative to the Department of Energy's proposed regulations, 10 CFR Part 960, as stated in John H. Gervers' February 16, 1983, letter to Robert T. Morgan.

2. We believe that the site-selection process should be premised on the stated realization that the public must be actively involved in decisions affecting the property and resources of local communities to ensure an effective partnership amoung citizens, government, and industry. It is evident, we believe, that public attitudes toward rapid community change, particularly that change caused by energy and energy-related development projects and facilities, reflect the desire for increased local control over siting decisions and the management of related growth. The subject report and those leading to it, appear to have underestimated the importance of cultivating the partnership of citizens, government, and industry. A tangible sign of improvement from the standpoint of our responsibilities, would be an immediate demonstration of concern by the Department of Energy and its several study contractors of the water-shortage crisis perceived by the citizens of the Texas High Plains.

ABBREVIATED BIOGRAPHICAL SKETCHES OF REVIEWERS

Dr. Alfred J. D'Arezzo - Registered Professional Engineer
Functional Title - Chief, Environmental Analysis Section

Degrees: B. S. Engineering - U. S. Military Academy, West Point, N. Y., 1938; M. S. Civil Engineering, Texas A. & M. University, College Station, Texas, 1950; M. S. International Affairs and Economics, George Washington University, District of Columbia, 1966; Ph. D. Civil Engineering, University of Texas, Austin, Texas, 1970.

Employed November 1971 by TDWR. Has been involved in environmental analysis evaluations to present.

Dr. Tommy Knowles - Registered Professional Engineer
Functional Title - Chief, Data Collection and Evaluation Section

Degrees: B. S. Agricultural Engineering, 1970; M. S. Civil Engineering 1971; Ph. D. Civil Engineering - Water Resources, 1972; all from Texas Tech University, Lubbock, Texas.

Employed January 1973 by TDWR. Has since been involved with studies of ground-water quality, quantity, and availability.

Robert D. Price - Certified Petroleum and Professional Geologist
Functional Title - Assistant Head, Ground Water Studies Unit

Degree: Bachelor of Geology, School of Engineering, University of Tulsa, Tulsa, Oklahoma, 1955.

Employed August 1966 by TDWR. Twelve years experience as a petroleum geologist. Has since been involved in ground-water availability studies.

Richard D. Preston - Geologist
Functional Title - Head, Ground Water Studies Unit

Degree: B. S. Geology, Baylor University, Waco, Texas, 1965.

Employed July 1965 by TDWR. Has since been involved in ground-water availability studies.

Dr. Herbert W. Grubb - Agricultural Economist
Functional Title - Director, Planning and Development Division

Degrees: B. S. Agricultural Education, Berea College, Berea, Kentucky, 1958; M. S. Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, 1960; Ph. D. Agricultural Economics, North Carolina State University, Raleigh, North Carolina, 1964.

Employed March 1976 by TDWR. Has supervised professional staff involved in all phases of water resources planning.

April 8, 1983

Mr. Steve Frishman
Manager
Office of High Level Nuclear
  Waste Affairs
TENRAC
200 East 18th St.
Austin, Texas 78701

Re: Permian Basin Location Recommendation Report

Dear Mr. Frishman:

My office appreciates the opportunity to review the Permian Basin Location Recommendation Report. We have been involved with this issue since its inception and take a significant interest in ensuring that any decision by the Department of Energy be as accurate and factual as possible. However, after reviewing the document I take great exception to the location recommendations.

Specifically, the location recommendations in Deaf Smith County are based on unsubstianted assumptions, lack of necessary technical data, and omissions of critical screening specifications such as geohydrology, geochemistry, tectonics, and socioeconomics.

Further, the site location process is continuing under the assumptions that if the technical data is not available that it is not necessary or such will be developed at a later point in time. I am strongly opposed to any further action in this process until our concerns are fully addressed. Specific comments on a page-by-page basis are attached.

Sincerely,

Garry Mauro

Garry Mauro

GM/MH/jh
Attachment

Garry Mauro
Commissioner
General Land Office

Stephen F. Austin Building
1700 North Congress Avenue
Austin, Texas 78701
(512) 475-2071

[illegible]

Page/Paragraph	Comment
11/4	This document relies heavily upon the AGCR report for the Palo Duro and Dalhart Basin. However, we had significant problems with that document due to data deficiencies in several categories. How can the Permian Basin Location Recommendation Report draw recommendations and conclusions based upon the AGCR when it has significant categories where data is insufficient? (Copy of our comments on the AGCR attached)
11/2	It is premature in the siting process to make assumptions and recommendations for a location recommendation based upon core samples, geophysical logs and hydrologic test data yet to be analyzed.
15/4	The statement is made that, "The Wolfcamp Series is a major saline aquifer of concern in evaluating the Palo Duro Basin." Yet, it is scarcely mentioned or even evaluated in this document. We agree it is of major concern and thus should be addressed in this report before any recommendations for site locations are made.
29/2	This one paragraph analysis of the Wolfcamp Series is insufficient from which to make a determination as to the effects of such as it relates to underground storage of nuclear waste.
31/3	Interior dissolution of salt formations relevant to geologic stability for nuclear waste storage is an important factor. Yet, the statement is made that "The age, extent and significance of interior dissolution are the subjects of ongoing investigations." Relevant data on this issue must be obtained and analyzed before further recommendations for site locations are made in salt beds.
31/4	What is meant by low levels of seismicity? Further, recent faulting in the area is treated lightly and "is the subject of continuing structural and stratigraphic investigations." Recent faulting in an area considered for nuclear waste disposal must be thoroughly examined and analyzed before further decisions are made.
43/1	Since agriculture is the most important land-use activity in the Palo Duro Basin area, and this

agriculture is dependent upon groundwater for irrigation, then why isn't there a discussion and analysis of the effects of nuclear waste storage on groundwater resources? Geohydrology must be thoroughly examined.

53/1 Since screening specifications are essential for site location recommendations, then how can one make the statement that such criteria can only be developed where there is an adequate data base on an issue of this importance? Further, when the performance criteria are essential, required by NWTS (Table 2.1) and then not fully considered, then how can a thorough evaluation of the study area occur - much less proceed any further in the site selection process until additional data can be developed to adequately address the NWTS site qualification criteria?

53/3 Because "data are insufficient" or "not useful" is totally unacceptable for not using other site performance criteria - especially when the omissions are as important as geohydrology, geochemistry, tectonics and socioeconomics. Also, what data substantiates these assumptions for deletion of the site performance criteria? These are major concerns in the Palo Duro Basin area and must be addressed before further recommendations are even considered.

56/2 Twenty feet high rooms in the salt are required for the uncut spent fuel rods yet on page 9 the statement is made as follows: "The major element of potential risk in disposal in salt is that the cavity will collapse, structurally in time." Neither is there any analysis presented relating the size of cavities in salt formations to structural stability nor is there any definition of time provided. The data here is insufficient to draw conclusions.

