DOE/CH-10(1)

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME 1—PALO DURO LOCATION A

NOVEMBER 1984

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 1—Palo Duro Location A,* DOE/CH-10(1), prepared for the Salt Repository Project Office by the Office of Nuclear Waste Isolation, Battelle Project Management Division, Columbus, OH.

NOTICE

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(1)
DISTRIBUTION CATEGORY UC-70

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME 1—PALO DURO LOCATION A

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 ptoential nuclear waste repository sites in the Palo Duro Basin of the Texas Panhandle. Volume 1 narrows à 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 Deaf Smith/Oldham Counties 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 A. Descriptors identified as discriminators are listed in Table 2.

TABLE 1. NWTS-33(2) CRITERIA DESCRIPTORS

- SITE GEOMETRY
  - Expected Erosion/Denudation
  - Depth to Host Rock[(a)]
  - Thickness of Host Rock
  - Lateral Extent of Host Rock
- GEOHYDROLOGY
  - 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
  - Brine Content and Chemistry
  - Solubility or Radionuclides
  - Radionuclide Retardation
- GEOLOGICAL CHARACTERISTICS
  - Subsurface Characterization
  - Thermally Induced Fractures/ Stresses
  - Chemical/Thermal Effects
  - Radiation Effects
  - Depth to Host Rock[(a)]
  - Presence of Interbeds
  - Gassy Conditions
- TECTONIC ENVIRONMENT
  - Volcanic Activity/Geothermal Gradient
  - Faults–Wolfcampian and Older
  - Faults–Younger Than Wolfcampian
  - Quaternary Faults
  - Tectonic Uplift/Subsidence
  - Seismicity and Ground Motion
- HUMAN INTRUSION
  - 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
  - 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
  - Population Density
  - Population Risk–Operations
  - Population Risk–Transportation
- ENVIRONMENTAL PROTECTION
  - 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
  - Construction and Operations Socioeconomic Impacts
  - Access and Utility Socioeconomic Impacts

(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 A)

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 Water Bodies (playas)
Proximate Transportation Installations (paved roads, pipelines, and electrical transmission facilities)

DEMOGRAPHY

Population Risk (operations)

ENVIRONMENTAL PROTECTION

Cultural Resources
Aesthetics
Ecological Habitat
Prime Farmland
Industrial/Commercial Installations
Proximity to Road Access (major highways)
Proximity to Rail Rights-of-way
Projected Saturated Thickness of Ogallala in the Year 2030

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. Because the available data show this location has relatively uniform subsurface characteristics throughout, few subsurface descriptors were identified as discriminators. The discriminators in the long-term performance category are 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; Projected saturated thickness of Ogallala in year 2030.

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 flood plains (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); 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 A, after applying long-term and operational performance and environmental/constructibility impacts priority categories 1, 2, and 3, is shown in Figure 1.

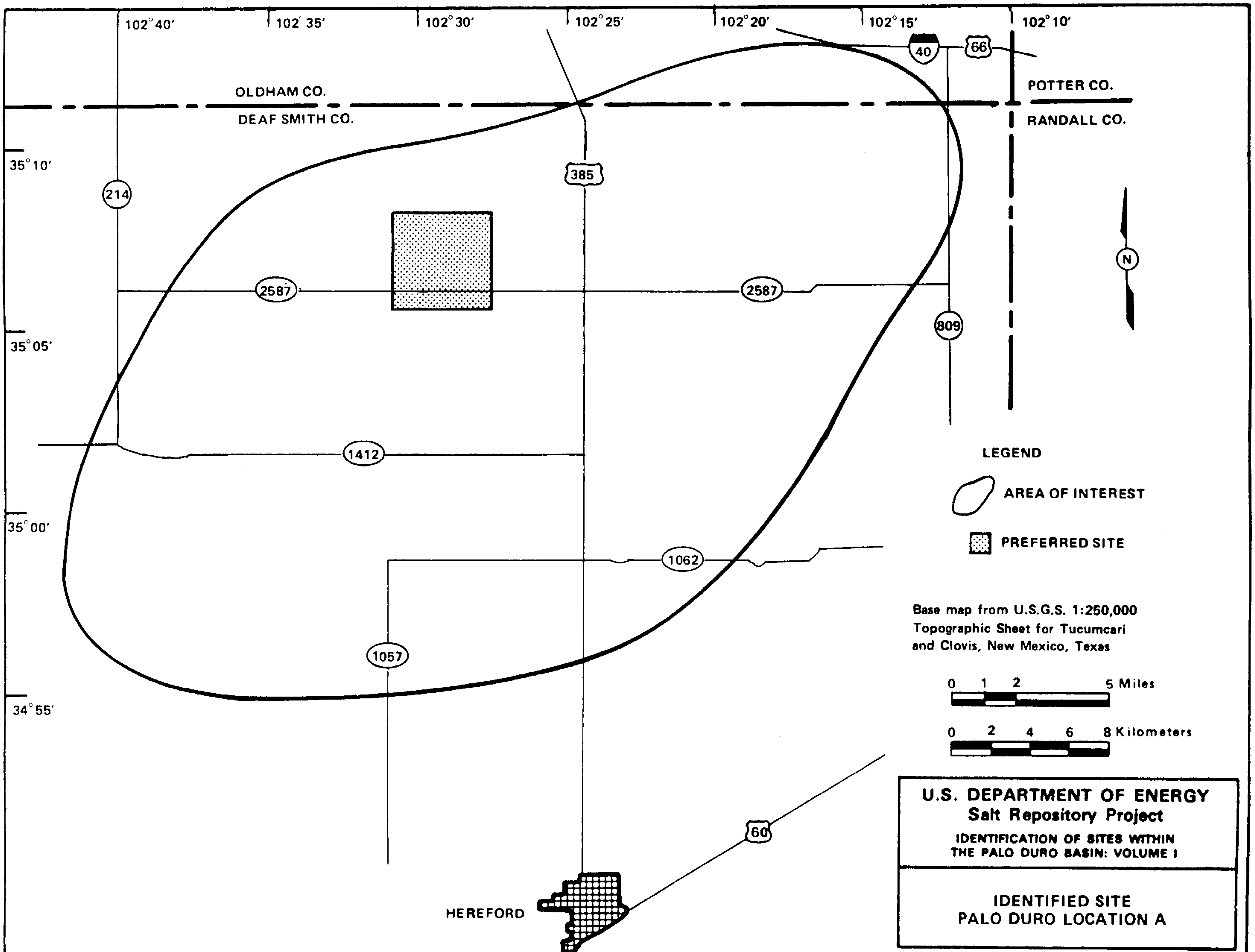

102°40′
102°35′
102°30′
102°25′
102°20′
102°15′
102°10′
40
66
OLDHAM CO.
DEAF SMITH CO.
POTTER CO.
RANDALL CO.
35°10′
35°05′
35°00′
34°55′
214
385
2587
2587
809
1412
1062
1057
60
N
HEREFORD
LEGEND
AREA OF INTEREST
PREFERRED SITE
Base map from U.S.G.S. 1:250,000
Topographic Sheet for Tucumcari
and Clovis, New Mexico, Texas
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 I
IDENTIFIED SITE
PALO DURO LOCATION A

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

LIST OF TABLES

1 INTRODUCTION

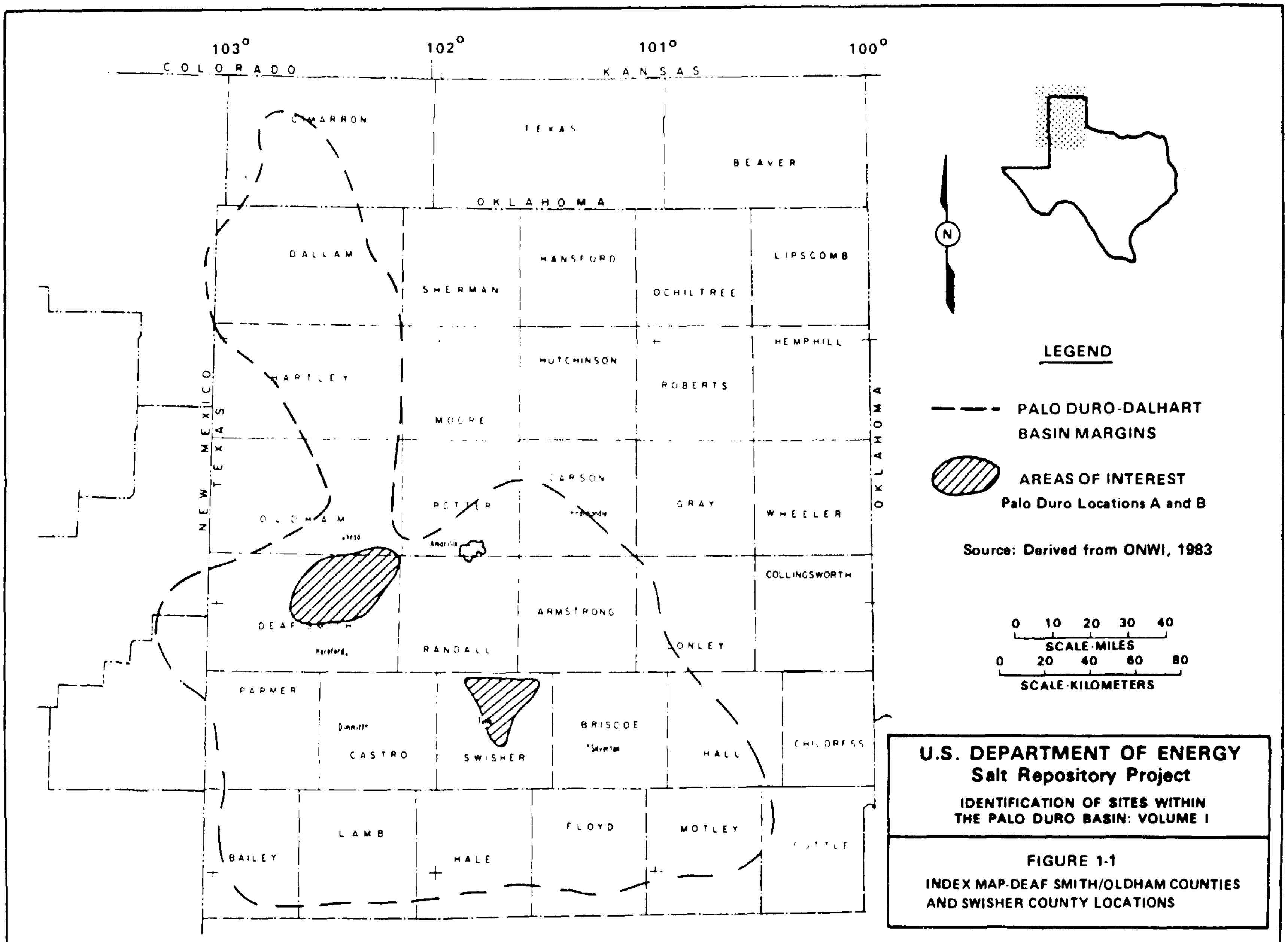
Two locations in the Palo Duro Basin of the Texas Panhandle (Figure 1-1) were identified as containing potentially acceptable sites for a nuclear waste repository (ONWI, 1983). These Palo Duro locations, Deaf Smith/Oldham Counties (Location A) and Swisher County (Location B), were named as potentially 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 rational employed, and identifies the site-sized area in Palo Duro Location A.

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



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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 <u>Site Geometry</u>

"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 emcompass 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.

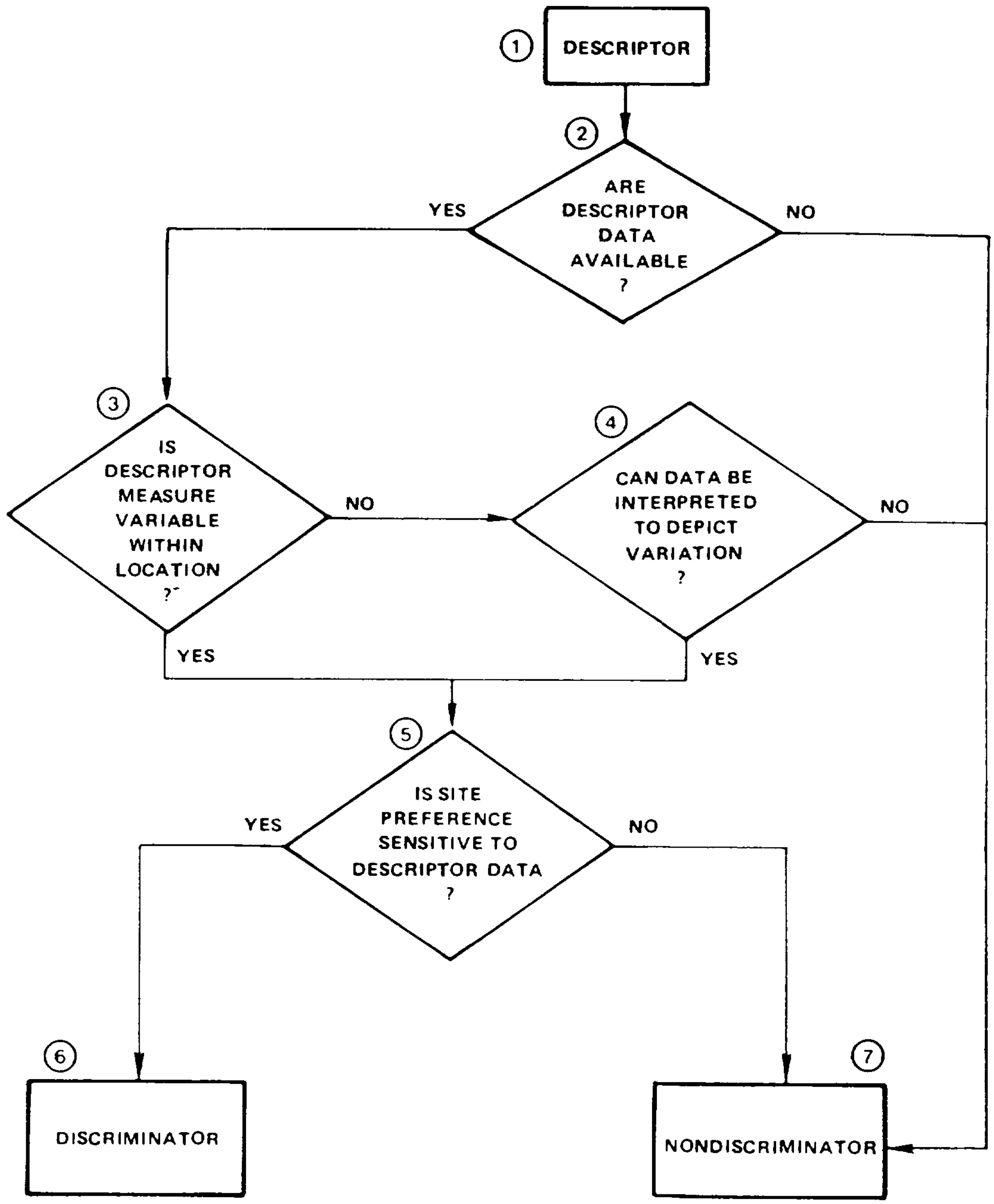
Step 5 Is site preference sensitive to descriptor data? Two sets of conditions were evaluated in this step: data that directly exhibit discernible variation within a location (from Step 3) and interpreted data that exhibit variation within the location (from Step 4). Preference with regard to the site-narrowing 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.



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 2-1
LOGIC DIAGRAM

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

Report Section No.	Performance Criteria Descriptor	Logic Path[a] Discriminator	Logic Path[a] 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		1-2-3-5-7
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. NWTS 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		1-2-3-5-7
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	Logic Path[a] Nondiscriminator
3.8	DEMOGRAPHY		
3.8	Population Density		1-2-3-4-5-7
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	1-2-3-5-6	
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

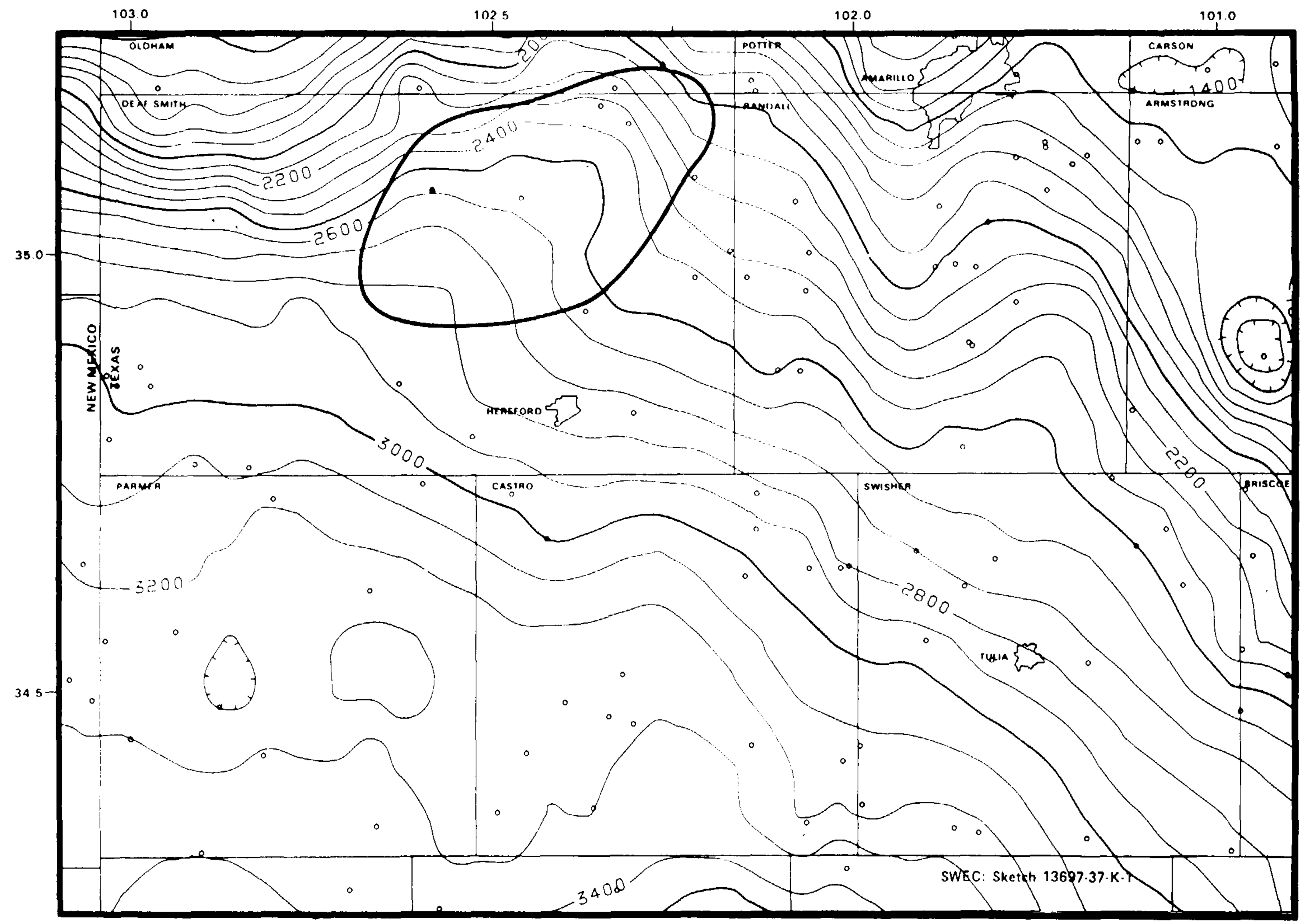
The sections that follow (3.1 to 3.10) describe each NWTS criterion and applicable identified descriptors, present data relevant to each descriptor, and track each descriptor through the logic path (Figure 2-1) to a final determination of discriminator or nondiscriminator.

3.1 SITE GEOMETRY

The lower San Andres unit 4 and unit 5 salts were previously identified as possible host rocks (ONWI, 1983). Recent detailed core analysis and evaluations made during preparation of conceptual underground designs have resulted in selection of the lower San Andres unit 4 salt as the planned host rock in the Deaf Smith/Oldham Counties location. While the lower San Andres unit 5 salt is potentially advantageous in that it is at shallower depths where constructibility problems may be fewer, the lower San Andres unit 4 salt is more favorable due to its greater thickness and relatively fewer interbeds. Both of these conditions are likely to permit greater design flexibility and possibly provide long-term performance advantages. Most evaluations in this volume are made only with regard to the lower San Andres unit 4 salt as a host medium. The lower San Andres unit 5 salt does, however, remain an alternative host rock.

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 2,050 feet (623 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



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 CUMULATIVELY NOT EXCEEDING 15% OF TOTAL BED THICKNESS

LEGEND

WELL CONTROL SHOWN BY OPEN CIRCLES

AREA OF INTEREST

SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

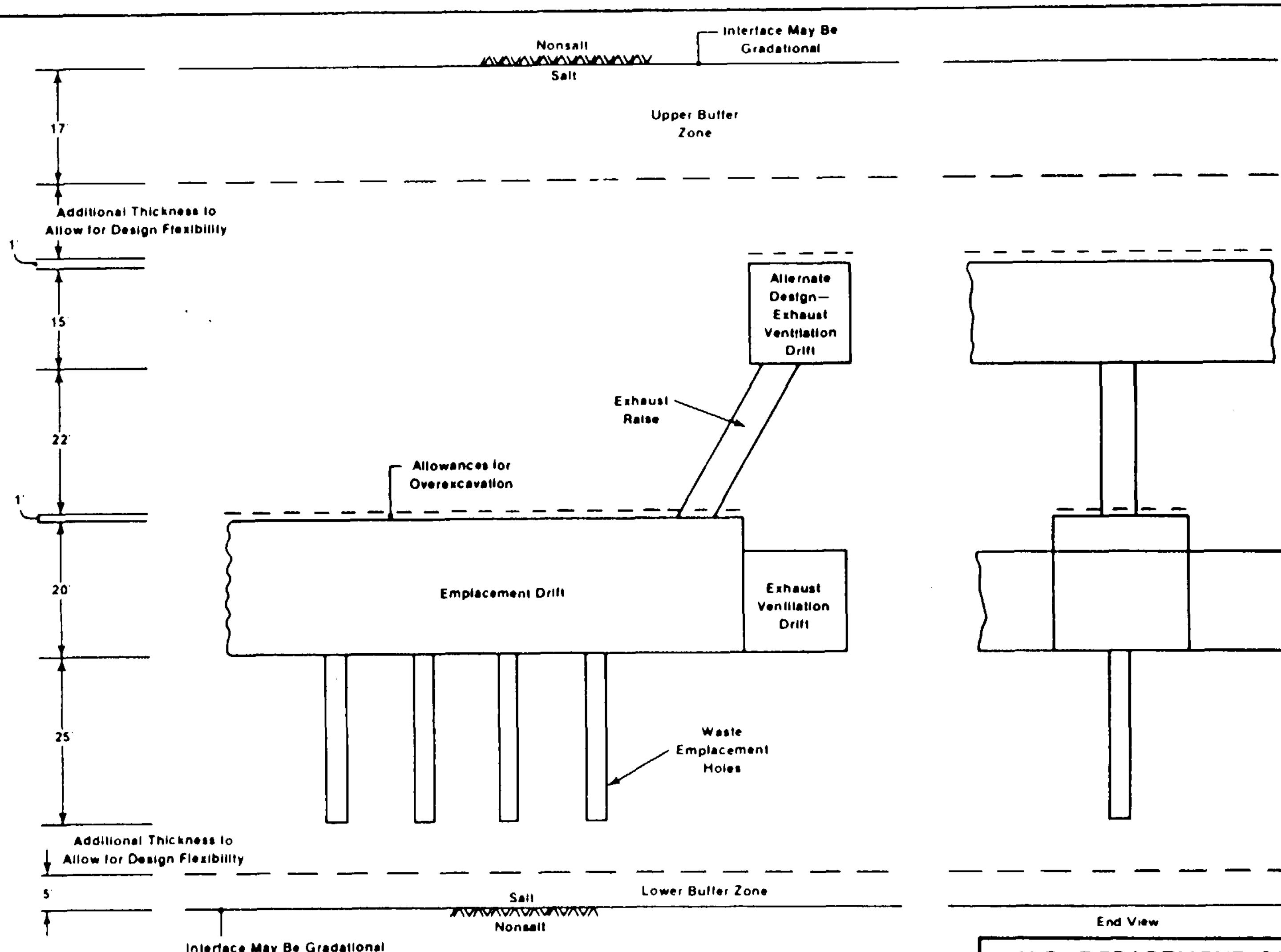
FIGURE 3-1
DEPTH TO LOWER SAN ANDRES UNIT 4

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 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 800 feet (240 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

*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

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

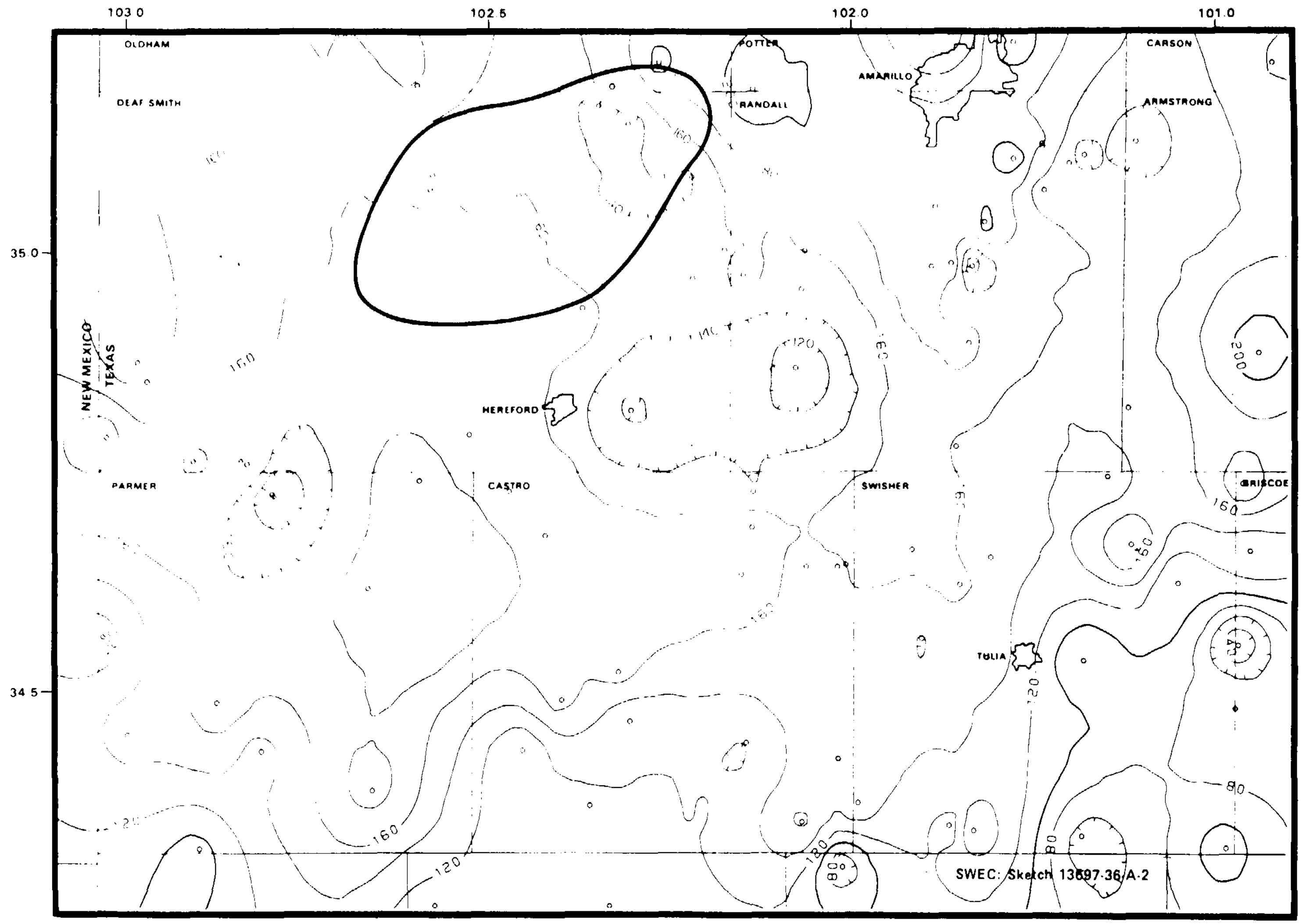
FIGURE 3-2
CONCEPTUAL REPOSITORY DESIGNS IN BEDDED SALT

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 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) shows that there is relatively little variation across the location with thickness everywhere in the location greater than 125 feet (38 meters). Most of the location appears to contain a thick salt bed of approximately 160 feet (49 meters). Small areas in the east-central and extreme northeast may vary from this value by 15 to 20 percent. However, the thickness variation across the location is not considered significant because the minimum thickness exceeds 125 feet (38 meters) which is thought to be conservatively restrictive. The descriptor, thickness of host rock, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

*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

N

SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

3.1.3 Lateral Extent of the Geologic System

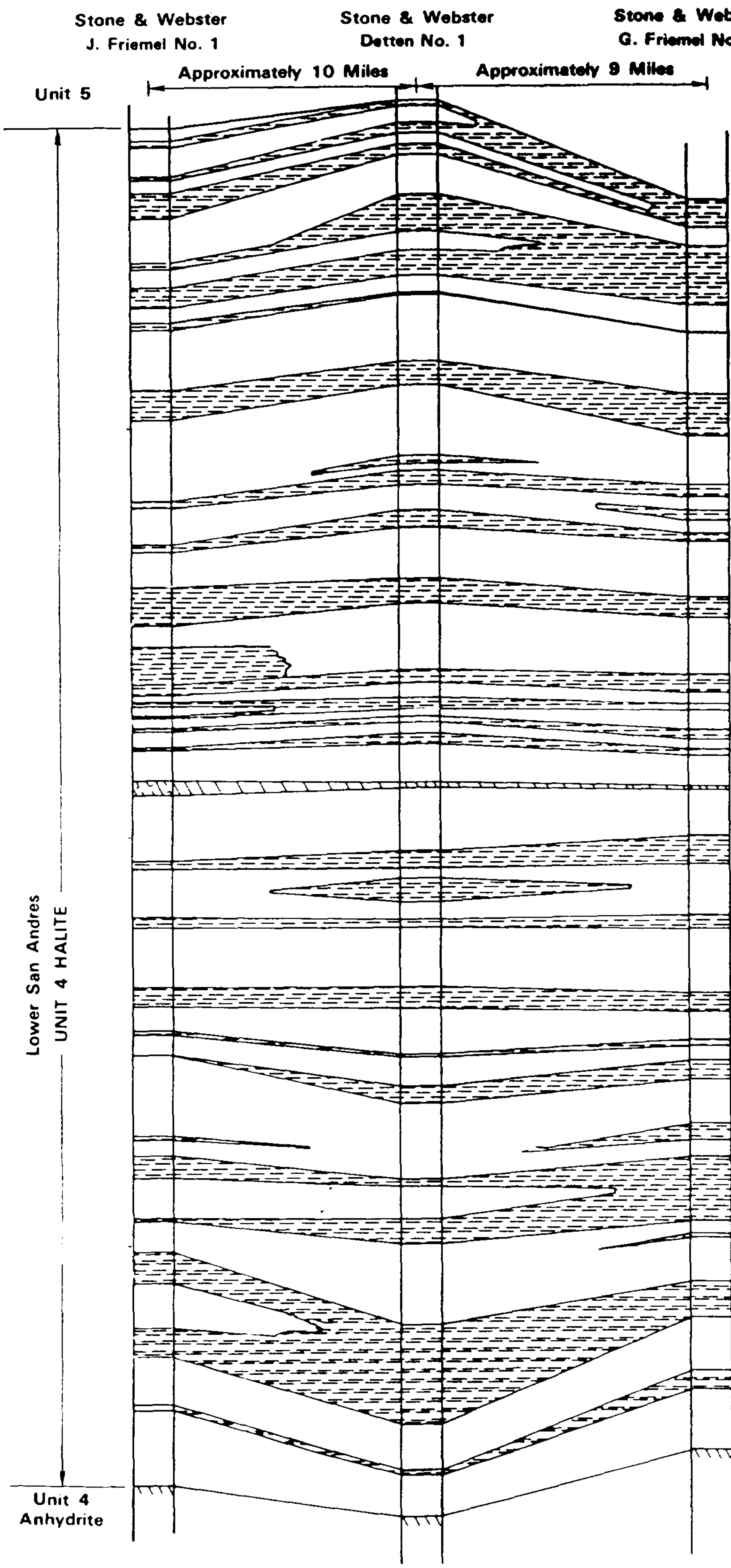
The lower San Andres unit 4 salt bed is believed to have been deposited in large brine pans (Presley, 1981). Thick salt within this unit has been mapped throughout the location (Figure 3-3) and for several miles beyond the location boundary. Individual interbeds or zones of interbeds have also been correlated 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 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).

