

TRIASSIC PARK WASTE  
DISPOSAL FACILITIES

**PRELIMINARY GEOLOGIC  
INVESTIGATION REPORT**

**GANDY PROJECT**

*Stoller*  
established 1959

THE S.M. STOLLER CORPORATION

**EXHIBIT**  
tabbies  
GMI-3

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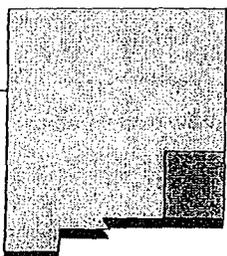
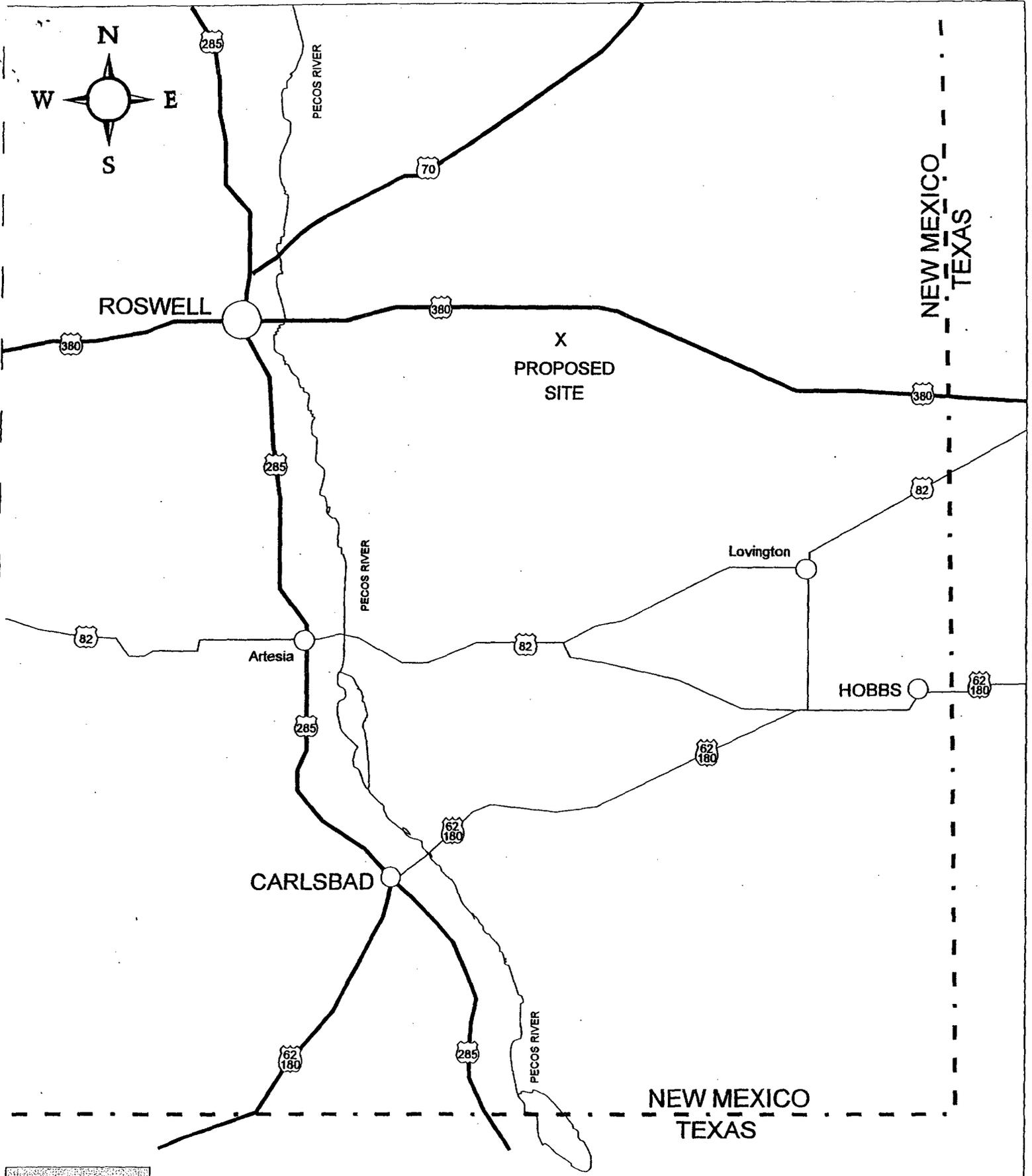
## 1.0 INTRODUCTION

This report presents preliminary characterization data from several geologic investigation programs which support the Gandy property as possessing a suitable geologic environment for the purpose of hosting a hazardous waste disposal site.

As shown in Figure 1 — Index Map, the Gandy property is located in a remote portion of eastern Chavez County, in southeastern New Mexico. The proposed site is situated on privately-owned lands in section 17 & 18, T11S, R31E. The predominant land use in the project area is cattle grazing. There are no surface water drainages or water bodies within the project area. The proposed site lies within the drainage basin at the Pecos River, which is approximately 30 miles west of the property.

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This report describes the regional and local geologic setting of the Gandy site and the geologic investigation conducted to demonstrate the site's capability to provide a host rock and a geologic environment which is suitable for long-term isolation of hazardous waste. The results of this preliminary investigation indicate that the Triassic sediments underlying the proposed site have sufficiently low permeabilities and are separated from ground and surface waters in such a manner as to assure long-term isolation of wastes from the environment.



**INDEX MAP - PROPOSED SITE**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 1

ONE INCH ≈ 16 MILES

## 2.0 REGIONAL GEOLOGIC SETTING

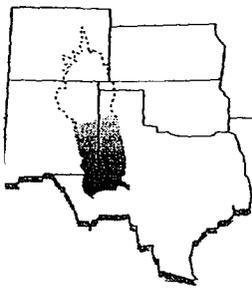
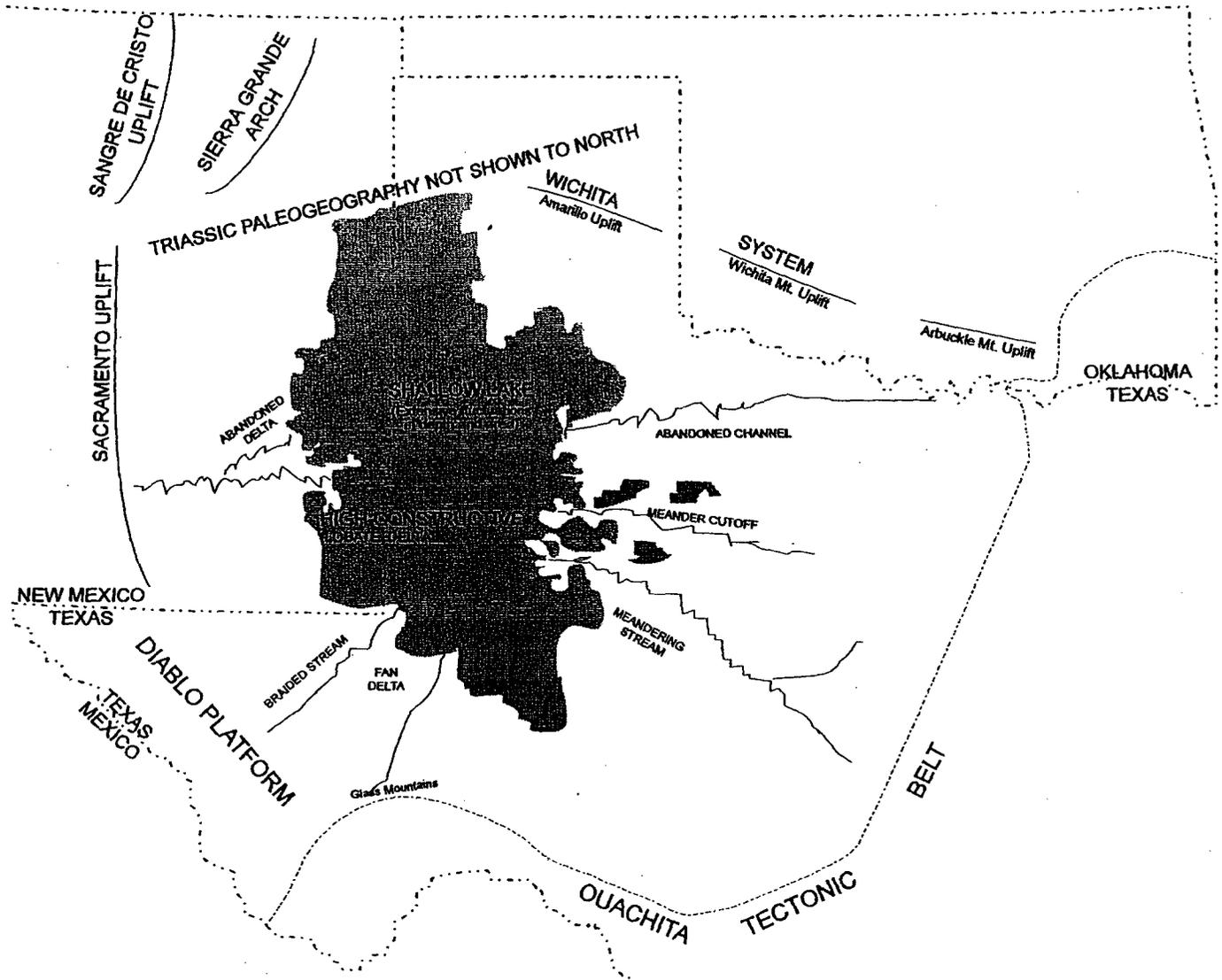
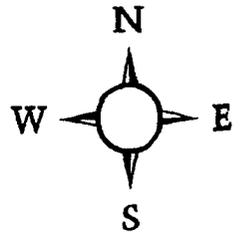
This section will describe the large-scale depositional system and the geologic conditions under which Triassic sediments were deposited in eastern New Mexico and western Texas. From this regional description, a better understanding of the characteristics of the Triassic sediments in the Gandy project area can be obtained. The Depositional Framework of the Lower Dockum Group (Triassic), Texas Bureau of Economic Geology No. 97, 1979, was used as the major reference in the preparation of this section.

