10/20/99

Prepared for:

TRIASSIC PARK WASTE DISPOSAL FACILITY
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GROUNDWATER MONITORING WAIVER REQUEST

TRIASSIC PARK WASTE DISPOSAL FACILITY

Draft

DRAFT

October 1999

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1.0 INTRODUCTION

The Gandy-Marley Corporation is requesting that the Hazardous and Radioactive Materials Bureau (HRMB) of the New Mexico Environment Department (NMED) grant a Groundwater Monitoring Waiver for its proposed Triassic Park Waste Disposal Facility. This request is based on a demonstration that the site-specific geologic and hydrologic conditions at the site combined with the engineered barriers in the regulated units at the Facility will ~~Facility~~ prevent migration of liquids ~~from the regulated~~ unit to the uppermost aquifer.

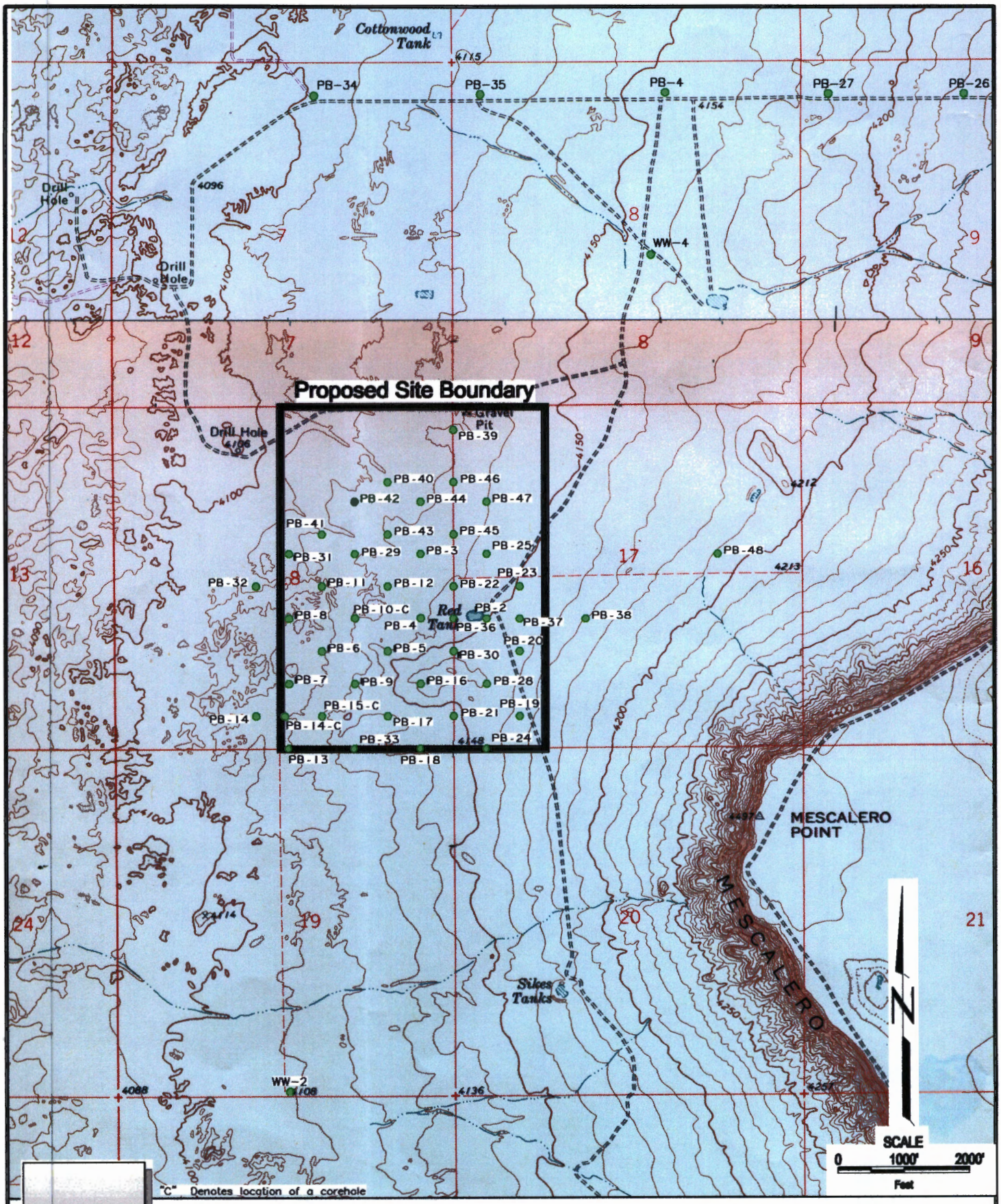
An alternative to groundwater monitoring is also presented in this document. The proposed alternative monitoring system is a Vadose Zone Monitoring System (VZMS) that will be superior to traditional groundwater monitoring for detecting potential leaks from the facility in a timely manner. The VZMS is proposed~~,~~ because it will be more protective of human health and the environment than groundwater monitoring of the upper most aquiter.

Triassic sediments in eastern Chaves County, New Mexico were identified as host rocks for this proposed Facility because they (1) contain thick sequences of low permeability clays; (2) occur in remote, unpopulated areas; and (3) locally produce no groundwater. These sediments have been characterized by drilling programs in 1993, 1994, 1995 and 1999. Fifty (50) drill holes have been completed on the proposed site (Figure 1-1, Drill Hole Locations), with lithologic and geophysical logs recorded for each of these holes. Data obtained from these drilling programs have been incorporated into this demonstration.

This demonstration or justification will evaluate the potential for migration of hazardous waste or hazardous waste constituents from the facility to the uppermost aquifer, through:

- A geologic and hydrologic characterization of host sediments,
- A water balance of precipitation, evapotranspiration, runoff, and infiltration; and
- Unsaturated zone contaminant transport modeling

The following sections provide a summary of the regulatory authority to allow modification of the groundwater monitoring requirements and the technical justifications required to support the groundwater monitoring waiver.



DRILL HOLE LOCATIONS

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 1-1

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2.0 REGULATORY REQUIREMENTS

NMED's authority to grant a groundwater monitoring waiver lies in the New Mexico Hazardous Waste Management Regulations (20 NMAC 4.1.500), which adopts by reference 40 CFR § 264.90(b)(4). The relevant regulation states that the owner or operator of regulated units is not subject to regulations of 40 CFR 264.90 for releases into the uppermost aquifer under this part if:

The Regional Administrator finds that there is no potential for migration of liquid from a regulated unit to the uppermost aquifer during the active life of the regulated unit (including the closure period) and the post-closure care period specified under § 264.117. This demonstration must be certified by a qualified geologist or geotechnical engineer. In order to provide an adequate margin of safety in the prediction of potential migration of liquid, the owner or operator must base any predictions made under this paragraph on assumptions that maximize the rate of liquid migration.

3.0 GEOLOGY

This section describes the regional and geologic setting of the proposed facilities. The proposed facilities will be founded in unsaturated materials consisting of Quaternary alluvial sediments, Upper Dockum interbedded siltstones and mudstones, and Lower Dockum mudstone and thinly interbedded siltstone.

3.1 REGIONAL STRATIGRAPHY

The geologic formations present within the region range in age from Quaternary through Triassic. Those include Quaternary alluvium, Tertiary Ogallala Formation, and the Triassic Dockum Group. Permian sediments do not outcrop in this region but, because they underlie the proposed host sediments, they are also discussed in this section. The stratigraphic relationship of the formations discussed in this section is illustrated in Figure 3-1, Stratigraphic Column. Information concerning formation tops and thicknesses was obtained from well logs from the New Mexico OCD office in Hobbs, New Mexico.

