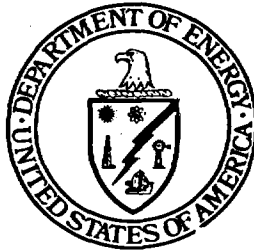


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**IDENTIFICATION OF SITES
WITHIN THE PALO DURO BASIN:
VOLUME 2—PALO DURO LOCATION B**



NOVEMBER 1984

DOE-CH-10(2)

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SALT REPOSITORY PROJECT OFFICE**

BIBLIOGRAPHIC DATA

U.S. Department of Energy, 1984. *Identification of Sites Within the Palo Duro Basin: Volume 2—Palo Duro Location B*, DOE/CH-10(2), prepared for the Salt Repository Project Office by the Office of Nuclear Waste Isolation, Battelle Project Management Division, Columbus, OH.

NOTICE

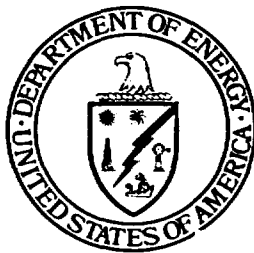
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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A10
Microfiche copy: A01

DOE/CH-10(2)
DISTRIBUTION CATEGORY UC-70

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NOVEMBER 1984

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SALT REPOSITORY PROJECT OFFICE**

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

ABSTRACT

This three-volume document narrows to two sites for continued investigations for potential nuclear waste repository sites in the Palo Duro Basin of the Texas Panhandle. Volume 1 narrows a site previously identified in Deaf Smith County, Texas; Volume 2 narrows a site previously identified in Swisher County, Texas; and Volume 3 contains responses to comments received regarding the drafts of Volumes 1 and 2 (BMI/ONWI-531).

These volumes discuss the methodology and logic used as well as the results that narrowed these sites. Each of the 10 site performance criteria was divided into descriptors related to site performance characteristics. Each descriptor was evaluated by a systematic logic to determine if it could be used as a discriminator. Then more- and less-preferred areas for groups of discriminators were defined and composite maps were prepared and evaluated to identify the sites.

EXECUTIVE SUMMARY

This three-volume document narrows to two sites for continued investigations for potential nuclear waste repository sites in the Palo Duro Basin of the Texas Panhandle. Volume 1 narrows a site previously identified in Deaf Smith County, Texas; Volume 2 narrows a site previously identified in Swisher County, Texas; and Volume 3 contains responses to comments received regarding the drafts of Volumes 1 and 2 (BMI/ONWI-531). The narrowing of these sites does not change the number of sites under consideration by the U.S. Department of Energy's Office of Civilian Radioactive Waste Management (formerly the Office of National Waste Terminal Storage); it only narrows two existing sites.

This volume narrows a site previously identified within the Swisher County location that may be investigated in detail if nominated, recommended, and approved for characterization.

The repository siting process rationale and 10 site performance criteria specified in DOE/NWTS-33(2) (DOE, 1981) are described. These criteria include: (1) site geometry, (2) geohydrology, (3) geochemistry, (4) geologic characteristics, (5) tectonic environment, (6) human intrusion, (7) surface characteristics, (8) demography, (9) environmental protection, and (10) socioeconomic impacts. These criteria and interpretations by the National Waste Terminal Storage Program (DOE, 1981) were used to determine a listing of descriptors (parameters) which, when considered as an integrated group, describes and represents the performance criteria. This list of descriptors is shown in Table 1.

The logic sequence used to identify which descriptors could be used as discriminators is described. Data relevant to each descriptor are discussed, and each descriptor is tracked through the logic sequence to determine whether it is a discriminator or a nondiscriminator. The logic path requires answers to the following questions:

- Are descriptor data available?
- Is descriptor measure variable within the location?
- Can data be interpreted to depict variation?
- Is site preference sensitive to descriptor data?

The objective was to address each descriptor as it pertains to site performance and in terms of available data to determine its usefulness in narrowing to a more-preferred site-sized area within Palo Duro Location B. Descriptors identified as discriminators are listed in Table 2.

TABLE 1. NWTS-33(2) CRITERIA DESCRIPTORS

<ul style="list-style-type: none"> ● SITE GEOMETRY <ul style="list-style-type: none"> Expected Erosion/Denudation Depth to Host Rock^(a) Thickness of Host Rock Lateral Extent of Host Rock ● GEOHYDROLOGY <ul style="list-style-type: none"> Present Aquifer Recharge/Discharge Existing Surface Impoundments/ Ground Water Injection Potentiometric Surfaces Thermally Induced Flow Expected Aquifer Depletion Impoundment Potential Injection Potential Expected Geohydrologic Regime Recent Saturated Thickness of Ogallala Depth to Base of Dockum Character of Strata Between Host Rock and Overlying Aquifers Salt Dissolution ● GEOCHEMISTRY <ul style="list-style-type: none"> Brine Content and Chemistry Solubility or Radionuclides Radionuclide Retardation ● GEOLOGICAL CHARACTERISTICS <ul style="list-style-type: none"> Subsurface Characterization Thermally Induced Fractures/ Stresses Chemical/Thermal Effects Radiation Effects Depth to Host Rock^(a) Presence of Interbeds Gassy Conditions ● TECTONIC ENVIRONMENT <ul style="list-style-type: none"> Volcanic Activity/Geothermal Gradient Faults—Wolfcampian and Older Faults—Younger Than Wolfcampian Quaternary Faults Tectonic Uplift/Subsidence Seismicity and Ground Motion 	<ul style="list-style-type: none"> ● HUMAN INTRUSION <ul style="list-style-type: none"> Current/Previous Mineral Production Previous Production from Shallow Aquifers Location of Boreholes Reaching Host Rock Presence of Potential Mineral Resources Exploration/Utilization of Ground Water Hydrocarbon Resource Potential Land Ownership Complexity ● SURFACE CHARACTERISTICS <ul style="list-style-type: none"> Proximate Streams and Floodplains Proximate Water Bodies Proximate Impoundments Proximate Embayments Surface Topography Anticipated Climatic Change Extreme Meteorological Phenomena Proximate Military Installations Proximate Industrial and Commercial Installations Proximate Transportation Installations ● DEMOGRAPHY <ul style="list-style-type: none"> Population Density Population Risk—Operations Population Risk—Transportation ● ENVIRONMENTAL PROTECTION <ul style="list-style-type: none"> Cultural Resources Aesthetics Ecological Habitat Air Quality Noise Water Quality Prime Farmland Industrial/Commercial Installations Proximity to Road Access Proximity to Rail Rights-of-Way Projected Saturated Thickness of Ogallala in Year 2030 Extreme Conditions ● SOCIOECONOMIC IMPACTS <ul style="list-style-type: none"> Construction and Operations Socioeconomic Impacts Access and Utility Socioeconomic Impacts
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(a) Depth to Host Rock is listed twice as a descriptor. Evaluation from a long-term performance standpoint is discussed under the Site Geometry criterion. Evaluation from a constructibility standpoint is discussed under the

Table 2. Siting Discriminators (Location B)

SITE GEOMETRY

Thickness of Host Rock

GEOHYDROLOGY

Recent Saturated Thickness of the Ogallala
Depth to Base of Dockum

GEOLOGIC CHARACTERISTICS

Depth to Host Rock

HUMAN INTRUSION

Location of Boreholes Reaching Host Rock
Hydrocarbon Resource Potential

SURFACE CHARACTERISTICS

Proximate Streams and Floodplains
(probable maximum flood areas)
Proximate Impoundments
Proximate Water Bodies (playas)
Proximate Transportation Installations
(paved roads, pipelines, and electrical
transmission facilities)

DEMOGRAPHY

Population Risk-Operations
Population Density

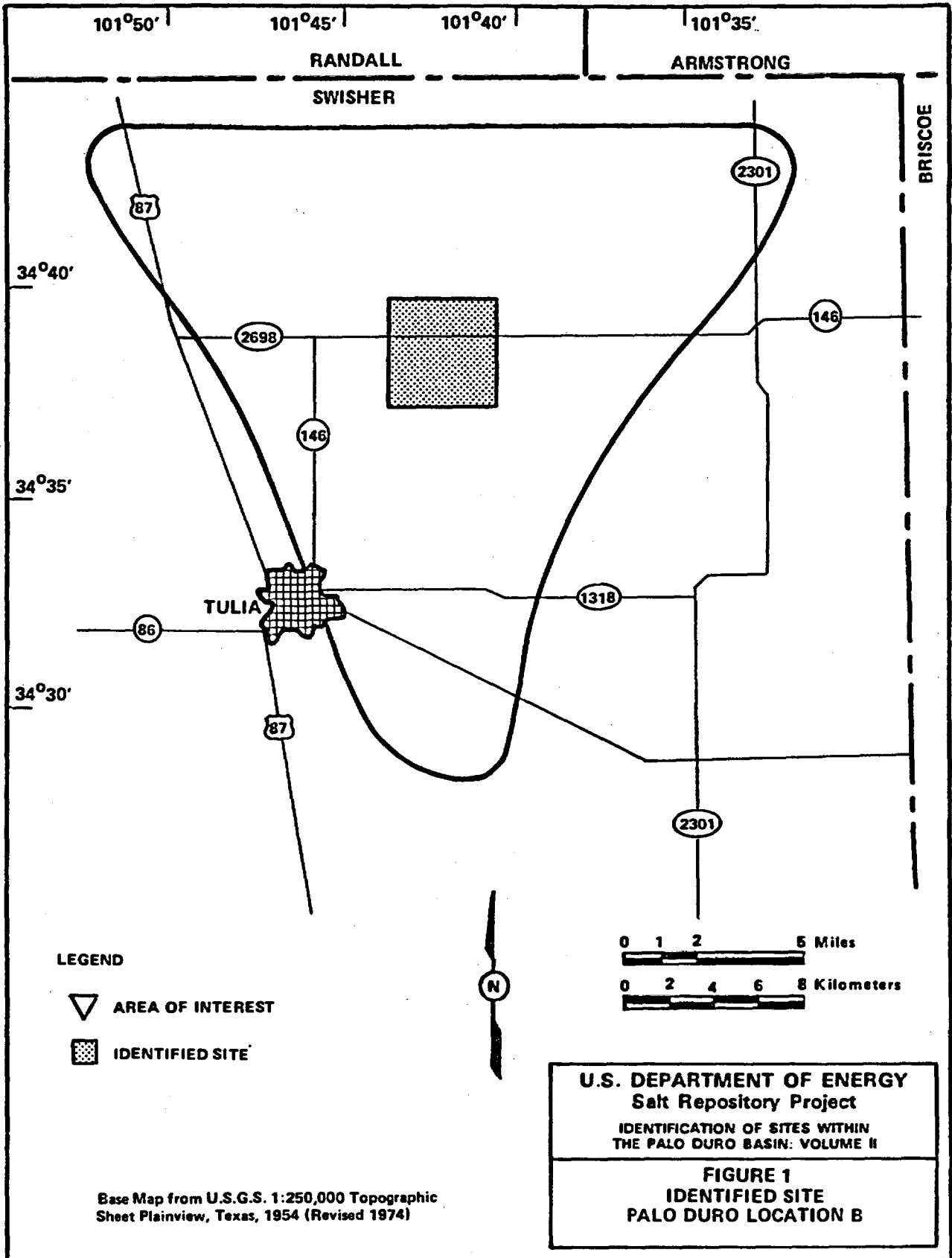
ENVIRONMENTAL PROTECTION

Cultural Resources
Aesthetics
Ecological Habitat
Industrial/Commercial Installations
Prime Farmland
Proximity to Road Access (major highways)
Proximity to Rail Rights-of-Way

The rationale supporting the method of narrowing utilized and the results which led to identification of the more-preferred area are provided. The discriminators identified were grouped according to whether they could affect long-term performance, operational performance, or produce environmental/construction impacts. Previous site screening steps identified Palo Duro Location B as a potentially acceptable site primarily on geologic characteristics. Because the available data show this location has relatively uniform subsurface characteristics throughout, few subsurface descriptors were identified as discriminators. Because NWPA precludes siting a repository in a highly populated area, land within the corporate boundaries of Tulia (1980 population of 5,033) was excluded from further consideration. Therefore, consideration under the discriminator, population density, was not applicable to the city of Tulia. The discriminators in the long-term performance category are thickness of host rock, location of boreholes reaching host rock, and hydrocarbon resource potential. The discriminator for operational performance is population risk-operations. Within the environmental/constructibility impacts category, specific discriminators were grouped in the following six descending priorities:

- Priority 1. Ecological habitat.
- Priority 2. Recent saturated thickness of the Ogallala; Depth to host rock.
- Priority 3. Proximity to rail rights-of-way; Proximity to road access.
- Priority 4. Proximate streams and floodplains (probable maximum flood areas); Proximate water bodies (playas); Depth to base of Dockum.
- Priority 5. Cultural resources; Prime farmland; Aesthetics.
- Priority 6. Proximate transportation installations (paved roads, pipelines, and electrical transmissions facilities); Proximate impoundments; Industrial/commercial installations.

An overlay process was followed, starting with long-term performance and continuing through operational performance and environmental/constructibility impacts according to the priority groupings until a more-preferred area was identified. The area identified in Palo Duro Location B, after applying long-term and operational performance and environmental/constructibility impacts priority categories one and two, is shown in Figure 1.



LEGEND

- ▽ AREA OF INTEREST
- IDENTIFIED SITE

Base Map from U.S.G.S. 1:250,000 Topographic Sheet Plainview, Texas, 1954 (Revised 1974)

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN
THE PALO DURO BASIN: VOLUME II

FIGURE 1
IDENTIFIED SITE
PALO DURO LOCATION B

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1 INTRODUCTION

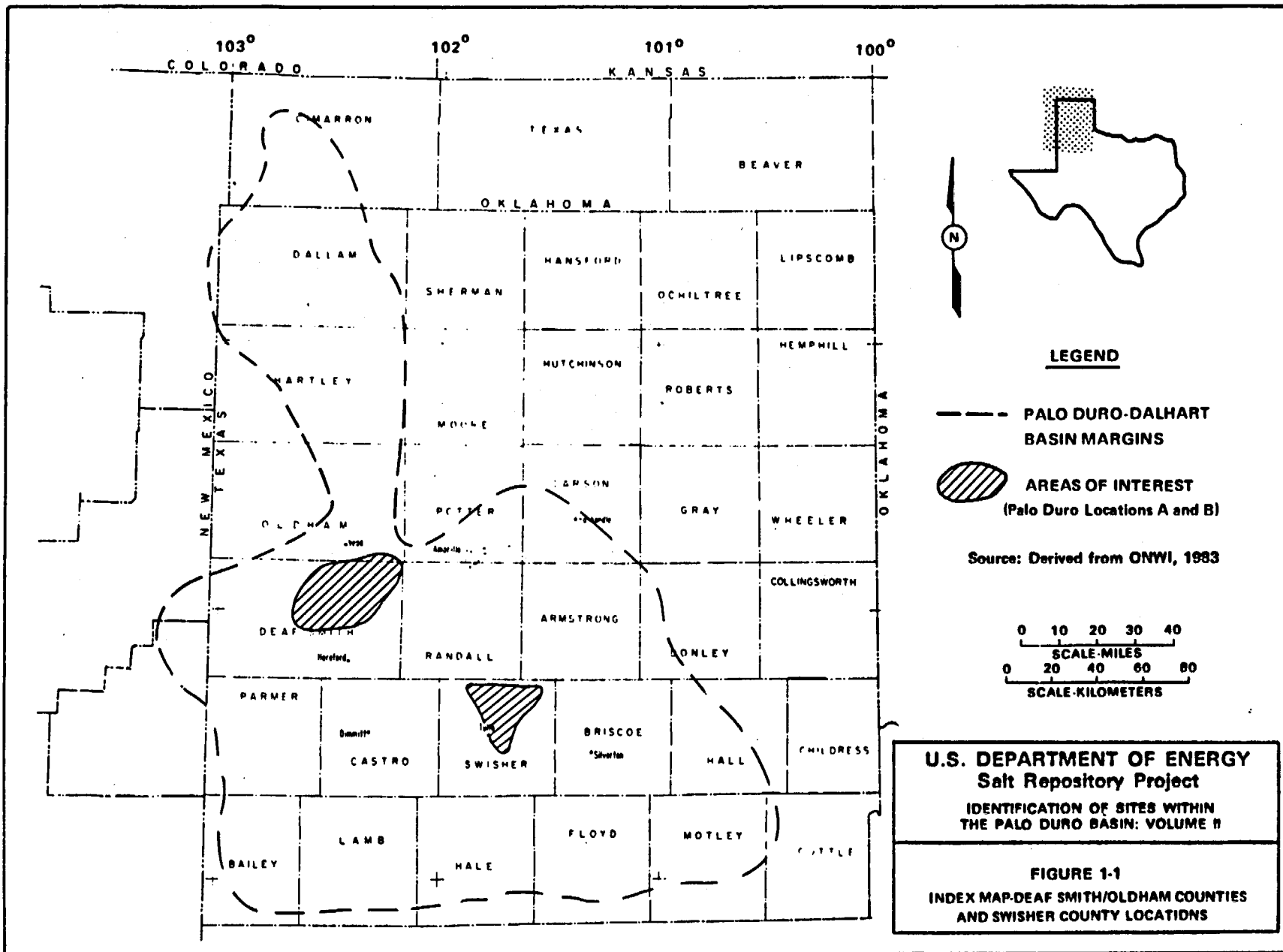
Two locations in the Palo Duro Basin of the Texas Panhandle (Figure 1-1) were identified as containing potentially acceptable sites for a nuclear waste repository (ONWI, 1983). These Palo Duro locations, Deaf Smith/Oldham Counties (Location A) and Swisher County (Location B), were named as potentially acceptable sites by the Secretary of the U.S. Department of Energy (DOE) in February 1983. Because these locations cover areas of approximately 400 and 200 square miles (1,040 and 520 square kilometers), respectively, DOE requested the Office of Nuclear Waste Isolation (ONWI) to further define site locations within these potentially acceptable sites.

Any portion of the Palo Duro potentially acceptable sites could be suitable for characterization; therefore, a systematic method was required to narrow to smaller, more-preferred sites on which to concentrate detailed characterization studies if nominated, recommended, and approved. This volume describes that method, the criteria and rationale employed, and identifies the site-sized area in Palo Duro Location B.

1.1 BACKGROUND

The Nuclear Waste Policy Act of 1982 (NWPA) requires DOE to: (1) identify potentially acceptable sites; (2) nominate at least five sites as suitable for characterization; (3) recommend three sites for such characterization by January 1985; and (4) recommend one site for development as a nuclear waste repository.

The salt repository siting process is currently evaluating potentially acceptable sites for nomination for characterization that will ultimately result in recommendation of at least one salt site for detailed characterization. The subsequent site characterization will define and investigate in detail the site-specific geology, hydrology, and constructibility of a repository at the site. Site characterization activities will include the sinking of an exploratory shaft(s) and the development of underground test facilities. Site characterization will add requisite information designed to further enhance a site's qualification or lead to its disqualification. The specific characterization activities will be described in the site characterization plan to be submitted by the DOE for comment to the U.S. Nuclear Regulatory Commission (NRC), the State, any



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FIGURE 1-1
INDEX MAP-DEAF SMITH/OLDHAM COUNTIES
AND SWISHER COUNTY LOCATIONS

affected Indian Tribes, and the public. The specific sites to be characterized will be recommended by the Secretary of the DOE in early 1985, and subsequently approved or disapproved by the President.

1.2 SITE PERFORMANCE CRITERIA

The National Waste Terminal Storage (NWTs) Program established performance criteria governing the suitability of sites for a nuclear waste repository (DOE, 1981). Criteria defined relate to:

- Site Geometry
- Geohydrology
- Geochemistry
- Geologic Characteristics
- Tectonic Environment
- Human Intrusion
- Surface Characteristics
- Demography
- Environmental Protection
- Socioeconomic Impacts.

1.3 DESCRIPTOR IDENTIFICATION APPROACH

The 10 NWTs site performance criteria cover those characteristics of a site that bear upon performance requirements in the broadest sense. These criteria were evaluated to identify and compile a listing of criteria-related descriptors (parameters) to be used in the systematic method developed for identifying site-sized potentially acceptable areas. The criteria are cited as direct quotations from DOE/NWTs-33(2) (DOE, 1981).

1.3.1 Site Geometry

"The site shall be located in a geologic environment that physically separates the radioactive wastes from the biosphere and that has geometry adequate for repository placement.

- (1) The minimum depth of the repository waste emplacement area shall be such that credible human activities and natural processes acting at the surface will not unacceptably affect system performance.

- (2) The thickness and lateral extent of the geologic system surrounding the waste emplacement area shall be sufficient to accommodate the repository and a buffer zone and to ensure that impacts induced by construction of the repository and by waste emplacement will not unacceptably affect system performance."

A minimum depth specification of 305 meters (1,000 feet) was applied during the area-to-location screening (ONWI, 1983, p. 51). This method considers depth to host rock and expected erosion and denudation as descriptors of this criterion.

Thickness of the potential repository horizon host rock is a descriptor that includes consideration of construction-induced mechanical stress and heat and radiation effects on the host rock.

Lateral extent of the host rock is considered with respect to repository orientation flexibility and the lateral sufficiency to accommodate the underground workings and a buffer zone.

1.3.2 Geohydrology

"The geohydrologic regime in which the site is located shall have characteristics compatible with waste containment, isolation, and retrieval.

- (1) The site shall be located so that the present and probable future geohydrological regime will minimize contact between ground water and wastes and will prevent radionuclide migration or transport from the repository to the accessible environment in unacceptable amounts.
- (2) The site shall be located so that the hydrological regime can be sufficiently characterized to permit modeling to show that present and probable future conditions have no unacceptable impact on repository performance.
- (3) The site shall be located so that the geohydrological regime allows construction of repository shafts and maintenance of shaft liners and seals.
- (4) The site shall be located so that subsurface rock dissolution that may be occurring, or is likely to occur, can be shown to have no unacceptable impact on system performance."

The present geohydrological regime is considered with respect to water recharge/discharge locations, rates of recharge/discharge, and the various potentiometric surfaces within the location. Expected geohydrologic conditions encompass ground-water path orientation and length, residence time, and travel time.

The hydrologic system considerations include presence of surface impoundments, depletion rates for aquifers, and injection of fluids into aquifers. Expected hydrologic conditions comprise surface impoundment potential, thermally induced changes in flow patterns, projected aquifer depletion rates, and projected injection of fluids into aquifers.

Characterization of geologic strata above the host rock includes consideration of the aquifers present in this zone and the intervening strata that may function as aquitards. Strata thickness and composition are both important considerations with respect to constructibility and design of shafts and seals.

Existing dissolution features are identified and projected dissolution rates considered with respect to potential site location and system performance impact.

1.3.3 Geochemistry

"The site shall have geochemical characteristics compatible with waste containment, isolation, and retrieval.

- (1) The site shall be located so that the chemical interactions between radionuclides, rock, ground water, or engineered components will not unacceptably affect system performance."

Consideration of geochemical characteristics centers around expected performance of the engineered and natural barrier systems and includes expected waste package life, solubilities of radionuclides in repository host rock brines, and the expected retardation of radionuclide species in nonpotable ground waters.

1.3.4 Geologic Characteristics

"The site shall have geologic characteristics compatible with waste containment, isolation, and retrieval.

- (1) The site shall be located so that the subsurface setting can be sufficiently characterized to permit identification and evaluation of conditions that are potentially adverse or favorable to waste containment, isolation, and retrieval.
- (2) The site shall provide a geologic system which can be shown to accommodate anticipated geomechanical, chemical, thermal, and radiological stresses caused by waste/rock interactions.

- (3) The site shall be located so that development, operation, and closure of underground areas can be accomplished without undue hazard to repository personnel."

Detailed stratigraphic sections and core testing results from boreholes provide a geologic information base and are used to evaluate the potential suitability of an area. The location of existing wells is considered in the evaluation. Additional information is developed from seismic survey data and the geologic literature.

Anticipated stress phenomena include thermally induced fractures, hydration/dehydration, brine migration, moisture content, and radiation effects.

Evaluation of hazards to repository personnel includes consideration of the presence of interbed materials in, depth to, and potential gassy conditions in the lower San Andres unit 4 salt horizon.

1.3.5 Tectonic Environment

"The site shall be located such that credible phenomena will not degrade system performance below acceptable limits.

- (1) The site shall be located so that its tectonic environment can be evaluated with a high degree of confidence to identify tectonic elements and their impact on system performance.
- (2) The site shall be located so that Quaternary faults can be identified and shown to have no unacceptable impact on system performance.
- (3) The site shall be located so that the centers of Quaternary igneous activity can be identified and shown to have no unacceptable impact on system performance.
- (4) The site shall be located so that long-term, continuing uplift or subsidence rates can be shown to have no unacceptable impact on system performance.
- (5) The site shall be located so that ground motion associated with the maximum credible earthquake will not have unacceptable impact on system performance.

Evaluation of the tectonic environment includes consideration of regional and local evidence or trends of faulting, volcanism, and anomalous geothermal gradients.

Presence and proximity of Quaternary faulting and igneous activity are considered in addition to historical trends in uplift and subsidence.

Seismic activity and potential ground motion associated with the maximum credible earthquake are examined from a historical perspective for the region.

1.3.6 Human Intrusion

"The site shall be located to reduce the likelihood that past or future human activities would cause unacceptable impacts on system performance.

- (1) The site shall be located so that exploration history or relevant past use of the site or adjacent areas can be determined and can be shown to have no unacceptable impact on system performance.
- (2) The site shall be located on land for which the federal government can obtain ownership, control access, and obtain all surface and subsurface rights necessary to ensure that surface and subsurface activities at the site will not cause unacceptable impact on system performance."

Past resource use and exploration in the region are considered to assess the potential impacts on system performance. The locations of potentially exploitable resources such as water, petroleum, thermal energy, and minerals are considered also.

Surface and subsurface land and resource ownership are considered with respect to complexity of ownership.

1.3.7 Surface Characteristics

"The site and its surrounding area shall be such that surface characteristics or conditions can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operation and system performance.

- (1) The site shall be located so that the surficial hydrological system, both during anticipated climatic cycles and during extreme natural phenomena, will not cause unacceptable impacts on repository operations or system performance.
- (2) The site shall be located in an area where surface topographic features do not unacceptably affect repository operation.
- (3) The site shall be located where meteorological phenomena can be accommodated by engineering measures and can be shown to have no unacceptable effect on repository operation.

- (4) The site shall be located where present and projected effects from nearby industrial, transportation, and military installations and operations can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operations."

Consideration of surface features includes potential hydrologic system impacts characterized as the proximity of natural water bodies, impoundments, embayments, streams, floodplains, and large natural surface depressions (playas).

Surface topography is considered with respect to its potential as a hazard to waste shipment.

Meteorological conditions are evaluated in terms of the probable maximum precipitation event. Climate and anticipated climatic changes are considered for potential impact on the surface hydrologic system.

Proximity to existing incompatible industrial, transportation, and military installations is considered in terms of potential impact to operations.

1.3.8 Demography

"The site shall be located to minimize the potential risk to and potential conflict with the population.

- (1) The site shall be located in an area of low population density and at a distance away from population concentrations and urban areas.
- (2) The site shall be located such that risk to the population from transportation of radioactive wastes and from repository operation can be reduced below acceptable levels to the extent reasonably achievable."

Risk to population and potential conflicts with population are considered in terms of proximity to population concentrations, urban areas, and access routes, and population density variability.

1.3.9 Environmental Protection

"The site shall be located with due consideration to: potential environmental impacts; air, water, and land use; and ambient environmental conditions.

- (1) The site shall be located with due consideration to potential environmental impacts.
- (2) The site shall be located to reduce the likelihood or consequence of air, water, and land use conflicts.

- (3) The site shall be located with due consideration to normal and extreme environmental conditions."

Considerations of potential environmental impacts cover ecological habitat, cultural resources, aesthetics, air quality, noise, water quality, and dedicated lands.

Land use conflicts are considered with respect to agricultural land use, location of industrial and commercial installations, projected water availability, and road and railroad access proximity.

Consideration of extreme environmental conditions includes evaluations of extreme winds, precipitation, and resultant flooding that might have impacts as a consequence of repository activities.

1.3.10 Socioeconomic Impacts

"The site shall be selected giving due consideration to social and economic impacts on communities and regions affected by the repository.

- (1) The site shall be located so that adverse social and/or economic impacts resulting from repository construction and operation can be accommodated by mitigation or compensation strategies.
- (2) The site shall be located so that adequate access and utility capability required for the repository either exists or can be provided without unacceptable impact on affected communities."

Social and economic impact considerations include potential effects of repository construction and operation related to labor force, housing, services, local government, community land use patterns, population changes, road and railroad systems, and availability of utility services.

2 IDENTIFICATION OF DISCRIMINATING DESCRIPTORS

The primary bases for the systematic method developed were the NWPA and the DOE NWTS program site performance criteria (DOE, 1981). From the NWTS criteria, a list of parameters or parameter groups (descriptors) was compiled to be used within the potentially acceptable site to identify the more-preferred, site-sized area. Analyses were conducted to determine and identify those descriptors which could be used to discriminate within the potentially acceptable site.

Once the descriptor listing was established, a logic diagram (Figure 2-1) was constructed to ensure that (1) each descriptor was considered in the same stepwise manner, (2) the same questions were asked concerning the available data, (3) the discussion concerning each descriptor was structured, and (4) the results were documented as a specific path through the logic diagram.

A brief explanation of the steps comprising the logic path follows:

- Step 1 Descriptors. Parameters identified from 10 NWTS site performance criteria for use as potential discriminators.
- Step 2 Are descriptor data available? A response to this question required that any relevant data be located. If data relevant to the descriptor were identified, they were subjected to Step 3. If relevant data were not identified, the descriptor was a nondiscriminator.
- Step 3 Is descriptor measure variable within location? Identified relevant data were inspected to determine if variation across a location was evident. The existing form of the data (data table, map, report text, etc.) was often the basis for determining variability within a location. If the data were already in a variation-depicting form, such as isopleths of depth to the lower San Andres unit 4, the next decision point was that of Step 5. If data variation within a location was not directly evident due to the existing form of the data or to the lack of actual variation, the next decision point was Step 4.
- Step 4 Can data be interpreted to depict variation? In this step, data were examined to determine whether variation could be shown through extrapolation, interpretation, an appropriate mathematical manipulation, or a change in the form of data presentation. If variation

within the location could be shown, the next decision point was Step 5. If it was shown that variation within the location did not exist, if data were not considered representative of the entire location because the variation was not predictable and exceeded the data control (i.e., too few data points within or proximate to the location), or if the data were available only on a gross regional or national scale, the descriptor was a nondiscriminator.

- Step 5 Is site preference sensitive to descriptor data? Two sets of conditions were evaluated in this step: data that directly exhibit discernible variation within a location (from Step 3) and interpreted data that exhibit variation within the location (from Step 4). Preference with regard to the site-narrowing process requires consideration of the descriptor's effect on performance and whether it produces criteria-related impacts. Descriptors (from Steps 3 or 4) were examined individually to determine if the noted variation translated into potential impacts or performance differentials. Descriptors with data variations that translated into potential performance or impact variations were identified as discriminators. All others were nondiscriminators.
- Step 6 Discriminator. A discriminator is a descriptor that exhibits relevant variation within the location. This variation can be depicted on a map that can be related to potential performance effects or potential impacts.
- Step 7 Nondiscriminator. A nondiscriminator is a descriptor that does not exhibit relevant variation within the location, or for which effects on potential performance or impact cannot be related to the data variation.

The process described in this volume is not site selection. The purpose of this process is to use available data to identify a more-preferred area within the location on which detailed characterization activities could be concentrated. Descriptors which pass through the logic path to Step 7 (nondiscriminator) are not dropped from further consideration. All descriptors (nondiscriminators and discriminators) will be addressed during site characterization and/or site selection activities. The environmental assessment prepared to support site nomination will evaluate this 9-square-mile (23-square-kilometer) site against all

guidelines included in the final DOE siting guidelines to be published at a later date.

Table 2-1 lists the descriptors, depicts the logic diagram path for each, and indicates the chapter subsection where each is discussed.

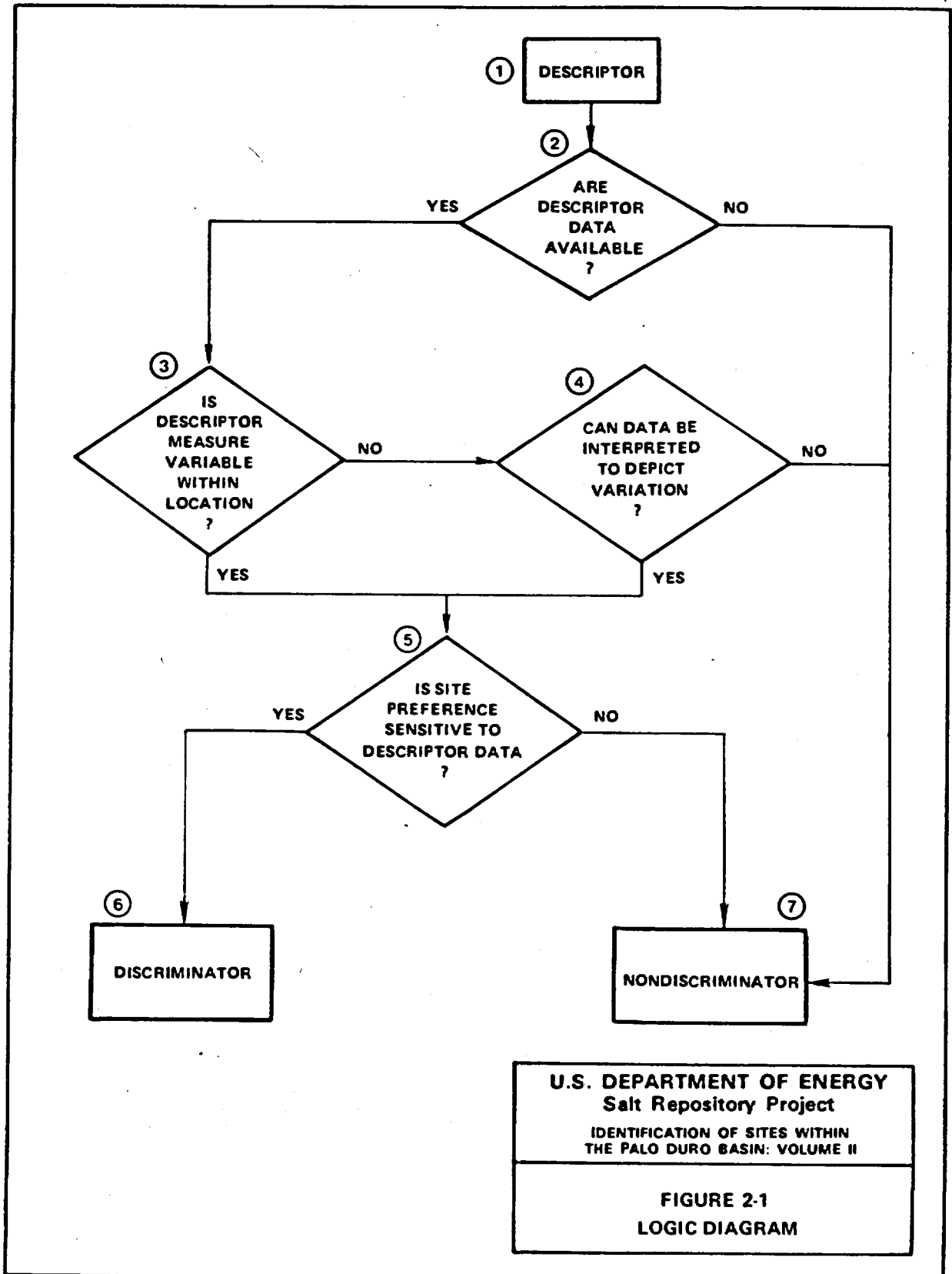


Table 2-1. NWTS Site Performance Criteria Descriptors and Discriminator Determinations

Report Section No.	Performance Criteria Descriptor	Logic Path ^a	
		Discriminator	Nondiscriminator
3.1	SITE GEOMETRY		
3.1.1	Expected Erosion Denudation		1-2-3-4-5-7
3.1.1	Depth to Host Rock ^b		1-2-3-5-7
3.1.2	Thickness of Host Rock	1-2-3-5-6	
3.1.3	Lateral Extent of Host Rock		1-2-3-5-7
3.2	GEOHYDROLOGY		
3.2.1	Present Aquifer Recharge/Discharge		1-2-3-4-5-7
3.2.1	Existing Surface Impoundments/ Ground Water Injection		1-2-3-5-7
3.2.1	Potentiometric Surfaces		1-2-3-4-7
3.2.2	Thermally Induced Flow		1-2-3-4-7
3.2.2	Expected Aquifer Depletion		1-2-3-5-7
3.2.2	Impoundment Potential		1-2-3-5-7
3.2.2	Injection Potential		1-2-7
3.2.2	Expected Geohydrologic Regime		1-2-3-4-5-7
3.2.3	Recent Saturated Thickness of Ogallala	1-2-3-5-6	
3.2.3	Depth to Base of Dockum	1-2-3-5-6	
3.2.3	Character of Strata Between Host Rock and Overlying Aquifers		1-2-3-4-7
3.2.4	Salt Dissolution		1-2-3-4-5-7
3.3	GEOCHEMISTRY		
3.3.1	Brine Content and Chemistry		1-2-3-4-7
3.3.2	Solubility of Radionuclides		1-2-3-4-7
3.3.3	Radionuclide Retardation		1-2-3-4-7
3.4	GEOLOGIC CHARACTERISTICS		
3.4.1	Subsurface Characterization		1-2-3-5-7
3.4.2	Thermally Induced Fractures/Stresses		1-2-3-4-7
3.4.2	Chemical/Thermal Effects		1-2-3-4-7
3.4.2	Radiation Effects		1-2-3-4-7
3.4.3	Depth to Host Rock ^b	1-2-3-5-6	
3.4.3	Presence of Interbeds		1-2-3-4-7
3.4.3	Gassy Conditions		1-2-3-4-7

Table 2-1. NWS Site Performance Criteria Descriptors
and Discriminator Determinations
Continued

Report Section No.	Performance Criteria Descriptor	Logic Path ^a	
		Discriminator	Nondiscriminator
3.5	TECTONIC ENVIRONMENT		
3.5.1	Volcanic Activity/Geothermal Gradient		1-2-3-4-7
3.5.1	Faults-Wolfcampian and Older		1-2-3-4-5-7
3.5.1	Faults-Younger Than Wolfcampian		1-2-3-4-7
3.5.1	Quaternary Faults		1-2-3-4-7
3.5.1	Tectonic Uplift/Subsidence		1-2-3-4-7
3.5.1	Seismicity and Ground Motion		1-2-3-4-7
3.6	HUMAN INTRUSION		
3.6.1	Current/Previous Mineral Production		1-2-3-5-7
3.6.1	Previous Production From Shallow Aquifers		1-2-3-5-7
3.6.1	Location of Boreholes Reaching Host Rock	1-2-3-5-6	
3.6.2	Presence of Potential Mineral Resources		1-2-3-5-7
3.6.2	Exploration/Utilization of Ground Water		1-2-3-5-7
3.6.2	Hydrocarbon Resource Potential	1-2-3-4-5-6	
3.6.3	Land Ownership Complexity		1-2-3-5-7
3.7	SURFACE CHARACTERISTICS		
3.7.1	Proximate Streams and Floodplains	1-2-3-4-5-6	
3.7.2	Proximate Water Bodies	1-2-3-5-6	
3.7.3	Proximate Impoundments	1-2-3-5-6	
3.7.4	Proximate Embayments		1-2-3-4-7
3.7.5	Surface Topography		1-2-3-5-7
3.7.6	Anticipated Climatic Change		1-2-3-4-7
3.7.7	Extreme Meteorological Phenomena		1-2-3-4-7
3.7.8	Proximate Military Installations		1-2-3-4-7
3.7.9	Proximate Industrial and Commercial Installations		1-2-3-5-7
3.7.10	Proximate Transportation Installations	1-2-3-5-6	

Table 2-1. NWTS Site Performance Criteria Descriptors
and Discriminator Determinations
Continued

Report Section No.	Performance Criteria Descriptor	Logic Path ^a	
		Discriminator	Nondiscriminator
3.8	DEMOGRAPHY		
3.8	Population Density	1-2-3-4-5-6	
3.8	Population Risk-Operations	1-2-3-4-5-6	
3.8	Population Risk-Transportation		1-2-3-4-7
3.9	ENVIRONMENTAL PROTECTION		
3.9.1.1	Cultural Resources	1-2-3-5-6	
3.9.1.2	Aesthetics	1-2-3-5-6	
3.9.1.3	Ecological Habitat	1-2-3-5-6	
3.9.1.4	Air Quality		1-2-3-4-7
3.9.1.5	Noise		1-2-3-4-7
3.9.1.6	Water Quality		1-2-3-4-7
3.9.2.1	Prime Farmland	1-2-3-5-6	
3.9.2.2	Industrial/Commercial Installations	1-2-3-5-6	
3.9.2.3	Proximity to Road Access	1-2-3-5-6	
3.9.2.4	Proximity to Rail Rights-of-Way	1-2-3-5-6	
3.9.2.5	Projected Saturated Thickness of Ogallala in Year 2030		1-2-3-5-7
3.9.3	Extreme Conditions		1-2-3-4-7
3.10	SOCIOECONOMIC IMPACTS		
3.10	Construction and Operations Socioeconomic Impacts		1-2-3-4-7
3.10	Access and Utility Socioeconomic Impacts		1-2-3-4-7

(a) See Figure 2-1, Logic Diagram.

(b) Depth to Host Rock is listed twice as a descriptor. Evaluation from a long-term performance standpoint is discussed under the Site Geometry criterion. Evaluation from a constructibility standpoint is discussed under the Geologic Characteristics criterion.

3 EVALUATION OF DESCRIPTORS

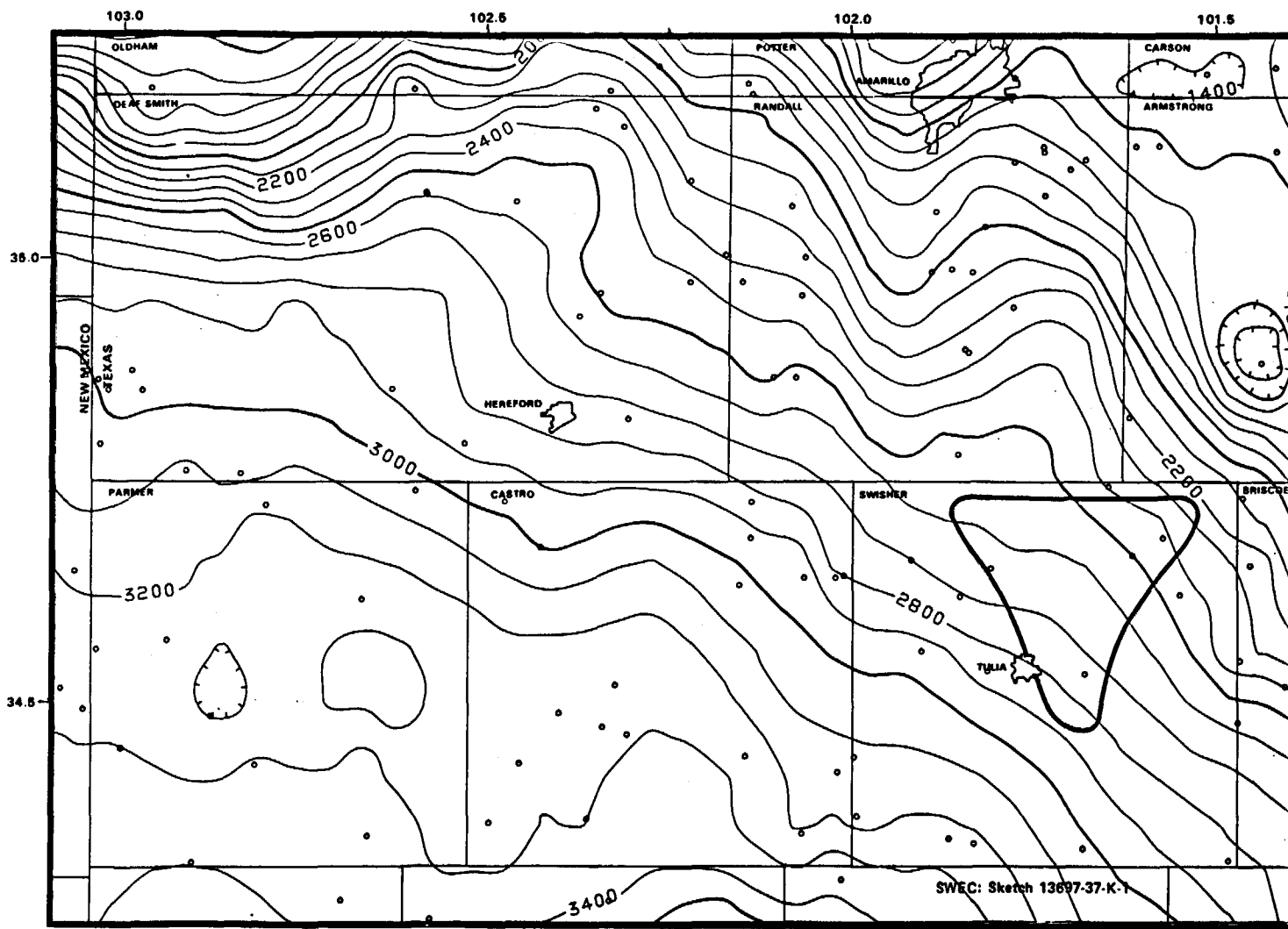
The sections that follow (3.1 to 3.10) describe each NWTS criterion and applicable identified descriptors, present data relevant to each descriptor, and track each descriptor through the logic path (Figure 2-1) to a final determination of discriminator or nondiscriminator.