### 2.1 Triassic Sediments

The Upper Triassic Dockum Group of Texas and New Mexico is composed of 200 to 2,000 feet of complexly interrelated clastic facies ranging from mudstone to conglomerate. The lower 200 to 1,000 feet of the Dockum accumulated in a fluvial lacustrine basin defined by the Amarillo Uplift - Bravo Dome on the north and the Glass Mountains on the south (see Figure 2 — Triassic Basin Paleomap). This basin was peripherally filled, receiving sediment from the east, south, and west. Chief sediment sources were Paleozoic sedimentary rocks. Lowlands to the east and west were traversed chiefly by meandering streams. Higher gradient streams with flashy discharge existed at northern and southern ends of the basin. The large shallow lake (or lakes) was the last portion of the basin to be filled. These lacustrine sediments consisted primarily of low-energy mudstone.

Figure 3 is an outcrop map showing Triassic sediments encircling and dipping into this basin. The extensive outcrops at the northern and southern portion correspond to early deposition of alluvial fans and fan deltas. Sediment transport in these areas was primarily through braided streams. In the New Mexico portion of this basin, these outcrops are related to the occurrence at the Santa Rosa Sandstone. This medium-to-coarse-grained, white to buff sandstone represents the lowermost Triassic depositional unit.

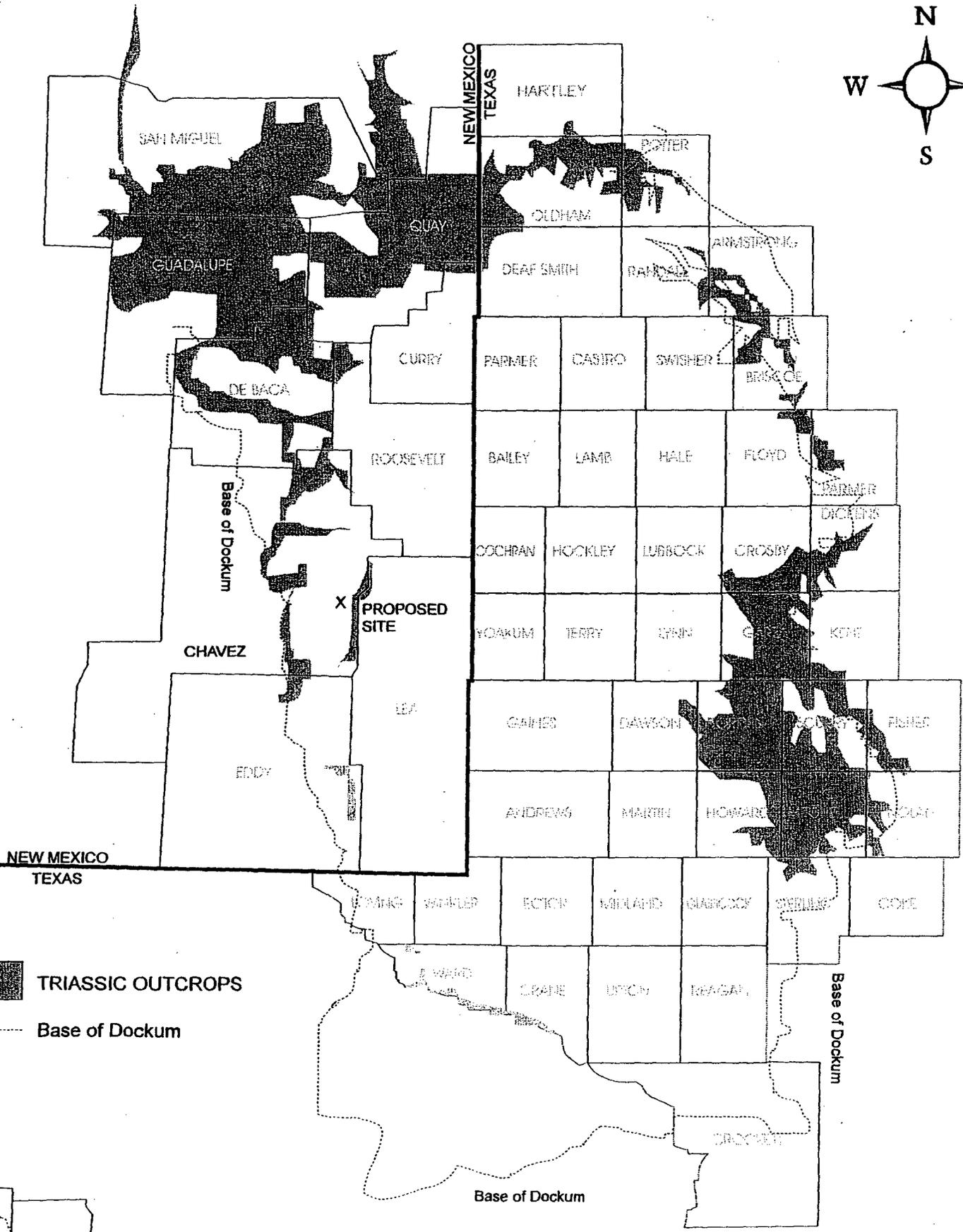
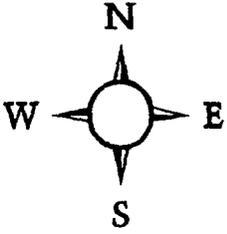
There are fewer outcrops along the eastern and western margins of this basin. These areas were dominated by meandering streams in Triassic time. The former tectonic belts were over 200 miles away and the regional slopes were relatively low. This resulted in the deposition of



**TRIASSIC BASIN-PALEOMAP**  
NEW MEXICO - TEXAS  
GANDY PROJECT

Figure 2

ONE INCH ~100 MILES



 TRIASSIC OUTCROPS  
 Base of Dockum

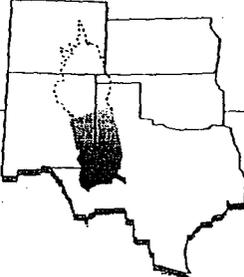
# TRIASSIC BASIN-OUTCROPS

## NEW MEXICO - TEXAS

### GANDY PROJECT

Figure 3

ONE INCH ≈ 54 MILES



predominately mudstones. Surface exposures today in these areas consist of thick sequences of maroon-red, variegated clays and silts with thin discontinuous sandstones.

Figure 4 is a subsurface sand percent map of Triassic sediments throughout this basin. Drill hole data from over 1500 oil wells were compiled to construct this map. It correlates with the surface outcrop map in that the thick sequences of sandstones at the northern and southern portions of the basin are shown projecting inward toward the center of the basin.

This figure also illustrates the lack of sandstone in the subsurface along the western margin of the basin. This is important as it relates to the lack of groundwater potential in the Gandy project area (to be discussed in detail in section 3.5)

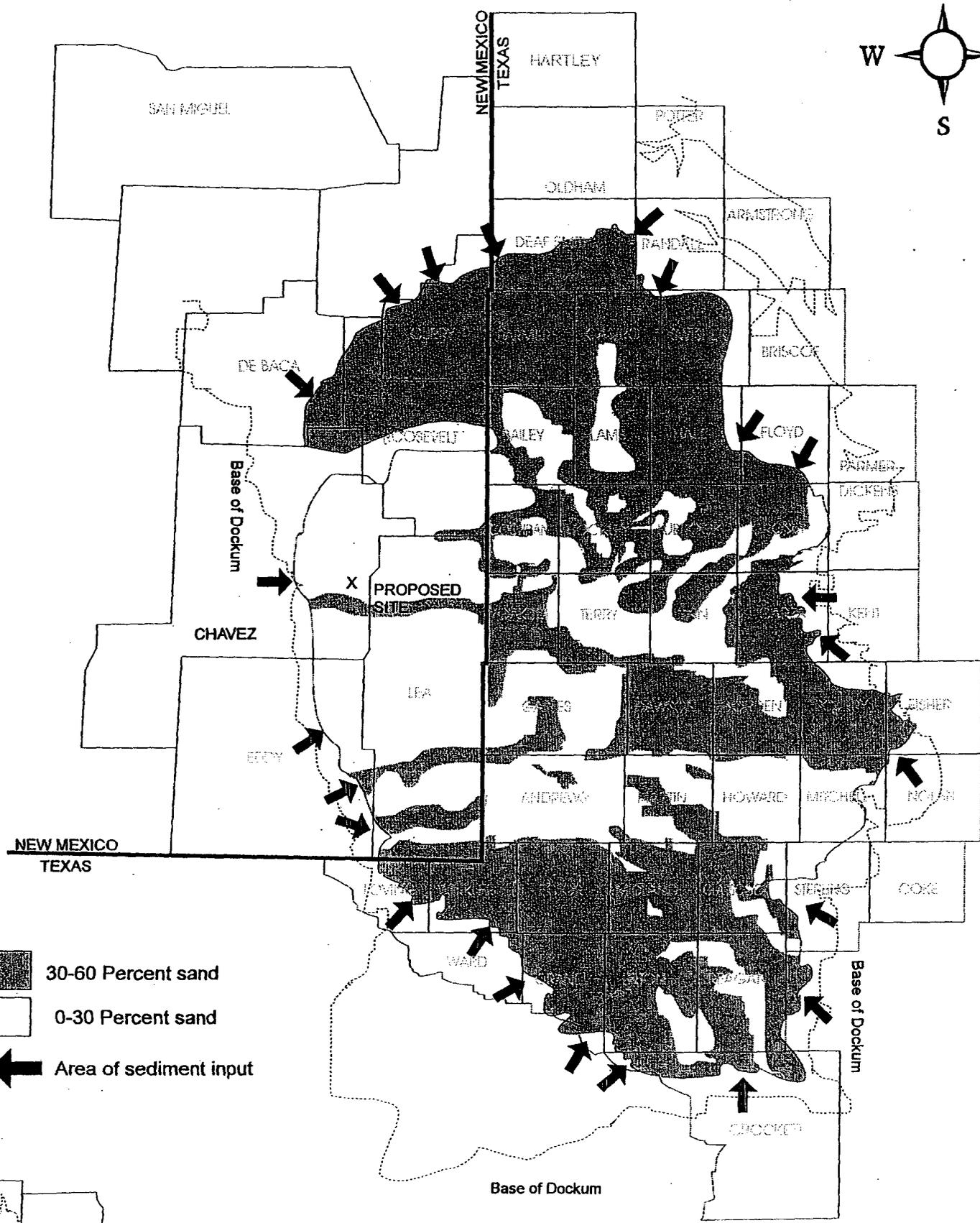
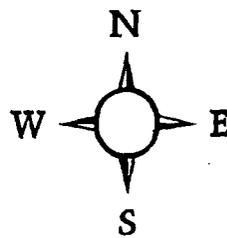
## **2.2 Underlying Sediments**

A transition from non-marine deposition to marine sediments is reflected in the underlying Permian sediments. The actual Permo-Triassic boundary can be difficult to recognize as both lower Triassic and upper Permian strata can be non-marine redbed sequences.