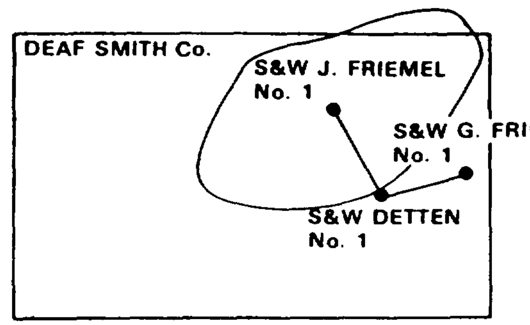
3.2 GEOHYDROLOGY

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





Legend

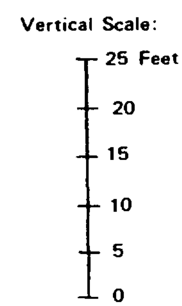
Halite generally containing less than 10 perc impurities

Halite generally containing greater than 10 percent mudstone impurities and/or abundant mudstone partings

Anhydritic zone

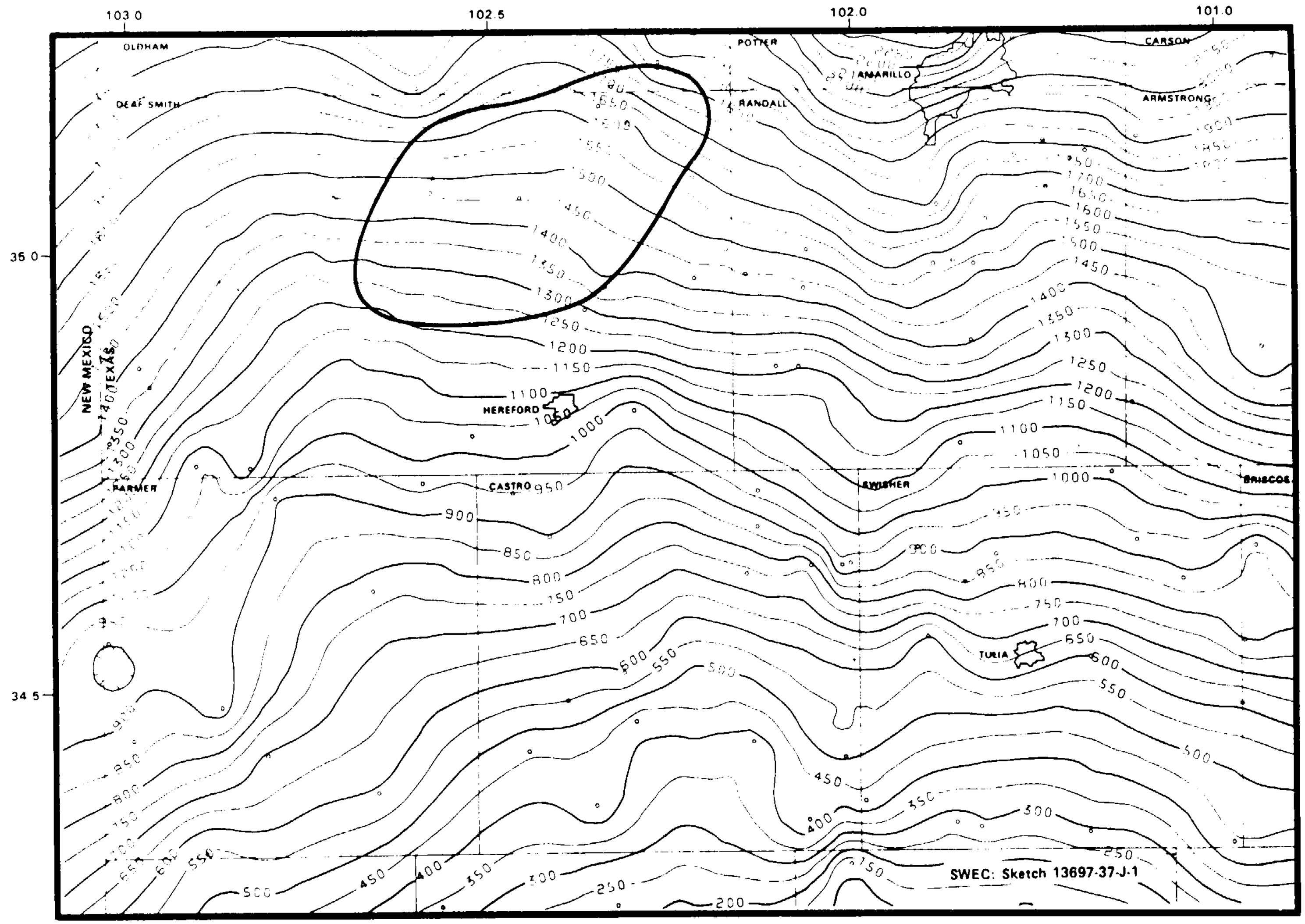
Note:
This illustration is an example of a correlation of zones of similar type salt. It depicts the overall continuity of rock types. Because it is a simplification and generalization of actual lithologic variation, this illustration should not be used for other purposes. Detailed logs of salt core 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



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

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

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-6
STRATIGRAPHIC COLUMN AND MAJOR HYDROSTRATIGRAPHIC UNITS

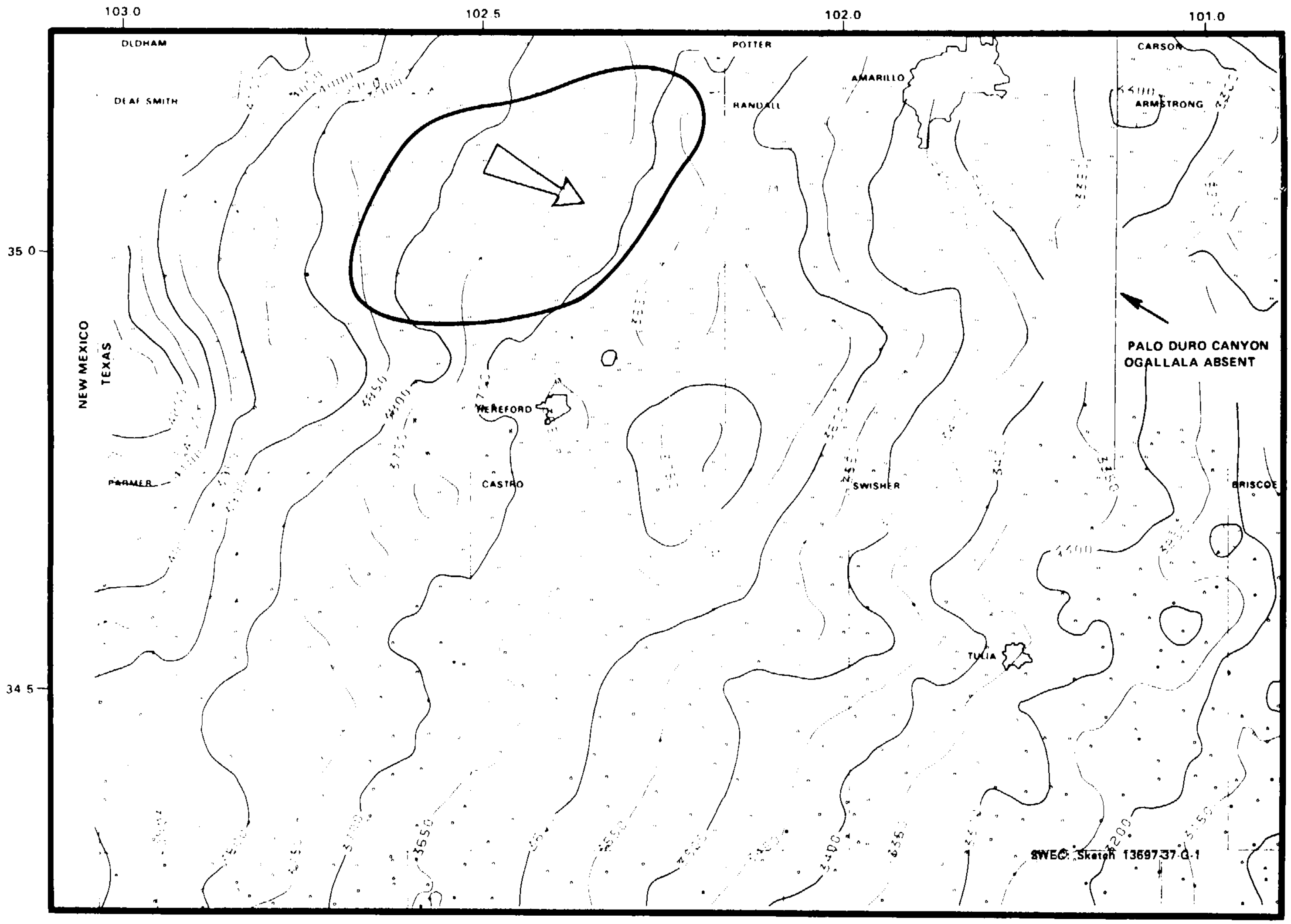
Group. This shallow unit overlies a thick, predominantly shale and evaporite aquitard, the middle hydrostratigraphic unit. The lower (deep-basin) hydrostratigraphic unit (Wolfcampian and Pennsylvanian strata) contains thick, carbonate and sandstone brine aquifers separated by shale.

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; and 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.

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).



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

SCALE

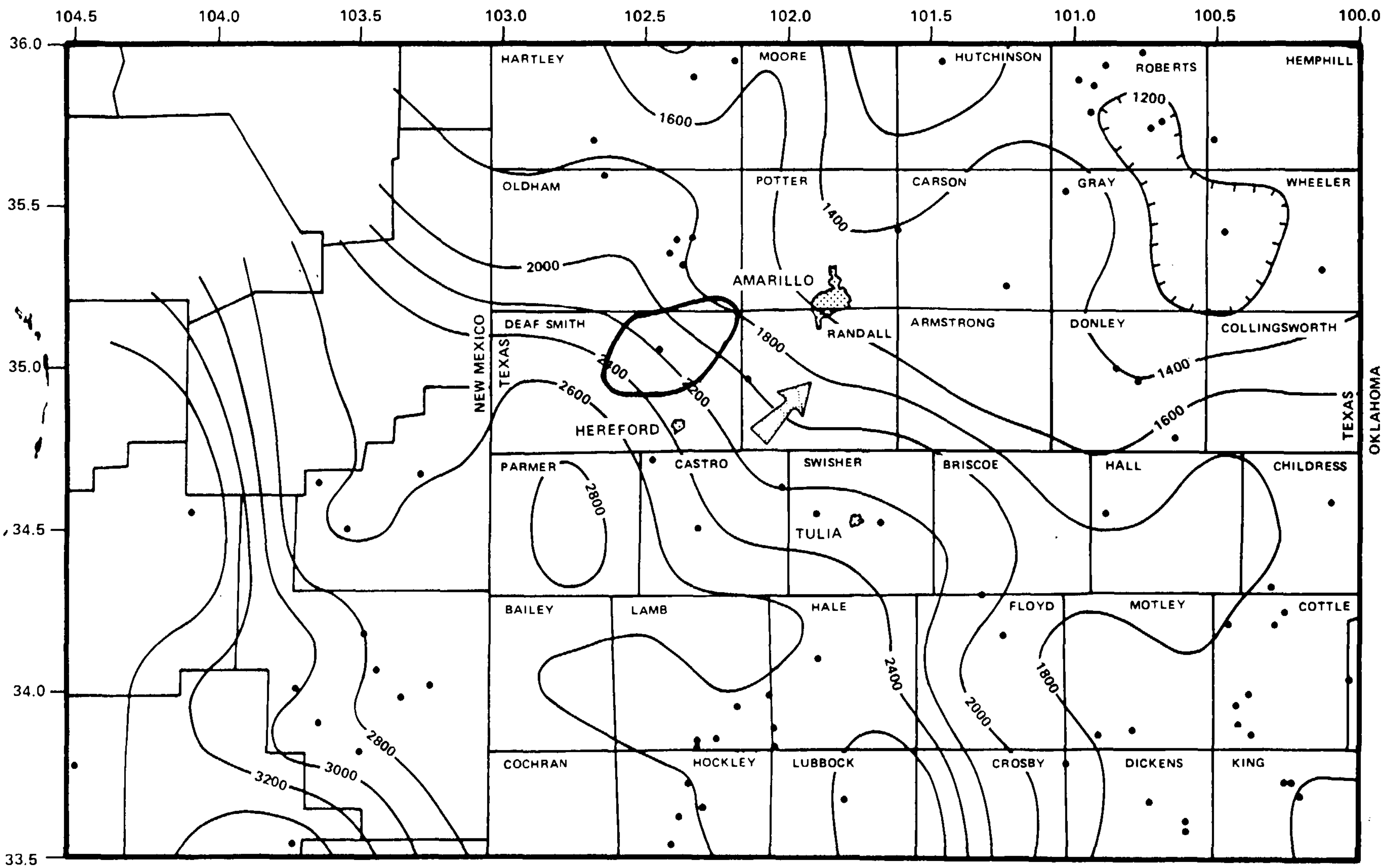
0 5 10 15 20 Mi

0 10 20 30 Km

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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



NOTES

CONTOUR INTERVAL 200 FEET

DATUM MEAN SEA LEVEL

LEGEND

WELL CONTROL SHOWN BY SOLID CIRCLES

AREA OF INTEREST

GENERALIZED GROUND-WATER FLOW DIRECTION

SOURCE: MODIFIED FROM SWEC, 1984a, FIGURE 18

SCALE

10 0 10 20 Mi

10 0 10 20 30 Km

N

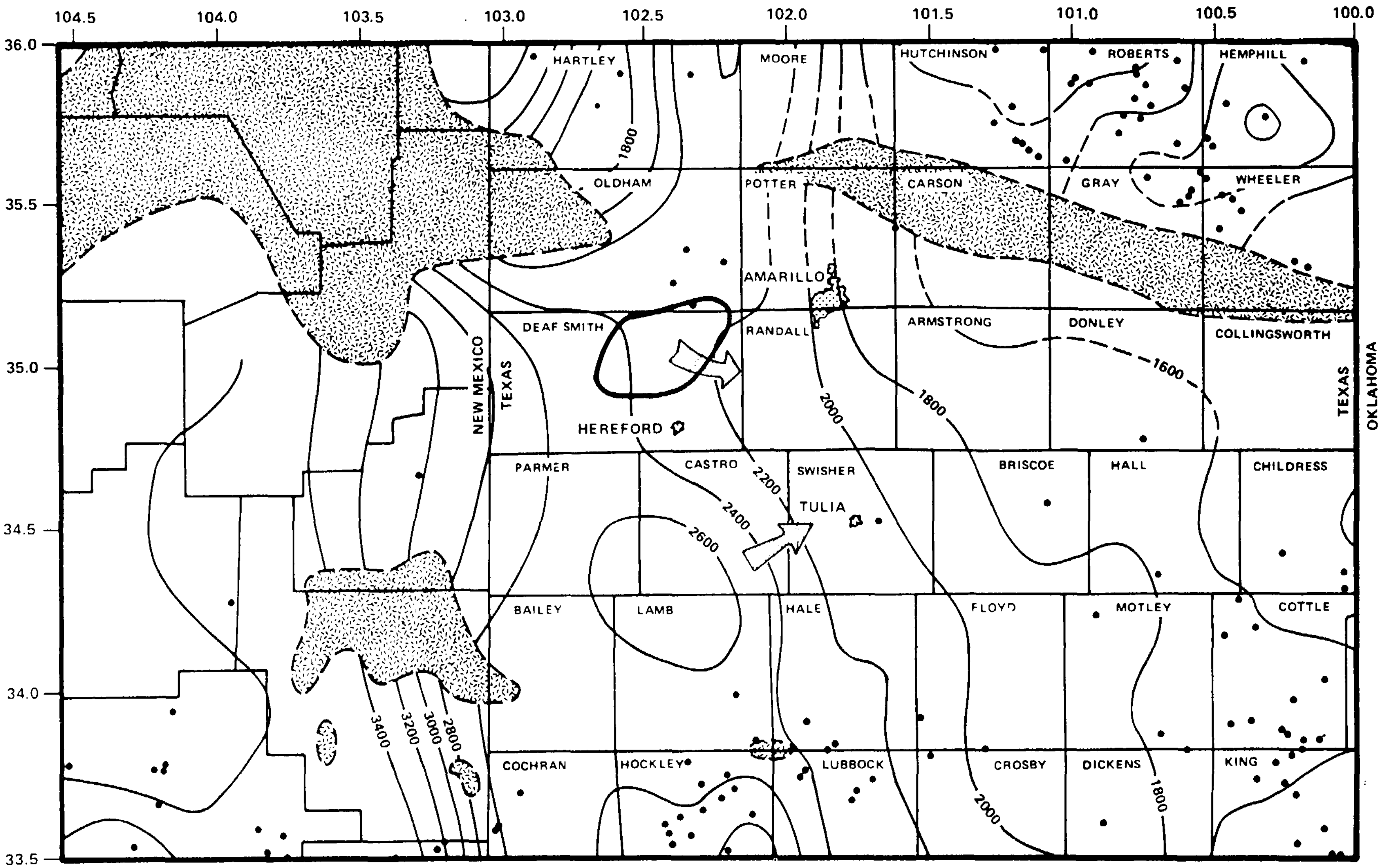
U.S. DEPARTMENT OF ENERGY

Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-8

WOLFCAMP POTENTIOMETRIC-SURFACE MAP



NOTES

CONTOUR INTERVAL 200 FEET

DATUM MEAN SEA LEVEL

GENERALIZED GROUND-WATER FLOW DIRECTION

LEGEND

WELL CONTROL SHOWN BY SOLID CIRCLES

AREA OF INTEREST

PENNSYLVANIAN ABSENT

SOURCE: MODIFIED FROM SWEC, 1984a, FIGURE 19

SCALE

10 0 10 20 Mi

10 0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-9
PENNSYLVANIAN POTENTIOMETRIC-SURFACE MAP

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 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 north of the location) 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. The Mansfield No. 1 (PD-4) borehole is in an area of known salt dissolution and faulting which was avoided in screening to this location. Isotopic data have also been obtained from sampling of deep brine aquifers at the J. Friemel No. 1 (PD-9) borehole in Deaf Smith County. These data indicate a lesser degree of mixing of shallow water and deep basin brines and are interpreted by Hubbard (1984) to be a result of ancient mixing of waters which occurred up-gradient, possibly in the vicinity of the western escarpment in New Mexico. If nominated for characterization, additional data will be obtained to further evaluate potential for vertical flow between upper and lower hydrostratigraphic units.

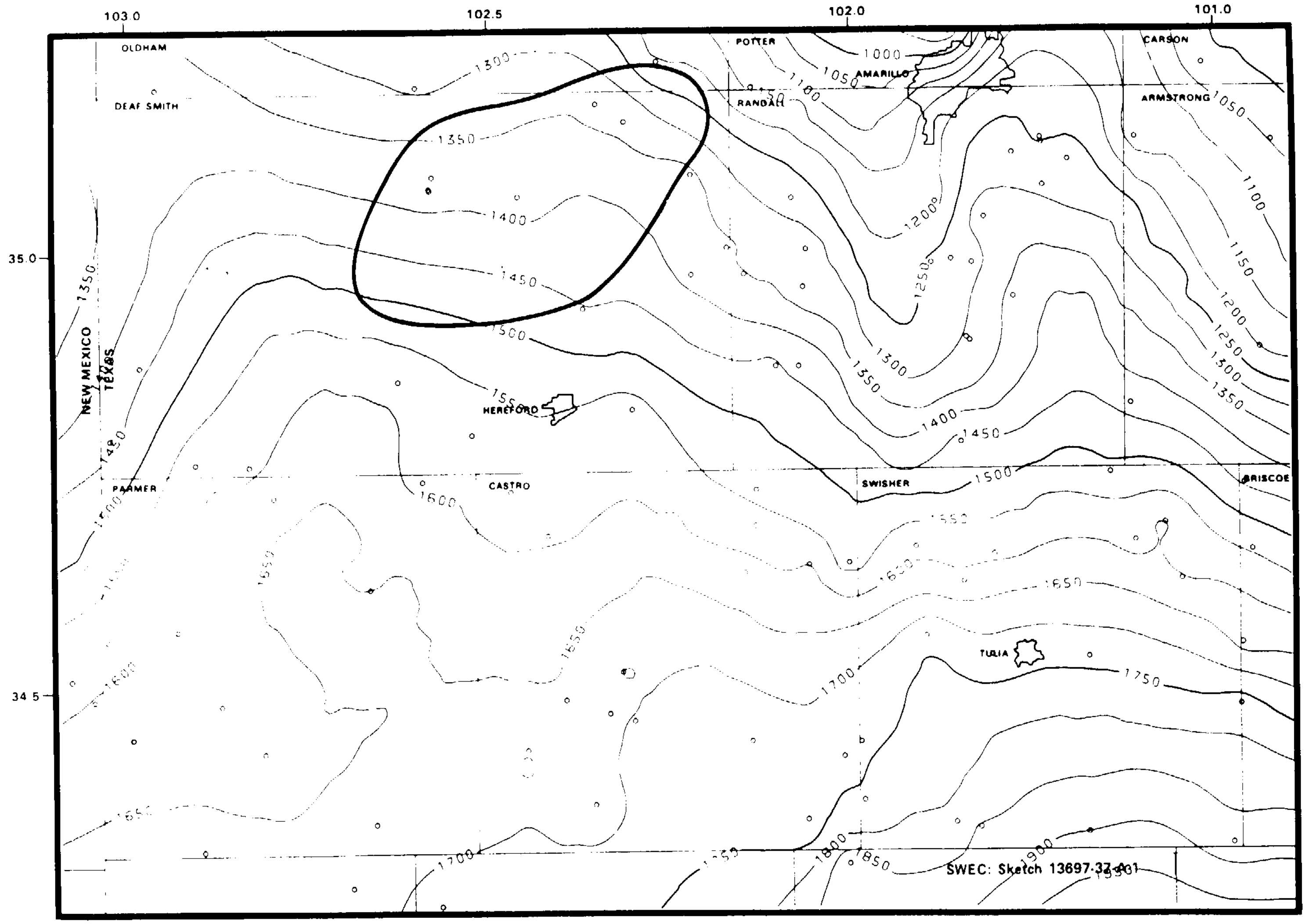
3.2.2 Expected Geohydrologic Regime

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 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

---

*The average amount of water applied for irrigation in Deaf Smith County during 1979 was 1.1 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.



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

0 5 10 15 20 Mi

0 10 20 30 Km

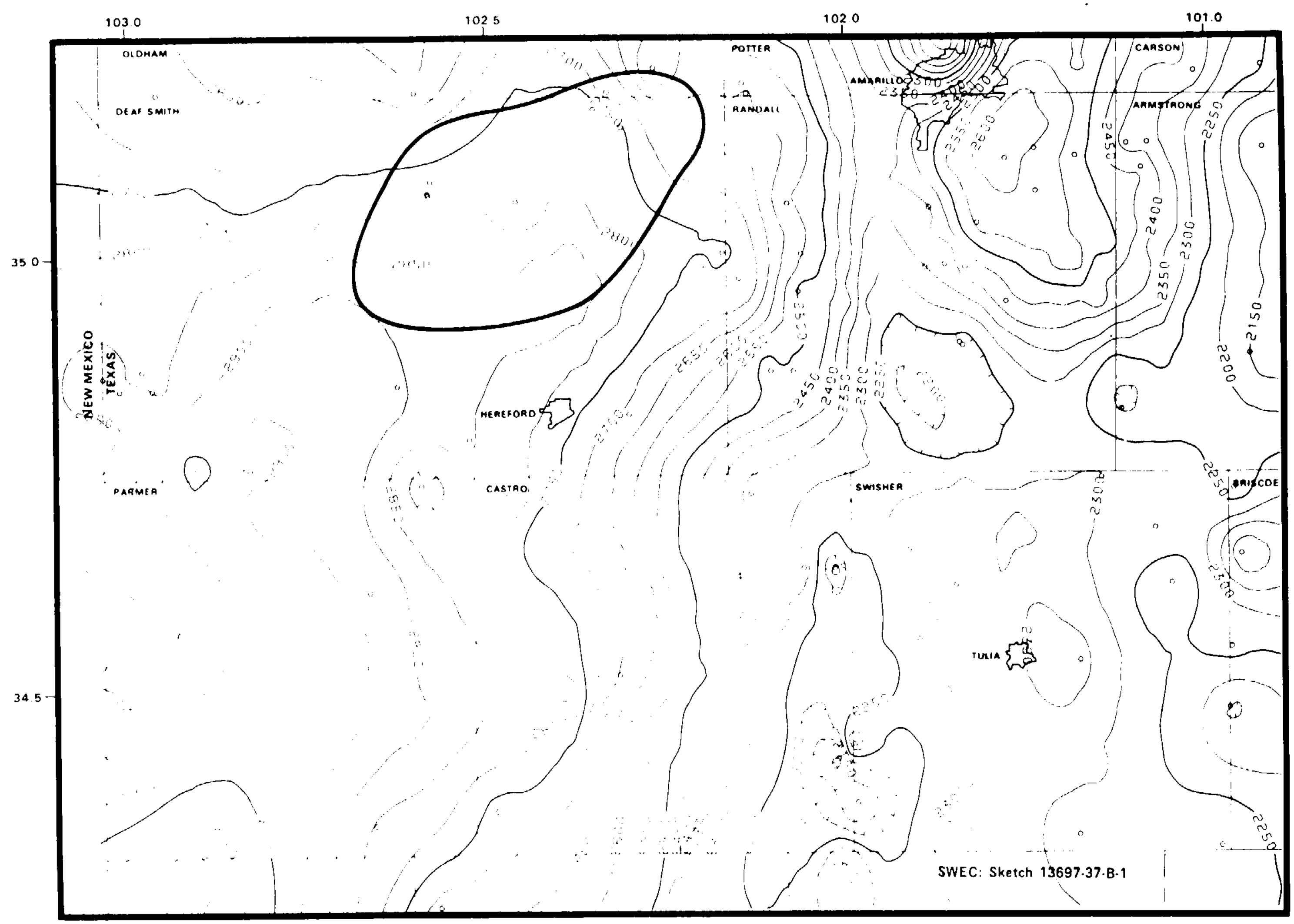
N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN, VOLUME I

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

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-11
THICKNESS OF AQUITARD BELOW THE REPOSITORY HORIZON

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 geohydrologic 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 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

---

*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.

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 (groundwater 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 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 varies in character across the location from a predominantly anhydrite unit in the southeast to a dolomite unit in the northwest (SWEC, 1984b,c,d). Insufficient well control exists to determine exactly where this transition occurs or 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).

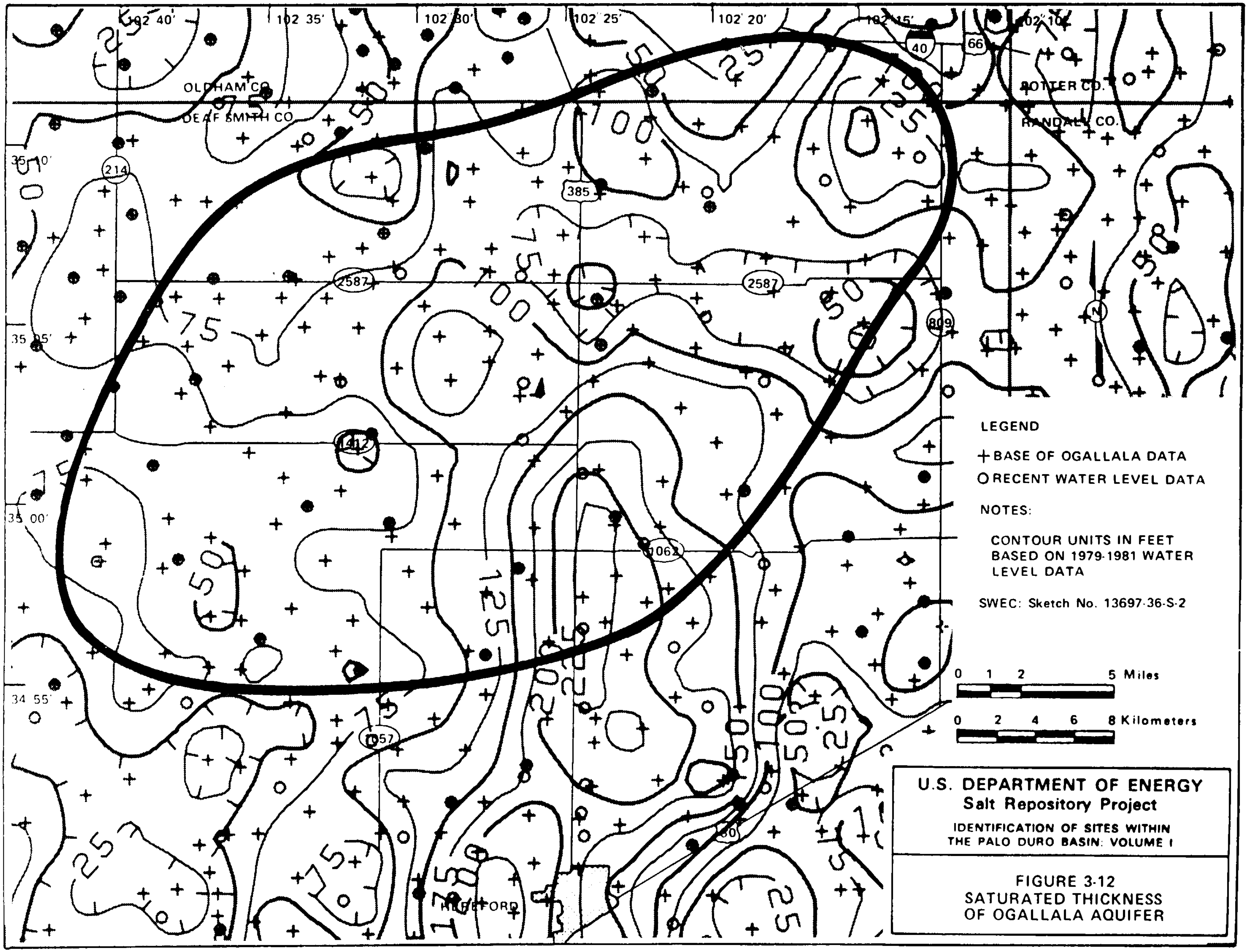
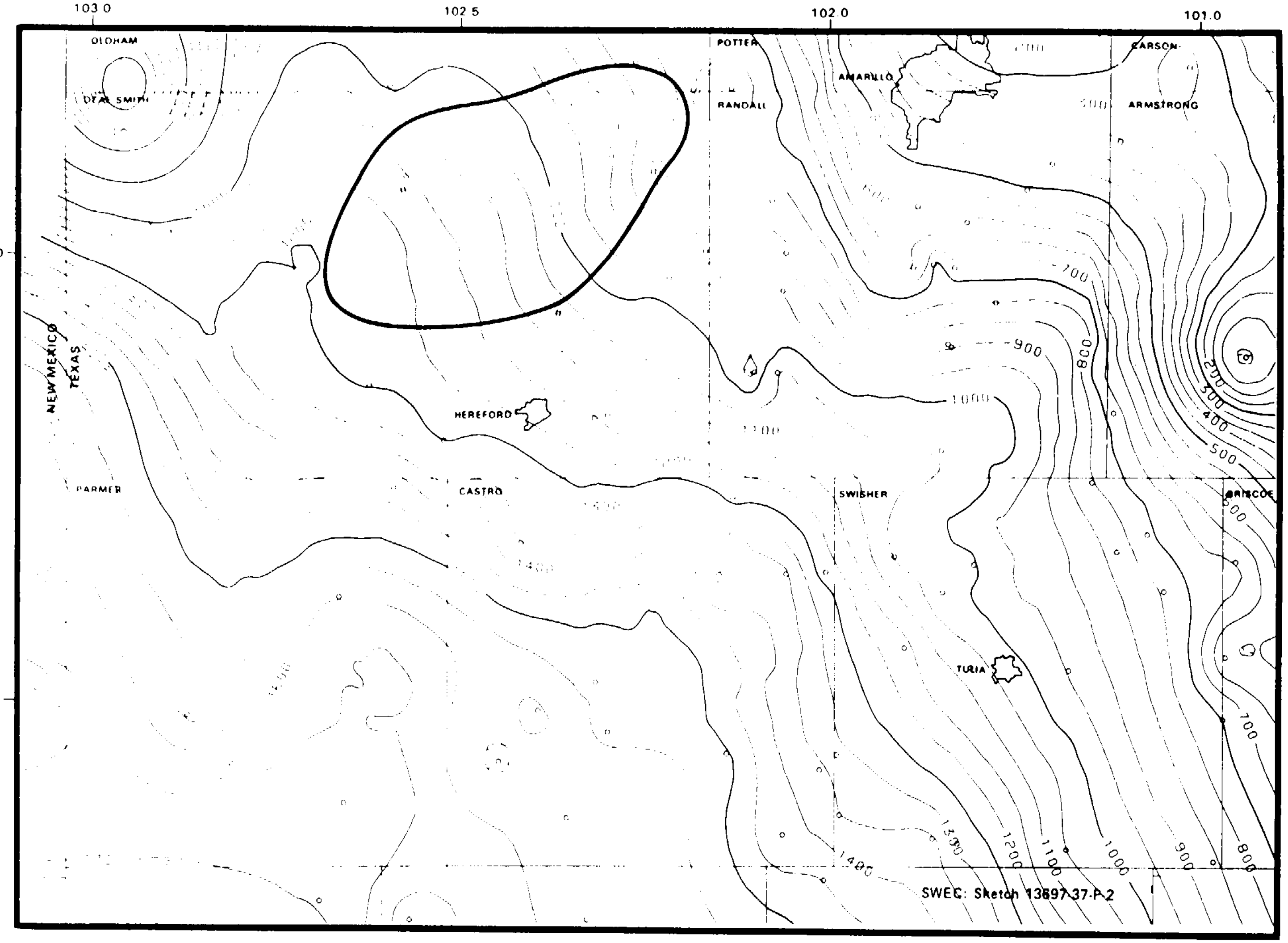


FIGURE 3-12
SATURATED THICKNESS OF OGALLALA AQUIFER



LEGEND

WELL CONTROL SHOWN BY OPEN CIRCLES

AREA OF INTEREST

NOTES

CONTOUR INTERVAL IS 50 FEET

GROUND SURFACE DATUM

SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

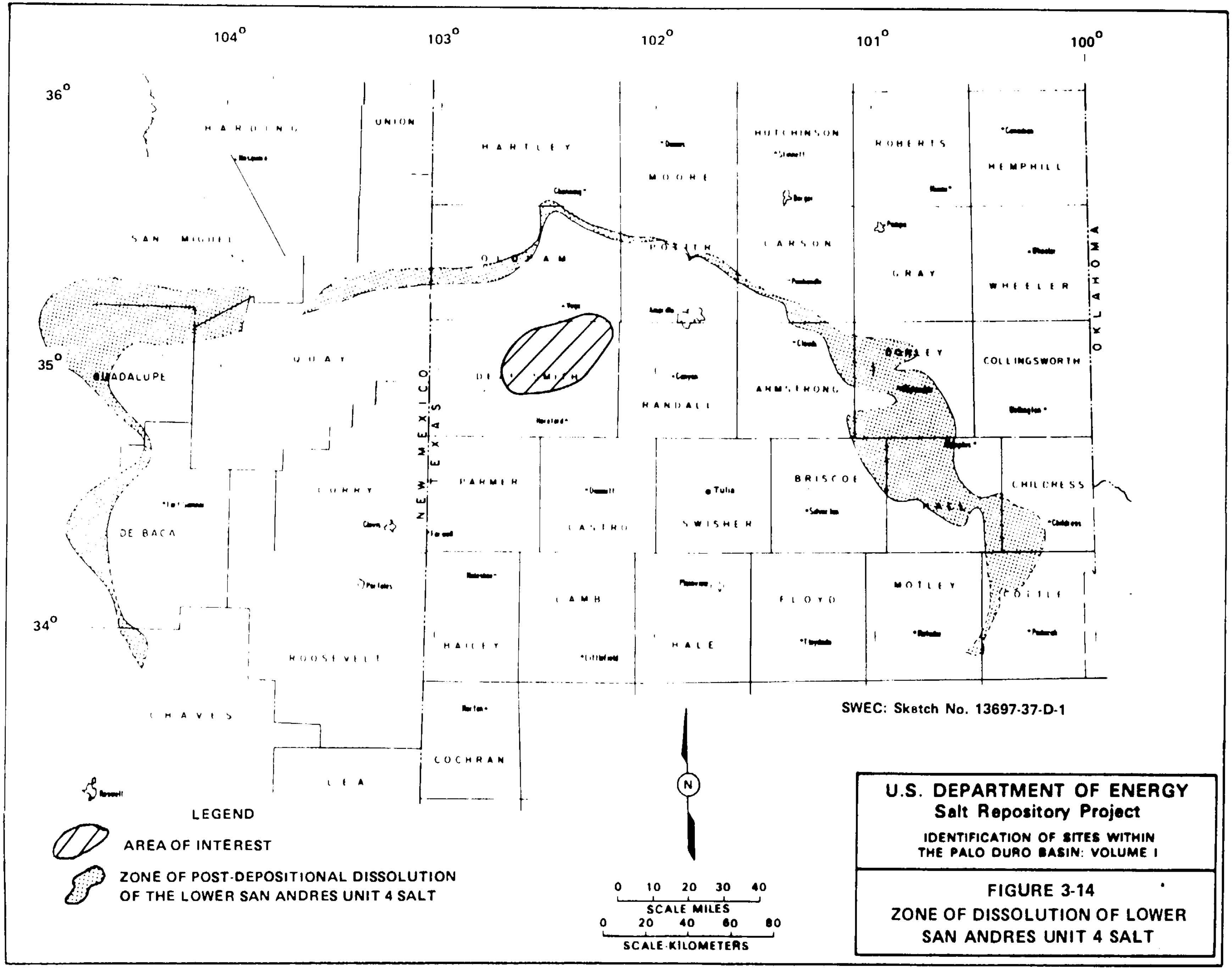
FIGURE 3-13
DEPTH TO BASE OF DOCKUM GROUP

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.