58/3 Page 56 states there are non-salt stringers in the Palo Duro and Dalhart basins. When this geologic formation occurs, it requires an additional salt thickness. To locate the repository site in the necessary salt bed thickness would require lateral movement and thus relocation to the desired thickness; therefore with this lateral movement, one would assume that the lateral extent of the lost rock would be considered. But as stated here under 5.1.1.3 - such is considered to be unimportant. This statement contradicts statements prviously made. Further, data is not presented to substantiate this conclusion.

71/4 Under NWTS criteria for which screening specifications were not adopted, we take extreme exception to the justifications provided for not using certain screening specifications. The analysis presented is unjustified, undocumented and totally inadequate.

79/5 The areas discussed do not meet the adopted screening specifications because all were not considered or analyzed.

80/1 How can areas A and B have no obvious unfavorable characteristics when data was not available, arbitrary assumptions made, and important screening criteria not considered.

81/1 Again, these final location recommendations are made with insufficient data, inclusive screening criteria, and undocumented assumptions.

APR 18 1983

Texas Department of Health

Robert Bernstein, M.D., F.A.C.P.
Commissioner

Robert A. MacLean, M.D.
Deputy Commissioner
Professional Services

Hermas L. Miller
Deputy Commissioner
Management and Administration

1100 West 49th Street
Austin, Texas 78756
(512) 458-7111

April 11, 1983

Mr. Bill Carter, Acting Executive Director
Texas Energy and Natural Resources
Advisory Council
200 East 18th Street, Suite 513
Austin, Texas 78701

ATTN: T.J. Taylor, Ph.D., Director
Policy Analysis Division

Dear Mr. Carter:

The Environmental Programs staff of the Bureau of Radiation Control, Texas Department of Health, has reviewed Department of Energy document number DOE/CH/10140-2, Permian Basin Location Recommendation Report and has the following comments.

The discussions of adopted screening specifications are inadequate, especially those concerning site geometry and geologic characteristics. While the minimum depth to salt specification of 1,000 ft. is close to "favorable condition" recommendations made elsewhere [eg., 10 CFR 60.12 (b)(6) and 10 CFR 960.5-1-1(a)(1)], the specifications for maximum depth and thickness are not adequately explained or documented. There were virtually no data presented in the Area Geological Characterization Report (AGCR) concerning what might be appropriate limits for these parameters. Likewise, the use of an average gamma-ray geophysical log response of 15 API units or less is certainly a major screening factor and as such it should have been much more fully explained and justified both in this report and in the AGCR.

The decisions not to develop and adopt screening specifications for other geological site performance criteria, especially geohydrology, need elaboration and justification. It should be made clear and thoroughly justified by DOE, if indeed it is the case, that screening specifications were not adopted for these criteria because to do so would require a level of detail more appropriate to intensive location and site investigations.

The role, if any, that construction constraints or anticipated repository operating parameters should play in the site selection process is not adequately discussed. If there are factors which will affect eventual site selection, DOE should indicate at what point in the selection process screening specifications should be adopted and applied.

The proximity of the Pantex facility north of Amarillo should be additional justification for the elimination of areas C and E.

Throughout the document are numerous references to pending detailed location investigations to be performed before tentative site selection and intensive site studies. This seems misleading in view of recent actions suggesting that location investigations will largely be skipped as an intermediate step in the selection process.

If there are any questions regarding our comments, please do not hesitate to contact Mr. Joseph Thiel or Mr. Tim Dziuk at 835-7000.

Sincerely,

Bob Bernstein

Robert Bernstein, M.D., F.A.C.P.
Commissioner of Health

TEXAS ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS
PO Box 13206, Capitol Station
Austin, Texas 78711

March 30, 1983

Mr. T. D. Smith
Assistant Manager
Office of High-Level Nuclear
Waste Affairs
TENRAC
200 East 18th Street
Austin, Texas 78701

Dear Mr. Smith:

Thank you for the opportunity to review the most recent documents concerning potential disposal of high level radioactive waste in Texas. Our staff analysis of the *Permian Basin Location Recommendation Report* (ONWI-288) and the *Proposed General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories* is limited to sections covering demographic and socioeconomic factors.

Section 4.2.1 of the Location Recommendation Report (p.39) states that population in the Dalhart Basis area "is expected to decline in the future." This prediction is based on projections made by the U.S. Water Resources Council nearly ten years ago (1974). More recent projections by the Texas Department of Water Resources (June 1981) indicate that the two counties making up the Dalhart Basin (Oldham and Deaf Smith) will increase from the 1980 population of 23,448 to 30,782 by the year 2000. Rather than showing a decline, these forecasts indicate a 31.3% increase. In addition, 1970 to 1980 population growth averaged 10.3%. It is reasonable to conclude that population growth rather than decline is to be expected in Oldham and Deaf Smith counties. More up-to-date forecasts should be incorporated into the analysis in this section and others which rely on dated information.

Section 5.2.4 (p.73) alludes to socioeconomic impacts which would accompany a nuclear waste repository site although socioeconomic impacts are not among the criteria used to screen for location identification (p.53). It is unclear from the discussion why socioeconomic impacts should not be considered as location criteria. Because the

Mr. T. D. Smith
March 30, 1983
Page 2

candidate locations are relatively sparsely populated, a waste site would have a very significant impact on the population and economy of the area. An analysis appears needed to assess the capacity of the candidate locations to absorb the expected changes and to predict the degree and nature of socioeconomic impacts.

We hope these comments will be of assistance in your overall review process.

Sincerely,

Jay G. Stanford
Executive Director

JGS:wh

TEXAS HISTORICAL COMMISSION

CURTIS TUNNELL
EXECUTIVE DIRECTOR

P.O. BOX 12276
AUSTIN, TEXAS 78711
(512) 475-3092

APR 1 2 1983

April 7, 1983

Mr. Milton L. Holloway
Executive Director
Texas Energy and National Resources
Advisory Council
200 East 18th Street
Austin, Texas 78701

Re: Review of the Permian Basin Location Recommendation Report & 10 CFR Part 960, proposed General Guidelines

Dear Mr. Holloway:

Thank you for the opportunity to review the Permian Basin Location Recommendation Report and 10 CFR Part 960, prposed General Guidelines. Our comments for each of these documents follow.

Permian Basin Location Recommendation Report.

The report deals mainly with geologic questions, only briefly with sociological and environmental factors and not at all with cultural resources. It is probable that archeological sites eligible for inclusion in the National Register of Historic Places are present in the project area. Cultural resources are to be considered in the course of all federal undertakings in accordance with the National Historic Preservation Act of 1966 as amended and implementing regulations 36 CFR 800.

The American Indian Religious Freedom Act of 1978 is also pertinent to the matter at hand and should be referenced as well. Our office has no information concerning sites in the Panhandle area that are of importance to American Indian groups, so further research is needed.