Older Permian strata contain exclusively marine sediments and contain thick sequences of anhydrite, halite, limestone and dolomite. There is abundant geologic literature on these sediments because the San Andres Formation and Artesia Group are prolific petroleum producing horizons in the Midland Basin region of Texas. Brief descriptions of upper Permian sediments are contained in section 3.4 of this report.

## **2.3 Structure**

As shown on the paleomap in Figure 2, there was regional uplift in southern Oklahoma and east-central New Mexico during Triassic time. There is no evidence to suggest structures associated with these uplifts extended into this Triassic basin. The only structure observable in Permian and Triassic rocks is a gentle tilting toward the center of the Triassic depositional basin. This is simply a result of subsidence due to the extensive accumulation of Triassic sediments in the basin.



-  30-60 Percent sand
-  0-30 Percent sand
-  Area of sediment input

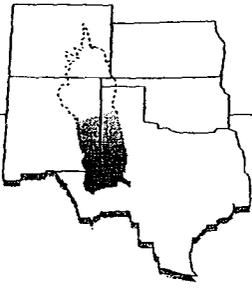
# TRIASSIC BASIN-SUBSURFACE

## NEW MEXICO - TEXAS

### GANDY PROJECT

Figure 4

ONE INCH = 54 MILES



### **3.0 LOCAL GEOLOGIC SETTING**

This section will describe the geologic characteristics of the Triassic sediments and adjacent units in eastern Chavez County, New Mexico as they relate to the identification of favorable host rocks for a hazardous waste disposal facility.

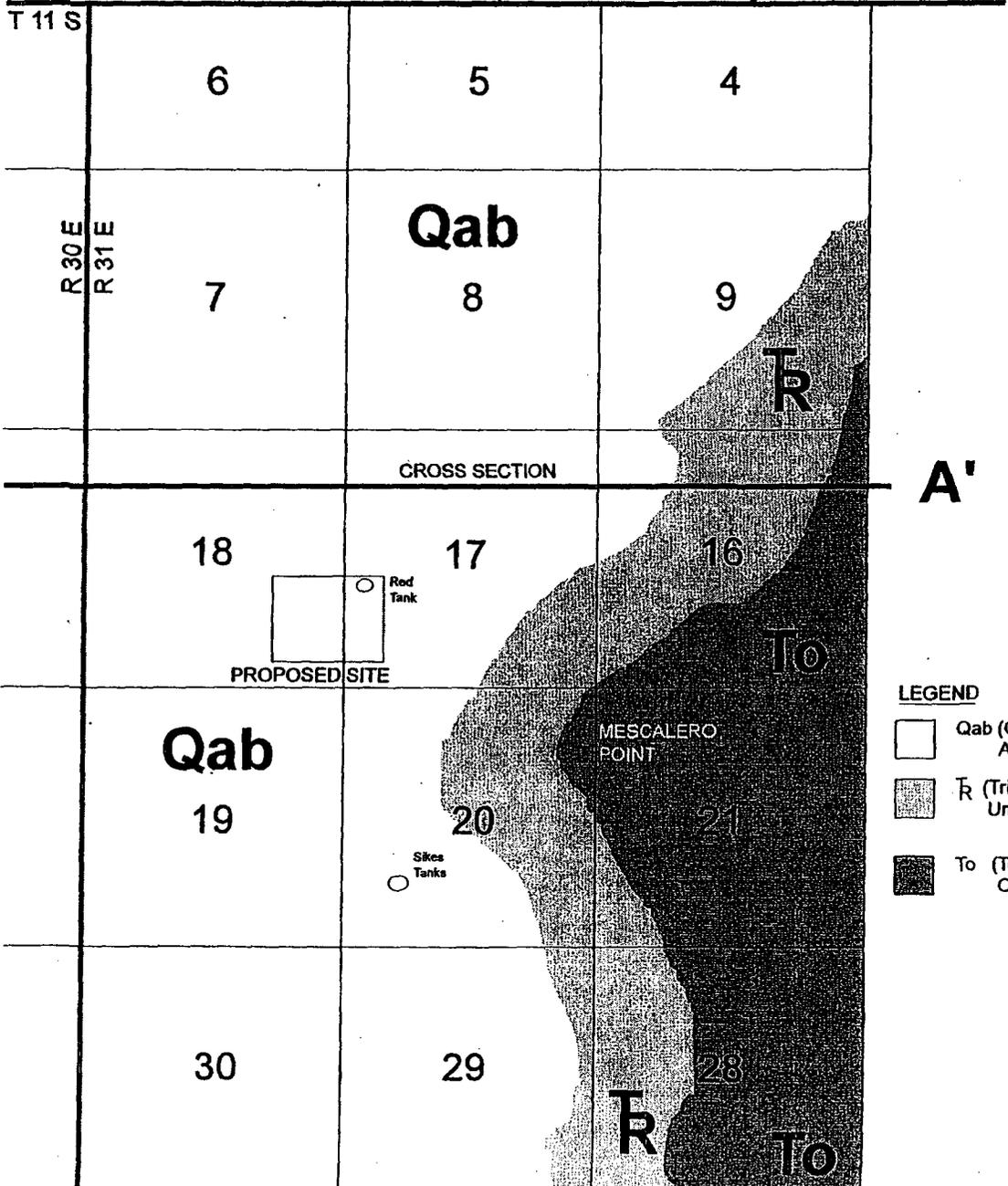
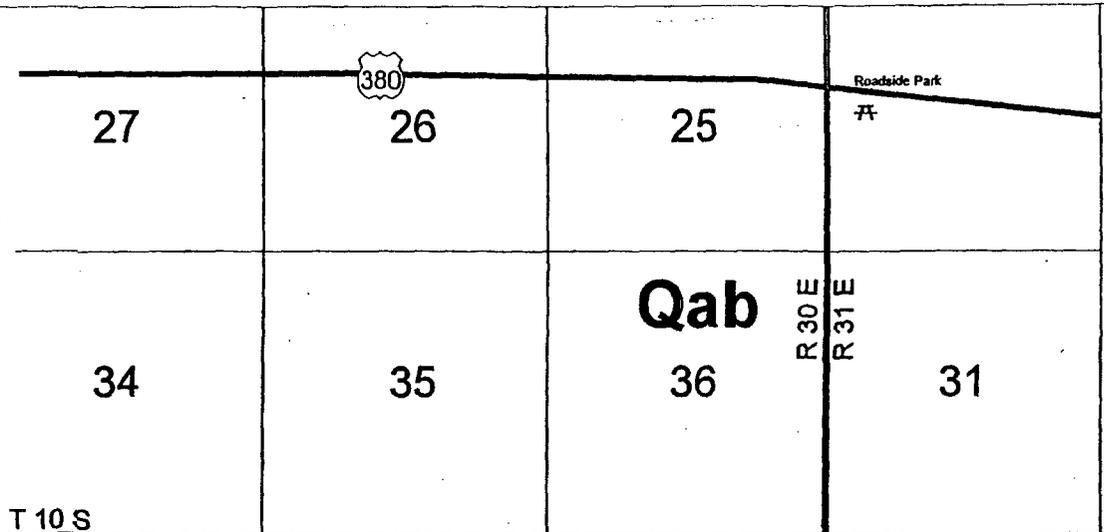
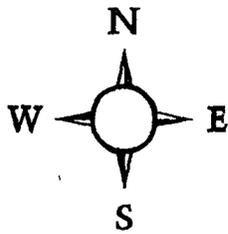
#### **3.1 Triassic Sediments**

As indicated on the Geologic Map of New Mexico, published by the U.S. Geological Survey (USGS), there is a surface expression of Triassic sediments in eastern Chavez County immediately underlying the "caprock" or "Llano Estacado." This unit is approximately 20 miles long and one mile wide, the northern portion of which is shown in Figure 5.

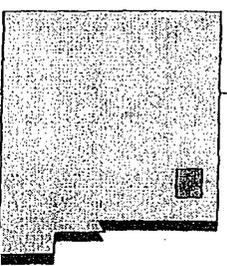
Actual outcrops within the area delineated on the map are difficult to observe. Triassic sediments are mostly covered with a thin veneer of alluvium. Where outcrops are available, the Triassic sediments are a typical sequence of redbeds, consisting of red-maroon mudstones and siltstones. The fact that there are not more exposed outcrops indicates that the sediments are predominately non-resistant clays and silts. These sediments dip slightly to the east.

Because of the lack of outcrops, it was necessary to conduct subsurface drilling operations to gather information on the character of Triassic sediments in the project area. These drilling programs are discussed in detail in section 4.0 of this report. Information from this subsurface exploration concerning the physical characteristics (lithology) and depositional environment of the Triassic sediments is presented below.

The estimated total thickness of Triassic sediments in the project area is 1,200 feet. Over 90 percent of this stratigraphic section is variegated redbed sequences, consisting of alternating beds of red-maroon-purple-blue mudstones and interbedded siltstones. Approximately midway in the Triassic section, a 70 foot sandstone interval was observed. These fine-grained red sands were well sorted and stratigraphically displayed a "coarsening upward" character. This would suggest these sands were deposited in a deltaic environment, which is consistent with overall depositional history of the region depicted in Figure 4.



- LEGEND**
-  Qab (Quaternary Aluvium)
  -  R (Triassic Undivided)
  -  To (Tertiary Ogallala Fm.)