3.1 SITE GEOMETRY

The lower San Andres unit 4 salt was previously identified as a possible host rock in Palo Duro Location B (ONWI, 1983). Evaluations in this volume are made only with regard to the lower San Andres unit 4 salt as a host medium.

3.1.1 Minimum Depth of the Repository

The NWTS criteria (DOE, 1981, p. 6) require that the repository be sited at a depth sufficient to separate the repository from any surficial process or event that might cause a breach of the repository. Further, 10 CFR 60.122 (NRC, 1983, p. 28225) specifies that a favorable condition is one that permits "the emplacement of waste at a minimum depth of 300 meters from the ground surface." Both conditions were considered during the area-to-location screening. The NRC specified condition is met because the proposed host unit is deeper than 2,200 feet (670 meters) everywhere within the location (Figure 3-1). Information potentially useful in assessing achievement of compliance with the NWTS criteria includes erosion and denudation rate data. These data are available for portions of the region (Gustavson et al, 1981). No erosion or denudation studies have been performed within the location. Recent soil erosion rate (eolian transport) estimates (Machenberg, 1984) have been made for one locale on the Southern High Plains. Neither these data nor regional erosion data can be directly extrapolated to forecast long-term processes in the location. However, the High Plains surface in the location has been only slightly modified since the late Pliocene (approximately 1.6 million years ago) by development of relatively shallow and unintegrated stream valleys; the expectation of similar surface

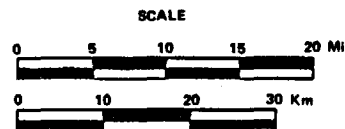


NOTES

CONTOUR INTERVAL IS 50 FEET
 GROUND SURFACE DATUM
 THICK SALT BED: A SALT BED WITH INTERBEDS OF NONSALT AND POOR QUALITY SALT INDIVIDUALLY NOT EXCEEDING 10 FEET THICK AND COMBINATIVELY NOT EXCEEDING 15%

LEGEND

- WELL CONTROL SHOWN BY OPEN CIRCLES
- ▽ AREA OF INTEREST



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FIGURE 3-1
DEPTH TO LOWER SAN
 ADDRESS PART 2

processes and rates over tens of thousands of years* results in a determination that repository integrity will not be compromised due to the depths being considered. Caprock escarpment retreat rates (Gustavson et al, 1981) can similarly be extrapolated to show that no part of the location will be affected by this process. Because the proposed repository horizon is at a depth and location that will be unaffected by erosional processes, site preference is not sensitive to differences that may exist in local erosion rates or processes. The descriptor, expected erosion/denudation, was identified as a nondiscriminator (Steps 1, 2, 3, 4, 5, and 7).

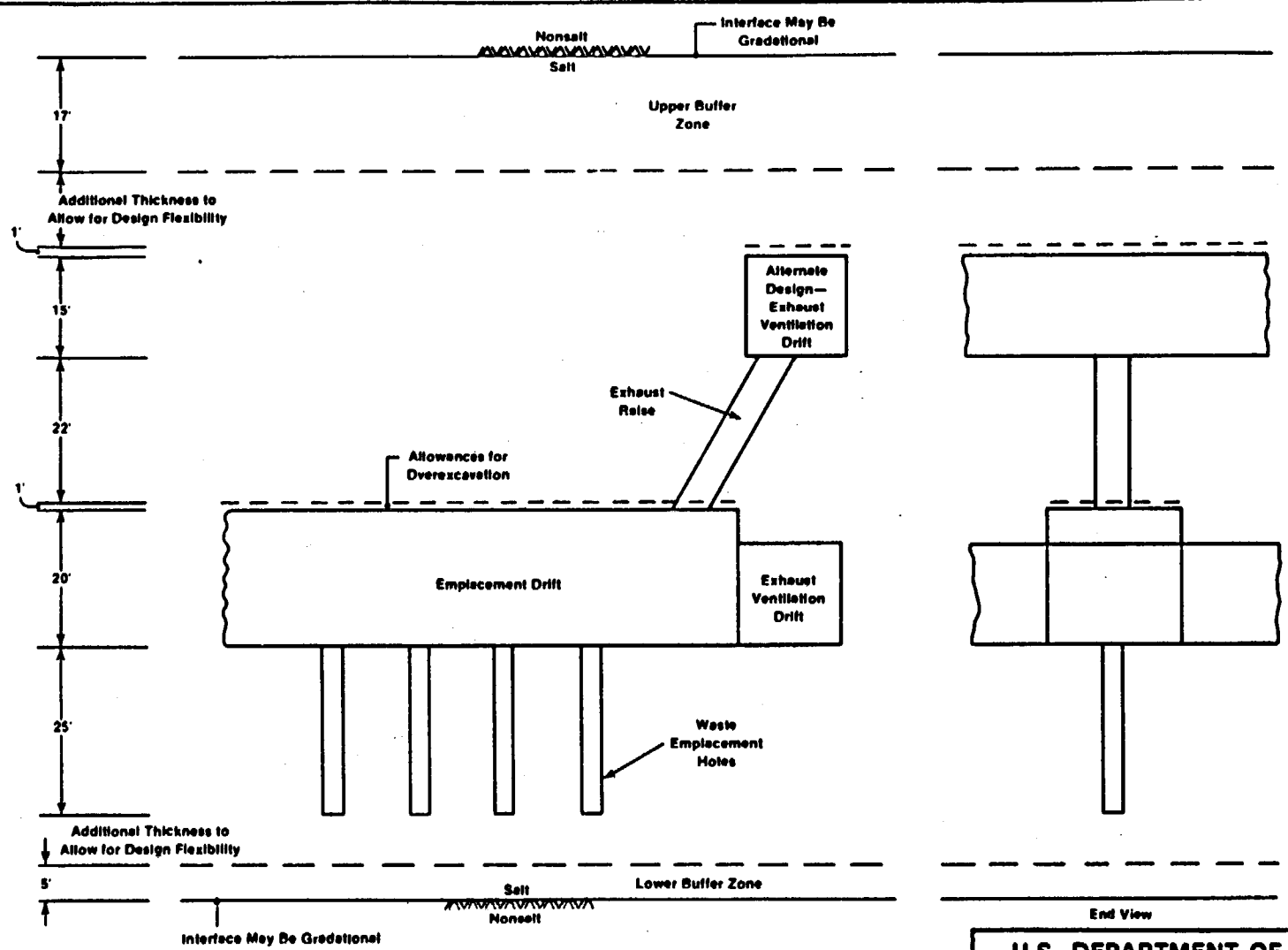
Once a minimum depth is obtained below which waste isolation concerns from surface-related processes are not expected, it is appropriate to consider preferred depths from other long-term performance and constructibility factors. Depth to host rock as a long-term performance factor is discussed here. The preferred depth from a constructibility standpoint is discussed in Section 3.4.3.

Simplistically, the further radioactive material is placed from the ground surface and shallow potable water supplies, the better. Depth to the proposed host rock, lower San Andres unit 4, varies by over 700 feet (210 meters) across the location (Figure 3-2). The thickness of the aquitard which separates the repository horizon from the overlying aquifers varies by approximately 250 feet (76 meters) across the location (see Section 3.2.2). However, these variations are not used to indicate a preference for siting at deeper areas because radionuclides will migrate only short distances within the host salt under expected conditions. Ultimate site performance is more sensitive to the potential for occurrence of natural or man-made breaches, regardless of the absolute depth of the repository. Because the repository will be sited well below depths of concern from surface-related processes and long-term performance is not particularly sensitive to the absolute depth selected, the descriptor, depth to host rock, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

3.1.2 Thickness of the Geologic System

A salt thickness specification of 125 feet (38 meters) was one factor used during screening to the location (ONWI, 1983, p. 52). Suitable rock thickness

*40 CFR 191 (EPA, 1982) specifies a 10,000-year period. In addition, the National Academy of Sciences (NAS, 1983) indicates a societal responsibility for longer time periods.



Note: Not to scale

Source: Derived from Kaiser Engineers, 1978; ONWI, 1983

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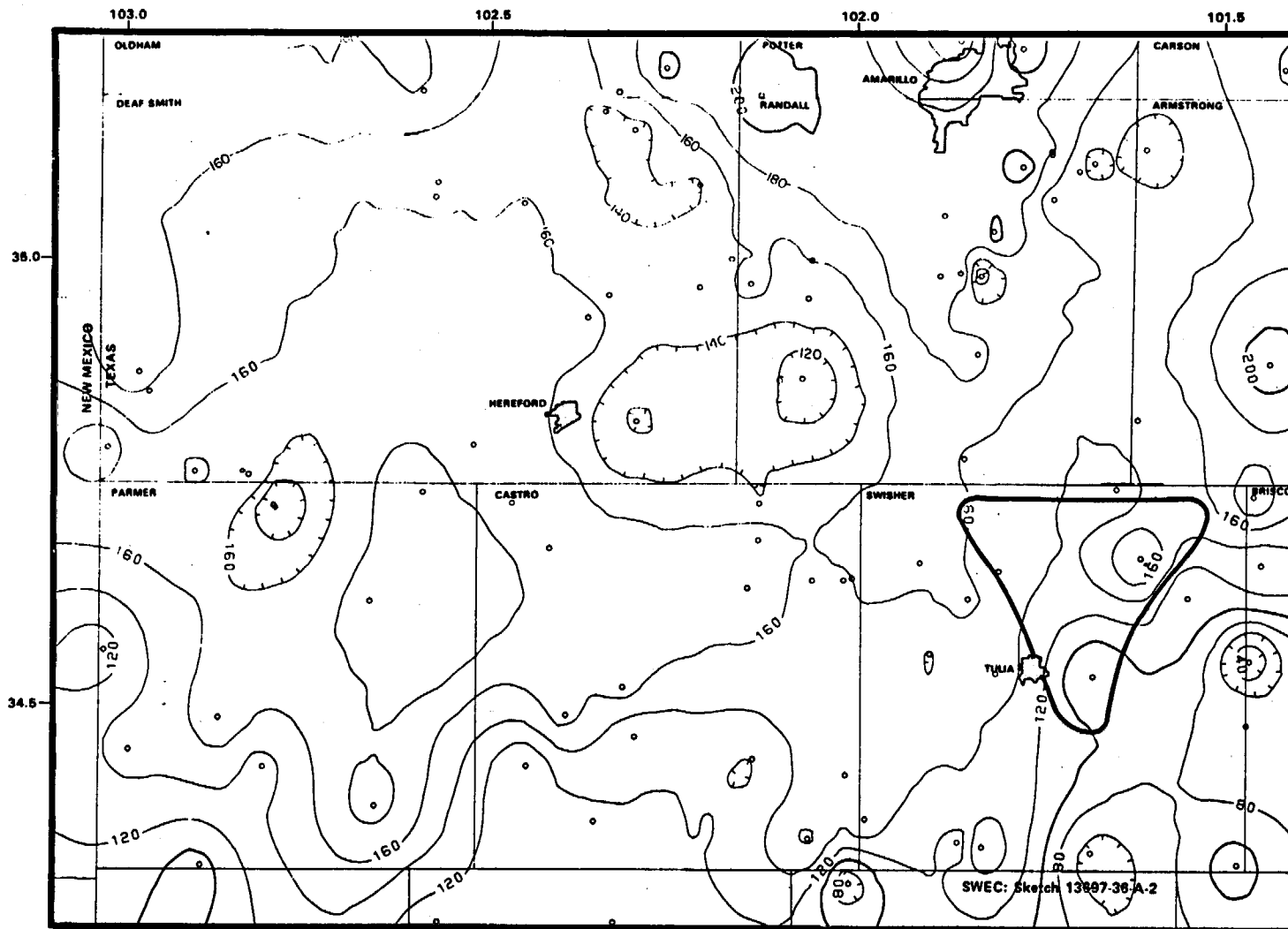
FIGURE 3-2
 CONCEPTUAL REPOSITORY
 DESIGNS IN BEDDED SALT

is dependent upon the character of the host unit (i.e., number and type of interbeds) and the dimensions of the repository workings and surrounding rock mass required to assure structural stability (Figure 3-2). The location and type of interbedded material, important from a construction standpoint, are described in Section 3.4.3. For the purposes of this study, the host rock unit has been mapped as a "thick salt bed" (Figure 3-3) which, by definition, provides a representation of the thickness of the host rock with a specific quality. The thick-salt-bed map indicates the presence of a salt bed with interbeds of nonsalt and poor quality salt (as determined from geophysical logs) individually not exceeding 10 feet (3 meters) thick and cumulatively not exceeding 15 percent of the total bed thickness*. The thick-salt-bed map (Figure 3-3) illustrates that there is significant variation across the location. Cumulative salt thickness in the southern portion of the location (see Figure 4-7) is greater than 125 feet (38 meters); this area does not, however, contain a "thick salt bed" of 125 feet (38 meters) as mapped for this study (Figure 3-3). Siting preference is therefore for areas of salt thicker than 125 feet (38 meters) mapped in Figure 3-3. The descriptor, thickness of host rock, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.1.3 Lateral Extent of the Geologic System

The lower San Andres unit 4 salt bed is believed to have been deposited in large brine pans (Presley, 1981). Thick salt within this unit has been mapped throughout the location (Figure 3-3) and for several miles beyond the location boundary. Individual interbeds or zones of interbeds have also been correlated between wells more than 10 miles (16 kilometers) apart (Figure 3-4). Rapid facies changes in the salt bed are not expected in this location because this area is not near the depositional basin margins. No postdiagenesis tectonic or dissolution events have disrupted the lower San Andres salt beds so as to alter the original extensive lateral continuity within the location. This broad lateral continuity is depicted as uniform variation in elevation to the top of the thick salt in lower San Andres unit 4 (Figure 3-5). Gradual changes that

*A detailed description of how geophysical logs were used to identify salt beds and how these type maps have been prepared is available (SWEC, 1983b).

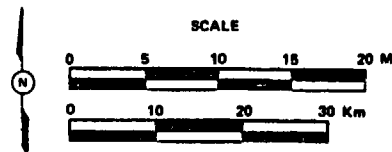


NOTES

CONTOUR INTERVAL IS 20 FEET
THICK SALT BED: A SALT BED WITH INTERBEDS OF NONSALT AND POOR QUALITY SALT INDIVIDUALLY NOT EXCEEDING 10 FEET THICK AND CUMULATIVELY NOT EXCEEDING 15% OF TOTAL BED THICKNESS

LEGEND

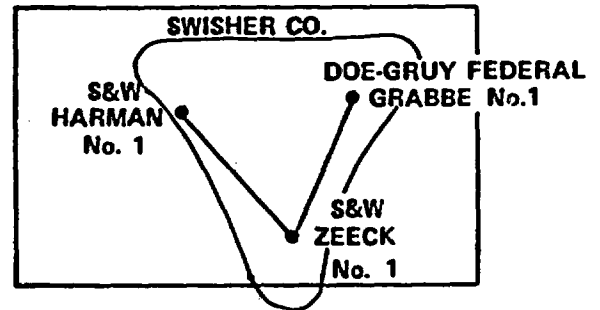
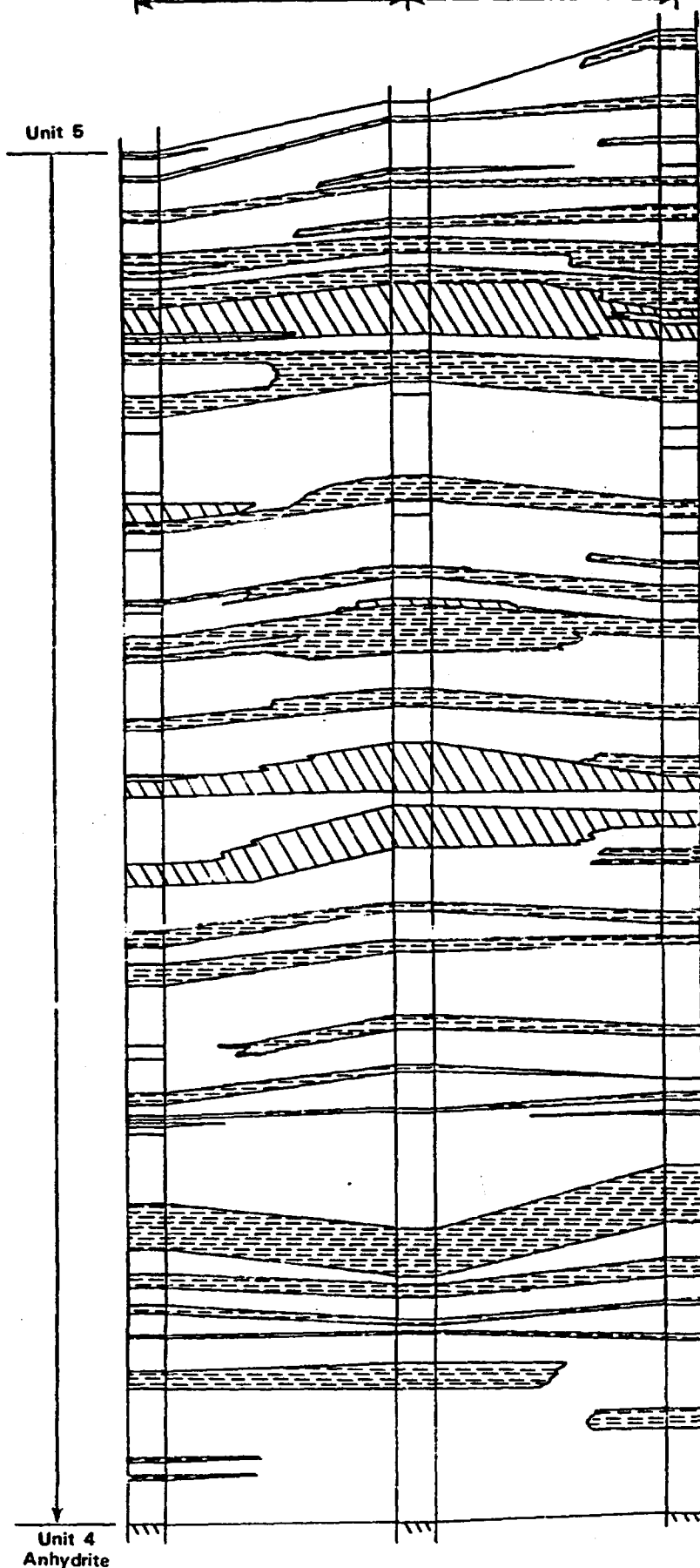
- WELL CONTROL SHOWN BY OPEN CIRCLES
- ▾ AREA OF INTEREST






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FIGURE 3-3
THICKNESS OF THICK SALT BED IN
LOWER SAN ANDRES UNIT 4

Stone & Webster Harman No. 1 Stone & Webster Zeeck No. 1 DOE-Gruy Federal Grabbe No. 1

Approximately 12 Miles Approximately 11 Miles



Legend

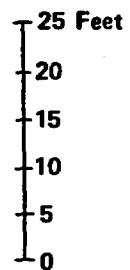
-  Halite generally containing less than 10 percent impurities
-  Halite generally containing greater than 10 percent mudstone impurities and/or abundant mudstone partings
-  Anhydritic zone

Note:

This illustration is an example of a correlation of zones of similar type salt. It depicts the overall continuity of rock types. Because it is a simplification and generalization of actual lithologic variation, this illustration should not be used for other purposes. Detailed logs of salt core from these wells are available from the DOE Salt Repository Program Office, Columbus, Ohio.

Derived from correlation by S. Hovorka of the Texas Bureau of Economic Geology

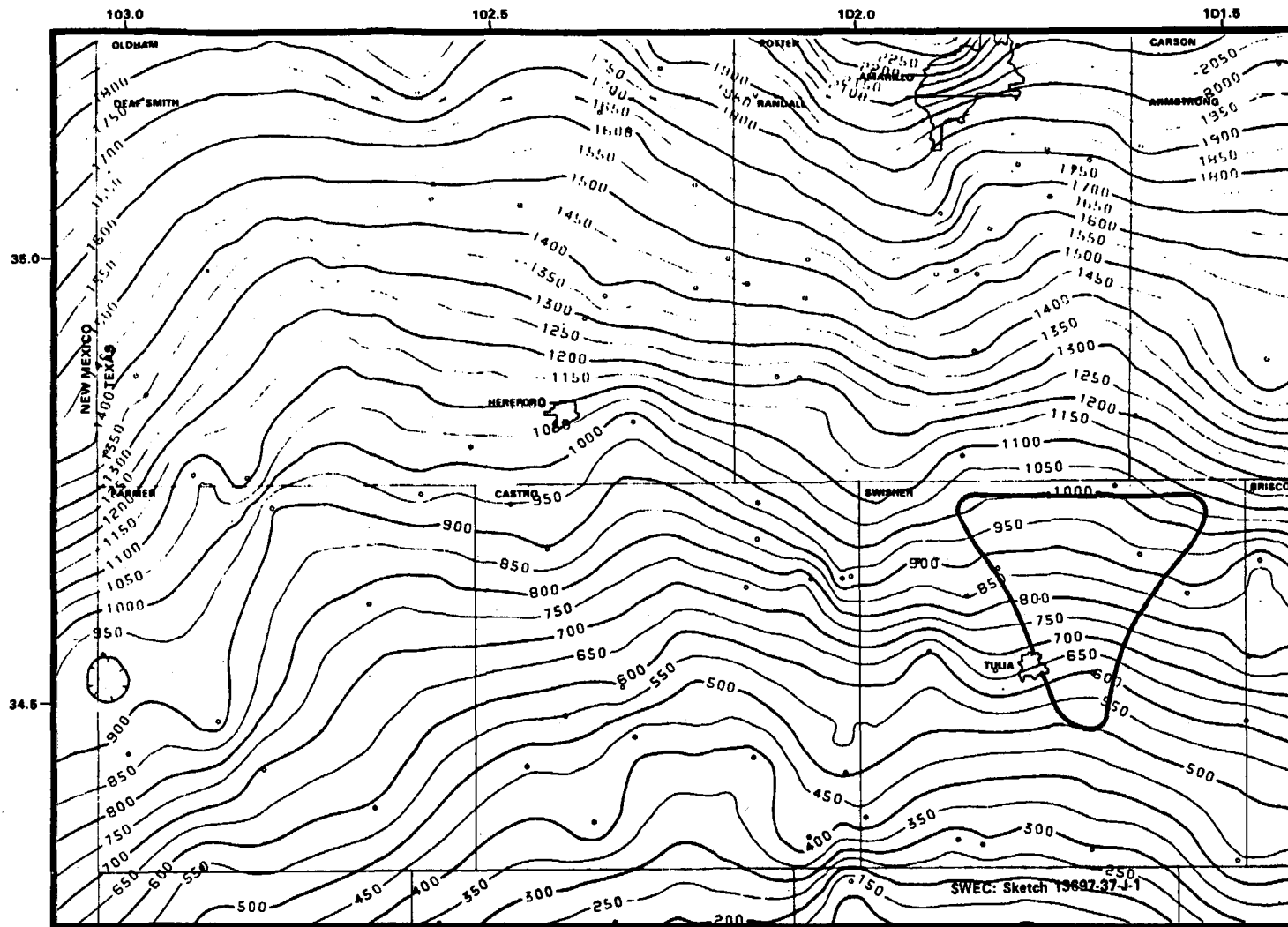
Vertical Scale:



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FIGURE 3-4
GENERALIZED WELL-TO-WELL
CORRELATIONS WITHIN THE LOWER
SAN ANDRES UNIT 4 SALT



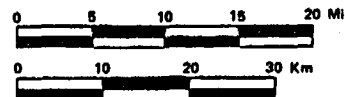
NOTES

CONTOUR UNITS IN FEET
 DATUM MEAN SEA LEVEL
 THICK SALT BED: A SALT BED WITH INTERBED
 INTERBEDS OF NONSALT AND POOR
 QUALITY SALT INDIVIDUALLY NOT
 EXCEEDING 10 FEET THICK AND
 CUMULATIVELY NOT EXCEEDING 15%
 OF TOTAL BED THICKNESS

LEGEND

WELL CONTROL SHOWN BY OPEN CIRCLES
 ▽ AREA OF INTEREST

SCALE



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FIGURE 3-5
ELEVATION OF THICK SALT BED IN
LOWER SAN ANDRES UNIT 4

occur laterally across the location (over 20 to 30 miles [32 to 48 kilometers]) are not likely to be significant within the boundaries of a mined repository (extending laterally about 2 miles [3.2 kilometers]). The potential for small changes in thickness or lithology within the proposed repository horizon were considered when conservatively adopting a thickness specification of 125 feet (38 meters) (ONWI, 1983, p. 52). The descriptor, lateral extent of host rock, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

3.2 GEOHYDROLOGY

The NWTS criteria (DOE, 1981) require evaluation of the present and probable future surface and subsurface hydrologic system to assess its performance and ability to minimize radionuclide migration or transport from the repository. The criteria also require assessment of ground water aquifers from the standpoint of construction of shafts and maintenance of shaft liners and seals. The effects of subsurface rock dissolution must be addressed also.

3.2.1 Present Geohydrologic Regime

The present geohydrologic regime may be represented as three major hydrostratigraphic units (Figure 3-6). The upper hydrostratigraphic unit consists of a freshwater aquifer primarily developed in the Ogallala Formation and Dockum Group. This shallow unit overlies a thick, predominantly shale and evaporite aquitard, the middle hydrostratigraphic unit. The lower (deep-basin) hydrostratigraphic unit (Wolfcampian and Pennsylvanian strata) contains thick, carbonate and sandstone brine aquifers separated by shale.

Ground-water head data, water level measurements, and geochemical data are being used in investigations of ground-water flow direction and recharge-discharge locations within the region (SWEC, 1984a; INTERA, 1984a; Senger and Fogg, 1983; Kreitler and Bassett, 1983). The Ogallala aquifer is recharged within the location by infiltration of precipitation and downward seepage from small surface impoundments. Utilization of the aquifer results in a net water level decline, therefore, the rates and amounts of recharge are insignificant on a broad scale. Ground water in the Ogallala aquifer flows to the east-southeast (Figure 3-7) and discharges at the caprock escarpment and locally as springs on the High Plains surface.

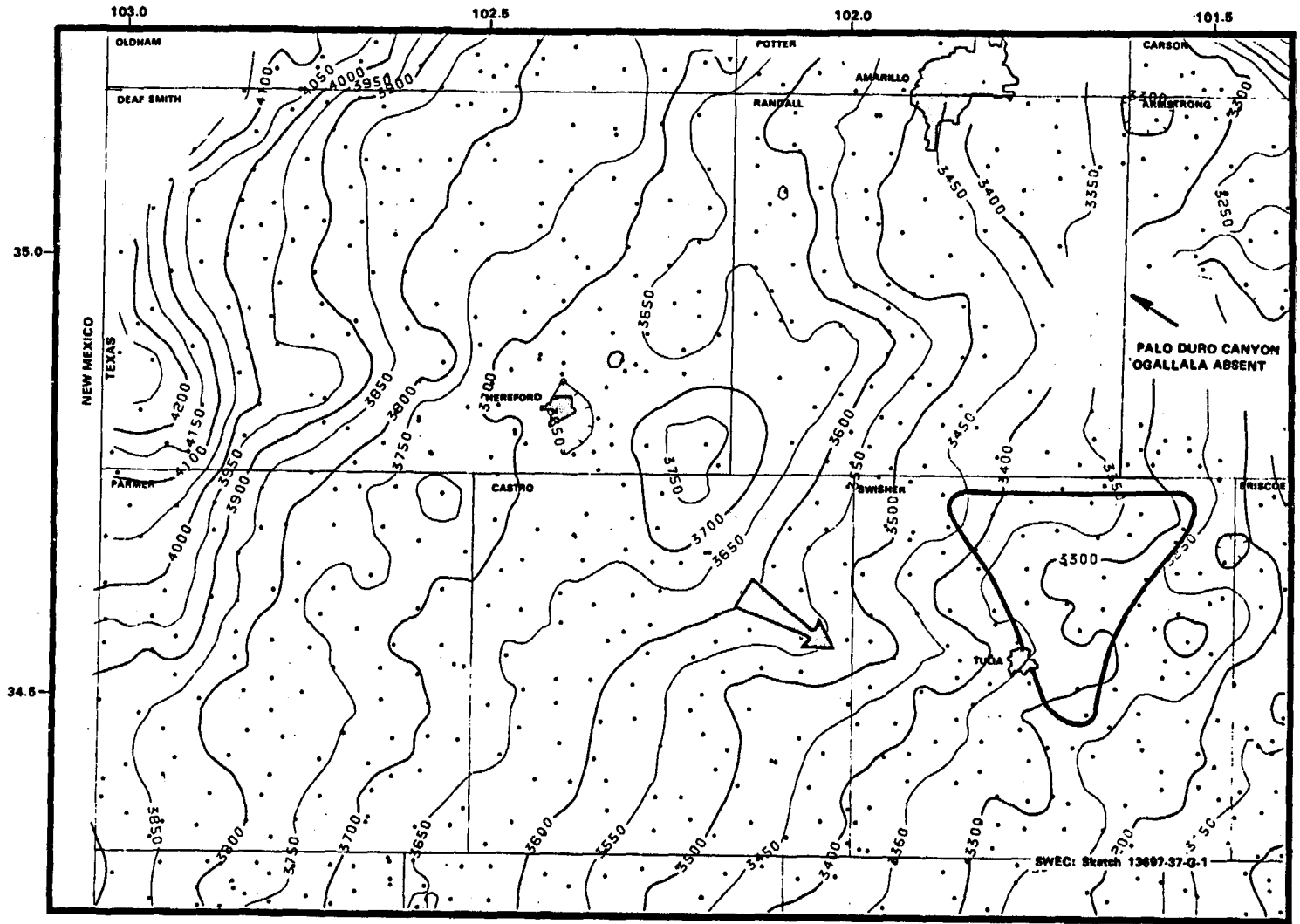
ERA	SYSTEM	SERIES	GROUP	FORMATION	LITHOLOGY	HYDROSTRATIGRAPHIC UNIT		
CENOZOIC	QUATERNARY				GRAVEL, SAND, SILT AND CLAY ALONG VALLEY FLOORS	UPPER HYDROSTRATIGRAPHIC UNIT (Approx. 1100 Feet)		
	TERTIARY			OGALLALA	FINE TO COARSE GRAINED GRAY SAND AND SILT WITH SOME GRAVEL AND RED OR YELLOW CLAY		OGALLALA AQUIFER	
MESOZOIC	TRIASSIC		DOCKUM		MUDSTONE, SANDSTONE, SILTSTONE, AND SILTY DOLOMITE	DOCKUM AQUIFER		
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE	ANHYDRITE, DOLOMITE, SHALE AND SILTSTONE	MIDDLE HYDROSTRATIGRAPHIC UNIT (Approx. 4000 Feet)		
				ALIBATES				
		GUADALUPE	ARTESIA		SALADO/TANSILL		ANHYDRITE, SALTY MUDSTONE AND SALT (THICK AND EXTENSIVE) WITH INTERBEDS OF SHALE, SANDSTONE AND DOLOMITE	AQUITARD
					YATES			
					SEVEN RIVERS			
					QUEEN/GRAYBURG			
	LEONARD	CLEAR FORK		SAN ANDRES	CARBONATES, EVAPORITES, SHALES, FINE SANDSTONE AND SILTSTONE	SAN ANDRES SALT (REPOSITORY HORIZON)		
				GLORIETA				
				UPPER CLEAR FORK				
				TUBB				
		WICHITA		RED CAVE	AQUITARD			
		WOLFCAMP			LIMESTONE, SHALE, DOLOMITE AND ARKOSIC SANDS	WOLFCAMP AQUIFER		
PENNSYLVANIAN		VIRGIL	CISCO	ARKOSIC SANDSTONE AND SHALE INTERBEDDED WITH LIMESTONE	LOWER HYDROSTRATIGRAPHIC UNIT (Approx. 4000 Feet)			
		MISSOURI	CANYON					
		DES MOINES	STRAWN					
		ATOKA	BEND					
		MORROW				UPPER PALEOZOIC GRANITE WASH AQUIFER		
					LIMESTONE AND DOLOMITE LOCALLY INTERBEDDED WITH SHALE AND SANDSTONE	LOWER PALEOZOIC CARBONATE AQUIFER		
PRECAMBRIAN					IGNEOUS AND METAMORPHIC ROCKS	BASEMENT AQUICLUDE		

LEGEND:
 EROSIONAL UNCONFORMITY

SOURCE: DERIVED FROM HANDFORD AND DUTTON, 1980; DUTTON ET AL, 1982; BASSETT AND BENTLEY, 1982

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FIGURE 3-6
 STRATIGRAPHIC COLUMN AND MAJOR
 HYDROSTRATIGRAPHIC UNITS



LEGEND

WELL CONTROL SHOWN BY OPEN CIRCLES

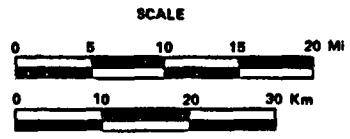
▽ AREA OF INTEREST

↘ GENERALIZED GROUND WATER FLOW DIRECTION

NOTES

CONTOUR INTERVAL IS 50 FEET

DATUM MEAN SEA LEVEL



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FIGURE 3-7
ELEVATION OF RECENT (1979-1981)
GROUND WATER LEVEL IN
OGALLALA AQUIFER

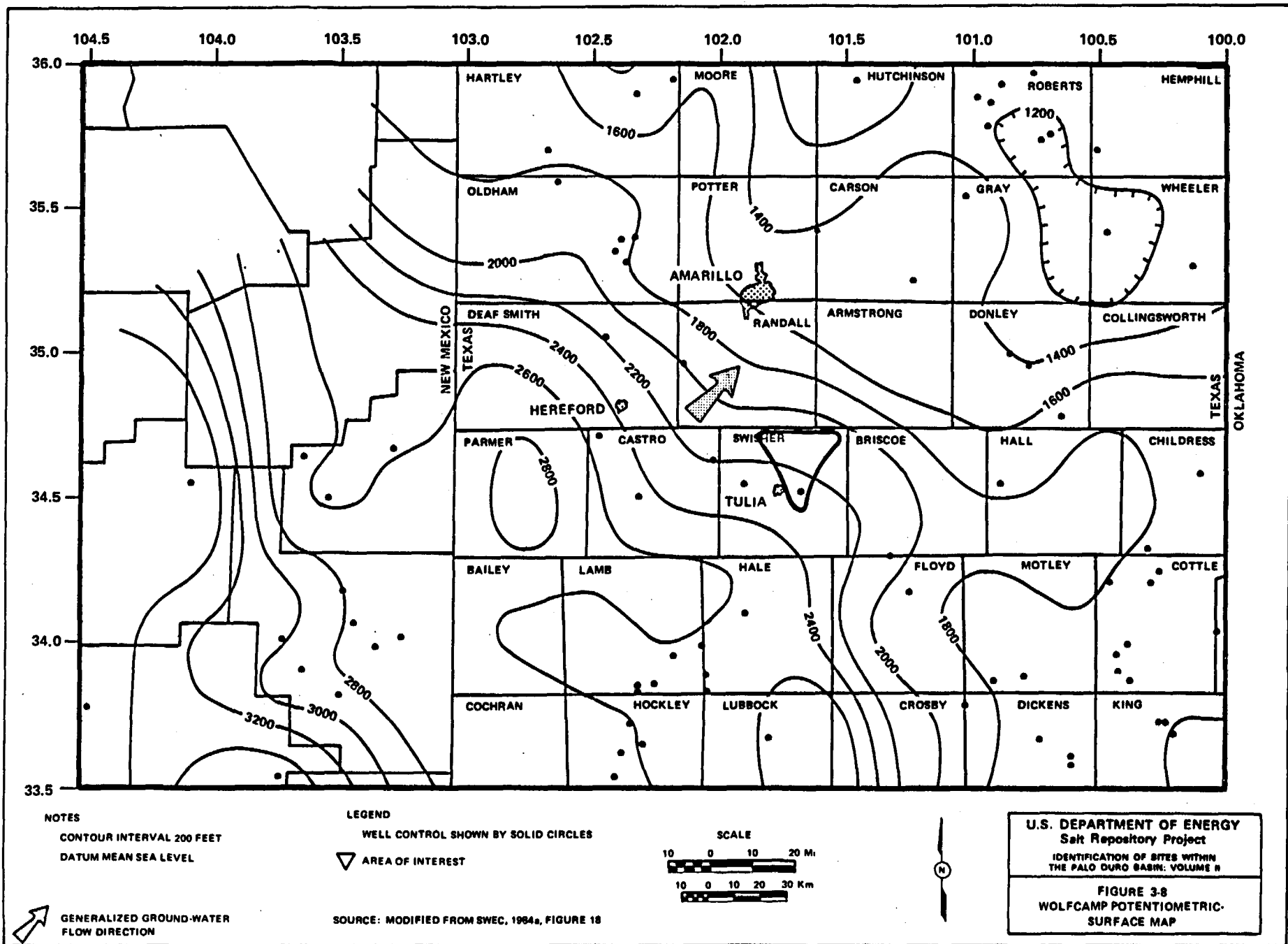
SWEC: Sketch 13697-37-G-1

The Dockum Group consists of relatively permeable sandstone and conglomerate lenses (locally known as Santa Rosa) bounded by less permeable shale and clay layers. Recharge to the water-bearing units is thought to result principally from precipitation along the northern and western escarpments (Fink, 1963, p. 19). Potentiometric heads in the Dockum aquifer are a couple of hundred feet below Ogallala water levels across the location. Dockum heads and Ogallala heads are nearly equal at outcrop areas. Ground-water flow in the Dockum aquifer is thought to be to the east and southeast.

Flow within the deep basin aquifers is to the east and northeast (Figures 3-8 and 3-9); there is no known discharge of these deep aquifers within the Palo Duro Basin. Fluids flowing through deep basin aquifers beneath the location are thought to discharge east of the Palo Duro Basin, in Oklahoma. Flow within the middle unit has not been measured, but is thought to be very small and limited to thin dolomitic or silty interbeds. Dutton (1983) has suggested that, in the Palo Duro Basin, the transmissivity of one of these dolomite interbeds, the San Andres unit 4 carbonate, may be less than 0.043 square foot (0.004 square meter) per day.