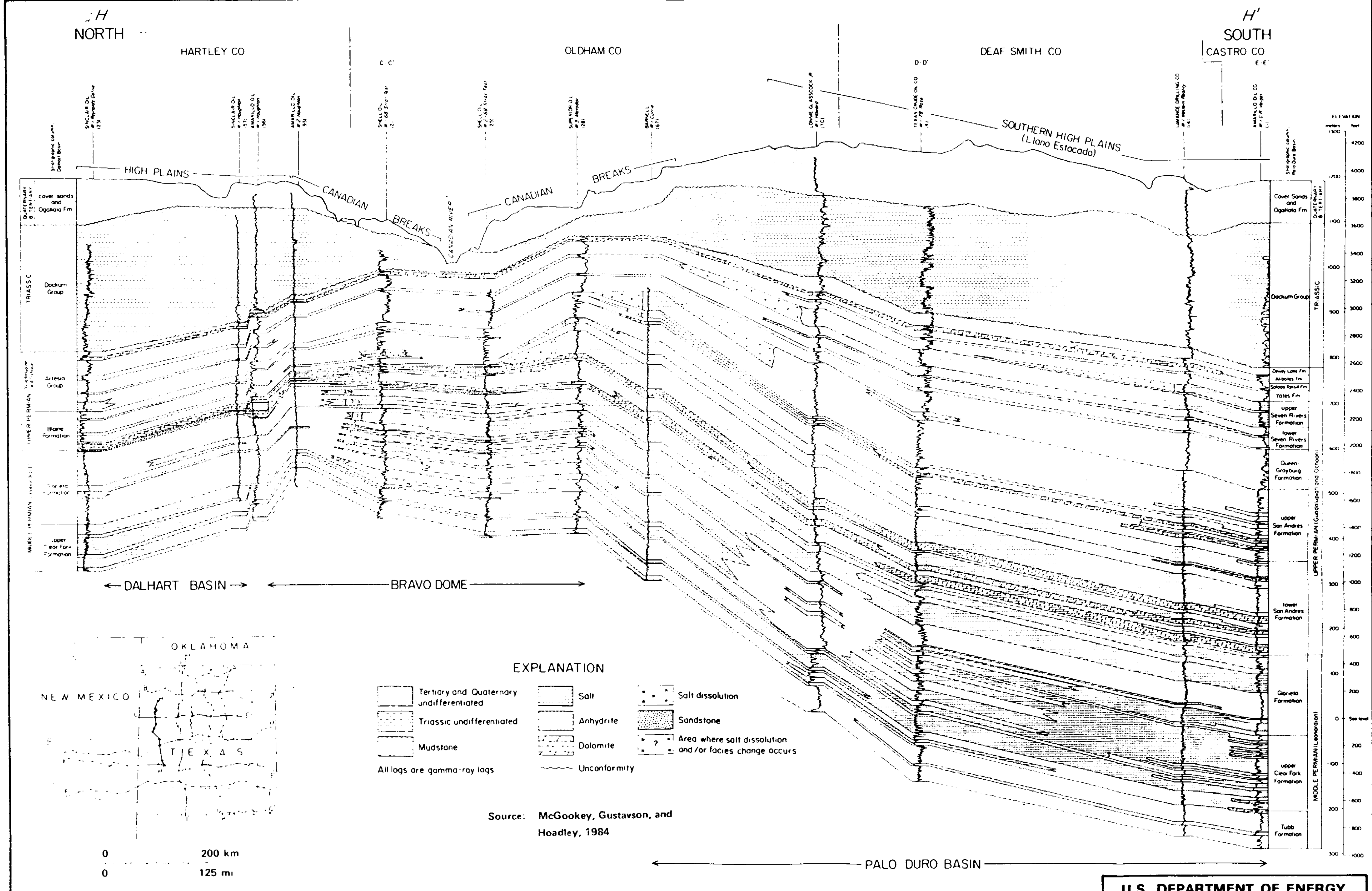
Dissolution of the lower San Andres unit 4 salt at the basin's periphery is thought to occur at distances of greater than 30 miles (48 kilometers) from the location, beyond the eastern and western margins of the Southern High Plains, and 15 miles (24 kilometers) from the location, in the Canadian River Valley (Figure 3-14). These areas are called active dissolution zones or fronts. 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 Detten No. 1 (PD-5) and G. Friemel No. 1 (PD-6) boreholes (SWEC, 1984c,d). 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



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

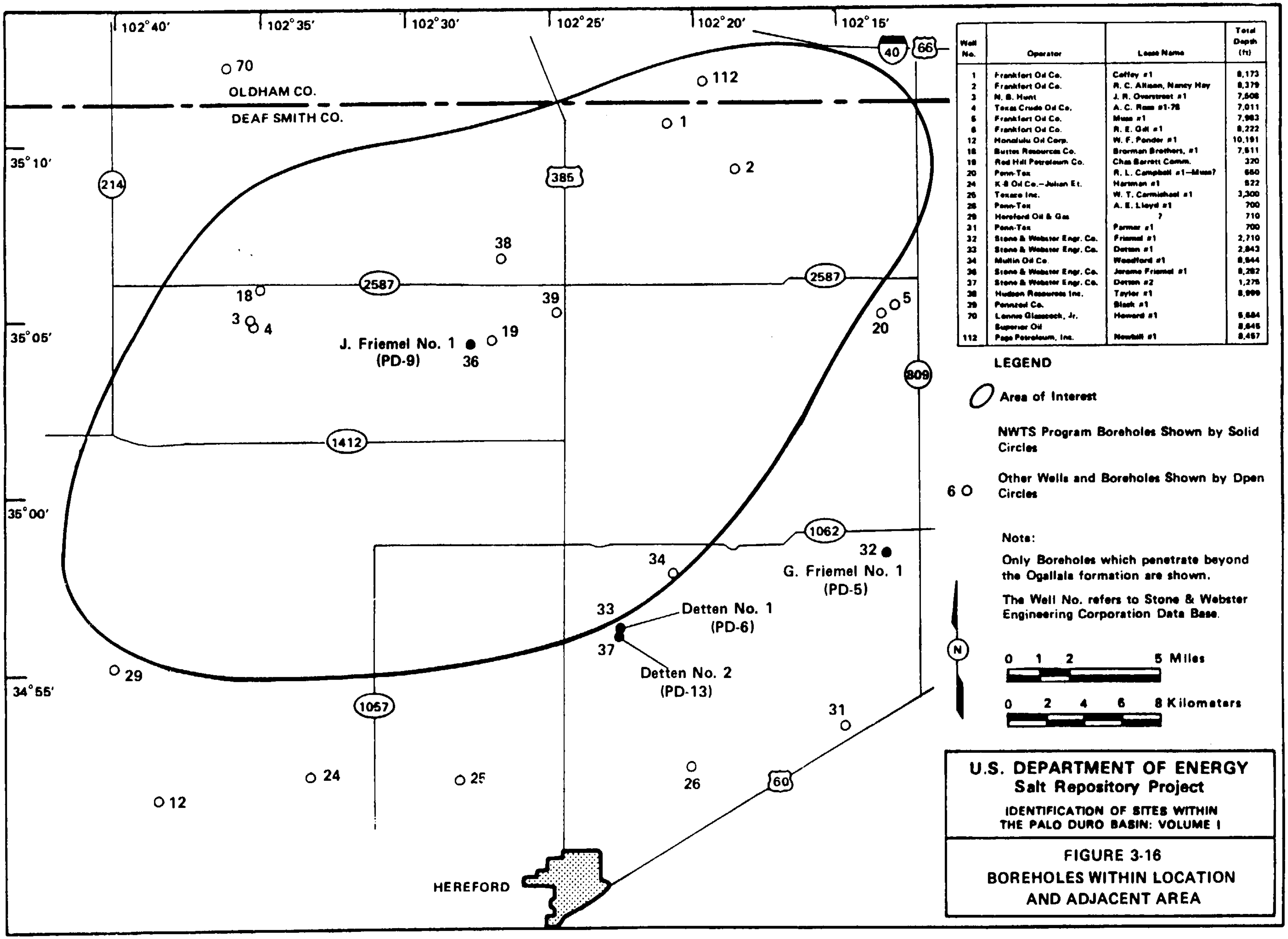
FIGURE 3-14
ZONE OF DISSOLUTION OF LOWER SAN ANDRES UNIT 4 SALT



U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-15
STRATIGRAPHIC SECTION ILLUSTRATING SALT DISSOLUTION



Well No.	Operator	Lease Name	Total Depth (ft)
1	Frankfort Oil Co.	Coffey #1	8,173
2	Frankfort Oil Co.	R. C. Allison, Nancy Hay	8,379
3	N. B. Hunt	J. R. Overstreet #1	7,508
4	Texas Crude Oil Co.	A. C. Ross #1-78	7,011
5	Frankfort Oil Co.	Muss #1	7,983
6	Frankfort Oil Co.	R. E. Gill #1	8,222
12	Honolulu Oil Corp.	W. F. Ponder #1	10,191
18	Buttes Resources Co.	Brorman Brothers, #1	7,511
19	Red Hill Petroleum Co.	Chas Barrett Comm.	320
20	Penn-Tex	R. L. Campbell #1—Muss?	660
24	K-8 Oil Co.—Julian Et.	Hartman #1	822
25	Texaco Inc.	W. T. Carmichael #1	3,300
26	Penn-Tex	A. E. Lloyd #1	700
29	Hereford Oil & Gas	?	710
31	Penn-Tex	Parmer #1	700
32	Stone & Webster Engr. Co.	Friemel #1	2,710
33	Stone & Webster Engr. Co.	Detten #1	2,843
34	Mullin Oil Co.	Woodford #1	8,644
36	Stone & Webster Engr. Co.	Jerome Friemel #1	8,282
37	Stone & Webster Engr. Co.	Detten #2	1,275
38	Hudson Resources Inc.	Taylor #1	8,999
39	Pennzoil Co.	Black #1	
70	Lennie Glasscock, Jr.	Howard #1	5,684
	Superior Oil		8,646
112	Page Petroleum, Inc.	Newbill #1	8,457

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-16
BOREHOLES WITHIN LOCATION AND ADJACENT AREA

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 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 (SWEC, 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.

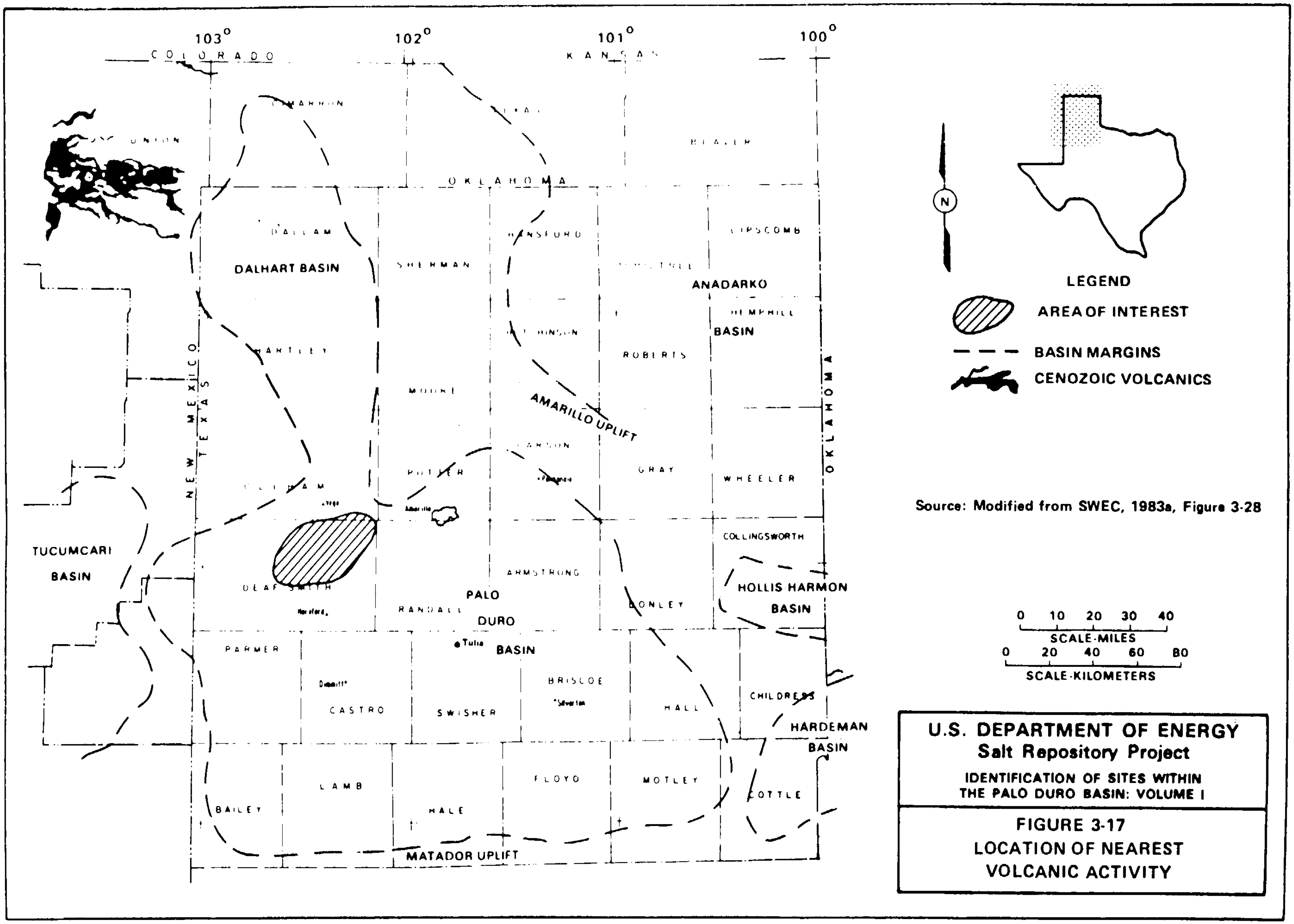
Interbeds in salt may exacerbate roof, floor, and pillar instability. Examination of rock core indicates that total avoidance of interbeds will not be possible in the Palo Duro Basin. Interbed location within the lower San Andres unit 4 salt varies somewhat in both vertical and lateral directions; however, 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).

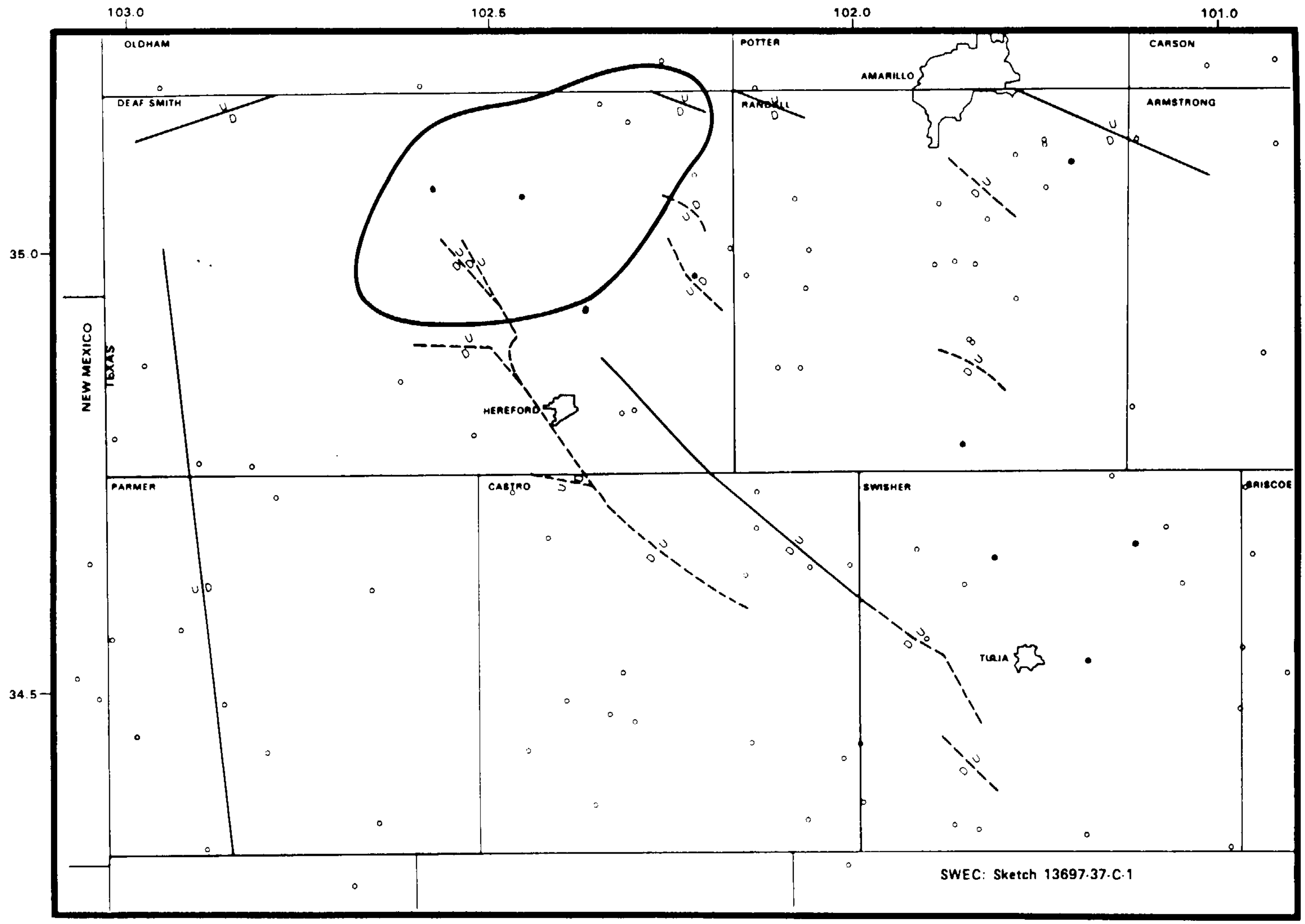
Structures in the location and surrounding areas have been mapped by various investigators (Goldstein, 1982; Budnik and Smith, 1982). For purposes of this study, a fault map (Figure 3-18) has been used that provides an interpretation of the location of faults in the northern Palo Duro Basin. Seismic coverage and well control have permitted the construction of this preliminary map. The faults mapped in the location in Figure 3-18 offset rocks of Wolfcampian age and older. Recurrent movement of faults in basement and Wolfcampian rocks may 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).



U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN
THE PALO DURO BASIN: VOLUME I

FIGURE 3-17
LOCATION OF NEAREST
VOLCANIC ACTIVITY



LEGEND

AREA OF INTEREST

FAULT INFERRED FROM SEISMIC REFLECTION PROFILES

ADDITIONAL FAULTS INFERRED FROM WELL LOG CORRELATIONS

U – UPTHROWN

D – DOWNTHROWN

NOTE: THE YOUNGEST ROCKS OFFSET BY THE INFERRED FAULTS WITHIN THE LOCATION ARE WOLFCAMPIAN IN AGE

SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-18
INFERRED FAULTS IN NORTHERN PALO DURO BASIN

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

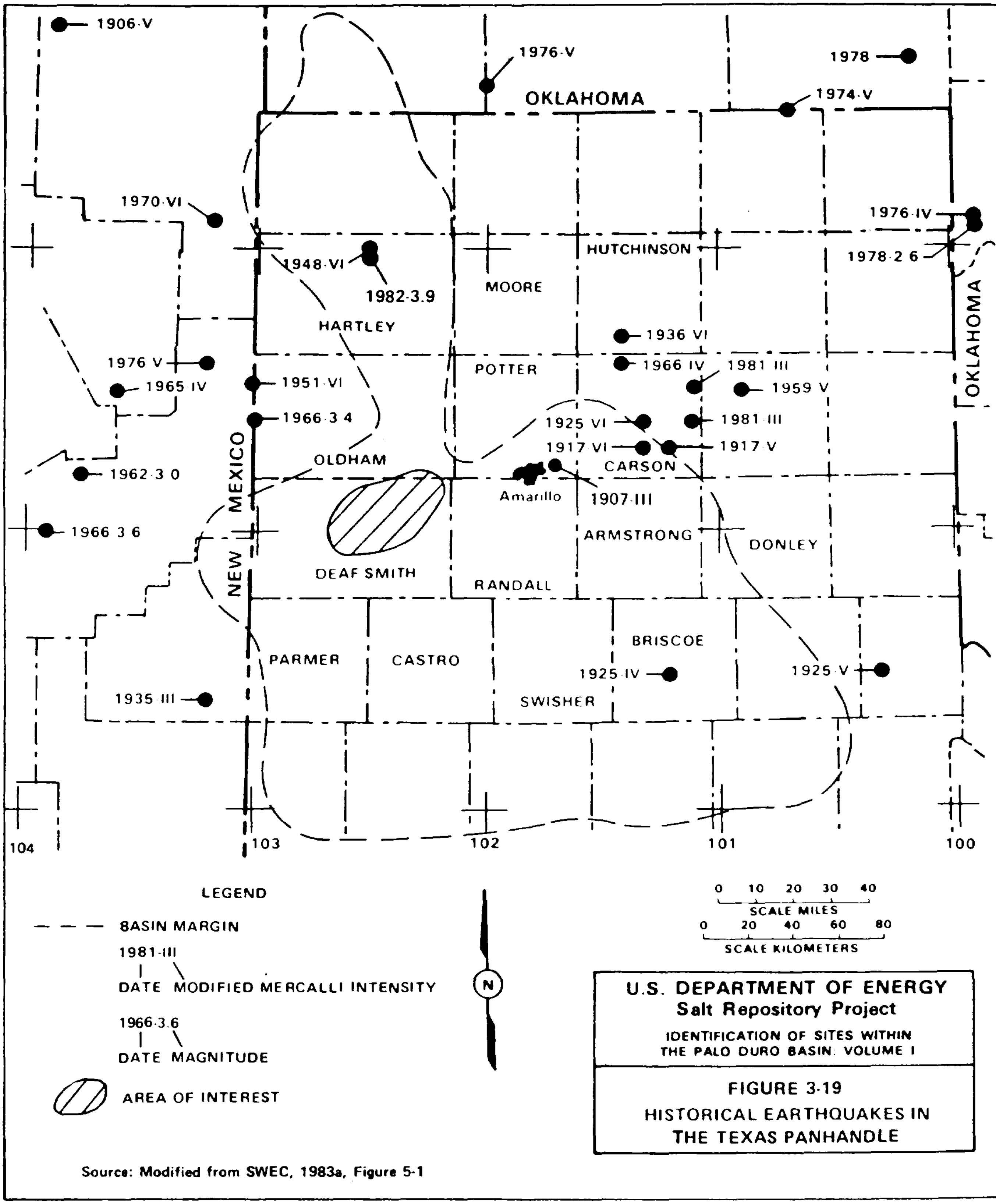


FIGURE 3-19
HISTORICAL EARTHQUAKES IN THE TEXAS PANHANDLE

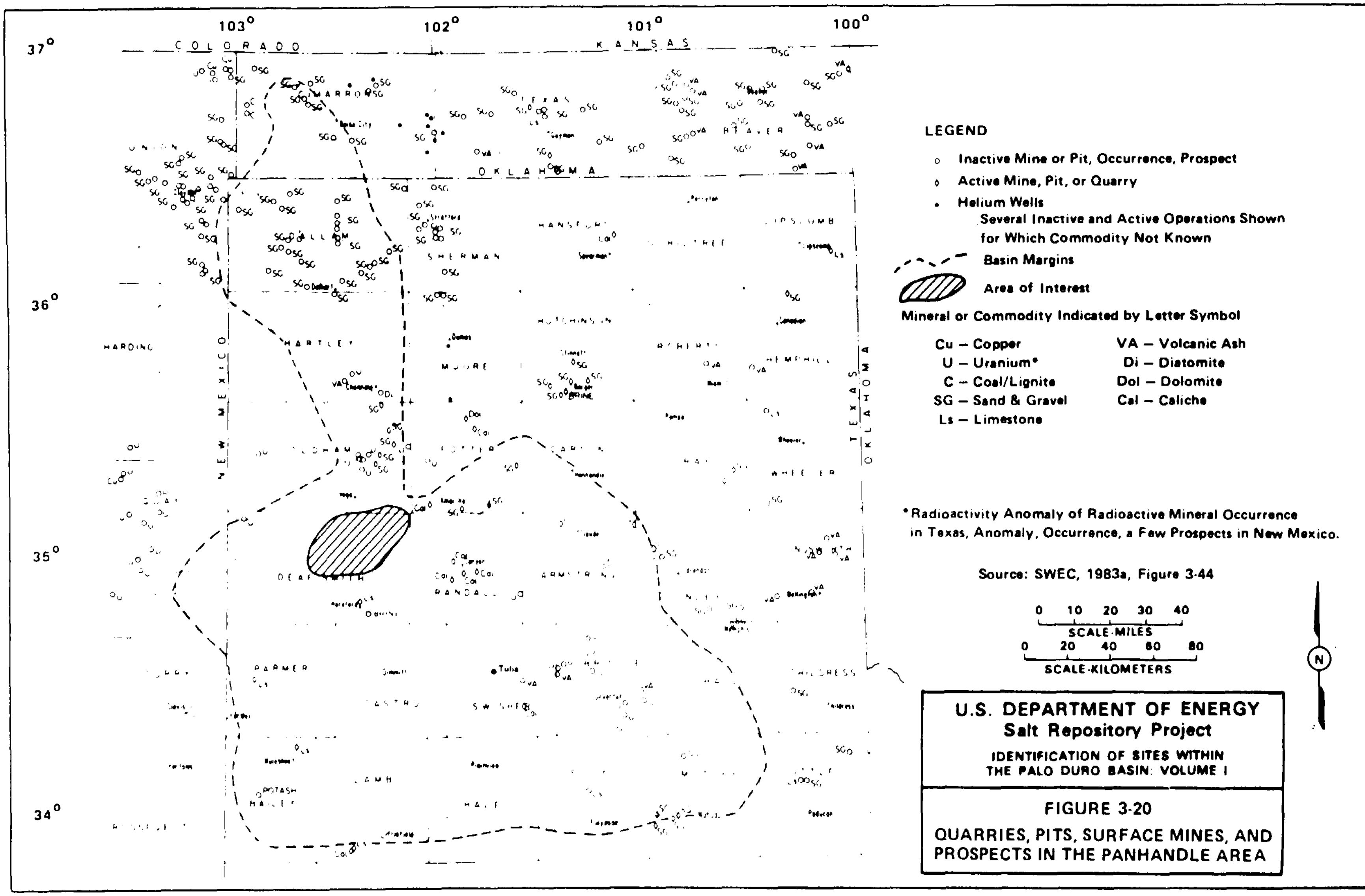
these locations is not expected to compromise site performance. For these reasons site preference is not sensitive to their location. The descriptor, current/previous mineral production, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

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).

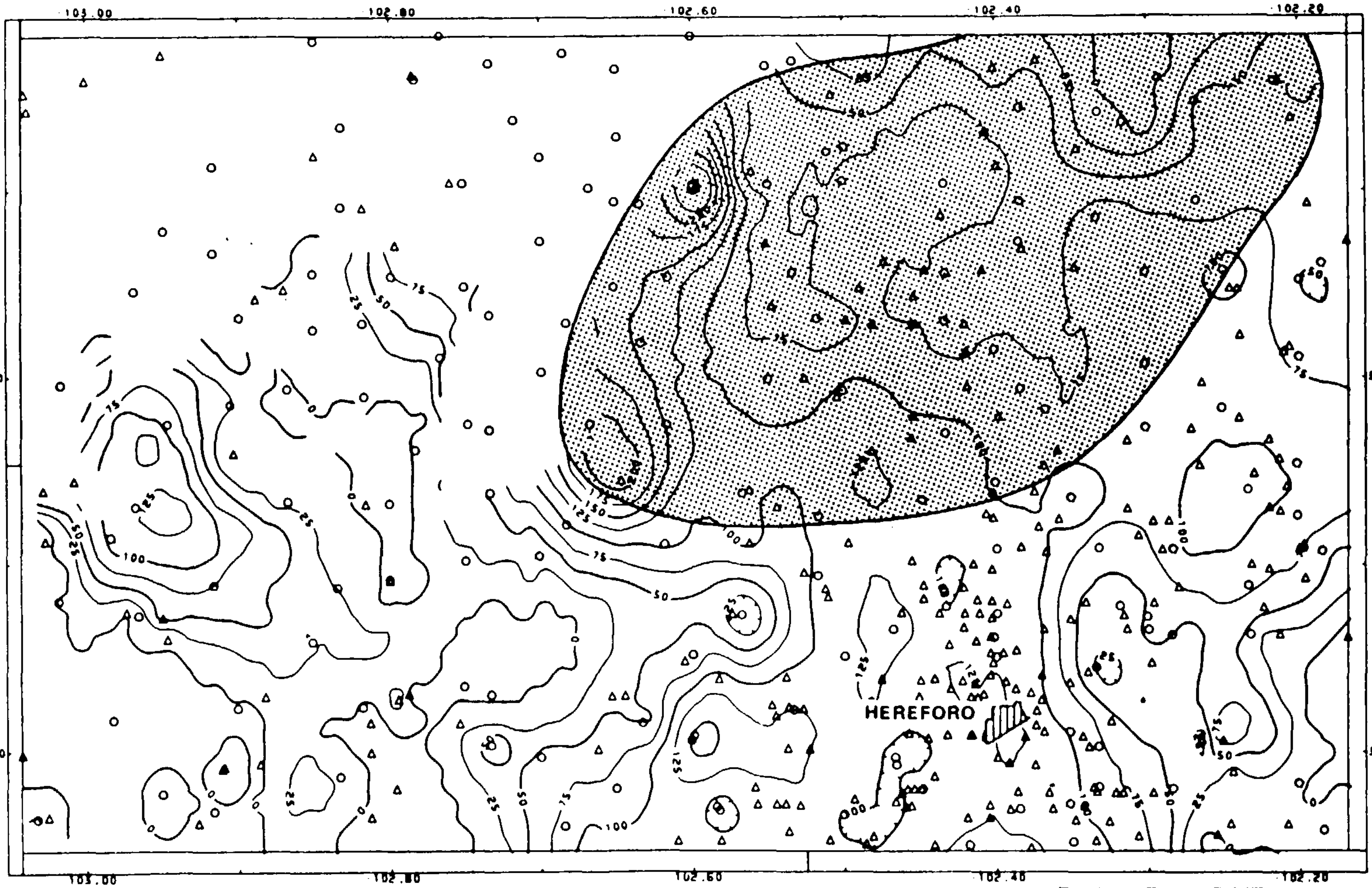
3.6.2 Presence of Potentially Exploitable Resources

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



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-20
QUARRIES, PITS, SURFACE MINES, AND PROSPECTS IN THE PANHANDLE AREA



Notes:

1. Contour Interval: 25 Feet
2. Contours not complete where insufficient data exists
3. Values represent declines in water level

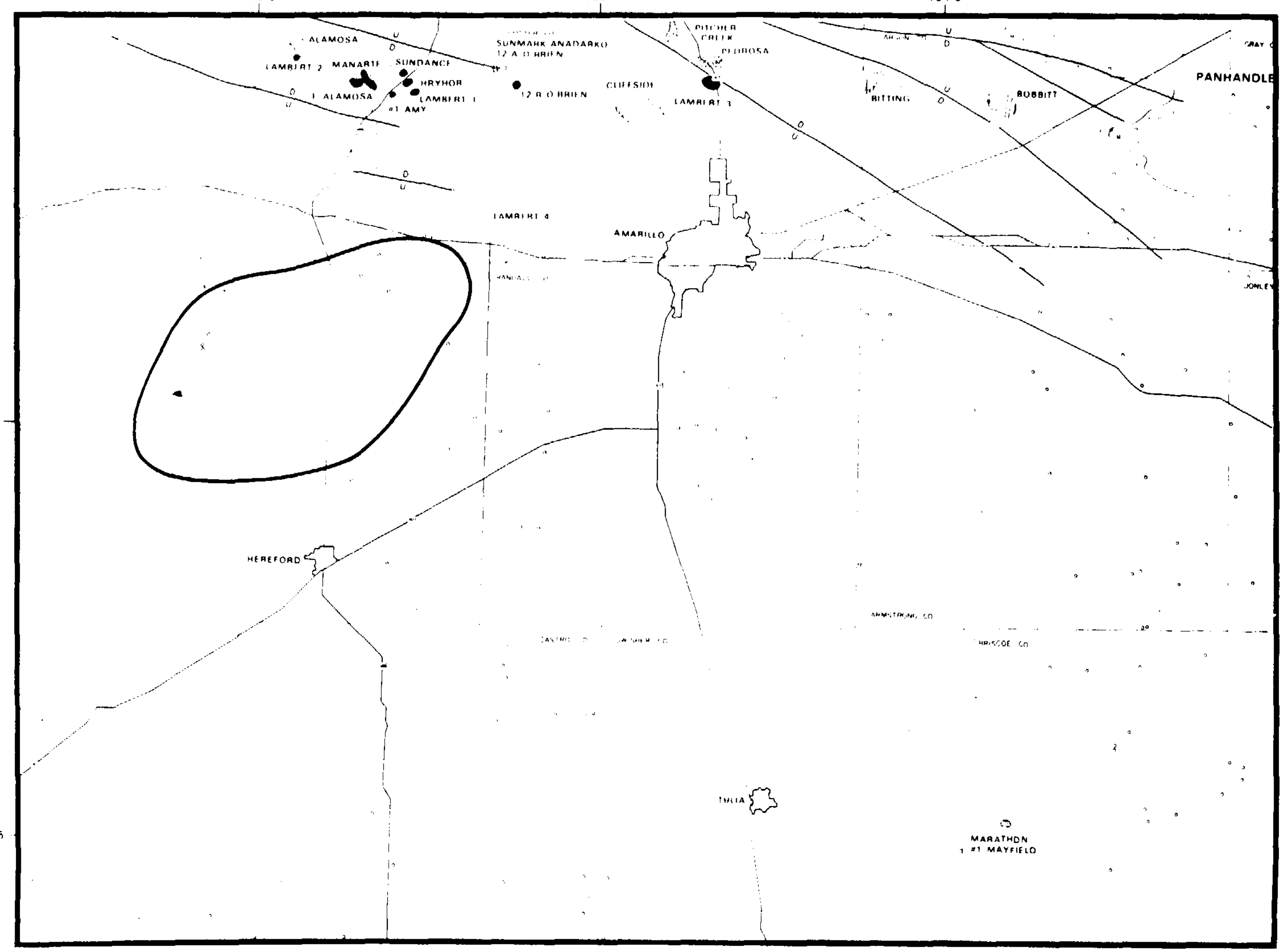
Source: SWEC, 1984e, Figure 29

Legend:
Well Control:
o Recent Water Levels
Pre-1942 Water Levels
Area of Interest

SCALE
5 0 5 MILES
5 0 5 10 KILOMETERS

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-21
DIFFERENCE BETWEEN PRE-1942 AND 1979-1981 WATER LEVELS IN DEAF SMITH COUNTY



LEGEND

AREA OF INTEREST
PANHANDLE OIL FIELD
FAULTS
U– UPTHROWN
D– DOWNTHROWN

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

SCALE
0 5 10 15 20 Mi
0 10 20 30 Km

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

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

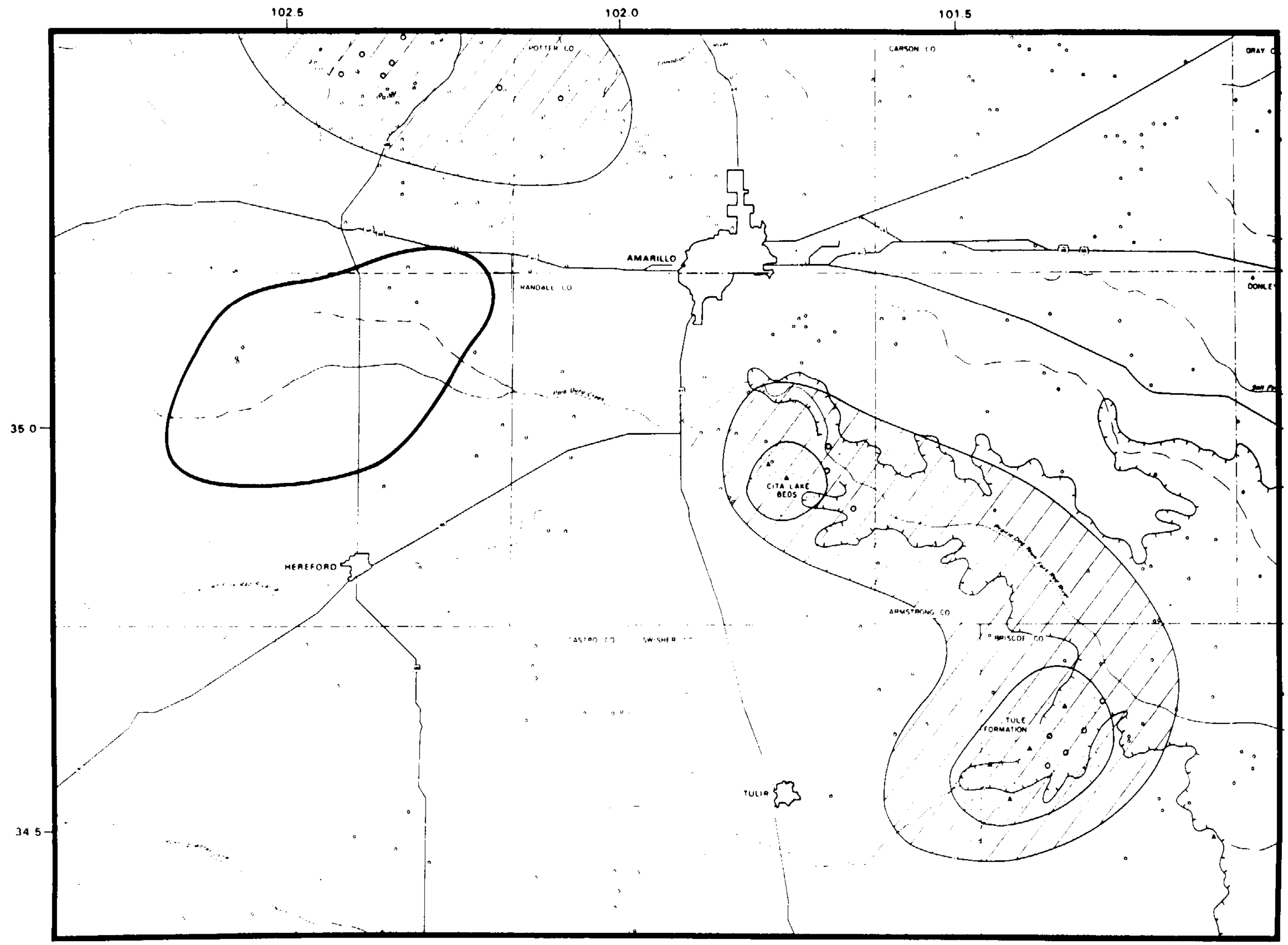
FIGURE 3-22
OIL AND GAS FIELDS IN PALO DURO BASIN