**SURFACE GEOLOGY - PROJECT AREA**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 5  
 ONE INCH ≈ 3500'

In addition to the above described sand interval, very little sand was observed throughout the remainder of the Triassic section. Occasionally, 2-5 foot, fine-grained, red sandstones would be encountered within the variegated redbed sequence. These thin, isolated sands displayed no lateral continuity and are considered to reflect only localized depositional patterns.

A geologic literature review of Triassic lithologies from other locations within New Mexico and Texas was completed. These sections were compiled from detailed mapping in areas with good surface exposure and contain excellent detail. They provide the basis for classifying Triassic sediments into mappable geologic units or formations. In the project area, because no surface mapping can be done, the USGS has grouped Triassic sediments into an "undivided" classification. A comparison of these stratigraphic sections is presented in Figure 6.

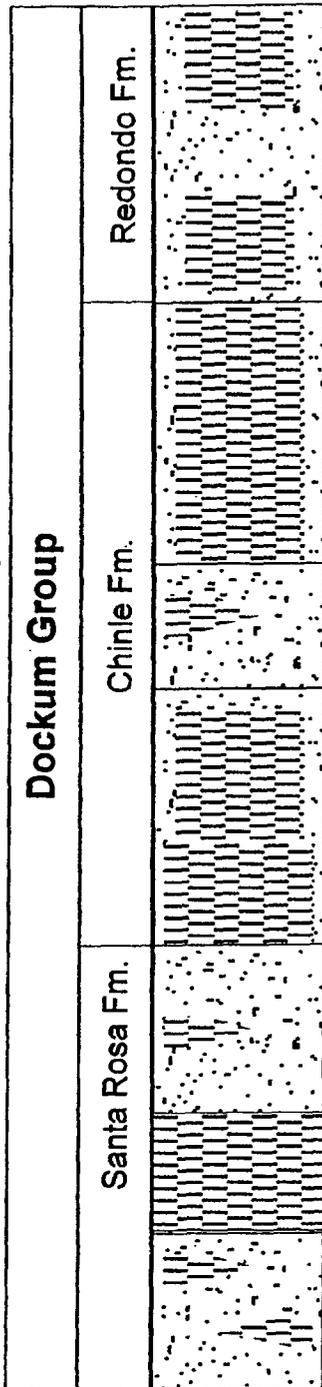
Clearly, there is a great deal of variability in these sections with respect to total thickness and lithology. These factors are directly related to depositional environment of the Paleo Triassic basin as previously discussed.

### **3.2 Tertiary Ogallala Formation**

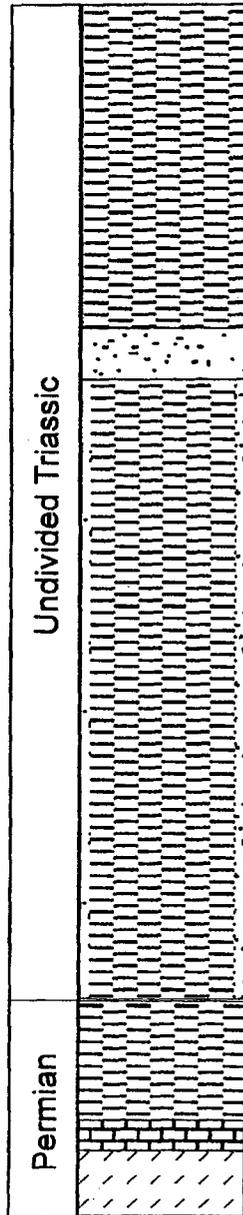
The "caprock", which is the surface expression of the Tertiary Ogallala Formation, unconformably overlies Triassic sediments in the project area. This flat-lying sandstone and conglomeritic unit is approximately 400-500 feet thick. Granitic cobbles and chert pebbles are interbedded with buff colored medium- to coarse-grained sands. There are abundant petrified wood fragments throughout this unit. The relationship between the Ogallala Formation and the underlying sediments is illustrated in Figure 7.

The Ogallala Formation is a major aquifer throughout many of the western states. Adjacent to the project area, there are several small springs at the contact between the Ogallala Formation and the Triassic sediments. The water from these springs originated within the Ogallala and, because it could not penetrate the underlying redbeds, it migrated along the contact with the impermeable Triassic sediments until it reached the surface. The Ogallala Formation in this area represents a "perched" water table in that the sediments underlying this unit are dry.

**EAST  
CENTRAL  
NEW MEXICO**

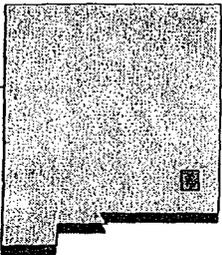
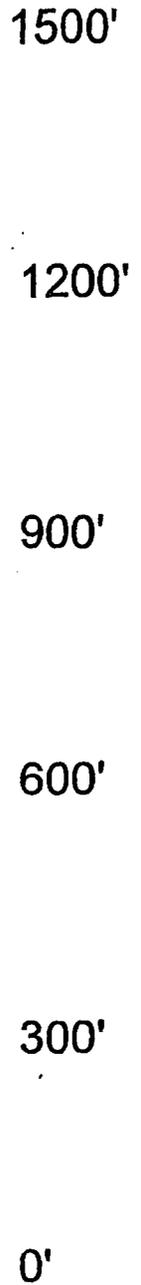
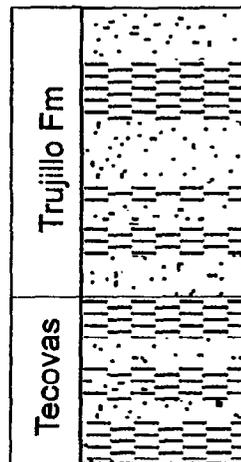


**PROJECT  
AREA**



*POSITION  
OF  
PROPOSED  
HOSTS*

**WEST  
CENTRAL  
TEXAS**



**TRIASSIC SECTIONS  
SOUTH EAST NEW MEXICO  
GANDY PROJECT**

**Figure 6**

## PROJECT AREA - CROSS SECTION

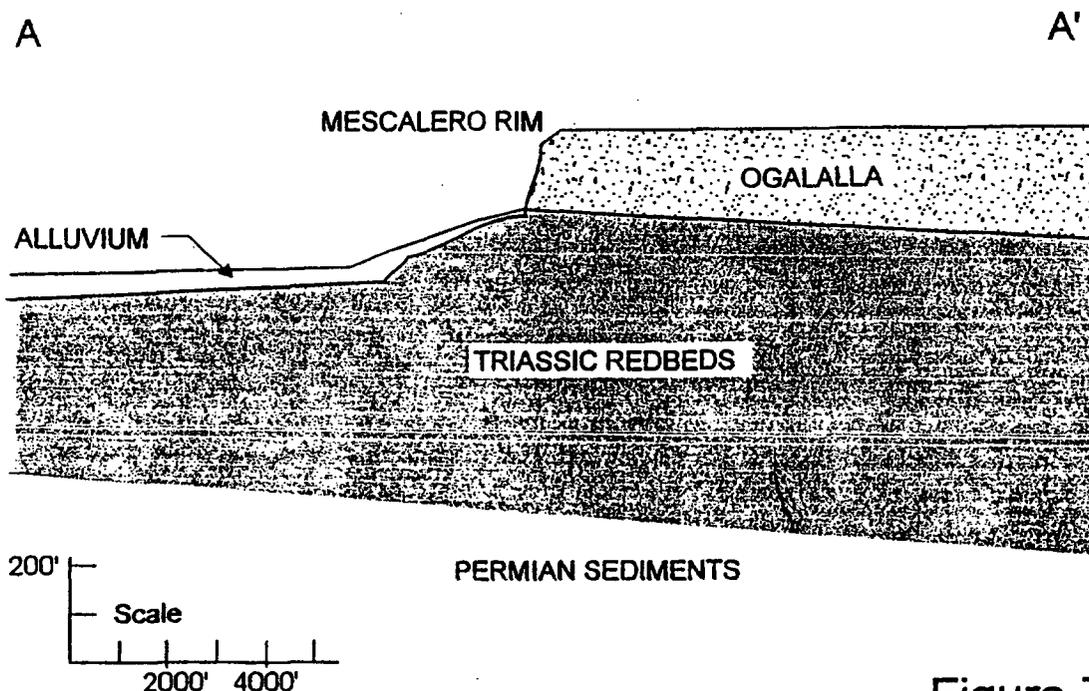


Figure 7

### 3.3 Quaternary Alluvium

The surface throughout the project area is covered by alluvial deposits of Quaternary age. These deposits are comprised of fine-grained, red-brown sands, interbedded with red-brown silts and clays. A major source of these sediments was the topographically higher Ogallala Formation, as evidenced by the abundant granitic cobbles, chert pebbles and fragments of petrified wood found throughout this unit. The thickness of these alluvial deposits within the project area varies from a few feet to as much as 35 feet.

### 3.4 Permian Sediments

Permian sediments underlying the Triassic in the project area are assigned to the Artesia Group. Investigation of oil well logs from the New Mexico Oil Conservation Division (OCD) in Hobbs, New Mexico has provided sufficient data to identify the Dewey Lakes Formation, Rustler Formation and Yates Formation from the upper portion of this Group. Figure 8 is an oil well log from the project area which shows the electric and gamma ray log response for Triassic and upper Permian sediments.

**TRIASSIC**

**PERMIAN**

Dewey  
Lakes  
Fm.