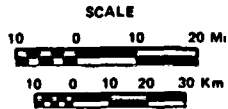
Because aquifer recharge in the location is insignificant and no aquifers discharge in or near the location, the descriptor, present aquifer recharge/discharge, was identified as a nondiscriminator (Steps 1, 2, 3, 4, 5, and 7). Site selection is not sensitive to the presence of small surface impoundments in the location (see Table 3-1 in Section 3.7.3) because of their insignificant effect on the geohydrologic regime. There is no known injection of fluids into ground water in the location. The descriptor, existing surface impoundments/ground water injection, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

Ongoing investigations of the deep basin aquifers may demonstrate that significant local variations exist in porosity and hydraulic conductivity of the Wolfcampian or deeper units, particularly where thick shelf carbonate units may exist. However, site preference was not considered sensitive to this anticipated variation because, under expected conditions, radionuclides will not get to these deep basin aquifers within the tens of thousands of years of concern. The available potentiometric maps, while considered reliable general representations of the potential flow conditions, do not portray in detail the variation anticipated over the location due to the sparse data base from which they



NOTES
 CONTOUR INTERVAL 200 FEET
 DATUM MEAN SEA LEVEL

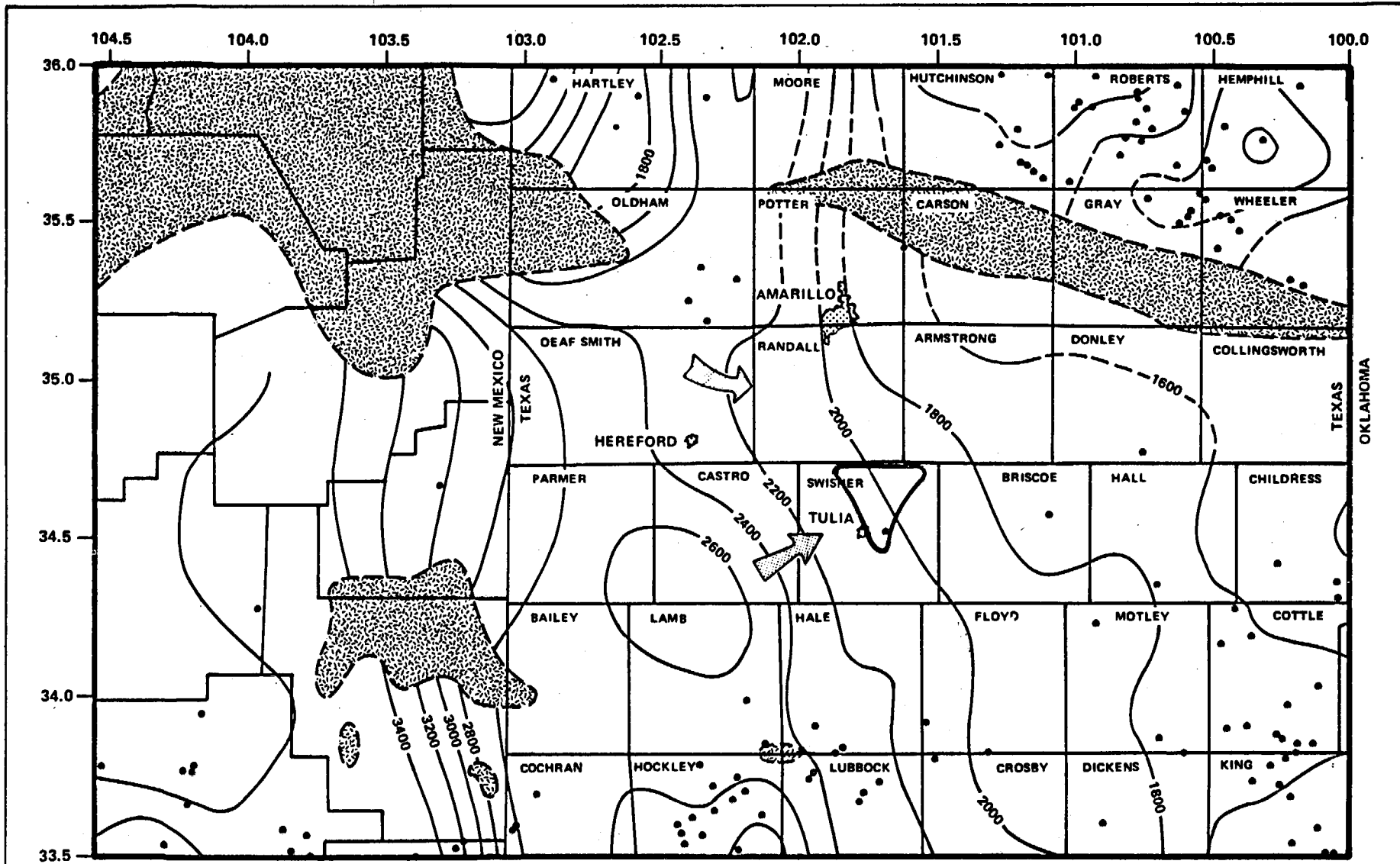
LEGEND
 WELL CONTROL SHOWN BY SOLID CIRCLES
 ▽ AREA OF INTEREST



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FIGURE 3-8
WOLF CAMP POTENTIOMETRIC-
SURFACE MAP

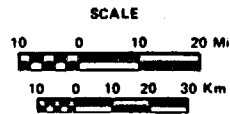
SOURCE: MODIFIED FROM SWEC, 1984a, FIGURE 18



NOTES
 CONTOUR INTERVAL 200 FEET
 DATUM MEAN SEA LEVEL

LEGEND
 WELL CONTROL SHOWN BY SOLID CIRCLES
 ▽ AREA OF INTEREST
 [Stippled Box] PENNSYLVANIAN ABSENT

SOURCE: MODIFIED FROM SWEC, 1984a, FIGURE 19



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 THE PALO DURO BASIN: VOLUME II
 FIGURE 3-9
 PENNSYLVANIAN POTENTIOMETRIC-
 SURFACE MAP

➔ GENERALIZED GROUND-WATER
 FLOW DIRECTION

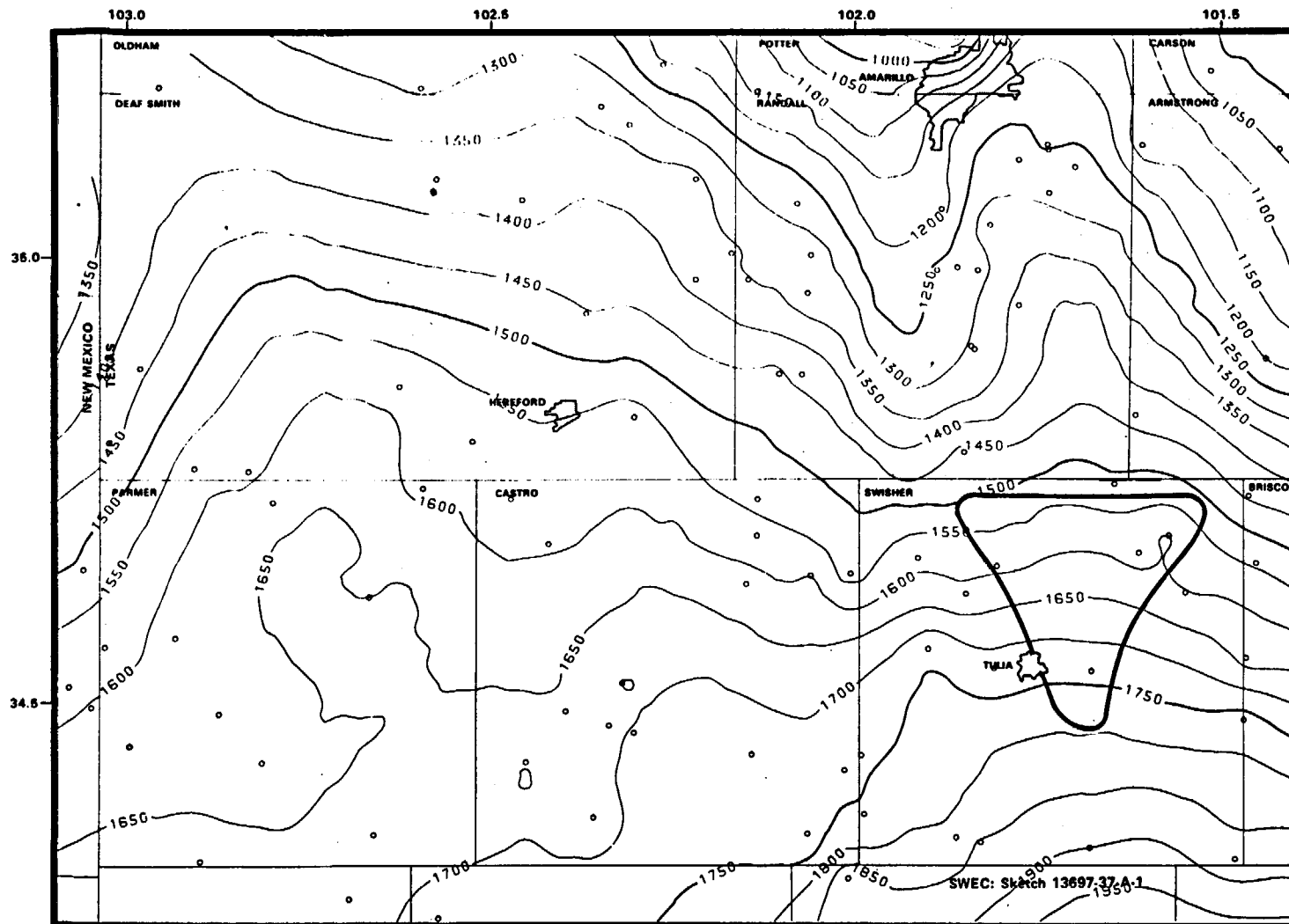
were constructed. The descriptor, potentiometric surfaces, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7). The existing potentiometric maps are useful in predicting the expected ground-water path and travel times (Section 3.2.2). The difference in the potentiometric heads in the Wolfcamp and the Ogallala provides an indication of the magnitude of the downward hydrologic potential across the location. The variation in this potential difference across the location was considered insignificant in terms of site preference.

Vertical communication between the upper and lower units within the location is not thought to exist because available data provide very little indication of, or reason to anticipate, natural pathways in unfaulted areas away from the basin margins. Geochemical data for the Wolfcamp aquifer in the Mansfield No. 1 (PD-4) borehole (in Oldham County) show isotopic composition, which by one model suggests that, in that particular area, there may have been communication between the upper and lower aquifer units. Data from the Zeeck No. 1 (PD-7) borehole in the southern part of the location indicate that no communication has occurred at that site. If nominated for characterization, additional data will be obtained to further evaluate the potential for vertical flow between the upper and lower hydrostratigraphic units.

3.2.2 Expected Geohydrologic Regime

Emplacement of radioactive waste in a repository in the lower San Andres unit 4 salt is not expected to affect the major upper and lower aquifer systems due to their vertical separations from the repository horizon. The thickness of the aquitards separating the repository from the upper and lower aquifers is depicted in Figures 3-10 and 3-11. Data are not available to estimate the variation in potential thermally induced flow in the middle hydrostratigraphic unit that might exist across the location. However, thermally induced flow within the middle hydrostratigraphic unit is estimated to be of little consequence (Appendix A). The descriptor, thermally induced flow, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

The rate at which the Ogallala or Dockum aquifers are being depleted should not be affected significantly by siting a repository in the location. A mined repository operation is anticipated to consume less water than was used in 1979



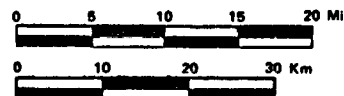
LEGEND

- WELL CONTROL SHOWN BY OPEN CIRCLES
- ▽ AREA OF INTEREST

NOTES

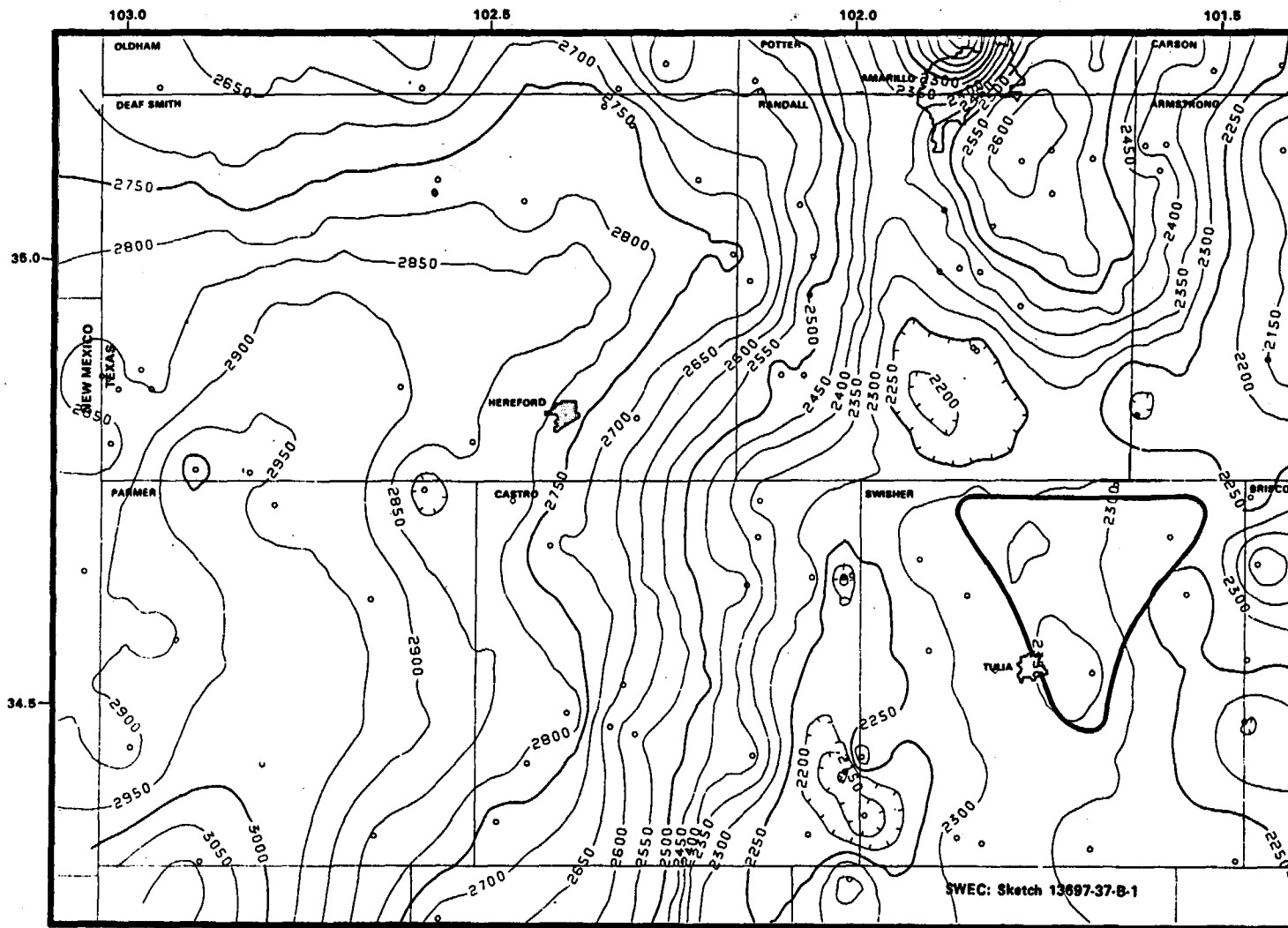
CONTOUR INTERVAL IS 50 FEET
 THICKNESS OF SEQUENCE BETWEEN BASE OF LOWER
 SAN ANDRES UNIT 5 AND TOP OF ALIBATES

SCALE



U.S. DEPARTMENT OF ENERGY
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 THE PALO DURO BASIN: VOLUME II

FIGURE 3-10
**THICKNESS OF AQUITARD ABOVE
 THE REPOSITORY HORIZON**



NOTES

CONTOUR UNITS IN FEET

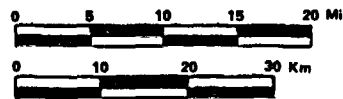
THICKNESS OF SEQUENCE BETWEEN WOLFCAMP AND TOP OF LOWER SAN ANDRES UNIT 3

LEGEND

WELL CONTROL SHOWN BY OPEN CIRCLES

▽ AREA OF INTEREST

SCALE



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FIGURE 3-11
THICKNESS OF AQUITARD BELOW
THE REPOSITORY HORIZON

to irrigate a comparable area of land.* Anticipated depletion of the Ogallala aquifer by farming and other normal practices will not alter significantly the hydrogeologic system (INTERA, 1984b). Complete depletion of the Ogallala and Dockum aquifers would reduce significantly the magnitude of the downward flow potential between the upper hydrostratigraphic unit and the lower hydrostratigraphic unit. The downward flow potential would not be reversed, however, and radionuclide isolation (site performance) within the middle aquitard would not be compromised. The descriptor, expected aquifer depletion, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7) in consideration of long-term performance factors. This descriptor is used in consideration of potential water use conflicts (Section 3.9.2). Future construction of surface impoundments will likely be limited to stream valley areas and playas. The potential size of these impoundments is limited by the low relief of the region. Water from surface impoundments may slowly recharge the Ogallala aquifer by infiltration; however, any such infiltration will have an insignificant effect on the overall hydrogeologic regime or site performance. The descriptor, impoundment potential, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

Injection of fluids into shallow or deep aquifers can have local effects on the hydrologic system; data have not been collected to assess the potential for injection or change in the hydrogeologic system. The descriptor, injection potential, was identified as a nondiscriminator (Steps 1, 2, and 7).

Under expected conditions, radionuclides will not leave the lower San Andres unit 4 salt within the tens of thousands of years of interest. If a vertical ground water pathway cutting the repository and connecting the upper and lower aquifer systems was created, radionuclide transport from the site

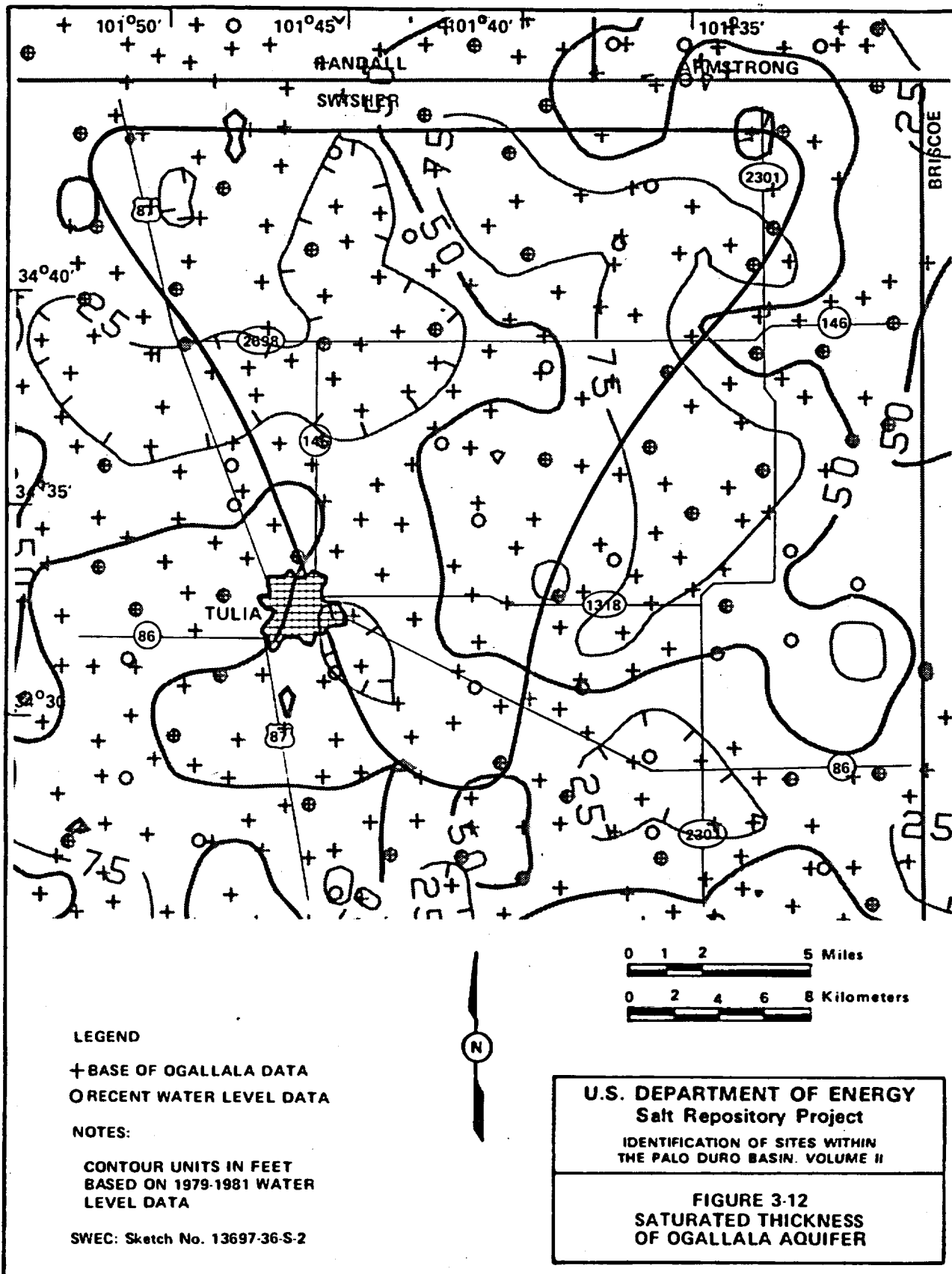
*The average amount of water applied for irrigation in Swisher County during 1979 was 1.2 acre-feet of water per irrigated acre of land as calculated from data in Table 2-18 (NUS, 1984a, p. 48). A per acre calculation of repository water use, based on an average requirement of 223 gallons per minute (360 acre feet per year) and a surface facility area of 440 acres, indicates that 0.84 acre foot of water per acre of land would be used.

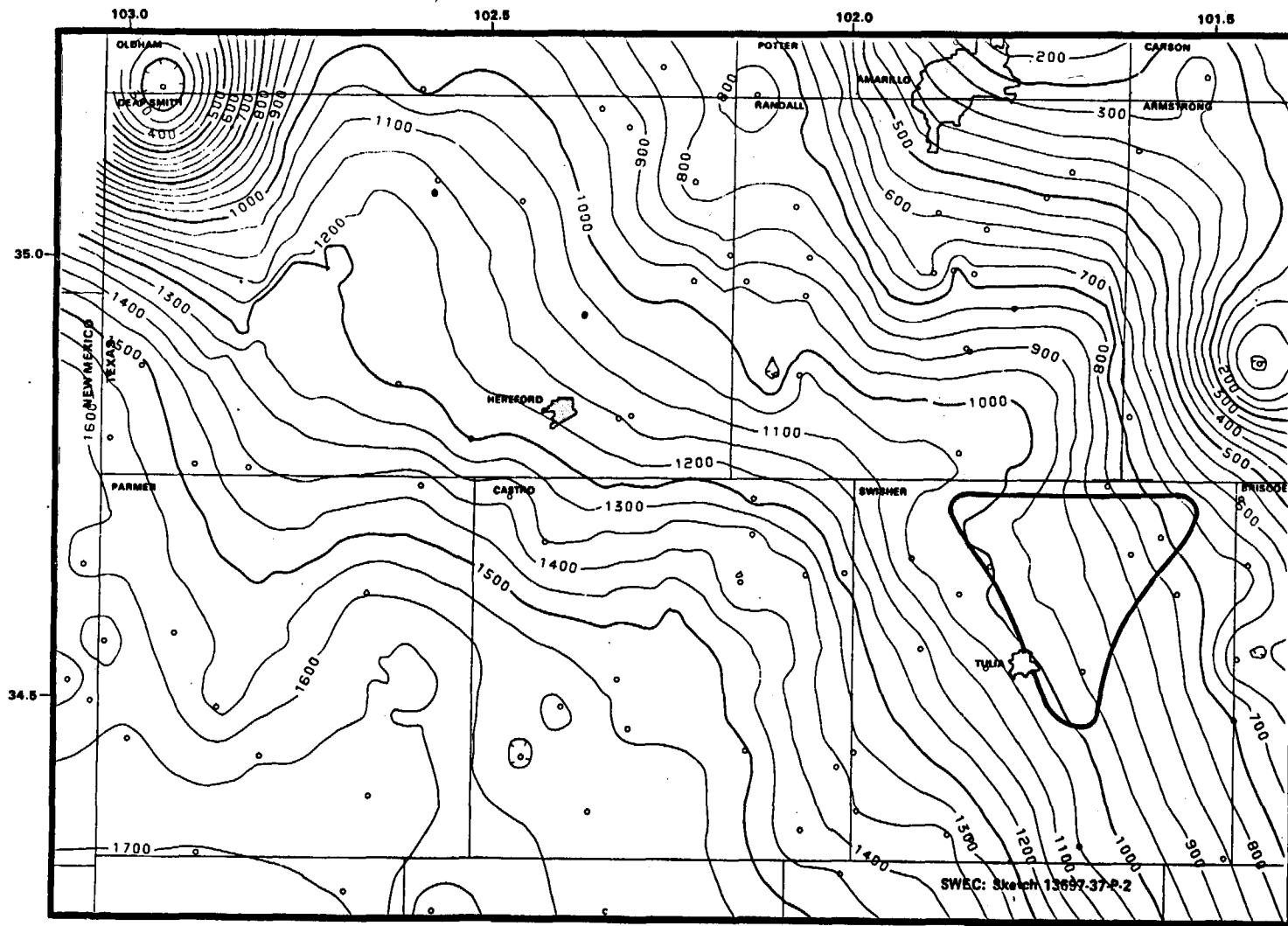
would be downward* followed by lateral flow to the east and northeast. INTERA (1984a) has used the available data to compute both the travel time required for ground water to flow 6 miles (10 kilometers) within the Wolfcamp and the distance ground water would travel over a 10,000-year period from a site in the location. The Wolfcamp flow rates are such that ground water is expected to travel less than 0.6 mile (1 kilometer) during a 10,000-year period (INTERA, 1984a, Table 4-8). Given this estimate of ground-water movement, radionuclides that might have reached the Wolfcamp are not expected to migrate to the accessible environment in quantities in excess of the U.S. Environmental Protection Agency (EPA) requirements (EPA, 1982). While the distance to natural discharge areas for deep-basin fluids varies from one side of the location to the other (greater distance to discharge in the southwestern portion of the location), the likely distance of transport of radionuclides from a site in 10,000 years is so small in relation to the total distance to a natural discharge location, on the order of 124 miles (200 kilometers) away, that it is a relatively unimportant factor. In summary, site preference is not sensitive to variations in the expected geohydrologic regime (ground-water path, travel time, etc.). The descriptor, expected geohydrologic regime, was identified as a nondiscriminator (Steps 1, 2, 3, 4, 5, and 7).

3.2.3 Expected Suitability for Construction

Effective sealing and maintenance of shaft liner and seals are requirements for isolation of the upper freshwater aquifers from the repository horizon. The saturated thickness of the Ogallala aquifer is one measure of the potential difficulty of this task. The descriptor, recent saturated thickness of the Ogallala, is variable across the location (Figure 3-12) and was identified as a discriminator (Steps 1, 2, 3, 5, and 6). The overall thickness of potentially water-bearing rocks in the upper unit is another measure. Depth to the base of the Dockum Group (Figure 3-13) varies across the location and is an

*Preliminary assessments (INTERA, 1984b) of climatic and tectonic perturbations, such as return of pluvial conditions and uplift of recharge areas, indicate that the downward potential for flow will not be reversed, and little change in overall hydrologic system performance is likely in the tens of thousands of years of interest.





SWEC: Sketch 13697-37-P-2

LEGEND

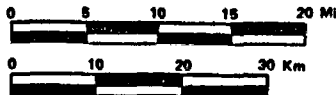
WELL CONTROL SHOWN BY OPEN CIRCLES

▽ AREA OF INTEREST

NOTES

CONTOUR INTERVAL IS 50 FEET
GROUND SURFACE DATUM

SCALE



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FIGURE 3-13
DEPTH TO BASE OF DOCKUM GROUP

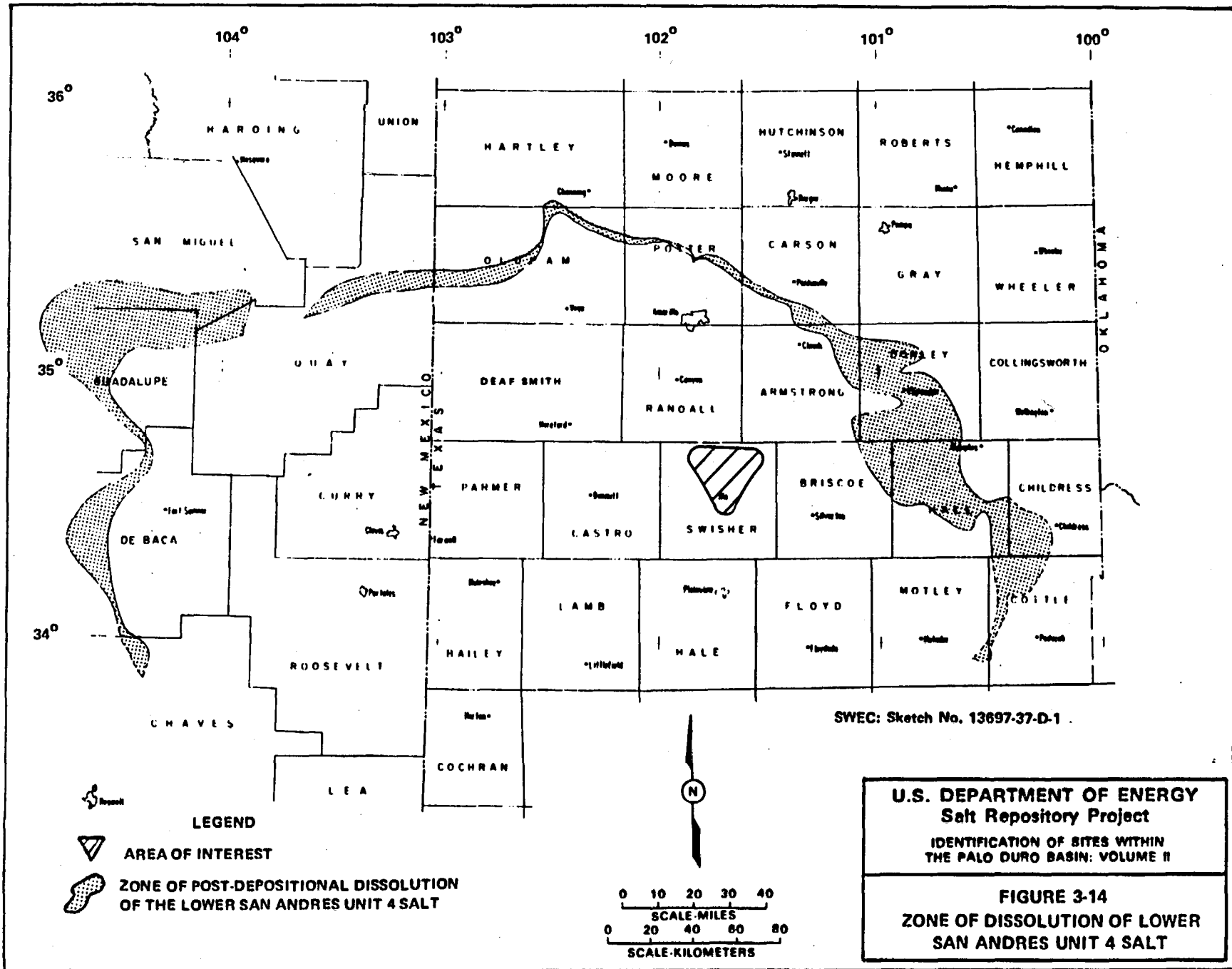
indication of the total thickness of potential water-bearing rock to be dealt with during shaft construction and maintenance. The descriptor depth to base of Dockum, was identified as a discriminator within the location (Steps 1, 2, 3, 5, and 6).

The character of strata between the host rock and overlying aquifers must be adequate to support seals that effectively prevent water from entering the repository. While the exact location and design of seals have not been determined, the Alibates Formation is expected to be the location of the intermediate seal (Parsons-Brinckerhoff/PB-KBB, 1983). The Alibates is predominately an anhydrite unit in the location (SWEC, 1984b,c). Insufficient well control exists to determine what areas of the location might be more preferred from a sealing standpoint. For this reason, the descriptor, character of strata between host rock and overlying aquifers, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.2.4 Subsurface Rock Dissolution

Salt dissolution can be discussed in three broad categories: syndepositional processes; dissolution of the host rock at the basin's periphery; and interior basin dissolution of the shallowest salt bed. Syndepositional salt dissolution, recrystallization, and diagenesis are of interest from a repository and waste package design standpoint. Numerous precipitation and alteration events have produced the mineralogic and chemical (including water) compositions which affect the engineering properties of the host unit and ultimately the system's performance. Manifestations of salt dissolution phenomena of this type are expected to be quite similar across the location.

Dissolution of the lower San Andres unit 4 salt at the basin's periphery is thought to occur at distances of greater than 25 miles (40 kilometers) from the location, beyond the eastern margin of the Southern High Plains, (Figure 3-14). This area is called the active dissolution zone or front. Dissolution in these areas is of concern because it is possible for the zone to migrate basinward and cause direct exhumation of the nuclear waste. The available data (Gustavson et al, 1980) show, however, that current rates of down-dip migration of salt dissolution are such that the lower San Andres salt anywhere in the location will not be affected by the results of salt dissolution



at the basin's periphery in the tens of thousands of years of concern. Because this dissolution phenomenon will not affect site performance, site preference could not be made based on distance from dissolution zones within the lower San Andres unit 4 salt.

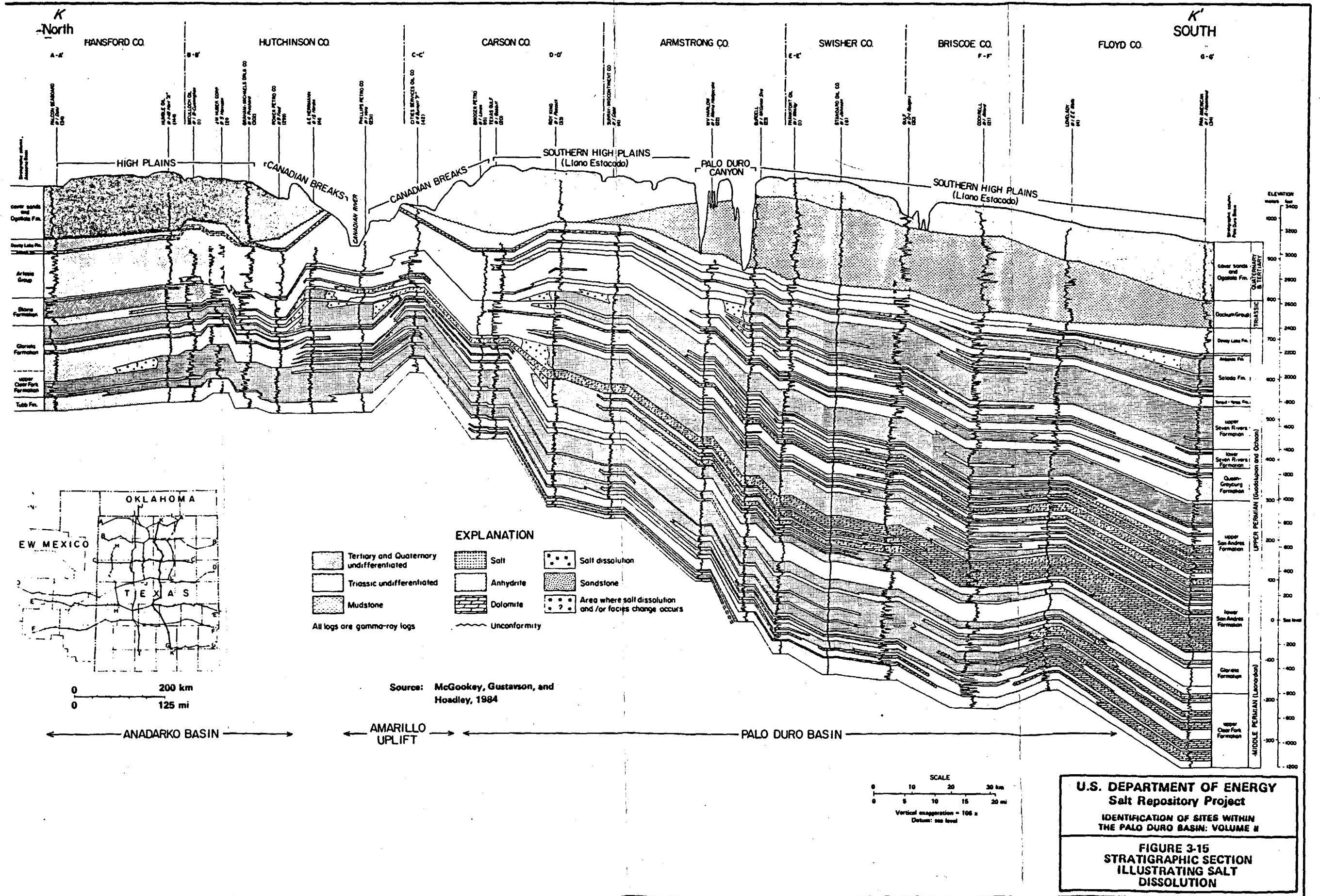
Progressively younger (shallower) salt beds have been subjected to dissolution toward the interior of the Palo Duro Basin (Figure 3-15). Evidence for such dissolution comes from recent DOE drilling at the Zeeck No. 1 (PD-7), Harman No. 1 (PD-8), and Grabbe No. 1 (PD-2) boreholes (SWECC, 1984b,c; Hovorka, 1983). The locations of these boreholes are depicted on Figure 3-16. The repository horizon is separated sufficiently from the uppermost salts by a thick, generally impervious section and rates of dissolution are so low that downward migration of this salt "dissolution zone" is negligible (Appendix B) and; therefore, not expected to impact repository integrity. Previous dissolution or ongoing dissolution of shallow salts at the basin's interior is of concern only from the standpoint of construction and maintenance of shafts and seals. Data are not available to demonstrate that this upper "dissolution zone" at any one part of the location is more preferred than another from a constructibility standpoint. From both long-term performance and constructibility standpoints, the descriptor, salt dissolution, was identified as a nondiscriminator (Steps 1, 2, 3, 4, 5, and 7).

3.3 GEOCHEMISTRY

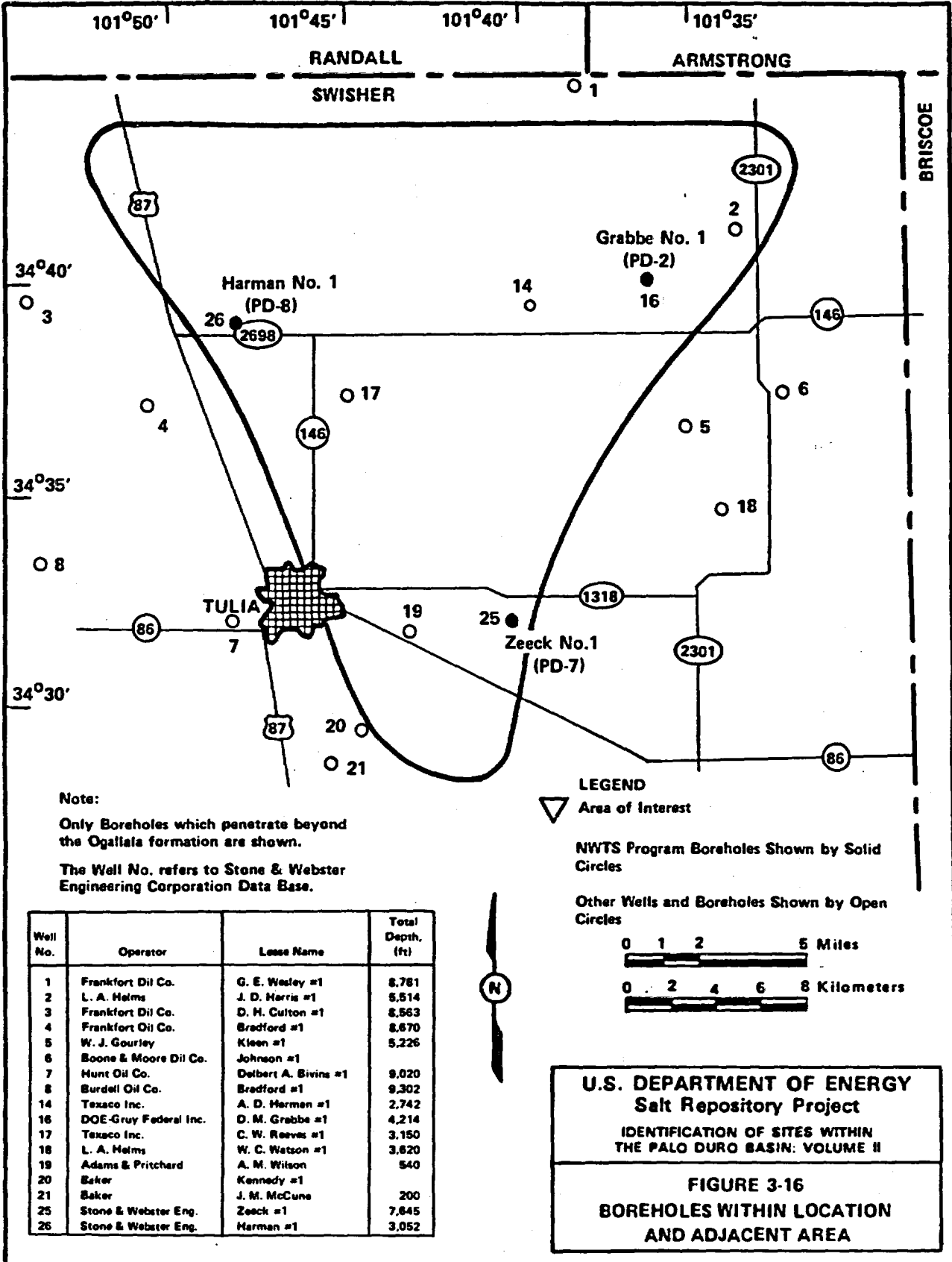
Geochemical data that could bear upon site preference within a location can be considered within the context of three broad aspects of the total waste isolation system. These aspects are waste package lifetime, radionuclide solubility in repository brines, and radionuclide retardation potential in nonpotable ground water below the host rock.

3.3.1 Lifetime of the Waste Package

The first major barrier to release of radionuclides from the repository is the waste package. As long as the waste package does not fail, the waste will be retained inside. The waste package lifetime is dependent in large part upon the chemical and thermal environments in the repository and the materials



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FIGURE 3-15
STRATIGRAPHIC SECTION
ILLUSTRATING SALT
DISSOLUTION



chosen for use in the waste package. Host rock mechanical properties and stress conditions may also affect waste package life (see Section 3.4.2). Site-specific geochemical factors that could be used in this evaluation are (1) the amount of brine presently in the salt that could be released and contact the waste package, and (2) the chemical composition and properties (pH, Eh) of that brine. Hubbard et al (1984a) have suggested that the following compositions be adopted as likely for fluid inclusion brine at a site in the lower San Andres unit 4 salt of the Palo Duro Basin:

1,336	mg/l	Ca ⁺⁺
50,000	mg/l	Mg ⁺⁺
25,290	mg/l	Na ⁺
15,690	mg/l	K ⁺
3,200	mg/l	SO ₄ ⁼
200,000	mg/l	Cl ⁻

Halite in the lower San Andres unit 4 is expected to contain 0.1 to 1.0 weight percent water. Clay-rich salt and claystone beds with higher water contents (up to about 20 weight percent water for clay-rich materials) have been avoided to some degree by establishment of a preference for "thick salt" beds (Section 3.1.2). Variations that may exist on a local scale are unknown and cannot be specifically predicted due to the sparse data base. The descriptor, brine content and chemistry, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.3.2 Solubility of Radionuclides

Should brines in a repository breach the waste package, the next barrier to transport depends on the solubility limits of radionuclides in these brines. Should there be a flow of brine through the repository, only the soluble fraction of the radioactive waste can be transported. Thus, slightly soluble radionuclides can only slowly leave the repository, whereas the more soluble ones can leave at a greater rate. Radionuclide solubilities are partly determined by site-specific chemical and thermal conditions and partly by the material used in the waste package. The site-specific factors of concern in this regard are the same as those for the waste package lifetime. Site-specific data are not yet available, thus variations that may exist on a local scale are unknown.

The descriptor, solubility of radionuclides, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.3.3 Retardation of Radionuclides

Should radionuclides exit the repository and traverse the salt-bearing section between the repository and the nearest downgradient transmissive aquifer (Wolfcampian rock), the next barriers to their transport are conditions in the nonpotable ground water of that aquifer. These barriers slow (retard) the transport of individual radionuclides (e.g., ^{234}U) to rates less than the flow rate of ground water. Some chemical and isotopic data required to determine the amount of retardation have been collected for the Wolfcamp and deeper brine aquifers (Hubbard et al, 1984b; Langmuir, 1983). These data indicate little variation in potential retardation over large areas. Because variation in potential radionuclide retardation over the location cannot be demonstrated, the descriptor, radionuclide retardation, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.4 GEOLOGIC CHARACTERISTICS

3.4.1 Subsurface Characterization

NWTS criteria require that: "The site shall be located so that the subsurface setting can be sufficiently characterized to permit identification and evaluation of conditions that are potentially adverse or favorable to waste containment, isolation, and retrieval" (DOE, 1981, p. 8). Information available for assessing this criterion includes DOE borehole data and logs, borehole data collected by others, and stratigraphic studies performed as a part of geologic characterization. Figure 3-16 shows locations for DOE exploration boreholes and holes drilled by others in and around the location. Figure 3-6 (Section 3.2) provides a generalized stratigraphic section for this location. Additional stratigraphic information is found in the area geological characterization report (SWECC, 1983a) and numerous geological circulars, reports of investigations, and cross section reports published by Texas Bureau of Economic Geology (TBEG).

The subsurface is presently best characterized in areas close to existing boreholes. Data from these boreholes can be used to evaluate a site and identify potentially adverse or favorable conditions. Existing data can result in higher levels of confidence during early design or site screening decisions. Because of the relative uniformity of subsurface conditions, information can be extrapolated throughout much of the location. Further, it is expected that no one portion of the location will be substantially more difficult to characterize than another; numerous exploration boreholes would be required for characterization regardless of the site identified. The descriptor, subsurface characterization, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

3.4.2 Geologic System Ability to Accommodate Stresses

NWTS criteria require that: "The site shall provide a geologic system which can be shown to accommodate anticipated geomechanical, chemical, thermal, and radiological stresses caused by waste/rock interactions" (DOE, 1981, p. 8).

This criterion has been addressed according to the following three descriptors:

- Thermally induced fractures/stresses
- Chemical/thermal effects (i.e., hydration/dehydration of mineral components, brine migration, and moisture content)
- Radiation effects.

The nature and extent of thermally induced fracturing and stress conditions are dependent in large part upon the character (extent of interbeds and lithologies) of the host salt. Induced stresses or differential creep may reduce the life of the waste package. The character of the proposed host salt is not known everywhere within the location; however, minimal differences in these conditions are anticipated (Section 3.1.3). Similarly, information on chemical/thermal effects (i.e., hydration/dehydration of mineral components, brine migration, and moisture content) is not available across the location. Radiation effects will extend only a short distance from the confines of the repository (RRC-IWG, 1983, pp. 27-29). The thickness and lateral extent of the host rock is such that sufficient competent salt is available so that radiation effects will not be of concern. In summary, the specific ability of a site in the location to accommodate the stresses resulting from waste emplacement is

unknown. It will remain unknown until in situ testing is completed during site characterization. However, because significant differences in rock properties are not expected across the location, minimal differences in the ability of sites to accommodate stresses are anticipated. All of the descriptors, thermally induced fractures/stresses, chemical/thermal effects, and radiation effects, were identified as nondiscriminators (Steps 1, 2, 3, 4, and 7).

3.4.3 Hazards to Repository Personnel

The NWTS criteria require that: "The site shall be located so that development, operation, and closure of underground areas can be accomplished without undue hazard to repository personnel" (DOE, 1981, p. 8). Potential underground hazards include roof falls, floor heave, pillar instability, and gassy (or gas outburst) conditions. While various design options exist to minimize these problems at any site, the potential for these hazards may be lessened by practices such as selection of shallower repository horizons, avoidance of interbeds, and avoidance of suspected gassy rocks.

While differences in depth to host rock (i.e., the lower San Andres unit 4) across the location are not considered significant in terms of long-term performance (see Section 3.1.1), in general the shallower a repository is sited, the easier it will be to maintain mine openings during operation. This is because creep closure, differential stress conditions, and resultant mine roof, floor, and pillar instability problems will likely be more easily dealt with at shallower depths. Thus, the descriptor, depth to host rock, was identified as a discriminator (Steps 1, 2, 3, 5, and 6) from a constructibility standpoint.