36 CFR Part 960

The proposed guidelines fail to reference the National Historic Preservation Act of 1966 as amended, 36 CFR 800, and Executive Order 11593. The guidelines do allow for comment from American Indian groups but the American Indian Religious Freedom Act is not referenced. Although other federal laws and regulations governing cultural resources may apply, these are the principal ones; to omit them is a major oversight.

Sincerely,

LaVerne Herrington

LaVerne Herrington, Ph.D.
Deputy State Historic Preservation Officer

cc: Steve Frishman

The State Agency for Historic Preservation

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APR 21 1983

TEXAS PARKS AND WILDLIFE DEPARTMENT

CHARLES D. TRAVIS
EXECUTIVE DIRECTOR

4200 Smith School Road
Austin, Texas 78744

April 20, 1983

Copy to Steve Allen
file G.C.

Mr. Bill Carter
Acting Executive Director
Texas Energy and Natural Resources
Advisory Council
200 East 18th Street
Austin, Texas 78701

Re: Permian Basin Location Recommendation Report and Proposed DOE Guidelines for Recommendation of Sites for Nuclear Waste Repositories

Dear Mr. Carter:

With reference to the above-reference documents, the following comments are provided.

Concerning the Permian Basin Report, this agency can foresee no significant adverse impacts that should result upon extant wildlife resources from selection of this site. Assuming that the site would be purchased and allowed to revegetate naturally, wildlife in the area could benefit.

With reference to the "Proposed Guidelines for Recommendations of Sites," we feel that the 4th sentence in paragraph 960.5.9, Environmental Protection, should be changed. It indicates a site shall be disqualified from consideration if it is located in the boundaries of a significant nationally protected resource, such as a National Park, National Wildlife Refuge, or Wilderness Area, and its (the waste site) presence conflicts irreconcilably with the previously designated use of the site. We feel

Mr. Bill Carter
Page -2-
April 20, 1983

the sentence should also read "that state/local government protected resources would also be disqualified from consideration."

I appreciate the opportunity to review and comment on both the reports.

Sincerely,

Charles D. Travis
Executive Director

CDT:RWS:jlm

Department of Energy
National Waste Terminal
Storage Program Office
505 King Avenue
Columbus, Ohio 43201

September 27, 1983

Steve Frishman
Nuclear Waste Projects Office
Office of the Governor
General Council Division
P.O. Box 12428
Austin, Texas 78711

Dear Mr. Frishman:

PERMIAN BASIN LOCATION RECOMMENDATION REPORT: RESPONSE TO TEXAS COMMENTS

We have carefully reviewed the state comments on the subject document provided to us on May 16, 1983. Those comments identifying factual errors have resulted in corrections to the report. Other comments have been individually responded to in the attachment to this letter. The Location Recommendation Report will now be finalized; your letter of review and the DOE responses will be bound into the report as an appendix.

We appreciate the time and effort of the state agency staffs in reviewing this report. The DOE accepts the recommendation in the LRR, and will distribute copies of the document upon completion of printing. Thank you for your continued cooperation in the development of NWTS program documents.

Sincerely,

J. O. Neff

J. O. Neff
Program Manager
NWTS Program Office

NPO:LKM:ksw

Enclosure: Response to Texas comments

cc: M. McDaniel, NWPO
W. Fisher, TBEG
W. Bennett, DOE-HQ
S. Goldsmith, ONWI

GS# 779-83

DOE RESPONSES TO MAY 16, 1983
TENRAC COMMENTS ON
PERMIAN BASIN LRR

1. "A total of ten site qualification criteria with a total of thirty subcriteria appear in Table 2-1, but only eight of those subcriteria are used to identify the potential conditions....critical geological characteristics including geohydrology, geochemistry, and tectonics have not been considered, primarily because of lack of data."

This and other comments by TENRAC and other state reviewers suggest that the role and purpose of the criteria document (NWTS 33(2): Site Performance Criteria) need to be placed in context, in order that reviewers recognize the document's intended role within the Nuclear Waste Terminal Storage (NWTS) Program.

NWTS-33(2) was developed (prior to 10 CFR 60 and the DOE Guidelines) to outline the broad set of considerations against which the adequacy of any proposed repository site would be measured when site characterization was completed. At that time, all factors will have been measured and compared to the requirements for adequacy. Where useable for areas many orders-of-magnitude larger than a site, the criteria have been employed to rapidly defer large areas that are clearly inadequate or inferior. This approach focuses the most careful technical scrutiny on places having the highest likelihood of proving adequate. It was never intended, nor is it possible, that the amount of data required to definitively evaluate performance of a specific site (a few square miles) be collected for places measuring 100's to 1,000's of square miles.

When screening is performed, some criteria are simply not useful at a scale much larger than a site and, therefore, are not used. Some reviewers then comment that criteria have been ignored because data are insufficient, which amounts to requesting the answer to the as-yet-unposed question: "Is a place adequate for a repository?"

The Department, however, is answering the entirely different question: "Is a place adequate to justify continued exploration to determine whether site characterization is a reasonable activity?" The distinction between these questions is important to a rational process of site identification.

All site qualification criteria in Table 2-1 have been the subject of investigation for over 5 years. Each criterion was considered during the screening process. Regional data, albeit sparse in some instances, suggest that the Palo Duro Basin may be suitable for waste isolation. While some risk is incurred by extrapolation from regional data, the Department recognizes and accepts this risk. Future investigations will continue to consider all performance criteria.

2. "....decisions have been made based on insufficient or preliminary information which has since been reevaluated and updated."

Study locations have been recommended by the Department's contractor using the best data available to them. The Department and its contractors have worked with the Texas Bureau of Economic Geology, since the first recommendation in mid-1981, to assure that the latest data and concerns are properly considered during the decision process. Recommended study locations have changed little since mid-1981, because continued evaluation and new data have indicated that early decisions are supportable.

3. "...screening specifications that quantify the corresponding subcriteria used in the LRR were selected with little or no published substantiation or justification."

Screening specifications are simply tools used to aid in a step-wise selection of smaller land areas having the highest likelihood of containing an adequate site. Screening specifications are not qualification or suitability limits. For example, the maximum possible repository depth should not be interpreted as being 3,000 feet based on the use of that specification in the LRR. This specification has been used since the NWTS program's inception as a guideline to identify (as stated above) areas having the highest likelihood of containing an adequate site. The actual depth at which a repository could be sited depends on the site-specific conditions. Final "acceptable quantitative limits" can not be determined for most parameters in the absence of site-specific data. The Department has no choice but to select conservative screening specifications during these early stages of site selection.

RESPONSES TO TENRAC COMMENTS
"SPECIFIC COMMENTS"

4(a). "Geohydrology, Section 4.1.3---the raw data to derive the values presented in the geohydrology section are the same numbers presented in the AGCR and are still inadequate. The Intera, 1982 reference appears to provide some new data but it is, upon further examination, only a statistical manipulation of earlier BEG data."