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 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



LEGEND

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

SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

NOTE:

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

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

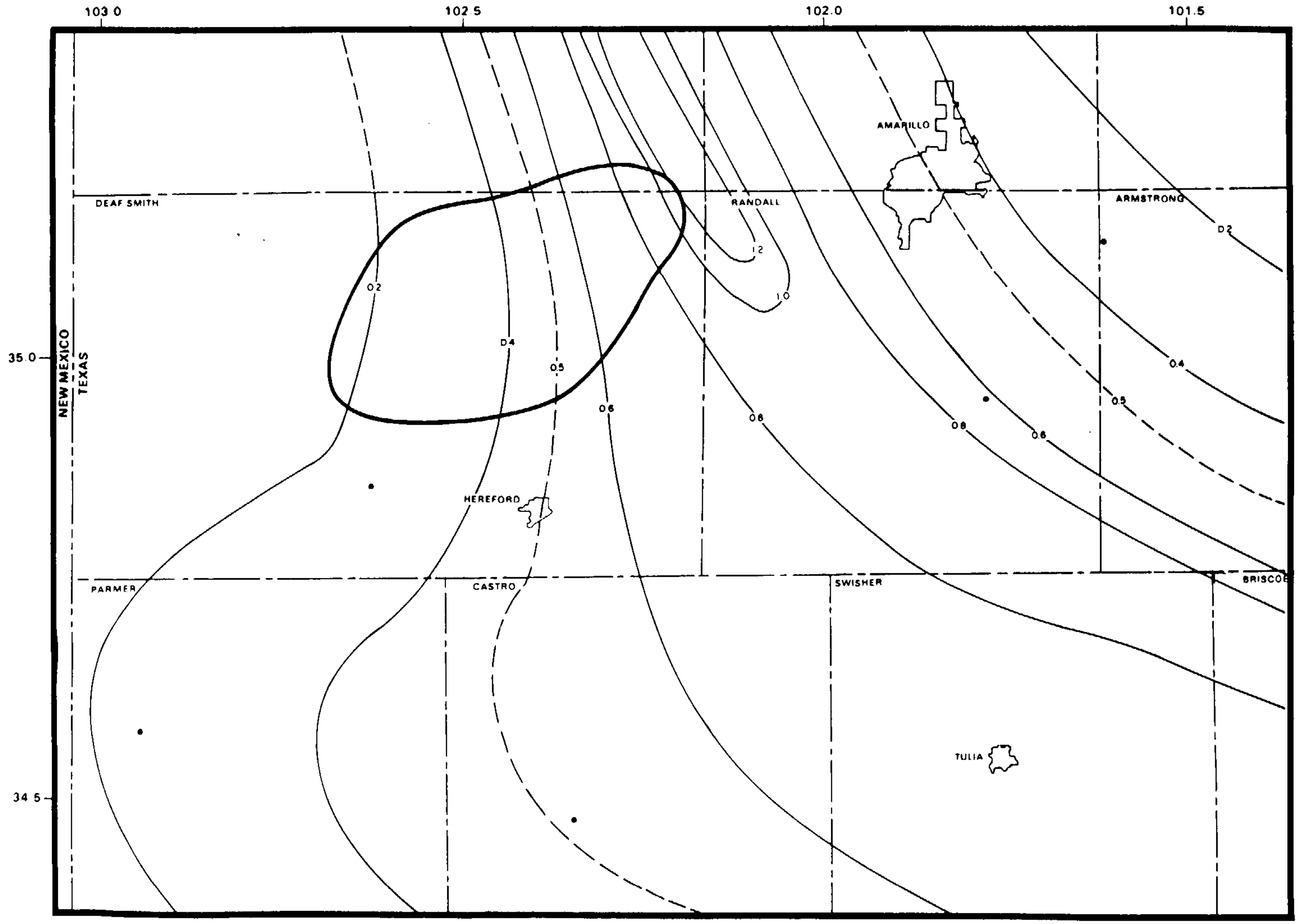
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-23
LOCATION OF URANIUM OCCURENCES

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 to good source rock potential exists in the northeastern portion of the location. The primary potential porous reservoir rocks in the location are the Pennsylvanian and Lower Permian (Wolfcampian) shelf margin carbonates (Figures 3-26, 3-27, and 3-28)



NOTES:

CONTOUR INTERVAL = 0.2% T.O.C.

MODIFIED FROM TEXAS BUREAU OF ECONOMIC GEOLOGY DRAFT MAP QA-881

LEGEND

AREA OF INTEREST

CONTOUR LINES

SELECTED INTERMEDIATE CONTOURS

WELL CONTROL SHOWN BY SOLID CIRCLES

SCALE

0 5 10 15 20 Mi

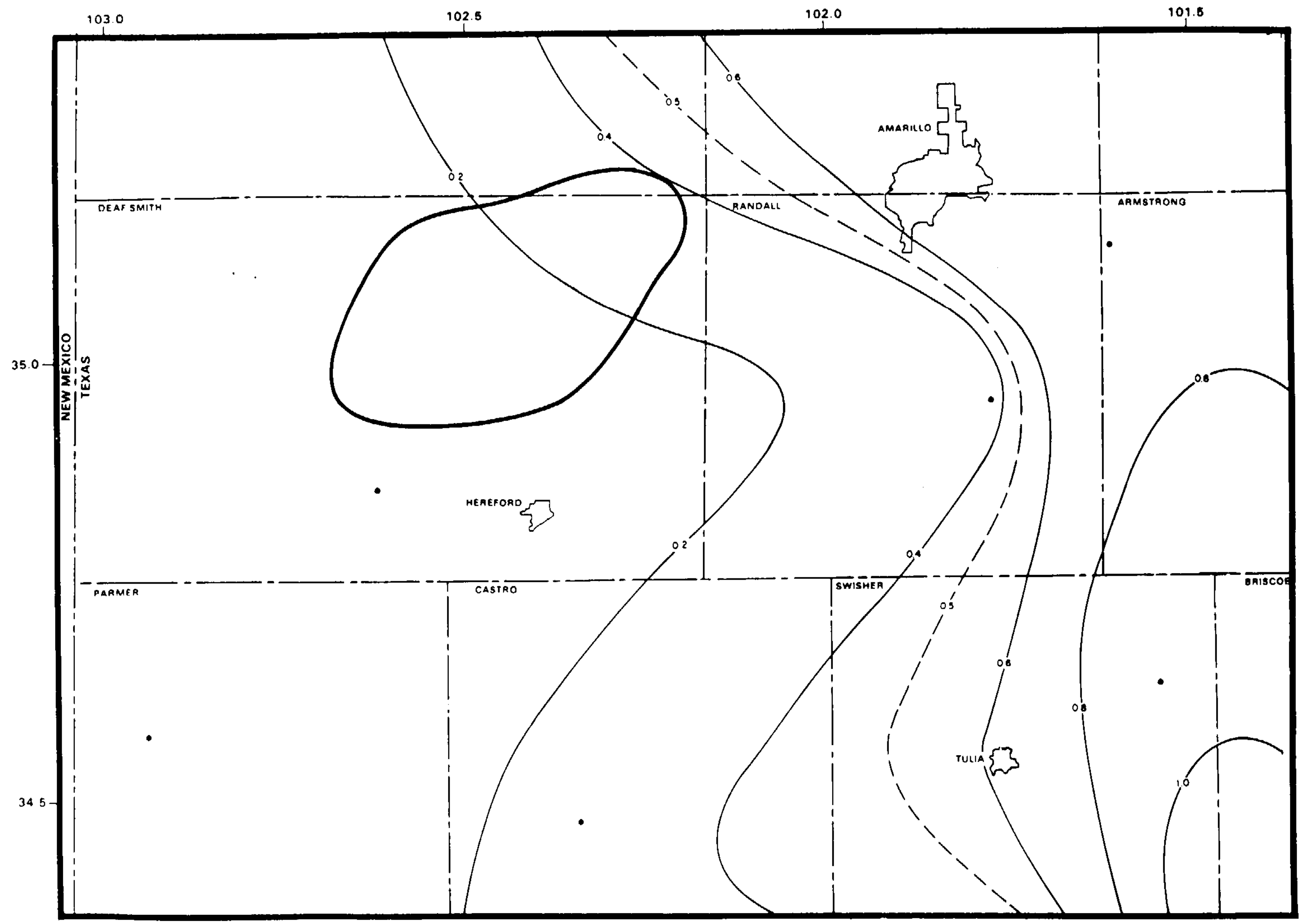
0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-24
PERCENT TOTAL ORGANIC CARBON OF PENNSYLVANIAN ROCKS



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

MODIFIED FROM TEXAS BUREAU OF ECONOMIC GEOLOGY DRAFT MAP QA 882

LEGEND

AREA OF INTEREST

WELL CONTROL SHOWN BY SOLID CIRCLES

SCALE

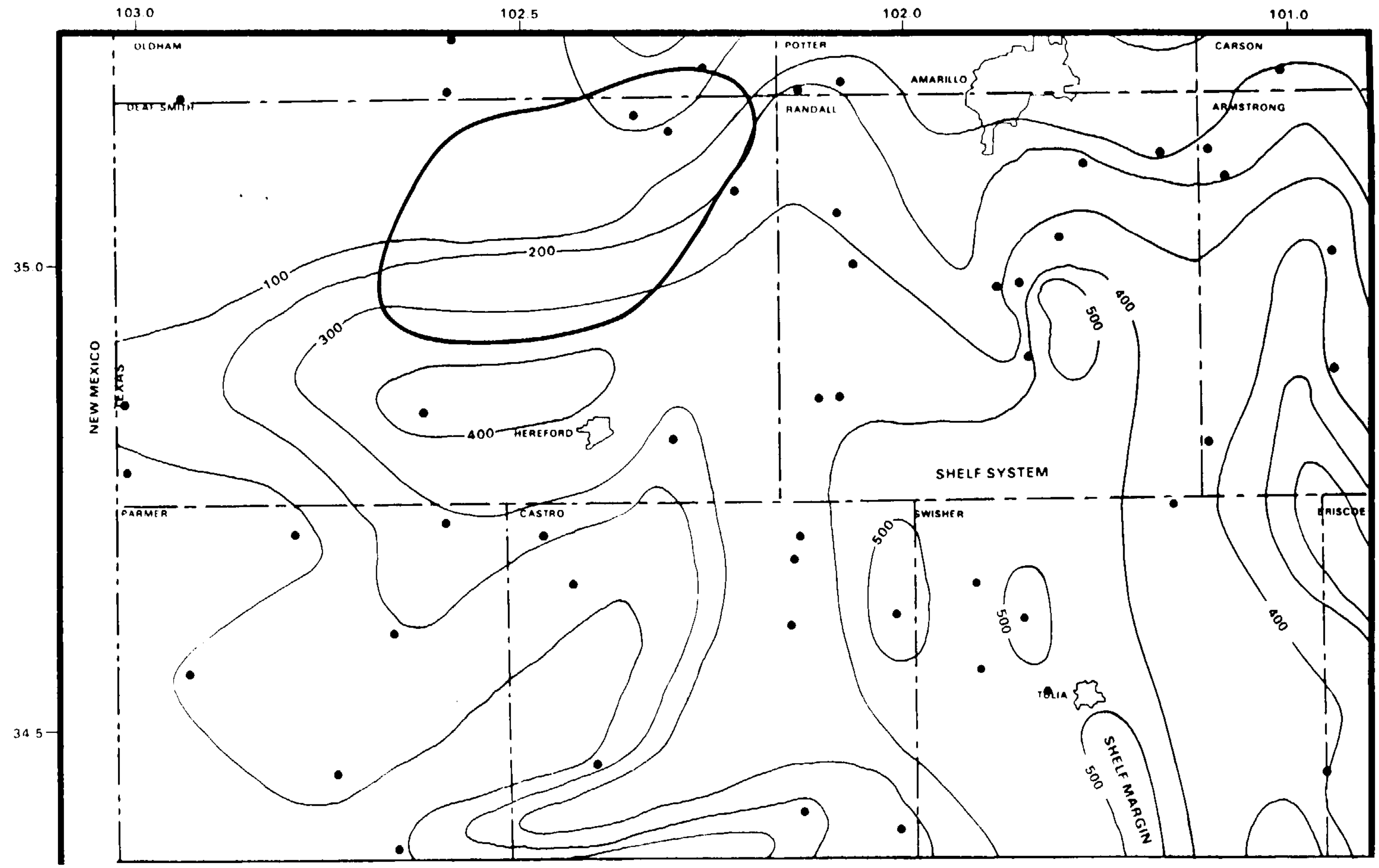
0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

N

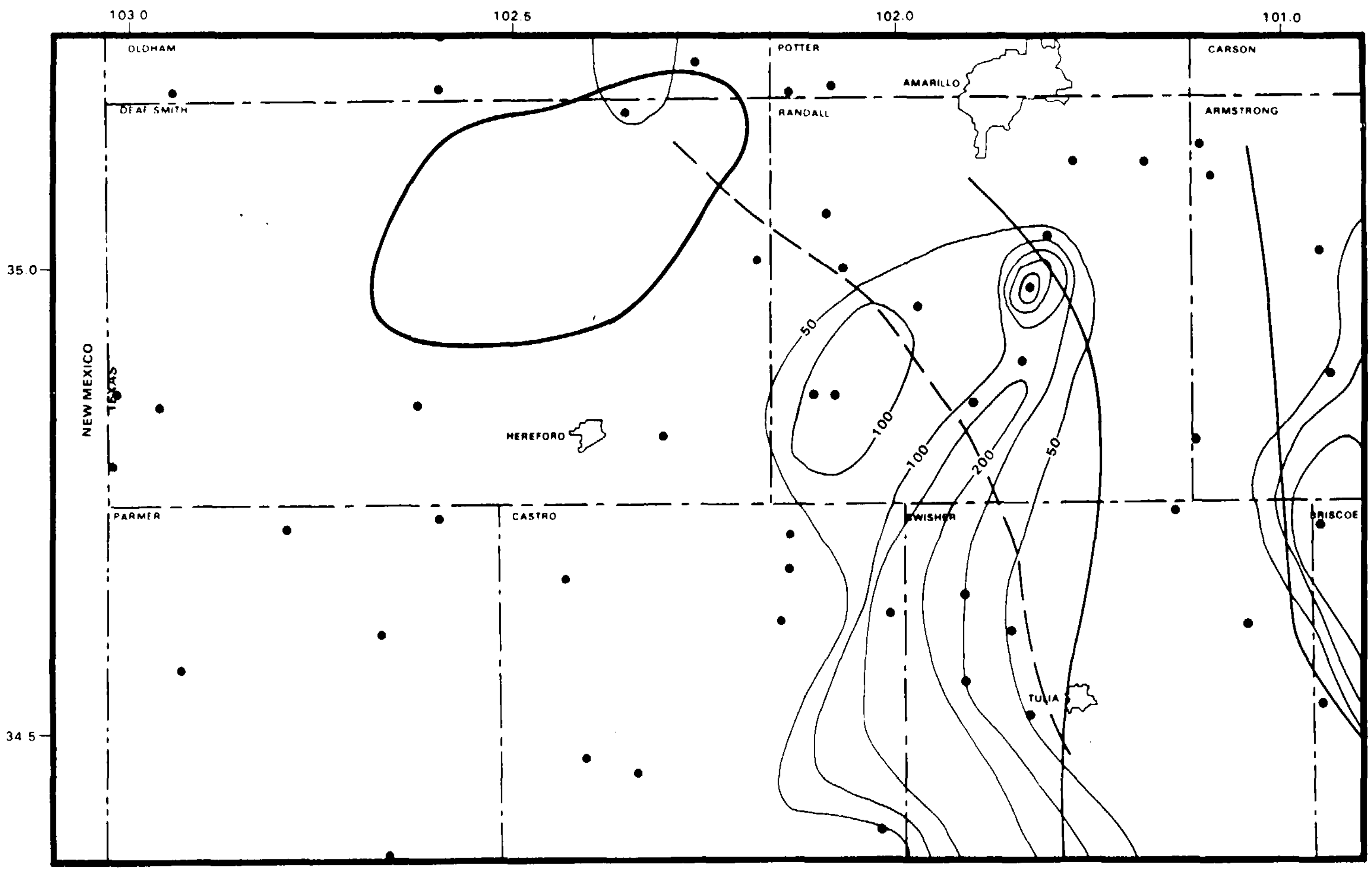
SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-26
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

N

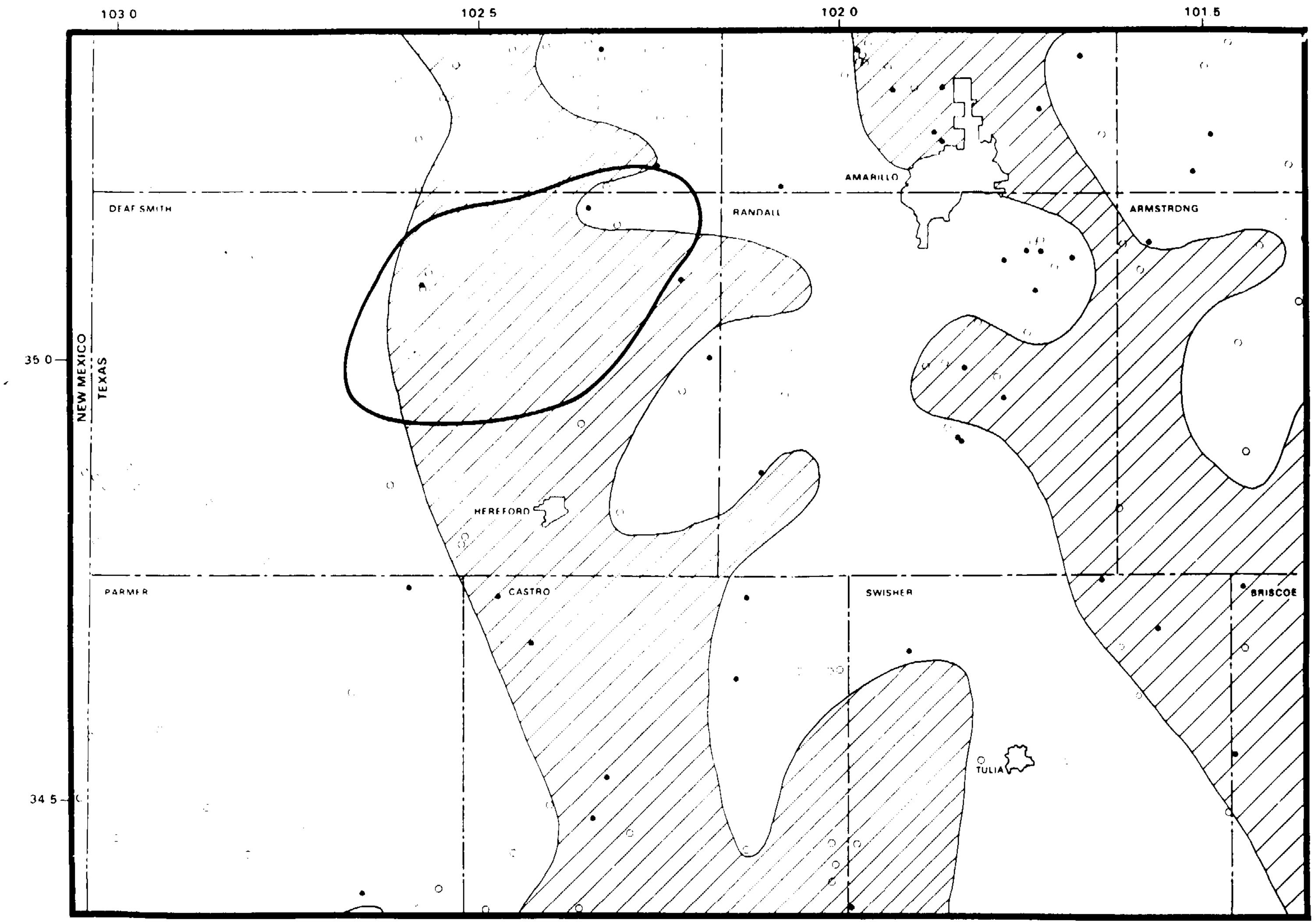
SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-28
POROUS WOLFCAMP CARBONATE

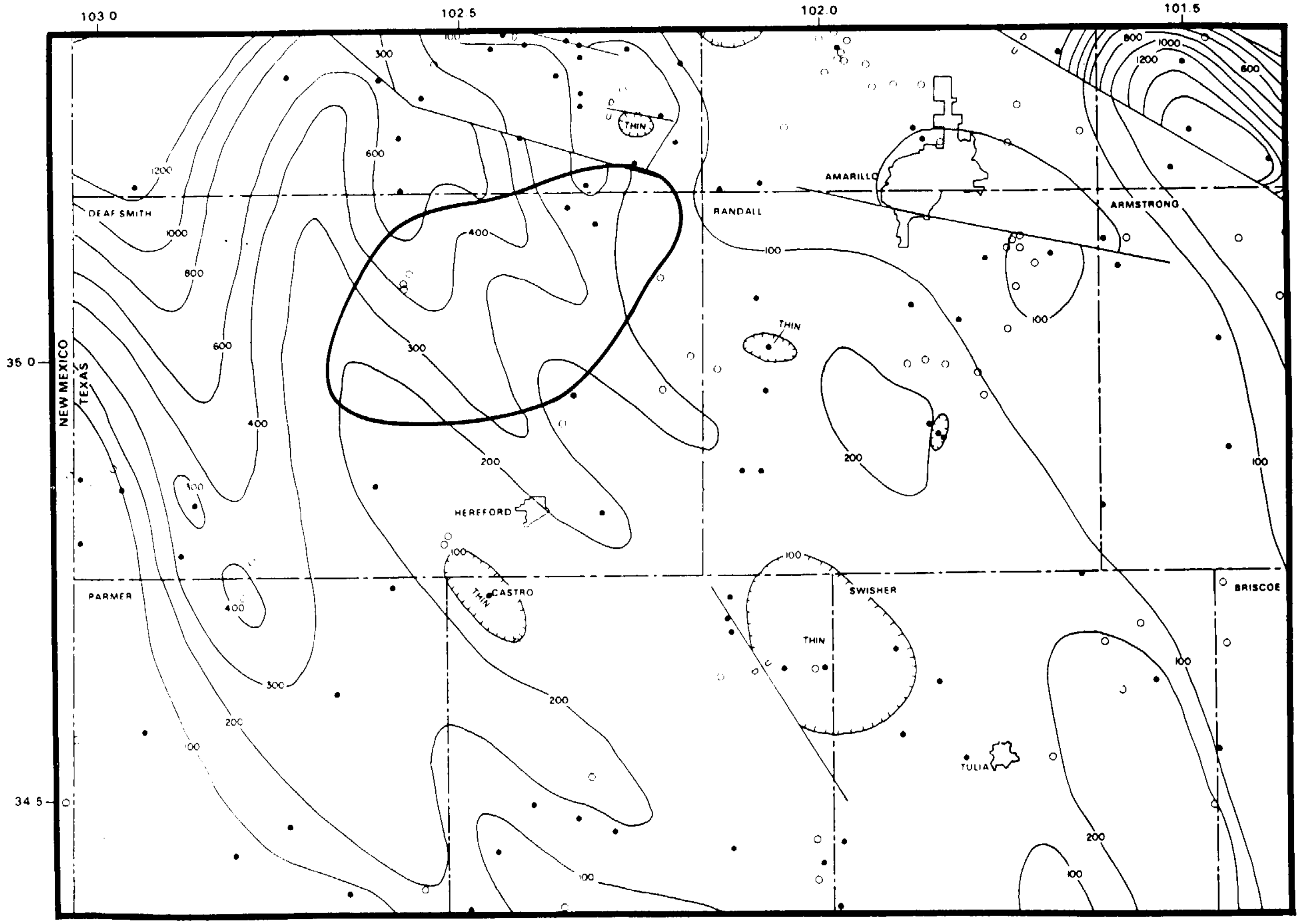
and Pennsylvanian granite wash sediments. Thick granite wash sediments exist throughout much of the location (Figure 3-29). The northeastern portion of the location lies closest to production of hydrocarbon in Oldham and Potter Counties (Figure 3-22).

The juxtaposition of thick porous reservoir rocks with fair source rocks (>0.5 percent TOC) has been used to suggest areas (fairways) with relatively higher potential for hydrocarbon reservoirs (Dutton et al, 1982, Figures 52 and 53). No hydrocarbon fairways were identified by Dutton et al (1982) in Deaf Smith County. Based on available information, it can be provisionally concluded that the hydrocarbon potential is very low throughout the location. Nevertheless, the northeastern portion of the location is judged to have somewhat greater potential for human intrusion (penetration of the host rock) by purposeful hydrocarbon exploration because it: (1) overlies Pennsylvanian shelf margin carbonates -- possible reservoirs; (2) is an area of richer source rocks; (3) is an area of greater present-day oil and gas leasing; and (4) is closer to existing oil production. 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.

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,



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

MODIFIED FROM TEXAS BUREAU OF ECONOMIC GEOLOGY DRAFT MAP QA-869-1

LEGEND

WELL CONTROL SHOWN BY SOLID CIRCLES
OTHER WELLS SHOWN BY OPEN CIRCLES
U/D FAULT
U - UPTHROWN
D - DOWNTHROWN

PRECAMBRIAN BASEMENT EXPOSED DURING THE PENNSYLVANIAN

AREA OF INTEREST

SCALE

0 5 10 15 20 Mi

0 10 20 30 Km

N

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-29
ISOPACH MAP OF TOTAL GRANITE WASH

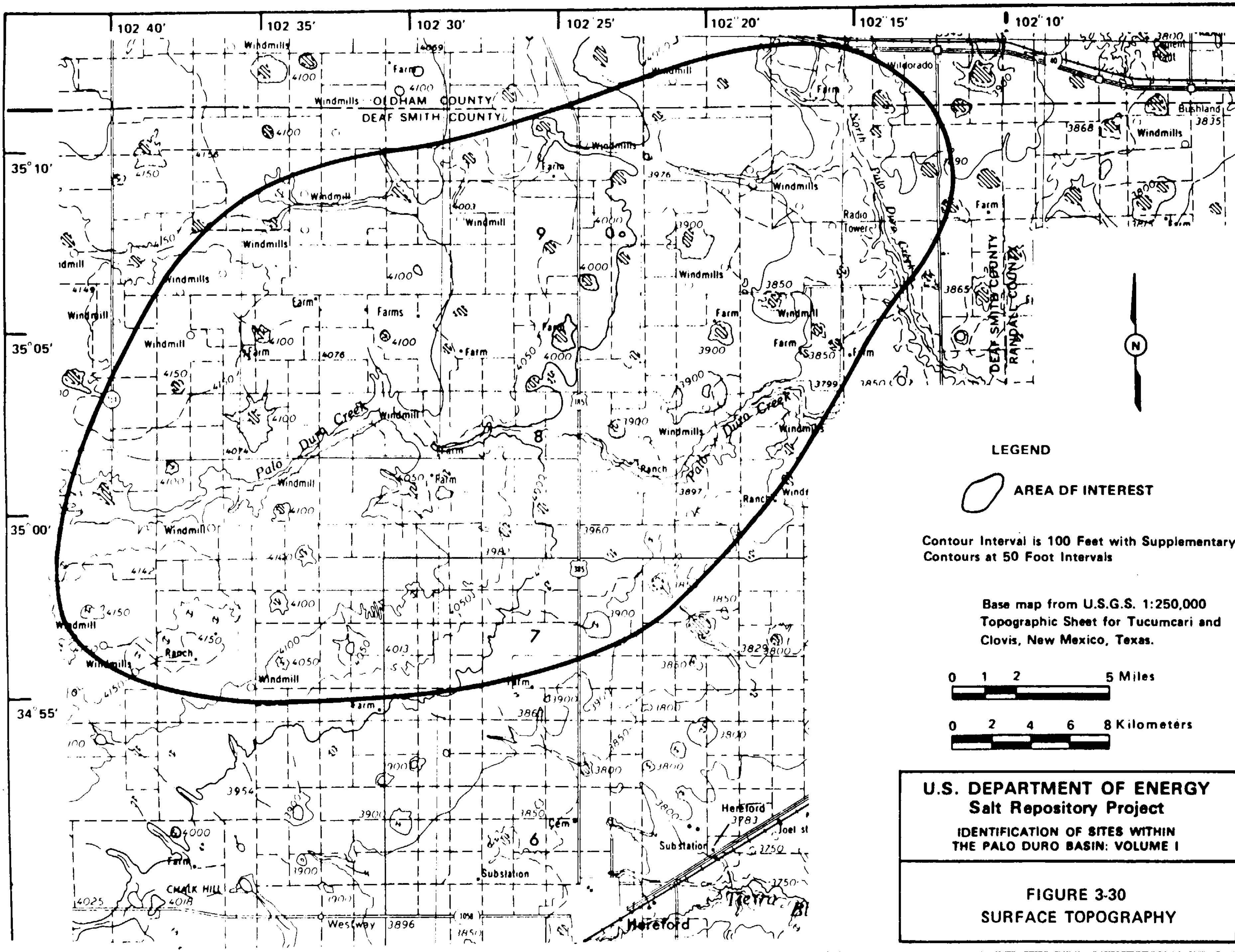
the applicability or sensitivity of site location to this information cannot be determined for a future time when actual acquisition activities may begin. As a result, the descriptor, land ownership complexity, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7) even though present-day variation 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.

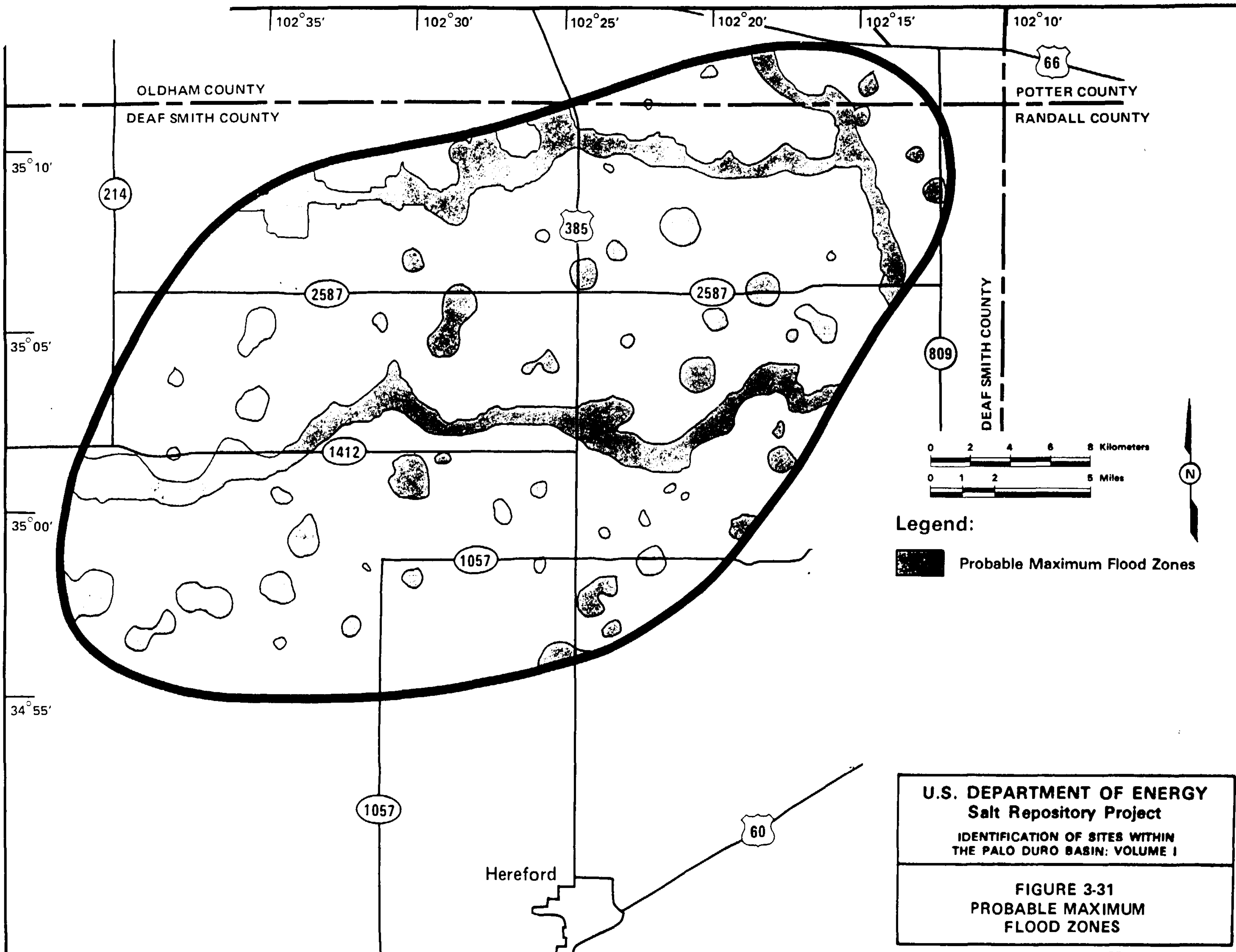
3.7.1 Proximate Streams and Floodplains

Streams that flow through the location are illustrated by Figure 3-30. These streams are Palo Duro Creek, North Palo Duro Creek, and an unnamed tributary to North Palo Duro Creek. These are ephemeral creeks, each of whose drainage area is limited to its creek valley and the narrow belts of sloping land adjacent to the valley. When adjacent land without topographic relief is available, it is 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



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-30
SURFACE TOPOGRAPHY



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-31
PROBABLE MAXIMUM FLOOD ZONES

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 88 percent higher than the annual mean precipitation (18.04 inches [45.82 centimeters]) experienced at Hereford from 1937 to 1962 (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. However, because of their small size, they are not of concern in siting a repository. The descriptor, proximate impoundments, was identified as a nondiscriminator (Steps 1, 2, 3, 5, and 7).

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, 1984c). 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.

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).