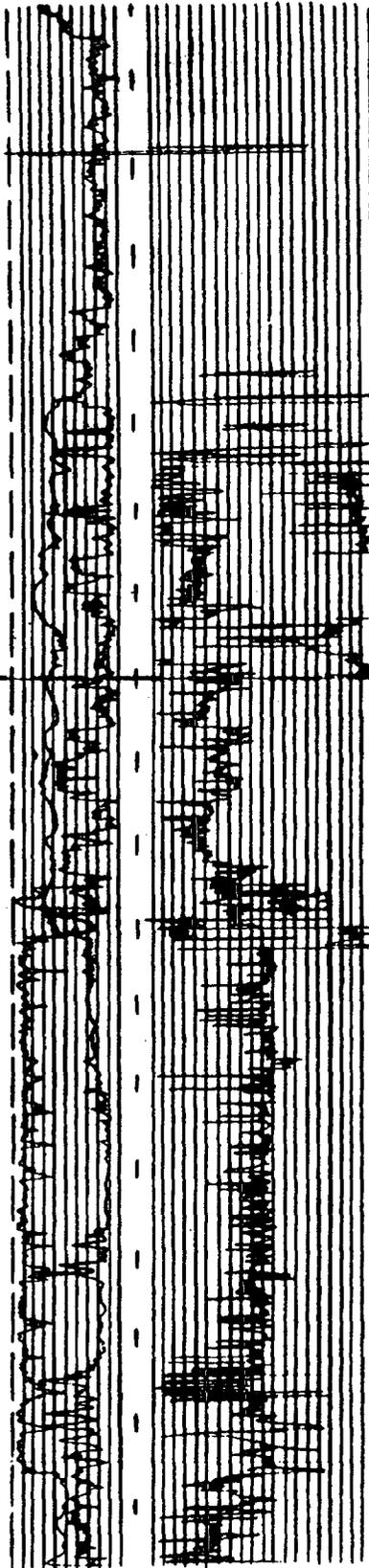
Rustler  
Fm.

Yates  
Fm.

Redbeds  
(Mudstones)

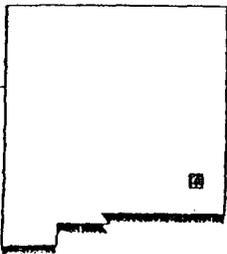
Anhydrite

Salt



**STRATIGRAPHIC COLUMN**  
SOUTH EAST NEW MEXICO  
GANDY PROJECT

Figure 8



Geologic literature describes these Permian sediments to be gently dipping to the east. This was confirmed using oil well log data and constructing a graphic 3-point solution. Using the top of the anhydrite (Rustler) as a marker bed, the strike of the formation was calculated to N-S and the dip is less than 1° to the east.

Dewey Lake Redbeds — The uppermost Permian sediments underlying the Triassic sequence in the project area would correlate to the Dewey Lakes Formation. These sediments are predominately red to red-brown mudstones and siltstones and are virtually indistinguishable from the overlying Triassic sediments. Geologic literature reports a conformable relationship between these sediments and the overlying Triassic sediments. There is approximately 240 feet of Permian redbeds in this section.

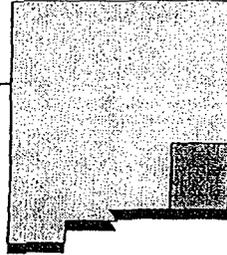
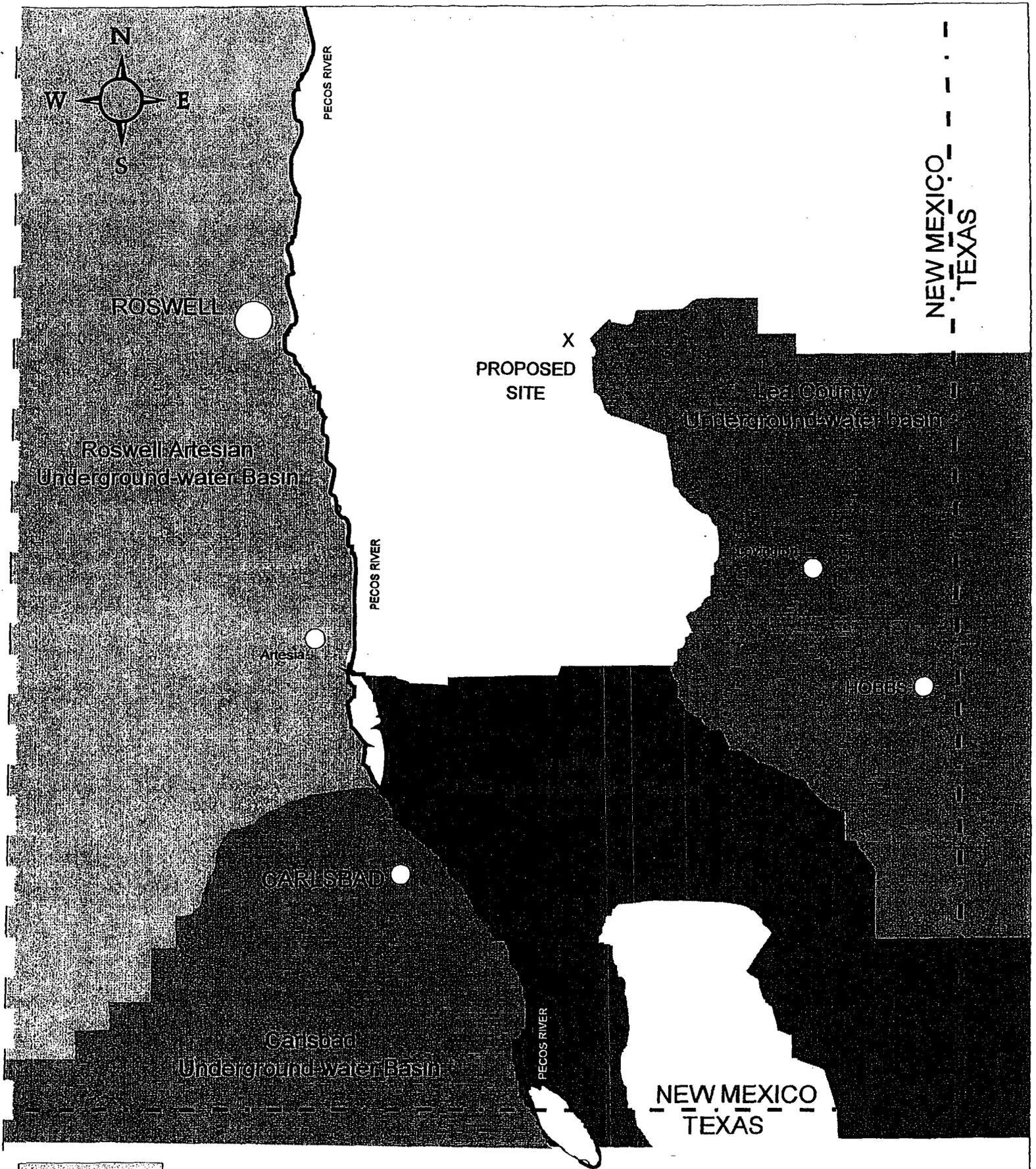
Rustler Formation — The top of the Rustler Formation was identified on OCD well logs and corresponds to the top of a 40 foot bed of anhydrite. These anhydrites are visible in outcrop on the hills immediately east of the Pecos River drainage east of Roswell, New Mexico. Underlying the anhydrite is approximately 500 feet of halite (salt).

Yates Formation — Underlying the Rustler, the Yates Formation is composed primarily of interbedded sandstone, with minor dolostone and limestone. The sands are light gray and fine- to very fine-grained. Limestone is white to very light gray, microcrystalline lime mudstone with a chalky texture. Dolostone is pink to light gray and microcrystalline.

### **3.5 Groundwater Potential**

The groundwater potential within Triassic sediments in the project area is negligible due to the lack of sands to act as aquifers. The Santa Rosa Sandstone (Triassic), a known aquifer in east-central New Mexico, is not present in the project area. The thin deltaic sands encountered in the drilling program carried no groundwater and are located stratigraphically above the proposed host clays.

In reviewing Ground-Water Levels in New Mexico, a technical report prepared by the New Mexico State Engineer's office, there are no groundwater monitoring programs within the Project area. Figure 9 illustrates the state-recognized underground water basins within southern New Mexico. The proposed site is situated outside of all these basins.



**UNDERGROUND-WATER BASINS**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 9

ONE INCH ≈ 16 MILES

## **4.0 SITE GEOLOGIC INVESTIGATION**

This section describes the systematic approach applied to evaluation of the Triassic sediments in the project area to determine their suitability as host rocks for the long-term isolation of hazardous waste.

A set of site characterization criteria was established for this project and applied to the investigation process. These site criteria included:

- Depth to Triassic sediments of less than 10 feet
- A minimum thickness of 50 feet of low permeability Triassic clays
- Several hundred feet separation of potential Triassic host clays from the groundwater table

With the favorability criteria in mind, a regional investigation program to examine Triassic sediments of eastern Chavez County was initiated in July 1993. A registered, professional geologist, was contracted to oversee all investigation activities.