An extensive program of drilling and hydrological (including geochemical) testing has been carried out in 13 DOE-drilled wells since 1980. In addition, the Department's contractors have scoured the existing data base from petroleum exploration to collect all other data which bear upon the characteristics of fluid-bearing (or potentially fluid-bearing) units beneath the Texas High Plains (including wells in New Mexico and Oklahoma). To date, data have been collected from about 6,000 wells in the Ogallala formation. In the deep basin (beneath the evaporite section), we have evaluated data from about 7,000 drill-stem tests. On this basis, potentiometric surfaces for the Ogallala, Wolfcamp and Pennsylvanian fluid-bearing sections have been defined. On the basis of this considerable data base, the following conclusions are drawn independently (with a high degree of confidence) by all contractors involved in the modeling:

1. The deep-basin aquifer potentials are lower than those of the High Plains aquifer. The potential for flow between them (if they were connected) is vertical and downward.

2. Flow direction in the deep-basin aquifers is northeast or east, depending on the specific place of reference. The flow direction of the Ogallala/Dockum is southeast.

3. On the basin-wide scale, the characteristics of the aquifers are very uniform. Local variations of significance to site performance can only be evaluated meaningfully by detailed testing at a specific site.

4(b). "Although the TDWR, 1982 report "Evaluation of Groundwater Resources of the High Plains of Texas" is acknowledged in the LRR, there is little indication that data from this publication are considered. There are considerable data in the TDWR report that could provide an additional basis for screening locations."

The TDWR report contains extensive data on the fresh water Ogallala aquifer. These data will be especially useful on a site-specific basis. In siting a repository the major concern is to identify the travel path along which any radionuclides that may be released from a repository would move. In the Palo Duro Basin, the pathway of a hypothetical release from a repository is downward from the salt horizon to the deep brine aquifers (below 5,000 feet depth). Therefore, more emphasis is placed on the deeper units at this stage of the project. The Department is not aware of data in the TDWR report which would affect the screening recommendation.

5(a). "How much lowering of the ground surface has resulted from salt dissolution?"

Gustavson and Finley (in preparation) have suggested that "...as much as 60 m (200 feet) of salt have been removed from beneath portions of the Palo Duro Canyon....subsidence, therefore could account for as much as 20 percent of the Canyon's depth." In the same paper, Gustavson and Finley suggest that at least 20 m (65 feet) of salt have been removed by dissolution in an area beneath the Southern High Plains surface, and that subsequent perferential surface erosion has resulted in a total ground-surface lowering of 60 to 75 m (200 - 250 feet). The Department has not completed its technical review of the data which may support these hypotheses.

Questions 5(b), 5(c) and 6(a) are closely related. Considerable discussion of this subject is included below:

5(b). "Is there a relationship between seismic activity and loci of dissolution?"

In a brief response to question 5(b): There is no demonstrated relationship. Some shocks might be attributable to dissolution-induced faulting.

5(c). "Is any active faulting associated with dissolution?"

In a brief response to question 5(c): If salt dissolution is active, material is removed and overburden must be settling. Faulting is possible, but it could be seismic or aseismic. Reference to active faulting related to salt dissolution was made by Gustavson, Finley and McGillis, 1980, page 30, but the existence of active faults related to dissolution is as yet not demonstrated.

6(a). Paraphrased - will the planned seismic network detect dissolution-induced faulting?

In a brief response to 6(a): Few dissolution-induced seismic events are expected to be recorded due to the low magnitude of expected events (see below) and to the infrequent spacing of the network's stations in active dissolution areas.

BACKGROUND DISCUSSION: Outcrops at Caprock Canyons State Park contain small faults that are attributed by Goldstein (1982) to salt dissolution and subsequent fracturing and settling of the salt's overburden. Salt dissolution extends to depths on the order of 500 to 1,600 feet near the Caprock Escarpment. The largest faults observed are on the order of 10 to 40 m in length (Dr. Arthur Goldstein, oral communication, August, 1983). No active or holocene faulting is recognized at the surface. Although some larger faults could be present, the oberservations suggest that the affected rocks are rather weak and tend to fail along many small faults rather than along individual large faults. When a fault under stress slips, elastic energy stored in the nearby surrounding rock volume can be released as work on the fault surface, crushing, heating, and seismic waves. The seismic waves constitute an earthquake. Some faults can move so slowly that very little seismic energy is radiated.

Although the details of the rock-failure mechanism and slip mechanics are not fully known, the processes that produce micro-fractures in a laboratory rock specimen are similar to those which produce damaging earthquakes. The size of an earthquake depends on the fault's size, slip amount, and rock strength. Weak rocks can support only low stress levels (low elastic-energy storage) before they break, and conversely for strong rocks.

Seismic moment, M_o, is a quantity defined to measure earthquake size.

$$M_o = \mu A \bar{u} = (16/7) \Delta\sigma \; r^3$$

Where μ is the rock shear modulus, A is the fault area, $\bar{u}$ is the average fault displacement, $\Delta\sigma$ is the stress drop, and r is the radius of a circular fault with Area A (Kanamori and Anderson, 1975). Measured stress drops for earthquakes range from about 1 bar (1 bar = 10^6 dynes/cm^2) to 100 bars. A moderate value is 30 bars, but the shallow formations above the salt dissolution may well fail with lesser stress drops. Earthquake magnitude, M_L, is related to seismic moment by the equation;

$$M_L = (\text{Log } M_o - 16)/1.5$$

from Thatcher and Hanks (1973). This equation is an empirical relation developed for California earthquakes, and must be considered only approximately correct for presumed dissolution-induced earthquakes. However, the approximation is adequate for estimating what magnitude earthquakes might be caused by dissolution.

For the largest observed faults attributable to salt dissolution, say an equivalent fault radius of 20 m,

$$M_o = 16 \cdot \Delta\sigma \cdot r^3 = 16 \cdot (30 \times 10^6) \cdot (20 \times 10^2)^3,$$

$$M_o = 5.49 \times 10^{17} \text{ dyne-cm.}$$

Then, $M_L = (\text{Log } M_o - 16)/1.5 = 1.16$

Higher stress drop (100 bars) increases the magnitude estimate to 1.51.

As an upper limit on earthquake magnitude from salt dissolution, consider a fault rupture extending to the deepest salt dissolution, about 1,600 feet (490 m), and twice as far along strike. The equivalent radius is r = 391 m, and 30-bar stress drop leads to a magnitude 3.7 earthquake. No faults this large have been observed at the surface in salt dissolution areas.

The ability of a seismograph to detect microearthquakes depends on the level of background seismic noise and the distance to the hypocenters.