Table 3-1. Impoundments Located Within the Deaf Smith/Oldham County Location Boundaries

Dam	River	Location	Normal Impoundment, acre-feet[a]	Surface Area, acres[b]	Owner
Harris & Thrush	Palo Duro Creek	Deaf Smith County Lat. 35°02.0' Long. 102°28.3'	55	7	Texas Agronomics Farming
Montgomery Lake	North Palo Duro Creek Tributary	Deaf Smith County Lat. 35°10.8' Long. 102°15.1'	26	5	Richard Montgomery
Schulte Lake	Palo Duro Creek	Deaf Smith County Lat. 35°02.6' Long. 102°31.4'	32	10	Bill Schulte
Grigsby Lake	Palo Duro Creek	Deaf Smith County Lat. 35°02.7' Long. 102°29.9'	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.

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 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, 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).

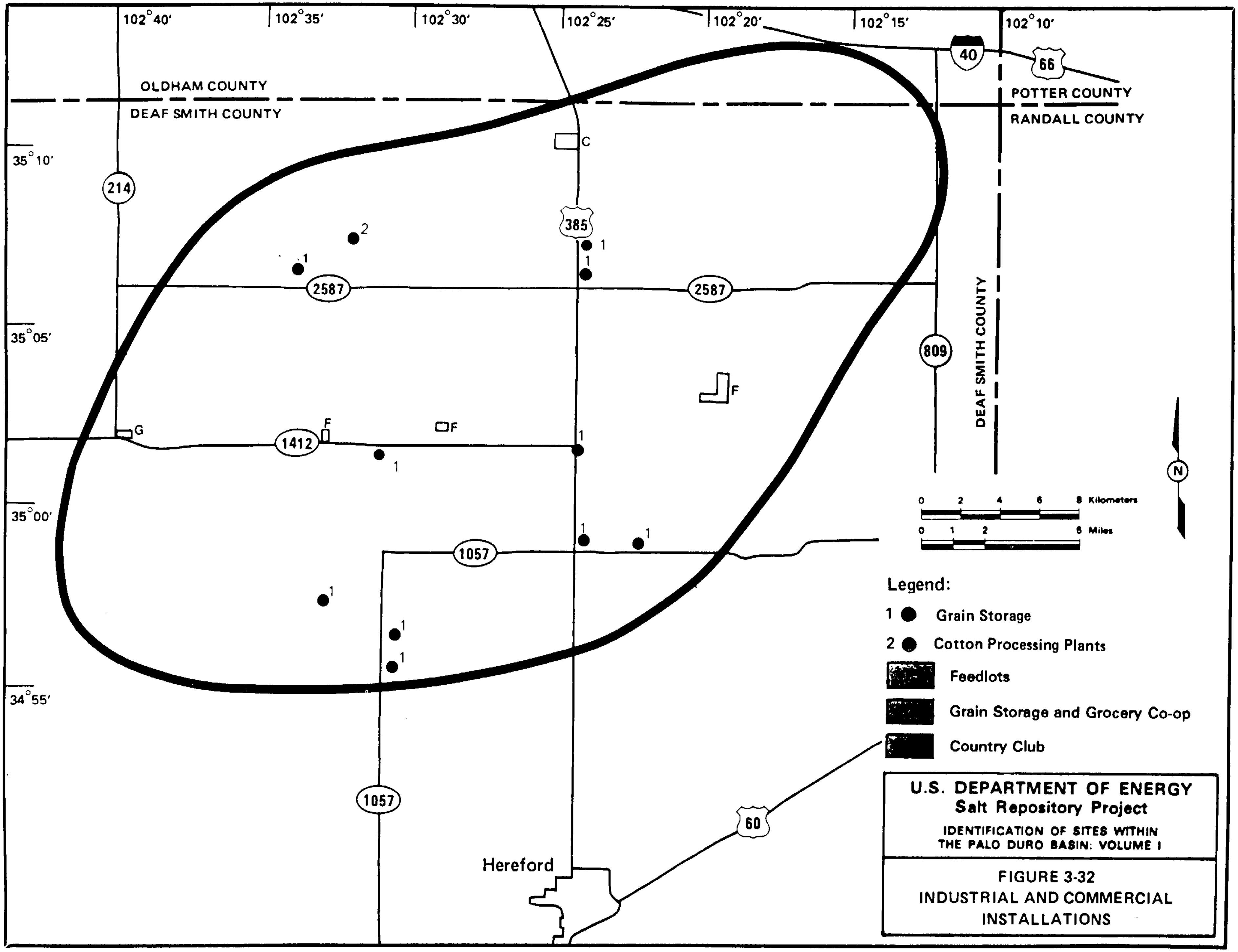
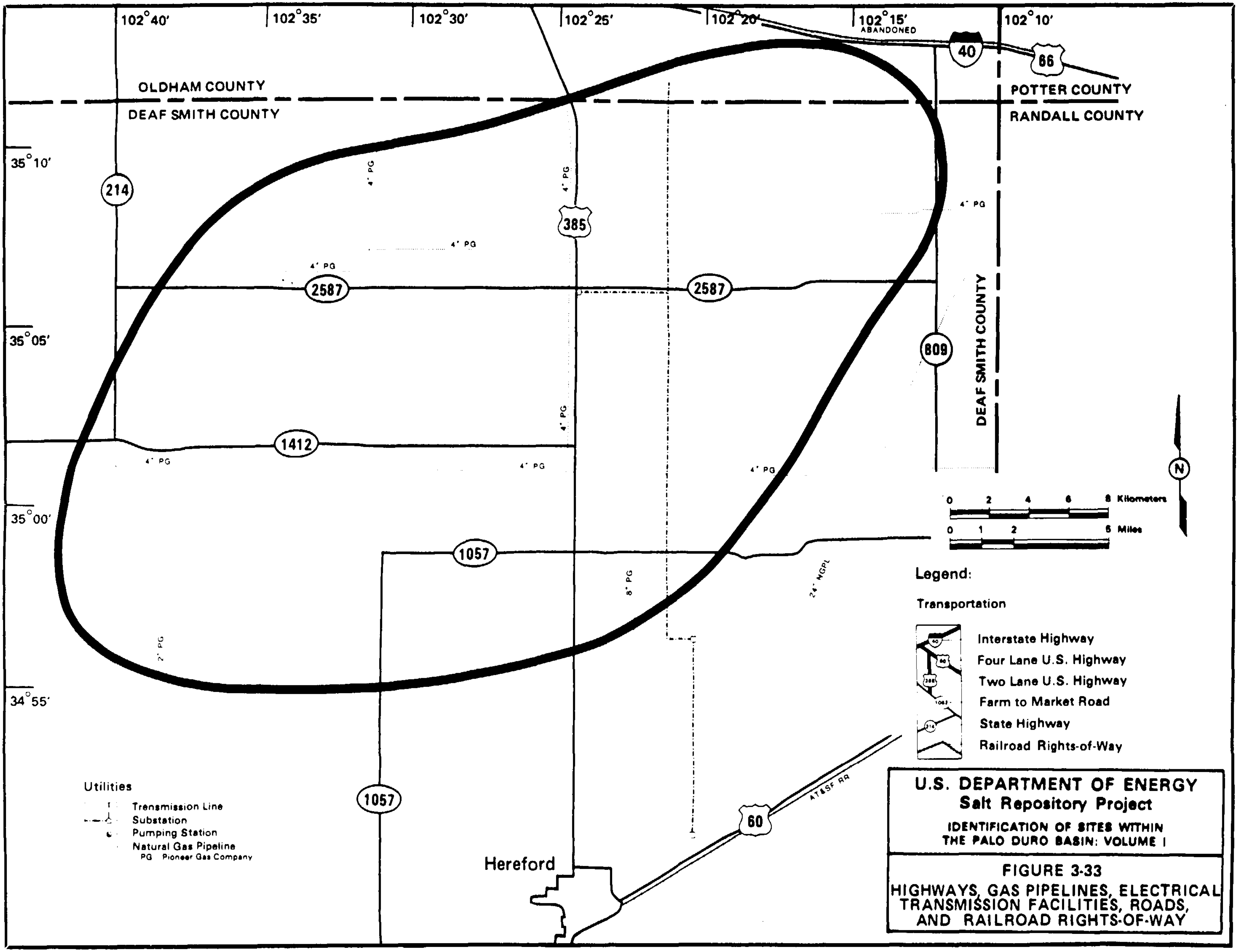


FIGURE 3-32
INDUSTRIAL AND COMMERCIAL INSTALLATIONS



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

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 no highly populated areas within its boundaries. "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). There are highly populated areas outside the location; Hereford, with a 1980 population of 15,853 (DOC, 1982b; NUS, 1984d), is the nearest at 7 miles (11.3 kilometers) from the location.

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 kilometers by 1.6 kilometers) within or adjacent to the location that have a population of not less than 1,000 individuals.

---

* 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.

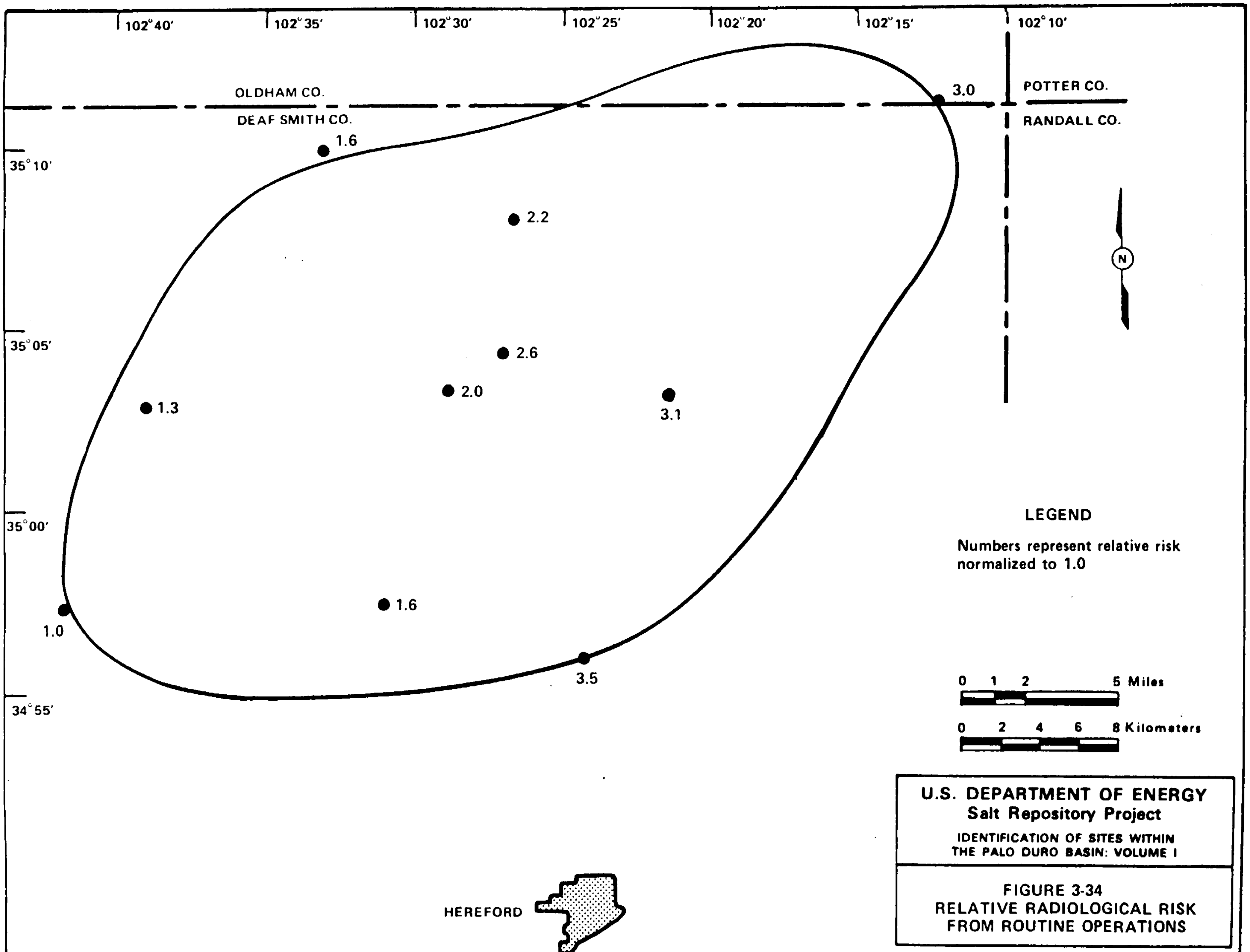
** Maps of residential structures in the Deaf Smith County location were prepared by NUS Corporation. These maps are based on 1:12,000 (1 inch = 1,000 feet), color infrared (CIR) aerial photographs taken by R&D Aerographics in 1981, 1982, and 1983. These photographs were supplemented by 1:80,000 (1 inch = 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.

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.

Deaf Smith County has an average population density of 14.1 persons per square mile, which is lower than the national average (DOC, 1982b). The city of Hereford, which is outside the location boundary, is included in this population density. If the land area and population of Hereford are excluded from the county calculation, the rural population density is 3.5 persons per square mile. Thus, the entire location meets the low density criterion.

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 are no population concentrations in this location. Thus, the descriptor, population density, was identified as a nondiscriminator (Steps 1, 2, 3, 4, 5, and 7).

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 10 points within the location on the basis of this subcriterion was performed. The locations of the 10 calculation points are depicted on Figure 3-34.



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-34
RELATIVE RADIOLOGICAL RISK FROM ROUTINE OPERATIONS

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 proportion 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 distance, and population versus distance, an index of the population risk from routine releases is derived.* Normalizing the indices for the 10 points involved to the lowest risk index indicates the relative risk across the location. For the calculation points, the lowest risk was posed at the far southwestern boundary of the location (index 1.0) and the highest along the southern boundary near Hereford; (index 3.5) (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 3.5 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 reasonable achievable, taking into account technical, social, and economic considerations ..." Consequently, the factor of 3.5 is important even through 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 on site location. This determination

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

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

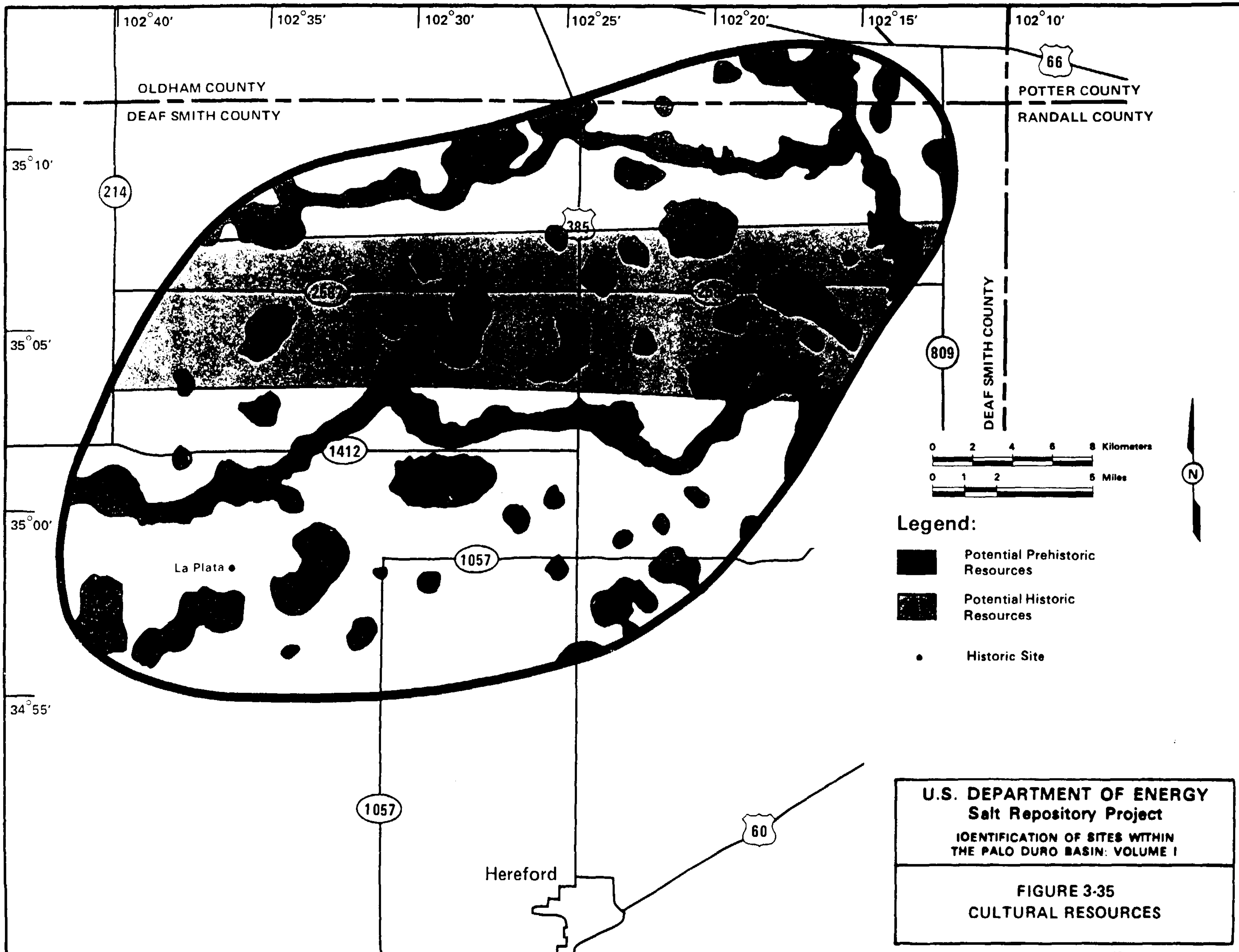
The primary intent of the environmental protection criterion is (1) to avoid or mitigate potentially adverse impacts to environmental resources or conditions and (2) to avoid potential conflicts with land use activities or conditions resulting from siting, construction, or operation of a repository.

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. Although there are known historic and archaeological resources within the location, only the former La Plata site, the original county seat of Deaf Smith County has been recognized by the Texas Antiquities Committee (NUS, 1984e). There are no known sites of national significance (National Register Sites) within the location (NUS, 1984e). However, there is a National Register Site and Texas Historic Landmark in Hereford; the E. B. Black residence at 508 West Third Street. 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).



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-35
CULTURAL RESOURCES

The approximate location of a historic trail is also shown in Figure 3-35. The exact location of this trail is unknown and, hence, depicted by a swath of land approximately 5 miles (8 kilometers) wide. Because this represents only an estimation of the actual route, it is considered less significant from a cultural resource perspective than the playas and waterways, but more important than the remainder of the location.

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/historic resources, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).

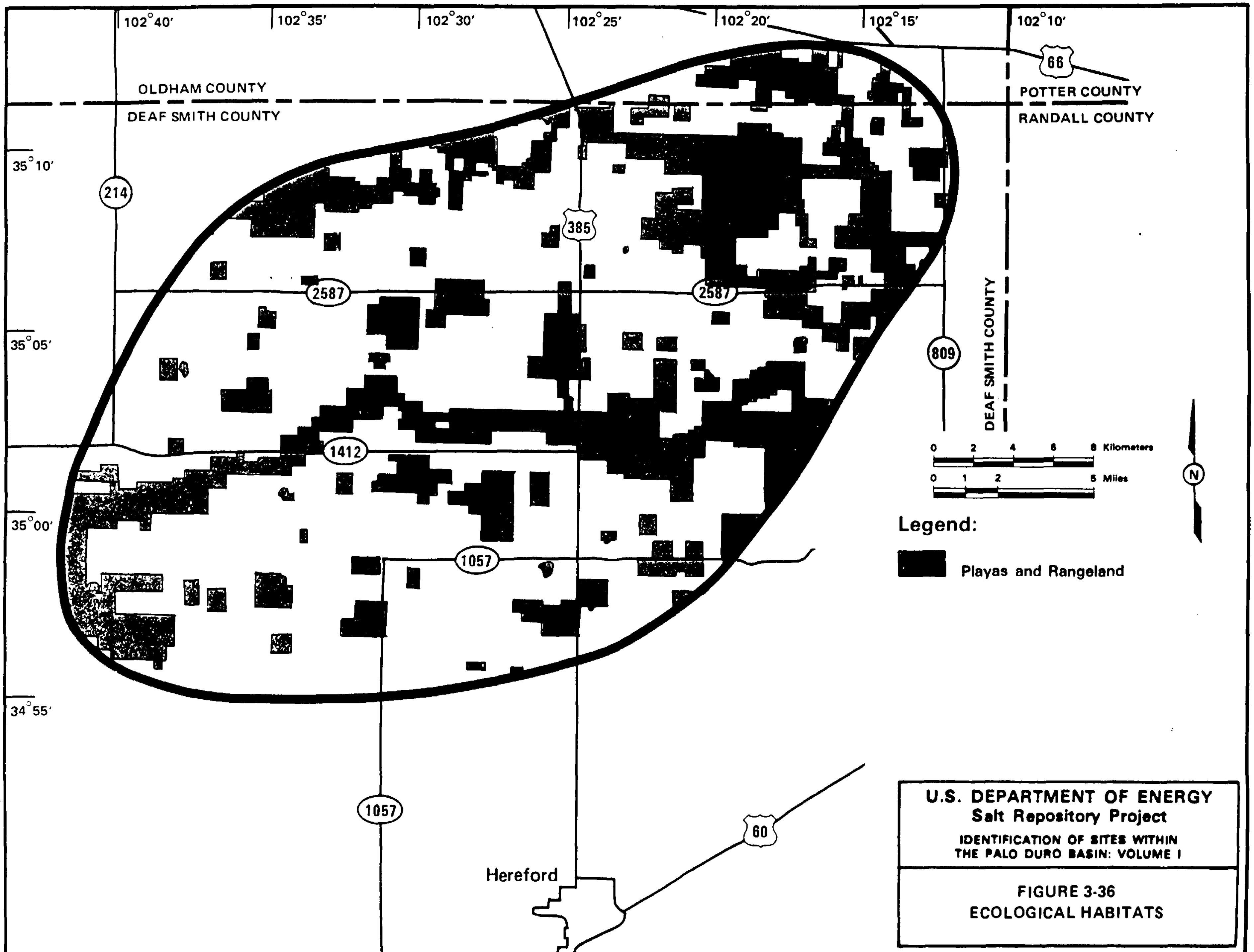
3.9.1.2 Aesthetics

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

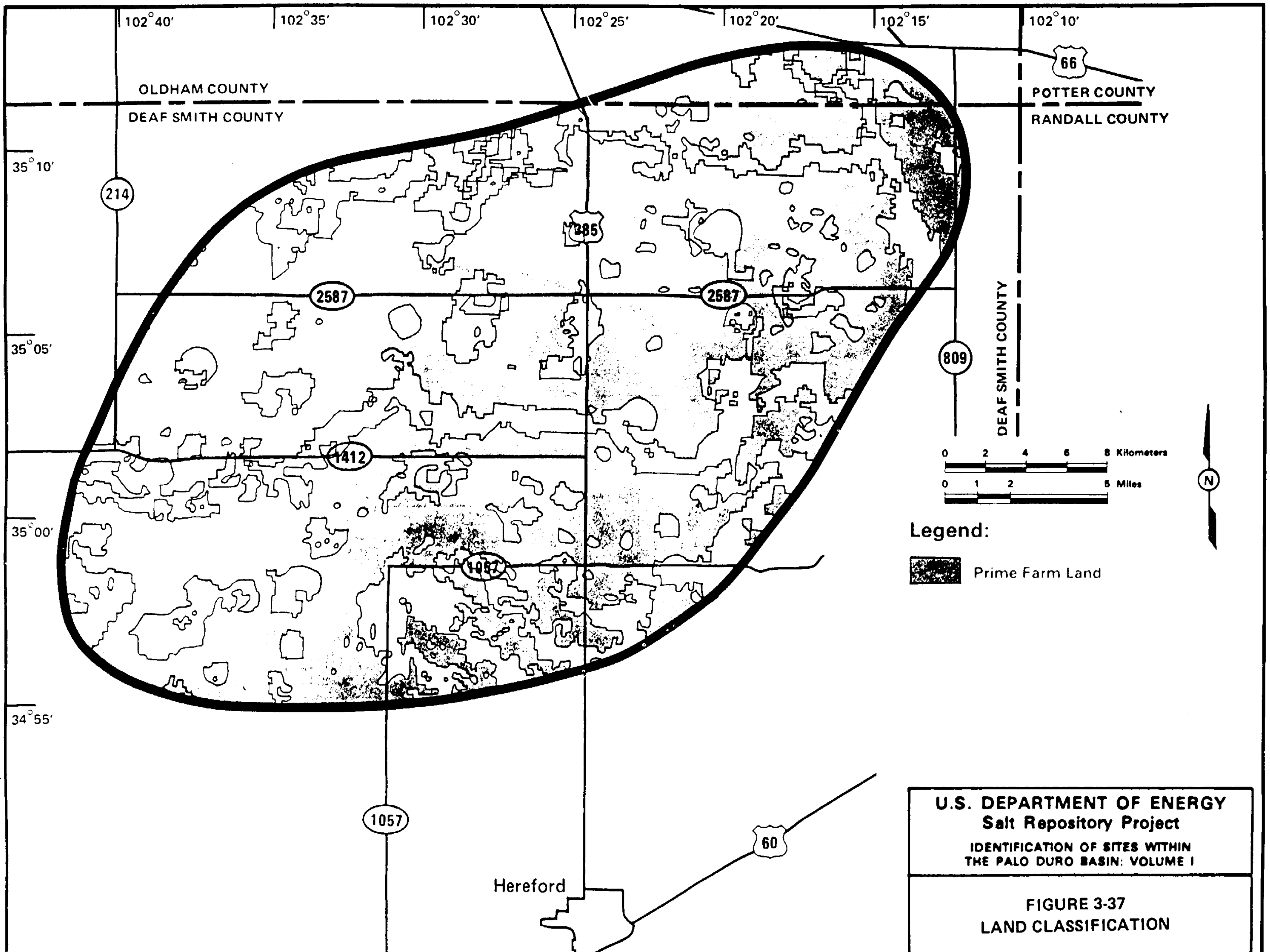
Ecological habitat can be visualized as a complex pattern of plant groups covering the surface of the land. This plant-group pattern results from the influence of local topography, soil types, climate, and cultural practices. It is also strongly influenced by the presence of surface or near-surface water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

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



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-36
ECOLOGICAL HABITATS



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 3-37
LAND CLASSIFICATION

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).

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 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 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

---

*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.

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 Palo Duro Creek and Tierra Blanca Creek in the Deaf Smith 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. aratrim), 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 Deaf Smith County (Oberholser, 1974). Migrating eagles have been observed at various times of the year in the Palo Duro Canyon and at Buffalo Lake National Wildlife Refuge (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 Deaf Smith 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 Deaf Smith 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 Palo Duro and North Palo Duro Creeks and numerous playa lakes, all of which 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 to 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. Areas proximate to streams and water bodies were identified as discriminators in Sections 3.7.1 and 3.7.2. 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 78 percent of the land in the Deaf Smith 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) may 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 less than 0.1 percent of the prime farmland within the county. The 9-square-mile (23-square-kilometer) site represents 1 percent of the prime farmland in Deaf Smith 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 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. Interstate 40 and U.S. Highway 384 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

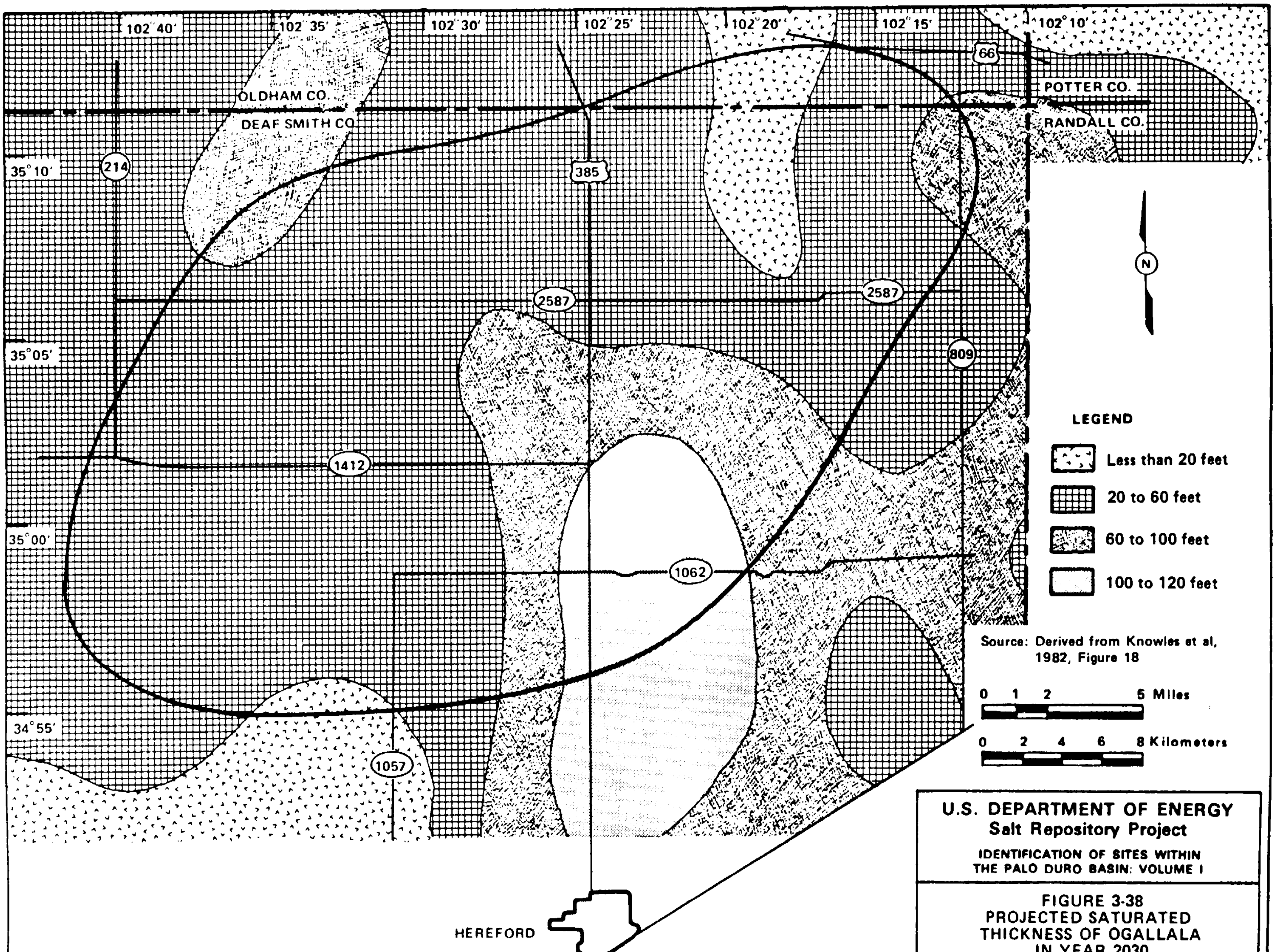
There are two railroad rights-of-way in the vicinity of the location that could provide points of origin for a railroad spur serving the repository site (Figure 3-33, NUS, 1984a). Distance from a right-of-way will determine the cost and environmental impact of building such a spur. Assuming a 200-foot (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 saturaged 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. The descriptor, projected saturated thickness of Ogallala in year 2030, was identified as a discriminator (Steps 1, 2, 3, 5, and 6).



U.S. DEPARTMENT OF ENERGY
Salt Repository Project

IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

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 thought to be available throughout the Deaf Smith location (Fink, 1963). 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 considerable production from the Santa Rosa sand near Hereford, 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 the location (NUS, 1984g). Consequently, the descriptor, extreme conditions, was identified as a nondiscriminator (Steps 1, 2, 3, 4, and 7).

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, 1984b). New residents, for example, will primarily locate in communities such as Canyon, Amarillo, Hereford, and Vega, 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 16 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

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 Water Bodies (playas)
Proximate Transportation Installations (paved roads, pipelines, and electrical transmission facilities)
DEMOGRAPHY
Population Risk-Operations
ENVIRONMENTAL PROTECTION
Cultural Resources
Aesthetics
Ecological Habitat
Prime Farmland
Industrial/Commercial Installations
Proximity to Road Access (major highways)
Proximity to Rail Rights-of-Way
Projected Saturated Thickness of Ogallala in Year 2030

4 SITE IDENTIFICATION

To identify a smaller, more-preferred site suitable for characterization within Palo Duro Location A, a systematic method for narrowing the 400-square-mile (1,040-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 achieveable, 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.

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

One discriminator identified in Section 3 was considered to depict variability from an operational performance standpoint. That discriminator, population risk-operations, is 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:

- Water supply is very important in the relatively arid Texas Panhandle; hence, a higher priority.
- 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 less than 1 percent of area of prime farmland in Deaf Smith County; hence, a lower priority.

Table 4-1. Discriminator Groupings

Group	Discriminator
Long-Term Performance	Location of Boreholes Reaching Host Rock Hydrocarbon Resource Potential
Operational Performance	Population Risk-Operations
Environmental/Constructability Considerations	
Priority 1	Ecological Habitat Projected Saturated Thickness of Ogallala in Year 2030
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/Historical Resources Prime Farmland Aesthetics
Priority 6	Proximate to Transportation Installations (paved, roads, pipelines, and electrical transmission facilities) Industrial/Commercial Installations

The Priority 1 category included consideration of ecological habitat and potential future water use conflicts. These two discriminators, ecological habitat and projected saturated thickness of the Ogallala in year 2030, are discussed in Section 3.9.1.3 and 3.9.2.5, respectively.

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, and electrical transmission facilities) and industrial and commercial installations, are discussed in Sections 3.7.10 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 two discriminators in this group. As described in Section 3.6, the greatest risk of human intrusion is in the northeastern portion of the location. This area: (1) overlies Pennsylvanian shelf edge carbonates-possible reservoir rock; (2) is an area of richer source rocks; (3) is an area of greater present-day oil and gas leasing; and (4) is closer to existing oil production.