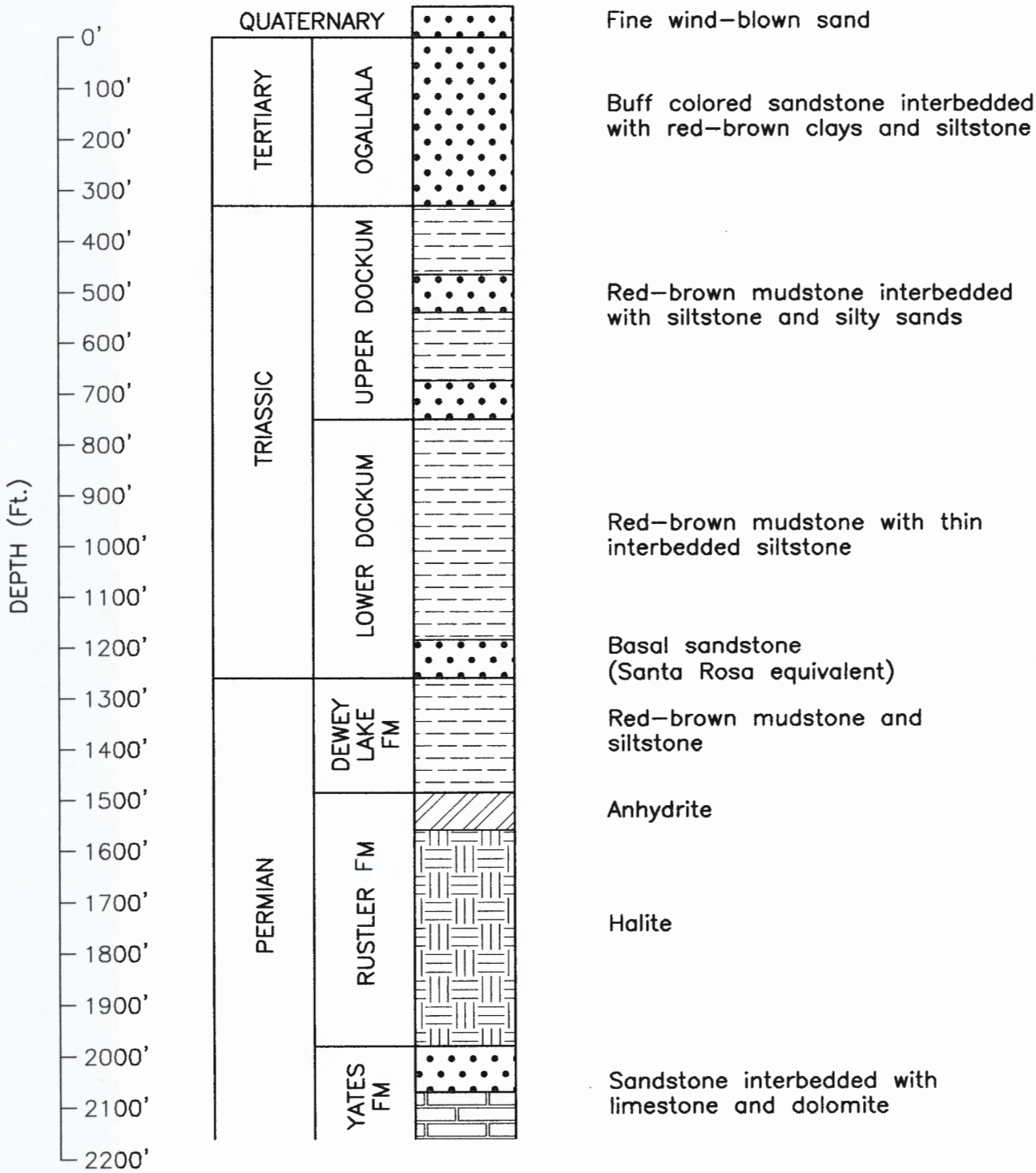
3.1.1 Quaternary

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 along the eastern flank of the Pecos River Basin in Chaves County varies from a few feet to as much as 50 feet.

3.1.2 Tertiary

The "Caprock," which is the surface expression of the Tertiary Ogallala Formation, unconformably overlies Triassic sediments in southeastern New Mexico. This flat-lying sandstone and conglomeritic unit is approximately 300 to 400 feet thick. It consists of fluviatile sand, silt, clay, and gravel capped by caliche. The sand deposits of the Ogallala Formation consist of fine- to medium-grained quartz grains, which are silty and calcareous. Bedding features range from indistinctly bedded to massive to crossbedded. The formation varies from unconsolidated to weakly cohesive and contains local quartzite lenses. The sand intervals of the Ogallala Formation occur in various shades of gray and red.

Ogallala Formation silt and clay deposits are reddish brown, dusky red, and pink and contain caliche nodules. Gravels occur as basal conglomerates in intra-formational channel deposits and consist primarily of quartz, quartzite, sandstone, limestone, chert, igneous rock, and metamorphic rock. There are abundant petrified wood fragments throughout this unit.



STRATIGRAPHIC COLUMN

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 3-1

AutoCAD FILE: GANDY-FIG3-4

3.1.3 Triassic

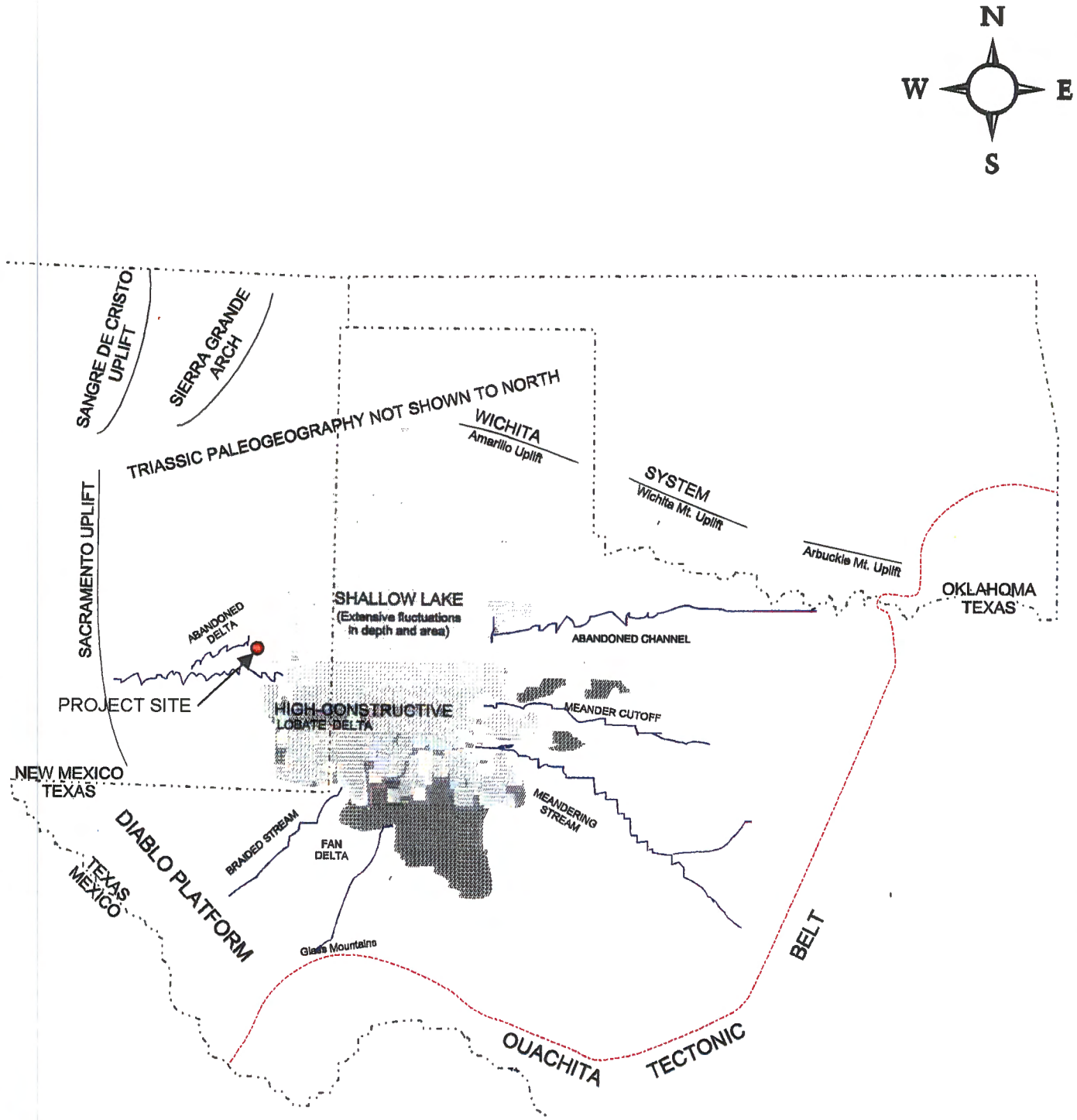
Triassic sediments are the potential host rocks for the proposed Facility and, as such, are described in more detail than the other formations. The Depositional Framework of the Lower Dockum Group (Triassic), Texas Bureau of Economic Geology, No. 97, 1979, by McGowen was used as a major reference for gathering information on the characteristics of Triassic sediments.

Triassic sediments unconformably overlie Permian sequences in Texas and New Mexico and have been classified as the Triassic Dockum Group. The Dockum Group is comprised of a complexly interrelated series of fluvial and lacustrine mudstone, siltstone, sandstone, and silty dolomite deposits that can be as much as 2,000 feet thick in this part of the Permian Basin. These sediments accumulated in a variety of continental depositional settings, including braided and meandering streams, alluvial fan deltas, lacustrine deltas, lacustrine systems, and mud flats.

The Triassic Dockum Group is divided into an Upper and Lower Unit. The Upper Dockum Unit is very near the surface within the project boundary, covered only by a thin veneer of Quaternary sediments. The character of this unit, also know as the Chinle Formation, is a series of fluvial sediments. These sediments conformably overlie the Lower Dockum Unit and consist of red-green micaceous mudstones, interbedded with thin, discontinuous lenses of siltstone and silty sandstones. A continental fluvial depositional environment predominated during Upper Dockum time, when the Triassic basin was filled with lacustrine sediments. The Chinle Formation is widespread in the southwestern United States.

The Lower Dockum accumulated in a fluvial lacustrine basin defined by the Amarillo Uplift on the north and the Glass Mountains on the south (Figure 3-2, Basin Paleomap for Triassic Period). These former tectonic belts were more than 200 miles away, and the regional slopes were relatively low. As presented in this basin map, the Lower Dockum represents sediments from a large, regional depositional system. For any given portion of this basin, these sediments tend to be very homogeneous and not subject to abrupt local changes. 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. The lacustrine sediments that accumulated here consist primarily of low-energy mudstone. Surface exposures today in these areas consist of thick sequences of maroon-red-purple variegated mudstones with thin discontinuous layers of siltstones and silty sandstones.