Seismic energy attenuates with distance, and shocks are seldom noticed (without special analysis) when their waveforms are comparable to, or less than, the background noise. Exact detection capabilities wil' depend on each site as the instrumentation becomes fully operational. Generally, microearthquakes with magnitudes of 1.0 to 1.5 are detected only at distances up to about 10 km, unless background noise is low. One network station is sited in Caprock Canyons State Park and may detect any local microearthquakes. Most microearthquakes from salt dissolution would be smaller than the maximum estimates and might not be observed beyond about 5 km. Earthquakes must be recorded by at least three stations if the epicenters are to be calculated. At the state park, local microearthquakes may be detected, but the observations would not permit epicenter determinations.

6(b). "The probability of horizontal accelerations should be calculated for 10,000 years."

This calculation has not yet been done. However, the probability will be very strongly dependent upon the maximum earthquake ascertained from geologic and tectonic analysis. The recurrence characteristics of such maximum earthquakes are such that the average return periods are on the order of 5,000 to 10,000 years. Seismic-design criteria are chosen so that engineered structures related to safety will withstand those design' earthquakes. This choice for maximum design earthquake ensures that the longterm probabilities are acceptable in terms of seismic hazard. The regional geology and tectonics in the area are such that all locations within the area are considered equally susceptible to the same maximum earthquake. Therefore, probabilities for accelerations during 10,000 years do not discriminate among Locations within the study area.

7(a). "Land Use, Section 4.2.2--no mention is made of the Pantex facility in Amarillo. This is an important nuclear facility which should be considered during the screening process."

The Pantex facility is an important land-use consideration in the Palo Duro Basin. Application of this consideration in Section 6.2 of the report (Recommendation of Preferred Locations) would result in Areas C and E having an additional "less desirable characteristic". Application of this consideration does not alter the recommendation to focus future siting and characterization efforts on Areas A and B.

7(b). "Depletion figures for the Ogallala in the last paragraph of this section do not agree with figures given to TDWR, 1982."

The figures will be changed to reflect an estimated 50 percent depletion. This is more consistent with the TDWR calculations.

8(a). "The omission of geohydrology, geochemistry, and tectonic environment from the screening process makes this document totally inadequate for the screening..."

Please see the response to TENRAC questions 1, 4(a), and 6(b).

8(b). "In Figure 5-2, the boundary of "Area Meeting Screening Specifications" is incorrect...."

Figure 5-2 has been corrected in the revised report.

9. Geohydrology, Section 5.2.1--the incomplete nature of the geohydrologic studies as stated in sentence 3 of paragraph 1 makes it impossible to say that conditions are relatively uniform and always favorable. In fact, the data now available indicate that the hydrology is not uniform and perhaps should be utilized as a screening criterion.

On a regional scale, the geohydrology is relatively uniform, particularly based on all currently available data. The geohydrology consists of an upper fresh-water-aquifer system, a relatively impermeable sequence of evaporites, and an underpressured deep-brine-aquifer system. The aquifer potentials indicate that flow would be downward from the upper to lower aquifers anywhere beneath the Southern High Plains. The calculated travel velocities are very slow in the deep aquifer, and discharge areas are believed to be east and/or northeast of the Palo Duro Basin.

Investigations completed since the original writing (mid-1981) of the LRR have confirmed that earlier indications of favorable hydrologic conditions were correct. Local hydrologic variability does indeed exist; however, this must be studied on a site-specific basis. Detailed site characterization activities will focus on site-specific geohydrology, in addition to resolving important regional questions.

For example, the non-DOE exploration well data base contains some anomalously high and low heads. The significance of this is under investigation regionally and must be resolved should a repository site be proposed for the Texas Panhandle.

Please see also the response to TENRAC question 4(a).

10. "Geochemistry, Section 5.2.2--no information is given to show the relationship of geochemical conditions to dissolution or potential rock/waste interactions. Samples are available from the salt intervals, yet there is no mention of studies underway to determine these critical factors for the High Plains area. Geochemistry is certainly relevant to waste package design, but its implications for basin wide geohydrology and its impacts must be recognized and evaluated."

A substantial amount of information exists about potential rock/waste interactions in a repository in Palo Duro salt. Studies have been under way with Permian brines since the fourth quarter of Fiscal Year 1982 (ONWI-9) [82-4] pages 38-42. In addition, the chemical composition of Permian brines is very close to brines from the Waste Isolation Pilot Plant (WIPP) that have been used in testing programs for many years (SAND 83-0526), allowing direct application of those many data to the design of waste packages for a potential repository in Permian salt. The Department has chosen not to use this report to summarize the results of these studies.

The collection and application of geochemical data to characterize salt dissolution and basin-wide geohydrology have been very active during the past calendar year. The early results are being presented at national scientific meetings and papers are being prepared for publication as ONWI technical reports or in scientific journals. This work is directed toward gathering the information needed for licensing, and is being closely followed by NRC, the Texas Bureau of Economic Geology, and the United States Geological Survey.

Geochemical data on both rock and water have been collected on a basin-wide basis to, among other things, develop an understanding of the geohydrologic regime within the deep-basin aquifers. This work is being undertaken by the Bureau of Economic Geology and by ONWI and its subcontractors. Data evaluation is continuing. The Department agrees that geochemistry is an important element of basin analysis and site specific characterization, but knows of no rational way to use geochemical data on rock or water to screen to Locations.

11(a). "Tectonic Environment, Section 5.2.3--a seismic monitoring network is essential. No adequate data can be obtained without such a system. Ground-surface acceleration data should be an important factor in screening. Studies should also be initiated to determine stress conditions within the basin. Preliminary interpretations indicate that this criterion is not insignificant for screening to to the location level."

An earthquake-monitoring network is now installed in the Panhandle. This 16-station network, with data telemetered to a central recording facility in Amarillo, is expected to be fully operational by the end of 1983.

The earthquake-monitoring network will be able to provide data on stress orientation if shocks are well recorded by most stations in the network, i.e. for larger shocks. Otherwise, stress conditions must be measured using borehole techniques. Such measurements will be undertaken in the the Fall of 1983, initially in the Holtzclaw #1 well. Because the region is very stable, there is no young geologic deformation to indicate current stress conditions. The Department knows of no interpretation which indicates that this criterion can be used intelligently in screening to Locations.

Ground-surface acceleration data have not been measured in the Texas Panhandle region. No accelerographs have been installed prior to these siting studies because earthquakes strong enough to trigger strong-motion instruments have been extremenly rate. Some site-specific accelerograph sites should be established for this program, when a specific-site is identified, but the probability of recording significant data from earthquakes is quite low. For design purposes, ground-acceleration criteria will probably be developed from model studies and from recordings in other places that have experienced strong earthquakes and were instrumtented.

11(b). "Have any studies been initiated to determine the effect of reactivation of volcanic activity in adjacent areas? It seems likely that ash falls could have a negative impact on the area."

Evaluation of data available from the region shows that the nearest recurrence of volcanism would be expected in the Raton area (New Mexico) or farther northeast (DOE/NE/10140-1, Section 3.3.2). This area is far enough away to pose no direct hazard to an underground facility. The potential effect of ash fall on operation of surface facilities has not been specifically evaluated, as this is a site-specific exercise. It is expected, however, that standard engineering systems (e.g. filters or scrubbers) can be used to mitigate potential problems in the unlikely event that significant ash fall is deemed a credible event.