While there is no discrete cut-off between clearly less-preferred and more-preferred areas, the 0.5 percent total organic carbon in Pennsylvanian rocks isopleth (Figure 3-24) was selected as the western boundary as a means of visually (and reproducibly) discriminating within the location. Locations of boreholes which reach the host rock are also less-preferred areas. Six such locations exist in the central and western portions of the location. Approximately two-thirds of the location is more-preferred from a long-term performance standpoint (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. Figure 4-2 depicts more-preferred and less-preferred areas from an operational performance standpoint, with roughly the western half 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 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. This area coincides closely with the more-preferred area illustrated by Figure 4-2. This result occurred because the less-preferred area of Figure 4-2 encompasses the less-preferred area of Figure 4-1,

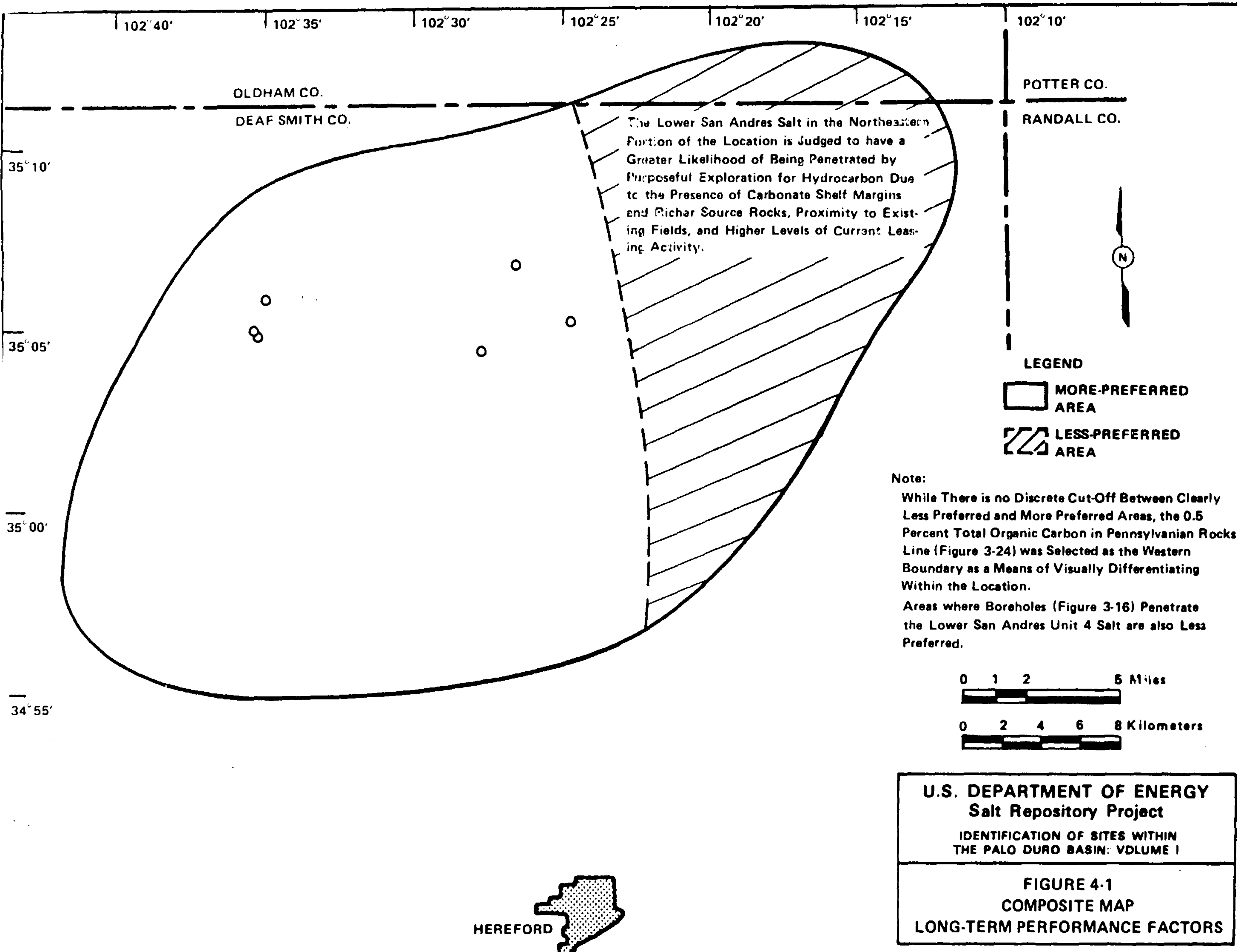
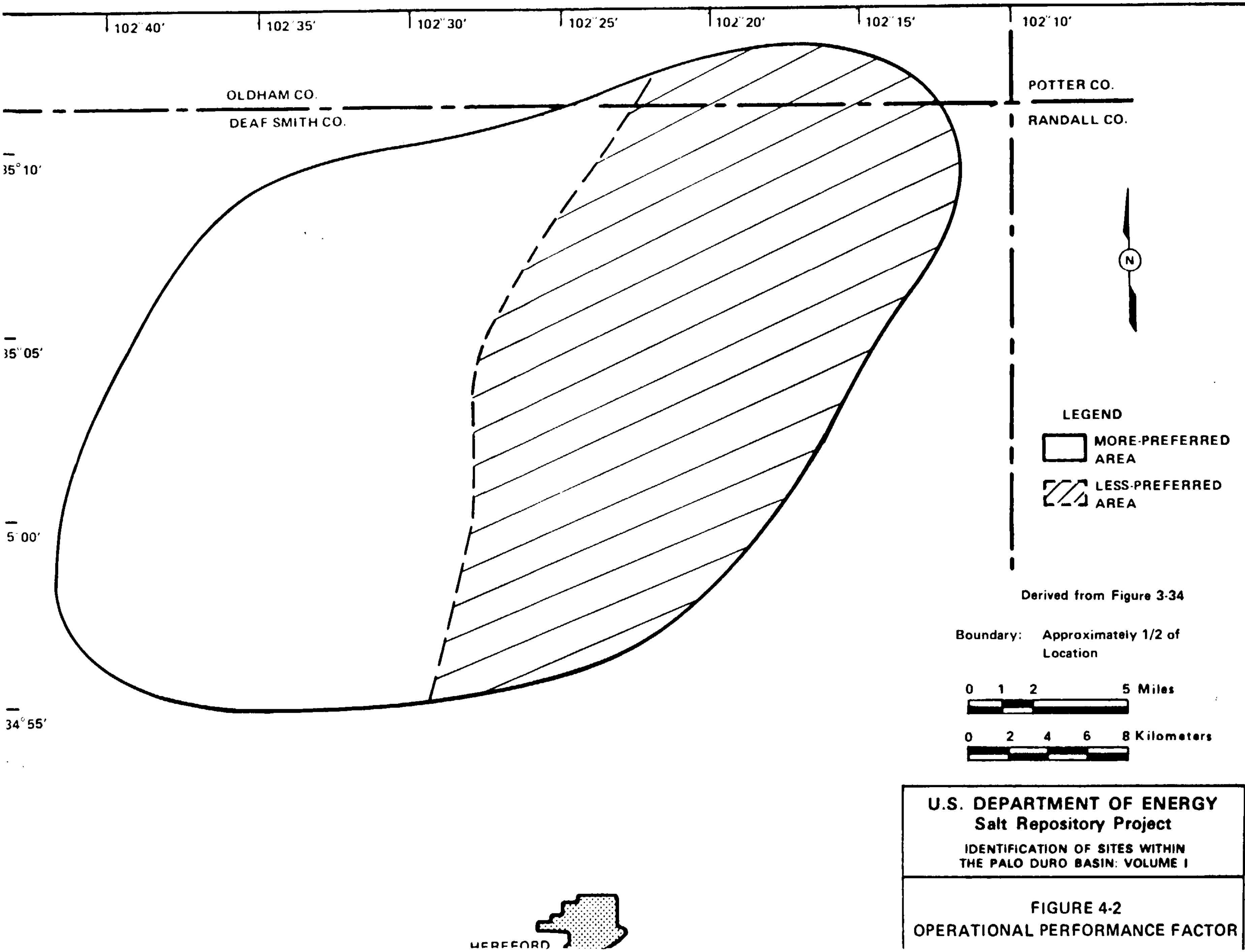


FIGURE 4-1
COMPOSITE MAP
LONG-TERM PERFORMANCE FACTORS



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 4-2
OPERATIONAL PERFORMANCE FACTOR

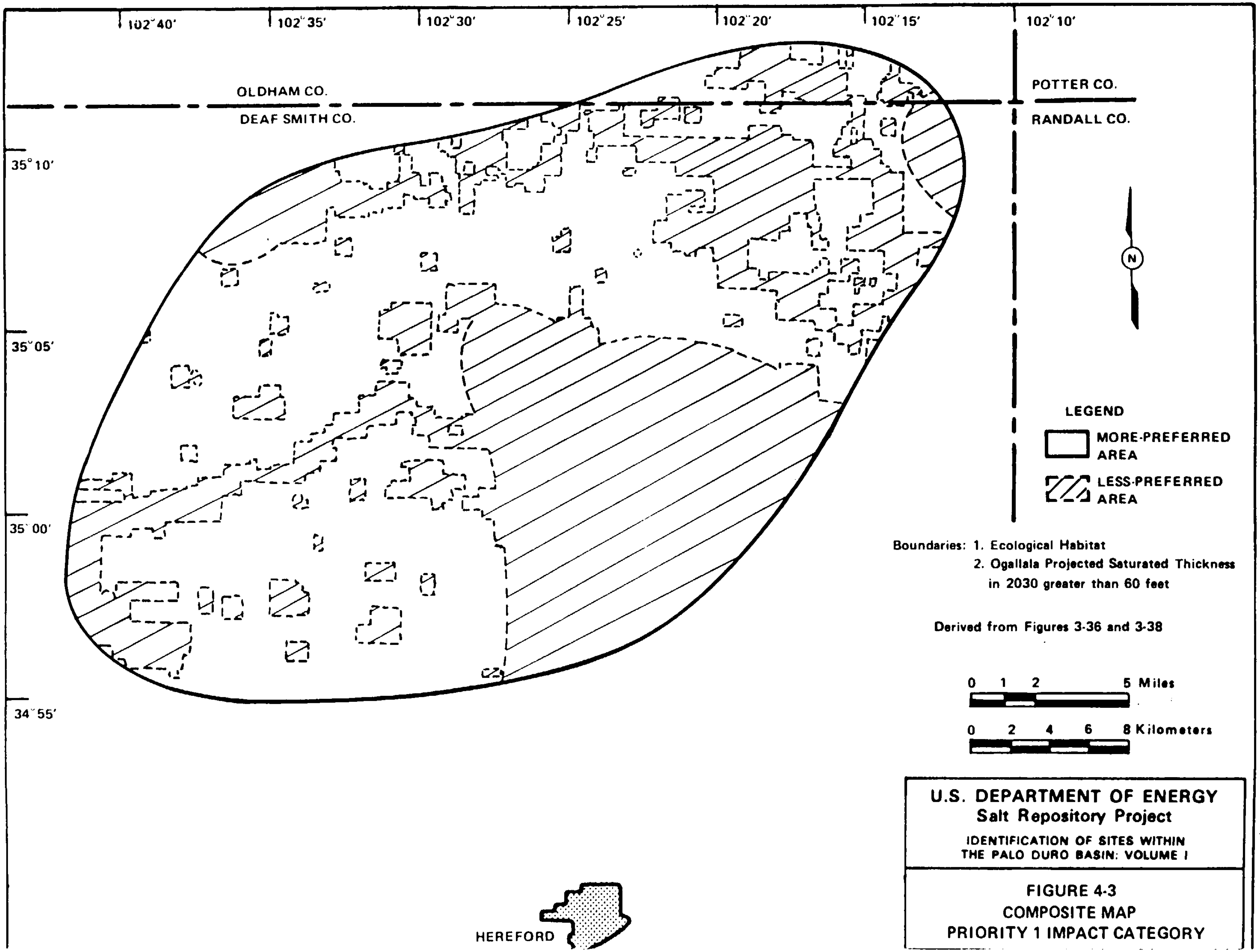
except for the borehole locations and a small area in the northern part of the location. Thus, Figure 4-2 approximates an intermediate result (the overlay of Figure 4-1 and 4-2) of the overlay process.

The Priority 1 impact category, ecological habitat, was then considered. Discrete boundaries between more-preferred and less-preferred areas were identified for these discriminators. The more-preferred areas, from a standpoint of reducing the potential for adverse impact on valued ecological habitat, are the areas identified as "other land" in Figure 3-37.

From the standpoint of reducing potential future water use conflict, more-preferred areas are those with lower projected saturated thicknesses of Ogallala in the year 2030 (Section 3.9.2.5). The 60-foot (18-meter) contour on the TDWR map (Figure 3-38) was selected as a discrete boundary. While irrigation could occur in areas of less than 60 feet (18 meters) of saturated thickness, the 60-foot (18-meter) value is below the saturated thickness of 100 feet (30 meters) which is generally required if well yields are not to be a limiting factor on irrigation. As such, this contour was believed to represent a conservative value which could be used to reduce the potential for siting in areas with greatest likelihood of using the Ogallala for irrigation.

The composite map from this impact category (Figure 4-3) results in large more-preferred areas in the north-central and western portions of the location. Overlaying Figures 4-2 and 4-3 results in the more-preferred area according to the three highest priority groupings (Figure 4-4), about 125 square miles (325 square kilometers) in the western half of the location.

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 3-12, Section 3.2.3) and shallower depths to the lower San Andres unit 4 (Figure 3-2, Section 3.1.1.1). Both of these factors are continually variable across the location. A contour value was selected on each map (Figures 3-12 and 3-1) such that approximately one-half the area of the location would be classified as less-preferred for that individual discriminator. For recent Ogallala saturated thickness, the selected boundary value was 100 feet (30 meters). A boundary value of 2,500-foot (760-meter) depth to the lower San Andres unit 4 approximated one-half the location. The more-preferred area shown in Figure 4-5 results from combining these factors.



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 4-3
COMPOSITE MAP
PRIORITY 1 IMPACT CATEGORY

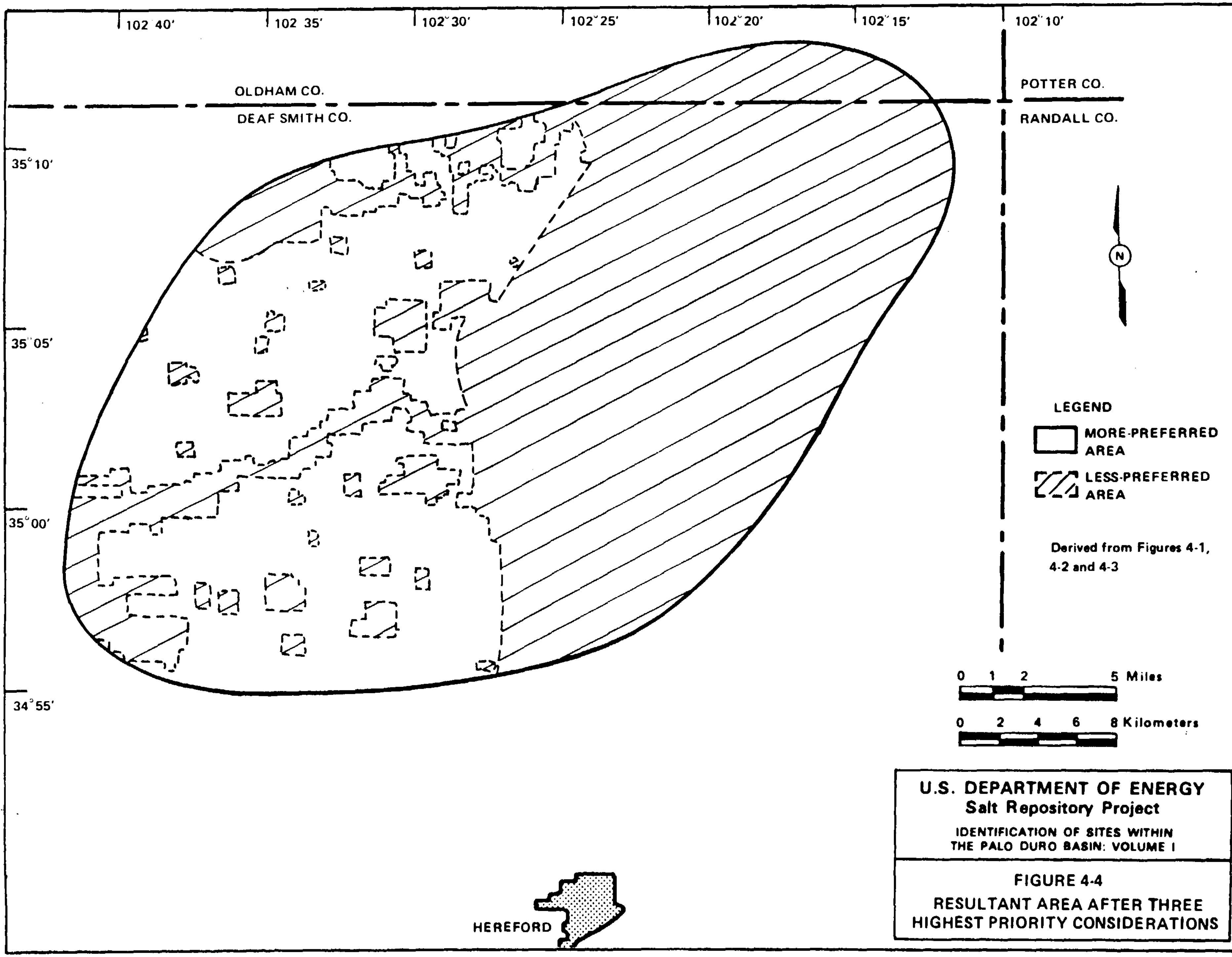


FIGURE 4-4
RESULTANT AREA AFTER THREE HIGHEST PRIORITY CONSIDERATIONS

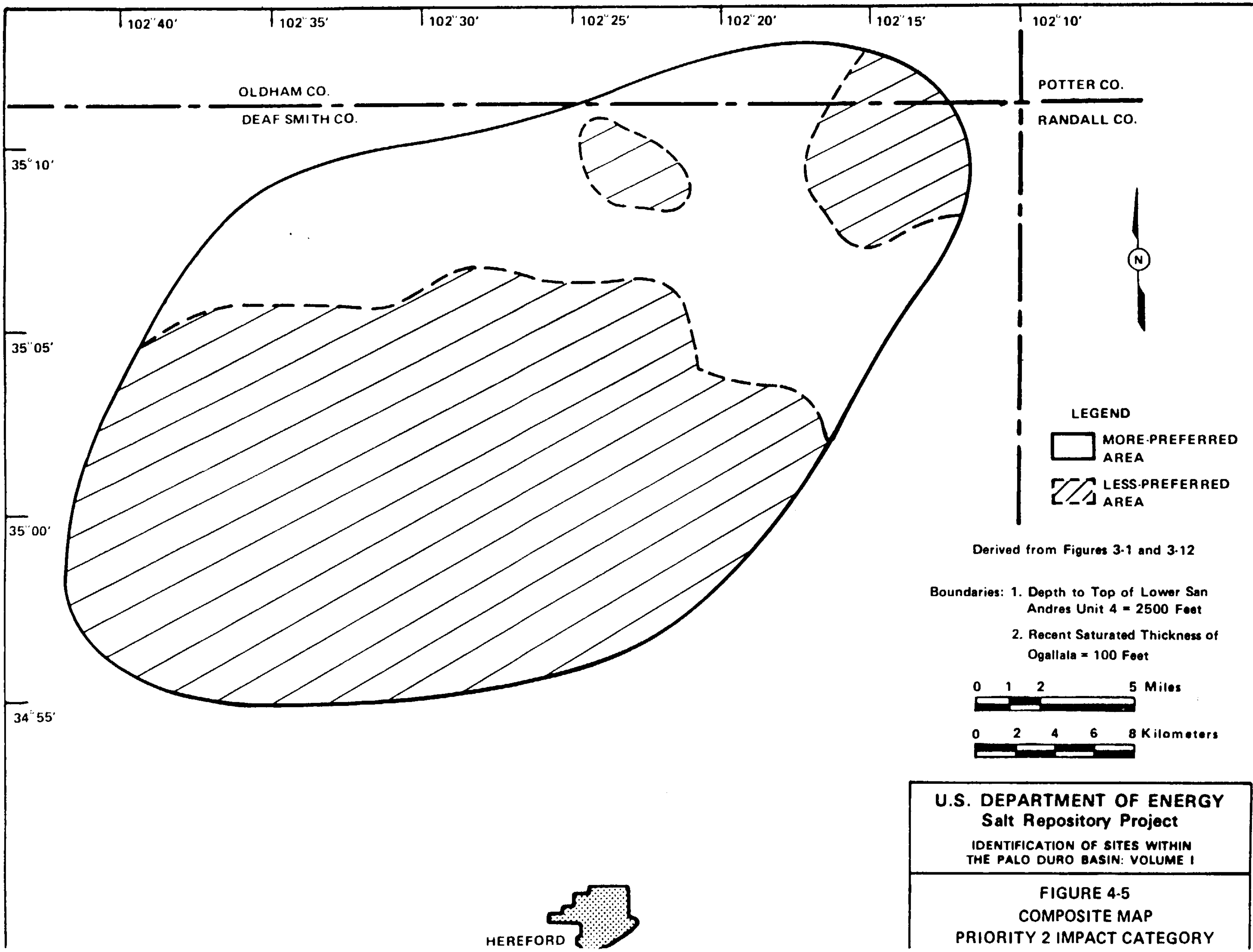


FIGURE 4-5
COMPOSITE MAP
PRIORITY 2 IMPACT CATEGORY

Overlaying Figures 4-4 and 4-5 results in more-preferred area according to the four highest priority groupings, totaling approximately 30 square miles (78 square kilometers) (Figure 4-6).

The Priority 3 impact category, proximity to road access (major highways) and proximity to rail rights-of-way, was then considered. Preference is for siting closer to roads and rails to reduce disruption of land areas and to minimize costs (Section 3.9.2.3 and 3.9.2.4). Both discriminators are continuously variable across the location. A distance was chosen from U.S. Route 385 and Interstate 40 and existing rail rights-of-way such that approximately one-half of the area of the location would be classified as more-preferred for each individual discriminator. This distance was 5 miles (8 kilometers) from main highways and 11 miles (18 kilometers) from rail rights-of-way. The more-preferred and less-preferred areas for this impact category are illustrated in Figure 4-7.

Overlaying Figure 4-6 and Figure 4-7 results in smaller more-preferred areas in the north-central part of the location (Figure 4-8). The largest of these areas is approximately 10 square miles (26 square kilometers). Because the application of these higher priority groupings resulted in a more-preferred area of approximately the site size desired, no further rigorous overlay of lower priority discriminators (Priority 4, 5, and 6 categories) is warranted.

The northern more-preferred areas (Figure 4-8) are constrained on the south by ecological habitat and on the north by the location boundary. A less-preferred area containing a borehole which penetrates the host rock precludes positioning of the site in the eastern portion of the large resultant area; in addition, relative risk to population is higher to the east. The lower priority discriminators which constrain the larger more-preferred area are depth to host rock and proximity to roads (major highways). These discriminators are continuously variable across the location; thus, the boundaries selected during this narrowing process are not absolute. Minimal potential for adverse impacts according to priority is achieved by identification of a site to include most of the larger more-preferred area (Figure 4-8) and land south and west of it.

The desired 9-square-mile (23-square-kilometer) site area was delineated (Figure 4-9) along section lines in accord with the priorities just described.

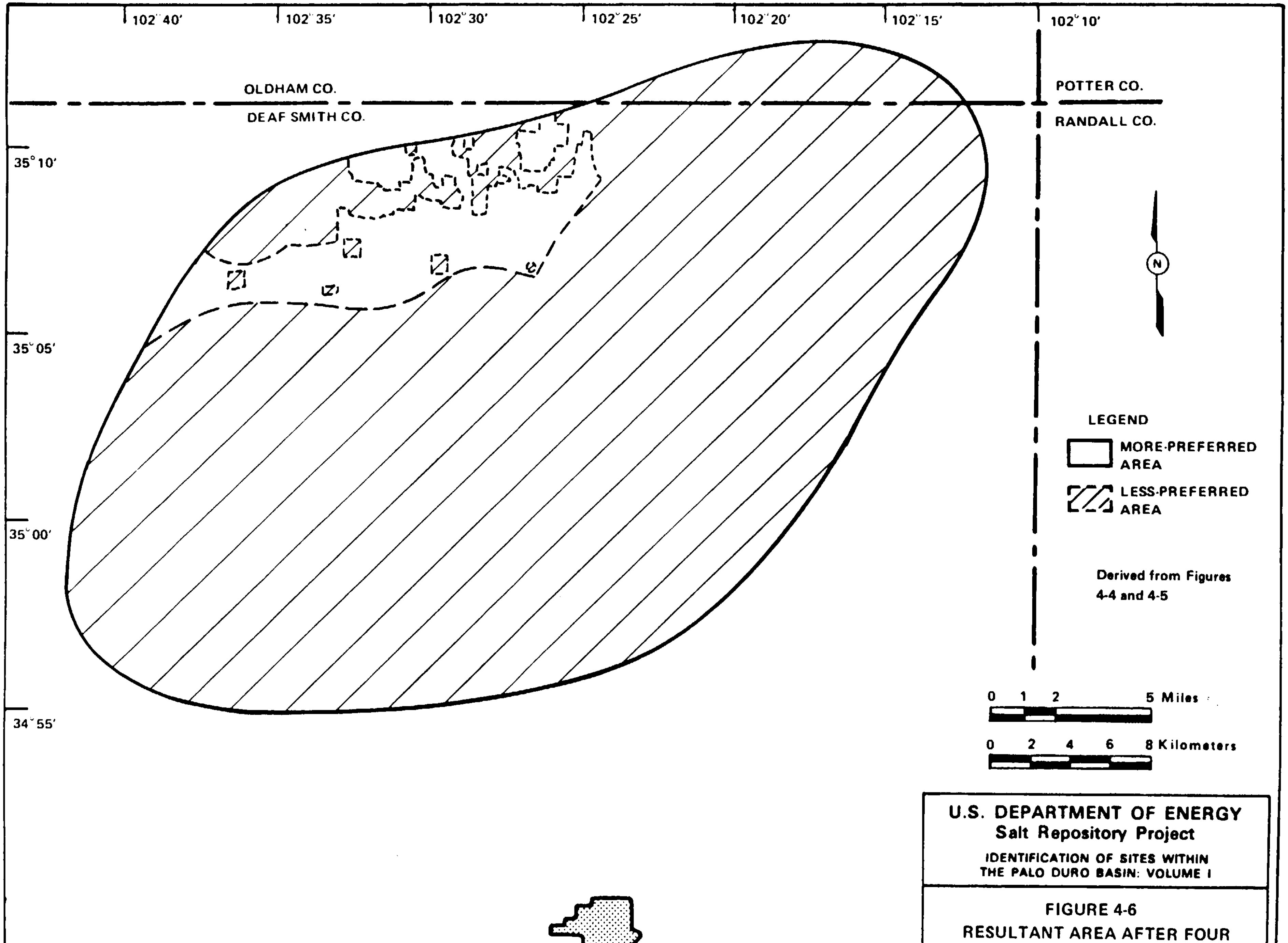
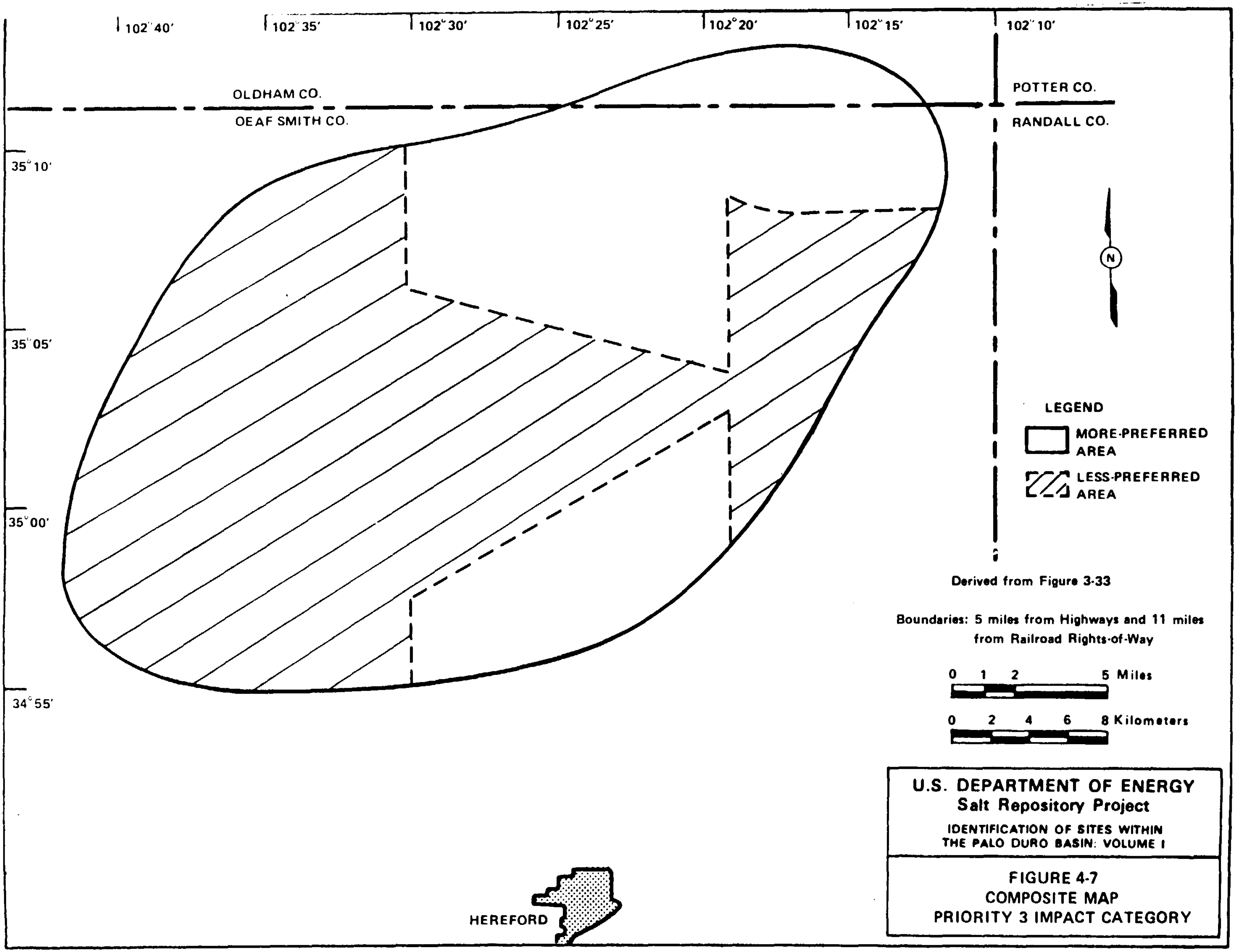
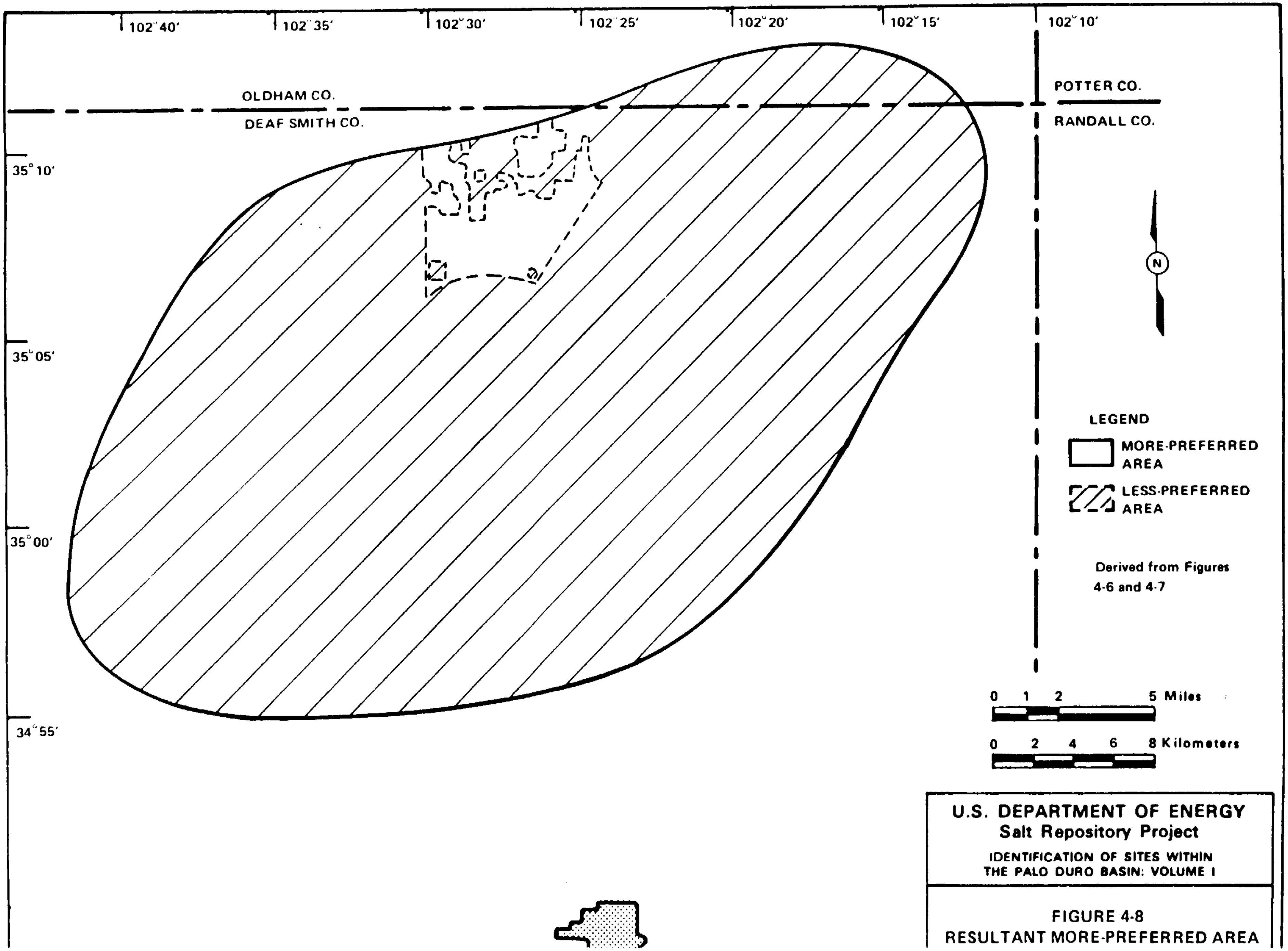


FIGURE 4-6
RESULTANT AREA AFTER FOUR HIGHEST PRIORITY CONSIDERATIONS



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 4-7
COMPOSITE MAP
PRIORITY 3 IMPACT CATEGORY



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE 4-8
RESULTANT MORE-PREFERRED AREA

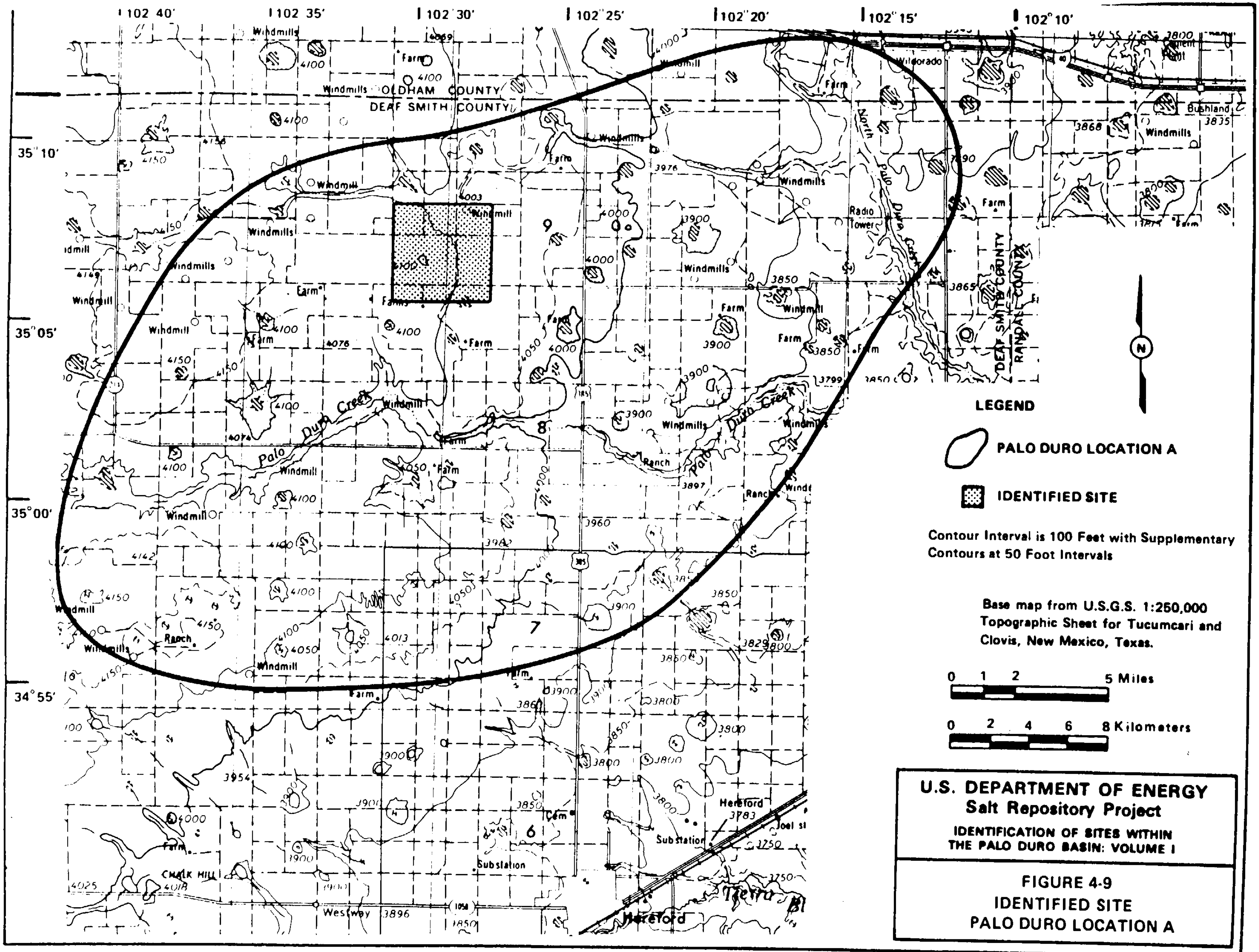


FIGURE 4-9
IDENTIFIED SITE
PALO DURO LOCATION A

119/120

5 REFERENCES

Algermissen, S. T., and D. M. Perkins, 1976. A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States, U. S. Geological Survey Open-File Report 76-416, U.S. Department of the Interior, Washington, DC.