Interbeds in salt may exacerbate roof, floor, and pillar instability. Examination of rock core indicates that total avoidance of interbeds will not be possible in the Palo Duro Basin. Interbed location within the lower San Andres unit 4 salt varies somewhat in both vertical and lateral directions; however, it is likely that interbeds of similar lithology will have similar characteristics and similar underground problems would be expected anywhere in the location. A minimum thickness criterion of 125 feet (38 meters) of "thick salt" has been adopted (Section 3.1.2) for screening to identify a host material to accommodate proposed repository designs and assure adequate long-term performance. Additional data would be required to make a siting preference

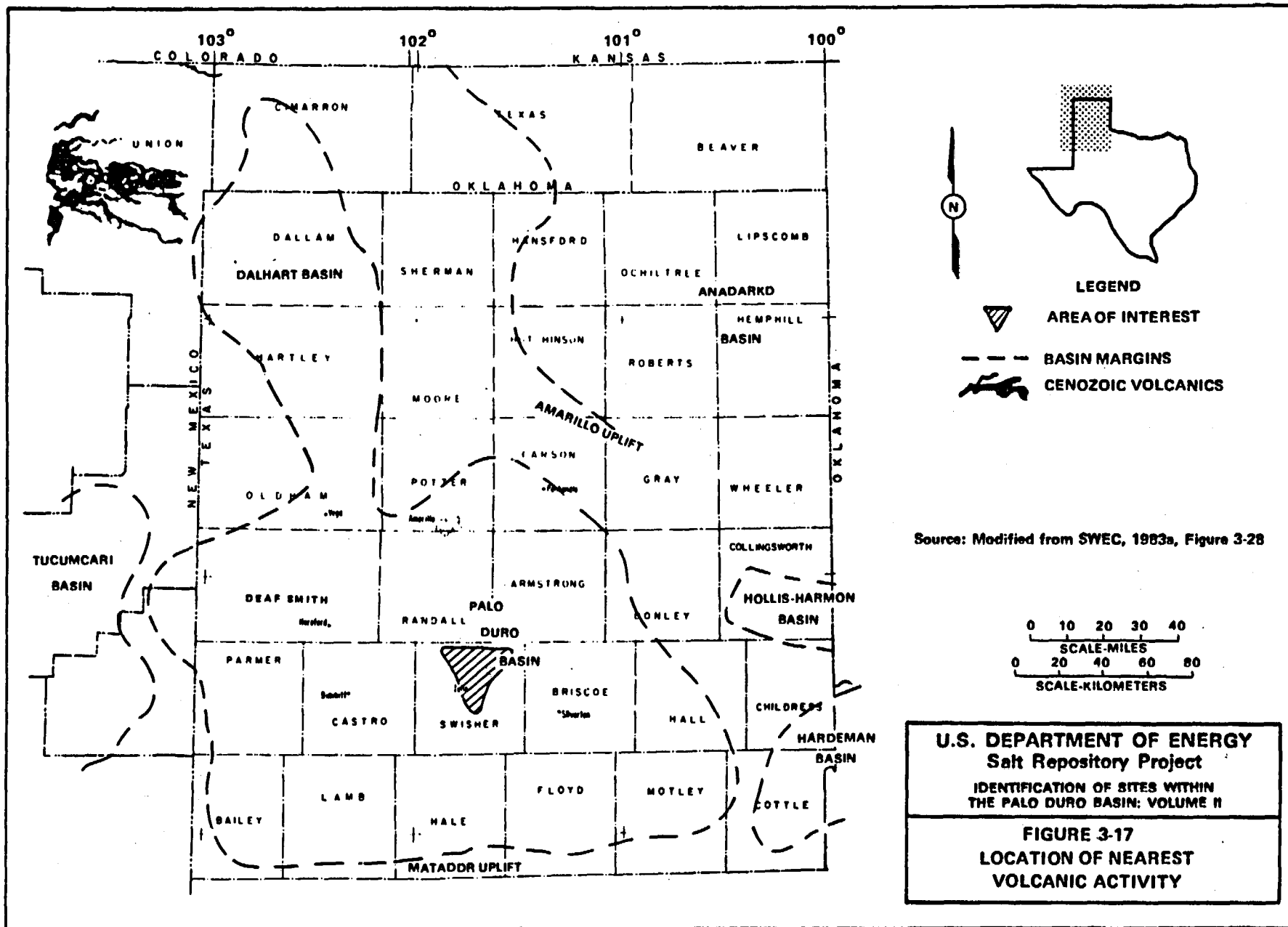
from a constructibility standpoint based on the nature or location of interbeds. Therefore, the descriptor, presence of interbeds, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

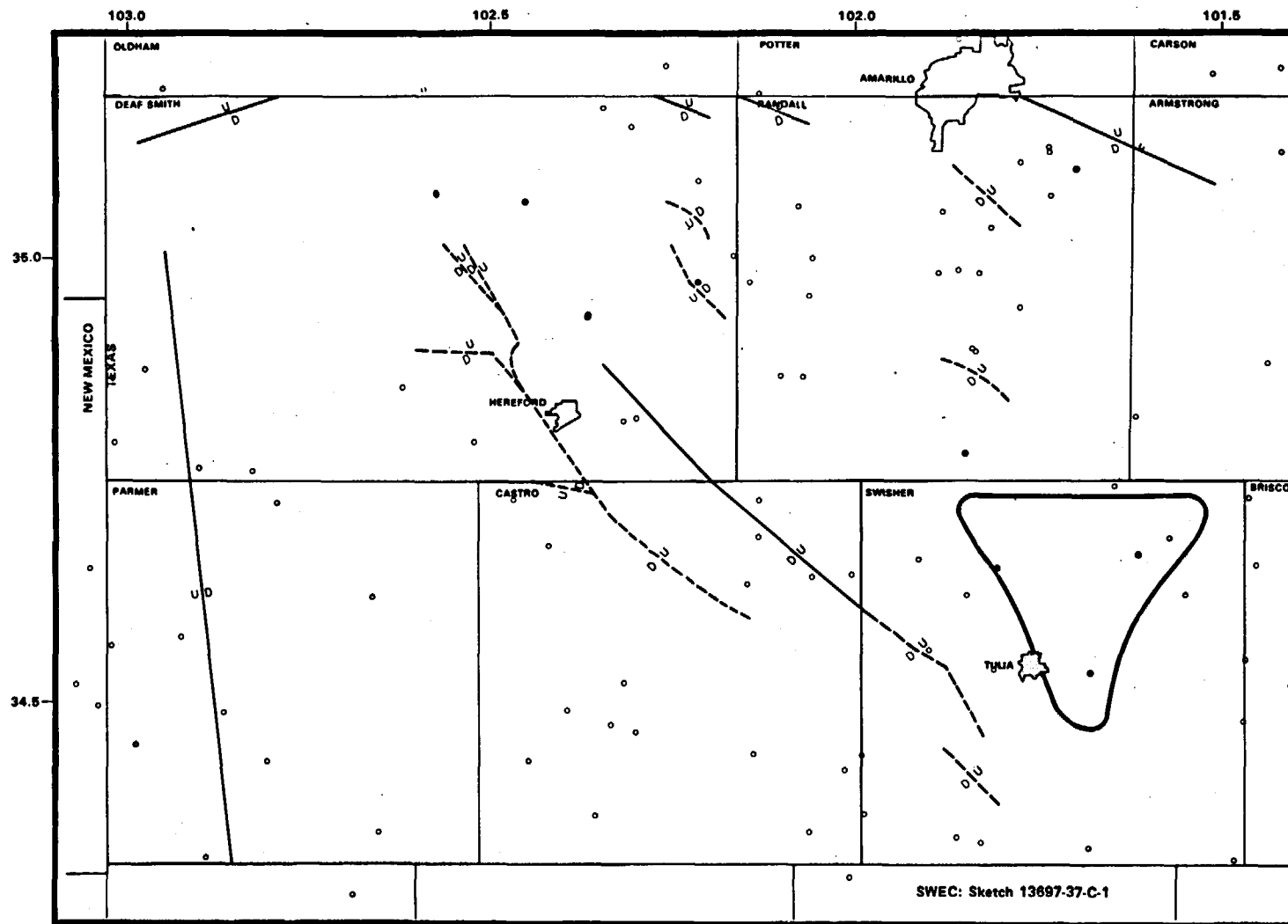
The potential for gassy conditions in the San Andres salt of the Palo Duro Basin is thought to be low. This conclusion is made based primarily on the lack of any record of gas encountered during drilling through the San Andres salt, in the absence of any deep mining in the region. Further support of this conclusion comes from the absence of evidence of deformed salt or surrounding strata which might be gas conduits or traps. The conditions that do exist within the Palo Duro Basin are likely to be uniform over regions as large as the location. For this reason, the descriptor, gassy conditions, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).




3.5 TECTONIC ENVIRONMENT

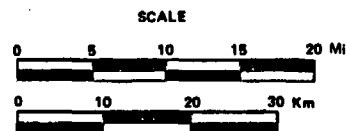
The NWTS criteria require that tectonic elements and anomalous features be identified and assessed to determine their impact on site performance. No tectonic features anomalous to this basin have been identified within or near the location. The nearest and most recent volcanic activity was late Pleistocene and Holocene extrusion of basalt (Stormer, 1972) in Union County, New Mexico (Figure 3-17). This extrusion is regarded as the latest manifestation of a chain of magmatic events that have progressed northeastward across New Mexico. No portion of the location would be subject to volcanic hazard. The current geothermal gradient of the Palo Duro Basin is reported to be 20 C/km (Dutton, 1980, p. 37). Bottomhole temperatures measured in DOE program boreholes have not suggested anomalous conditions; variations which may exist across the location are not expected to be significant. The descriptor, volcanic activity/geothermal gradient, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

Structures in the location and surrounding areas have been mapped by various investigators (Goldstein, 1982; Budnik and Smith, 1982). A fault map has been used for this study that provides an interpretation of the location of faults in the northern Palo Duro Basin. Seismic coverage and well control have permitted the construction of this preliminary map. There are no faults within the location. Recurrent movement of faults in basement and Wolfcampian rocks may





- LEGEND**
-  AREA OF INTEREST
 -  FAULT INFERRED FROM SEISMIC REFLECTION PROFILES
 -  ADDITIONAL FAULTS INFERRED FROM WELL LOG CORRELATIONS
 - U - UPTHROWN
 - D - DOWNTHROWN



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FIGURE 3-18
INFERRED FAULTS IN NORTHERN
PALO DURO BASIN

have affected deposition of younger rocks in some parts of the basin (McGookey and Budnik, 1983); however, facies changes, or thickened or thinned sections, are not well expressed within the location. Site preference is sensitive to deep fault location only if it can be established that the presence of deep faults will significantly affect expected site performance. Under expected conditions (i.e., no direct pathways), radionuclides cannot get to Wolfcampian rocks within the tens of thousands of years desired for isolation; therefore, site preference is not sensitive to the location of faults which offset Wolfcampian or older rocks. The descriptor, faults-Wolfcampian and older, was identified as a nondiscriminator (Steps 1, 2, 3, 4, 5, and 7). If a direct pathway from the host rock to the Wolfcamp were to exist via natural faulting or human-induced breach, it could be postulated that such pathways would allow radionuclide transport to deeper, possibly more transmissive Pennsylvanian carbonates or granite wash units. Consequently, the distance radionuclides travel beneath the repository site during a specific period would presumably be greater in these deep aquifers than in the Wolfcampian aquifer. However, if these hypothetical conditions were to exist, the radionuclide path to likely natural discharge areas from these deep aquifers would be on the order of 124 miles (200 kilometers).

Researchers at TBEG have used stratigraphic mapping techniques, seismic reflection data, Fracture Identification Logs, and evidence from surrounding areas to postulate the presence of faults or zones (trends) where fractures might exist (Budnik, 1983; Gustavson and Budnik, 1983). However, because of the sparsity of data and range of possible interpretations, it was not possible to document the presence or absence of faults or fractures within the Permian section above Wolfcampian rocks. Therefore, it was not considered reasonable to try to make a site preference using existing interpretations of faults above Wolfcampian rocks. The descriptor, faults-younger than Wolfcampian, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

No Quaternary faults of tectonic origin are known to exist within the Palo Duro Basin (SWEC, 1983a, p. 103). The descriptor, Quaternary faults, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7). If nominated for characterization, the presence and impact of faults on site performance will be addressed.

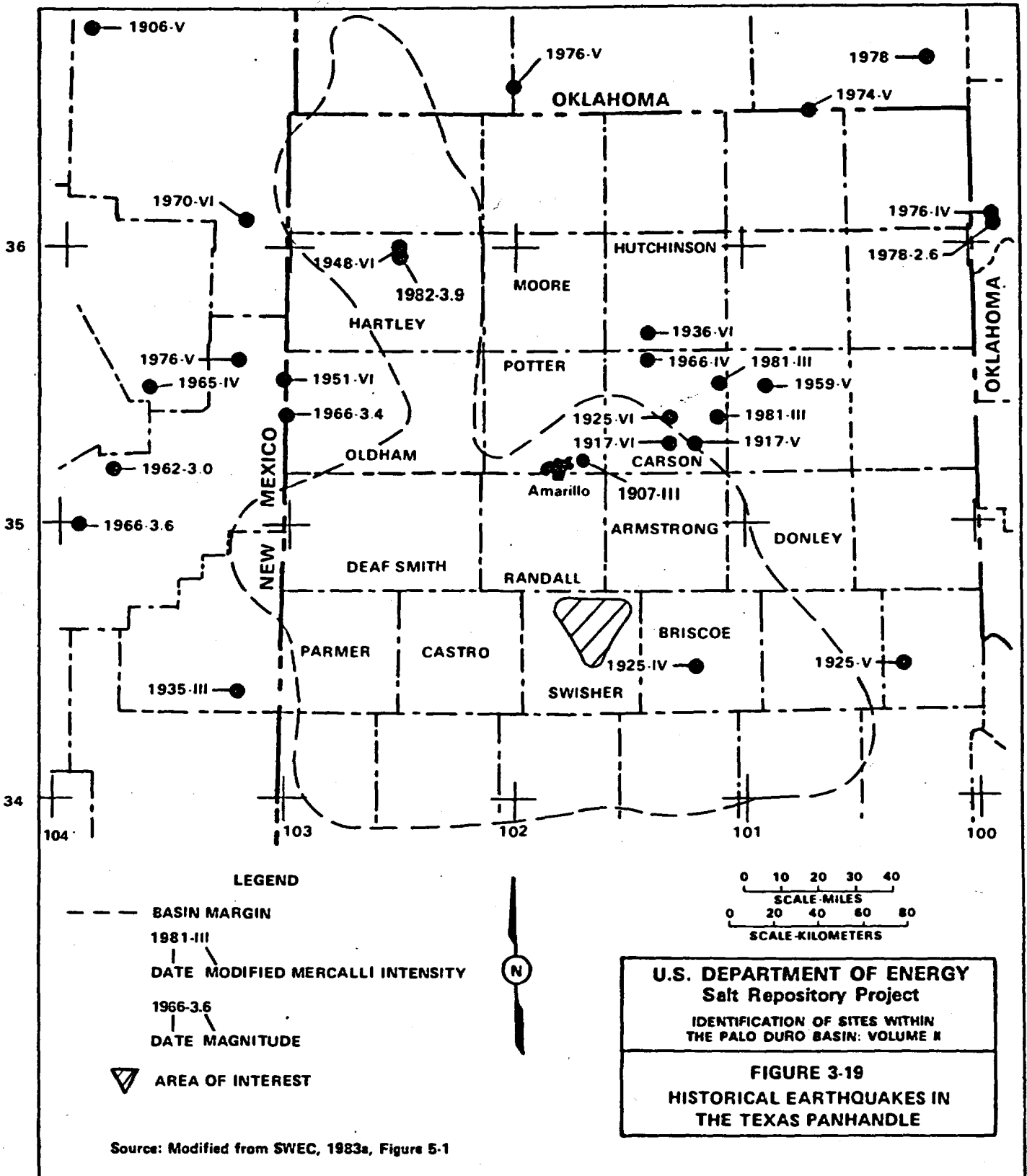
The NWTS criteria require that "long-term, continuing uplift or subsidence rates can be shown to have no unacceptable impact on system performance" (DOE,

1981, p. 9). The most recent significant regional uplift of the area began in late Cretaceous time during the Laramide orogeny and continued into early Tertiary time (SWEC, 1983a, p. 43). The current regional uplift or subsidence of the location has not been specifically studied, but regional investigations indicate it should be uniform across the location. The absence of deformed Ogallala sediments indicates that local Quaternary differential uplift or subsidence has not occurred within the location. No basis exists for site preference in the location because regional tectonic uplift or subsidence is expected to be uniform in nature and there is no evidence of local Quaternary uplift or subsidence. The descriptor, tectonic uplift/subsidence, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

Available data describing earthquake and strong ground motion affecting the location have been collected. Most of the data are derived from intensity reports rather than from instrumental observations. The data are recognizably incomplete for earthquakes with low Modified Mercalli (MM) intensities (SWEC, 1983a). Most of the earthquake activity in the Texas Panhandle appears to be outside the Palo Duro Basin (Figure 3-19). However, in the absence of instrumentation data, it is not possible to determine the exact location of an earthquake epicenter, origin time, or many other parameters useful in characterizing an earthquake. Algermissen and Perkins (1976, Figure 4) have evaluated peak ground acceleration for the area and reported a value of less than 0.04 g for a return period of about 500 years; conservative estimates using more recent data give somewhat larger values, as high as 0.2 g. These levels pose no difficulty for repository design. Notwithstanding the uncertainties in these earthquake and ground motion evaluations, the seismicity hazard is expected to be similar anywhere within the location. The descriptor, seismicity and ground motion, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.6 HUMAN INTRUSION

The NWTs criteria state that a site "be located to reduce the likelihood that past or future human activities would cause unacceptable impacts on system performance" (DOE, 1981, p. 9). The criterion therefore requires a consideration of previous exploration and exploitation activities and the presence of potentially exploitable resources. The NAS, in commenting on proposed

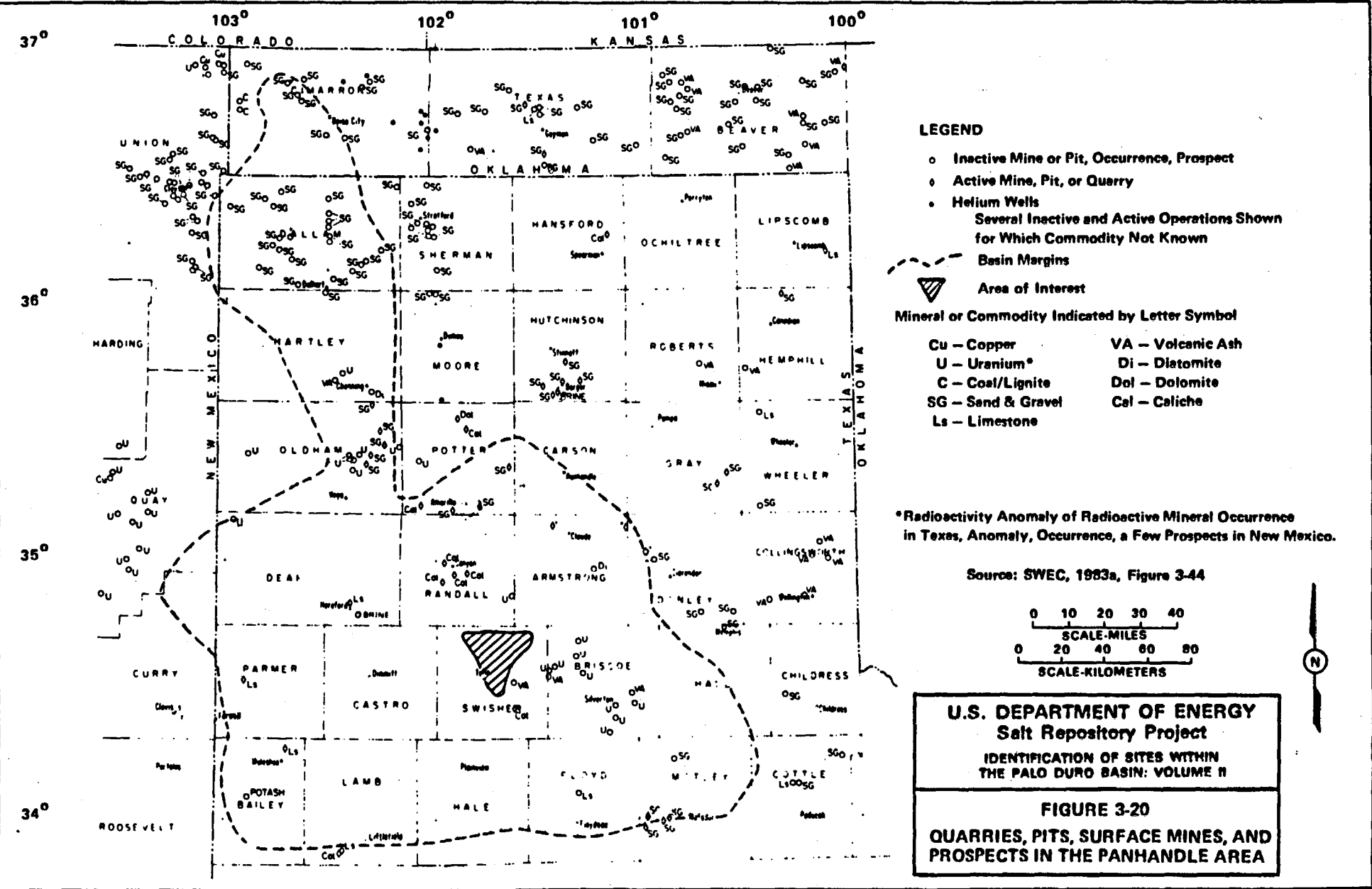


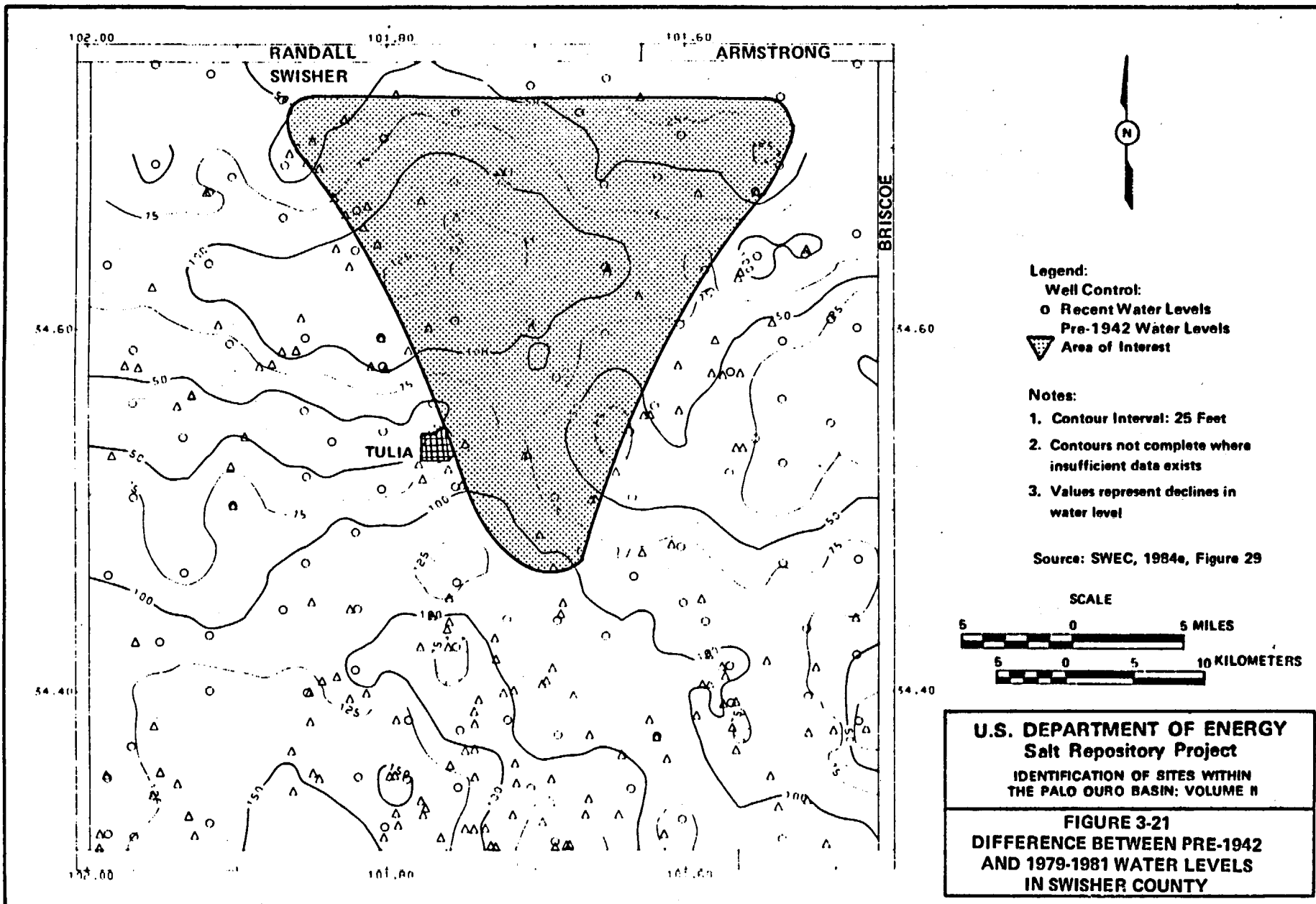
methods for radioactive waste disposal, has concluded: "The nearest to complete natural containment can be expected in a suitable salt deposit, whereby radionuclides could be released to the environment only by human intrusion or through some naturally disruptive event, such as water intrusion" (NAS, 1983, p. 10). In the Palo Duro Basin, the greatest risk of human intrusion is related to exploration or exploitation of hydrocarbon resources beneath a mined repository.

3.6.1 Previous Exploration/Exploitation of Resources

Mineral commodities currently or previously extracted in the Palo Duro Basin include caliche, crushed stone, gravel, sand, clay, and brine (SWEC, 1983a, p. 138). All of these commodities (with the exception of brine) have been extracted from near the surface. The locations of all previous extraction pits are unknown. One well near Hereford has produced brine from the Upper Seven Rivers Formation; it is currently inactive. Current or previous mineral production locations (Figure 3-20) are of the size that they can be avoided during surface facility design. Previous and continuing mineral extraction at these locations is not expected to compromise site performance. For these reasons site preference is not sensitive to their location. The descriptor, current/previous mineral production, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

Water is the commodity of prime value in the location. It has been obtained primarily from the Ogallala Formation. Recent saturated thickness of the Ogallala Formation is illustrated in Figure 3-12. The Ogallala aquifer is not being significantly recharged (Knowles et al, 1982); the extent of utilization of this aquifer is illustrated in Figure 3-21. The Ogallala has been drilled and tested quite uniformly over the location. Water-bearing units of the Dockum Group (the Santa Rosa sandstone) have also been locally developed where the Ogallala is depleted. Previous well drilling and production of water from the Ogallala or other shallow formations are not of concern in terms of site performance because wells do not penetrate the proposed host rock. Therefore; the descriptor, previous production from shallow aquifers, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).



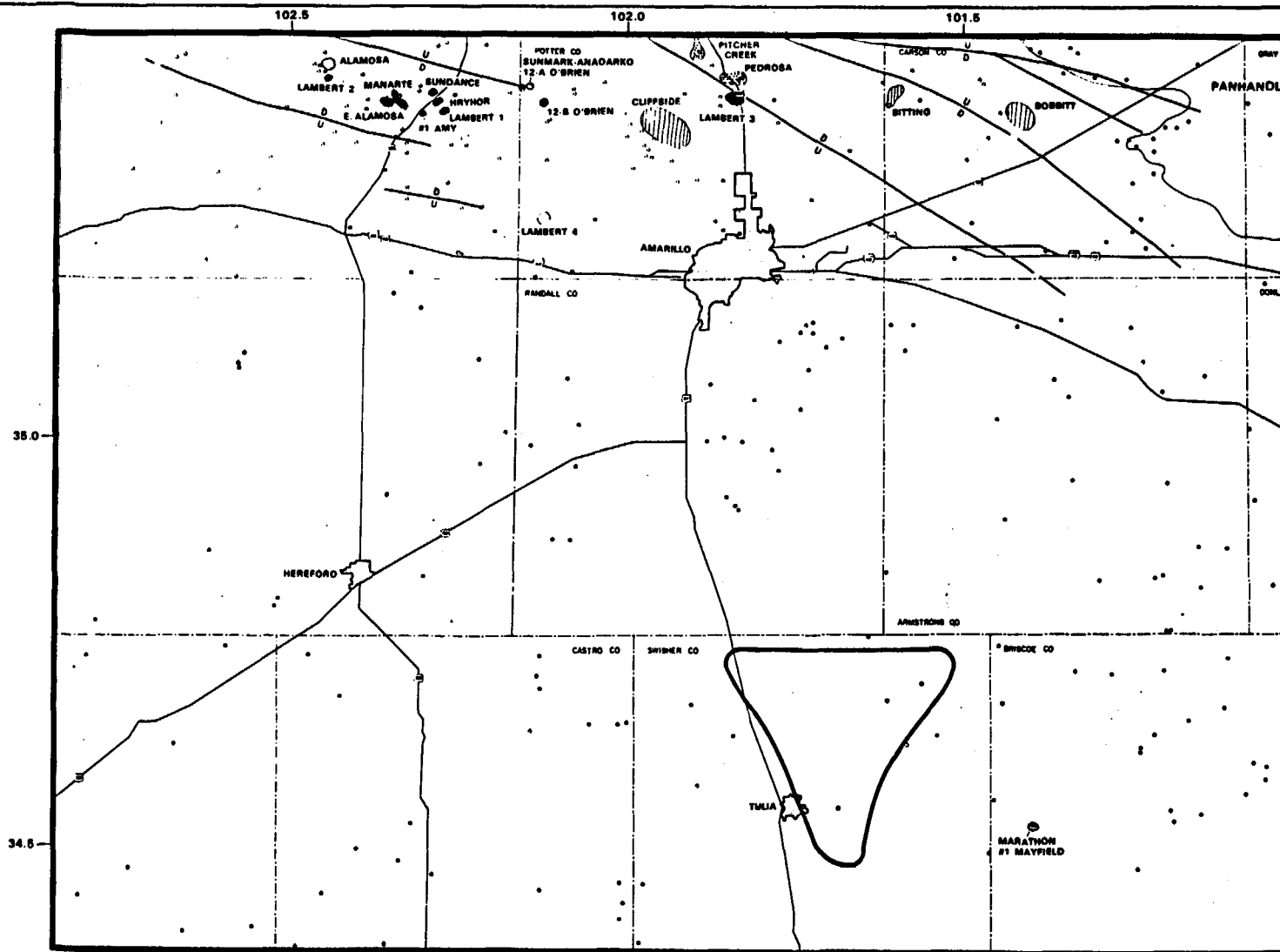


Oil and gas production has occurred primarily at the margins of the Palo Duro Basin (Figure 3-22). Recent production at the Marathon No. 1 Mayfield Well in Briscoe County is an exception. No production has occurred within the location. Hydrocarbon exploration has occurred within the location as evidenced by the deep exploratory test wells in Figure 3-16. While most borehole locations are believed to have been identified, it is possible that unrecorded boreholes exist within the location. Whether existing boreholes provide potential shortcuts in the hydrologic system can be determined only with further evaluation of drilling and plugging histories for specific areas. It is preferable to avoid locating the site in areas containing boreholes that penetrate to target host rock, the lower San Andres unit 4 salt. Therefore, the descriptor, location of boreholes reaching host rock, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.6.2 Presence of Potentially Exploitable Resources

Potential mineral resources such as caliche, sand, and brine are broadly available across the location and are not expected to be uniquely located or of high value (Arnold et al, 1983). Gravel may be a resource if suitable gravel lenses occur in the Ogallala in the near surface. Caliche, sand, and possibly gravel will be extracted from surface pits; their use will not affect site performance. Less common commodities such as copper and uranium have also been suggested as potential resources in the Palo Duro Basin. Uranium resource potential for the region is considered speculative (Hetland, 1979). No occurrences of uranium (Figure 3-23) or copper have been found in the location, and significant discoveries of these minerals are unlikely. For economic reasons, exploration to prove mineral occurrence or reserves will likely be limited to drilling or testing of strata that are shallower than the proposed repository horizon. Because mineral exploration will not impact site performance, the descriptor, presence of potential mineral resources, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

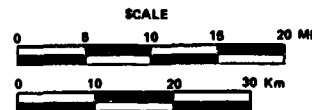
Ground water resources will be explored for and utilized over the entire location. Both the Ogallala Formation and Dockum Group (Santa Rosa) will be tested and utilized. Because these aquifers are well above the expected repository horizon, their exploration and utilization are not a concern from a



- △ AREA OF INTEREST
- PANHANDLE OIL FIELD
- FAULTS
- U- UPTHROWN
- D- DOWNTHROWN

LEGEND

- RESERVOIR UNIT AND LITHOLOGY
- PENNSYLVANIAN GRANITE WASH
 - ▨ RED CAVE SANDSTONE
 - WOLFCAMPIAN CARBONATE
 - PENNSYLVANIAN CARBONATE

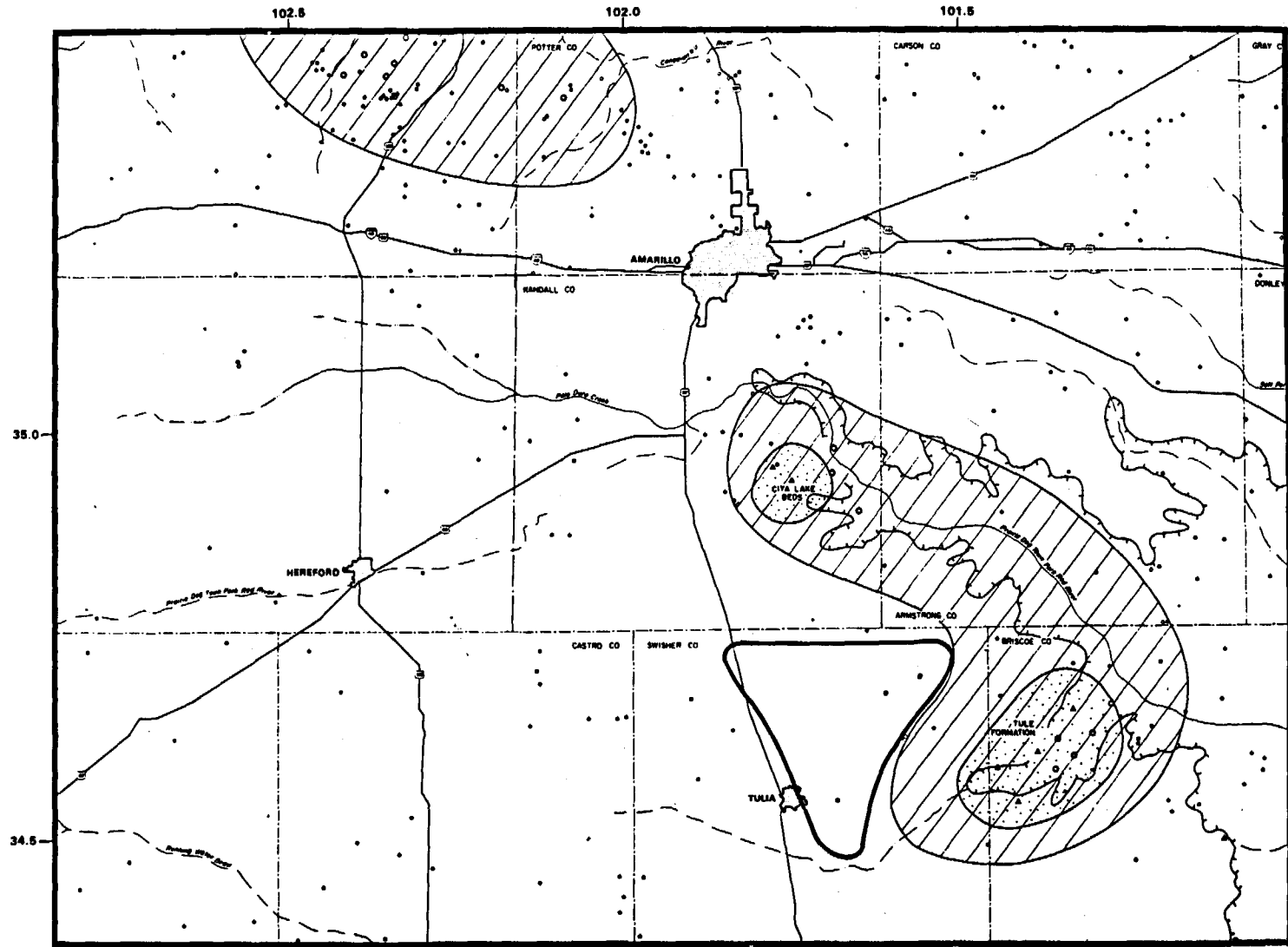


NOTE:
MODIFIED FROM TEXAS BUREAU OF ECONOMIC
GEOLOGY DRAFT MAP QA-711-1

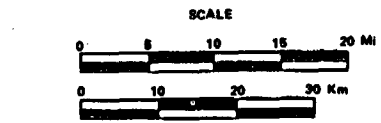


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FIGURE 3-22
OIL AND GAS FIELDS IN
PALO DURO BASIN



- LEGEND**
- EARLY PLEISTOCENE LACUSTRINE SYSTEMS
 - FAVORABLE AREAS FOR URANIUM DEPOSITS
 - AREA OF INTEREST
 - ASH
 - URANIUM OCCURRENCE
 - HIGH PLAINS ESCARPMENT



NOTE:
 MODIFIED FROM TEXAS BUREAU OF ECONOMIC GEOLOGY DRAFT MAP QA-891

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FIGURE 3-23
LOCATION OF URANIUM OCCURRENCES

human intrusion standpoint. The effect of the use of these aquifers on the overall hydrologic system is discussed in Section 3.2.2. The importance of these aquifers from a constructibility and resource conflict standpoint is discussed in Section 3.2.3 and 3.9.2, respectively. The only other potentially productive water-bearing rocks of the location are in the Lower Permian and Pennsylvanian carbonates and granite wash units (Section 3.2). These units are too deep and contain too high a total dissolved solids content (Bassett and Bentley, 1982) to consider them likely exploitable water resources.

In summary, the potential for human intrusion with the resulting compromise of site performance due to exploration or utilization of ground water resources is considered minimal. Therefore, the descriptor, exploration/utilization of ground water, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

Human intrusion into a mined repository in the Palo Duro Basin is most likely to occur either as a result of random drilling or during deep exploration for or extraction of hydrocarbons that may lie beneath the site. Random drilling means drilling that is haphazard and lacks any relationship to expected subsurface resource locations. No rationale can be developed to show that any portion of the location is more subject to random drilling than another. In contrast, TBEG (Dutton et al, 1982) has produced maps based on interpretations of geophysical logs, examination of well cuttings and core, and knowledge of hydrocarbon production from surrounding areas, which can be used to delineate areas or trends that may represent the most likely targets of future purposeful hydrocarbon exploration.

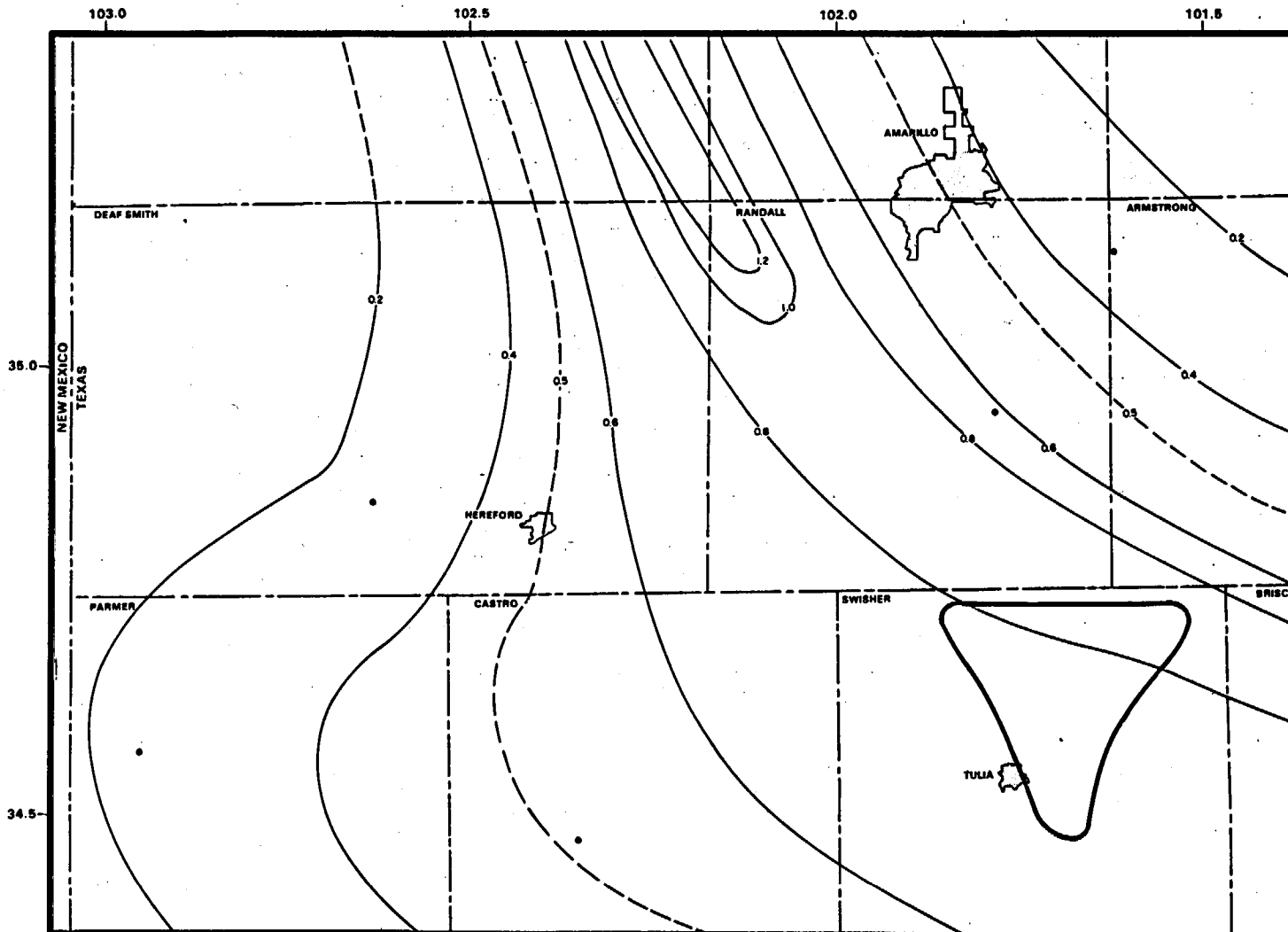
Dutton et al (1982, p. 73) believe the Palo Duro Basin exhibits "... all the necessary elements for the generation and entrapment of oil-source rocks, appropriate thermal history, reservoirs, and traps". Of these elements, lack of appropriate thermal history, timing of hydrocarbon migration, or suitable seal (trapping rocks) is probably the reason significant oil and gas resources have not developed in the location. These are also elements for which the fewest analyses have been completed. As a result, hydrocarbon assessments of the location are not yet complete. Thermal-maturity indicators show that source beds reached the threshold of the oil-generation window (Dutton et al, 1982) in some parts of the basin. Detailed mapping has not been accomplished to provide maps that indicate a preference from this standpoint for any portion of

the location. Likewise, suitable seals (trapping rocks) undoubtedly exist in parts of the basin, as indicated by production from the Marathon No. 1 Mayfield well in Briscoe County. Detailed mapping is not available to document where suitable seals (trapping rocks) are most likely to exist within the location. This factor alone may be the most important in identifying the areas with the greatest potential for hydrocarbons.