11(c). "The fault that extends from Swisher County, through Castro County, to Deaf Smith County is still under investigation. This fault should be an important factor in screening considerations. Faulting associated with salt dissolution and collapse could have a negative impact on maintaining stable shaft and repository conditions and should be considered during screening."

It is true that the subject fault is still under investigation. Recent seismic-reflection-survey data have shown that faulting has occurred in this area. Various investigators have mapped the fault(s) in different ways. The fault(s) are interpreted to be pre-mid Permian in age and have not offset any salt horizons.

We further agree that faults associated with salt dissolution and collapse ought to be avoided in site selection, and indeed they have been as the recommended locations are away from active dissolution zones. The fault referred to in this comment is not demonstrably associated with salt dissolution or collapse.

12. "Socioeconomic Impacts Section 5.2.4--the socieconomic analysis is far from the level of development necessary for impact analysis, but some predictive work could be performed. The economic mainstays of the Panhandle could be more fully described at this point and screening relative to current and future land use could have been performed.

The primary socioeconomic factors used in screening during the location phase were 1) to exclude Standard Metropolitan Statistical areas and 2) to avoid urban areas. While these factors are related to population, they also help to avoid land-use conflicts. That is, population centers are the most intensely developed areas. By avoiding them, we also avoid land-use conflicts. For additional information on land use conflicts, see Setion 4.2.2. Socioeconomic impacts were identified in a general way due to the size of the region being screened. Detailed socioeconomic impact analyses require a more specific project location in order to evaluate affects on nearby communities. Factors which are important in projecting community impacts include size of workforce, size of communities near project site, distance of site from communities, and the availability of housing and community services. Thus, detailed socioeconomic data collection and impact analysis are more appropriate for subsequent phases of work. Based on the locations identified in the Location Recommendation Report, these activities are currently underway. Information on population, economy, community services, government, and social structure appears in the Permian Basin Socioeconomic Analysis Report, which has been reviewed by the State of Texas. Impact projections will be prepared for the environmental assessment.

DRAFT REPONSES TO THE TEXAS DEPARTMENT OF WATER RESOURCES COMMENTS ON PERMIAN LRR

1. "On page 17, paragraph 2, the formations of the Guadalupe Series are listed, however, the Salado-Tansill Formation is not listed but is shown in Figure 4-2 to be at least partly a member of the Guadalupe Series."

The Salado-Tansill Formation is in part a member of the Guadalupe Series as shown in Figure 4-2. The paragraph referred to has been modified to reflect this fact.

2. "On page 19, paragraphs 5 and 6, are the references to to the Salado-Formation referring to the formation shown as Salado-Tansill Formation in Figure 4-2?"

The text has been modified to consistently refer to the Salado as the Salado-Tansill.

3. "On page 21, Figure 4-4, the word `Andres' is misspelled in the title block."

"ADRES" has been changed to ANDRES.

4. "On page 26, paragraph 4, the reference at the end of the first sentence should be (Knowles and others, 1982)."

The reference has been changed to Knowles et al, 1982.

5. "On page 43, paragraph 3, it is stated that the Ogallala will, in 50 years, be producing between 50 and 75 percent less water. Our recent planning work shows that in the Palo Duro Basin, the 2,030 production rate will be at least 50 percent of current. The 75 percent reduction value listed in the report is too great a reduction."

Please refer to the response to TENRAC's comment 7(b).

6. "On page 46, paragraph 4, sentence 2, Figure 4-1 does not show the Red and Brazos Rivers as stated in the report."

The Red and Brazos Rivers are indicated in the right-central part of Figure 4-1 (photo reproduction may have made them illegible in your review copy).

7. "On page 56, paragraph 3, summary of the dimensions illustrated in Figure 5-1 yields 25.6 meters, not the 25 meters shown in the text."

The repository workings are shown in Figure 5-1 as requiring 82 feet. Conversion of 82 feet to metric units, using the conversion factor listed in Appendix A (1 foot = 0.305 meter), yields a value of 25.01, rounded to 25 m in the text.

8. "On page 59, Figure 5-2 is in error. The map is purported to show the area containing at least one salt unit that is at least 125 feet thick and is between 1,000 and 3,000 feet below land surface. Three units were considered: Upper San Andres Formation (Figures 4-3 and 4-4), Unit 5 Salt - Lower San Andres Formation (Figures 4-5 and 4-6), and Unit 4 Salt - Lower San Andres Formation (Figures 4-7 and 4-8).

   The southern boundary line running from New Mexico to central Swisher County appears to be the most significant error. This line apparently is the 125-foot thickness line for Unit 4 (from Figure 4-7), but Figure 4-8 shows that Unit 4 in that area is more than 3,000 feet deep.

   Also, we were unable to identify the source of the lines showing the north and east boundaries of the area shown in Figure 5-2. One place we disagree with the northern boundary is in central Potter County where all three units appear to be within 1,000 feet of the surface."

Figure 5-2 was in error and has been revised. The northeastern boundary of the area is not accurately determined because of incomplete mapping in this area.

Figures 5-3, 5-4, 5-5 and the depositional history of the area suggest, however, that salt in areas to the northeast is less pure and would not meet the 15 API screening specification used to identify the most favorable locations.

9. "On page 67, paragraph 3, it is stated that specific exploration trends are not well enough understood to be used as a screening specification. It appears inappropriate to make this decision because Figures 39a and 39b of the 1979 progress report by the Bureau of Economic Geology (Geological Circular 79-1) show trends that could easily invite exploratory drilling. Exploration trends appear to be better understood than is implied in the subject report."

The Department chose not to use hydrocarbon exploration trends in screening to Locations for several reasons: (1) the location of hydrocarbon resources is a function of variables including the location of suitable source and reservoir rocks, the thermal and the fluid migration history of the basin, and the trapping mechanism. The maps referred to in the comment provide only an indication of where potential reservoir rock may exist, and are not, in and of themselves, a basis for exploring for hydrocarbons, (2) maps, such as those prepared by the BEG for each major potential reservoir rock, show broad trends which, if overlayed, suggest that exploration trends exist throughout much of the central Palo Duro Basin. If used in this manner, they do not provide very good discriminators, (3) hydrocarbon resource potential is considered low for the entire central portion of the basin; witness the relative absence of exploratory drilling. Even if a site were selected in an area later discovered to contain hydrocarbon resources, the effect of removing this small resource from the market would be minimal.

10. "On page 70, paragraph 3, Figure 5-10 is referenced but is not included in the report."

The reference to Figure 5-10 has been removed.

11. "Page 78, Figure 6-2, the westernmost portion of Area E apparently should be excluded because the salt is within 1,000 feet of the land surface as shown in Figure 4-8."