Arnold, V. L., J. Zarnikau, S. Goodman, and M. Chapman, 1983. Texas Panhandle Mineral Assessment: Summary Report, The Bureau of Business Research, The University of Texas at Austin, Austin, TX.

Bassett, R. L., and M. E. Bentley, 1982. "Geochemistry and Hydrodynamics of Deep Formation Brines in the Palo Duro and Dalhart Basins, Texas", Journal of Hydrology, Vol. 59, pp. 331-372.

Bellrose, F. C., 1968. Waterfowl Migration Corridors East of the Rocky Mountains in the United States, Biological Notes No. 61, Illinois Natural History Survey.

Brownlee, W. C., 1977. Nongame Wildlife Investigation: Black-Footed Ferret Status, Federal Aid Project No. W-103-R-7, Job No. 10, Texas Parks and Wildlife Department, Austin, TX.

Budnik, R. T., 1983. "Influence of Basement Structure on Distribution and Facies of Overlying Strata, Palo Duro Basin, Texas Panhandle", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Annual Report for 1982, Geological Circular 83-4, prepared for the U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Budnik, R. T., and D. Smith, 1982. "Regional Stratigraphic Framework of the Texas Panhandle", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Geological Circular 82-7, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

DOA, see U.S. Department of Agriculture.

DOC, see U.S. Department of Commerce.

DOD, see U.S. Department of Defense.

DOE, see U.S. Department of Energy.

DOI, see U. S. Department of the Interior.

Dutton, A. R., 1983. "Regional Ground-Water Flow System of the San Andres Formation", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Annual Report for 1982, Geological Circular 83-4, prepared for U.S. Department of Energy by Bureau of Economic Geology, the University of Texas at Austin, Austin, TX.

Dutton, S. P., 1980. Depositional Systems and Hydrocarbon Resource Potential of the Pennsylvanian System, Palo Duro and Dalhart Basins, Texas Panhandle, Geological Circular 80-8, Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Dutton, S. P., A. G. Goldstein, and S. C. Ruppel, 1982. Petroleum Potential of the Palo Duro Basin, Texas Panhandle, Report of Investigations, No. 123, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

EPA, see U.S. Environmental Protection Agency.

Fink, B. E., 1963. Ground-Water Geology of Triassic Deposits, Northern Part of the Southern High Plains of Texas, High Plains Underground Water Conservation District No. 1, TX.

Goldstein, A. G., 1982. "Quantitative Analysis of Regional Bouguer Gravity Data", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Ceological Circular 82-7, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Gould, F. W., 1975. The Grasses of Texas, Texas A&M University Press, College Station, TX.

Gustavson, T. C., and R. T. Budnik, 1983. "Structural Control of Geomorphic Processes, Physiographic Features, and Lithologies, Texas Panhandle", Proceedings with Abstract, Geological Society of America Annual Meeting, October.

Gustavson, T. C., R. J. Finley, and R. W. Baumgardner, Jr., 1981. "Retreat of the Caprock Escarpment and Denudation of the Rolling Plains in the Texas Panhandle", Bulletin of the Association of Engineering Geologists, Vol. 28, No. 4, pp. 413-422.

Gustavson, T. C., R. J. Finley, and K. A. McGillis, 1980. Regional Dissolution of Permain Salt in the Anadarko, Dalhart, and Palo Duro Basins of the Texas Panhandle, Report of Investigations, No. 106, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Guthery, F. S., 1981. "Playa Basins and Resident Wildlife in the Texas Phahandle", Playa Lakes Symposium Proceedings, December 4-5, 1979, Arlington, Texas, U.S. Fish and Wildlife Service, Washington, DC, pp. 47-51.

Handford, C. R., and S. P. Dutton, 1980. "Pennsylvanian-Lower Permian Depositional Systems and Shelf-Margin Evolution, Palo Duro Basin, Texas," American Association of Petroleum Geologists Bulletin, Vol. 64, pp. 88-106.

Hetland, D. L., 1979. "Potential Uranium Resources", in Uranium Industry Seminar, October 16-17, Grand Junction, CO, pp. 151-172.

Hubbard, N., 1984. Hydrochemical and Isotope Hydrology Results for the Palo Duro Basin, Texas Panhandle: A Summary Report of Material Presented at the June 5, 1984 Discussion Meeting, Columbus, Ohio, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Hubbard, N., D. Livingston, and L. Fukui, 1984a. "The Composition and Stratigraphic Distribution of Materials in the Lower San Andres Salt Unit 4", Proceedings of the 1983 Materials Research Society, November 1983.

Hubbard, N., J. C. Laul, and R. W. Perkins, 1984b. "The Use of Radionuclides to Predict the Behavior of Radwaste Radionuclides in Far-Field Aquifers", Proceedings of the 1983 Materials Research Society, November 1983.

INTERA Environmental Consultants, Inc., 1984a. First Status Report on Regional Ground-Water Flow Modeling for the Palo Duro Basin, Texas, ONWI-504, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

INTERA Environmental Consultants, Inc., 1984b. Second Status Report on Regional Ground-Water Flow Modeling for the Palo Duro Basin, Texas, (Final Draft), prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Kaiser Engineers, 1978. Conceptual Design for a National Waste Terminal Storage Repository in a Bedded Salt Formation for Spent Unreprocessed Fuel, KE-78-57-RE, prepared for Office of Waste Isolation, Union Carbide Corporation, Nuclear Division, Oak Ridge, RN.

Knowles, T., P. Nordstrom, and W. B. Klemt, 1982. Evaluating the Ground-Water Resources of the High Plains of Texas: Final Report, Vol. 1, LP-173, Texas Department of Water Resources, Austin, TX.

Kreitler, C. W., and R. L. Bassett, 1983. "Chemical and Isotopic Composition of Saline Ground-Water and Saline Springs in the Rolling Plains East of the Ogallala Escarpment, Texas Panhandle", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Annual Report for 1982, Geological Circular 83-4, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Langmuir, D., 1983. "Barite-Radium Sulfate Solid Solution: Solubility Control on Ra-226 Mobility in Uranium Mill Tailings and Saline Ground-Waters from a Potential Nuclear Waste Repository", Proceedings with Abstracts, Geological Society of America Annual Meeting, October.

Machenberg, M. D., 1984. "Modern Rates of Eolian Erosion and Deposition on the Southern High Plains", abstract submitted to the 1984 Geological Society of America, South-Central Section Meeting.

McGookey, D. A., and R. T. Budnik, 1983. "History of Faulting in the Palo Duro Basin", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Annual Report for 1982, Geological Circular 83-4, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

McGookey, D. A., T. C. Gustavson, and A. D. Hoadley, 1984. Regional Structure Cross Sections of Mid-Permian to Quaternary Strata of the Texas Panhandle: Distribution of Evaporites and Areas of Evaporite Dissolution and Collapse, Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

NAS, see National Academy of Sciences.

National Academy of Sciences, 1983. A Study of the Isolation System for Geologic Disposal of Radioactive Wastes, National Research Council, Washington, DC.

NRC, see U.S. Nuclear Regulatory Commission.

NUS Corporation, 1984a. Land Use/Land Cover in Swisher County and Deaf Smith County Locations, BMI/ONWI-509, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984b, draft. Flooding Potential of Two Locations in Deaf Smith and Swisher Counties, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984c, draft. Surface Hydrologic Characteristics of Two Locations in Deaf Smith and Swisher Counties, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation 1984d. Socioeconomic Data Base Report for the Permian Basin, ONWI-461, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984e. Cultural Resources: Deaf Smith and Swisher County Locations, Texas, BMI/ONWI-560, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984f. Characteristics of Terrestrial and Aquatic Ecosystems of Two Locations in Deaf Smith and Swisher Counties, BMI/ONWI-508, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984g. Meteorological and Air Quality Characterization of the Deaf Smith and Swisher County Locations in the Palo Duro Basin, BMI/ONWI-527, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984h. Summer Sound-Level Characterization of the Deaf Smith and Swisher County Locations in the Palo Duro Basin, BMI/ONWI-528, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984i. Winter Sound-Level Characterization of the Deaf Smith County Location in the Palo Duro Basin, BMI/ONWI-526, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Office of Nuclear Waste Isolation, 1983. Permian Basin Location Recommendation Report, DOE/CH/10140-2, prepared for Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Washington, DC.

ONWI, see Office of Nuclear Waste Isolation.

Parsons Brinckerhoff/PB-KBB, 1983. Exploratory Shaft Facility Preliminary Designs - Permian Basin, ONWI-498, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Presley, M. W., 1981. Permian Salt-Bearing Units of the Texas Panhandle: Lithologic and Facies Cross Sections, Special Publication, Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

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.

RRC-IWG, see Reference Repository Conditions Interface Working Group.

Schreiner, L. C., and J. T. Riedel, 1978. Probably Maximum Precipitation Estimates, United States East of the 105th Meridian, Hydrological Report 51, National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington, DC.

Senger, R. K., and G. E. Fogg, 1983. "Regional Modeling of Ground-Water Flow in the Palo Duro Basin, Texas Pandle", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Annual Report for 1982, Geological Circular 83-4, prepared for the U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Simpson, C. D., F. A. Stormer, E. G. Bolen, and R. L. Moore, 1981. "Significance of Playas to Migratory Wildlife", Playa Lakes Symposium Proceedings, December 4-5, 1979, Arlington, Texas, U.S. Fish and Wildlife Service, Washington, DC, pp. 35-45.

Stebbins, R. C., 1966. A Field Guide to Western Reptiles and Amphibians, Houghton Mifflin, Boston, MA.

Stone & Webster Engineering Corporation, 1983a. Area Geological Characterization for the Palo Duro and Dalhart Basins, Texas, DOE/CH/10140-1, prepared for Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Washington, DC.

Stone & Webster Engineering Corporation, 1983b. Major Salt Beds of the Palo Duro and Dalhart Basins, Texas, BMI/ONWI-518, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Stone & Webster Engineering Corporation, 1984a, draft. Hydrogeologic Investigations Based on Drill-Stem Test Data, Palo Duro Basin Area, Texas and New Mexico, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Stone & Webster Engineering Corporation, 1984b. Well Completion Report - J. Friemel No. 1 (PD-9) Well, Palo Duro Basin, Texas: Unanalyzed Data, BMI/ONWI-5011, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Stone & Webster Engineering Corporation, 1984c. Well Completion Report - Detten No. 1 (PD-6) Well, Palo Duro Basin, Texas: Unanalyzed Data, BMI/ONWI-5008, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Stone & Webster Engineering Corporation, 1984d. Well Completion Report - G. Friemel No. 1 (PD-5) Well, Palo Duro Basin, Texas: Unanalyzed Data, BMI/ONWI-5003, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Stone & Webster Engineering Corporation, 1984e. Ogallala Aquifer Mapping Program - Topical Report Revision 1, October 1983, BMI/ONWI-524, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Stormer, J. C., Jr., 1972. "Ages and Nature of Volcanic Activity on the Southern High Plains, New Mexico and Colorado", Geological Society of America Bulletin, Vol. 83, pp. 2443-2448.

SWEC, see Stone & Webster Engineering Corporation.

Texas Department of Water Resources, 1982. Evaluating the Ground-Water Resources of the High Plains of Texas, Vol. 1, LP-173, TX.

Texas Natural Resources Information Service, 1982. Computer listing of data, Austin, TX.

Texas Parks and Wildlife Department, 1977. List of Endangered and Protected Non-game Species in Texas, Austin, TX.

Texas Organization for Endangered Species, 1979. TOES Watch List of Endangered, Threatened, and Peripheral Vertebrates of Texas, Austin, TX.

Tissot, B. P., and D. H. Welte, 1978. Petroleum Formation and Occurrence, Springer-Verlag, New York, NY, 538 pp.

TOES, see Texas Organization for Endangered Species.

TPWD, see Texas Parks and Wildlife Department.

U.S. Department of Agriculture, 1968. Soil Survey for Deaf Smith County, Texas, Soil Conservation Survey.

U.S. Department of Agriculture, 1981. "Farmland Protection Policy Act", PL 97-98, Title XV, Subtitle I, 7 USC Section 4201, Washington, DC, December 22.

U.S. Department of Agriculture, 1982. Soil Survey for Oldham County, Texas, Soil Conservation Survey.

U.S. Department of Commerce, Bureau of the Census, 1982a. Statistical Abstracts of the United States 1982-83, 103rd Edition, December.

U.S. Department of Commerce, Bureau of the Census 1982b. 1980 Census of Population (Texas), Vol. 1, part 45, March.

U.S. Department of Defense, 1981. HEC-2 Water Surface Profiles (Version of November 1976, updated April 1981), Users Manual, Army Corps of Engineers, Hydrologic Engineering Center, Sacramento, CA.

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

U.S. Department of the Interior, 1982. Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12), Fish and Wildlife Service, Washington, DC.

U.S. Environmental Protection Agency, 1982. "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes", 40 CFR Part 191, Federal Register, Vol. 47, pp. 58196-58206, December 29 (Proposed Rule).

U.S. Nuclear Regulatory Commission, 1983. "Disposal of High-Level Radioactive Wastes in Geologic Repositories - Technical Criteria", 10 CFR Part 60, Federal Register, Vol. 48, pp. 28194-28229, June 21 (Final Rule).

Waller, F. R., 1968. Vascular Flora of Deaf Smith County, Texas, M.S. thesis, Texas Tech University, Lubbock, TX.

Wyatt, A. W., A. E. Bell, and S. Morrison, 1977. Analytical Study of the Ogallala Aquifer in Deaf Smith County, Texas, Report 213, Texas Water Development Board, Austin, TX.

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:

Assumed Hydraulic Conductivity for Salt (m/day)	Steady-State (no heat) Velocity (m/yr)	Interstitial Velocity in Salt (m/yr) at Specified Time (yr)
$\sim 10^{-4}$	$\sim 1.0 \times 10^{-3}$	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 A 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

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

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 A (Budnik and Smith, 1982, Figures 51 and 53) of T_{SA} = 290 feet, T_{SR} = 400 feet, and t_p = 120 feet, the thickness of salt dissolved during the next 10,000 years at Palo Duro Location A is

$$\frac{290 + 400 - 120}{3{,}000{,}000} \times 10{,}000 = 1.9 \text{ feet}$$

REFERENCE

Budnik, R. T., and D. Smith, 1982. "Regional Stratigraphic Framework of the Texas Panhandle", in Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, Geological Circular 82-7, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

APPENDIX C

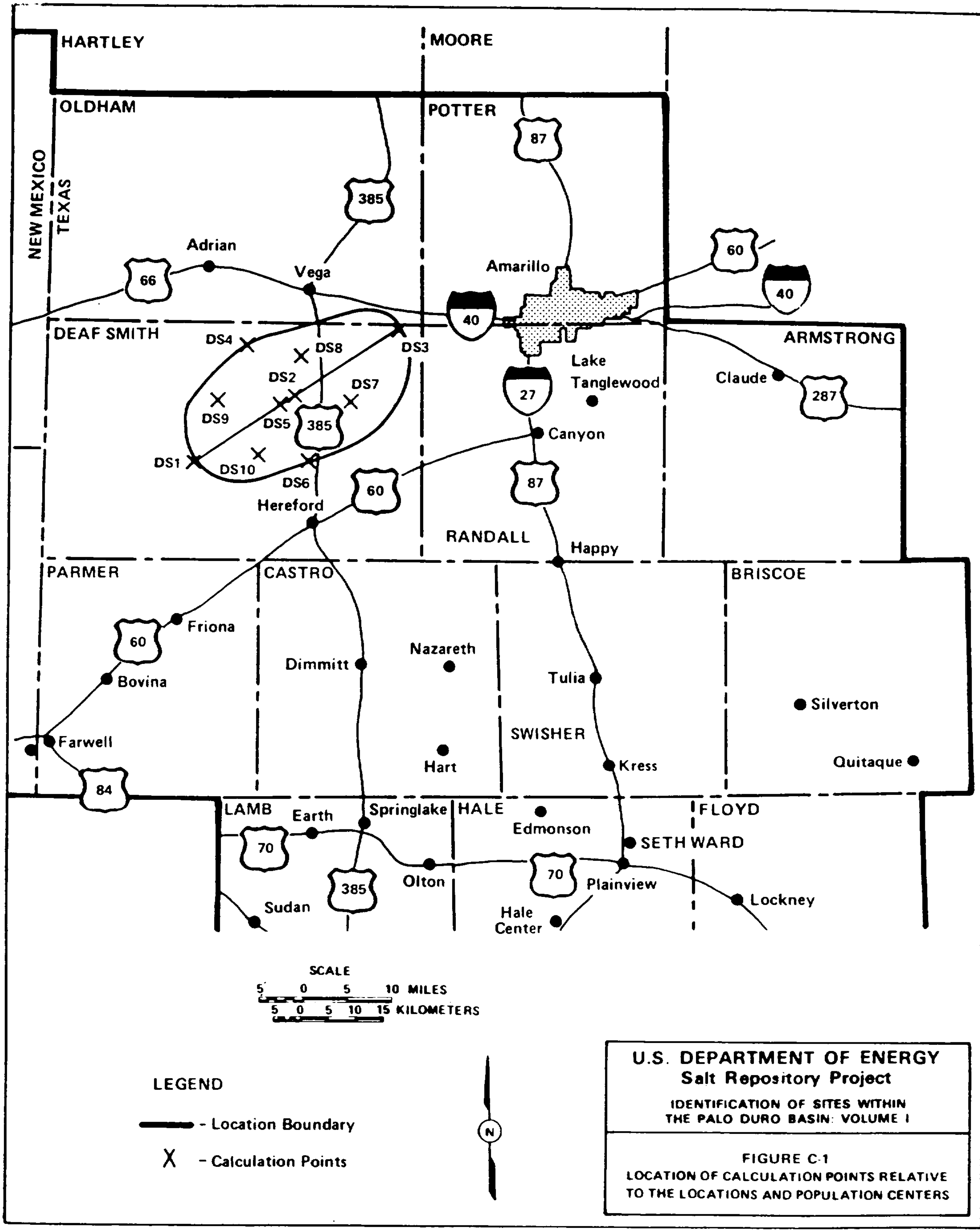
RADIOLOGICAL CONSIDERATIONS IN SITE SELECTION

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 10 points within the Deaf Smith location. These 10 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 50 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 50-mile (80-kilometer) radius grid (see Figure C-2) consisted of 80 sectors centered in the 16 major compass points (north, north-northeast, northeast, etc.) bounded by concentric circles of 10, 20, 30, 40, and 50 miles (16, 32, 48, 64, and 80 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.



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

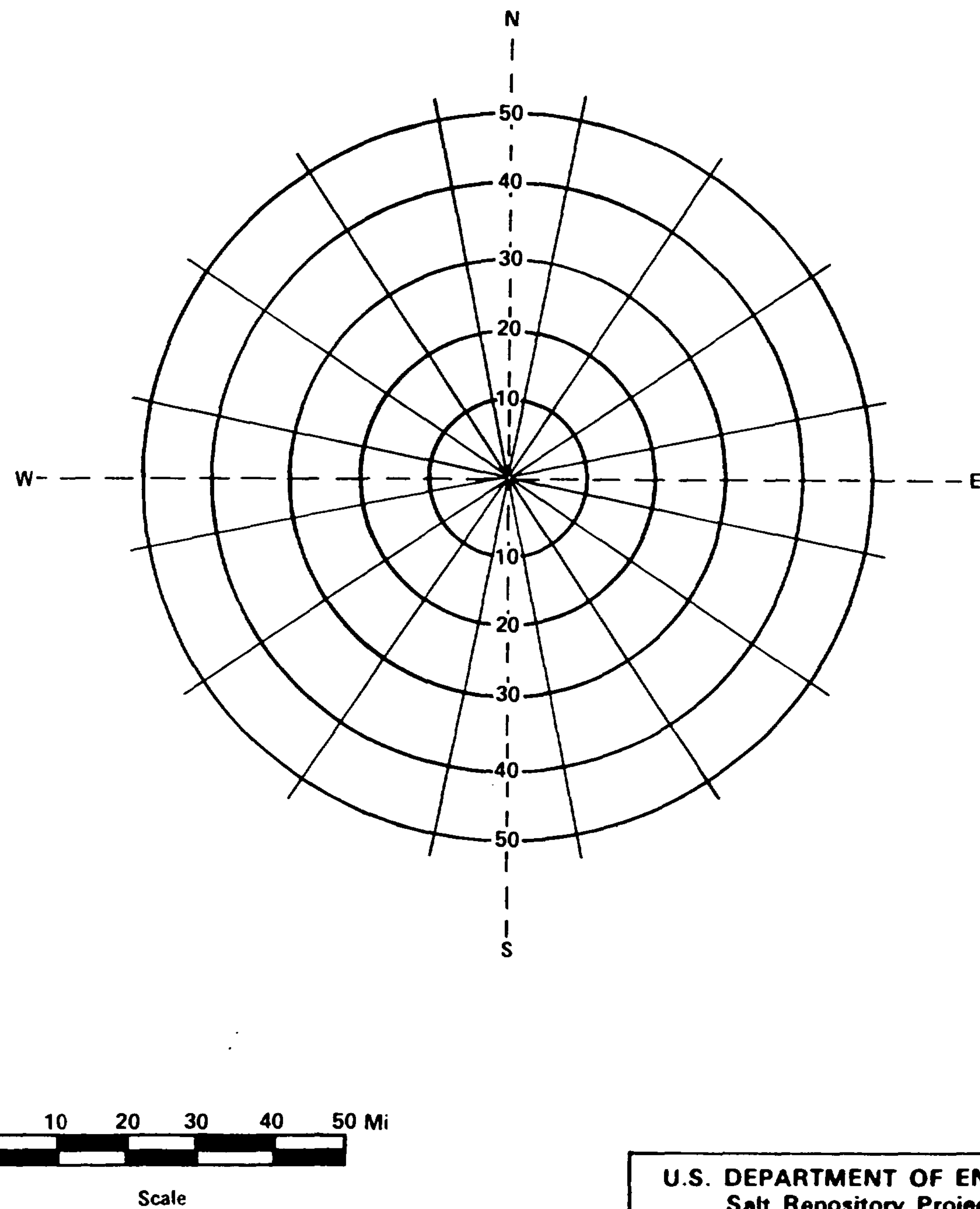
Table C-1. Population Distributions

County/State/ Population Center	County Area (mi²)	Population				
		County	Urban	Total Urban	Rural	Average Rural Density (person/mi²)
Armstrong TX	910	1,994	-	1,112	882	1.0
Claude			1,112			
Briscoe TX	887	2,519	-	1,614	965	1.1
Quitaque			696			
Silverton			918			
Carson TX	900	6,672	-	5,071	1,601	1.8
Panhandle			2,226			
Groom Town			736			
Skelly Town			899			
White Deer			1,210			
Castro TX	899	10,556	-	6,326	4,230	4.7
Dimmit			5,019			
Hart			1,008			
Nazareth			299			
Curry NM	1,408	42,019	-	36,721	5,298	3.8
Clovis			31,194			
Grady			122			
Melrose			649			
Texico City			958			
Cannon AFB			3,798			
Deaf Smith TX	1,497	21,165	-	15,853	5,312	3.5
Hereford			15,853			
Donley TX	905	4,075	-	2,765	1,310	1.4
Clarendon			2,220			
Howardwick			165			
Hedley			380			
Parmer TX	885	11,038	-	6,662	4,376	4.9
Bovina			1,499			
Farwell			1,354			
Friona			3,809			
Potter TX	902	98,637	-	90,588	8,049	8.9
Amarillo*			90,588			
Randall TX	917	75,062	-	69,851	5,211	5.7
Amarillo*			58,642			
Canyon			10,726			
Lake Tanglewood			485			
Swisher TX	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 (mi²)	Population				
		County	Urban	Total Urban	Rural	Average Rural Density (person/mi²)
Quay NM	2,874	10,577	-	7,958	2,619	0.9
House			117			
Logan			735			
San Jan			341			
Tucumcari			6,765			
Floyd TX	992	9,834	-	6,527	3,307	3.3
Floydada			4,193			
Lockney			2,334			
Hale TX	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			
Hantley TX	1,488	3,987	-	2,587	1,400	0.9
Channing			304			
Dalhart			2,283			
Lamb TX	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			
Moore TX	909	16,575	-	15,044	1,531	1.7
Cactus			898			
Dumas			12,194			
Sunray			1,952			
Oldham TX	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.



U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE C-2
POPULATION GRID

The meteorological characteristics of the area determines how any radionuclides 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 daytime 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, χ/Q:

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

where:

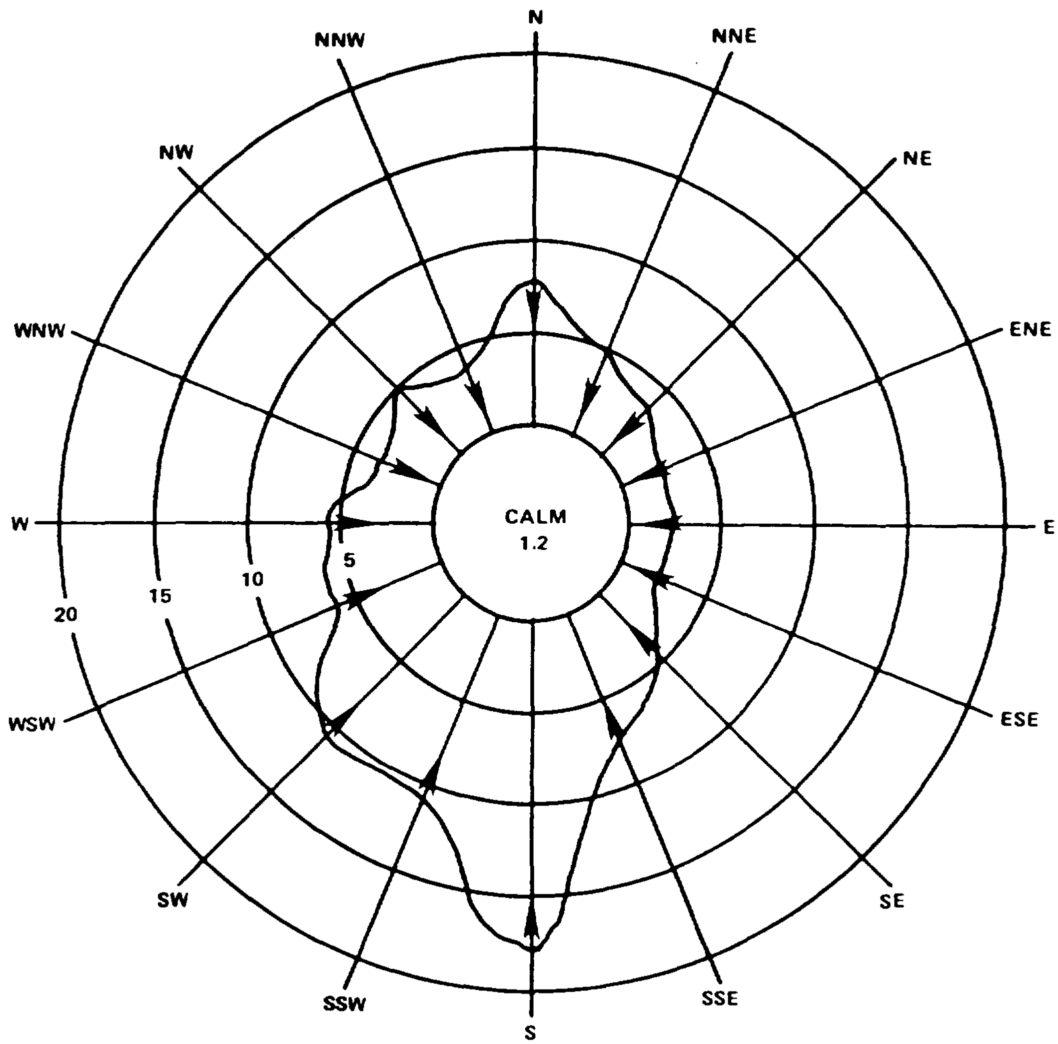
$\bar{u}$ = annual average wind speed, m/s

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).



Notes:

(1) Arrows Indicate Direction of Wind

(2) Numbers are Percent of Time

Source: Modified from NUS Corporation, 1982b, Figure 4-3

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE C-3
ANNUAL SURFACE WIND FREQUENCY FOR AMARILLO, TX

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.

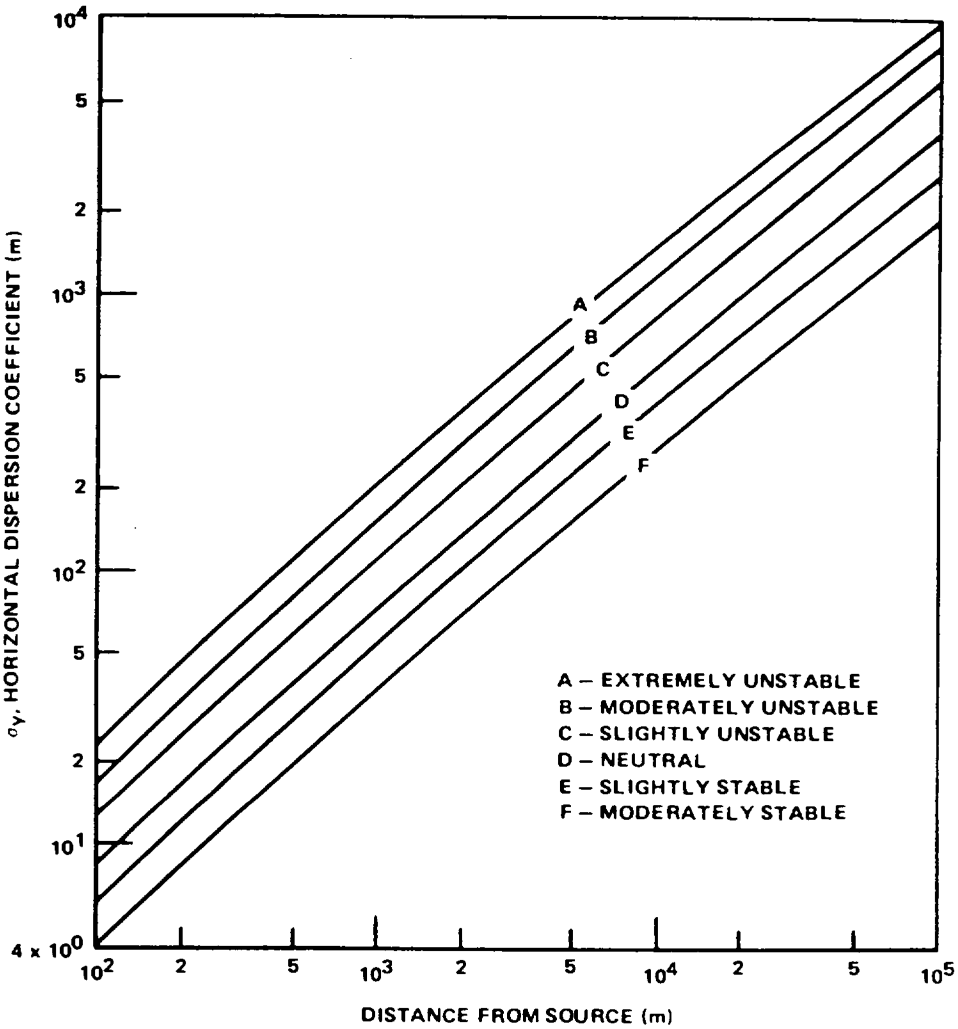
SOURCE: Turner, 1969.

Using Equation C-1, an assumed stability class of D (neutral conditions), and a mean wind speed of 13.6 miles per hour (6 meters per second), the χ/Q values for various distances (the midpoint distances for the 10-, 20-, 30-, 40-, and 50-mile [16-, 32-, 48-, 64-, and 80-kilometer] annuli) are shown in Table C-4.

Given the information on the population of the 80 sectors being evaluated, the percentage of time the wind is blowing toward the area being evaluated, and the five 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 Deaf Smith County. This sector has an area of approximately 137.4 square miles (355.9 square kilometers), a rural population density of 0.8 person per square mile, and no population centers. 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:

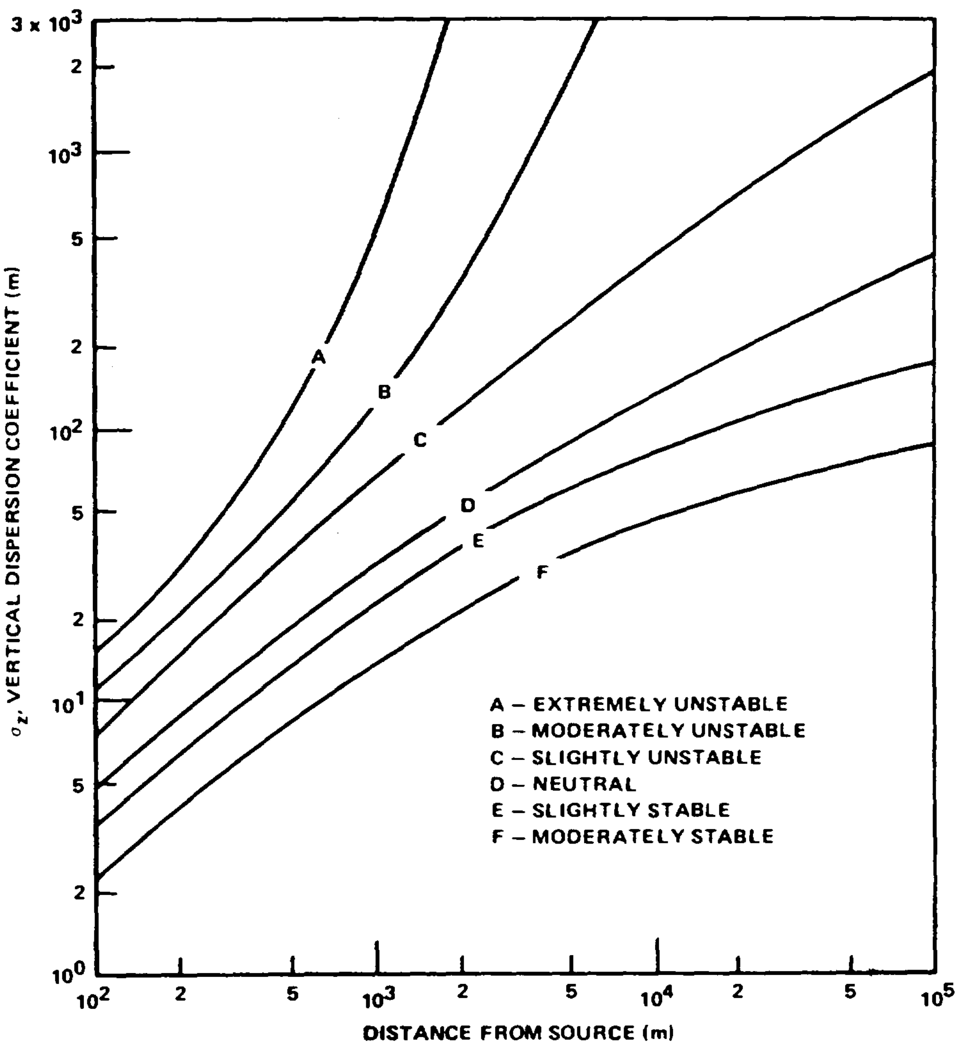
$$137.4 \times 0.8 \times 19 \times 6.37 \times 10^{-8} = 1.33 \times 10^{-4}$$



Source: Slade, 1968, Figure 3-10.