Information is available to indicate where organic-rich source rocks and porous reservoir rocks exist. Significant quantities of hydrocarbon could have been generated in the Palo Duro Basin only if adequate amounts of organic matter were present in source rocks. The boundary between what is considered a fair and a poor clastic source rock is usually defined at 0.5 percent total organic carbon (TOC) content (Tissot and Welte, 1978); good clastic source rocks generally contain more than 1.0 percent TOC. Pennsylvanian and Wolfcampian basinal shales contain up to 2.4 percent TOC (Figures 3-24 and 3-25) and range from poor to very good source rocks in the Palo Duro Basin. Fair source rock potential exists in both the Pennsylvanian and Wolfcampian rocks across the location. The primary potential porous reservoir rocks in the location are the Pennsylvanian and Lower Permian (Wolfcampian) granite wash and shelf margin carbonates (Figures 3-26, 3-27, 3-28, and 3-29). Thick granite wash sediments exist in the southeastern portion of the location. The northeastern and northwestern portions of the location lie within trends of thick shelf margin carbonates.

The juxtaposition of thick porous reservoir rocks with fair source rocks (>0.5 percent TOC) has been used to suggest areas (fairways) with relatively high potential for hydrocarbons (Dutton et al, 1982, Figures 52 and 53). For purposes of this narrowing, the areas identified by Dutton et al (1982) are considered to represent the areas in which a greater risk for deep exploration and human intrusion exists. The descriptor, hydrocarbon resource potential, was identified as a discriminator (Steps 1, 2, 3, 4, 5, and 6).





The Texas Panhandle area produces much of this nation's helium. Most production and reserves of helium are in association with oil and gas fields along the Amarillo uplift (SWEC, 1983a, p. 135). Exploration for and reserves of helium are not expected to occur within the Palo Duro Basin.

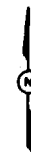
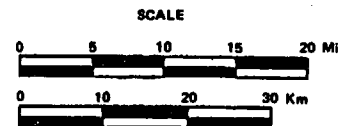


NOTES:
 CONTOUR INTERVAL = 0.2% T.O.C.

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 GEOLOGY DRAFT MAP QA-881

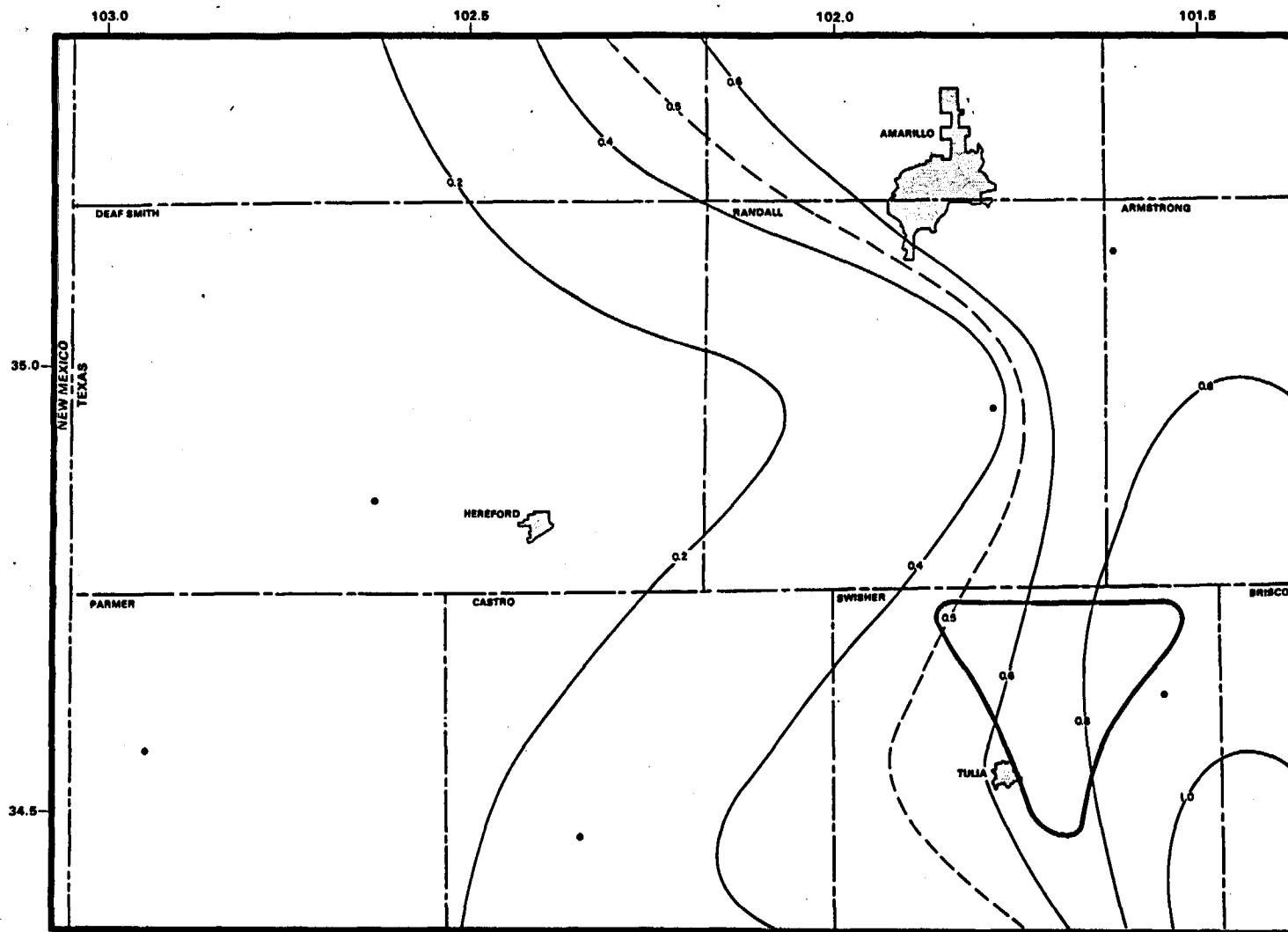
LEGEND

-  AREA OF INTEREST
-  CONTOUR LINES
-  SELECTED INTERMEDIATE CONTOURS
-  WELL CONTROL SHOWN BY SOLID CIRCLES



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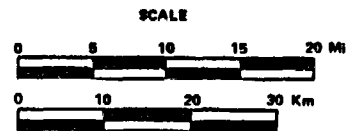
FIGURE 3-24
 PERCENT TOTAL ORGANIC CARBON
 OF PENNSYLVANIAN ROCKS



NOTES:
 CONTOUR INTERVAL - 0.2% T.O.C.

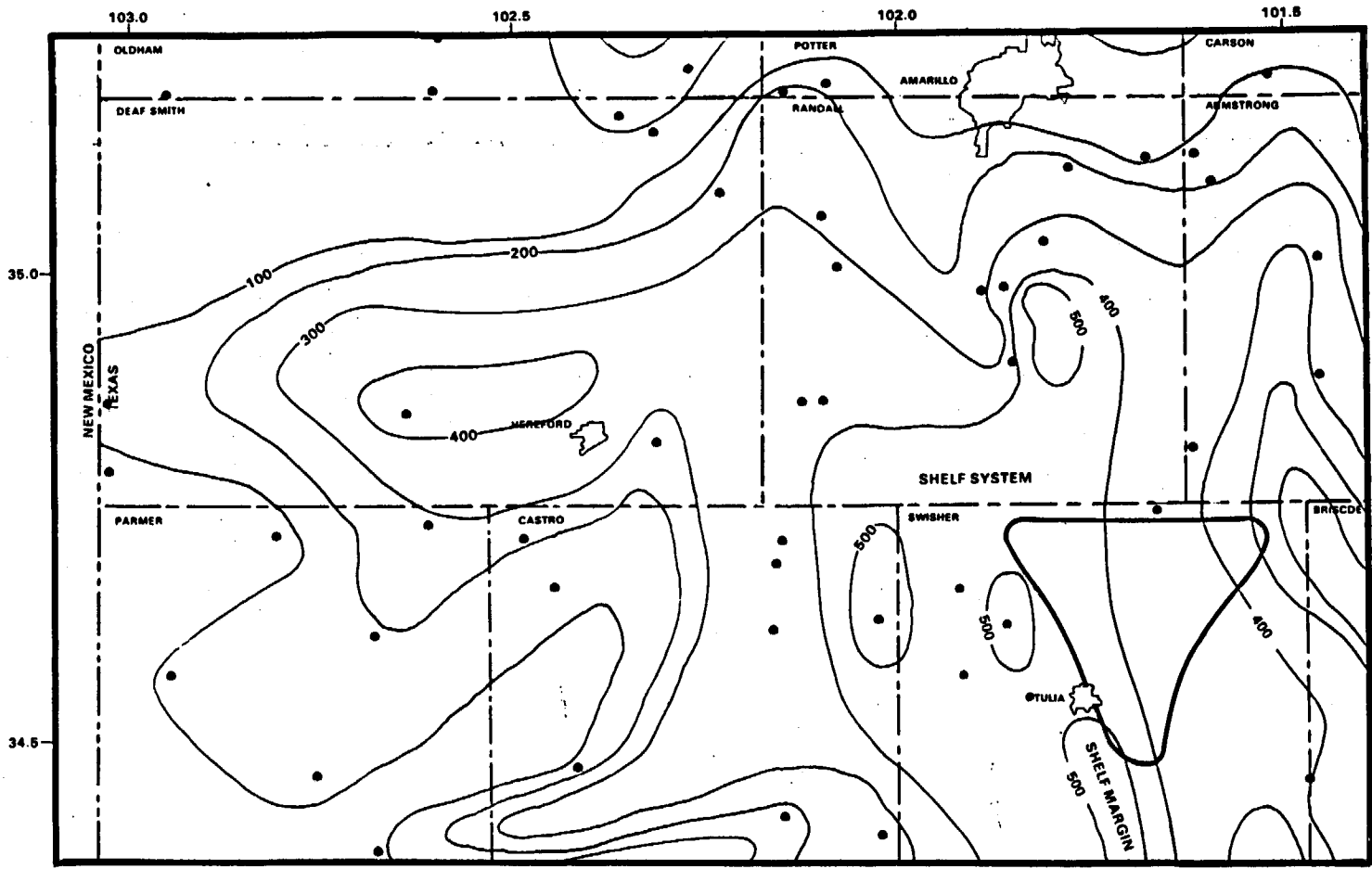
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 GEOLOGY DRAFT MAP QA-882

LEGEND
 ▽ AREA OF INTEREST
 ● WELL CONTROL SHOWN BY SOLID CIRCLES



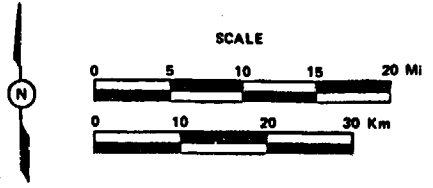
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FIGURE 3-25
 PERCENT TOTAL ORGANIC CARBON
 OF WOLFCAMPIAN ROCKS



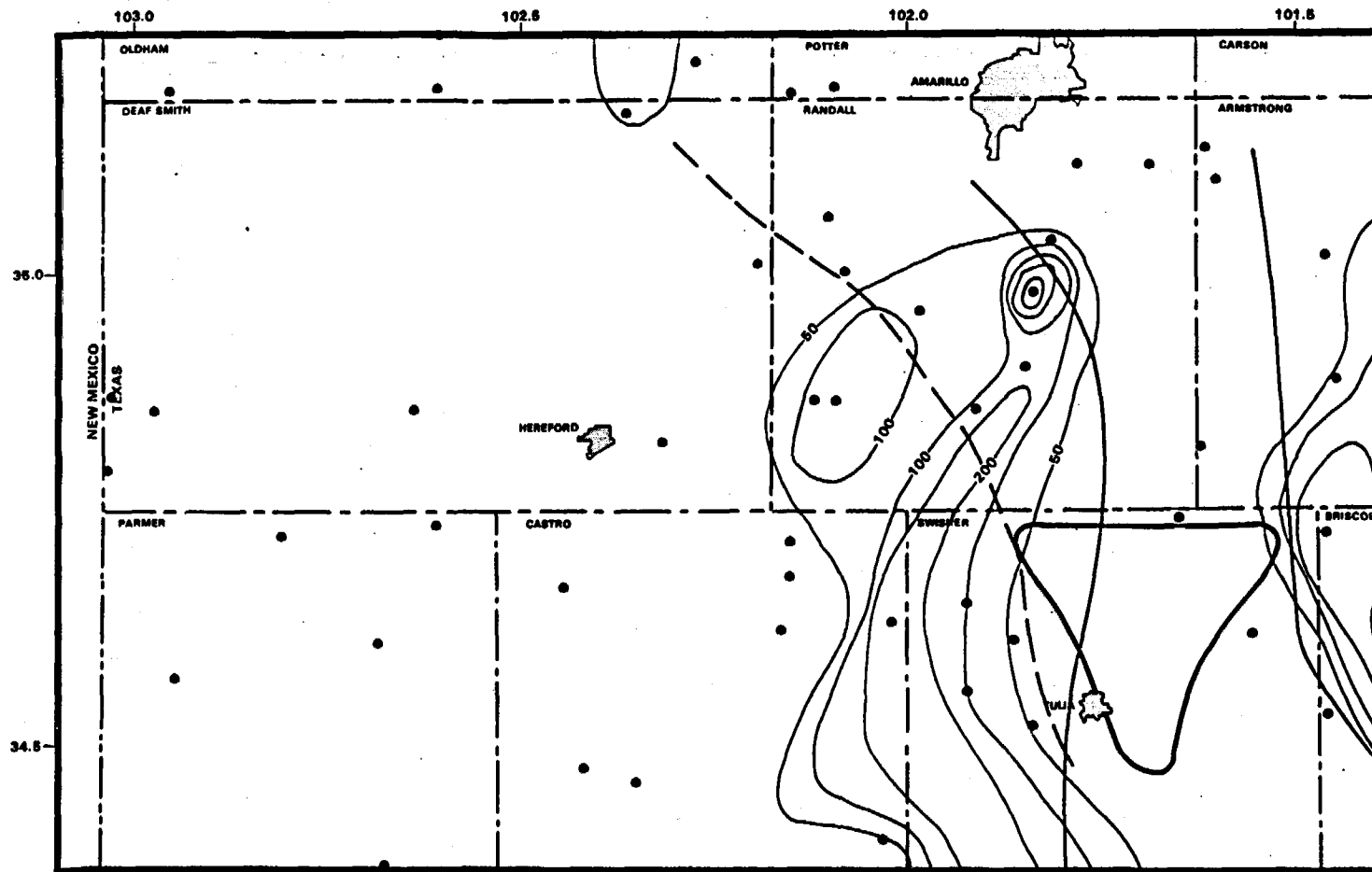
NOTES:
 CONTOUR INTERVAL - 100 FT
 DERIVED FROM DUTTON ET AL,
 1982, FIGURE 26

- LEGEND
- PRECAMBRIAN BASEMENT
PENNSYLVANIAN SYSTEM ABSENT
 - WELL CONTROL SHOWN BY SOLID CIRCLES
 - AREA OF INTEREST



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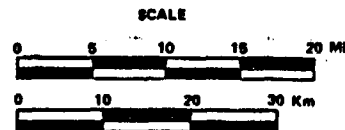
FIGURE 3-28
 NET-CARBONATE MAP OF LOWER PART
 OF PENNSYLVANIAN SYSTEM



NOTES:
 CONTOUR INTERVAL VARIABLE
 POROUS CARBONATE DEFINED AS DOLOMITE
 POROSITY AVERAGING 8 TO 10 PERCENT AS
 INTERPRETED FROM GEOPHYSICAL LOGS
 UPPER PART OF PENNSYLVANIAN SYSTEM
 GENERALLY THE CANYON AND CISCO GROUPS
 DERIVED FROM DUTTON ET AL,
 1982, FIGURE 30

LEGEND

- PENNSYLVANIAN SHELF MARGIN
- - - RETREAT POSITION OF PENNSYLVANIAN SHELF MARGIN
- WELL CONTROL SHOWN BY SOLID CIRCLES
- ▽ AREA OF INTEREST



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FIGURE 3-27
 ISOPACH MAP OF POROUS CARBONATE
 STRATA IN UPPER PART OF THE
 PENNSYLVANIAN SYSTEM







NOTES:

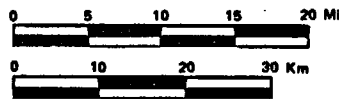
POROUS CARBONATE DEFINED AS DOLOMITE POROSITY GREATER THAN 10 PERCENT AS INTERPRETED FROM GEOPHYSICAL LOGS

MODIFIED FROM TEXAS BUREAU OF GEOLOGY DRAFT MAP QA-875

LEGEND

-  > 200 FEET POROUS CARBONATE
-  OIL STAIN OR SHOW
-  OTHER WELLS SHOWN BY OPEN CIRCLES
-  AREA OF INTEREST

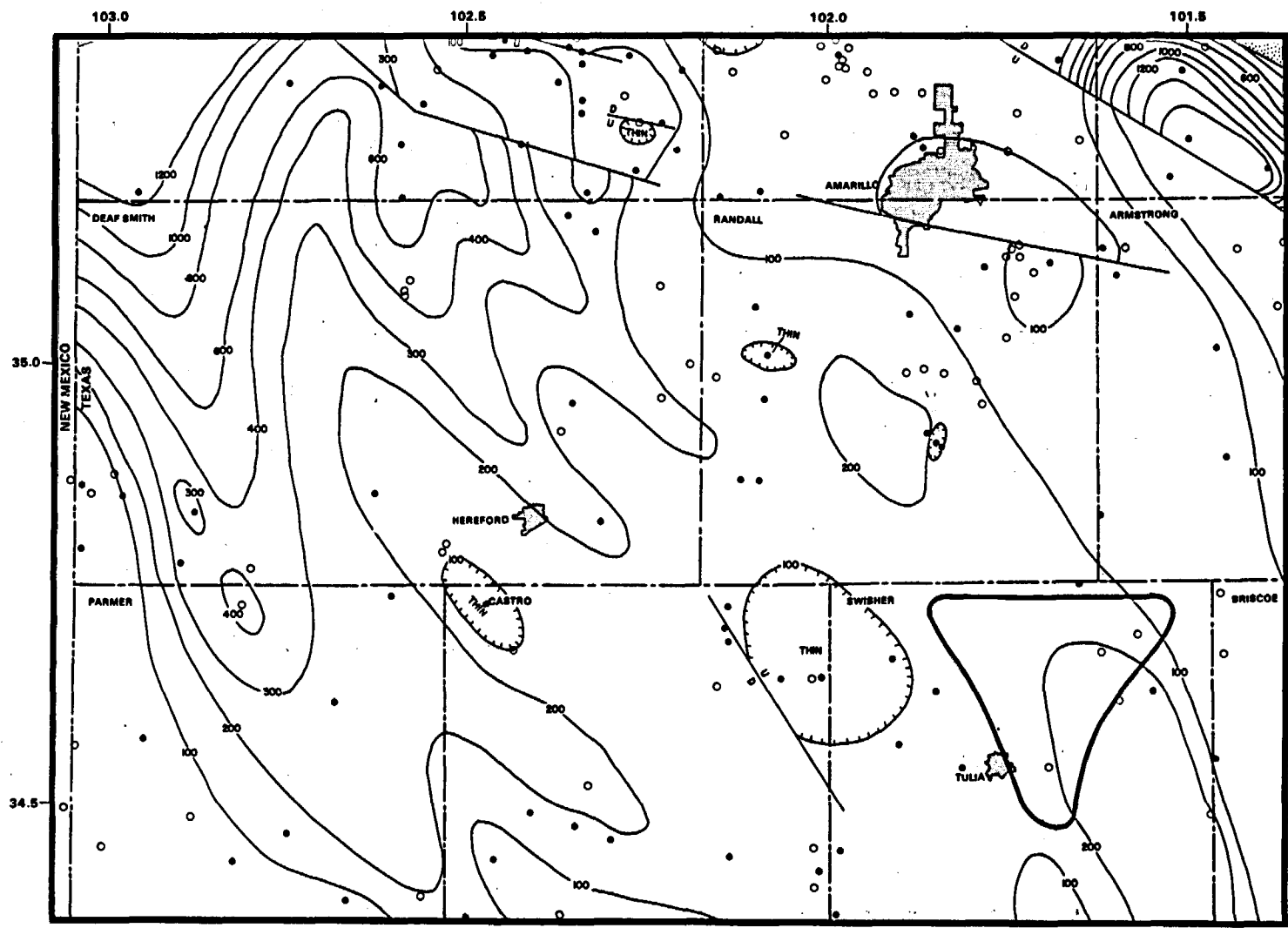
SCALE



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**FIGURE 3-28
POROUS WOLFCAMP CARBONATE**



NOTES:

CONTOUR INTERVALS ARE VARIABLE

0-400 ft at 100 ft Intervals
 400-1200 ft at 200 ft Intervals
 >1200-ft at 400 ft Intervals

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 GEOLOGY DRAFT MAP
 GA-889-1

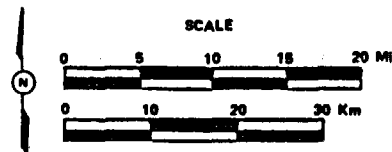
LEGEND

WELL CONTROL SHOWN BY SOLID CIRCLES
 OTHER WELLS SHOWN BY OPEN CIRCLES

U - FAULT
 D - UPTHROWN
 D - DOWNTHROWN

PRECAMBRIAN BASEMENT EXPOSED DURING THE PENNSYLVANIAN

AREA OF INTEREST



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FIGURE 3-29
ISOPACH MAP OF TOTAL
GRANITE WASH

3.6.3 Land Ownership and Control

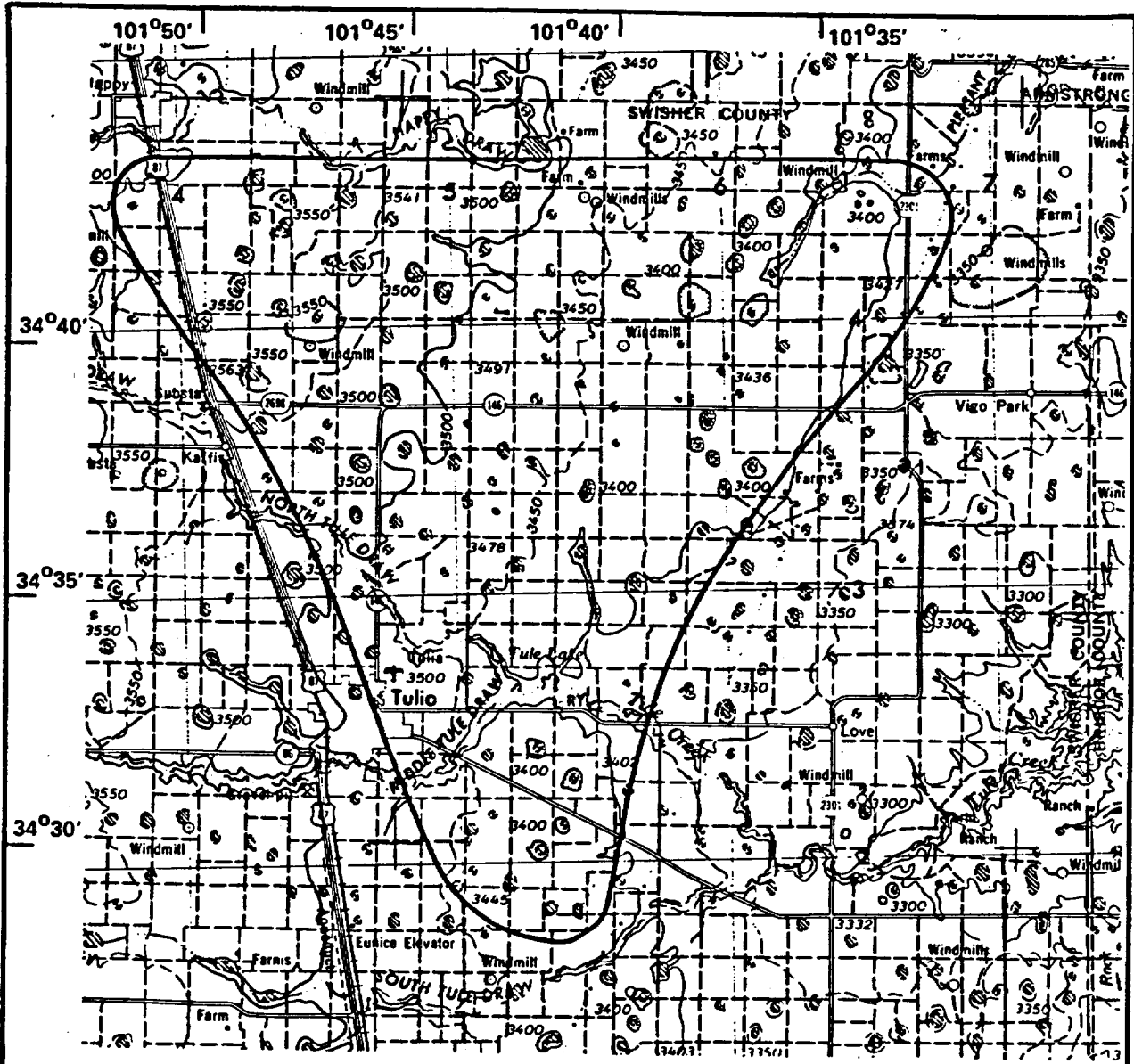
A primary concern expressed in the NWTS Human Intrusion criterion and 10 CFR 60.121 (NRC, 1983) is the ability of the Federal Government to control potential activities proximate to and within the repository controlled area. Information on surface and subsurface ownership and on oil and gas leasing is variously available. Ownership or rights to surface and subsurface water are also included in the mandated ownership controls (NRC, 1983, 10 CFR Part 60.121; NWPA, Section 124). The nature of these data is historical fact, but changes in ownership and leasehold status cannot be anticipated or predicted. Use of present ownership or lease status to predict potential ease of acquisition of land or water for future repository development is not appropriate. While the number of owners or leaseholds can be determined at a specific point in time, the applicability or sensitivity of site location to this information cannot be determined for a future time when actual acquisition activities may begin. As a result, the descriptor, land ownership complexity, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7) even though present-day variation exists across the location.

3.7 SURFACE CHARACTERISTICS

The descriptors considered under this criterion were identified and described in Section 1.3.7. The possible use of each of these descriptors as a discriminator is evaluated in this section based on the available data and information for the location. The primary intent of the surface characteristics criterion is to avoid unacceptable impacts on repository operation and system performance. However, runoff and drainage from the proposed facility will be managed to mitigate impact on the surficial hydrologic system.

3.7.1 Proximate Streams and Floodplains

Streams that flow through the location are illustrated by Figure 3-30. These streams are North Tule Draw, Middle Tule Draw, Tule Creek, and Happy Draw. These are ephemeral creeks, each of whose drainage area is limited to its creek valley. When adjacent land without topographic relief is available, it is



LEGEND

▽ AREA OF INTEREST

Contour Interval is 100 Feet
with Supplementary Contours
at 50 Foot Intervals

Base Map from U.S.G.S. 1:250,000 Topographic
Sheet Plainview, Texas, 1954 (Revised 1974)



0 1 2 5 Miles



0 2 4 6 8 Kilometers



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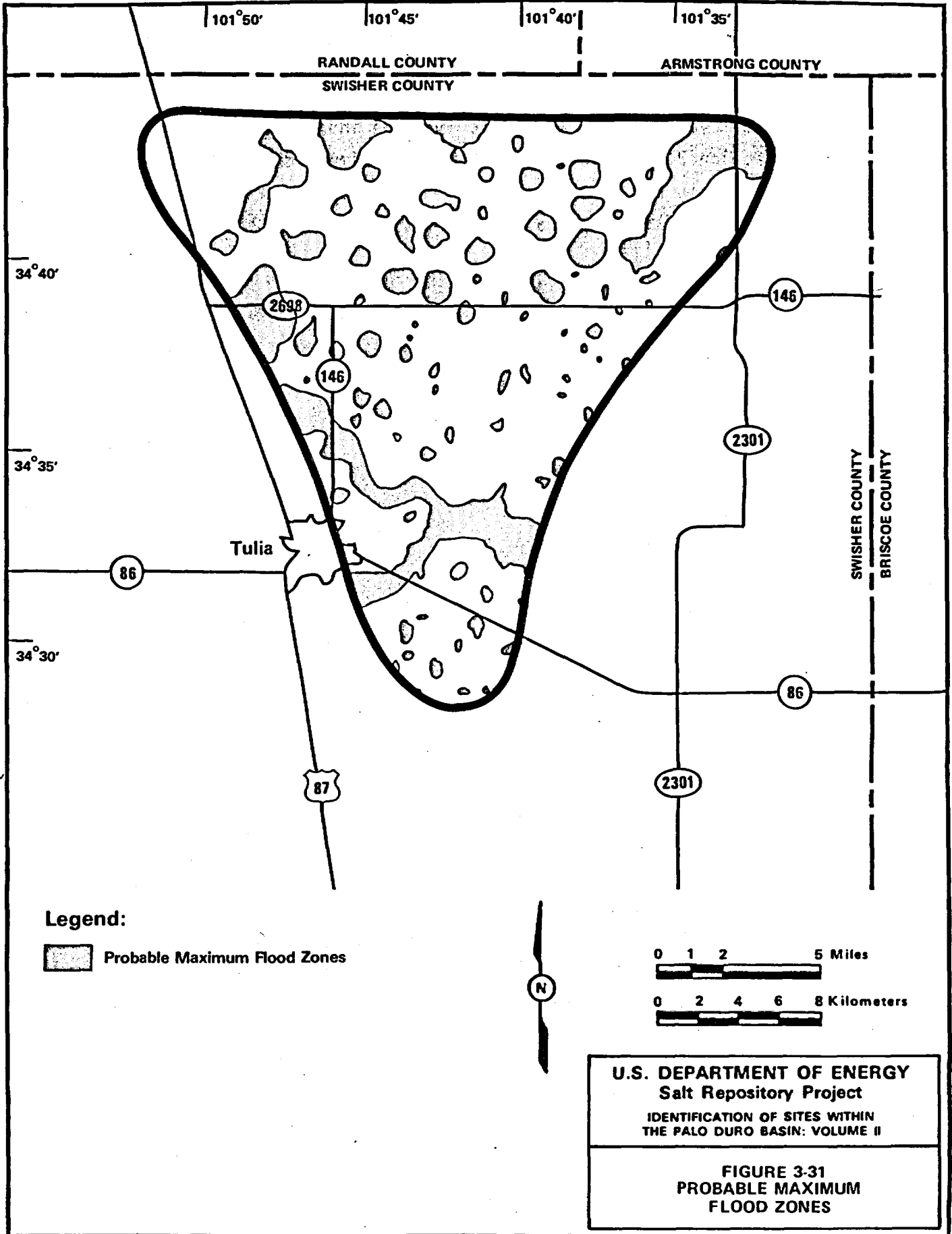
FIGURE 3-30
SURFACE TOPOGRAPHY

preferred over streams and their floodplains for ease of construction and to avoid the need for flood-protection measures. Figure 3-31 illustrates the probable maximum flood (PMF)-inundated areas for this location. These areas were determined (NUS, 1984b) using the HEC-2 Water Surface Profiles computer code developed by the U.S. Department of Defense (DOD) Army Corps of Engineers (DOD, 1981). The PMF comprises flood discharges resulting from the all-season probable maximum precipitation (PMP). These discharges were estimated conservatively assuming 100 percent impervious soils. The PMP for the location was determined from generalized estimates of PMP for areas east of the 105° meridian (passing approximately through the center of New Mexico). The 6-hour, 10-square-mile (26-square-kilometer) index PMP is estimated to be 27-inches (69 centimeters). The PMP for 48 hours, as determined from depth-area-duration curves (Schreiner and Riedel, 1978) is 126 percent of the 6-hour index PMP for a drainage area of 10 square miles (26 square kilometers), or 34 inches (86-centimeters). This projected 48-hour rainfall was used to calculate the PMF.

The PMP is over four times the precipitation expected with a return period of 100 years (NUS, 1984b). This projected 48-hour PMP is also 97 percent higher than the annual mean precipitation (17.24 inches [43.79 centimeters]) experienced at Tulia from 1949 to 1967 (NUS, 1984b). Thus, this approach results in an estimate of floodplain area that is conservatively large. The descriptor, proximate streams and floodplains, illustrated by Figure 3-31, was identified as a discriminator (Steps 1, 2, 3, 4, 5, and 6).

3.7.2 Proximate Water Bodies

The only significant natural water bodies are playa lakes that commonly fill with runoff following extensive precipitation. Figure 3-31 also illustrates playas that would fill as a result of the PMF. These playas would each contain some water if they were included in the 10-square-mile (16-square-kilometer), 48-hour PMP described in Section 3.7.1. Land not containing playas is preferred for ease of construction and to avoid the need for flood-protection measures. The descriptor, proximate water bodies, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).



3.7.3 Proximate Impoundments

Table 3-1 (NUS, 1984b) lists impoundments within the location. These impoundments are located in the area that would be inundated by the PMF as described in Section 3.7.1. Tule Lake is the only impoundment sufficiently large to consider in siting a repository. The descriptor, proximate impoundments, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.7.4 Proximate Embayments

There are no embayments within the study area. Thus, the descriptor, proximate embayments, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.7.5 Surface Topography

The location is in the Upper Red River Basin on the Southern High Plains. The Southern High Plains is essentially a plateau, bounded on the north by the deep valley of the Canadian River and on the east and west by prominent escarpments. It is characterized by a nearly flat surface that slopes generally southeastward at an average rate of 8 to 10 feet/mile (1.5 to 1.9 meters/kilometer) (NUS, 1984b). The principal features are small stream valleys and numerous playas. The topographic contours illustrated on Figure 3-30 for this specific location are typical of the Southern High Plains. Note that streams, floodplains, and playas were considered in Sections 3.7.1 and 3.7.2. The terrain is generally so flat in this location that specific consideration of topographic features is not necessary. The descriptor, surface topography, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

3.7.6 Anticipated Climatic Change

Meteorological phenomena must be accommodated by appropriate engineering measures and must not unacceptably affect repository operation. Repository operation will occur over less than 100 years so that gradual climatic changes brought about by phenomena such as the "greenhouse" effect or the next glacial age will not impact this operation.

Table 3-1. Impoundments Located Within the Swisher County Location Boundaries

Dam	River	Location	Normal Impoundment, acre-feet ^a	Surface Area, acres ^b	Owner
Bill Bivins	Middle Tule Draw	Swisher County Lat. 34°31.3' Long. 101°44.2'	144	21	Bill Bivins
Ray Bivins	North Tule Draw	Swisher County Lat. 34°33.9' Long. 101°43.7'	197	20	Ray Bivins
Tule Lake	North Tule Draw	Swisher County Lat. 34°33.9' Long. 101°42.5'	692	54	City of Tulia
Singleton Lake	Happy Draw	Swisher County Lat. 34°42.7' Long. 101°46.7''	64	10	Sam F. Grigsby

Source: Texas Natural Resources Information Service (1982).

a. To convert acre-feet to cubic meters, use conversion factor 1,233.5.

b. To convert acres to hectares, use conversion factor 0.40469.

During the four major continental glaciations of the Quaternary Period, the ice sheets terminated hundreds of miles to the north of the location. Because of its elevation and southerly latitude, the location will remain free of glaciation if Quaternary climate cycles continue. During prior continental glacial stages, the location received greater rainfall and developed heavier vegetation cover, which stabilized the soil. During the interglacial stages, the local climate was hot and arid. Neither of these climatic extremes are expected to significantly affect a deep geologic repository in this location or vary significantly across the location. The descriptor, anticipated climatic change, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.7.7 Extreme Meteorological Phenomena

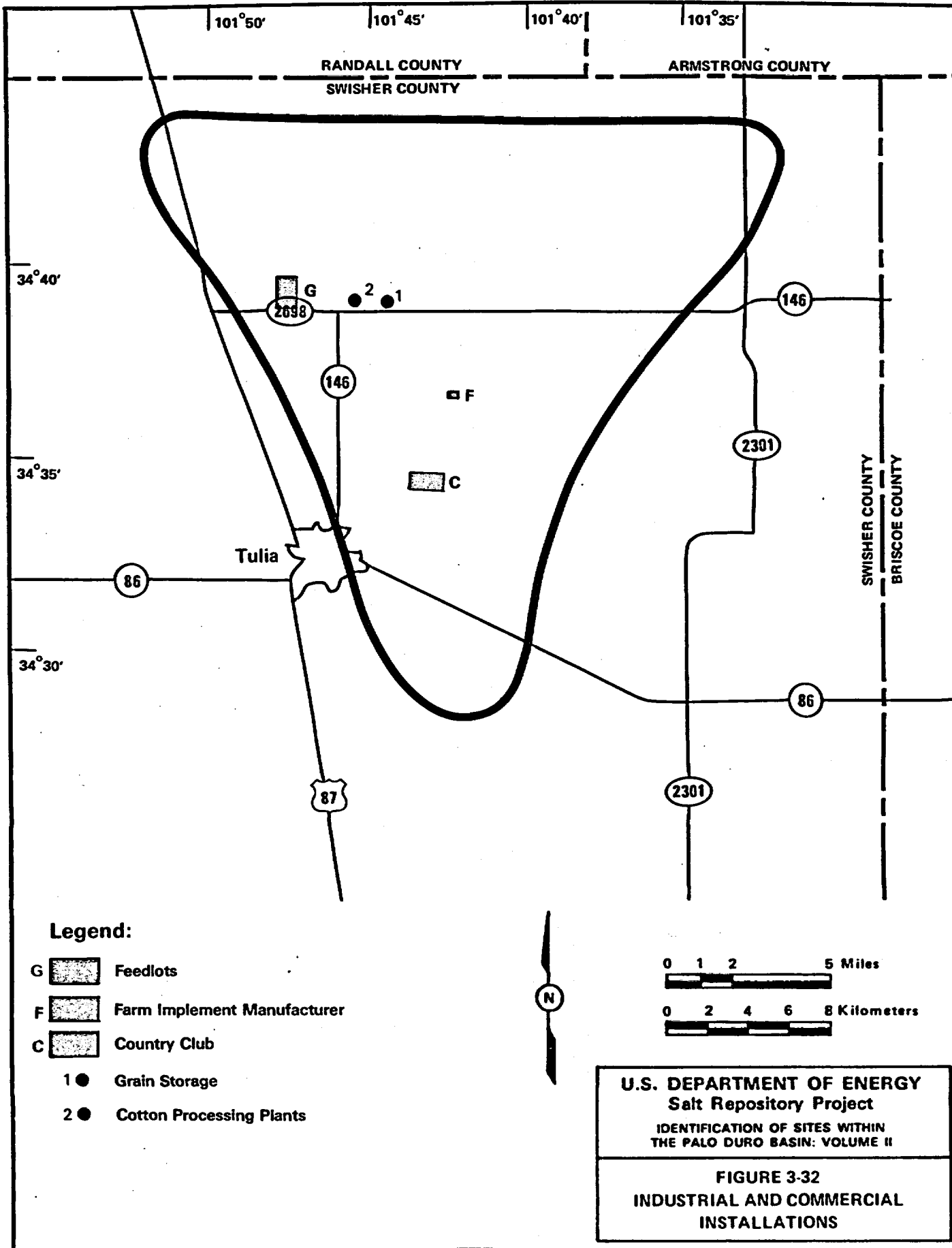
The surface facility design must accommodate natural phenomena such as heavy precipitation or tornadoes. The PMP event was described in Section 3.7.1. The major impact of this event is potential flooding. Roof structures must be designed to accommodate maximum snow accumulations. Buildings must accommodate persistent high winds and tornadoes. Existing meteorological data are regional in nature with negligible variation expected across an area the size of this location. The descriptor, extreme meteorological phenomena, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.7.8 Proximate Military Installations

There are no military installations in this location or nearby. The descriptor, proximate military installations, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.7.9 Proximate Industrial and Commercial Installations

The major existing industrial/commercial installations in the location are illustrated on Figure 3-32. These are primarily feedlots, cotton processing facilities, and grain storage facilities. If located outside of the controlled area, none of these operations is incompatible with repository operations because they could continue operation on adjacent land without impacting or being



impacted by the repository. The descriptor, proximate industrial and commercial installations, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

3.7.10 Proximate Transportation Installations

The major highways, gas pipelines, aqueducts and electricity transmission facilities are shown on Figure 3-33. Serious highway accidents involving commercial carriers of petroleum products, fertilizers, pesticides, or other chemical products could impact repository operations because of fires, explosions, or release of toxic materials. Gas pipelines and electricity transmission facilities are similarly considered. The descriptor, proximate transportation installations, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

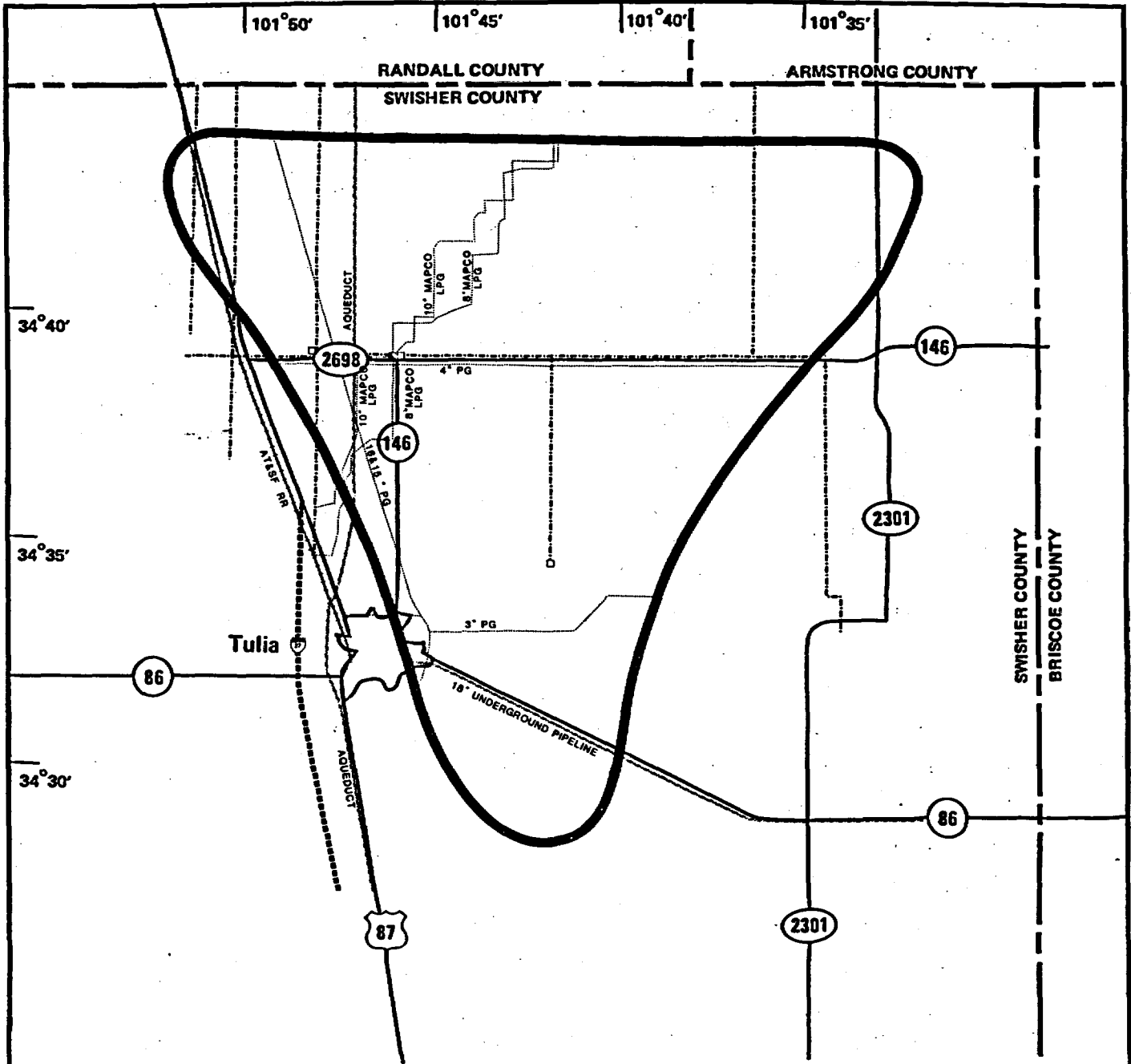
3.8 DEMOGRAPHY

Section 112(a) of NWPA stipulates that, "Such [siting] guidelines shall specify population factors that will disqualify any site from development as a repository if any surface facility of such repository would be located (1) in a highly populated area; or (2) adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals."

In addition, the NWTS Demography criterion requires that the site be located to minimize the potential risk to and potential conflict with the population. The criterion is subdivided into two parts: (1) requiring a low population density, and (2) minimizing population risk.