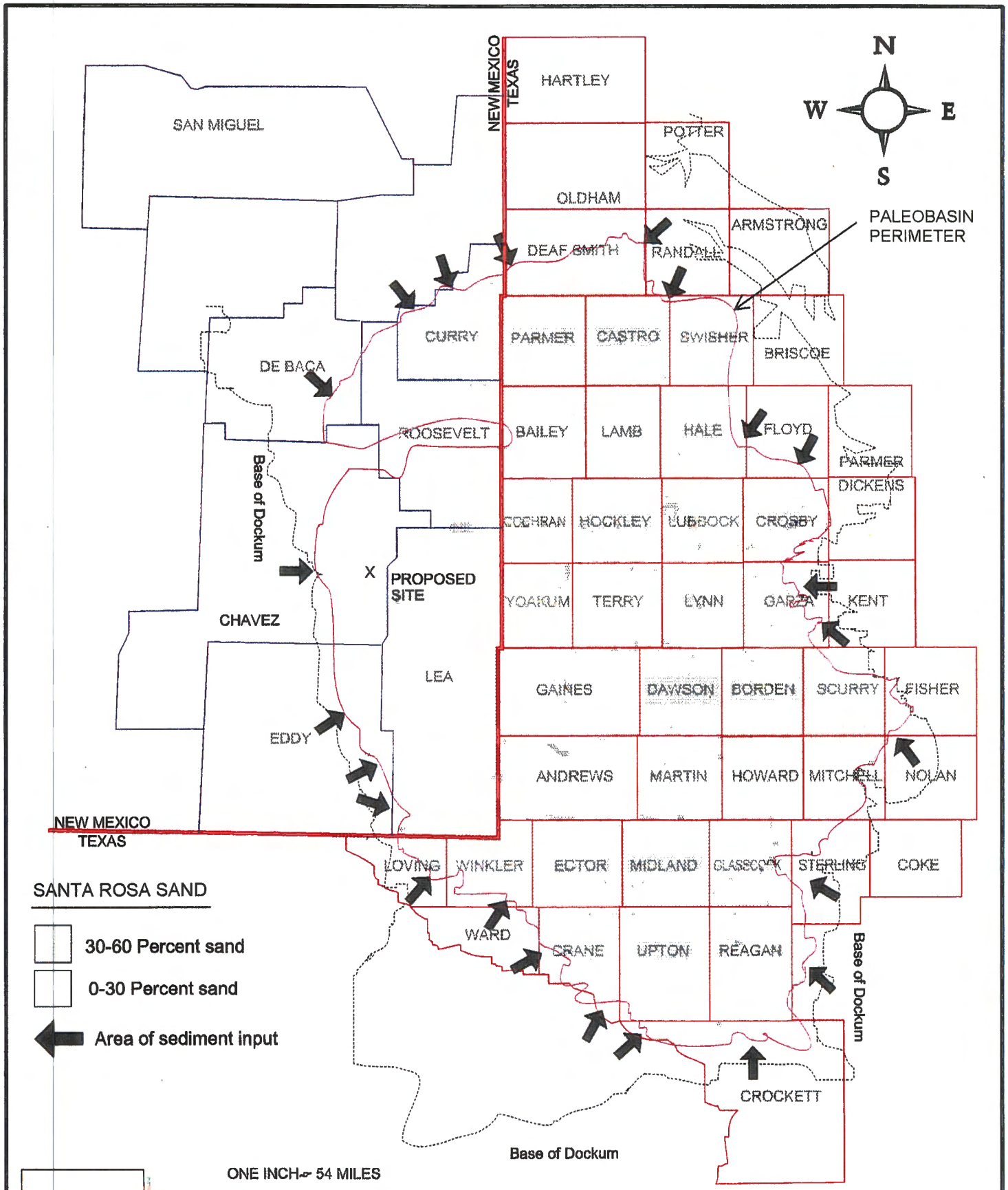
The stratigraphy of the basal Lower Dockum varies significantly throughout eastern New Mexico. Figure 3-3, Triassic Period Sand Accumulation in Paleobasin, a subsurface sand percent map of this unit, was compiled from drill hole data from more than 1,500 oil wells throughout the basin. Thick sequences of sandstones at the northern and southern portions of the basin are shown projecting inward toward the center of the basin. In the New Mexico portion of this basin, these sand accumulations are related to the occurrence of the Santa Rosa Sandstones. This medium-to-coarse grained, white to buff sandstone represents the lowermost Triassic depositional unit and is a major aquifer in many portions of New Mexico.



BASIN PALEOMAP FOR TRIASSIC PERIOD

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 3-2



TRIASSIC PERIOD SAND ACCUMULATION IN PALEOBASIN

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 3-3

3.1.4 Permian

Permian sediments are important to the geologic setting because they are immediately below the proposed Triassic host rocks. The deeper formations of Permian age were deposited in a restricted-marine environment and thus contain salt deposits, which make the groundwater produced from them too brackish for use.

Permian sediments underlying the Triassic units in the project area are assigned to the Artesia Group. Oil well logs from the New Mexico OCD in Hobbs, New Mexico, have provided sufficient data to identify the Dewey Lake Formation, Rustler Formation, and Yates Formation from the upper portion of this group. Geologic literature describes these Permian sediments to be gently dipping to the east. This fact was confirmed by using oil well log data to construct a graphic 3-point solution. These calculations indicate a north-south strike and a dip of less than 1° to the east. Consistent with the reported regional dip for Permian (and Triassic) sediments along the western flank of the Permian Basin.

Dewey Lake Formation - The uppermost Permian sediments underlying the Triassic sequence in the project area correlate to the Dewey Lake 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 are 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 are approximately 500 feet of halite (salt). The Rustler Formation represents the youngest anhydrite sequence in the Permian Basin.

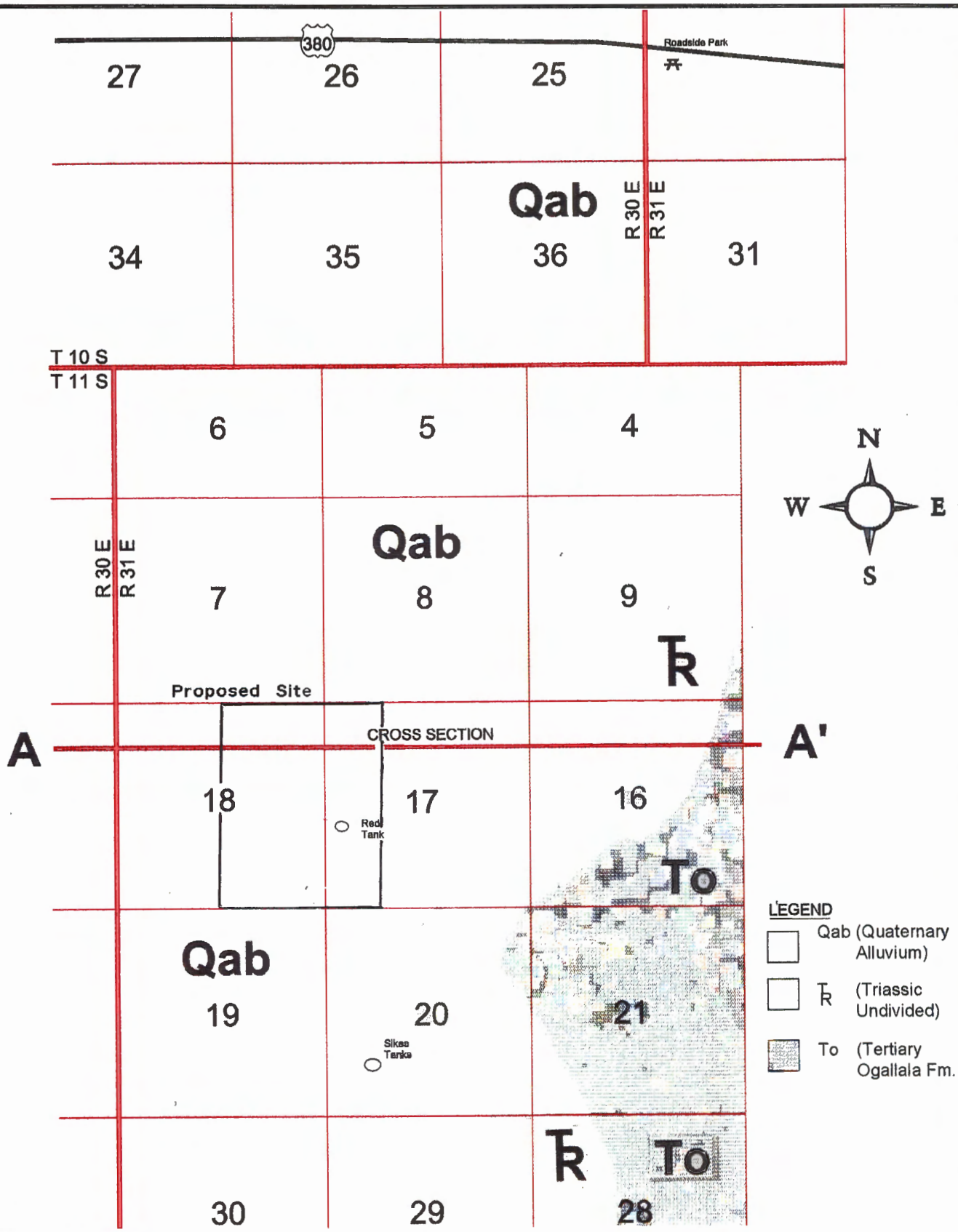
Yates Formation - Unconformably underlying the Rustler, the Yates Formation is composed primarily of interbedded sandstone with minor dolostone and limestone. The sands are light gray and fine to very fine grained. Limestone is white to very light gray microcrystalline lime mudstone with a chalky texture.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

3.2 SITE STRATIGRAPHY

This section will provide detailed descriptions of the proposed Triassic host sediments and the Quaternary alluvium that overlies these sediments Figure 3-4, Surface Geology – Project Area, illustrates the surficial geology on and adjacent to the proposed site. Figure 3-5, Stratigraphic Cross Section, is a stratigraphic cross-section based on site drilling, illustrating relationships between the proposed Triassic host sediments and adjacent formations.

3.2.1 Quaternary

The thickness of Quaternary alluvial deposits at the site varies from less than 10 feet to 35 feet. The upper portion of these sediments consists of fine to very fine, wind-blown yellow-brown sands. Below this sand are varying thicknesses of red-brown to yellow-brown siltstones and silty mudstones. Scattered throughout these sediments are small chert pebbles and granitic cobbles derived from the Tertiary Ogallala Formation.



SURFACE GEOLOGY - PROJECT AREA

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 3-4

A caliche zone (Mescalero Caliche) is present in most of this unit. The caliche is found immediately under the top, wind-blown sands and coats and fills fractures within the more consolidated siltstones. Where the Quaternary alluvium is quite thin, this caliche is found coating Triassic sediments.