### **4.1 Photo Geologic Interpretation**

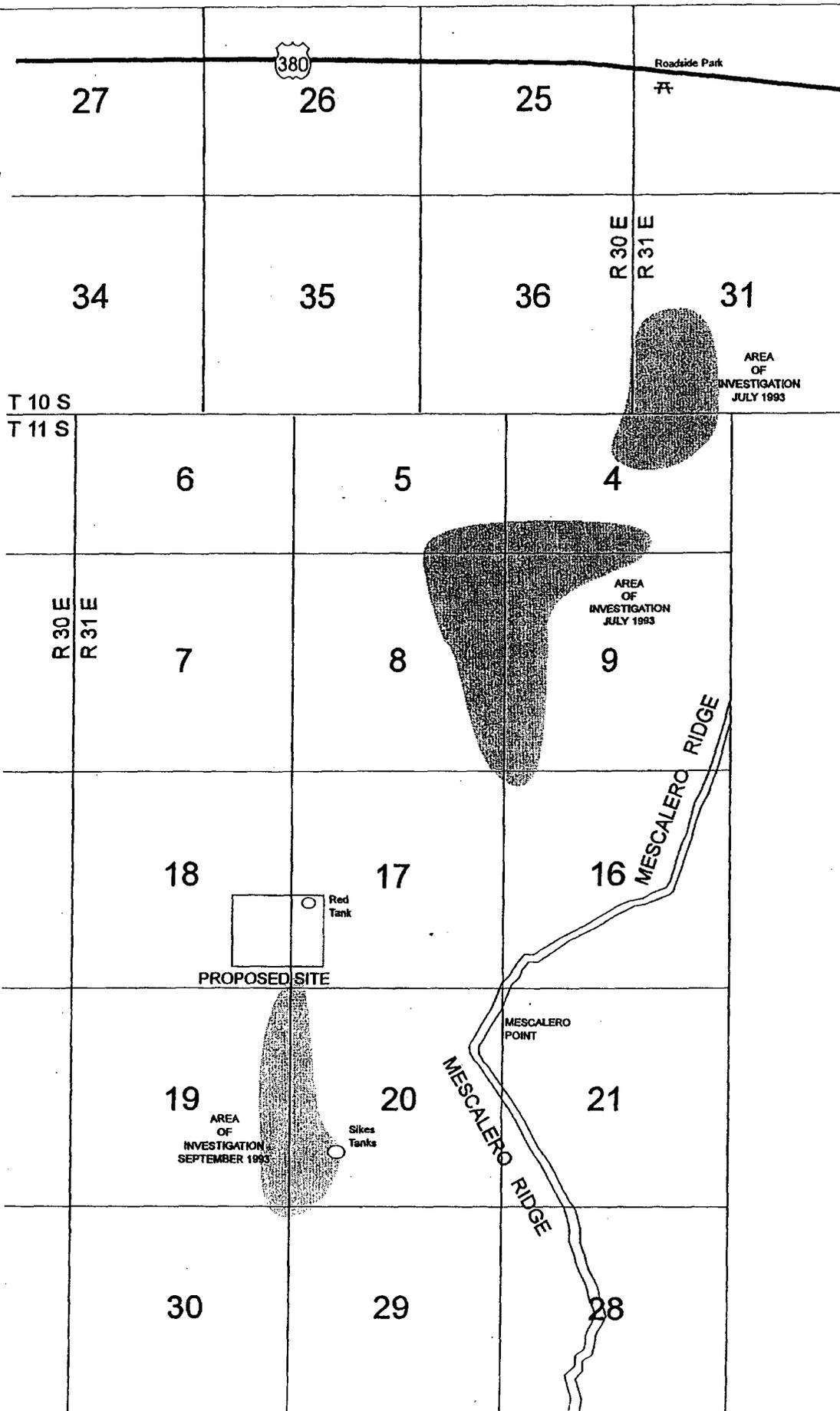
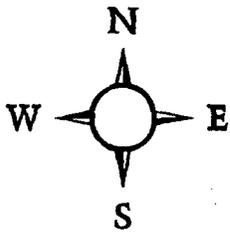
The first step in this investigation process was to obtain color air photos of areas underlain by Triassic sediments in eastern Chavez County. 1:24,000 color photos, flown in September 1973, were purchased from the Bureau of Land Management Service Center in Denver, Colorado.

These photos were examined for "color anomalies" associated with exposed or very near-surface Triassic outcrops. Areas exhibiting deep red coloration were identified on these photos and located on topographic maps.

These color anomalies, along with other factors, such as accessibility and land ownership, were considered in developing priorities for the initial exploratory drilling program.

### **4.2 July 1993 Air Rotary Drilling Program**

As shown in Figure 10, this first drilling program investigated two large areas in sections 4, 5, 8 and 9, T11S, R31E and section 31, T10S, R31E. Average depth of this drilling was 40



**PROJECT AREA**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 10

ONE INCH = 3500'

and there was a spacing of approximately 1,000 feet between holes. All cuttings were logged on lithology sheets and cross-sections prepared to illustrate stratigraphic relationships within the Triassic sediments.

A total of 28 shallow drill holes were completed on 20 July 1993. An Ingersol Rand 1500, drilling with air, was used to perform this work. This air rotary technique was used because of the high quality of drill cuttings it produced and because the presence of any subsurface water could be easily recognized.

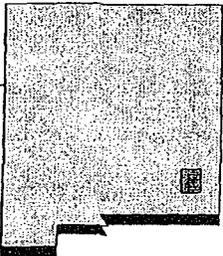
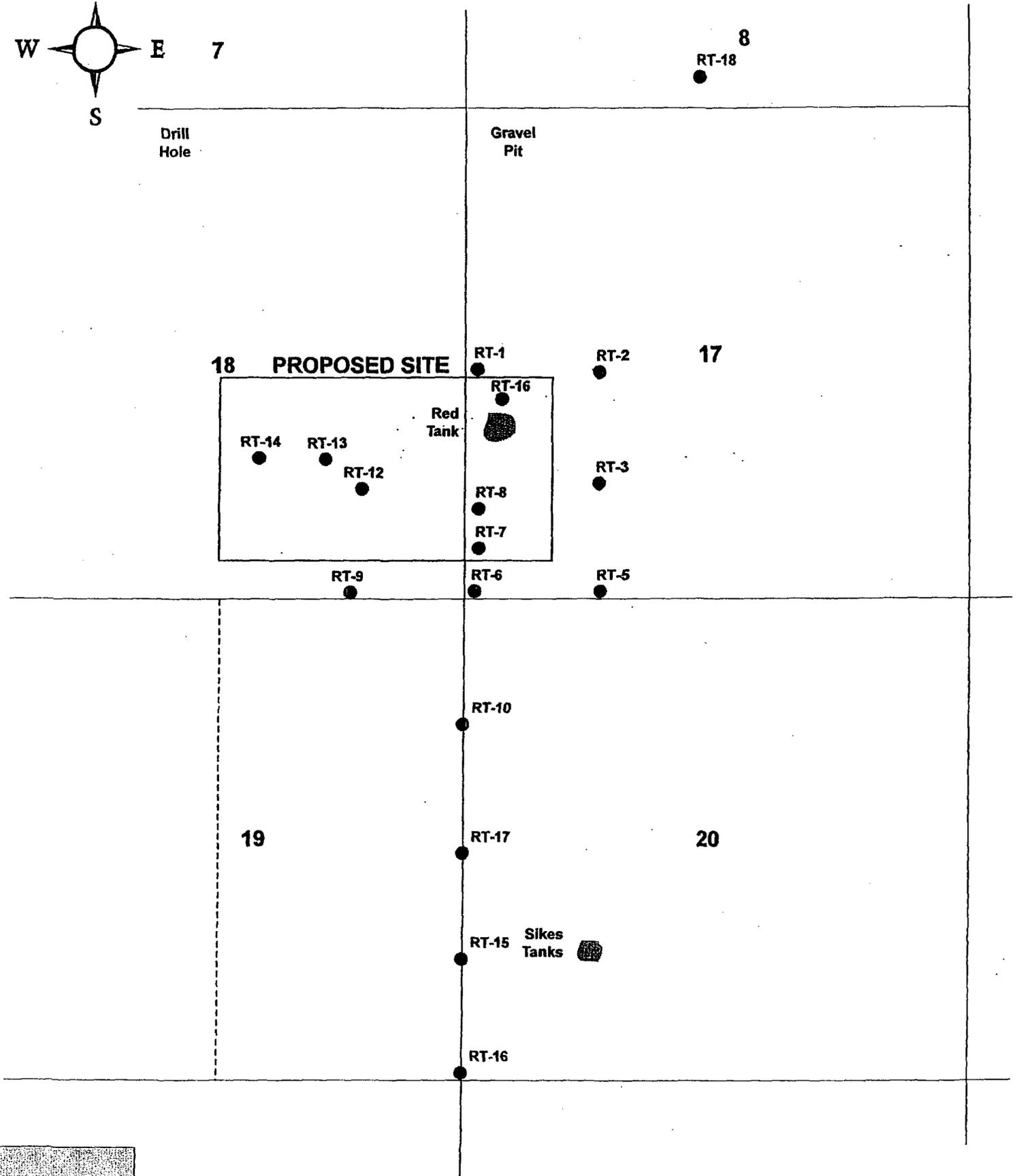
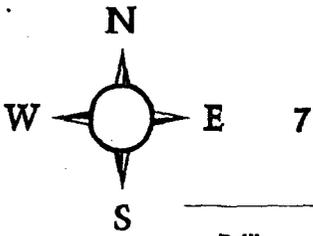
The favorability criteria were not met in these areas. While there were thick sequences of low permeability Triassic clays encountered, the thickness of the overlying Quaternary alluvium ranged from 15 to 35 feet. In sections 5 and 8, T11S, R31E, Triassic sandstones were observed underlying the alluvium. There was no water in these sands.

#### **4.3 September 1993 Air Rotary Drilling Program**

A second drilling program using the same equipment was conducted on September 23, 1993. Eighteen 40-60 foot deep rotary air holes were completed on a drill hole spacing of approximately ¼ mile in sections 17, 18, 19 and 20 T11S, R31E. This drilling, shown on Figure 11, encountered an area adjacent to Red Tank of approximately 120 acres, that satisfied all favorability criteria.

- Depth to Triassic sediments ranged from 4.5 to 10 feet
- Drilling encountered 40-60 feet of Triassic Clays
- All clays were dry and above the water table

The favorable site, located in sections 17 and 18, corresponds to a broad east-west topographic high. Shallow beds of purple and red clays were found underlying this broad ridge. These clays are stratigraphically below the sands encountered in the July drilling program. All drill cuttings were logged on lithology sheets and cross-sections prepared to illustrate stratigraphic relationships within the Triassic sediments.



**PROPOSED SITE**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 11

ONE INCH ≈ 16 MILES

#### 4.4 November Hollow Stem Auger Coring Program

To confirm the presence of shallow Triassic clays in the 120 acre site and to obtain cores for material testing, a limited coring program was conducted on November 17-19, 1993. A CME-55 hollow-stem auger rig was used and 2-inch diameter core samples were obtained drilling with air and a continuous sampler tool. Five core holes were completed and sampled (see Figure 12). Four of these core holes were located within 10 feet of earlier air holes to confirm information obtained from the rotary cuttings.

A total of 90 feet of shallow Triassic sediments were cored within this 120-acre site, with over a 90 percent core recovery. Due to the shallow depth of these sediments, many of the clays exhibited very dry and brittle characteristics. This presented some difficulty in obtaining "undisturbed" core samples. Minute secondary fractures, resulting from the recovery process, could be observed in the core samples.