The location contains one highly populated area, the city of Tulia, on and adjacent to its southwestern boundary. "Highly populated area" is used in this document in the context of the U.S. Department of Commerce (DOC) Bureau of the Census definition of urban population* (DOC, 1982b, Appendix A). Tulia had a 1980 population of 5,033 (DOC, 1982b; NUS, 1984d). Because NWPA precludes siting a repository in a highly populated area, land within the corporate boundaries

*Urban population comprises all persons living in urbanized areas and in places of 2,500 or more inhabitants outside urbanized areas. "Places" are recognized as incorporated places and census designated places.



Legend:

Transportation

- Four Lane U.S. Highway
- Farm to Market Road
- State Highway
- Planned Interstate Highway
- Railroad

Utilities

- Transmission Line
- Substation
- Pumping Station
- Natural Gas Pipeline
- PG - Pioneer Gas Company
- MAPCO - Mid America Pipeline Company
- Water Distribution Lines
- Aqueduct
- Underground Pipeline



0 1 2 5 Miles



0 2 4 6 8 Kilometers



**U.S. DEPARTMENT OF ENERGY
Salt Repository Project**

IDENTIFICATION OF SITES WITHIN
THE PALO DURO BASIN: VOLUME II

**FIGURE 3-33
HIGHWAYS, GAS PIPELINES, ELECTRICAL
TRANSMISSION FACILITIES, ROADS,
AND RAILROAD RIGHTS-OF-WAY**

of Tulia was excluded from further consideration. NWPA also precludes siting of a repository adjacent to an area 1 mile by 1 mile (1.6 kilometers by 1.6 kilometers) having a population of not less than 1,000 individuals. This excludes approximately a 1-mile (1.6-kilometer) wide zone bordering the Tulia corporate limits from consideration for siting. Except in the immediate vicinity of Tulia, an examination of population density data and recent structure maps* coupled with field verification substantiate that there are no areas 1 mile by 1 mile (1.6 kilometer by 1.6 kilometer) within or adjacent to the location that have a population of not less than 1,000 individuals.

Population density is a useful measure in identifying areas of low population. There is no clear cutoff point however, where a population density can be low, medium or high. Generally, in an urban area or an area with a concentration of people, the density is high and in rural areas it is quite low. The average national population density is 64.0 persons per square mile including both urban and rural areas (DOC, 1982a). Because a low density area is more preferred and the national average is 64.0 persons per square mile, it is appropriate to look for areas with a density lower than the national average.

Swisher County has an average population density of 10.8 persons per square mile, which is lower than the national average (DOC, 1982b). The city of Tulia is included in this population density. If the land area and population of Tulia are excluded from the county calculation, the rural population density is 3.6 persons per square mile. Thus, all areas in the location outside Tulia meet the low density criterion.

The population density of the city of Tulia is 2,036 persons per square mile which is higher than the national average. Hence, in addition to being

*Maps of residential structures in the Swisher County location were prepared by NUS Corporation. These maps are based on 1:12,000 (1 inch = 1,000 feet), color infrared (CIR) aerial photographs taken by R&D Aerographics in 1981, 1982, and 1983. These photographs were supplemented by 1:80,000 (1 inch = 6,700 feet) CIR aerial photographs purchased from the State of Texas. All structures were identified on these aerial photographs and then field verified. The structure maps indicate where houses are located. They are used to determine whether there are places in the location 1 mile by 1 mile (1.6-kilometer by 1.6 kilometer) having a population of not less than 1,000 individuals. The structure maps will be placed in the BPMD library for public review.

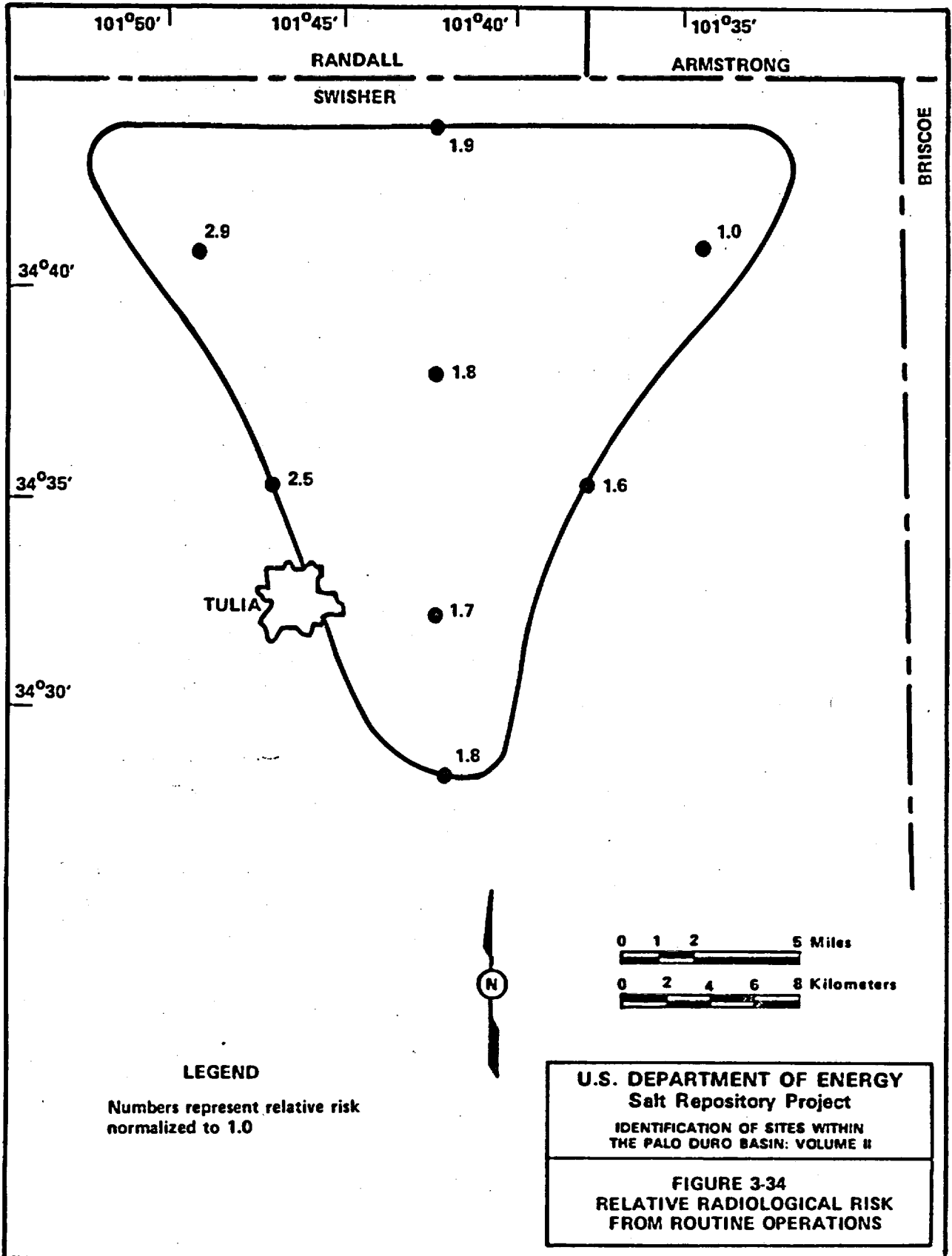
excluded by the NWPA consideration, Tulia is also excluded by the population density considerations.

Two factors were considered in analyzing "distance away from population concentrations and urban areas" (DOE, 1981, p. 11). In the area to location screening, standard metropolitan statistical areas were excluded. Thus, the Amarillo metropolitan area was eliminated from consideration. In defining "population concentrations", it is necessary to be consistent with the population density criterion. Thus, a population concentration was defined as being any place where the population is equal to or greater than 64.0 persons per square mile. This definition includes incorporated places as well as many unincorporated communities. Using the 64.0 persons-per-square-mile guide, there is one population concentration in this location, the city of Tulia. Thus, the descriptor, population density, was identified as a discriminator (Steps 1, 2, 3, 4, 5, and 6).

The second part of the NWTs criterion states that the site shall be located such that risk to the population from transportation of radioactive wastes and from repository operation can be reduced below acceptable levels to the extent reasonably achievable. An evaluation of population risk from repository operation for eight points within the location on the basis of this subcriterion was performed. The locations of the eight calculation points are depicted on Figure 3-34.

The variables that affect the population at risk from routine releases are (1) the number of people versus distance from the release point, (2) the direction of the people from the release point, (3) the percentage of time each direction is downwind from the release point, and (4) details of the site meteorology, captured here in the quantity X/Q (ground level concentration per unit release rate). Summing the appropriate products of the percentage of time downwind, X/Q versus the distance, and population versus distance, an index of the population risk from routine releases is derived.* Normalizing the indices for the eight points involved to the lowest risk index indicates the relative risk across the location. For the calculation points, the lowest risk was posed near the northeastern corner of the location (index 1.0) and

*The calculated annual exposure from repository operations to an individual living just outside controlled zone would be less than 0.1 percent of the natural background radiation.



the highest in the northwestern corner of the location (index 2,9) (Figure 3-34). Details are given in Appendix C.

Operational performance standards as set by 40 CFR 191, limits the maximum annual public doses during the operational period to 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ. Analysis of the effects of routine radiological releases potentially occurring during operations indicates that the maximally exposed individual (an individual living right at the fenceline of the surface facility) would receive less than 0.0028 millirem. This is approximately 0.01 percent of the standards established under 40 CFR 191 and less than 0.003 percent of the natural background radiation of 95 millirems per year. However, there is a factor of 2.9 difference across the location. Regulation 40 CFR 191, Subpart A (EPA, 1982) states "... that waste management operations be conducted so as to reduce exposures for members of the public ... to the extent reasonably achievable, taking into account technical, social, and economic considerations ..." Consequently, the factor of 2.9 is important even though the risk at any point in the location is well below standards. The relatively rigorous nature of the index derivation, the use and availability of existing location-specific data, and the magnitude of the derived indices combine to give results on which potential sites within the location can be differentiated. The descriptor, population risk-operations, was identified as a discriminator (Steps 1, 2, 3, 4, 5, and 6).

Risk to population from transportation of waste to any potential site in the location is not significantly dependent upon site location. This determination results from the fact that access to any potential site in this location is by the same major route so that the only difference is the extent of the population present within the boundaries of this location. The total population within this location is a very small fraction of the total number of people involved in any transportation route for waste to the Texas Panhandle. Thus, the descriptor, population risk-transportation, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.9 ENVIRONMENTAL PROTECTION

The primary intent of the environmental protection criterion is (1) to avoid or mitigate potentially adverse impacts to environmental resources or conditions and (2) to avoid potential conflicts with land use activities or conditions resulting from siting, construction, or operation of a repository.

3.9.1 Potential Environmental Impacts

3.9.1.1 Cultural Resources

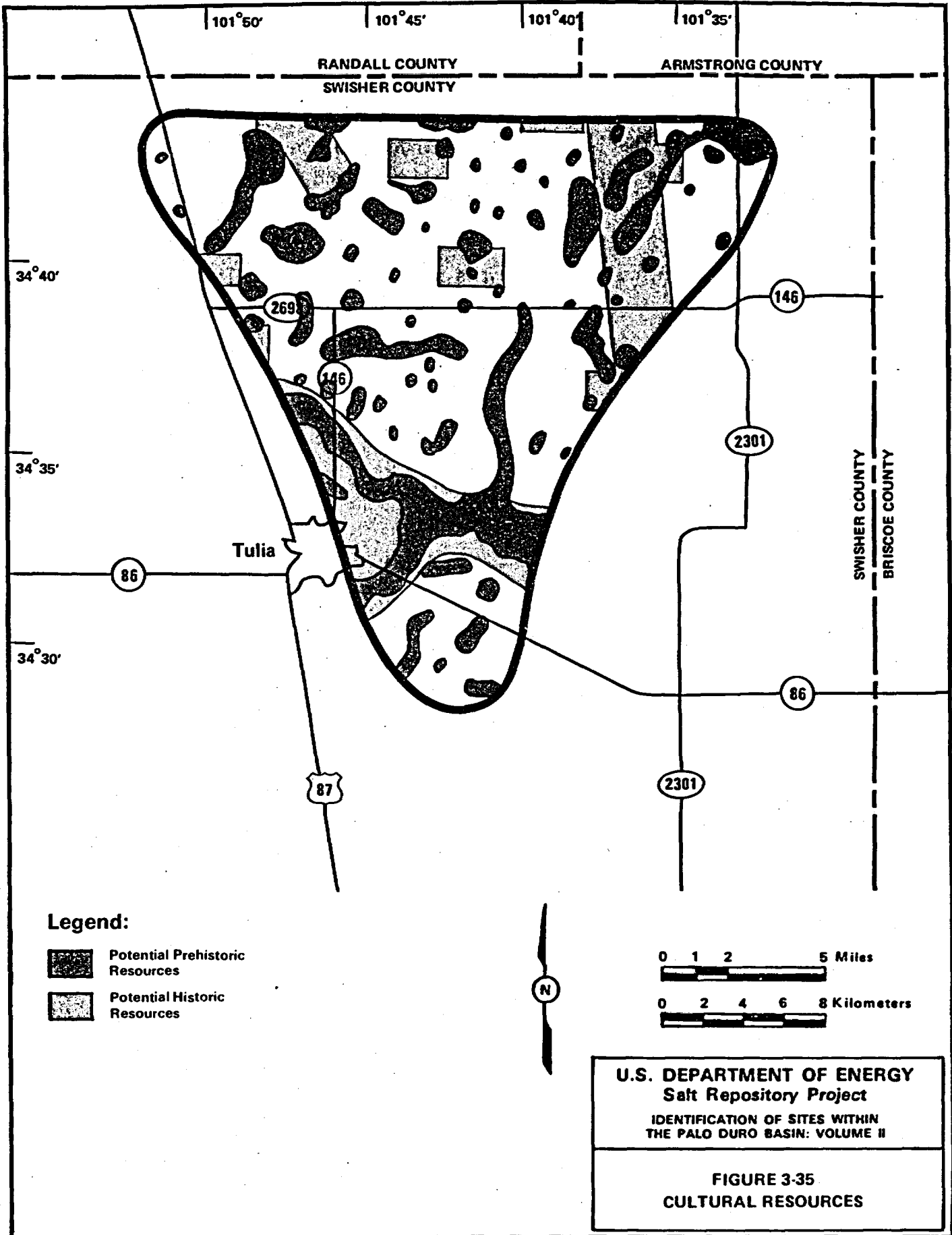
Cultural resources are historical and archaeological sites, structures, and other evidence of human history or prehistory that are considered important for scientific, cultural, religious, or other reasons. Significant cultural resources are protected by Federal and State regulations. There are no known sites of national significance (National Register Sites) within the location (NUS, 1984e). Although there are known historic and archaeological resources within the location, none have been accorded statewide recognition by the Texas Antiquities Committee (NUS, 1984e). Areas with a low probability of containing significant resources are preferred so that the potential for disruption is minimized. If significant cultural resources are encountered during construction, mitigation procedures will be employed.

In the location, as in most regions of the country, historic and archaeological resources are most frequently associated with water resources. Stream valleys and areas associated with playa lakes have been identified as having the highest probability of containing cultural resources. These areas are shown in Figure 3-35 (NUS, 1984e).

Little of the location has been systematically surveyed for cultural resources, but it is anticipated that all areas to be disturbed will be surveyed prior to actual construction. Avoidance of areas with a high probability of cultural resources may mitigate possible impact to these resources. The descriptor, cultural resources, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.9.1.2 Aesthetics

Aesthetics, usually indicated by visual quality, refers to existing visual characteristics of the location. To minimize potential aesthetic impacts, areas adjacent to paved roads were judged less preferred. Areas beyond 1 mile (1.6 kilometers) from a paved road are more preferred in that the visual impact would not be significantly reduced by any further increases in distance. Paved roads are shown on Figure 3-33. The descriptor, aesthetics, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).



3.9.1.3 Ecological Habitat

Ecological habitat can be visualized as a complex pattern of plant groups covering the surface of the land. This plant-group pattern results from the influence of local topography, soil types, climate, and cultural practices. It is also strongly influenced by the presence of surface or near-surface water and man-made structures.

The range of ecological habitat types within the Swisher location includes playa lakes, rangeland, fencerows, roadside ditches, riparian areas, and cropland. The most common habitat type in the location is cropland, with rangeland the second most common (Figures 3-36 and 3-37).

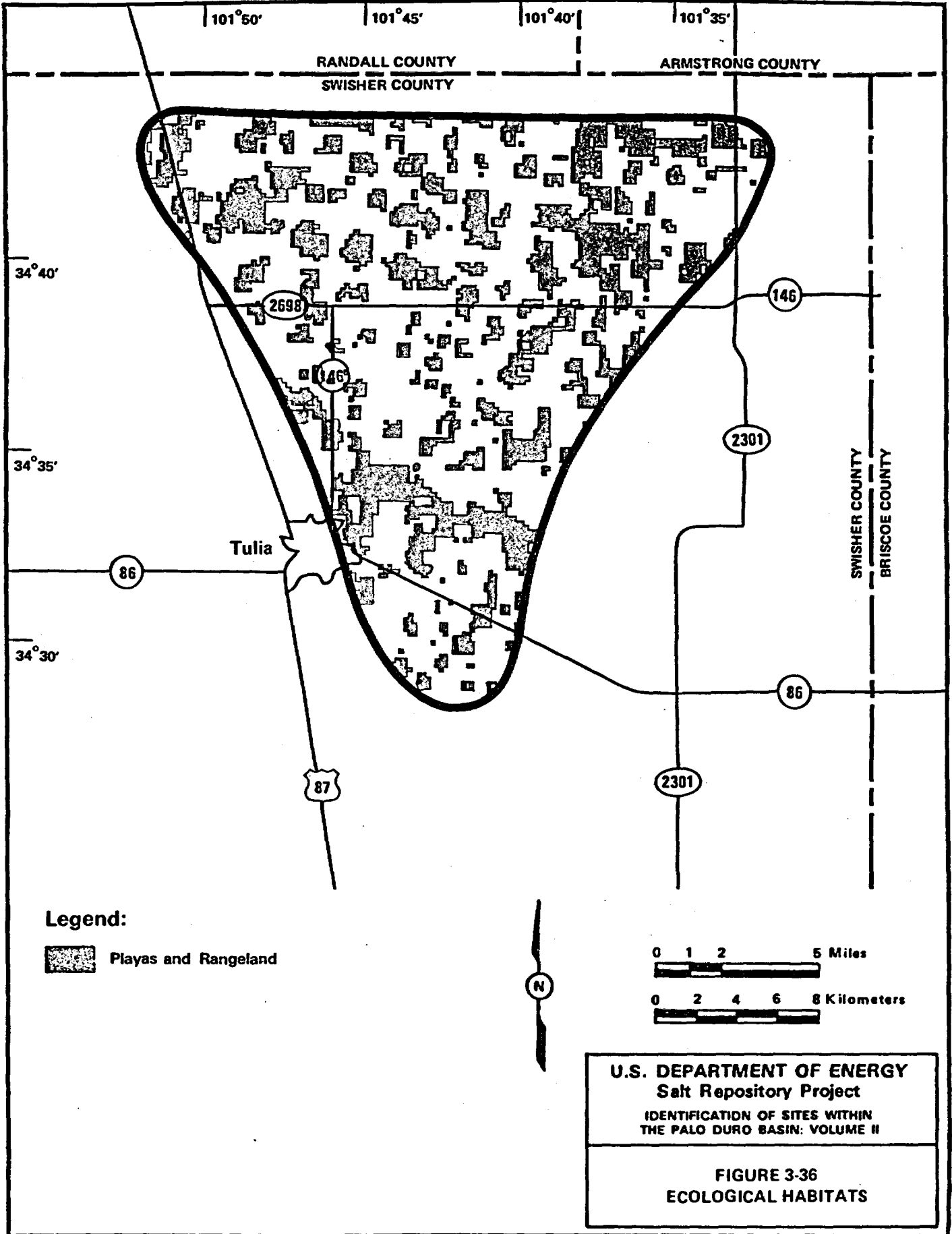
Playas represent regionally unique topographic depression features that are significant waters catchments. Because the presence of water on or near the surface in the semiarid Panhandle provides opportunities for colonization by mesic plant groups, playas attract and provide habitat for a wide range of wildlife and waterfowl.

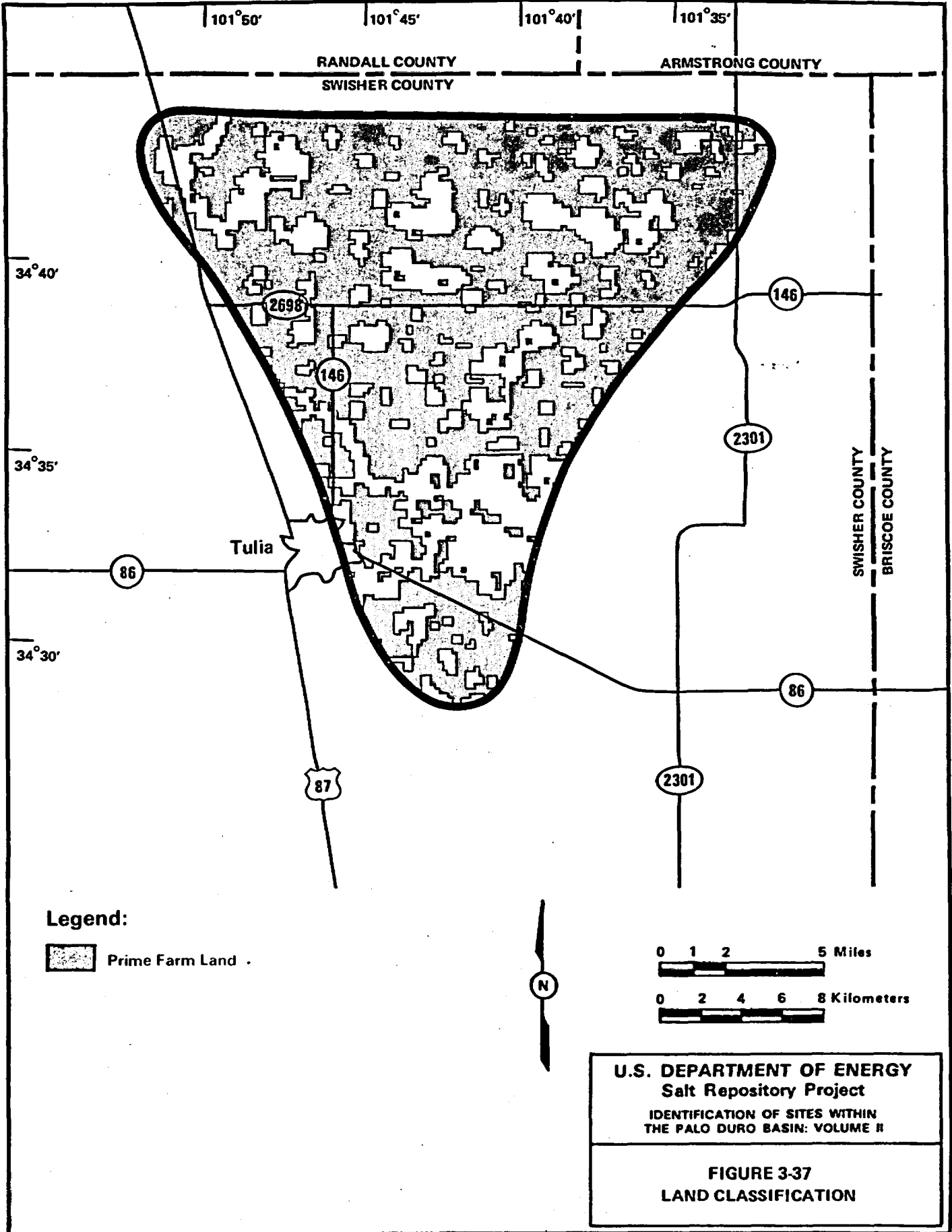
Playa lakes and regional reservoirs in the High Plains provide important feeding and resting areas for ducks and geese migrating between breeding grounds in the Northern Great Plains and the wintering grounds in the coastal region of southeast Texas (Bellrose, 1968; Guthery, 1981; Simpson et al, 1981). Cultivated crops in the area also provide a source of food for many species of migrating waterfowl. The ecological habitats favored by migrating waterfowl are the playa lakes.

Legally protected species and their designated critical habitats must be considered in repository siting. Literature reviews, consultation with representatives of the U.S. Department of the Interior (DOI) Fish and Wildlife Service and Texas Parks and Wildlife Department (TPWD), and preliminary field surveys were conducted to determine the presence and status of threatened and endangered species in the location (NUS, 1984f).

Within the Palo Duro Basin, one species of plant, the Panhandle euphorbia (*Euphorbia strictior*), is currently a candidate for protection under the Endangered Species Act.* It has been observed in northwestern Deaf Smith County in

*J. L. Johnson, U.S. Department of the Interior, Fish and Wildlife Service, letter to J. O. Neff, Program Manager, National Waste Terminal Storage Program Office, November 22, 1982.





sandy soils and limestone loams of sandhills, in the grasslands of the Rolling Plains north of the caprock escarpment (Gould, 1975), and on canyon sides (Waller, 1968). Optimal growing conditions for this species are not likely to be present in the Swisher location.

Two species of State-protected reptiles, the Texas horned lizard (Phrynosoma cornutum) and the central plains milk snake (Lampropeltis triangulum gentilis), may occur in the location (Stebbins, 1966). Preferred habitat for the Texas horned lizard is open, flat terrain with sparse, scattered vegetation; the reasons for its decline in Texas include heavy pesticide use and commercial exploitation (TOES, 1979).

The central plains milk snake prefers extensive tracts of mixed prairie habitat. Any undisturbed grassland along the Tule Creek, Happy Draw, and Pleasant Draw in the Swisher location may provide suitable habitat for this species. It is not expected to occur in areas of intensive agriculture.

The southern bald eagle (Haliaeetus leucocephalus leucocephalus) and two subspecies of the peregrine falcon, Arctic (Falco peregrinus tundrius) and American (F. p. atrium), are considered threatened or endangered by the Fish and Wildlife Service (DOI, 1982) and the State of Texas (TPWD, 1977).

Breeding activity by the southern bald eagle has been observed in the Texas Panhandle, but not in Swisher County (Oberholser, 1974). Migrating eagles have been observed at various times of the year in the Palo Duro Canyon northeast of the location in Randall County (NUS, 1984f). The bald eagle may frequent playa lakes during migration periods and the winter months since these areas attract large numbers of waterfowl.

The endangered Arctic and American peregrine falcons migrate through the region, but in extremely low numbers. Peregrines frequently follow migrating flocks of shorebirds and waterfowl. The playa lakes provide attractive resting and feeding habitats for both shorebirds and waterfowl and, thus, are potential feeding habitat for the peregrine. Breeding activity by the peregrine has not been observed in Swisher County (Oberholser, 1974).

The TPWD lists 13 protected (threatened) species of birds. Of these, the osprey (Pandion haliaetus) and wood stork (Mycteria americana) could occur in the region, primarily in association with wetland habitats (Oberholser, 1974). The lack of extensive wetland habitats in the location makes the occurrence of either species unlikely.

Any extensive short-grass prairie within the High Plains that contains colonies of black-tailed prairie dogs (Cynomys ludovicianus) could also provide habitat for the extremely rare and endangered black-footed ferret (Mustela nigripes) (DOI, 1982; TPWD, 1977). The most recent sighting in the Palo Duro Basin was in Briscoe County in 1976 (Brownlee, 1977). The extensive areas of agricultural land in Swisher County precludes major expanses of the preferred shortgrass habitat but does not eliminate the potential existence.

There are no legally designated critical habitats within the location. In general, playa lakes and rangeland are considered less preferred for a repository site (Figure 3-36) as all of the species identified by the TPWD and the Fish and Wildlife Service as threatened/endangered are associated with these habitats. There are large acreages of cropland within the location whose use would not significantly affect regional populations of vegetation, wildlife, and aquatic species and, therefore, are more-preferred areas for a site. The descriptor, ecological habitat, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.9.1.4 Air Quality

The operation of the repository facility must comply with applicable Federal and State air quality regulations. The ability to meet these air quality standards is a function of facility design, operation procedures, and the local dispersion characteristics. In general, favorable dispersion conditions are characteristic of the Texas Panhandle (NUS, 1984g). The entire location has the same Air Quality Control Region (AQCR) classification, Class II, and is not proximate to a designated Class I AQCR area.

Atmospheric transport and diffusion conditions are primarily dependent on wind speed, wind direction, and atmospheric stability. Existing data for Amarillo indicate relatively good dispersion conditions (NUS, 1984g). These data are reasonably applicable to the location but do not provide a basis for depicting variation. If nominated for characterization, site-specific meteorological data will be obtained. The descriptor, air quality, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.9.1.5 Noise

Results from sound-level surveys conducted during winter and summer seasons (NUS, 1984h,i) indicate that ambient sound levels across the location did not vary measurably. Repository construction and operation as a source of noise will, in general, be the same regardless of the site chosen.

The actual offsite noise level is dependent on the characteristics and orientation of the noise source, distance to the receptor, intervening topography and vegetation, and mitigation measures employed. Because vegetation is largely limited to agricultural crops and there is little topographic relief, there is little variation in the attenuation of the anticipated noise sources.

The EPA has identified the energy equivalent A-weighted, day-night noise level (L_{dn}) of 55 dB as sufficient to protect the public from the effects of environmental noise in normally quiet outdoor areas where people spend time (EPA, 1974).

A preliminary evaluation indicates that offsite noise would be greatest during the construction period. However, only a small area outside the controlled zone will exceed L_{dn} 55 and then only briefly. If a nearby resident were to be affected, a variety of mitigative measures can be employed to reduce the noise to an acceptable level. As a result of the low anticipated affect and ease of mitigation, the descriptor, noise, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.9.1.6 Water Quality

The repository facility must be designed, located, constructed, and operated to mitigate potential impacts to surface and subsurface water resources. Surface water resources in the location include Tule Lake, Middle and North Tule Draws, Tule Creek, Happy Draw, and Pleasant Draw, and numerous playa lakes, all of which except Tule Lake, are generally seasonal. The High Plains aquifer, which includes the economically important Ogallala Formation and Dockum Group (Santa Rosa) underlies the entire location.

Preliminary repository designs indicate that there will be no planned discharge of liquid waste materials to surface water systems during either construction or operation of the facility (Kaiser Engineers, 1978, pp. 12.7-11, 12.9-10, 12.9-19 - 12.9-27). All wastes, including drilling and sanitary waste, and all

runoff waters will be contained and disposed of onsite. Containment structures such as mudpits, settling ponds, and runoff overflow reservoirs are to be lined, despite research that indicates that infiltration rates from these containments are extremely slow and contamination of ground water is unlikely (NUS, 1984c). Engineering measures are also expected to provide adequate protection of the aquifer during construction, operation, and decommissioning of the various repository shafts.

Potentially discriminating are a preference for sites at greater distances from surface water systems, such as natural drainage areas, and a preference for sites that will allow drilling in areas where aquifers have less saturated thicknesses. If nominated for characterization, additional water quality data would be obtained. The descriptor, water quality, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.9.2 Potential Environmental Conflicts

3.9.2.1 Prime Farmland

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed fiber, forage, and other agricultural crops. Approximately 66 percent of the land in the Swisher location is classified as having prime native soils by the U.S. Department of Agriculture (DOA) Soil Conservation Service (NUS, 1984a).

The Farmland Protection Policy Act (DOA, 1981) was established to "... minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmland to nonagricultural uses, ..." Of the required site area (9 square miles [23 square kilometers]), approximately 440 acres (180 hectares) of land would be required for repository surface facilities (additional land would be required for access roads and railroads). The balance of the 9 square miles (23 square kilometers) would be available for uses that are considered compatible with the operation of a nuclear waste repository. These uses may include a continuation of current agricultural practices. If the 440 acres (180 hectares) of land dedicated to the repository surface facilities were all prime farmland, this would represent approximately 0.1 percent of the prime farmland within the county. The 9-square-mile (23-square-kilometer) site

represents 1.2 percent of the prime farmland in Swisher County. However, a preference should be given to siting the facility in a nonprime farmland area. Prime farmland areas are shown in Figure 3-37.

The majority of the prime farmland area is used for crop production; however, extensive area is not cropped and instead is used as rangeland (NUS, 1984a). The areas currently used for crop production represent either highly favorable natural conditions or a commitment of resources to clear and level the land and provide irrigation water. The prime farmland areas that are being used for crop production (Figure 3-37) represent the most favorable agricultural land and, therefore, areas less preferred for siting.

Prime farmland not being used as cropland still has the potential for high crop yields if irrigated. However, siting on these lands would have less impact than siting on cropped prime farmland areas. The descriptor, prime farmland, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.9.2.2 Industrial/Commercial Installations

Industrial/commercial installations include feedlots, cotton processing plants, grain silos and elevators, and farm co-ops. These types of facilities were also discussed in Section 3.7.9 and are shown in Figure 3-32 (NUS, 1984a). These facilities represent conflicting land uses if they are within the controlled area, but could operate on adjacent land without significant impact to or from repository operations. Industrial/commercial installations in the location are widely scattered and occupy relatively small acreages. Installations located within the site may have to be relocated; therefore, the descriptor, industrial/commercial installations, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.9.2.3 Proximity to Road Access

Highways in the location are shown on Figure 3-33 (NUS, 1984a). Highways having a maximum weight limit of at least 40 tons are capable of supporting the weight of transport trucks involved in the construction and operation of a repository. U.S. Highway 87 and State Highway 86 have such a capability. They can also provide adequate access for the required work force.

In siting a repository, preference would be given to potential sites with adequate access or which can be provided with access alternatives without unacceptable impacts on affected communities, agriculture, or natural resources.

The distance from highways has a direct impact on the environment (e.g., amount of land disturbed) and on the costs of upgrading existing routes or constructing entirely new access routes, i.e., a shorter distance from site to road is more preferred. Also affected is the amount of traffic moving to and from these highways. Thus, the descriptor, proximity to road access, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.9.2.4 Proximity to Rail Rights-of-Way

There is one railroad right-of-way in the vicinity of the location that could provide points of origin for a railroad spur serving the repository site (Figure 3-33, NUS, 1984a). Distance from a right-of-way will determine the cost and environmental impact of building such a spur. Assuming a 200-foot (61-meter) wide right-of-way, each 10 miles (16 kilometers) of new track may disturb almost 0.4 square mile (1 square kilometer) of land.

In siting a repository, preference is given to potential sites with adequate access to facilitate movement of supplies, equipment, and wastes, or to which access can be provided without unacceptable impact on the environment and affected communities. Distance from existing railroad rights-of-way is a continuous variable discriminator, i.e., a shorter distance from site to rail right-of-way is more preferred. The descriptor, proximity of rail rights-of-way, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

3.9.2.5 Water Use Conflicts

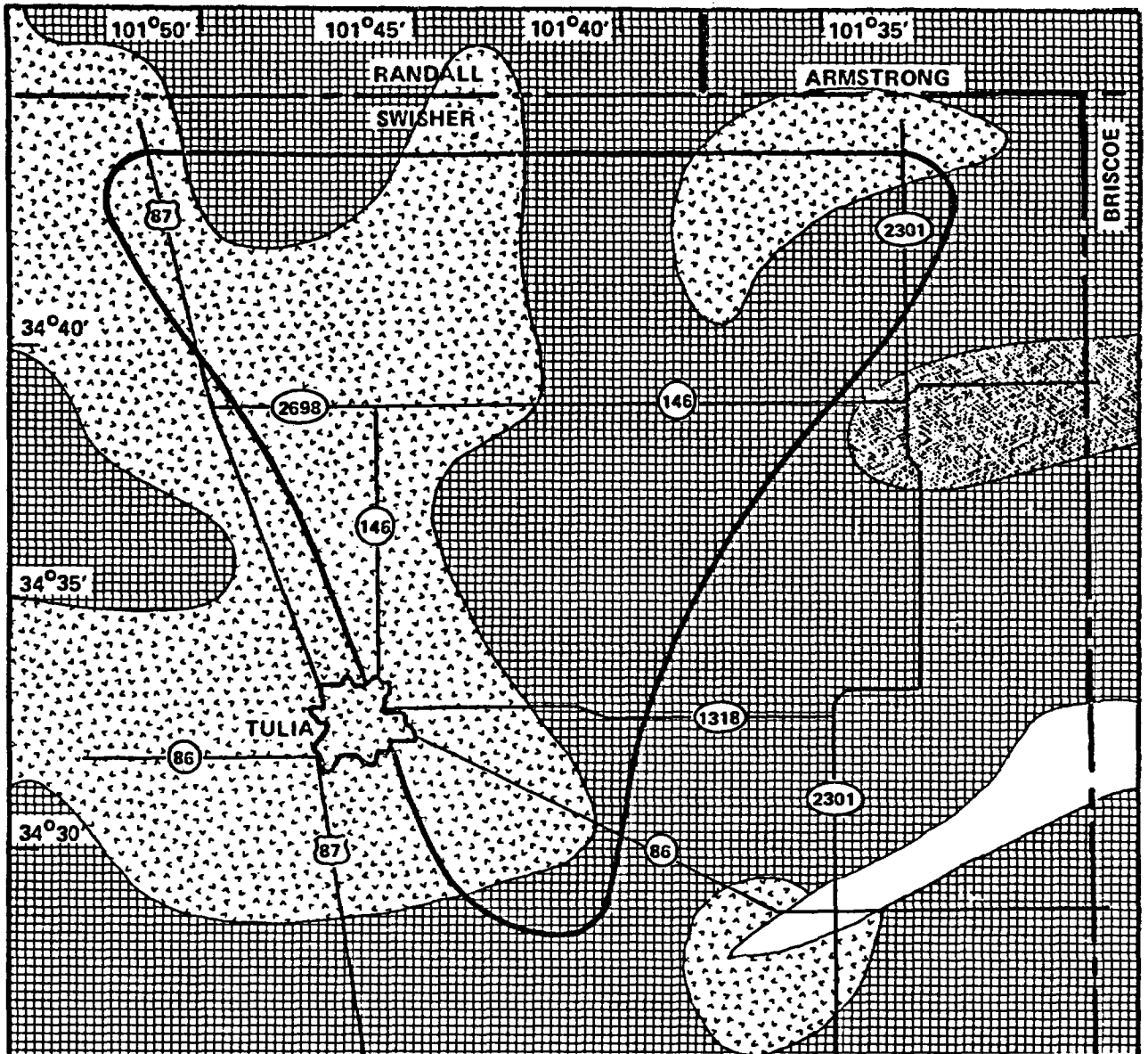
Potential water use conflicts between a repository and agricultural interests are of concern. However, the repository operation will consume less water than irrigation of a comparable area of land (Section 3.2.2). Likely sources for satisfying repository water requirements are the Ogallala and Dockum Group (Santa Rosa) aquifers. The Ogallala aquifer is an important agricultural resource which is being depleted under current irrigation practices.

The projected saturated thickness of the Ogallala aquifer has been used to identify areas with the best capability of supporting agriculture in the year 2030. According to the Texas Department of Water Resources (TDWR), it is difficult to obtain sufficient water for irrigation by wells where the saturated thickness is less than 20 feet (6 meters). Generally, well yields are not a limiting factor on irrigation if saturated thickness is 100 feet (30 meters) or greater (TDWR, 1982, p. 97). Figure 3-38 indicates how projected saturated thickness in 2030 varies across the location. Those areas of greater saturated thickness are potentially more preferred for irrigated agriculture. However, all projected saturated thicknesses are below 60 feet (18 meters); a conservative value (i.e., below the 100-foot [60-meter] saturated thickness) if well yields are not a limiting factor on irrigation. The descriptor, projected saturated thickness of Ogallala in year 2030, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).





As depletion of the Ogallala continues, the Dockum aquifer will become increasingly more important to the regional economy. Suitable quality ground water from the Dockum Group (Santa Rosa sandstone) is anticipated to be available throughout the Swisher location. Its development is dependent on the depth and thickness of the aquifer and limitations in spacing of wells. The Dockum Group is most likely to be developed in areas where the Ogallala is significantly depleted. Although there has been production from the Santa Rosa sand near Tulia, Texas, little is known about the distribution of this sand, its specific yield capacity, or its variability throughout the location. While the Dockum Group is a water resource for the area, the limited data precludes its use in differentiating among possible sites within the location.

3.9.3 Extreme Conditions

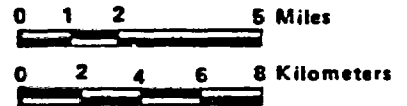
Extreme meteorological and related phenomena, including heavy precipitation and tornadoes, must be accommodated by appropriate engineering measures and must not unacceptably affect repository operation. The PMP event and potential impacts from flooding are described in Section 3.7.1. Accumulations of snow and high and persistent winds are described in Section 3.7.7. All data for this category are regional in nature, with negligible variation across this location (NUS, 1984g). Consequently, the descriptor, extreme conditions, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).



LEGEND

-  Ogallala Absent
-  Less than 20 feet
-  20 to 60 feet
-  60 to 100 feet

Source: Derived from Knowles et al, 1982, Figure 18



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**FIGURE 3-38
PROJECTED SATURATED
THICKNESS OF OGALLALA
IN YEAR 2030**

3.10 SOCIOECONOMIC IMPACTS

Socioeconomic impacts require consideration of social and economic impacts to communities and regions affected by the repository. This criterion is subdivided into two parts: (1) the site shall be located so that adverse social and/or economic impacts resulting from repository construction and operation can be accommodated by mitigation or compensation strategies; and (2) the site shall be located so that adequate access and utility capability required for the repository either exists or can be provided without unacceptable impact on affected communities.

The following specific socioeconomic indicators were used to evaluate the first part of this criterion: labor force, housing, services, local government, community land use patterns, and population. A repository project will affect each of these items as a result of new workers moving into the area, repository purchases, and added area employment. However, these impacts are spread over a region much larger than the location (NUS, 1984d). New residents, for example, will primarily locate in communities such as Canyon, Amarillo, Plainview and Tulia, that are near the project site. The same communities will be affected regardless of which part of the location is selected. The magnitude of impacts on a specific community relative to a specific site, whether they are positive or negative impacts, cannot be determined reliably until site characterization is complete. The descriptor, construction and operations socioeconomic impacts, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

The socioeconomic impacts resulting from building additional railroads and/or highways will be a small fraction of the total socioeconomic impact of the project. The differential impacts from one potential site to another in this location are very small and not considered significant. However, note that this same factor is evaluated relative to environmental impact. The descriptor, access and utility socioeconomic impacts, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

3.11 SUMMARY OF DISCRIMINATORS

Table 3-2 is a list of 19 descriptors identified as discriminators. These discriminators can be used for determining the more-preferred site for a repository within the location.

Table 3-2. Siting Discriminators

SITE GEOMETRY

Thickness of Host Rock

GEOHYDROLOGYRecent Saturated Thickness of the Ogallala
Depth to Base of Dockum**GEOLOGIC CHARACTERISTICS**

Depth to Host Rock

HUMAN INTRUSIONLocation of Boreholes Reaching Host Rock
Hydrocarbon Resource Potential**SURFACE CHARACTERISTICS**Proximate Streams and Floodplains
(probable maximum flood areas)
Proximate Impoundments
Proximate Water Bodies (playas)
Proximate Transportation Installations
(paved roads, pipelines, and electrical
transmission facilities)**DEMOGRAPHY**Population Risk-Operations
Population Density**ENVIRONMENTAL PROTECTION**Cultural Resources
Aesthetics
Ecological Habitat
Industrial/Commercial Installations
Prime Farmland
Proximity to Road Access (major highways)
Proximity to Rail Rights-of-Way

4 SITE IDENTIFICATION

To identify a smaller, more-preferred site suitable for characterization within Palo Duro Location B, a systematic method for narrowing the 200-square-mile (520-square-kilometer) area was required. In the Palo Duro Basin, the required site area was tentatively selected as 9 square miles (23 square kilometers) in a 3-mile by 3-mile (4.8-kilometer by 4.8-kilometer) configuration. An area of approximately 2,000 acres (800 hectares) in an approximately square configuration was used to represent underground repository operations. Such an area is approximately 1 3/4 miles by 1 3/4 miles (2.8 kilometers by 2.8 kilometers). In addition to approximating the required controlled area, this size and configuration allow flexibility during location of the requisite surface facilities.