3.2.2 Triassic

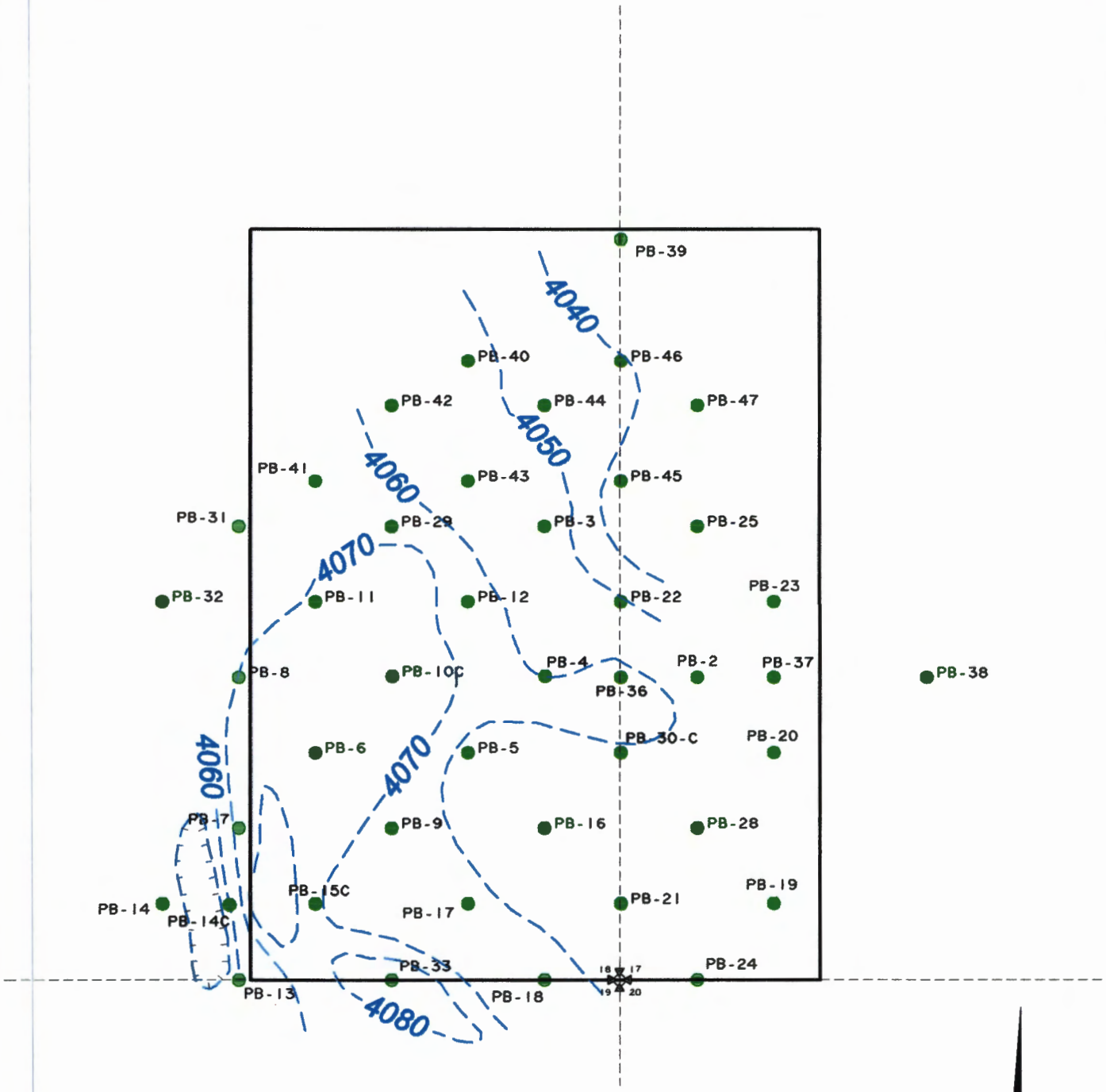
Drilling at the site has delineated 1,175 feet of Dockum sediments. Two distinct units can be identified in these sediments: the Upper Dockum (475 feet thick) and the Lower Dockum (700 feet thick). Within the proposed Facility boundary the thickness of the Upper Dockum unit never exceeds 100 feet. Upper Dockum sediments are in contact with the overlying Quaternary alluvium throughout the project area.

Upper Dockum - This unit consists of variegated (red-brown-green) mudstones interbedded with reddish gray siltstones and reddish-gray-green sandy siltstones. The siltstones are micaceous (predominantly muscovite), indicating they were part of a relatively active fluvial system capable of transporting material into the basin from distant source rocks. From examination of lithology and down-hole electric logs, it is estimated that 30 percent of the unit is comprised of mudstones. Lithologies of the remainder of the unit are evenly divided between siltstones and sandy siltstones. However, as the geotechnical properties of these two lithologies are very similar, this geologic discussion will simply refer to them both as siltstone. Mudstones were found to have an average permeability of ~~2.45~~ 2.5 x 10^{-7} cm/s, and the siltstones average ~~1.22~~ 1.2 x 10^{-5} cm/s.

These sediments were deposited in a fluvial environment. Mudstone and siltstone bodies are very lenticular and are found to pinch out abruptly. Accordingly, individual lithologies are not correlatable over significant distances (thousands of feet). The fluvial nature of the Upper Dockum Unit has led to the scouring of channels into the underlying Lower Dockum Unit. This scouring and the pinching-out of fluvial sediments have resulted in the local development of an undulatory surface on top of the Lower Dockum Unit (Figure 3-6, Structure Contour - Top of Lower Dockum).

Lower Dockum - The Lower Dockum Unit has a completely different character from the upper unit. The lower unit represents a time of relatively quiet lacustrine deposition, which resulted in the accumulation of thick sequences of predominantly mudstones interbedded with thin siltstones. These sediments are very homogeneous, in contrast with the abrupt facies changes present in the more active Upper Dockum depositional system.

Most of the close-spaced drilling within the proposed Facility boundary "bottomed" in Lower Dockum mudstones. These mudstones were consistently a moderate reddish brown color, which according to McGowen (1979), is associated with low stand lacustrine and mud flat deposition. Two deep holes (WW-1 and WW-2) were drilled adjacent to the proposed site to examine the total extent of the Lower Dockum mudstones. Results of this drilling, along with the examination of several oil well logs, demonstrated a consistent thickness of 600-650 feet of these sediments. Representative core samples of this material were sent for permeability analyses. The results of these analyses confirm the Lower Dockum to have a very low permeability (average permeability of 5.7 × 10^{-8} cm/s), capable of performing as a geologic barrier to downward migration of fluids from the proposed facilities.



LEGEND

PROPOSED SITE BOUNDARY

-4080- STRUCTURAL CONTOURS

PB-13 BOREHOLES

N

SCALE

0 1000' 2000'

Feet

STRUCTURE CONTOUR TOP OF LOWER DOCKUM

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 3-6

AutoCAD FILE: GAND-3-6.DWG

Underlying the thick sequence of mudstones, there is a basal sand unit in the Lower Dockum below the site. As illustrated in Figure 3-3, this sand unit is roughly equivalent to the Santa Rosa Formation. However, the major accumulation of Santa Rosa Sands that fills the northern portion of the Triassic paleobasin pinches out before reaching the Facility site. During the Lower Dockum time, the Facility site was part of a low-relief area with little fluvial deposition. The McGowen report specifies sand percentages of the Lower Dockum group in the Facility site area to be in the 10-20% range.

3.3 STRUCTURAL SETTING

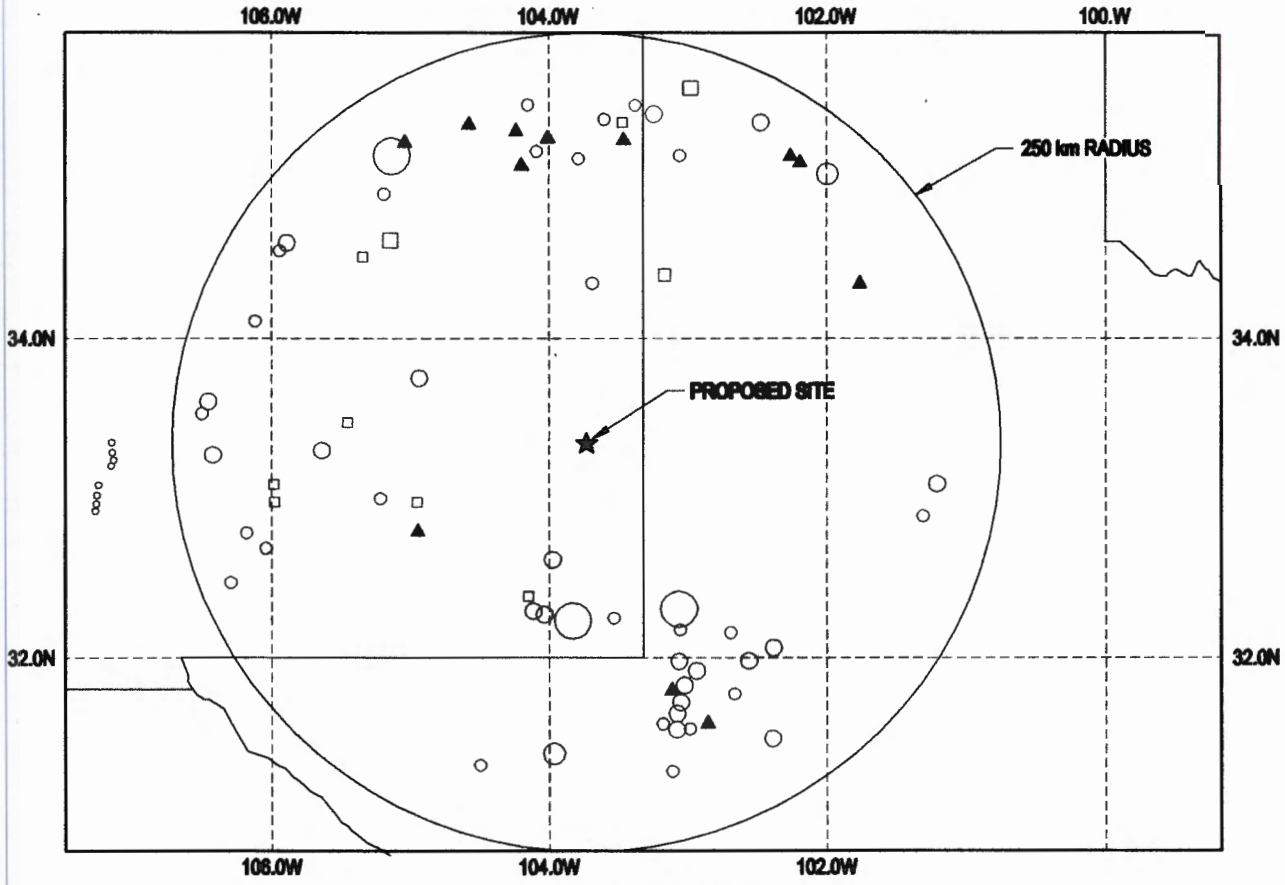
The proposed Facility site is located on the western flank of the Permian Basin of west Texas. Because of the distance from tectonic centers and the minimal seismic activity, this is considered one of the more geologically stable regions within the United States. Data obtained from the National Geophysical Data Center of NOAA indicate a total of 102 observed earthquakes within a 250-km (155-mile) radius of the proposed site. These data reflect observations made from 1930 to 1993.