The exact boundaries of the locations in Figure 6-2 are intentionally left indistinct in an attempt to communicate that the maps and specifications used to arrive at these locations are themselves not absolute. Precise boundaries between acceptable and unacceptable locations do not exist.

12. "The lack of dissolution of massive salt beds is a criterion for site selection and storage of nuclear wastes. Present saturation and slow movement of deep ground water prevents dissolution. Should dewatering of the facility be necessary during construction and operation, it is possible that ground-water flow would be accelerated resulting in dissolution processes not now significantly active."

Dewatering of the evaporite section is not an expected requirement. Water movement through water-bearing zones within the evaporite section appears to be negligible. Drill-stem tests in the Lower San Andres unit 4 dolomite yield permeabilities from 0.04 millidarcies to 0.40 millidarcies. Should dewatering be necessary, it could have a slight effect on hydraulic gradiant but would not affect other controls on salt dissolution, i.e. saturation levels or fluid in contact with salt, hydraulic conductivity, and effective porosity. The short time over which the (unlikely) dewatering might be done would not allow the hydrologic system time to respond to the miniscule perturbation; hence, the dissolution process would be unaffected.

Please refer also to TDWR question/response 14.

13. "Development of a storage site will involve excavation of a large volumes of materials. Tailings will be stored near the site at the surface. Improper storage will impact surface - (runoff) and ground-water (leaching and inflitrations beneath tailings) quality."

The handling of salt is being studied from several viewpoints. Various methods of surface storage are being considered with some type of protective covering to minimize exposure to the weather. Catch basins for local drainage will be used along with retention ponds as one precaution. Contaminated fluid will then be properly disposed of through licensed disposal companies. Other alternatives call for continual back-filling concurrent with repository operation and development. This will reduce the amount of surface storage. In any event, we recognize and agree that a carefully designed and monitored storage facility is essential to protect local surface and groundwater.

14. "The Lower San Andres Cycle 4 dolomite may be porous. Although Ramondetta (Bureau of Economic Geology, Geological Circular 81-2, ppg. 52-53) reports that the resource potential is poor due to a regional porosity pinout just north of the Matador Arch, it is believed that this dolomite might be porous, as it should be evaluated in future tests."

We recognize that the Lower San Andres unit 4 dolomite is porous in areas near the Palo Duro Basin margins and in adjacent basins. Drill-stem tests have been run in this dolomite in all wells since 1981; in all cases, the premeability has been less than 1 millidarcy (0.04 md. - 0.40 md). Long-term testing is ongoing in the unit 4 dolomite at the Zeeck No. 1 well in Swisher County and long-term testing is planned at the J. Friemel No.1 well in Deaf Smith County. Information to date from hydrologic testing, core analysis, and Alan Dutton's recent studies at the BEG, indicate that the porosity is salt-plugged and permeability is extremely low. This formation will continue to be tested in future program boreholes.

15. "We agree in principle with the recommendation that Areas A & B (portions of Deaf Smith and Swisher Counties, respectively) as shown in Figure 6-3 be considered for additional site characterization studies and surveys. This agreement is based on the assumption that presently unresolved hydrological and geochemical issues will be adequately addressed."

The assumption which the reviewer makes is exactly the program which the Department of Energy intends to carry out at each site selected for detailed characterization. The hydrological and geochemical issues for any site can only be resolved by site-specific studies.

16. "Reference is made to Section 5.2.1, pages 71 and 72 of of the subject report. We believe this report retains the weakness exhibited in previous reports in either minimizing the importance of, or postponing to the indefinite future, a proper comprehensive characterization and analysis of ground-water resource in the selected project areas. We emphasize our concerns regarding this persistent weakness in comment 6(c) of our review of an earlier version of this report (comments transmitted to TENRAC by March 18, 1982, letter addressed to T. J. Taylor). We believe that the subject report should provide a specific, definitive reply to this previously-stated concern, which we we now reiterate. Our continued emphasis of this point is reinforced by our perception of the emphasis also given in the Department of Energy's currently proposed new regulations, 10 CFR Part 960. This regulation places equal emphasis on <u>geohydrologic</u> characterization and evaluation, and host-rock <u>geologic</u> characterization and evaluation."

The Department has not minimized the importance of, or postponed to the indefinite future, the characterization and analysis of the ground-water system in the Palo Duro Basin. An extensive program of drilling and hydrological (including geochemical) testing has been carried out in 13 DOE-drilled wells since 1980. In addition, the Department and its contractors have scoured the existing data base from petroleum exploration to collect all other data which bear upon the characteristics of fluid-bearing (or potentially fluid-bearing) units beneath the Texas High Plains, and including wells in New Mexico and Oklahoma. To date, data have been collected from about 6,000 wells in the Ogallala Formation. In the deep basin, (beneath the evaporite section), we have evaluated data from about 7,000 drill-stem tests. On this basis, potentiometric surfaces for the Ogallala, Wolfcamp and Pennsylvanian fluid-bearing sections have been defined. On the basis of this substantial data base, we can say with high confidence:

1. The deep-basin aquifer potentials are lower than those of the High Plains aquifer. The potential for flow is verticial and downward.

2. Flow direction in the deep-basin aquifers is northeast and east, depending on the specific point of reference. The flow direction of the Ogallala/Dockum is southeast.

3. On the basin-wide scale, the characteristics of the aquifers are very uniform. Local variations of significance to site performance can only be evaluated meaningfully by detailed testing at a specific site.

We expect to continue collecting basin-wide information to keep the database current. Nevertheless, small-scale perturbations can only be defined by a comprehensive hydrologic program undertaken on a small area. Such a program will be undertaken if a Permian Basin site is recommended for characterization.

From the Department's viewpoint, a nearly equal empahsis has been placed geohydrological and host-rock geologic characterization and evaluation. The Department's newly proposed regulation 10 CFR Part 960 was prepared to see that this indeed happens and that issues raised by state agencies are not dismissed but resolved prior to license application.

DRAFT RESPONSE TO GENERAL LAND OFFICE COMMENTS ON PERMIAN BASIN LRR

> Page 15, paragraph 4: "The statement is made that, "The Wolfcamp is a major saline aquifer of concern in evaluating the Palo Duro Basin." Yet is is scarely mentioned or even evaluated in this document. We agree it is of major concern and thus should be addressed in this report before any recommendations for site locations are made."

The Department has chosen not to use the LRR as a geological characterization report summarizing the results of other investigations. (See reponse to TDWR Comment #16). The Texas Bureau of Economic Geology discusses the depositional history of the Wolfcamp in several of their Geological Circulars. Stone and Webster Engineering Corporation (SWEC) is preparing other topical reports related to the deep-basin aquifers. These reports, along with ongoing studies, have generated a very large amount of regional data all of which suggest that favorable geohydrologic conditions exist, and that the area warrants further consideration. Once sites have been chosen, additional site-specific studies of deep and shallow aquifers will be conducted.