4.1 DESCRIPTION OF NARROWING PROCESS

It is important that a consistent and reproducible site identification methodology be used. Several options exist; numerical and map overlay approaches were considered during this analysis. Given the current status of data, numerical methods are neither feasible nor warranted. Consequently, a map overlay approach was used so that the attributes of various areas within the location were visually apparent.

The objective of the overlay process used was to evaluate and visually depict the currently available information (in the form of discriminators) such that the more-preferred site in the location is identified. The more-preferred site, while expected to fulfill all regulatory requirements, must await detailed performance assessments using additional data collected during site characterization to confirm and assure its suitability without reservation.*

* NWTS criteria (DOE, 1981, p. B-4) states "...The siting process is a complex set of choices and tradeoffs that can be made in any number of ways, but the eventual proof of suitability of a selected site will be based on the assessment of its (acceptable) performance ..."

A map overlay (constraint mapping) approach has been used in many other projects in which the parameters applied had absolute or discrete boundaries. In these cases, inclusion or exclusion of land areas according to a specific set of methodological rules was possible. The effort reported herein differs in that it includes continuous variable discriminators as well as discrete variable discriminators. The continuous variable discriminators are characterized by gradual changes in preferability across the location, e.g., depth to the lower San Andres unit 4; while the discrete variable discriminators are characterized by step-changes in preferability across the location, e.g., favorable ecological habitat. Thus, movement of site boundaries a short distance when considering continuous variable discriminators is of little consequence; conversely, moving a short distance when considering discrete variable discriminators may have a greater consequence. The methodology used to screen within the location was based on defining more-preferred and less-preferred areas for each discriminator. These more-preferred/less-preferred areas were depicted on maps and overlaid to narrow the location to smaller land areas.

Each discriminator described in Section 3 was evaluated to define the more-preferred and less-preferred areas within the location. Ideally, as for the case of discrete variable discriminators, the definition of a boundary between more-preferred and less-preferred areas was clear-cut, e.g., flood-prone areas based on PMF criteria are obviously less preferred than nonflood-prone areas. It was not possible to define a discrete boundary between more-preferred and less-preferred areas for discriminators that are continuously variable across the location. Risk to population from radiation and depth to the lower San Andres unit 4 are two examples of this type of discriminator variability. In the case of population risk from radiation, draft 40 CFR 191 Subpart A (EPA, 1982) states "... that waste management operations be conducted so as to reduce exposures for members of the public... to the extent reasonably achievable, taking into account technical, social, and economic consideration". Thus, a lower risk is obviously more-preferred even if the risk at any point in the location is well below applicable standards. Similarly, all other factors being equal, shallower depths to the lower San Andres unit 4 salt are more preferred for ease and cost of construction, even though the underground facility could be constructed at any depth of unit 4 salt within the location.

In cases of continuous variable discriminators without clear preference thresholds, the boundary was chosen such that approximately one-half the area of the location would be placed in the less-preferred category as the result of application of any one discriminator. The selection of a boundary that results in significantly greater than one-half of the location was thought to potentially overemphasize the value of a particular continuous variable discriminator and reduce the opportunity of utilization of other discriminators. The selection of a boundary that results in significantly less than one-half the location was thought to potentially underemphasize the discriminator's importance. The selection of a boundary which approximates one-half of the location provides a reasonable compromise and a standard that permits discriminator variation to be visualized in the overlay process.

Discriminators were divided into three groups. In order of relative importance, these are:

- Long-Term Performance
- Operational Performance
- Environmental/Constructibility Considerations.

This prioritization results from the societal need for a long-term solution to the nuclear waste problem. Long-term performance is the essential requisite of a nuclear waste repository system. Nuclear waste must be isolated for generations to prevent societal consequences, including human health and safety. The release of radioactivity during facility operations should be minimized consistent with maximizing long-term performance. Operational performance is more important than construction costs or environmental impacts from construction and operation because operational performance has a direct impact on the health and safety of humans. Environmental impacts would be mitigated to the extent feasible.

This narrowing process consisted of six major methodologic steps.

Methodology Step 1

Maps of discriminators were prepared depicting the data as more-preferred/less-preferred areas, and the rationale was documented.

Methodology Step 2

Appropriately scaled maps for the long-term performance discriminators were overlaid to form a composite result representing the long-term performance as more-preferred/less-preferred areas. A map of this composite was prepared.

Methodology Step 3

A map depicting more-preferred/less-preferred areas for the discriminator related to operational performance was prepared.

Methodology Step 4

The operational performance map from Methodology Step 3 was then overlaid on the long-term performance composite from Methodology Step 2, and a more-preferred area was determined on the basis of common preference.

Methodology Step 5

Impact-related discriminators were grouped according to priority. Composite maps for priority groups were prepared. These maps were overlaid, one at a time, in order of priority on the overlay of long-term and operational performance maps until more-preferred areas were smaller than the desired 9-square-mile (23-square-kilometer) size. A map depicting the resultant more-preferred areas was prepared. The process does not require that all priority groups be used because a site-sized area was reached before some of the lower priority groups were overlaid.

Methodology Step 6

All discriminators were then examined in order of priority to identify the actual site boundary along section lines for ease of description and to generally coincide with surveyed land boundaries. A map of the identified site within the location was prepared.

4.2 APPLICATION OF NARROWING PROCESS

4.2.1 Grouping of Discriminators

The discriminators (Table 3-2) were grouped according to whether they possibly affected long-term performance, operational performance, or environmental/constructibility considerations (Table 4-1). These groups are discussed in order of descending priority.

Three discriminators were considered to depict variability which might significantly affect long-term performance. These were: thickness of host rock, location of boreholes reaching host rock, and hydrocarbon resource potential. Salt thickness considerations are discussed in Section 3.1.2. Location of boreholes and hydrocarbon resource potential concerns are discussed in Section 3.6.1 and 3.6.2, respectively.

Two discriminators identified in Section 3 were considered to depict variability from an operational performance standpoint. These discriminators, population risk-operations and population density, are discussed in Section 3.8 and Appendix C.

All remaining discriminators show variability which was related to environmental or constructibility considerations. Each discriminator within this group (see Table 4-1) is not of equal importance. Therefore, as a means of accomplishing narrowing in a logical stepwise manner according to priority concerns, discriminators of similar importance were grouped in categories of descending priority.

The prioritization of these discriminators was the consensus of the authors of this report and is specific for the Palo Duro Basin. Examples of reasoning for this prioritization are:

- The relative scarcity of quality ecological habitat; hence, a higher priority.
- Existing transportation and industrial/commercial installations can be relocated if necessary; hence, a lower priority.
- Prime farmland is plentiful within the location; the total desired site area is 1.2 percent of area of prime farmland in Swisher County; hence, a lower priority.

Table 4-1. Discriminator Groupings

Group	Discriminator
Long-Term Performance	Thickness of Host Rock Location of Boreholes Reaching Host Rock Hydrocarbon Resource Potential
Operational Performance	Population Risk-Operations Population Density*
Environmental/Constructability Considerations	
Priority 1	Ecological Habitat
Priority 2	Recent Saturated Thickness of the Ogallala Depth to Host Rock
Priority 3	Proximity to Road Access (major highways) Proximity to Rail Rights-of-Way
Priority 4	Proximate Streams and Floodplains (probable maximum flood areas) Proximate Water Bodies (playas) Depth to Base of Dockum
Priority 5	Cultural Resources Prime Farmland Aesthetics
Priority 6	Proximate to Transportation Installations (paved, roads, pipelines, and electrical transmission facilities) Proximate impoundments Industrial/Commercial Installations

*The city of Tulia was excluded from consideration per NWA, Section 112(a).

The Priority 1 category included consideration of ecological habitat impact. This discriminator is discussed in Section 3.9.1.3.

The Priority 2 category included constructibility considerations: recent saturated thickness of the Ogallala and depth to host rock. These discriminators are discussed in Section 3.2.3 and 3.4.3, respectively.

The Priority 3 category included considerations of potential impacts related to the necessity to construct or upgrade highways and railroads. The discriminators, proximity to road access and proximity to rail rights-of-way, are discussed in Sections 3.9.2.3 and 3.9.2.4, respectively.

The Priority 4 category includes both surface and subsurface constructibility considerations. The discriminators, proximate streams and floodplains (probable maximum flood areas), proximate water bodies (playas), and depth to base of Dockum are discussed in Sections 3.7.1, 3.7.2, and 3.2.3, respectively.

The Priority 5 category included considerations of potential impacts on existing or possible cultural resources, potential land use conflicts, and aesthetics. The discriminators, cultural resources, aesthetics, and prime farmland are discussed in Sections 3.9.1.1., 3.9.1.3, and 3.9.2.1, respectively.

The Priority 6 category included consideration of potential impact related to the necessity to relocate existing surface or near-surface installations, and potential disruption to industrial and commercial installations. The discriminators, proximate transportation installations (paved roads, railroads, pipelines, aqueducts, and electrical transmission facilities), proximate impoundments, and industrial and commercial installations, are discussed in Sections 3.7.10, 3.7.3, and 3.9.2.2, respectively.

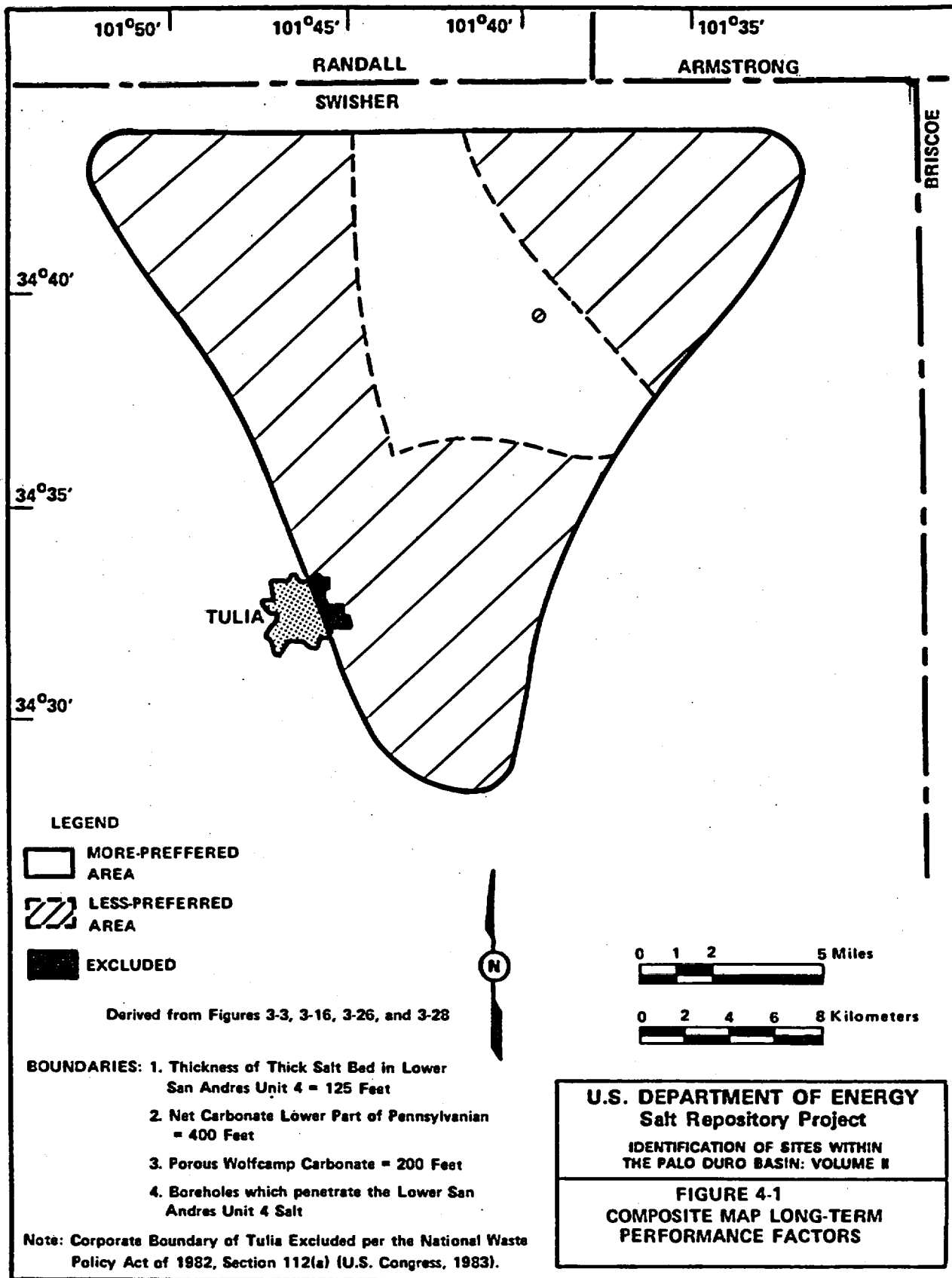
4.2.2 Application of Discriminators

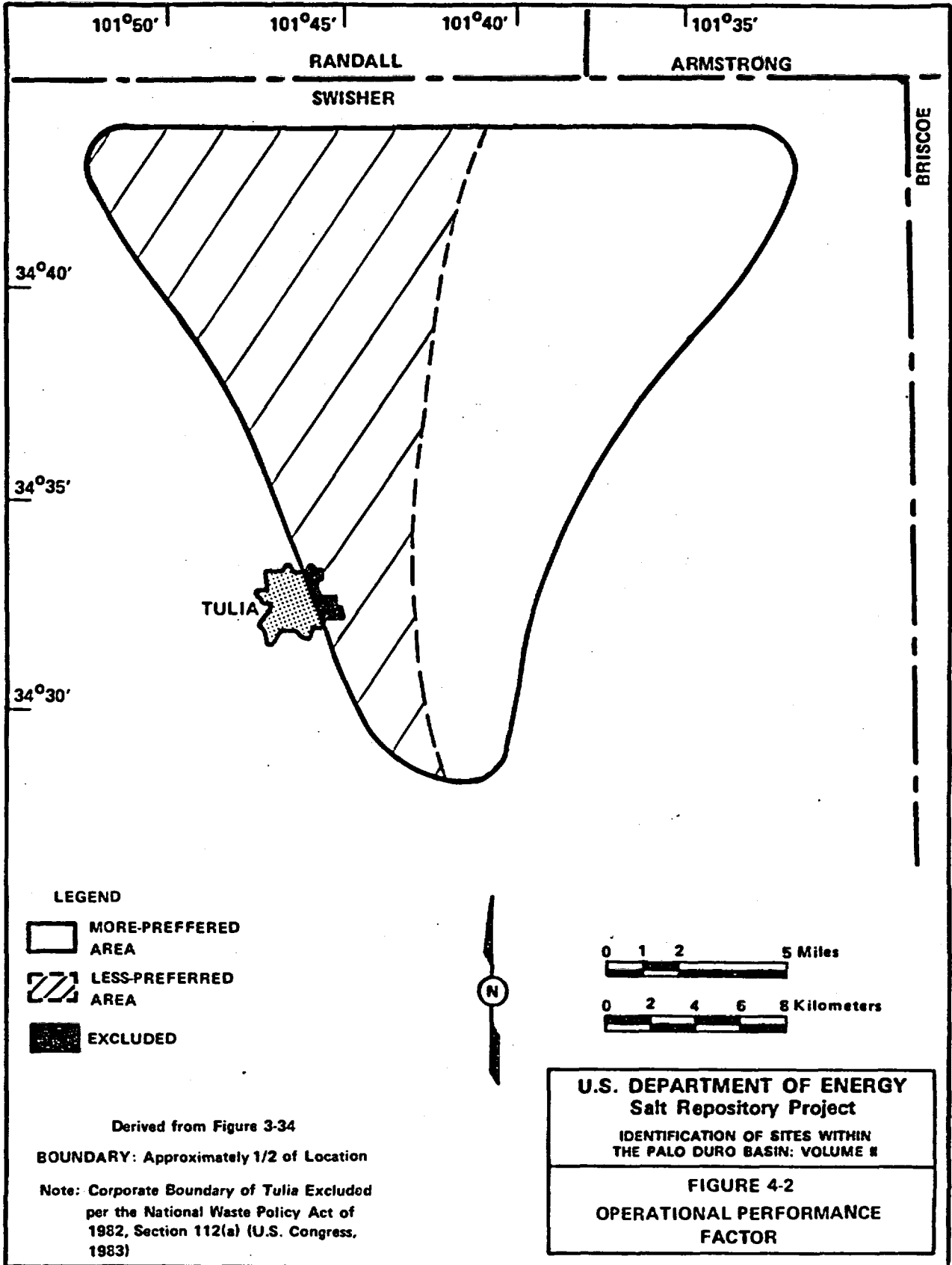
This section provides the rationale used in determining, by discriminator, the more-preferred and less-preferred areas within the location, and the overlay process which led to the identification of the site. As discussed in Section 4.1, the boundaries between more-preferred and less-preferred areas are not always absolute, and use of a strict inclusion/exclusion overlay method was precluded. Further, when preferred areas of approximately 9 square miles (23 square kilometers) or smaller are obtained, the overlay process stops and remaining lower priority categories are not utilized in identifying the site.

The more-preferred and less-preferred areas from consideration of the highest priority group, long-term performance, are depicted in Figure 4-1. This map results from the overlay of areas more-preferred and less-preferred for the three discriminators in this group. The areas identified as "potential hydrocarbon reservoir fairways" by Dutton et al (1982, Figures 52 and 53), result from juxtaposition of mapped areas with fair (0.5 percent) TOC content and thick and/or porous carbonate rock sequences. These "fairways" can be reproduced by overlaying Figures 3-24, 3-25, 3-26, and 3-27 to define areas within the location with presumed greater hydrocarbon potential. For the purposes of differentiating within the location, these "potential hydrocarbon reservoir fairways", identified by Dutton et al (1982, Figures 52 and 53) and reproduced herein, are less preferred for repository siting.




The preferred host rock thickness, as described in Section 2.1.2, is 125 feet (38 meters) or greater. For this narrowing, the 125-foot (38-meter) contour on the thickness of thick salt bed in lower San Andres unit 4 map (Figure 3-3) was defined as the discrete boundary between more-preferred and less-preferred areas. Locations of boreholes which reach the host rock are also less-preferred areas. One borehole is located within the boundary of the more-preferred area from hydrocarbon resource potential and host rock thickness determinations. The composite more-preferred area, from long-term performance considerations, is a zone of about 50 square miles (130 square kilometers) in the central and north-central part of the location (Figure 4-1).

Information available to evaluate operational performance consisted of normalized estimates of population dose (risk to population) resulting from potential routine radiologic emissions during operation. These data were calculated at various points within the location (see Section 3.8 and Appendix C) so that variability across the location was defined. Potential emissions from a facility anywhere in the location would be well below applicable standards. Estimated risk to population generally decreases in west and north directions within the location. The city of Tulia is excluded from consideration as a site location from population density considerations (Section 3.8). Figure 4-2 depicts more-preferred and less-preferred areas from an operational performance standpoint, with the eastern portion of the location being more-preferred. As previously noted, the boundary between more-preferred and less-preferred was chosen so that approximately half the area of the location would be included as





LEGEND

-  MORE-PREFERRED AREA
-  LESS-PREFERRED AREA
-  EXCLUDED

Derived from Figure 3-34

BOUNDARY: Approximately 1/2 of Location

Note: Corporate Boundary of Tulia Excluded per the National Waste Policy Act of 1982, Section 112(a) (U.S. Congress, 1983)

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FIGURE 4-2
OPERATIONAL PERFORMANCE
FACTOR

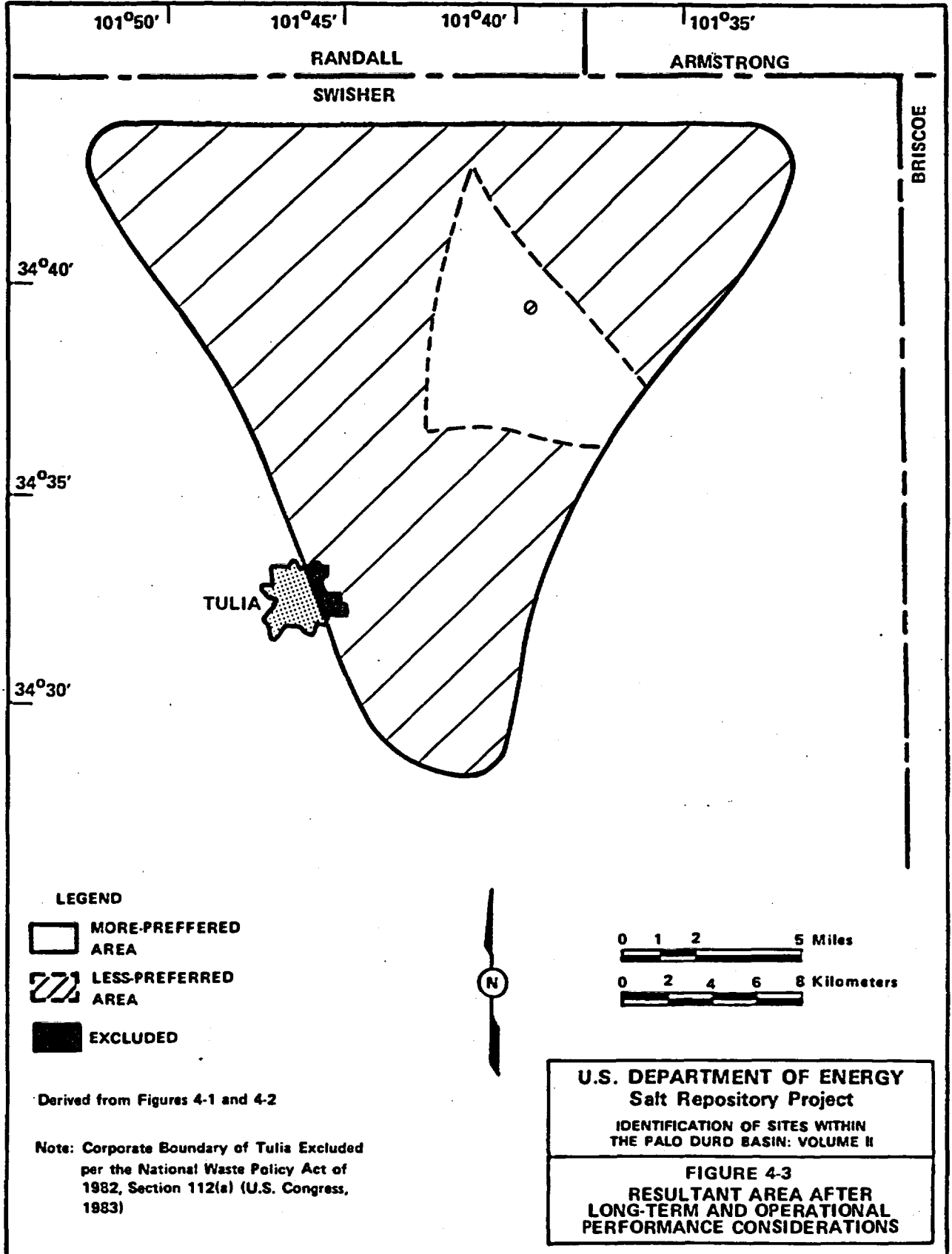
more preferred for this continuous variable discriminator. The line drawn corresponds to the isopleth of risk which approximately separates the area of the location into equal parts. Overlaying Figures 4-2 and 4-1 results in an area that is more preferred from both considerations (Figure 4-3); an area of about 25 square miles (65 square kilometers) near the north-central and east-central part of the location.

The Priority 1 impact category, ecological habitat, was then considered. Discrete boundaries between more-preferred and less-preferred areas can be identified for this discriminator. The more-preferred areas, from a standpoint of reducing the potential for adverse impact on valued ecological habitat, are the areas identified as "other features" in Figure 3-37 (Section 3.9.1.3). These areas, reproduced in Figure 4-4, are scattered throughout the location. Overlaying Figures 4-3 and 4-4 results in an irregular more-preferred area in the north-central and east-central portion of the location according to the three highest priority groupings (Figure 4-5).




The Priority 2 impact category, recent saturated thickness of the Ogallala and depth to host rock, was then considered. Preference for siting relative to this category is in areas of lesser Ogallala saturated thickness (Figure 3-13, Section 3.2.3) and shallower depths to the lower San Andres unit 4 (Figure 3-13, Section 3.1.1). Both of these factors are continually variable across the location. For the purpose of this narrowing, a contour value was selected on each map (Figure 3-12 and 3-2) such that approximately one-half the area of the location would be classified as less preferred for that individual discriminator. For the Ogallala saturated thickness, the selected boundary value was 50 feet (15 meters). A boundary value of 2,650 feet (808 meters) approximated one-half the location in consideration of depth to the lower San Andres unit 4. The more-preferred area shown in Figure 4-6 results from combining these factors.

Overlaying Figures 4-5 and 4-6 results in more-preferred areas according to the four highest priority groupings. These areas total about 5 square miles (13 square kilometers) near the central part of the location (Figure 4-7).

Because the application of these higher priority discriminators resulted in a more-preferred area smaller than the site size desired, no further rigorous overlay of lower priority discriminators (Priority 3, 4, 5, and 6 categories) is warranted.

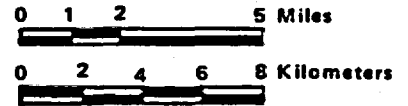


LEGEND

-  MORE-PREFERRED AREA
-  LESS-PREFERRED AREA
-  EXCLUDED

Derived from Figures 4-1 and 4-2

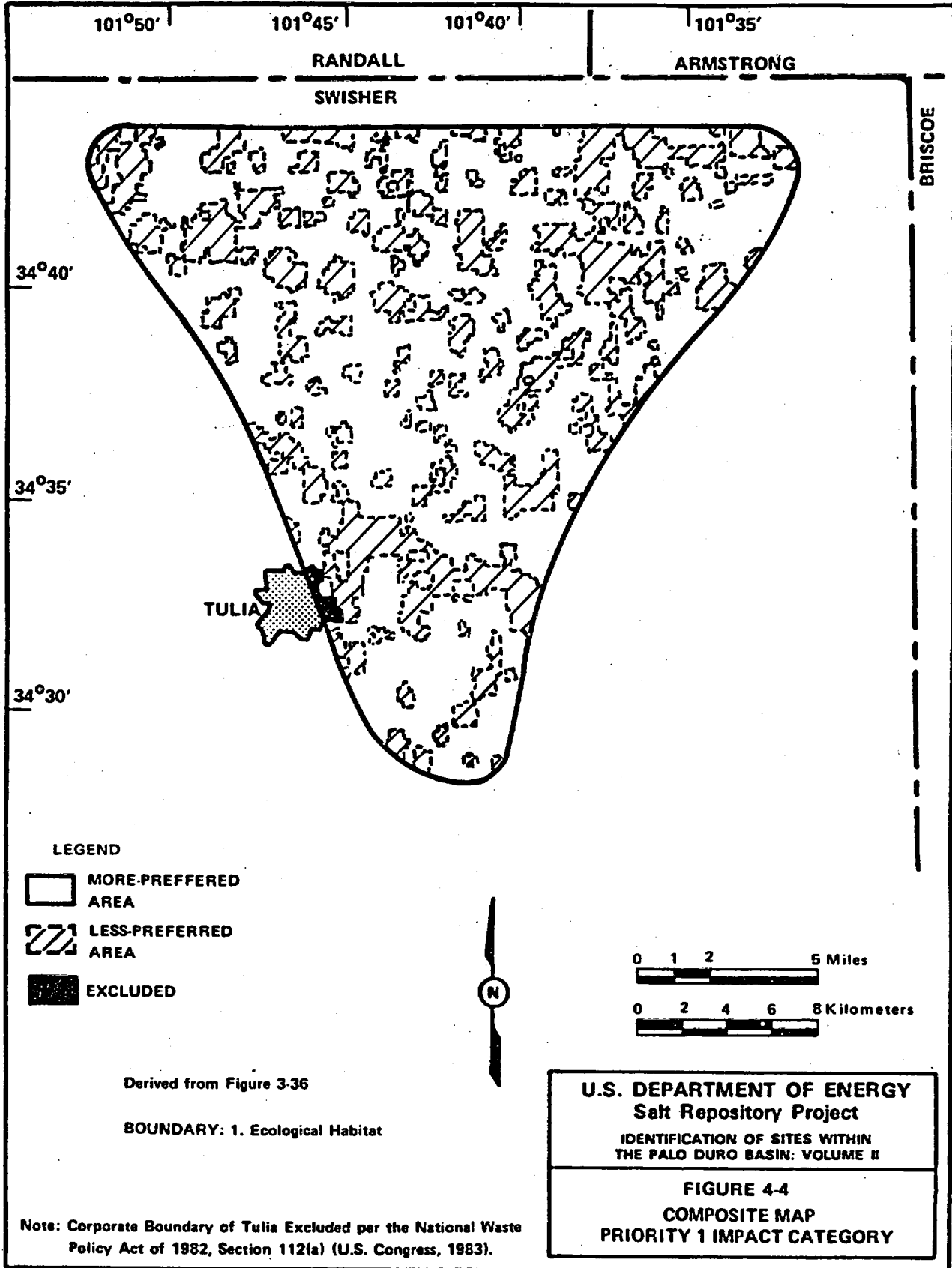
Note: Corporate Boundary of Tulia Excluded per the National Waste Policy Act of 1982, Section 112(a) (U.S. Congress, 1983)

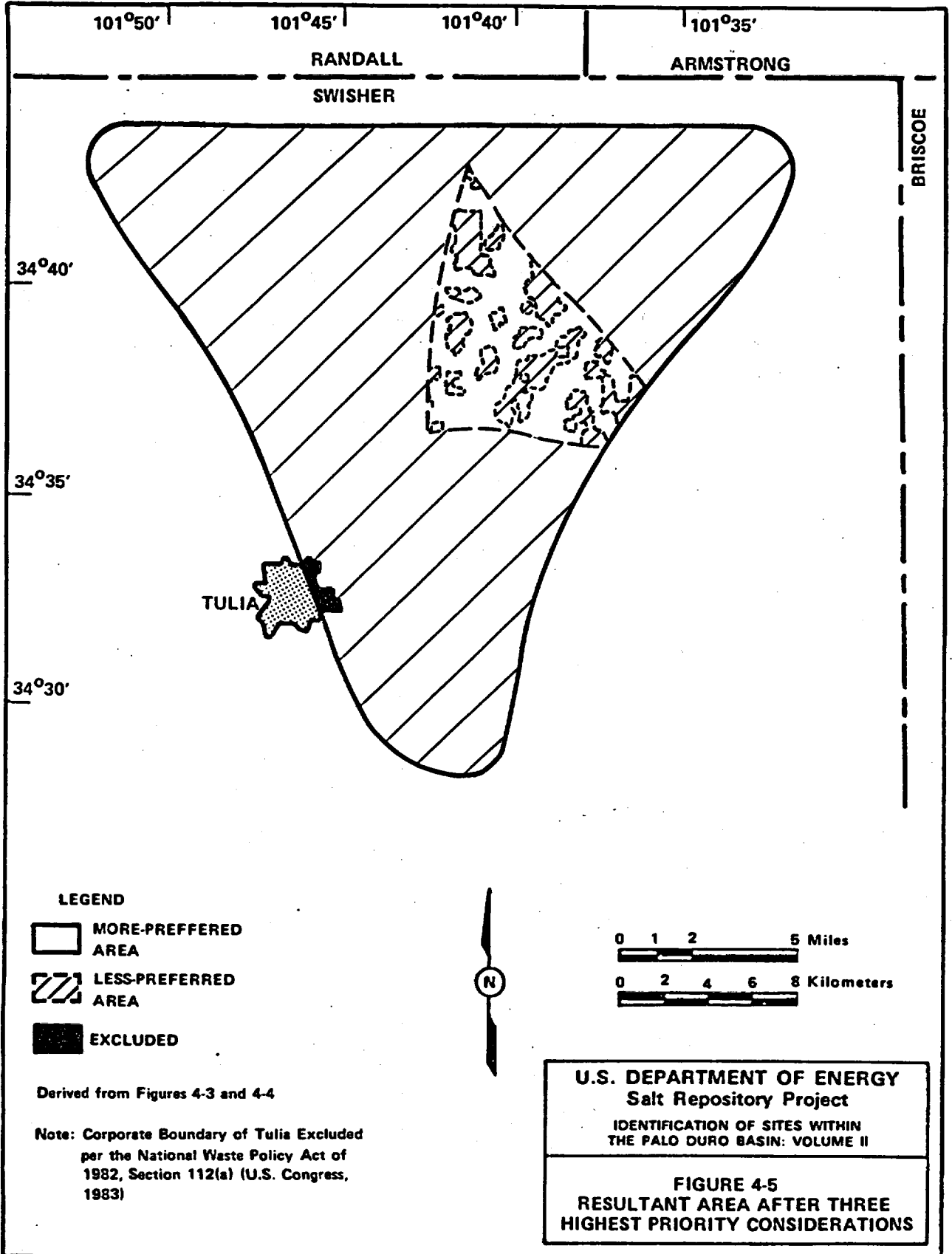


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**FIGURE 4-3
RESULTANT AREA AFTER
LONG-TERM AND OPERATIONAL
PERFORMANCE CONSIDERATIONS**





LEGEND

□ MORE-PREFERRED AREA

▨ LESS-PREFERRED AREA

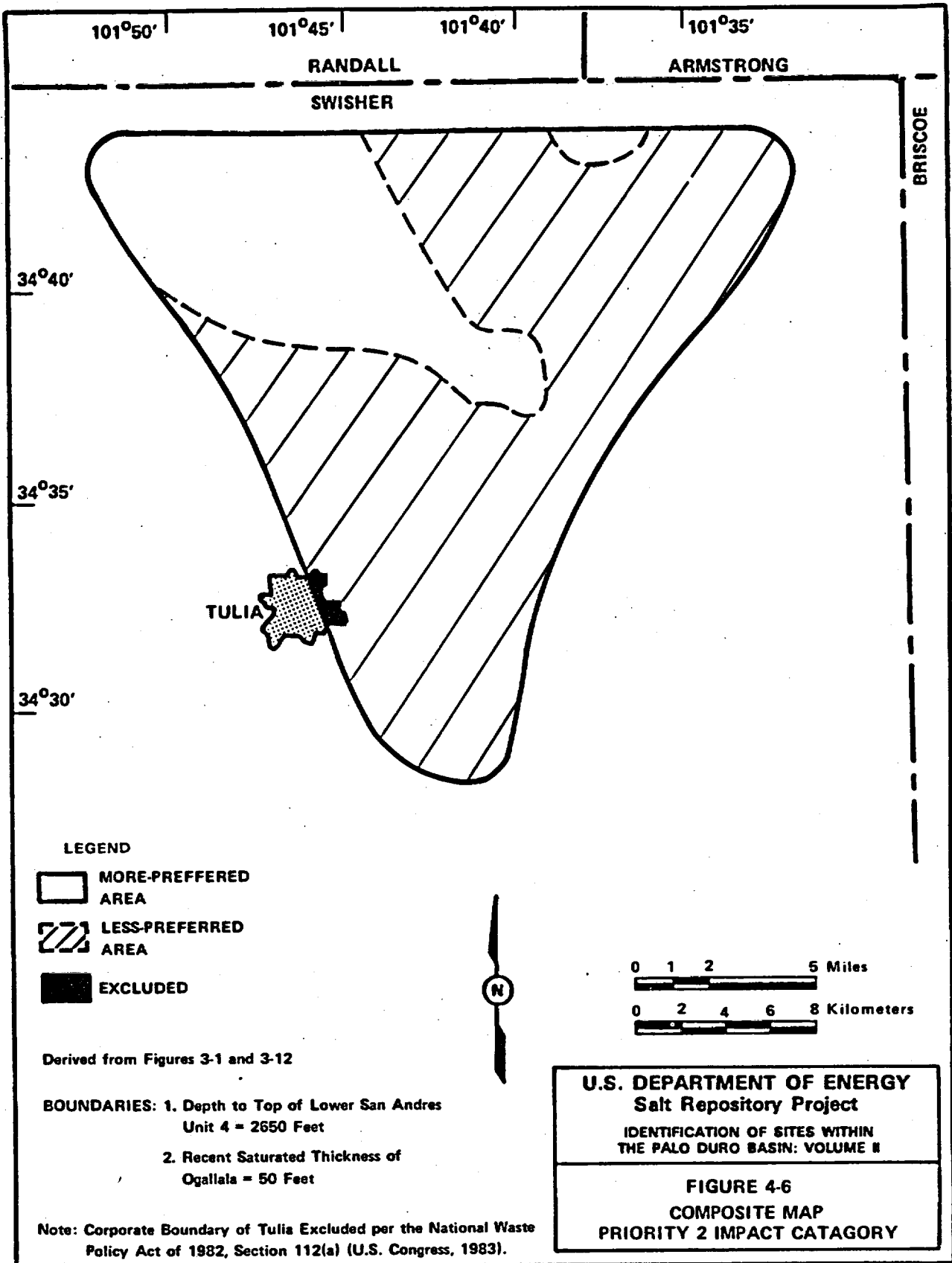
■ EXCLUDED

Derived from Figures 4-3 and 4-4




Note: Corporate Boundary of Tulia Excluded per the National Waste Policy Act of 1982, Section 112(a) (U.S. Congress, 1983)

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FIGURE 4-5
RESULTANT AREA AFTER THREE HIGHEST PRIORITY CONSIDERATIONS



LEGEND

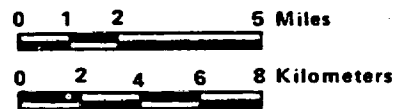
-  MORE-PREFERRED AREA
-  LESS-PREFERRED AREA
-  EXCLUDED

Derived from Figures 3-1 and 3-12

BOUNDARIES: 1. Depth to Top of Lower San Andres Unit 4 = 2650 Feet

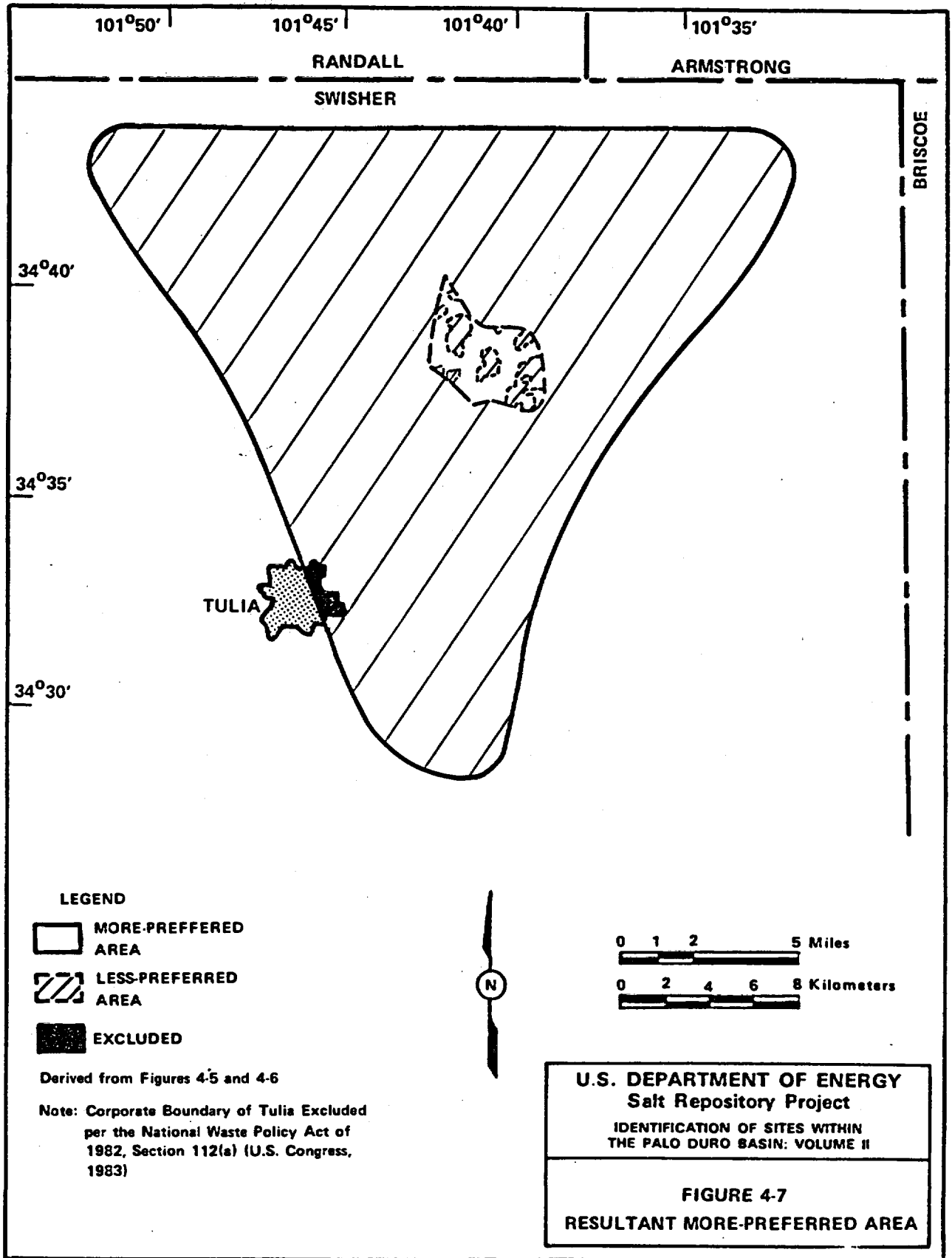
2. Recent Saturated Thickness of Ogallala = 50 Feet

Note: Corporate Boundary of Tulia Excluded per the National Waste Policy Act of 1982, Section 112(a) (U.S. Congress, 1983).






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FIGURE 4-6
COMPOSITE MAP
PRIORITY 2 IMPACT CATEGORY



LEGEND

-  MORE-PREFERRED AREA
-  LESS-PREFERRED AREA
-  EXCLUDED

Derived from Figures 4-5 and 4-6

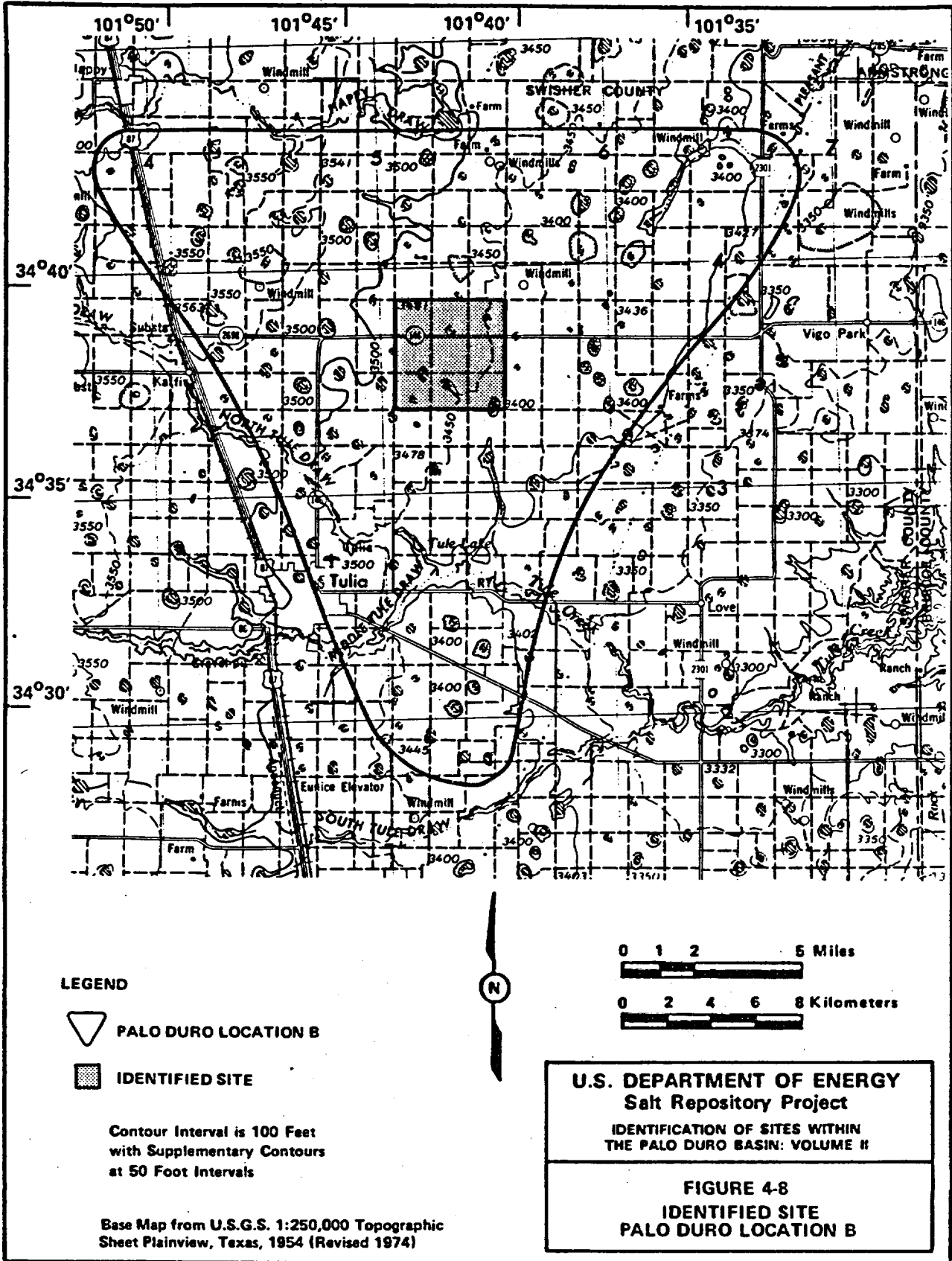
Note: Corporate Boundary of Tulia Excluded per the National Waste Policy Act of 1982, Section 112(a) (U.S. Congress, 1983)

0 1 2 5 Miles

0 2 4 6 8 Kilometers

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FIGURE 4-7
RESULTANT MORE-PREFERRED AREA



The outer boundaries of this more-preferred area are constrained by discriminators which are continuously variable across the location (i.e., operational performance, depth to lower San Andres unit 4, and recent Ogallala saturated thickness). Selection of a site along section boundaries was accomplished by encompassing much of the remaining more-preferred area, while not impinging on discrete variable discriminators of higher priority (i.e., location of boreholes which penetrate the host rock and thickness of host rock). The desired 9-square-mile (23-square-kilometer) site area (Figure 4-8) was delineated along section lines which extend approximately 1 mile (1.6 kilometers) west of the resulting more-preferred area in Figure 4-7. This is because a borehole which penetrates host rock precludes siting eastward and the 125-foot (38-meter) contour of "thick salt" in the lower San Andres unit 4 precludes siting to the south.