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

FIGURE C-4
LATERAL DIFFUSION, σ_y, VS. DOWNWIND DISTANCE FROM SOURCE FOR PASQUILL'S TURBULENCE TYPES



Source: Slade, 1968, Figure 3-11.

U.S. DEPARTMENT OF ENERGY
Salt Repository Project
IDENTIFICATION OF SITES WITHIN THE PALO DURO BASIN: VOLUME I

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

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

Increments From Point of Release	Annulus Midpoints	χ/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}

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

Performing the same mathematical operation for each of the 80 sectors and summing the product provides a relative index of the radiation risk associated with each site. After all 10 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.

REFERENCES

DOE, see U.S. Department of Energy.

NUS Corporation, 1982b. Area Environmental Characterization Report of the Dalhart and Palo Duro Basins in the Texas Panhandle, Vol. II - Palo Duro Basin, ONWI-102(2), prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

NUS Corporation, 1984b. Socioeconomic Data Base Report for the Permian Basin, ONWI-461, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Slade, D. H. (ed), 1968. Meteorology and Atomic Energy, U.S. Department of Energy, Washington, DC, July.

Turner, D. B., 1969. Workbook of Atmospheric Dispersion Estimates, U.S. Department of Health, Education, and Welfare, Washington, DC.

U.S. Department of Commerce, Bureau of the Census, 1982b. 1980 Census of Population (Texas), Vol. 1, part 45, Washington, DC, March.

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

DISTRIBUTION LIST

ACRES AMERICAN INC
ROBERT H. CURTIS
R. STRUBLE
AEROSPACE CORP
PETER J. ALEXANDRO
BARRETT R. FRITZ
ALABAMA STATE GEOLOGICAL SURVEY
THORNTON L. NEATHERY
AMARILLO PUBLIC LIBRARY
APPLIED MECHANICS INC
GRAHAM G. MUSTOE
ARGONNE NATIONAL LABORATORY
DAVID F. FENSTER
MARTIN SEITZ
MARTIN J. STEINDLER
ARIZONA STATE UNIVERSITY
PAUL KNAUTH
ARKANSAS GEOLOGICAL COMMISSION
WILLIAM V. BUSH
NORMAN F. WILLIAMS
ARTHUR D. LITTLE INC
CHARLES R. HADLOCK
ATKINS RESEARCH & DEVELOPMENT - UNITED KINGDOM
T. W. BROYD
ATOMIC ENERGY CONSULTANTS
DONALD G. ANDERSON
ATOMIC ENERGY OF CANADA LTD
T. CHAN
BATTELLE COLUMBUS DIVISION
JOHN T. MCGINNIS
JEFFREY L. MEANS
BATTELLE MEMORIAL INSTITUTE
JAMES DUGUID
BATTELLE NORTHWEST LABORATORIES
CHARLES R. COLE
BECHTEL NATIONAL INC
TOM S. BAER
WILLIAM LI
BELGISCHE GEOLOGISCHE DIENST - BELGIUM
NOEL VANDENBERGHE
BENDIX FIELD ENGINEERING CORP
BILL GRAHAM
CHARLES A. JONES
DONALD LIVINGSTON
MICHAEL H. MOBLEY
JOHN C. PACER
ANTHONY ZAIKOWSKI
BERKELEY GEOSCIENCES/HYDROTECHNIQUE ASSOCIATES
BRIAN KANEHIRO
BRIGHAM YOUNG UNIVERSITY
STAN L. ALBRECHT
BROOKHAVEN NATIONAL LABORATORY
M. S. DAVIS
P. W. LEVY
PETER SOO
HELEN TODOSOW (2)
BUNDESANSTALT FUR GEOWISSENSCHAFTEN UND ROHSTOFFE - W. GERMANY
MICHAEL LANGER
HELMUT VENZLAFF
BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES - FRANCE
BERNARD FEUGA
PIERRE F. PEAUDECERF
IURNS AND ROE INDUSTRIAL SERVICES CORP
JOHN PIRRO
:ALIFORNIA DEPT OF CONSERVATION
PERRY AMIMITO
CALIFORNIA DIVISION OF MINES & GEOLOGY
ROBERT H. SYDNOR
CARNEGIE-MELLON UNIVERSITY
INDIRA NAIR
CENTER FOR SPACE RESEARCH - NOAA
MICHAEL R. HELFERT
CHALMERS UNIVERSITY OF TECHNOLOGY - SWEDEN
BERT ALLARD
CHEVRON OIL FIELD RESEARCH COMPANY
BJORN PAULSSON
CITIZENS ASSOCIATION FOR SOUND ENERGY
JUANITA ELLIS
CLARK UNIVERSITY
JEANNE X. KASPERSON
CLIFFS ENGINEERING INC
GARY D. AHO
COLORADO GEOLOGIC INC
MIKE E. BRAZIE
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD
COLORADO SCHOOL OF MINES
W. HUSTRULID
DONALD LANGMUIR
COLUMBIA UNIVERSITY
TERRY ENGELDER
M. ASHRAF MAHTAB
CONROY ENGINEERING
PETER CONROY
COPPE/UFRJ
LUIZ OLIVEIRA
CORNELL UNIVERSITY
ARTHUR L. BLOOM
FRED H. KULHAWY
ROBERT POHL
D.R.E.
KARL J. ANANIA
DAMES & MOORE
RON KEAR
JEFFREY KEATON
CHARLES R. LEWIS
DAN L. WARD INC
DAN L. WARD
DEAF SMITH COUNTY LIBRARY
DISPOSAL SAFETY INC
BENJAMIN ROSS
DUGOUT RANCH
ROBERT & HEIDI REDD
DYNATECH R/D COMPANY
STEPHEN E. SMITH
E.I. DU PONT DE NEMOURS & CO
D. H. TURNO
E.L.H. PUBLICATIONS - THE RADIOACTIVE EXCHANGE
HELMINSKI & WILKEN
E.R. JOHNSON ASSOCIATES INC
E. R. JOHNSON
G. L. JOHNSON
EAL CORP
LEON LEVENTHAL
EARTH RESOURCE ASSOCIATES INC
SERGE GONZALES
EARTH SCIENCE AND ENGINEERING INC
LOU BLANCK
EARTH SCIENCES CONSULTANTS INC
HARRY L. CROUSE
EAST TENNESSEE STATE UNIVERSITY
ALBERT F. IGLAR
EBASCO SERVICES INC
ZUBAIR SALEEM
ECOLOGY & ENVIRONMENT INC
MICHAEL BENNER
EDISON ELECTRIC INSTITUTE
R. E. L. STANFORD
EDS NUCLEAR INC
C. SUNDARARAJAN
EG & G IDAHO INC
SCOTT HIRSCHBERGER
LOW-LEVEL RADIOACTIVE WASTE
ELEKTRIZITAETS-GES. LAUFENBURG - SWITZERLAND
H. N. PATAK
ELSAM - DENMARK
A. V. JOSHI
ARNE PEDERSEN
ENVIROLOGIC SYSTEMS INC
JIM V. ROUSE
ENVIRONMENT CANADA
CLAUDE BARRAUD
ENVIROSPHERE COMPANY
ROGER G. ANDERSON
EXXON NUCLEAR IDAHO COMPANY INC
ROGER N. HENRY
F-J SCHLUMBERGER
PETER ALEXANDER
FENIX & SCISSON INC
JOSE A. MACHADO
CHARLENE U. SPARKMAN
FERRIS STATE COLLEGE
MICHAEL E. ELLS
FLORIDA INSTITUTE OF TECHNOLOGY
JOSEPH A. ANGELO, JR.
FLORIDA STATE UNIVERSITY
JOSEPH F. DONOGHUE
FOSTER-MILLER ASSOCIATES INC
NORBERT PAAS
FOUNDATION SCIENCES INC
LOU BATTAMS
FRIENDS OF THE EARTH
RENEE PARSONS
GABIE BETTS BURTON MEMORIAL LIBRARY
GARTNER LEE ASSOCIATES LTD - CANADA
ROBERT E. J. LEECH
GENERAL ATOMIC COMPANY
MICHAEL STAMATELATOS
GEO/RESOURCE CONSULTANTS INC
ALVIN K. JOE, JR.
GEOLOGICAL SURVEY OF CANADA
LIBRARY
GEORGIA INSTITUTE OF TECHNOLOGY
CHARLES E. WEAVER
GEOSTOCK - FRANCE
R. BARLIER
GEOTECHNICAL ENGINEERS INC
RONALD C. HIRSCHFELD
GEOTHERMAL ENERGY INSTITUTE
DONALD F. X. FINN
GEOTRANS
JAMES MERCER
GESELLSCHAFT F. STRAHLEN U. UMWELTFORSCHUNG M.B.H. - W. GERMANY
WOLFGANG BODE
NORBERT FOCKWER
H. MOSER
GILBERT/COMMONWEALTH
JERRY L. ELLIS
GOLDER ASSOCIATES
DONALD M. CALDWELL
J. W. VOSS

GOLDER ASSOCIATES - CANADA
CLEMENT M. K. YUEN
GRAND COUNTY PUBLIC LIBRARY
GRIMCO
DONALD H. KUPFER
GSE NUCLEAR
MOHSEN NIROOMAND-RAD
GTC GEOLOGIC TESTING CONSULTANTS LTD - CANADA
JOHN F. PICKENS
GULF STATES UTILITIES COMPANY
JOHN E. BARRY
GUSTAVSON ASSOCIATES
RICHARD M. WINAR
H-TECH LABORATORIES INC
BRUCE HARTENBAUM
HAHN-MEITNER-INSTITUT FUR KERNFORSCHUNG BERLIN
KLAUS ECKART MAASS
HALEY AND ALDRICH INC
JANICE HIGHT
HAMILTON COLLEGE
DAVID K. SMITH
HANFORD ENGINEERING DEVELOPMENT LABORATORY
W. E. ROAKE
HART-CROWSER AND ASSOCIATES
MICHAEL BAILEY
HARVARD UNIVERSITY
CHARLES W. BURNHAM
DADE W. MOELLER
RAYMOND SIEVER
HECTOR & ASSOCIATES P.A.
ALICE G. HECTOR
HIGH PLAINS UNDERGROUND WATER DISTRICT
TROY SUBLETT
HIGH PLAINS WATER DISTRICT
DON MCREYNOLDS
DON D. SMITH
ILLINOIS DEPT OF NUCLEAR SAFETY
MILTON ZUKOR
ILLINOIS STATE GEOLOGICAL SURVEY
MORRIS W. LEIGHTON
E. DONALD MCKAY, III
IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY - ENGLAND
B. K. ATKINSON
INDIANA GEOLOGICAL SURVEY
MAURICE BIGGS
INDIANA UNIVERSITY
HAYDN H. MURRAY
CHARLES J. VITALIANO
INSTITUT FUR TIEFLAGERUNG - W. GERMANY
H. GIES
KLAUS KUHN
INSTITUTE OF GEOLOGICAL SCIENCES - ENGLAND
STEPHEN THOMAS HORSEMAN
INTERA TECHNOLOGIES INC
F. J. PEARSON, JR.
INTERNATIONAL SALT COMPANY
LEWIS P. BUSH
JOHN VOIGT
IT CORP
MORRIS BALDERMAN
AMINA HAMDY
PETER C. KELSALL
CARL E. SCHUBERT
ITASCA CONSULTING GROUP INC
ROGER HART
J.F.T. AGAPITO & ASSOCIATES INC
MICHAEL P. HARDY
JACOBY & COMPANY
CHARLES H. JACOBY
JAY L. SMITH COMPANY INC
JAY L. SMITH
JOHNS HOPKINS UNIVERSITY
JARED L. COHON
JOINT STUDY COMMITTEE ON ENERGY
T. W. EDWARDS, JR.
JORDAN GORRILL ASSOCIATES
JOHN D. TEWHEY
KAISER ENGINEERS INC
H. L. JULIEN
KANSAS DEPT OF HEALTH AND ENVIRONMENT
GERALD W. ALLEN
KANSAS STATE GEOLOGICAL SURVEY
WILLIAM W. HAMBLETON
KELLER WREATH ASSOCIATES
FRANK WREATH
KIERSCH ASSOCIATES GEOSCIENCES/RESOURCES CONSULTANTS INC
GEORGE A. KIERSCH, PH.D.
KIHN ASSOCIATES
HARRY KIHN
KIMBERLY MECHANICAL CONSULTANTS
KENNETH CROMWELL
KLM ENGINEERING INC
B. GEORGE KNIAZEWYCZ
KOREA INSTITUTE OF ENERGY AND RESOURCES (KIER)
CHOO SEUNG HWAN
KQIL
KYOTO UNIVERSITY - JAPAN
YORITERU INOUE
LACHEL HANSEN & ASSOCIATES INC
DOUGLAS E. HANSEN
LAWRENCE BERKELEY LABORATORY
JOHN A. APPS
EUGENE BINNALL
THOMAS DOE
NORMAN M. EDELSTEIN
M. S. KING
JANE LONG
ROBIN SPENCER
CHIN FU TSANG
J. WANG
PAUL A. WITHERSPOON
HAROLD WOLLENBERG
LAWRENCE LIVERMORE NATIONAL LABORATORY
TED BUTKOVICH
DAE H. CHUNG
EDNA M. DIDWELL
HUGH HEARD
FRANCOIS E. HEUZE
DONALD D. JACKSON
R. JEFF LYTLE
NAI-HSIEN MAO
LAWRENCE MCKAGUE
LAWRENCE D. RAMSPOTT (2)
TECHNICAL INFORMATION DEPARTMENT L-53
JESSE L. YOW, JR.
LEHIGH UNIVERSITY
D. R. SIMPSON
LOCKHEED ENGINEERING & MANAGEMENT COMPANY
STEVE NACHT
LOS ALAMOS NATIONAL LABORATORY
P. L. BUSSOLINI
D. G. FOSTER, JR
WAYNE R. HANSEN
KURT WOLFSBERG
LOUISIANA GEOLOGICAL SURVEY
RENWICK P. DEVILLE
CHARLES G. GROAT
LOUISIANA TECHNICAL UNIVERSITY
R. H. THOMPSON
LOVE OIL COMPANY INC
PAT ANDERSON
LUBBOCK COUNTY SOIL AND WATER CONSERVATION DISTRICT
DON LANGSTON
MASSACHUSETTS DEPT OF ENVIRONMENTAL QUALITY ENGINEERING
JOSEPH A. SINNOTT
MEMBERS OF THE GENERAL PUBLIC
STATE OF TEXAS
JAMES BOYD
THOMAS G. BRADFORD
TOM & SUSAN CLAWSON
JIM CONKWRIGHT
JOANN TEMPLE DENNETT
CHARLES S. DUNN
JEAN EARDLEY
THAUMAS P. EHR
ART FORAN
BRUCE GABOW
CARL A. GIESE
SHIRLEY M. GIFFORD
MICHAEL J. GILBERT
DOUGLAS H. GREENLEE
C. F. HAJEK
A. M. HALE
KENNETH S. JOHNSON
SCOTT KRAMER
THOMAS H. LANGEVIN
HARRY E. LEGRAND
LINDA LEHMAN
GEORGE LOUDDER
CLIVE MACKAY
W. D. MCDOUGALD
JEFF MEADOWS
THEA NORDLING
SHAILER S. PHILBRICK
RUS PURCELL
TOM & MARY REES
OWEN SEVERANCE
HARRY W. SMEDES
NORMAN C. SMITH
PATRICIA SNYDER
M. J. SZULINSKI
NED TILLMAN
A. E. WASSERBACH
RICHARD J. WILLIS
SUSAN WOOLLEY
STEPHEN G. ZEMBA
MERRIMAN AND BARBER CONSULTING ENGINEERS INC
GENE R. BARBER
MICHAEL BAKER, JR. INC
C. J. TOUHILL
MINNESOTA DEPT OF ENERGY AND DEVELOPMENT
MINNESOTA GEOLOGICAL SURVEY
MATT S. WALTON
MISSISSIPPI HOUSE OF REPRESENTATIVES
MACK MCINNIS
MISSISSIPPI MINERAL RESOURCES INSTITUTE
MISSISSIPPI STATE HOUSE OF REPRESENTATIVES
HILLMAN TEROME FRAZIER
MONTANA BUREAU OF MINES AND GEOLOGY
EDWARD C. BINGLER

MORRISON-KNUDSEN COMPANY INC
STEPHANIE NICHOLS
MURPHY OIL USA INC
RANDALL L. MAUD
NATIONAL ACADEMY OF SCIENCES
HAROLD L. JAMES
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MICHAEL ZOLENSKY
NATIONAL BUREAU OF STANDARDS
RILEY M. CHUNG
NATIONAL HYDROLOGY RESEARCH INSTITUTE - CANADA
DENNIS J. BOTTOMLEY
K. U. WEYER
NATIONAL PARK SERVICE
DONALD F. GILLESPIE
NATIONAL SCIENCE FOUNDATION
ROYAL E. ROSTENBACH
NAVAL WEAPONS STATION EARLE
GENNARO MELLIS
NEW ENGLAND NUCLEAR CORP
CHARLES B. KILLIAN
NEW JERSEY INSTITUTE OF TECHNOLOGY
BEN STEVENSON
NEW MEXICO BUREAU OF GEOLOGY
BILL HATCHELL
NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES
FRANK E. KOTTLOWSKI
NEW MEXICO ENVIRONMENTAL EVALUATION GROUP
ROBERT H. NEILL
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
JOHN L. WILSON
NEW YORK LEGISLATIVE COMMISSION ON SCIENCE & TECHNOLOGY
JAMES T. MCFARLAND
NEW YORK STATE ASSEMBLY
MAURICE D. HINCHEY
NEW YORK STATE GEOLOGICAL SURVEY
JAMES R. ALBANESE
ROBERT H. FICKIES
NEW YORK STATE SENATE RESEARCH SERVICE
DAVID WHITEHEAD
NORTH CAROLINA CONSERVATION COUNCIL
JANE SHARP
NORTH CAROLINA STATE SENATE
J. R. ALLSBROOK
NORTH CAROLINA STATE UNIVERSITY
M. KIMBERLEY
NORTH DAKOTA GEOLOGICAL SURVEY
DON L. HALVORSON
NORTH DAKOTA STATE UNIVERSITY
JOHN M. HALSTEAD
NORTH ILLINOIS UNIVERSITY
B. VON ZELLEN
NORTHEAST LOUISIANA UNIVERSITY
ROBERT E DOOLEY
NORTHWESTERN UNIVERSITY
BERNARD J. WOOD
NUCLEAR ENERGY AGENCY/OECD - FRANCE
ANTHONY MULLER
NUCLEAR REGULATORY COMMISSION
STEVE SMYKOWSKI
NUCLEAR SAFETY RESEARCH ASSOCIATION
IZUMI KURIHARA
OAK RIDGE NATIONAL LABORATORY
LESLIE R. DOLE
C. A. JOHNSON
DAVID C. KOCHER
T. F. LOMENICK
E. B. PEELLE
ELLEN D. SMITH
STEPHEN S. STOW
SUSAN K. WHATLEY
OKLAHOMA GEOLOGICAL SURVEY
CHARLES J. MANKIN
OKLAHOMA STATE DEPT OF HEALTH
R. L. CRAIG
ONR DETACHMENT
DAVID EPP
ONTARIO MINISTRY OF THE ENVIRONMENT - CANADA
JAAK VIIRLAND
ORANGE COUNTY COMMUNITY COLLEGE
LAWRENCE E. OBRIEN
OREGON STATE UNIVERSITY
JOHN C. RINGLE
OTHA INC
JOSEPH A. LIEBERMAN
P.O.W.E.R.
RALPH DILLER
TIM REVELL
PACIFIC NORTHWEST LABORATORY
DON J. BRADLEY
HARVEY DOVE
FLOYD N. HODGES
CHARLES T. KINCAID
R. JEFF SERNE
PB-KBB INC
JUDITH G. HACKNEY
PENNSYLVANIA STATE UNIVERSITY
MARY BARNES
MICHAEL GRUTZECK
DELLA M. ROY
WILLIAM B. WHITE
PHYSIKALISCH-TECHNISCHE BUNDESANSTALT - W. GERMANY
HORST SCHNEIDER
POINT BEACH NUCLEAR PLANT
JAMES J. ZACH
POTASH CORP OF SASKATCHEWAN MINING LTD - CANADA
PARVIZ MOTTAHED
PRESQUE ISLE COURTHOUSE
PSE & G
JOHN J. MOLNER
PURDUE UNIVERSITY
PAUL S. LYKOUDIS
R.J. SHLEMON AND ASSOCIATES INC
R. J. SHLEMON
RALPH M. PARSONS COMPANY
JERROLD A. HAGEL
RANDALL COUNTY LIBRARY
RE/SPEC INC
GARY D. CALLAHAN
WILLIAM C. MCCLAIN
RHOADS MEMORIAL LIBRARY
RHODE ISLAND GOVERNORS ENERGY OFFICE
BRUCE VILD
RIO ALGOM CORP
DUANE MATLOCK
ROCKWELL HANFORD OPERATIONS
RONALD C. ARNETT
L. R. FITCH
STEVEN J. PHILLIPS
ROCKWELL INTERNATIONAL ENERGY SYSTEMS GROUP
HARRY PEARLMAN
ROGERS & ASSOCIATES ENGINEERING CORP
ARTHUR A. SUTHERLAND
ROGERS, GOLDEN & HALPERN
JACK A. HALPERN
ROY F. WESTON INC
WILLIAM IVES
RONALD MACDONALD
MICHAEL V. MELLINGER
VIC MONTENYOHL
SAM PANNO
S.E. LOGAN & ASSOCIATES INC
STANLEY E. LOGAN
SAN JOSE STATE UNIVERSITY SCHOOL OF ENGINEERING
R. N. ANDERSON
SANDIA NATIONAL LABORATORIES
G. C. ALLEN
SHARLA BERTRAM
MARGARET S. CHU
A. R. LAPPIN
NESTOR R. ORTIZ
SCOTT SINNOCK
WOLFGANG WAWERSIK
WENDELL D. WEART
WIPP CENTRAL FILES
SARGENT & LUNDY ENGINEERS
LAWRENCE L. HOLISH
SAVANNAH RIVER LABORATORY
CAROL JANTZEN
I. WENDELL MARINE
SCIENCE APPLICATIONS INC
NADIA DAYEM
BARRY DIAL
MICHAEL B. GROSS
DAVID H. LESTER
HOWARD PRATT
M. D. VOEGELE
KRISHAN K. WAHI
ROBERT A. YODER
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
MARY LOU BROWN
SCRIPPS INSTITUTE OF OCEANOGRAPHY (A-015)
HUBERT STAUDIGEL
SENATE RESEARCH SERVICE
DAVID WHITEHEAD
SERATA GEOMECHANICS INC
FRANK TSAI
SERIOUS TEXANS AGAINST NUCLEAR DISPOSAL (S.T.A.N.D)
DELBERT DEVIN
SHAFER EXPLORATION COMPANY
WILLIAM E. SHAFER
SHANNON & WILSON INC
HARVEY W. PARKER
SHELL OIL COMPANY
PHILIP BERGER
SIERRA CLUB
MARVIN RESNIKOFF
BROOKS YEAGER
SIERRA CLUB - COLORADO OPEN SPACE COUNCIL
ROY YOUNG
SIERRA CLUB LEGAL DEFENSE FUND
H. ANTHONY RUCHEL
SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
CANER ZANBAK
SOUTHERN METHODIST UNIVERSITY
GEORGE W. CRAWFORD
SOUTHERN STATES ENERGY BOARD
J. E. CLARK
NANCY KAISER
SOUTHWEST RESEARCH AND INFORMATION CENTER
ALISON P. MONROE

ST & E TECHNICAL SERVICES INC
STANLEY M. KLAINER
STANFORD UNIVERSITY
KONRAD B. KRAUSKOPF
STATE UNIVERSITY OF NEW YORK AT BINGHAMTON
FRANCIS T. WU
STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND
JAMES E. BUGH
STATE WORKING GROUP
JOHN GERVERS
STAUFFER CHEMICAL COMPANY
RANDY L BASS.BASSETT
STONE & WEBSTER ENGINEERING CORP
ARLENE C. PORT
EVERETT M. WASHER
SWEDISH GEOLOGICAL
LEIF CARLSSON
SYRACUSE UNIVERSITY
WALTER MEYER
J. E. ROBINSON
SYSTEMS SCIENCE AND SOFTWARE
PETER LAGUS
T.M. GATES INC
TODD M. GATES
TERRA TEK INC
KHOSROW BAKHTAR
TERRA THERMA INC
ADRIAN BROWN
TERRAMETRICS INC
HOWARD B. DUTRO
TEXAS A & M UNIVERSITY
P. DOMENICO
JOHN HANDIN
EARL HOSKINS
STEVE MURDOCK
GARY ROBBINS
JAMES E. RUSSELL
TEXAS BUREAU OF ECONOMIC GEOLOGY
WILLIAM L. FISHER
TEXAS DEPT OF AGRICULTURE
ROBERT J. KING
TEXAS DEPT OF WATER RESOURCES
ALFRED DAREZZO
W. KLEMT
T. KNOWLES
TEXAS ENERGY COORDINATORS OFFICE
ARNULFO ORTIZ
TEXAS STATE HOUSE OF REPRESENTATIVES
PETE LANEY
ELLEN SALYERS
TEXAS WORLD OPERATIONS INC
DAVID JEFFERY
THE BENHAM GROUP
KEN SENOUR
THE EARTH TECHNOLOGY CORP
FRED A. DONATH (2)
JOSEPH G. GIBSON
DAN MELCHIOR
FIA VITAR
MATT WERNER
KENNETH L. WILSON
THE NORWEGIAN GEOTECHNICAL INSTITUTE
NICK BARTON
THOMSEN ASSOCIATES
C. T. GAYNOR, II
TRU WASTE SYSTEMS OFFICE
K. V. GILBERT
TUN ISMAIL ATOMIC RESEARCH CENTRE (PUSPATI)
SAMSURDIN BIN AHAMAD

U.H.D.E. - W. GERMANY
FRANK STEINBRUNN
U.S. ARMY CORPS OF ENGINEERS
DON BANKS
ALAN BUCK
ANDY OBROCHTA
U.S. BUREAU OF LAND MANAGEMENT
LYNN JACKSON
U.S. BUREAU OF MINES
ANTHONY IANNACCHIONE
U.S. BUREAU OF RECLAMATION
REGE LEACH
U.S. DEPT OF COMMERCE
PETER A. RONA
U.S. DEPT OF ENERGY
CHED BRADLEY
R. COOPERSTEIN
LAWRENCE H. HARMON
U.S. DEPT. OF ENERGY - ALBUQUERQUE OPERATIONS OFFICE
DENNIS KRENZ
U.S. DEPT OF ENERGY - CHICAGO OPERATIONS OFFICE
VICKI ALSPAUGH-PROUTY
CAROL MORRISON
U.S. DEPT OF ENERGY - DALLAS SUPPORT OFFICE
CURTIS E. CARLSON, JR.
U.S. DEPT OF ENERGY - DIVISION OF WASTE REPOSITORY DEPLOYMENT
RICHARD BLANEY
U.S. DEPT OF ENERGY - GEOLOGIC REPOSITORY DIVISION
J. W. BENNETT
U.S. DEPT OF ENERGY - GRAND JUNCTION OFFICE
WAYNE ROBERTS
U.S. DEPT OF ENERGY - OFFICE OF BASIC ENERGY SCIENCES
MARK W. WITTELS
U.S. DEPT OF ENERGY - OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
JANIE SHAHEEN
U.S. DEPT OF ENERGY - OFFICE OF ENERGY RESEARCH
FRANK J. WOBBER
U.S. DEPT OF ENERGY - OFFICE OF PROJECT AND FACILITIES MANAGEMENT
D. L. HARTMAN
U.S. DEPT OF ENERGY - OSTI (317)
U.S. DEPT OF ENERGY - SALT REPOSITORY PROJECT OFFICE
J. O. NEFF
U.S. DEPT OF LABOR
ALEX G. SCIULLI
KELVIN K. WU
U.S. DEPT OF THE INTERIOR
PAUL A. HSIEH
U.S. GENERAL ACCOUNTING OFFICE
CHARLES D. MOSHER
U.S. GEOLOGICAL SURVEY
E. B. EKREN
VIRGINIA M. GLANZMAN
JOHN A. GROW
GERHARD W. LEO
JACOB RUBIN
ADELE ZOHDY
U.S. GEOLOGICAL SURVEY - ALEXANDRIA
G. N. RYALS
U.S. GEOLOGICAL SURVEY - BATON ROUGE
DARWIN KNOCHENMUS
U.S. GEOLOGICAL SURVEY - COLUMBUS
A. M. LA SALA, JR

U.S. GEOLOGICAL SURVEY - DENVER
M. S. BEDINGER
JESS M. CLEVELAND
G. L. DIXON
JULES D. FRIEDMAN
S. S. GOLDICH
ROBERT J. HITE
W. SCOTT KEYS
WILLIAM SAVAGE
RAYMOND D. WATTS
WILLIAM WILSON
ROBERT A. ZIELINSKI
U.S. GEOLOGICAL SURVEY - JACKSON
GARALD G. PARKER, JR.
U.S. GEOLOGICAL SURVEY - MENLO PARK
JOHN BREDEHOEFT
J. BYERLEE
MICHAEL CLYNNE
ARTHUR H. LACHENBRUCH
U.S. GEOLOGICAL SURVEY - RESTON
I-MING CHOU
GEORGE DEBUCHANANNE
NEIL PLUMMER
JOHN ROBERTSON
EDWIN ROEDDER
EUGENE H. ROSEBOOM, JR.
PETER R. STEVENS
DAVID B. STEWART
NEWELL J. TRASK, JR.
U.S. HOUSE OF REPRESENTATIVES
B. JEANINE HULL
U.S. HOUSE SUBCOMMITTEE ON ENERGY AND THE ENVIRONMENT
MORRIS K. UDALL
U.S. NUCLEAR REGULATORY COMMISSION
J. CALVIN BELOTE
LEON BERATAN
GEORGE BIRCHARD
R. BOYLE
KIEN C. CHANG
EILEEN CHEN
PATRICIA A. COMELLA
F. ROBERT COOK
BARBARA A. COOKE
JULIA ANN CORRADO
MALCOLM R. KNAPP
WILLIAM D. LILLEY
JOHN C. MCKINLEY
THOMAS J. NICHOLSON
EDWARD OCONNELL
JEROME R PEARRING
EDWARD REGNIER
JAY E. RHODERICK
FREDERICK W. ROSS
R. JOHN STARMER
JOHN TRAPP
MICHAEL WEBER
KRISTIN B. WESTBROOK
ROBERT J. WRIGHT
UNION CARBIDE CORP
GARY M. ANGELINO
UNION OF CONCERNED SCIENTISTS
MICHAEL FADEN
GORDON THOMPSON
UNIVERSITY OF AKRON
LORETTA J. COLE
UNIVERSITY OF ALBERTA - CANADA
J. R. BRANDT
F. W. SCHWARTZ
UNIVERSITY OF ARIZONA
J. DAEMEN
JAAK DAEMEN
STANLEY N. DAVIS

I. W. FARMER
SHLOMO P. NEUMAN
ROY G. POST
UNIVERSITY OF BRITISH COLUMBIA - CANADA
R. ALLAN FREEZE
UNIVERSITY OF CALIFORNIA AT BERKELEY
NEVILLE G. W. COOK
RICHARD E. GOODMAN
UNIVERSITY OF CALIFORNIA AT RIVERSIDE
LEWIS COHEN
UNIVERSITY OF CINCINNATI
ATTILA KILINC
UNIVERSITY OF HAWAII AT MANOA
MURLI H. MANGHNANI
UNIVERSITY OF MISSOURI AT COLUMBIA
W. D. KELLER
UNIVERSITY OF MISSOURI AT KANSAS CITY
EDWIN D. GOEBEL
SYED E. HASAN
UNIVERSITY OF MISSOURI AT ROLLA
ALLEN W. HATHEWAY
UNIVERSITY OF NEW MEXICO
HAROLD M. ANDERSON
DOUGLAS G. BROOKINS
RODNEY C. EWING
UNIVERSITY OF OKLAHOMA
DANIEL T. BOATRIGHT
UNIVERSITY OF RHODE ISLAND
EDWARD P. LAINE
UNIVERSITY OF SOUTHERN MISSISSIPPI
DANIEL A. SUNDEEN
GARY C. WILDMAN
UNIVERSITY OF TENNESSEE AT CHATTANOOGA
HABTE G. CHURNET
UNIVERSITY OF TEXAS
JOHN M. SHARP, JR.
UNIVERSITY OF TEXAS AT AUSTIN
CAROLYN E. CONDON
EARNEST F. GLOYNA
THOMAS C. GUSTAVSON
MARTIN P. A. JACKSON
DALE KLEIN
JOE O. LEDBETTER
DOUGLAS C. RATCLIFF
THE GENERAL LIBRARIES
E. G. WERMUND

UNIVERSITY OF TOLEDO
DON STIERMAN
UNIVERSITY OF UTAH
STEVEN J. MANNING
MARRIOTT LIBRARY
LEE STOKES
UNIVERSITY OF UTAH RESEARCH INSTITUTE LIBRARY
HOWARD P. ROSS
UNIVERSITY OF WATERLOO - CANADA
PETER FRITZ
F. SYKES
UNIVERSITY OF WISCONSIN
B. C. HAIMSON
UNIVERSITY OF WISCONSIN AT MILWAUKEE
HOWARD PINCUS
UNIVERSITY OF WISCONSIN CENTER
LIBRARY - DOCUMENTS
UPPER PEASE SOIL AND WATER CONSERVATION DISTRICT
W. H. MARSHALL
URS-BERGER
TONY MORGAN
URS/JOHN A. BLUME & ASSOCIATES, ENGINEERS
ANDREW B. CUNNINGHAM
USAID/CAIRO EQYPT
DAVID SNOW
UTAH DIVISION OF WILDLIFE RESOURCES
DARRELL NISH
UTAH ENVIRONMENTAL CENTER
JUNE WICKHAM
UTAH GEOLOGICAL AND MINERAL SURVEY
GENEVIEVE ATWOOD
MAGE YONETANI
UTAH MULTIPLE USE ADVISORY COUNCIL
DIXIE BARKER BARKSDALE
UTAH STATE GEOLOGIC TASK FORCE
DAVID D. TILLSON
UTAH STATE UNIVERSITY
DEPT OF GEOLOGY 07
JACK T. SPENCE
UTILITY DATA INSTITUTE
FRED YOST
VANDERBILT UNIVERSITY
FRANK L. PARKER
VEPCO
B. H. WAKEMAN

VERMONT STATE NUCLEAR ADVISORY PANEL
VIRGINIA CALLAN
VIRGINIA POLYTECHNICAL INSTITUTE AND STATE UNIVERSITY
GARY L. DOWNEY
WASHINGTON STATE UNIVERSITY
NACHHATTER S. BRAR
WATTLAB
BOB E. WATT
WEST VALLEY NUCLEAR SERVICES COMPANY INC
ERICH J. MAYER
WESTERN STATE COLLEGE
FRED R. PECK
WESTINGHOUSE ELECTRIC CORP
GEORGE V. B. HALL
WILLIAMS AND ASSOCIATES INC
GERRY WINTER
WIPP PROJECT
WESTINGHOUSE ELECTRIC CORPORATION
WISCONSIN DIVISION OF STATE ENERGY
ROBERT HALSTEAD
WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY
MEREDITH E. OSTROM
WOODWARD-CLYDE CONSULTANTS
F. R. CONWELL (2)
RANDALL L. LENTELL
ASHOK PATWARDHAN
WESTERN REGION LIBRARY
WRIGHT STATE UNIVERSITY
A. A. BAKR
MICHAEL FARRELL
WYOMING GEOLOGICAL SURVEY
JAMES C. CASE
YALE UNIVERSITY
G. R. HOLEMAN
BRIAN SKINNER