As shown in Figure 3-7, there were no recorded earthquakes with a magnitude greater than 3.9 within 70 miles of the proposed site and no recorded seismic activity within a radius of 45 miles. The distance from any tectonic centers and the low-recorded seismic activity suggest that the proposed site is located in an extremely stable environment where activity is not expected. Consequently, little damage from earthquake activity is anticipated.

There are no identified faults within the project area. As previously discussed, the proposed site is located in a geologically stable area. There are no mapped faults on or adjacent to the project area. Color air photos of the area were examined for surface lineations, which can reflect faulting in the subsurface. All surface lineations observed on these photos were attributed to man-made features (i.e., fences, roads, etc.).

Subsurface drilling did not encounter displacement or repeating of geologic sequences that would be indicative of faulting. In the Upper Dockum Unit, there are abrupt changes in lithologies, but these are attributed to depositional processes associated with an active fluvial system. Due to the stable structural setting and the plasticity exhibited in Lower Dockum mudstones, the development of secondary permeabilities within this unit is not expected.

SEISMICITY WITHIN 250 KM OF 33.367N 103.850W



102 EARTHQUAKES PLOTTED

MAGNITUDES

0.1-1.9 =	○	4.0-4.4 =	○
2.0-2.9 =	○	4.5-4.9 =	○
3.0-3.4 =	○	5.0-5.4 =	○
3.5-3.9 =	○	> 5.4 =	○

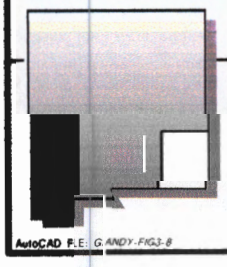
NO INTENSITY OR MAGNITUDE ▲

INTENSITIES

I-III	▫	VII	□
IV	▫	VIII	□
V	▫	IX	□
VI	□	X-XII	□

National Geophysical Data Center/NOAA Boulder, Colorado 80303

N



SEISMIC ACTIVITY MAP

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 3-7

AutoCAD F.E. G:ANDY-FIG3-8

4.0 HYDROLOGY

4.1 SURFACE WATER

There are no perennial stream drainages on or near the proposed site. The nearest surface drainage is the Pecos River, approximately 30 miles to the west.

There is one small stock tank (Red Tank) within the proposed Facility boundary and several additional tanks on adjacent lands. These tanks are approximately 200 feet by 200 feet and contain water for livestock. The tanks are clay-lined and retain water from run-off or receive water from an underground pipeline. Water in the underground pipeline is supplied from three water wells on the Marley Ranch located in Section 10, T11S, R31E. These wells are east of the Mescalero Rim and produce water from the Ogallala Formation. In the past, water from the springs along the Caprock excarpment was used in this pipeline, but now water is pumped from the Ogallala Formation. The pipeline is personally owned and maintained by the Marley Ranch to provide water to cattle operations below the Caprock.

It was observed in the 1999 drilling that "pooled" surface waters have the potential of migrating through the surface alluvial sediments. Once the site is designated as a disposal area, cattle operations on this property will cease and the Marley Ranch will stop using Red Tank. They will also re-route their personal pipeline, as appropriate, to avoid waste disposal facility operations and continue to supply water to their cattle operations below the Caprock. It should be noted that pits that could pool surface water over the alluvium will ~~would~~ be backfilled and graded to drain as part of the initial construction activities prior to operations.

4.2 GROUNDWATER

This section describes regional and local aquifers.

4.2.1 Regional Aquifers

In the region surrounding the proposed site, there are two geologic units that have produced groundwater, the Triassic and the Tertiary Ogallala Formation. Very minor amounts of groundwater have been produced from Triassic sediments; but the Tertiary Ogallala Formation is a major aquifer in southeastern New Mexico, west Texas, and several other western states.

4.2.1.1 Ogallala Aquifer

The Ogallala Aquifer is the primary freshwater aquifer within the regional study area and serves as the principal source of groundwater in the Southern High Plains. The saturated thickness of the Ogallala Aquifer ranges from a few feet to approximately 300 feet in the Southern High Plains. Groundwater within the Ogallala Aquifer is typically under water table conditions, with a regional hydraulic gradient toward the southeast ranging from approximately 10 feet/mile to 15 feet/mile. The average hydraulic conductivity of the Ogallala Aquifer ranges from 1 foot/day to 27 feet/day.

The Ogallala Aquifer is recharged primarily through the infiltration of precipitation. The rate of recharge is believed to be less than 1 inch/year. Groundwater discharge from the Ogallala Aquifer occurs naturally through springs, underflow, evaporation, and transpiration, but

groundwater is also removed artificially through pumpage and catchment. Currently, the rate of withdrawal exceeds the rate of recharge for much of the Ogallala Aquifer.

4.2.1.2 Lower Dockum Aquifer

The major aquifer within the Lower Dockum is the Santa Rosa Sandstone. This sandstone is present along the northern and southern flanks of the Permian Basin and is a principal source of groundwater in Roosevelt and Curry Counties, New Mexico. The Santa Rosa Sandstone is not mapped along the western flank of the Permian Basin, which includes the proposed site. Where the Santa Rosa Aquifer has been studied, hydrochemical analyses and groundwater oxygen isotopes indicate that it is distinctly different from the Ogallala Aquifer. The thick, impermeable clays within the Triassic section have been sufficiently impermeable to prevent hydraulic communication between these aquifers.

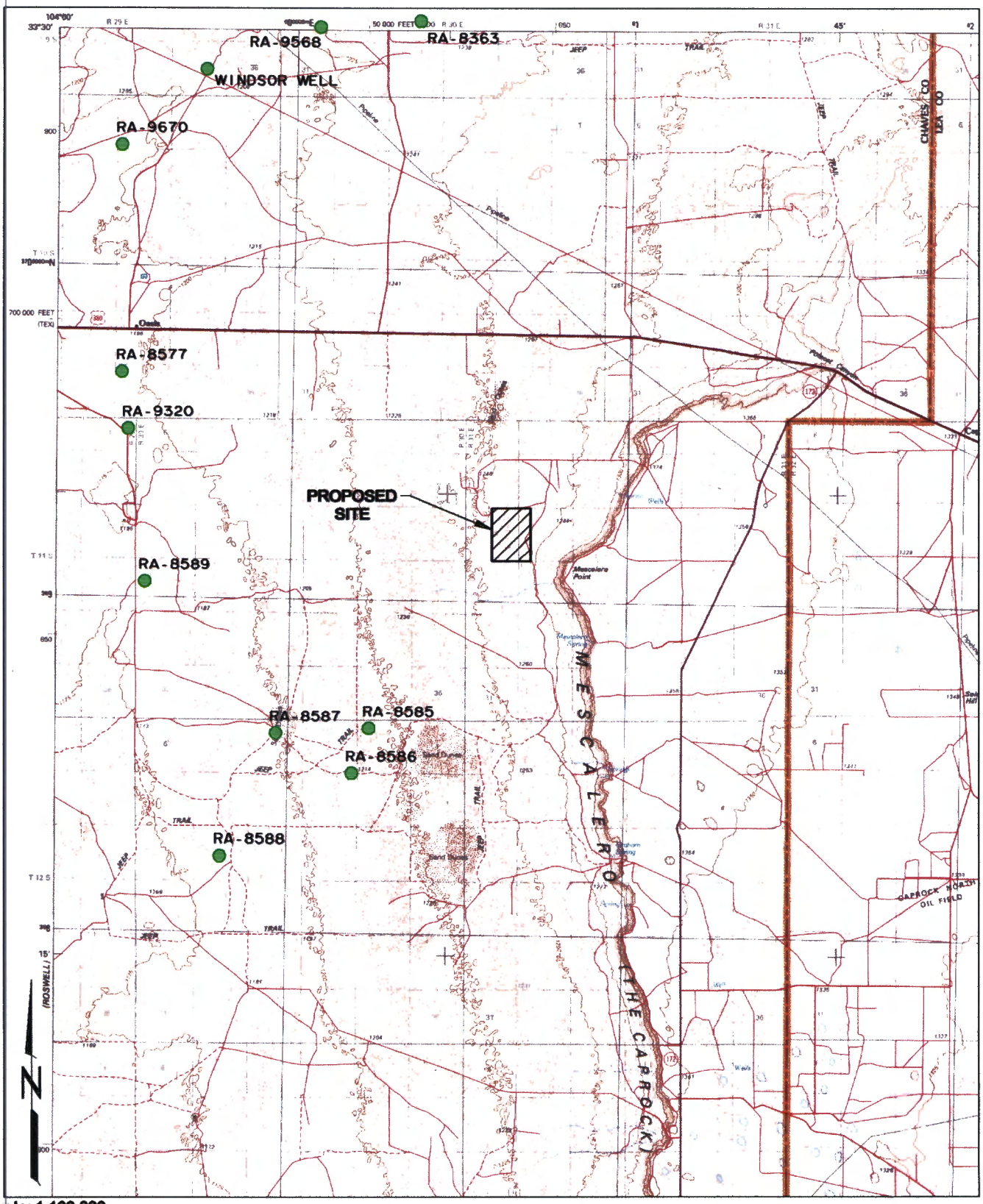
Figure 4-1 is a map of ten water wells developed in Triassic sediments within a 10-mile radius of the proposed site. This information was obtained from the New Mexico State Engineer's office and represents the results of a records search of six townships surrounding the proposed site (T11S - T13S, R29E & R30E). Six of these wells are shallow completions (100 feet or less) from the 1910's and 1940's and are used with windmills to supply water to livestock and wildlife. The numbers of these wells are RA-8585 through RA-8589 and RA-8363. These are included as wells penetrating Triassic sediments because of their surface locations. However, due to their shallow depths, the source of water could be from surface alluvial sediments.