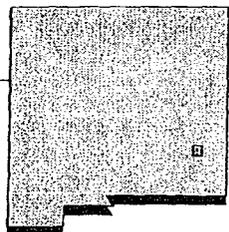
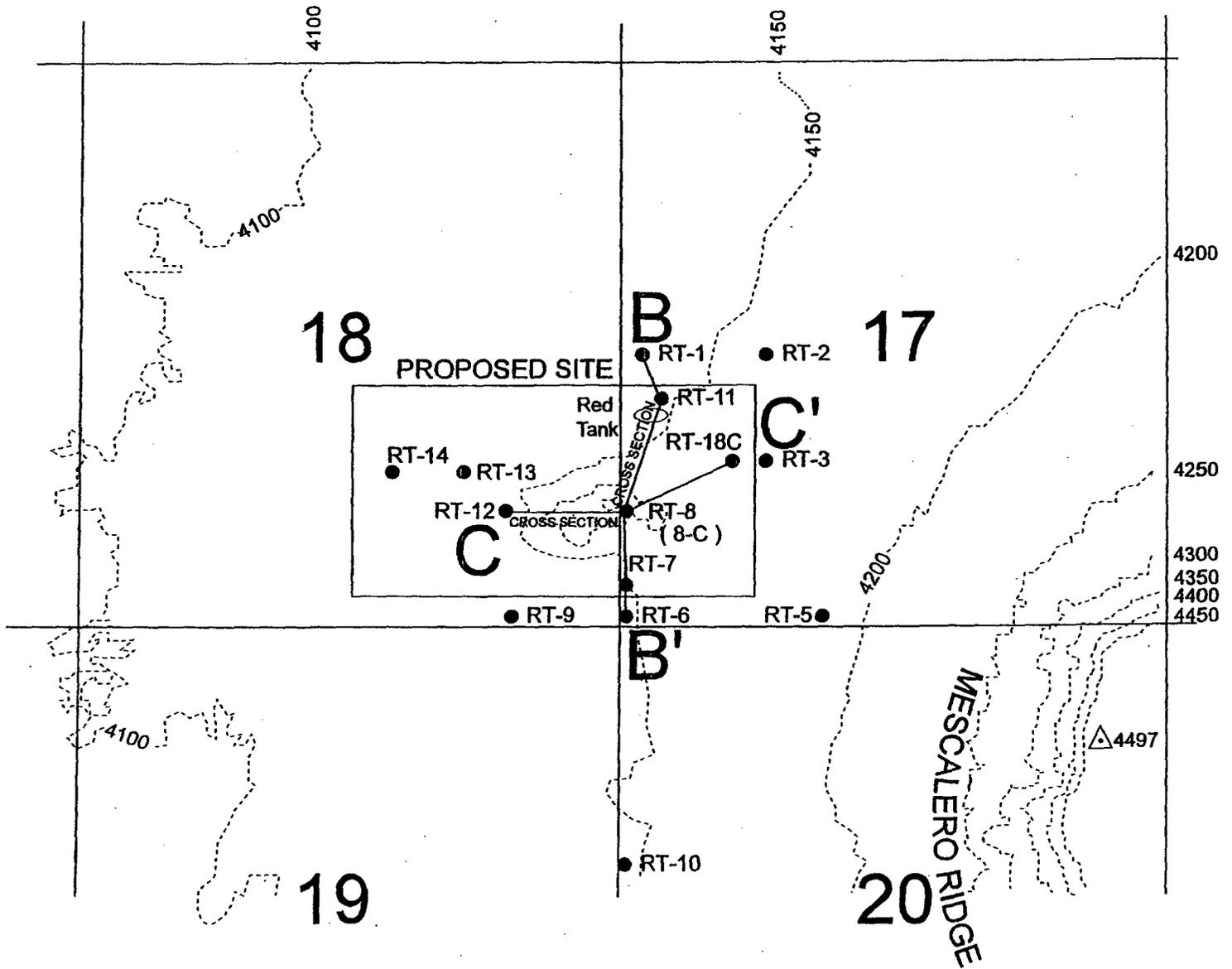
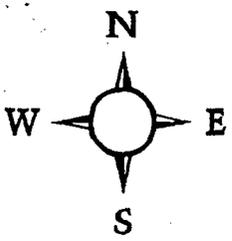
Six representative core samples were sent to SHB, AGRA's material testing laboratory. These tests included triaxial permeability, sieve analysis (to examine grain size to classify lithology type), and a plasticity index (PI). The location of these six representative samples from within the core holes are shown on the cross-sections in Figure 13. The following summary table presents test results from these analyses.

Sample	Hole	Lithology	P.I.	Permeability
1	8-C	Clay	20	$1 \times 10^{-7}$ *
2	18-C	Clay	30	$3 \times 10^{-8}$
3	8-C	Clay	22	— **
4	12-C	Clay	14	$6 \times 10^{-5}$ *
5	11-C	Clay	14	— **
6	12-C	Silt	7	— **

\* Secondary fractures in core presented difficulty in permeability testing — results underestimated true permeability

\*\* Secondary fractures in core prevented permeability testing

TABLE 1. Summary of Representative Samples Analyses



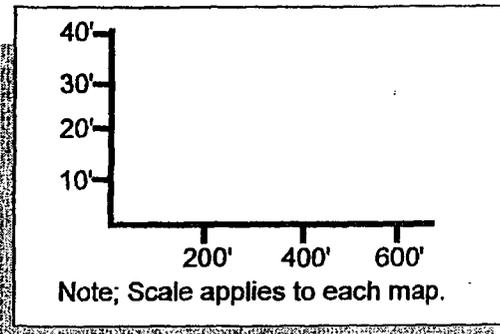
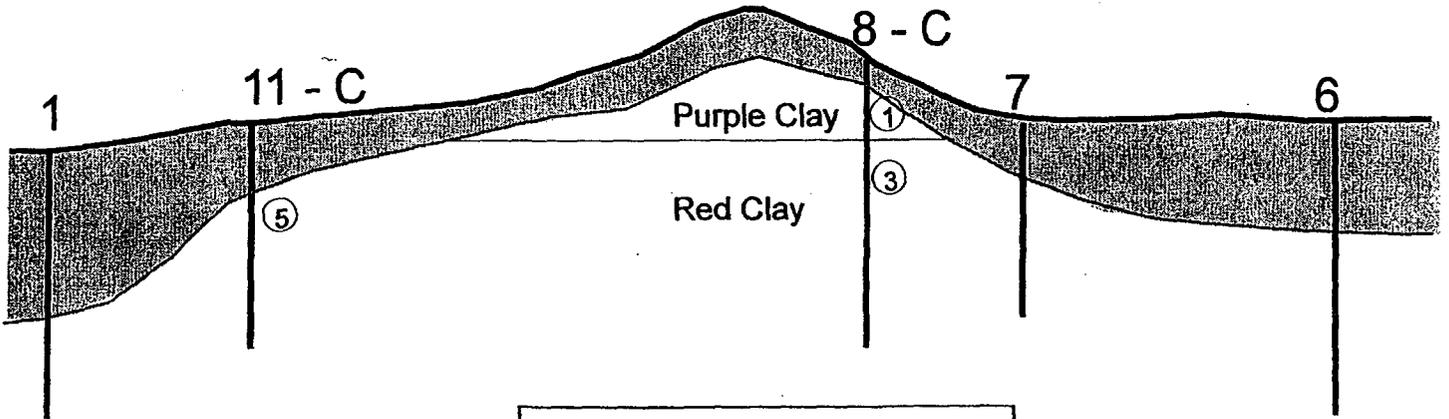
**PROPOSED SITE**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 12

ONE INCH  $\approx$  2000'

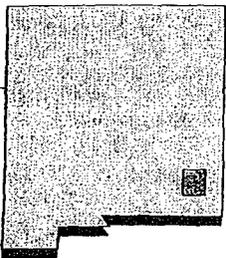
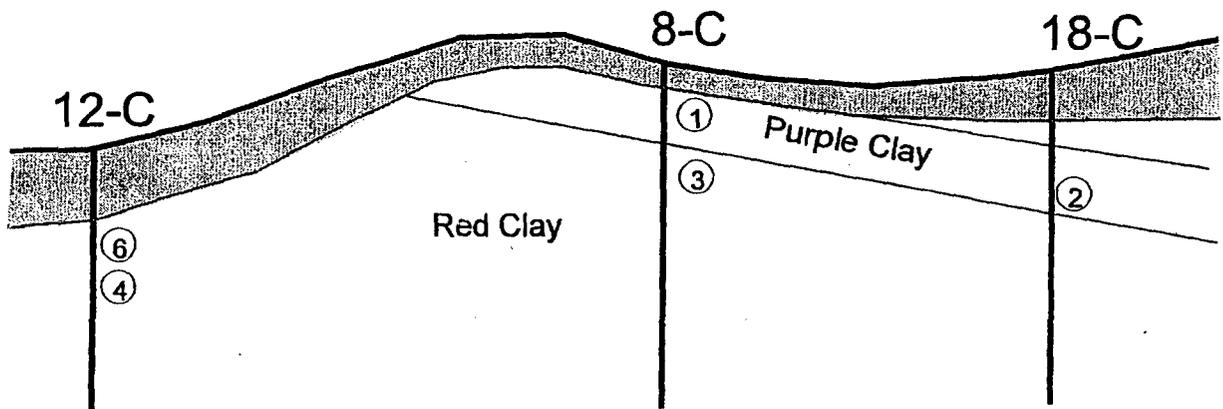
B  
North