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DOC, see U.S. Department of Commerce.

DOD, see U.S. Department of Defense.

DOE, see U.S. Department of Energy.

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6 GLOSSARY

Accessible environment - the atmosphere, land surface, surface water, oceans, and the portion of the lithosphere that is outside the controlled area.

Aquifer - a formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquitard - a confined stratum or water-bearing zone below the surface of the earth that retards the movement of water.

Biota - the animal and plant life of a region.

Borehole - A hole drilled into the earth, often to a great depth, as a prospective production 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.

Brine - Water containing dissolved minerals in greater concentration than ordinary seawater. In salt deposits, brine may be present as fluid inclusions.

Brine migration - transport of brine inclusions through salt as a result of a sufficiently large gradient existing in the chemical potential of the salt.

Buffer Zone - a portion of the site geologic and surficial environment that surrounds the repository facility which is expected to be essentially undisturbed.

Characterization - the collection of information necessary to evaluate suitability for a potential nuclear repository site.

Clastic - consisting of fragments of rocks or of organic structures that have been moved individually from their places of origin.

Containment - the confinement of radioactive waste within a designated boundary.

Controlled area - a surface location, to be marked by suitable monuments extending horizontally no more than 10 kilometers (6 miles) in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be prohibited before and after permanent closure.

Critical habitat - any air, land, or water area (exclusive of those existing man-made structures or settlements that are not necessary to the survival and recovery of a listed species) and constituent elements thereof, the loss of which would appreciably decrease the likelihood of the survival and recovery of a listed species or a distinct segment of its population. The constituent elements of critical habitat include, but are not limited to, physical structures and topography, biota, climate, human activity, and the quality and chemical content of land, water, and air. Critical habitat may represent any portion of the present habitat of a listed species and may include additional areas for reasonable population expansion.

Demography - the study of characteristics of human populations, such as size, growth, density, distribution, and vital statistics.

Denudation - the sum of the natural processes by which the earth's surface is progressively worn away.

Descriptor - a characteristic or parameter that, if related data are available, describes a feature or behavior of a site which is important to performance or impacts from construction or operation of a repository.

Discriminator - a descriptor for which sufficient information is available to exhibit relevant variation within a location.

Disposal - the emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the isolation of such waste from the accessible environment.

Dissolution - the process by which solids or minerals, such as salts, are dissolved by liquids, typically water.

Ecological habitat - the area or type of environment in which an organism or biological population normally lives or occurs.

Endangered species - any plant or animal species protected under U.S. Public Law 93-205 which is in danger of extinction throughout all or a significant portion of its range (other than species of insects determined to be pests).

Expected - assumed to be probable or certain on the basis of existing evidence and in the absence of significant evidence to the contrary.

Facility - any structure, system, or system component, including engineered barriers, created by the U.S. Department of Energy to meet repository performance or functional objectives.

Fault - a fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture or zone of fractures.

Flood-prone areas - the lowland and relatively flat areas which would fill with water resulting from the Probable Maximum Flood.

Geochemical - of or pertaining to geochemistry (the chemical characteristics of materials that constitute the earth).

Geohydrology - pertaining to ground water and its movements through geologic environment.

Geologic repository - a system, requiring licensing by the U.S. Nuclear Regulatory Commission, that is intended to be used, or may be used, for the disposal of radioactive waste in excavated geologic media. A geologic repository includes (1) the geologic-repository operations area and (2) the portion of the geologic setting that provides for isolation of the radioactive waste and is located within the controlled area.

Geologic setting - the geologic, hydrologic, and geochemical systems of the region in which a geologic-repository operations area is or may be located.

Geomorphic processes - geologic processes that are responsible for the general configuration of the earth's surface, including the development of present landforms and their relationships to underlying structures, and are responsible for the geologic changes recorded by these surface features.

Ground water - all subsurface water in an aquifer as distinct from surface water.

Host rock - the geologic medium in which the waste is emplaced, specifically the geologic materials that directly encompass and are in close proximity to the underground facility.

Hydraulic conductivity - the volume of water that will move through a medium in a unit time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Hydraulic gradient - a change in the static pressure of ground water, expressed in terms of the height of water above a datum, per unit of distance in a given direction.

Hydrologic process - any hydrologic phenomenon that exhibits a continuous change in time, whether slow or rapid.

Igneous activity - the emplacement (intrusion) of molten rock material (magma) into material in the Earth's crust or the expulsion (extrusion) of such material onto the earth's surface or into its atmosphere or surface water.

Isolation - the act of inhibiting the transport of radioactive material so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

Likely - possessing or displaying the qualities, characteristics, or attributes that provide a reasonable basis for confidence that what is expected indeed exists or will occur.

Maximum credible earthquake - the highest magnitude earthquake that, considering the earthquake history and the tectonic setting of a place, could be expected to occur during the operation of a repository.

Mitigation - (1) avoiding the impact altogether by not taking a certain action or parts of an action; (2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; or (5) compensating for the impact by replacing or providing substitute resources or environments.

Modified Mercalli Intensity (MMI) - a subjective scale used to estimate the intensity of an earthquake. The scale varies from I to XII. A reading of I indicates an earthquake so slight it was not felt; IV indicates that chandeliers shake; and XII indicates very extensive damage.

Potentiometric Surface - The surface to which the water from a given confined aquifer would rise by hydrostatic pressure.

Probable Maximum Flood (PMF) - that flood discharge which would result from the probable maximum precipitation in combination with the most extreme hydrologic conditions which cause higher discharges that are reasonably possible in the region.

Probable Maximum Precipitation (PMP) - the theoretically greatest depth of precipitation for a given duration over a particular drainage area at a certain time of year that results from maximized intensity-duration values obtained from all types of storms.

Prime Farmland - Land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion as determined by the Secretary of Agriculture pursuant to the Farmland Protection Policy Act (PL 97-98). Prime farmland includes land that possesses the above characteristics and is being used currently to produce livestock and timber but it excludes land already in or committed to urban development or water storage.

Quaternary Period - the second period of the Cenozoic Era, following the Tertiary, beginning 2 to 3 million years ago and extending to the present.

Radioactive waste or waste - high-level radioactive waste and other radioactive materials, including spent nuclear fuel, that are received for emplacement in a geologic repository.

Radioactive waste facility - a facility subject to the licensing and related regulatory authority of the U.S. Nuclear Regulatory Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat. 1244).

Radionuclide retardation - the process or processes that cause the time required for a given radionuclide to move between two locations to be greater than the ground water travel time, because of physical and chemical interactions between the radionuclide and the geohydrologic unit through which the radionuclide travels.

Repository - is synonymous with "geologic repository".

Repository construction - all excavation and mining activities associated with the construction of shafts, shaft stations, rooms, and necessary openings in the underground facility, preparatory to radioactive waste emplacement, as well as the construction of necessary surface facilities, but excluding site characterization activities.

Repository operation - all of the functions at the site leading to and involving radioactive-waste emplacement in the underground facility, including receiving, transportation, handling, emplacement, and, if necessary, retrieval.

Repository support facilities - all permanent facilities constructed in support of repository construction, operation, and closure activities, including surface structures, utility lines, roads, railroads, and similar facilities, but excluding the underground facility.

Restricted area - any area, access to which is controlled by the U.S. Department of Energy for purposes of protecting individuals from exposure to radiation and radioactive materials before repository closure, but not including any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.

Retrieval - the act of intentionally removing radioactive waste before repository closure from the underground location at which the waste had been previously emplaced for disposal.

Screening - the process of evaluating an area, on the basis of criteria, to identify places that best fulfill the criteria.

Site - a potentially acceptable site or a candidate site, as appropriate, until such time as the controlled area has been established, at which time the site and the controlled area are the same.

Site characterization - activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and ranges of the parameters of

a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken.

Seismic - pertaining to, characterization of, or produced by earthquakes or earth vibrations.

Seismicity - the tendency for the occurrence of earthquakes.

Shaft - a man-made hole, either vertical or steeply inclined, that connects the surface with the underground working of a mine.

Site (system) performance - the total, integrated result of all acting processes and events caused by or affecting a repository.

Socioeconomic - of or pertaining to social and economic factors and their combination.

Subsidence - sinking of a part of the earth's crust relative to adjacent parts.

Surface facilities - repository support facilities within the restricted area.

Surface water - any waters on the surface of the earth, including fresh and salt water, ice, and snow.

System - the site, engineered components, and associated processes and events that affect expected repository performance, considered as an integrated entity.

Tectonic - of, or pertaining to, the forces involved in, or the resulting structures or features of, "tectonics".

Tectonics - the branch of geology dealing with the broad architecture of the outer part of the earth, that is, the regional assembly of structural or deformational features and the study of their mutual relations, origins, and historical evolution.

Thick salt - a salt bed with interbeds of nonsalt and poor quality salt individually not exceeding 10 feet thick and cumulatively not exceeding 15 percent of total bed thickness.

Threatened species - Any plant or animal species protected by U.S. Public Law 93-205 which is likely to become an endangered species within the foreseeable future throughout all or a portion of its range.

Topography - the physical surface features of a district or region, especially the relief and contour of the land.

Uplift - the process that results in elevation of a portion of the earth's crust relative to an adjacent portion.

Volcanism - the processes by which magma and its associated gases rise into the crust and are extruded onto the earth's surface and into the atmosphere.

Waste package - the waste form and any containers, shielding, packing, and other sorbent materials immediately surrounding an individual waste container.

APPENDIX A

THERMAL-HYDROLOGICAL EFFECTS ON GROUND-WATER FLOW THROUGH SALT

One factor that can affect the extent of the disturbed zone is the effect of the waste-generated heat on ground-water flow through salt.

Only very preliminary calculations using finite element modeling have been accomplished to quantify the effect of heat on ground-water flow through salt. These calculations were performed by INTERA Environmental Consultants, Inc., under contract to Battelle. In these preliminary calculations, the Palo Duro Basin was selected as an example potential repository site. It was assumed that porous media (Darcy) flow was an appropriate representation of ground-water movement through salt. Under these assumptions, the pre-waste emplacement interstitial ground-water velocity in the salt strata was predicted to be downward at about 2×10^{-5} meter per year for a hydraulic conductivity of about 10^{-6} meter per day for the salt.

When a heat-generation equivalent to that in conceptual repository designs (RRC-IWG, 1983, Table 2-1) was superimposed on the salt formation, a time-dependent flow velocity was predicted in the salt between the two interbeds modeled (Yates sandstone and lower San Andres unit 4 dolomite); however, the velocities remained quite low for all cases modeled as summarized below:

<u>Assumed Hydraulic Conductivity for Salt (m/day)</u>	<u>Steady-State (no heat) Velocity (m/yr)</u>	<u>Interstitial Velocity in Salt (m/yr) at Specified Time (yr)</u>
$\sim 10^{-4}$	$\sim 1.0 \times 10^{-3}$	3.0×10^{-2} @ 100 1.2×10^{-3} @ 1,000 1.0×10^{-3} @ 10,000
$\sim 10^{-6}$	$\sim 2.0 \times 10^{-5}$	1.5×10^{-3} @ 100 4.0×10^{-4} @ 1,000 1.0×10^{-4} @ 10,000

From these data, it can be seen that although thermally induced flow through the salt might be experienced to some distance (e.g., the nearest major interbed), the distance traveled by water from the vicinity of the repository toward the accessible environment remains rather limited upon the considerations of these effects of the waste-generated heat. Even at a very high

value of hydraulic conductivity for salt (approximately 10^{-4} meter per day), the water is predicted to travel less than, or on the order of, 10 meters from the repository in 1,000 years; and, in less than 10,000 years, the flow regime would have returned to very near its steady-state condition. At a hydraulic conductivity of 10^{-6} meter per day (still fairly high for salt), the simulation indicated that the effects of the heat on the flow might remain longer in that the steady-state conditions had not returned in the 10,000 years. However, the water in the vicinity of the repository is predicted to travel less than 10 meters in the 10,000 years, since the velocities are lower at these lower hydraulic conductivities.

From these preliminary calculations, it would appear that the effects of waste-generated heat on ground-water flow through salt can affect "repository performance" only over distances of less than about 10 meters.

REFERENCE

Reference Repository Conditions Interface Working Group, 1983. Results of Repository Conditions Study for Commercial and Defense High-Level Nuclear Waste and Spent Fuel Repositories in Salt, ONWI-483, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

APPENDIX B

DISSOLUTION OF SHALLOW SALTS OVERLYING LOCATION B.
IN THE PALO DURO BASIN

Vertical (downward) migration of the so-called shallow (upper) dissolution zone (sometimes called interior basin dissolution) can be shown to occur at rates which will not compromise the ability of the lower San Andres salt beds to isolate radionuclides. The conclusion is arrived at through making the conservative assumptions and calculations listed below:

1. Both the Seven Rivers and Salado Formations originally extended across the location with cumulative thicknesses of salt equal to the greatest combined cumulative salt thickness of these formations now occurring anywhere in the Palo Duro Basin (i.e., Hale County).
2. The difference between the original cumulative thickness of salt in the Seven Rivers and Salado Formations and the cumulative thicknesses remaining in those formations in the location represents the amount of salt dissolved out.
3. All dissolution of the Seven Rivers and Salado Formations salt occurred after deposition of the Ogallala Formation (about 3 million years ago).
4. Salt is still being actively dissolved from the uppermost salt in the Upper Seven Rivers Formations (there is little or no salt remaining in the Salado Formation).
5. Dissolution will continue at the same rate for the next 10,000 years, then

$$t = \frac{(T_{SA} + T_{SR}) - t_p}{3 \times 10^6} \times 10^4 \quad (B-1)$$

where:

t = thickness of salt dissolved from top of uppermost salt during the next 10,000 years

T_{SA} = original thickness of Salado

T_{SR} = original thickness of Seven Rivers

t_p = thickness of Seven Rivers remaining at site.

Using Equation B-1 and values for Palo Duro Location B (Budnik and Smith, 1982, Figures 51 and 53) of $T_{SA} = 290$ feet, $T_{SR} = 400$ feet, and $t_p = 230$ feet, the thickness of salt dissolved during the next 10,000 years at Palo Duro Location B is

$$\frac{290 + 400 - 230}{3,000,000} \times 10,000 = 1.5 \text{ feet}$$

REFERENCE

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APPENDIX C

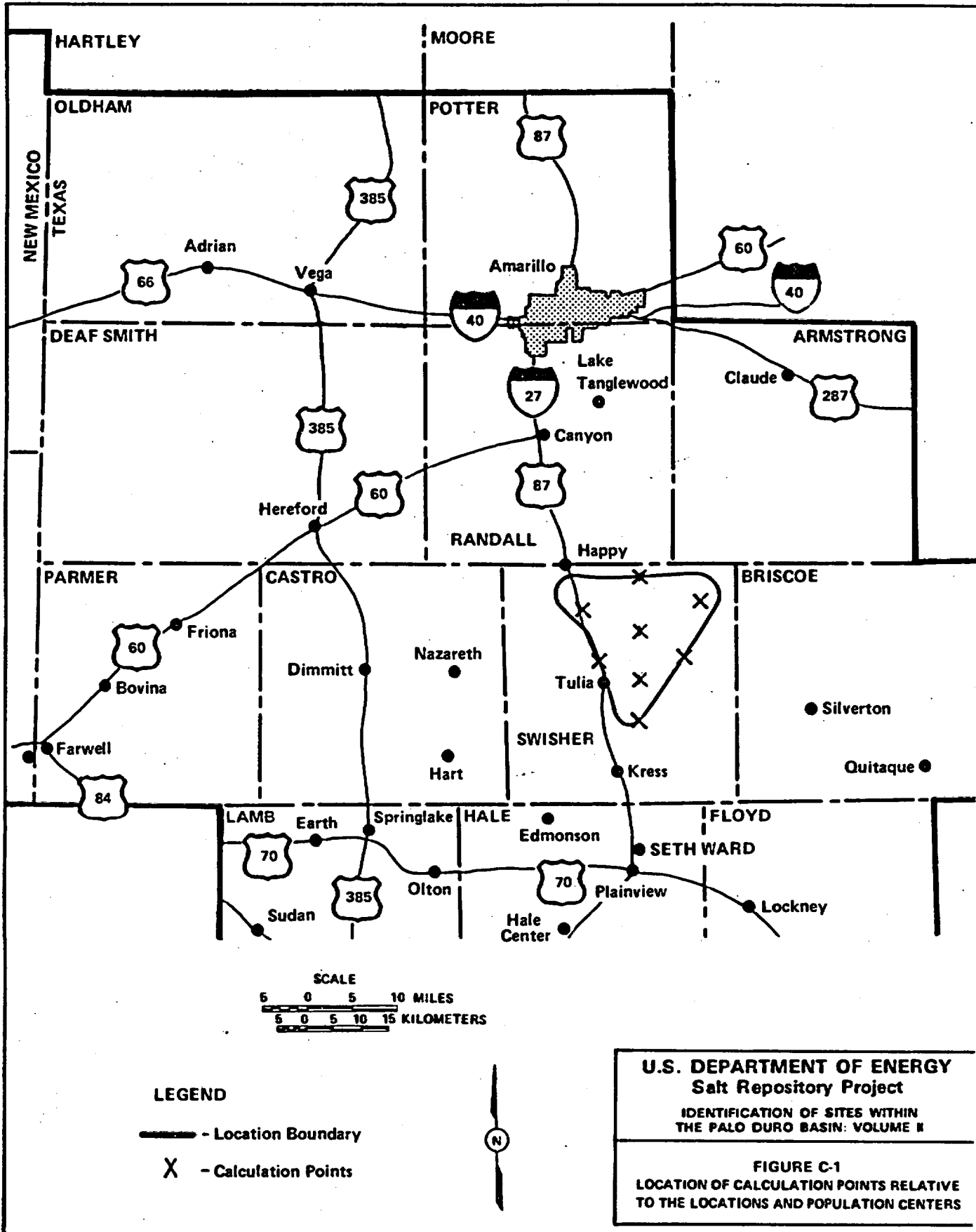
RADIOLOGICAL CONSIDERATIONS IN SITE SELECTION

The NWTS site performance criterion, Proximity to Population Centers, Demography (DOE, 1981), contains the statement that the repository site shall be located at a distance away from urban areas, or places that serve as urban centers, sufficient to minimize the potential risk to the population from radiation exposure. In evaluating the potential radiological risk, calculations of the potential radiological exposure from normal repository operations were made for eight points within the Swisher location. These eight points are shown in Figure C-1.

The variables that determine the radiological exposure to the population include: (1) the distance the people are from the point of release (i.e., the distance from the repository); (2) the direction of the people from the release point; (3) the percentage of the time each direction is downwind from the release point; and (4) the dispersion characteristics of the local meteorology that determine the ground-level radionuclide concentration per unit release rate.

The population distribution for areas within 60 miles of the location was determined using the 1980 census data (DOC, 1982b; NUS, 1984b). Rural population densities were estimated by subtracting the population of urban areas from the total county population and then dividing the results by the total area of the county. This information is provided in Table C-1.

A population grid was created for each point being evaluated within the location. Each 60-mile (96-kilometer) radius grid (see Figure C-2) consisted of 96 sectors centered in the 16 major compass points (north, north-northeast, northeast, etc.) bounded by concentric circles of 10, 20, 30, 40, 50, and 60 miles (16, 32, 48, 64, 84, and 96 kilometers). The population within each sector was determined by multiplying the rural population density per square mile by the number of square miles in that sector and adding the population of any population centers.



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FIGURE C-1
 LOCATION OF CALCULATION POINTS RELATIVE
 TO THE LOCATIONS AND POPULATION CENTERS

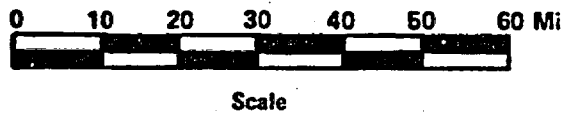
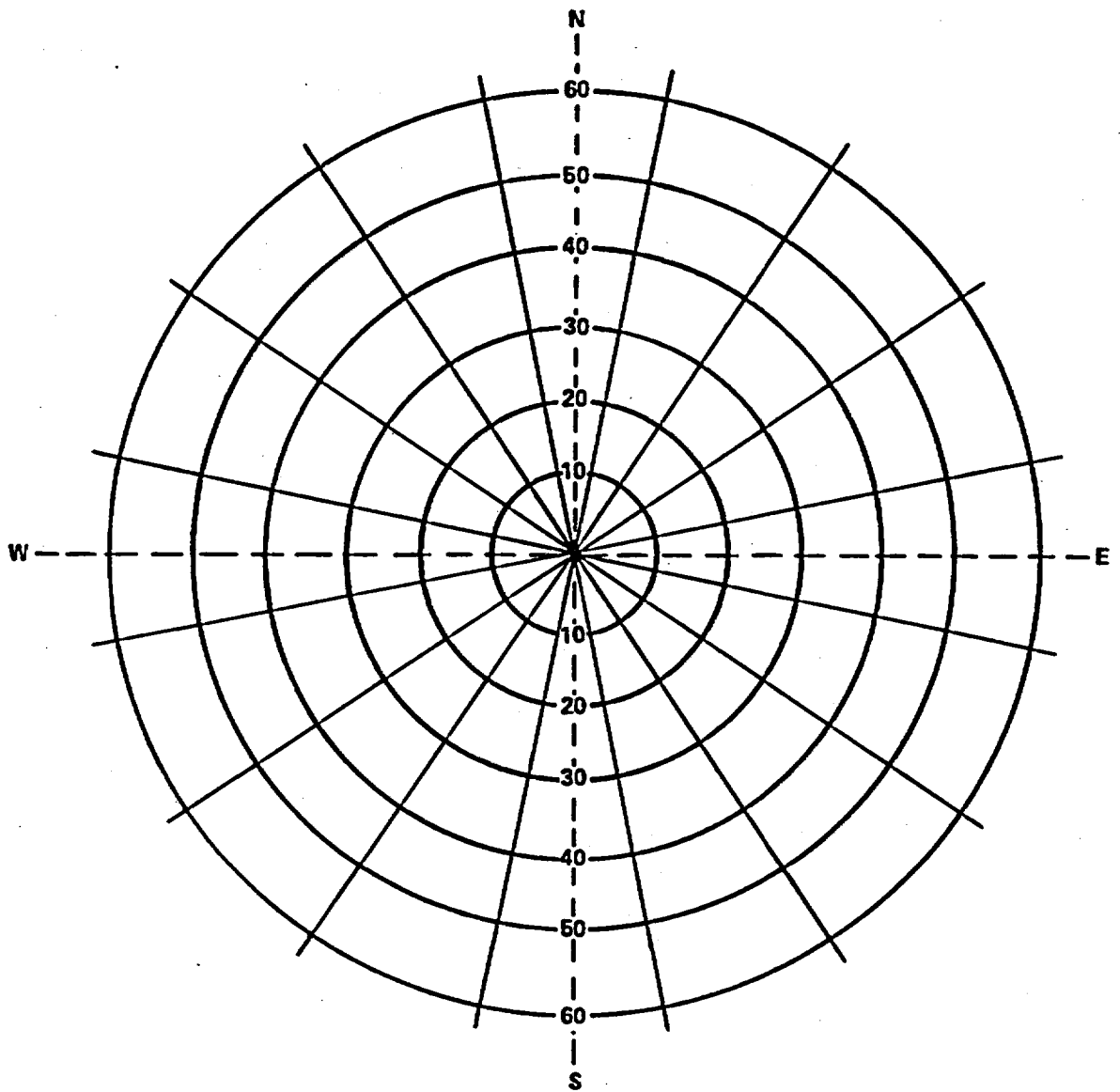
Table C-1. Population Distributions

County/State/ Population Center	County Area (mi ²)	Population				Average Rural Density (person/mi ²)
		County	Urban	Total Urban	Rural	
<u>Armstrong TX</u>	910	1,994	-	1,112	882	1.0
Claude			1,112			
<u>Briscoe TX</u>	887	2,519	-	1,614	965	1.1
Quitaque			696			
Silverton			918			
<u>Carson TX</u>	900	6,672	-	5,071	1,601	1.8
Panhandle			2,226			
Groom Town			736			
Skelly Town			899			
White Deer			1,210			
<u>Castro TX</u>	899	10,556	-	6,326	4,230	4.7
Dimmit			5,019			
Hart			1,008			
Nazareth			299			
<u>Curry NM</u>	1,408	42,019	-	36,721	5,298	3.8
Clovis			31,194			
Grady			122			
Melrose			649			
Texico City			958			
Cannon AFB			3,798			
<u>Deaf Smith TX</u>	1,497	21,165	-	15,853	5,312	3.5
Hereford			15,853			
<u>Donley TX</u>	905	4,075	-	2,765	1,310	1.4
Clarendon			2,220			
Howardwick			165			
Hedley			380			
<u>Parmer TX</u>	885	11,038	-	6,662	4,376	4.9
Bovina			1,499			
Farwell			1,354			
Friona			3,809			
<u>Potter TX</u>	902	98,637	-	90,588	8,049	8.9
Amarillo*			90,588			
<u>Randall TX</u>	917	75,062	-	69,851	5,211	5.7
Amarillo*			58,642			
Canyon			10,726			
Lake Tanglewood			485			
<u>Swisher TX</u>	902	9,723	-	6,490	3,233	3.6
Kress			783			
Tulia			5,033			
Happy			674			

Table C-1. Population Distributions (Continued)

County/State/ Population Center	County Area (mi ²)	Population				
		County	Urban	Total Urban	Rural	Average Rural Density (person/mi ²)
<u>Quay NM</u>	2,874	10,577	-	7,958	2,619	0.9
House			117			
Logan			735			
San Jan			341			
Tucumcari			6,765			
<u>Floyd TX</u>	992	9,834	-	6,527	3,307	3.3
Floydada			4,193			
Lockney			2,334			
<u>Hale TX</u>	1,005	37,592	-	30,498	7,094	7.1
Abernathy			2,904			
Edmonson			291			
Hale Center			2,297			
Petersburg			1,633			
Plainview			22,187			
Seth Ward			1,186			
<u>Hantley TX</u>	1,488	3,987	-	2,587	1,400	0.9
Channing			304			
Dalhart			2,283			
<u>Lamb TX</u>	1,013	18,669	-	13,440	5,229	5.2
Amherst			971			
Earth			1,512			
Littlefield			7,409			
Olton			2,235			
Spring Lake			222			
Sudan			1,091			
<u>Moore TX</u>	909	16,575	-	15,044	1,531	1.7
Cactus			898			
Dumas			12,194			
Sunray			1,952			
<u>Oldham TX</u>	1,485	2,283	-	1,122	1,161	0.8
Adrian			222			
Vega			900			

*Amarillo, Texas, has a total population of 149,230 in Potter and Randall Counties.



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**FIGURE C-2
POPULATION GRID**

The meteorological characteristics of the area determines how any radio-nuclides released during normal operations will be dispersed. The important meteorological factors in determining these dispersion characteristics are wind direction and speed and the amount of (solar) insolation. With this information, an estimate of the ground-level concentration per unit release rate can be determined through the use of a Gaussian diffusion model.

Meteorological data specific to each site are not available. The National Weather Service (NWS) station in Amarillo, Texas, is the nearest source of comprehensive meteorological data on wind direction and speed. These data are summarized in Figure C-3 and Table C-2. Because the terrain between the NWS station and the location is flat, this information is believed to be representative of the site.

As shown in Table C-3, the wind speed and an assumption of moderate day-time insolation can be used to determine the atmospheric stability class.

With information in the appropriate stability class, the annual average wind speed for each direction being evaluated and an assumed ground-level release (as required by the NRC), the following equation can be used to calculate the ground-level concentrations of each radionuclide in terms of curies per cubic meter (Ci/m^3) per unit release rate for that radionuclide, x/Q :

$$x/Q = \frac{1}{\pi \bar{u} \sigma_y \sigma_z} \quad (\text{C-1})$$

where:

- \bar{u} = annual average wind speed, m/s
- σ_y = horizontal dispersion coefficient
- σ_z = vertical dispersion coefficient
- π = 3.14159.

The \bar{u} value comes from Table C-2. The σ_y and σ_z coefficients can be read from Figures C-4 and C-5 and are dependent on the stability class (determined from Table C-3).

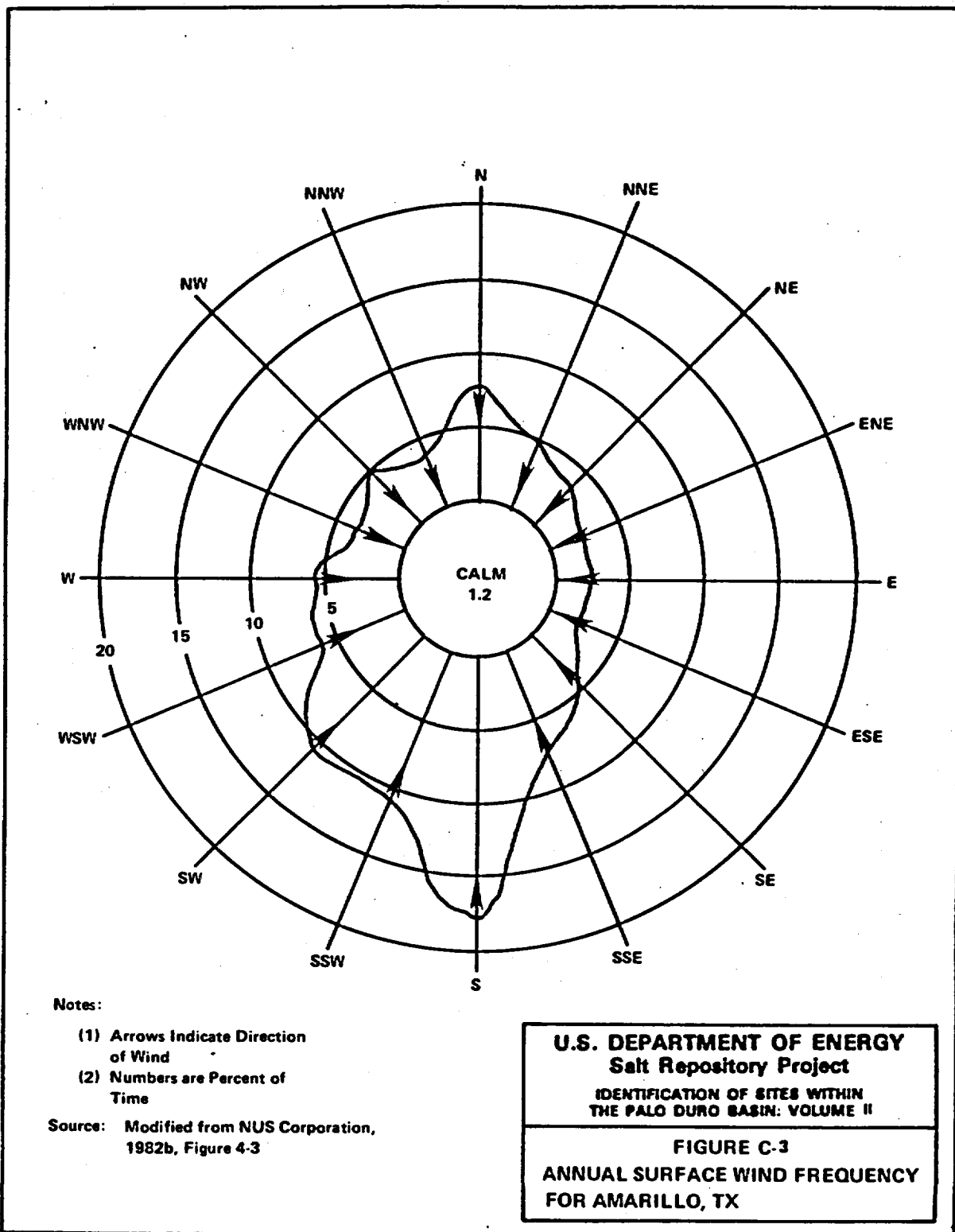


Table C-2. Annual Mean Wind Speed for the Texas Panhandle Area

Description	Frequency (%)	Average Wind Speed (mph)
N	8	15
NNE	5	15
NE	4	13
ENE	2	12
E	3	11
ESE	2	12
SE	5	13
SSE	7	13
S	19	15
SSW	11	15
SW	11	14
WSW	6	14
W	6	15
WNW	3	13
NW	4	13
NNW	3	14
Calm	1	--
Total	100	13.7 (Annual)

Period of Record: 1/1/74 - 12/31/78
(NUS, 1982b).

Table C-3. Key to Stability Classes

Surface Wind Speed at 10 m (m/s)	Day - Insolation			Night - Cloud Cover	
	Strong	Moderate	Slight	Mostly Overcast	Mostly Clear
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	C	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night. Class A is the most unstable and class F is the most stable, with class B moderately unstable and class E slightly stable.

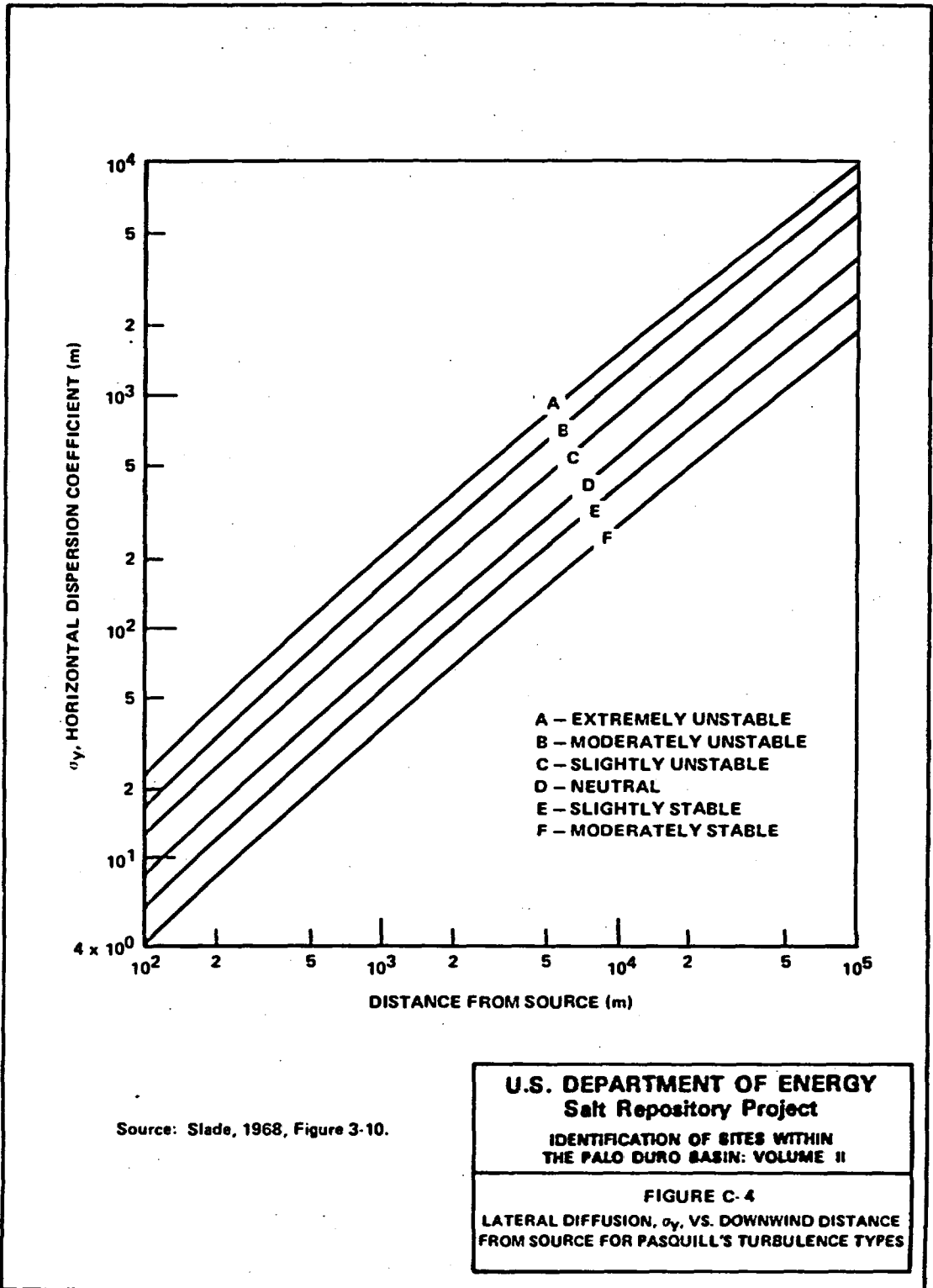
SOURCE: Turner, 1969.

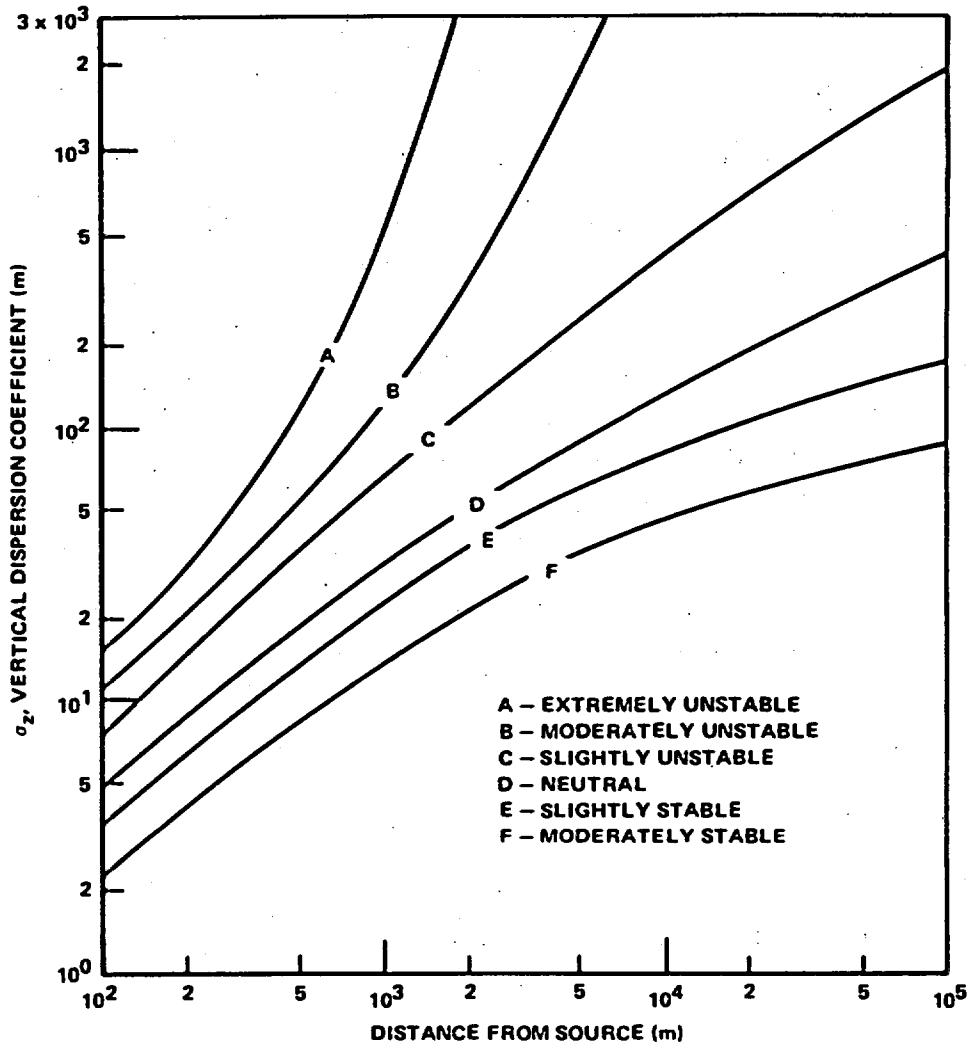
Using Equation C-1, an assumed stability class of D (neutral conditions), and a mean wind speed of 13.4 miles per hour (6 meters per second), the χ/Q values for various distances (the midpoint distances for the 10-, 20-, 30-, 40-, 50-, and 60-mile [16-, 32-, 48-, 64-, 80-, and 96-kilometer] annuli) are shown in Table C-4.

Given the information on the population of the 96 sectors being evaluated, the percentage of time the wind is blowing toward the area being evaluated, and the six χ/Q values from Table C-4, the "at risk" index can be calculated for each site by adding the products of the calculations for each sector.

For example, consider a sector that is 30 to 40 miles (48 to 64 kilometers) due north of a point in Swisher County. This sector has an area of approximately 137.4 square miles (355.9 square kilometers), a rural population density of 5.7 persons per square mile, and a population center of 58,642. The sector is downwind 19 percent of the time and has a χ/Q value of 6.37×10^{-8} . The calculations are as follows:

$$(137.4 \times 5.7 \times 58,642) \times 19 \times 6.37 \times 10^{-8} = 7.19 \times 10^{-2}$$





Source: Slade, 1968, Figure 3-11.

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FIGURE C-5
VERTICAL DIFFUSION, σ_z , VS. DOWNWIND DISTANCE
FROM SOURCE FOR PASQUILL'S TURBULENCE TYPES

Table C-4. Calculated x/Q Values for Normal Operations*

Increments From Point of Release	Annulus Midpoints	x/Q
0 - 10 mi (0 - 16 km)	5 mi (8,050 m)	4.71×10^{-7}
10 - 20 mi (16 - 32 km)	15 mi (24,100 m)	1.63×10^{-7}
20 - 30 mi (32 - 48 km)	25 mi (40,200 m)	9.57×10^{-8}
30 - 40 mi (48 - 64 km)	35 mi (56,300 m)	6.37×10^{-8}
40 - 50 mi (64 - 80 km)	45 mi (72,400 m)	4.56×10^{-8}
50 - 60 mi (80 - 96 km)	55 mi (88,500 m)	3.7×10^{-8}

*Mean wind speed is 13.4 mph (6 m/s), stability class D.

Performing the same mathematical operation for each of the 96 sectors and summing the product provides a relative index of the radiation risk associated with each site. After all eight points are evaluated, the data are normalized by dividing each sum by the lowest sum. This yields a relative index with the value of 1.0 indicating the lowest risk due to routine operations. The results of this process are presented in Figure 3-34 of the main body of the text.

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