The four other wells range in depth from 560 to 640 feet and have been completed within the past seven years. These wells would have penetrated the Lower Dockum sediments (including the Santa Rosa Sandstone equivalent). Following is a description of these wells:

- RA-8577 was drilled to a depth of 614 feet in 1992. It's initial production was 4 gallons per minute.
- RA-9320 was drilled in 1996 to a depth of 560. The estimated yield was 6 gallons per minute, however, the water was determined to be not potable. The well was plugged and abandoned on 11/25/96.
- RA-9568 was drilled to a depth of 640 feet in 1998. It was a dry hole and was plugged and abandoned on 08/14/98.
- RA-9670 was drilled in 1998 to a depth of 587. ~~Its~~ The estimated initial yield was 2 gallons per minute.

4.2.2 Site Groundwater

Potential Triassic host sediments within the proposed Facility boundary are unsaturated. Detailed drilling within this boundary has encountered no groundwater. Drilling outside the proposed Facility boundary has identified saturated zones in both the Upper and Lower Dockum Units. The following subsections contain descriptions of these saturated zones.



Scale: 1:100,000

WATER WELLS - 10 MILE RADIUS

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 4-1

AutoCAD FILE: 10-MIWELLS.DWG

4.2.2.1 Ogallala Aquifer

The western boundary of the Ogallala Aquifer, represented by the Caprock escarpment, is located topographically/stratigraphically above and 2 miles east of the proposed site. At the base of the escarpment, along the contact of the Ogallala Formation and the underlying Upper Dockum, are numerous springs, which are a result of downward-migrating Ogallala groundwater coming into contact with low permeability zones within the Upper Dockum and being diverted to the surface. Because of its stratigraphic and physical location, it is highly unlikely that the proposed disposal facility will have any impact on this aquifer.

4.2.2.2 Lower Dockum - "Uppermost Aquifer"

For the purpose of this application, the uppermost aquifer is considered to be the basal sand unit of the Lower Dockum because the Ogallala Aquifer is not present at the site. The EPA has defined the uppermost aquifer as the geologic formation, group of formations, or part of a formation that is the aquifer nearest to the ground surface capable of yielding a significant amount of groundwater to wells or springs. The Lower Dockum does not currently yield a significant amount of groundwater. However, preliminary drilling in the site area has found the basal portion of this unit to be water-bearing and to possess consistent hydrologic characteristics.

The identification of a confining layer is an essential factor in the identification of the uppermost aquifer. The 600 to 650 feet of Lower Dockum mudstones, which overly the basal sand unit, represents a high-integrity aquitard, effectively confining the aquifer. This thick sequence of mudstones is of sufficient low permeability to prevent hydraulic communication between the Upper and Lower Dockum Units.

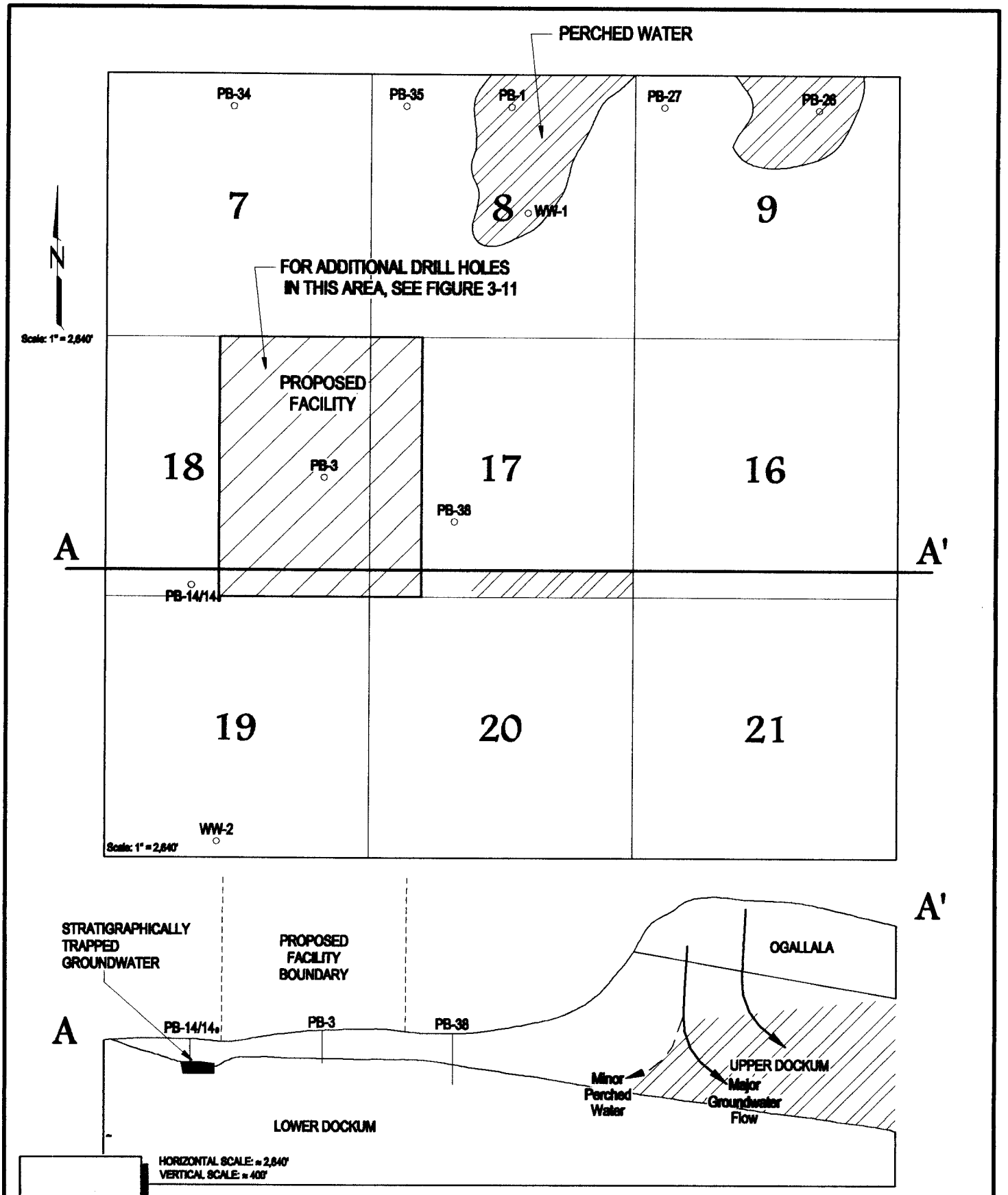
The basal sandstone of the Lower Dockum Unit is the water-bearing portion of this unit. The recharge area for the Lower Dockum Aquifer is the Pecos River drainage to the west. Groundwater flow direction is easterly, along the regional dip of this unit.

Most of the shallow drilling in the site area has "bottomed" in the upper portion of the aquitard. Two holes (WW-1 and WW-2) were drilled to approximately the base of the Triassic section and encountered water from the Lower Dockum Aquifer (Figure 4-2, Upper Dockum - Perched Water).

Hole WW-1 also penetrated a saturated zone in the Upper Dockum Unit, resulting in a mixing of these groundwaters in this drill hole.

Both holes were drilled with an air rotary rig and drill-cutting samples were collected. WW-1 was completed to a depth of 820 feet and, at the time of drilling, no water saturation was apparent in the drill cuttings. WW-2 was completed to a depth of 710 feet; however, circulation was lost at a depth of 645 feet. Loss of circulation commonly occurs when drill cuttings are too wet for the air pressure of the rig to remove the cuttings from the hole. It is likely that the basal sandstone of the Lower Dockum Unit was penetrated at this depth.

Water Level Measurements - Temporary plastic casing was placed in each of the two holes immediately after completion. In July 1994, geophysical logs were run for each hole, and water levels were identified. WW-1 had a water level of 155 feet. This level is 20 feet above the



UPPER DOCKUM - PERCHED WATER

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure 4-2

AutoCAD FILE: GANDY-FIG3-18

Upper/Lower Dockum contact, and it is likely that groundwaters from both units are present in this drill hole. A water level of 467 feet was observed for WW-2. This finding indicates that there is a hydrostatic head pressure within the Lower Dockum Aquifer of 178 feet.

Both of these cased holes were pumped and allowed to recover. After a sufficient recovery period, a static water level (155 feet for WW-1 and 467 feet for WW-2) was maintained.

Water Quality— Two sources of data have been used to evaluate water quality data for the Lower Dockum, 1) United States Geological Survey (USGS) Multistation Analyses and 2) site-specific analyses.