B'  
South



C  
West

C'  
East



**CROSS SECTIONS - PROPOSED SITE**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

Figure 13

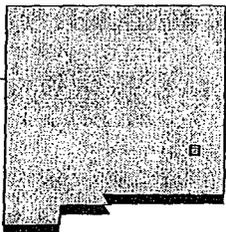
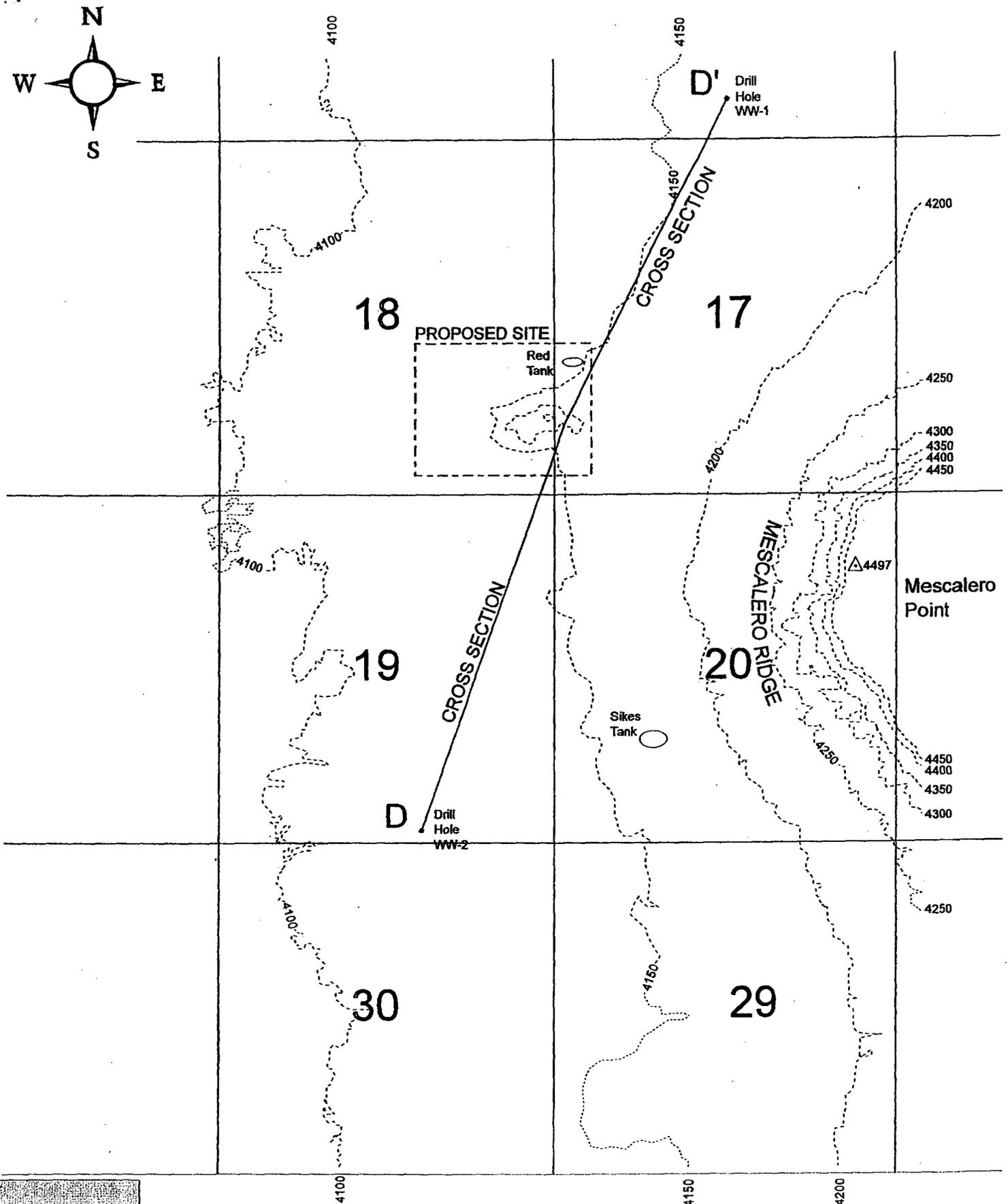
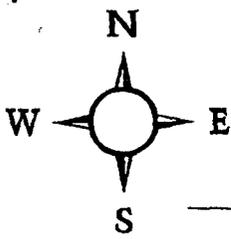
#### 4.5 Groundwater Investigation

Once a favorable site had been located, the final phase of the preliminary investigation was to complete some deeper drill holes in an effort to identify the water table within the Triassic sediments. As shown in Figure 14, two deep holes were drilled, each approximately one mile from the proposed site. These locations were chosen because 1) drilling in the proposed site would violate the integrity of those sediments and 2) the wider spacing would examine potential groundwater in an estimated "upgradient" and "downgradient" from the proposed site.

An Ingersol Rand 1500, drilling with air was used to complete these holes. These holes were drilled with air so that if groundwater was encountered, its presence would be known immediately. (Wet samples are difficult to air lift and drilling circulation is lost.)

The photos in Figure 15 illustrate this drilling technique. As shown in these photos, the "dryness" of the Triassic sediments that were penetrated was quite obvious. The air lifted samples were collected at five-foot intervals, logged, and bagged for possible future analyses. On completion, 3-inch tubing was placed in each hole to preserve it for possible future usage.

The depth to the base of the Triassic was estimated from oil well logs from the project area as shown earlier in Figure 6. These two drill holes were completed only to the projected base of the Triassic. As shown in the cross-section in Figure 16, WW-1 was drilled to a depth of 820 feet and WW-2 was drilled to 740 feet. Because the geologic literature refers to the presence of salt in the Permian section, these holes were terminated before encountering any salt and possibly contaminating the Triassic sediments.



**PROPOSED SITE**  
**SOUTH EAST NEW MEXICO**  
**GANDY PROJECT**

**Figure 14**

ONE INCH  $\approx$  2000'



**DRILL PHOTOS**  
SOUTH EAST NEW MEXICO  
GANDY PROJECT

Figure 15

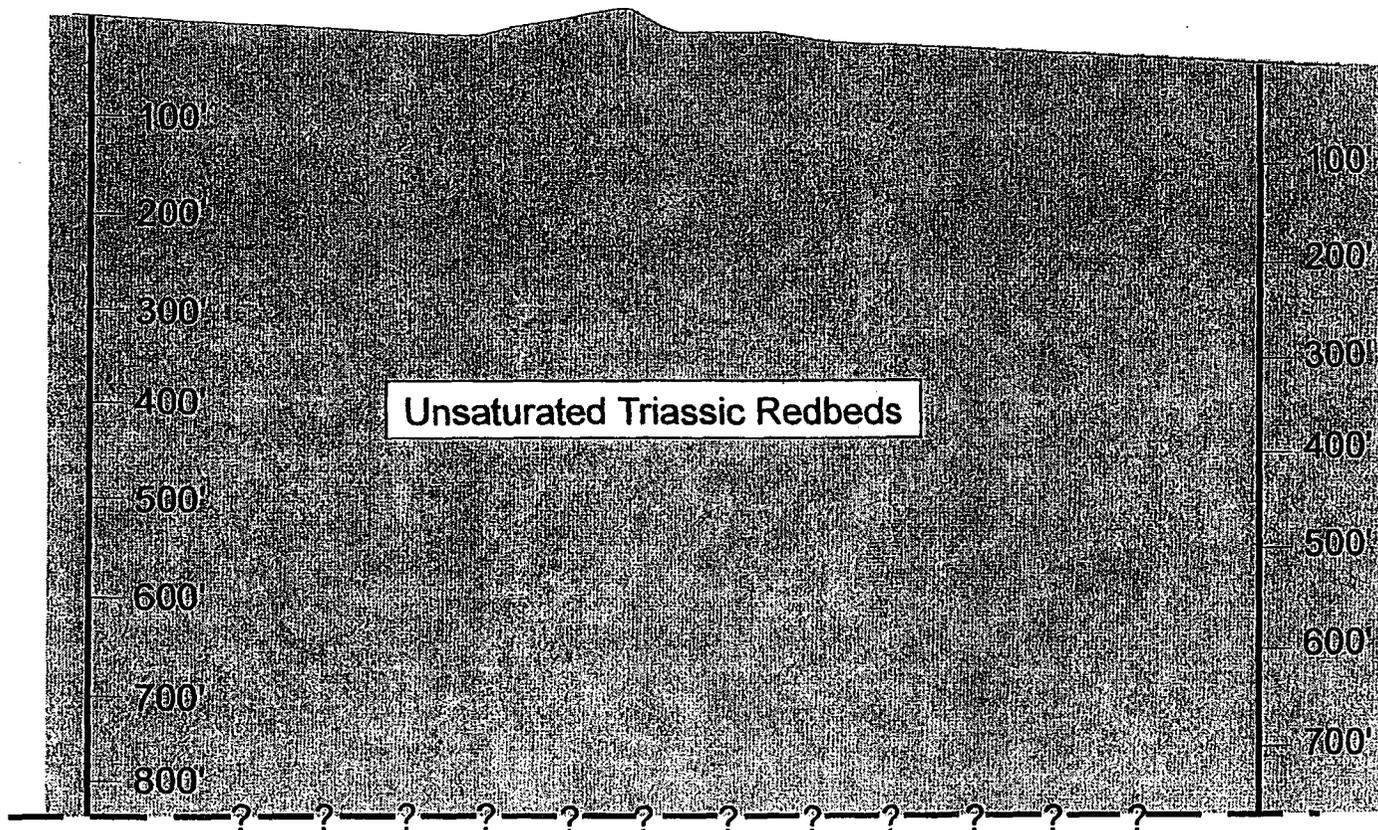
D  
North

D'  
South

WW-1

RT-11 RT-8

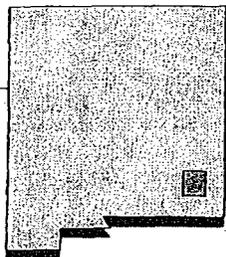
WW-2



Permian Redbeds

Anhydrite

Salt



**CROSS SECTION - PROPOSED AREA**  
SOUTH EAST NEW MEXICO  
GANDY PROJECT

Figure 16

## 5.0 CONCLUSION

The major concern facing any proposed hazardous waste disposal facility is the potential impact that facility may have on surface and groundwater resources. The Gandy site in eastern Chavez County, New Mexico represents an excellent candidate for the siting of such a facility due to the demonstrated facts that:

- The site is located outside of any groundwater basin and drilling to depths of over 800 feet has shown the proposed host sediments to be above any water table.
- The nearest surface water is the Pecos River, approximately 30 miles to the west.
- Clays within the proposed Triassic age host rocks have been delineated at a favorable depth (0-10 feet) and a sufficient thickness to prevent migration of hazardous constituents from the proposed facility. Material testing of these clays has yielded permeabilities of less than  $10^{-7}$ .

In addition to these favorable geologic site characteristics, the proposed facility location is in a remote portion of southeastern New Mexico, on private land (with the land owners participating in the project) where it will have minimal impact to the public. Considering all factors, the proposed Gandy site has the physical and geographical characteristics to assure long-term isolation of hazardous wastes from the environment.