> Page 29, paragraph 2: "This one paragraph analysis of the Wolfcamp Series is insufficient from which to make a determination as to the effect of such as it relates to underground storage of nuclear waste."

Statements related to the Wolfcamp must be considered in the regional sense at this level. We have generated a fairly large data base on the Wolfcamp and other deep brine aquifers (see response to TDWR Comment #16). The conditions on a regional scale indicate that the geohydrology is compatible with storage of nuclear waste in salt beds several thousand feet above the Wolfcamp.

No attempt has been or should be made to judge the relationship or importance of the Wolfcamp Series to underground storage of nuclear waste based on that paragraph; it is only a brief overview of the character of the Wolfcamp; considerable other data exist (Dutton, 1980A, 1980B; Handford, et al, 1981, Dutton et al, 1982; Bassett and Bentley, 1983; etc.)

> <u>Page 31, paragraph 3</u>: "Interior dissolution of salt formations relevant to geologic stability for nuclear waste storage is an important factor....Relevant data on this issue must be obtained and analyzed before further recommendation for site locations are made in salt beds."

While the Department agrees that interior dissolution of salt is an issue requiring further investigation, the available data can be used to show that interior dissolution of salt will not breach a repository and directly compromise safe performance. The assumed loss of 200 feet of Seven Rivers Formation salt (3 times the amount proposed by Gustavson and Finley (in preparation, page 42) by interior dissolution sometime since deposition over 225 million years ago suggests that this is not a significant process. Even if one assumes the 200 feet of salt were dissolved in the Quaternary Period (2 million years) or that 200 feet of salt could be removed in the next 10,000 years, a repository separated from the accessible environment by 500-600 feet of salt would not be breached. These speculations have, of course, assumed that a hydrologic, chemical, and physical regime exists by which interior dissolution could occur. No such regime has been demonstrated to exist today within the Palo Duro Basin.

The Department is charged with determining what conditions do exist today, and how they might change over the period for which nuclear waste must be isolated. The Department is working toward this end. The Department's major concern relative to interior salt-dissolution zones will be in designing shafts to remain stable and to adequately seal these horizons. This concern is relevant to the entire Palo Duro Basin and can have no affect on Location selection.

Page 58, paragraph 3: "Page 56 states there are non-salt stringers in the Palo Duro and Dalhart Basins. When this geologic formation occurs, it requires an additional salt thickness. To locate the repository site in the necessary salt bed thickness would require lateral movement and thus relocation to the desired thickness; therefore with this lateral movement, one would assume that the lateral extent of the host rock would be considered. But as stated here under 5.1.1.3 -- such is considered to be unimportant. This statement contradicts statements previously made. Further, data are not presented to substantiate this conclusion."

The chief importance of the lateral extent of both the proposed host rock and interbedded lithologies is that it demonstrates beyond question the very long-term tectonic stability of the Palo Duro Basin since deposition of the Permian salts over 225 million years ago. Seismic reflection profiles run by exploration companies, and by DOE as part of this program, demonstrate unbroken lateral extents in the evaporite section that are measureable for tens of miles and hundred of miles. The section is predictable as a result of this lateral continuity.

Non-salt stringers or partings do, in fact, occur quite frequently in salts of the Palo Duro Basin. These partings range from less than a centimeter to several feet in thickness. Identification of a preferred zone, with thickness which does not contain excessive or undesirable lithologic changes, is required for engineering and performance reasons. Because of the nature of the depositional environment reponsible for these units, the changes in lithologies are irregularly spaced vertically in the section, but are horizontally (laterally) quite uniform and extensive. Because few changes in the host rock are expected laterally throughout the the mined repository, there is no basis to define a screening specification based on host rock lateral extent.

We do not believe the statement in Section 5.1.1.3 contradicts others made in the document. As stated in a response to other comments, it is not the Department's intent to use this document to provide the results of other investigations. Information as to the depositional systems and lateral continuity of salt units in the Palo Duro Basin can be found in the following documents:

Presley, M. W., 1981 Middle and Upper Permian Salt-bearing Strata of The Texas Panhandle: Lithologic and Facies Cross Sections. BEG Cross Section Report.

McGillis, K. A., 1980, Mapping of Facies by Well Log Interpretation, in Gustavson, T. C., and others. BEG Circular 80-7 pages 8-11.

Ruppel, S. C., 1982, and Ramondetta, R. J., Determination of Salt Purity Using Gamma-Ray Logs: San Andres Formation, Palo Duro Basin. BEG Circular 81-7, pages 183-199.

Presley, M. W., in preparation, Evolution of the Permian Evaporite Basin in the Texas Panhandle.

DRAFT RESPONSES TO THE TEXAS ADVISORY COMMITTEE ON INTERGOVERNMENTAL RELATIONS COMMENTS ON PERMIAN BASIN LRR

1. ...."U. S. Water Resources council projections for Dalhart Basin are outdated.... More recent forecasts by the Texas Department of Water Resources indicate a population increase in Deaf Smith and Oldham counties rather than a decrease.... More up to date forecasts should be incorporated."

The 1974 U. S. Water Resources Council projections were the most recent general data available at the time the location recommendation report was prepared. While the projections indicate a population decrease in the region, they do not refer specifically to Deaf Smith and Oldham counties. The region referred to is the Bureau of Economic Analysis Area #122 (BEA). In 1972, this region consisted of the 25 northernmost Texas Panhandle counties except Childress, 3 northern bordering Oklahoma counties, and 7 New Mexico counties. In the decade preceding the 1974 projections (1960 to 1970), the Amarillo SMSA population dropped from 149,000 to 144,000 people. Amarillo is included in this region, and has a substantial influence on the projections because of its size. Thus, while other counties and communities may have increased during the 1960 to 1970 period, Amarillo's population decline overrode the positive change.

As indicated in the comments, however, new projections are available from both the Bureau of Economic Analysis and the Texas Department of Water Resources. These more current forecasts are based on population changes between 1970 and 1980. Both sources are projecting an increase in population for the Panhandle area through the year 2000. These new forecasts are being incorporated into subsequently prepared documents such as the Permian Basin Socioeconomic Analysis Report.

2. "....Socieconomic impacts should be used to screen for locations....analysis of candidate locations capacity to absorb expected changes is needed."

The socioeconomic criteria used in screening include 1) excluding Standard Metroplitan Statistical Areas (SMSA) and 2) avoiding urban centers. These factors consider conflicts with population and land use and were useful in discriminating between different locations within the region.

General socioeconomic impacts at the regional level are identified in Section 5.2.4. A more detailed assessment of community impacts depends to a large extent upon the location of the facility (i.e. distance from the facility and size of the surrounding communities).

Without such a location, it is not meaningful to evaluate impacts on anything other than a general level. Thus, beyond the use of population centers, socioeconomic impacts were not used as a criterion for screening. However, detailed analysis of socioeconomic impacts is an important part of the socioecoomic program. This type of analysis will be prepared for the environmental assessment and will be considered in selecting an exploratory shaft site.

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