The USGS works in conjunction with the State of New Mexico to establish sample and analyze ground water from monitor wells throughout the state. A request for data was made to the USGS on water quality information from wells within 12 townships surrounding the proposed site. This request was made for data from wells below the Caprock (Ogallala Aquifer). The search area consisted of T9S through T12S and R29E through R31E.

Data from a total of nine monitoring wells within the search area were received. Of these nine wells, only two could be confirmed as being within Dockum sediments. The depths of these two wells were 258 feet (Beadle well) and 14 feet (Winsor well). The Winsor well is shown on Figure 4-1, while the Beadle well is an additional two miles to the northwest, outside the 10-mile search radius.

The Beadle and Winsor wells, as are many of the USGS monitor wells, are not registered with the State Engineer's office. Any existing water wells drilled in this region prior to the closing of the Roswell Extended Basin in 1993 were not required to file applications.

Ten separate analyses were conducted on samples from these wells. Total results can be reviewed in Appendix A. For this section, to be consistent with results of site specific analyses, only values for Total Dissolved Solids, Magnesium and Sodium are presented.

	Beadle well	Winsor well
Total Dissolved Solids	38,400 mg/L	14,000 mg/L
Sodium	11,000 mg/L	3,200 mg/L
Magnesium	625 mg/L	519 mg/L

Site specific analyses are presented only for WW-2. This drill hole encountered groundwater from the Lower Dockum. Because groundwater from the Upper Dockum and Lower Dockum was mixed in drill hole WW-1, preliminary water quality data from WW-1 do not accurately characterize either aquifer and are not presented. The results from WW-2 include the following:

Total Dissolved Solids	18,800 mg/L
Alkalinity	83 mg/L
Sodium	7,030 mg/L
Magnesium	87 mg/L

The extremely high TDS values are indicative of long formation retention times, which reflects low groundwater flow and low permeability conditions within the Lower Dockum aquifer.

Water with TDS values of greater than ~~5,000~~ 500 mg/L is considered to be unfit for human consumption. These available data, along with the documented abandonment of ~~a well~~ other water wells due to encountering non-potable water within Lower Dockum sediments, indicate that the water quality of this unit is very low.

4.2.2.3 Upper Dockum - Perched Water

Several springs are present where the Ogallala Formation crops out, two miles east of the Facility site, along the 200-foot high Caprock escarpment. None of these springs occur near the proposed facility. These springs are present where the Ogallala sands unconformably overlie impermeable Dockum mudstones and claystones and the groundwater moves laterally to the surface. Where these water-bearing Ogallala sands are in contact with more permeable units of the Upper Dockum, saturation of these underlying sediments may occur. The result is sporadic accumulation of perched water within some Upper Dockum siltstones. As shown in Figure 4-1, three holes to the northeast of the proposed site (PB-1, PB-26 and WW-1) haven encountered this perched water. Due to the great variability in lithologies of the fluvial Upper Dockum sediments and the need for permeable sediments to be in contact with Ogallala source rocks, the occurrence of saturation within these sediments is extremely unpredictable.

It is extremely significant that this saturation does not extend beneath the Facility site. All 40 drill holes within the site boundary, as shown on Figure 1-1, have been unsaturated. For this reason, there were no groundwater production tests conducted.

Exploratory drilling west of the proposed Facility boundary (updip), near the outcrop of the Upper Dockum Unit, the small sandy hills located along the section line between Section 18, T11S, R31E and Section 13, T11S, R30E, encountered an isolated occurrence of groundwater (Figure 4-1). In a single drill hole (PB-14), at a depth of 42 feet, a small accumulation of groundwater was found in a depression developed on the surface of the underlying Lower Dockum mudstones. This depression is consistent with the "scouring" of the Upper Dockum fluvial sediments into the Lower Dockum mudstones. Closer spaced drilling in the vicinity of this occurrence encountered no other such accumulations. This isolated "pooling" is most likely a result of surface run-off entering the subsurface from the nearby outcrop and being caught in a small "stratigraphic trap."

Water Quality - Preliminary water quality data were obtained from limited chemical analyses on a sample of the stratigraphically trapped groundwater from drill hole PB-14. These results include the following measurements:

Total Dissolved Solids	4,920 mg/l
Alkalinity	396 mg/l
Sodium	1,640 mg/l
Magnesium	103 mg/l

Although this represents only one sampling point, these preliminary data suggest that water from the Upper Dockum, has a different geochemical character than does water from the Lower Dockum.

4.3 GENERAL DESCRIPTION

The Facility will be a full-service Resource Conservation and Recovery Act (RCRA) Subtitle C waste treatment, storage, and disposal operation. The Facility will offer the following RCRA-regulated services, which are described in this permit application.

Two treatment processes will be used at the Facility. The first is an evaporation pond for managing wastewater that meet LDR standards and a stabilization process for treating liquids, sludges, and solids to ensure that no free liquids are present. In addition, the stabilization process will ensure that LDR standards are met prior to placing wastes in the landfill. Both treatment units will be clean closed as part of the closure operations.

Two container storage areas (roll-off storage area and drum handling unit) will be used to stage waste at the Facility for treatment or disposal. These units will ensure that waste is stored in compliance with RCRA requirements for permitted storage. Neither of the units will be used for long-term storage of waste and will be clean closed during closure operations.

Four aboveground storage tanks will be utilized to accumulate regulated bulk liquid hazardous wastes prior to stabilization. Both of these units will be clean closed during closure operations.

A landfill will be utilized for final disposal of waste that meets LDR standards. The landfill will be the only unit that will remain after closure and will contain hazardous waste.

Support units and structures include a chemical laboratory, administration building, weigh scale area, maintenance shop, truck wash unit, clay processing area, clay liner material stockpiles, daily cover stockpiles, and a stormwater retention basin.

The facilities that pose the largest threat to release of large volumes of liquids to the subsurface are the evaporation ponds and the landfill. The evaporation ponds will store free liquids during operation of the facility. However, after operations have been completed the ponds will be removed and closed as clean facilities. The landfill is the only disposal facility that will include the permanent disposal of hazardous materials. The landfill will not accept any free liquids and will be covered after closure. However, since hazardous waste will remain in place after closure, it is a potential long-term source of release from the facility. All other facilities will be clean closed as part of the closure operations.

4.4 CONTAINMENT SYSTEMS

Since these two facilities pose the largest threat for release of hazardous material to the surface, we have described the engineered containment systems and leachate collection and removal systems for both facilities. These include the landfill and evaporation ponds.

4.4.1 Landfill

4.4.1.1 Liner Systems for Landfill

The liner system will be installed to cover all surrounding earth that may come in contact with waste or leachate. The primary system will consist of, from top to bottom, a 2-foot layer of protective soil, a geocomposite drainage layer, and a HDPE geomembrane liner. The

secondary system will consist of a geocomposite drainage layer, HDPE geomembrane liner, geosynthetic clay layer (GCL), and 6 inches of prepared subgrade. Both the primary and secondary systems will extend over the floor and slope areas of the landfill.

The primary and secondary geomembrane liners will be constructed of HDPE. This material will have sufficient strength and thickness to prevent failure as a result of pressure gradients, physical contact with waste or leachate, climatic conditions, stress of installation, and stress of daily operations. The liner systems and geosynthetic drainage layers will rest upon a prepared subgrade capable of providing support to the geosynthetics and preventing failure due to settlement, compression, or uplifting.

4.4.1.2 Landfill Leachate Collection and Removal System (LCRS)

The LCRS will be located above the primary liner system. A filtered LCRS layer consisting of a geocomposite drainage material will be constructed. Within the floor area of the LCRS layer will be the primary leachate collection piping, which is used to remove leachate from the landfill during the active life and post-closure care period.

The LCRS is sloped so that any leachate above the primary liner will drain to one of three sumps. The sumps and liquid removal methods will be of sufficient size to collect and remove liquids from the sumps and prevent liquids from backing up into the drainage layer.

The sump will be lined with the same liner system components as elsewhere in the landfill except that the drainage layer will expand to include gravel and a compacted clay liner material beneath the primary and secondary geomembranes which will fill the sump area. Leachate that collects in the sumps will be pumped through a pipe to the surface of the landfill where it will be collected in temporary storage tanks.

4.4.1.3 Landfill Leak Detection and Removal System (LDRS)

The design of the LDRS is similar to the design of the LCRS. The LDRS will be capable of detecting, collecting, and removing leaks of hazardous constituents through areas of the primary liner during the active life and post-closure care period. A filtered LDRS layer consisting of a geocomposite will be constructed below the primary geomembrane. Within the LDRS layer will be the LDRS piping, which will be used to detect and remove liquid from between the primary and secondary liners.

4.4.2 Evaporation Pond

4.4.2.1 Evaporation Pond Liner System

The liner system will include a primary (top) geomembrane liner above a geonet layer and a secondary (bottom) geomembrane liner, supported by 3 feet of compacted clay liner material with a hydraulic conductivity of no more than 1×10^{-7} cm/sec. Soil liner leachate compatibility tests (EPA 9090) will be conducted prior to construction. In addition, a test fill will be constructed, as per the procedures outlined in the CQA Plan.

Design and operating practices, together with the geologic setting of the Facility, will prevent the migration of any hazardous constituent to adjacent subsurface soil, surface water, or

groundwater. The top liner is designed to minimize the migration of hazardous constituents through the liner system during the active life. A 60-mil HDPE geomembrane material will be used for the primary liner component. HDPE liners have been shown to be chemically resistant to landfill leachates based on operational performance and on EPA 9090 compatibility tests conducted on actual landfill leachates and synthetically generated leachates.

4.4.2.2 Leak Detection and Removal System

The LDRS consists of a geonet layer of cross-linked ribbed HDPE, a sump, and associated detection and liquid removal pipes. A pump located in the LDRS pipe will be used to remove leachate accumulating in the leachate collection systems. When leachate accumulates, it will be pumped to a tanker truck and either returned to the evaporation pond, stabilized in the onsite treatment unit, or stored in one of the liquid waste storage tanks.

The LDRS unit will have the following characteristics:

- be constructed with a bottom slope of 1% or more;
- be constructed of synthetic or geonet drainage materials with a minimum transmissivity of 5×10^{-3} m^2/sec;
- be constructed of materials that are chemically resistant to the waste managed in the evaporation pond and any leachate generated in the landfill;
- of sufficient strength and thickness to prevent collapse under pressure exerted by overlying wastes, and equipment used at the evaporation pond;
- designed and operated to minimize clogging during the active life and closure period of the evaporation pond; and,
- constructed with sump and liquid removal methods.

The collection system has been designed to be of sufficient size to collect and remove liquids from the sump and prevent liquid from backing up into the drainage layer. A sump pump and associated piping will be installed in the lower portion of the sump. The sump system will be covered with gravel to bring the area to the level of the evaporation pond floor. The gravel will serve as an expanded drainage layer providing space for the piping. In addition, the sump system will be provided with a method for measuring and recording the volume of liquids present and the volume of liquid removed. All pumpable liquids in the sump will be removed in a timely manner to maintain the head on the bottom liner below 12 inches.

4.5 MONITORING SYSTEMS

4.5.1 General

The monitoring systems proposed for the Triassic Park facility has been developed to provide early detection for any release from the site. In addition, the systems are focused on the facilities that have the largest potential for releases to the subsurface. The monitoring systems include vadose zone sumps in the landfill and the evaporation pond and a series of vadose

zone/perched groundwater monitoring wells that will be installed along the east side of the facility. Each of these systems is described in more detail below.

4.5.2 Vadose Zone Sump

The vadose zone monitoring sump serves as a detection system for leaking in the secondary LDRS system. Located directly beneath the LDRS sump, leakage through the secondary liner system will flow into the vadose sump, allowing it to be detected and removed. The vadose pipe and gravel arrangement is similar to the LCRS and LDRS arrangements.

The evaporation pond vadose monitoring sump serves as a detection system for leakage of the LDRS sump. Leakage through the secondary liner system will flow into the vadose sump. This will allow the leakage to be detected and moved. The vadose pipe and gravel arrangement is similar to the LDRS arrangement.

4.5.3 Vadose Zone/Perched Groundwater Monitoring Holes

In the unlikely event that the release of liquids from any of the facilities is not detected by the leak detection systems or the vadose zone sumps, a series of vadose zone/perched groundwater monitoring wells will be installed along the eastern site boundary. The vadose zone/perched groundwater monitoring wells will be installed at or just below the contact between the Upper and Lower Dockum units. The intent of these wells is to detect any liquids that would be migrating down dip along the contact.

5.0 TECHNICAL JUSTIFICATION

This section presents technical data to support the Gandy Marley request for a Groundwater Monitoring Waiver. This data consists of water balance calculations for the region to establish hydrologic components and the results of contaminant transport modeling.

Gandy Marley recognizes the need for an effective release monitoring system for the protection of human health and the environment. Due to the unique geologic setting of the proposed Triassic Park Disposal Facility, an alternative release monitoring system is recommended. Because of the unsaturated nature of the proposed host rocks, technical data supports the implementation of a vadose zone monitoring system in lieu of traditional groundwater monitoring. For this environment, a vadose zone monitoring system is superior for detecting and characterizing potential releases.

5.1 WATER BALANCE

The purpose of this water balance is to provide a conceptual understanding of the hydrologic components at the site. This water balance analysis estimates groundwater recharge from direct precipitation, surface water bodies, and irrigation at the proposed landfill site. This information is useful for assessing the potential migration of contaminants released at or near the surface to groundwater. Groundwater recharge rate is directly related to the potential for contaminants spilled or leaked at the surface to reach groundwater. In areas with little or no groundwater recharge, there is less potential for groundwater contamination from releases of hazardous substances than in high recharge areas because the mechanisms to transport potential contamination are limited.

A water balance requires quantification of the hydrologic components, which can result in changes in the amount of water stored in the area of interest. Often, water balances are calculated for an entire watershed to understand the relative importance of the hydrologic components within that area. For this analysis, the water balance was performed to estimate groundwater recharge at the proposed landfill site.

Groundwater recharge at the proposed site can be estimated by summing precipitation, infiltration from surface water bodies, and irrigation at the site and subtracting evapotranspiration and surface run-off. As no natural surface water bodies or irrigation occur at the site, groundwater recharge is estimated as the difference between direct precipitation and evapotranspiration. This assumes no surface run-off at the site.

Precipitation data collected at the Roswell weather station indicate that mean annual precipitation is 10.61 inches. This annual mean is used as the average precipitation at the proposed site.

Evapotranspiration refers to the processes that return water to the atmosphere by a combination of direct evaporation and transpiration by plants and animals. It is the largest item in the water budget because most of the precipitation that falls in the area returns almost immediately to the atmosphere without becoming part of the surface water or groundwater systems. On unirrigated rangeland, much of the precipitation that does not evaporate immediately is taken up fairly rapidly by plants and transpired. In a regional water balance

conducted in southeastern New Mexico, it was estimated that approximately 96 percent of total precipitation is lost to evapotranspiration (Hunter, 1985). This number corresponds to data presented for the Rio Grande Basin by Todd (1983), that estimated that 95.4 percent of total precipitation was being lost to evapotranspiration.

Assuming a mean annual precipitation rate of 10.61 inches, of which 96 percent is lost to evapotranspiration, the net recharge to groundwater is estimated as 0.42 inch per year. This low groundwater recharge rate significantly reduces the potential for groundwater contamination from spills or leaks at the proposed Facility.

The amount of groundwater recharge is a reflection of the arid climate of the region. The net recharge estimate of 0.42 inch per year (based on average hydrologic components) represents the expected long-term annual conditions at the site. The relatively low recharge rate appears to be reasonable given the unsaturated conditions of the Upper Dockum within the site boundaries. Using the highest recorded annual precipitation value of 32.92 inches yields only a slightly higher recharge rate of 1.32 inches (assuming an evapotranspiration rate of 0.96). This short-term (1 year) increase in recharge is unlikely to have a significant impact on the unsaturated flow regime at the proposed site.

5.2 CONTAMINANT TRANSPORT MODELING

The geologic and hydrologic characteristics of the Lower Dockum sediments, as described in Sections 3.0 and 4.0, were used to estimate contaminant transport rates to the basal sand unit of the Lower Dockum referred as the Santa Rosa Formation (i.e. the upper most aquifer). Two different assessments of potential contaminant transport rates through the Lower Dockum are presented in this section.

5.2.1 Previous Unsaturated Flow Modeling

Previous unsaturated flow modeling for the site was reported in Stoller (1997). These calculations used a steady-state solution for unsaturated flow as reported in Bumb and McKee (1988). The modeling was based on the following steps.

- Estimate effective saturation using the Bumb and McKee model and HELP model predictions of leakage rates
- Determine unsaturated hydraulic conductivities using the Brooks-Corey model
- Estimate flow rates using Darcy's Law with a unit hydraulic gradient
- Calculate travel times using the interstitial velocity

The results from these calculations indicated that travel times from a hypothetical leak through the Lower Dockum would be on the order of millions of years. A more complete summary of this model analysis is presented in Appendix A. B

5.2.2 Alternative Modeling Approach

Based on feedback provided by the NMED, a more simplistic one-dimensional approach was used to further evaluate potential travel times through the Lower Dockum. Two main criteria were used to develop the alternative approach: 1) to make the calculations as conservative as possible; i.e. to maximize fluid migration and 2) to develop a simplistic approach that is easily verified and understandable.

The approach presented in this section differs from the earlier model in several areas and was developed to be as conservative as possible (i.e. to predict the maximum transport rate and the minimum transport time through the Lower Dockum). Because of the different approach used in the alternative calculations, the results are not directly comparable to those reported in Section 5.2.1. Several important assumptions were changed in the alternative model as shown below in Table 5.1.

Table 5.1
Assumptions Used to Develop Alternative Modeling Approach

Assumption	Alternative Model	Earlier Model	Justification
Flow dimensionality	1-dimensional flow	3-dimensional flow	A one dimensional flow simulation will require less water to reach a given depth and is therefore more conservative although the 3-d approach is more physically correct
Saturated hydraulic conductivity	1×10^{-7} cm/s	5.68×10^{-8} cm/s	The hydraulic conductivity value used in the earlier model was the average value based on core measurements. The value used in the alternative model was obtained by taking the maximum measured value (6.8×10^{-8} cm/s) and rounding up to the next order of magnitude (1×10^{-7} cm/s).
Saturation	Based on the range of possible values	Based on Bumb and McKee model (1988) and HELP model predictions	The earlier model used an exact steady-state solution to estimate saturation. The alternative model used the range of conditions theoretically possible (i.e. zero to complete saturation). Completely saturated conditions are considered highly unlikely given the arid conditions at the site but were used to present a maximum bound on the calculations.
Unsaturated hydraulic conductivity	Brooks-Corey Model	$K(\theta) = K_s (\theta/\theta s)^3$ Where theta is the water content and theta-s is the saturated water content.	The Brooks-Corey is commonly used to estimate unsaturated conductivity and was used in the earlier model predictions. The model used for the alternative model simulations is more simplistic and predicts higher values for unsaturated conductivity. A fully saturated hydraulic conductivity was also used in the alternative model to maximize flow rates although this condition is highly unlikely to occur at the facility. The alternative model, therefore, predicts higher hydraulic conductivities and flow rates.
Hydraulic gradient	Assumed to be unity	Assumed to be unity	This assumption ignores artesian conditions in the Santa Rosa Formation which would result in a lower gradient and is therefore conservative.

The alternative model used Darcy's Law to predict flow rates through the Lower Dockum based on the assumptions shown above. The calculations were conducted for the full range of conditions theoretically possible at the site (i.e. residual saturation to full saturation). It should

be noted, however, that the fully saturated condition is considered highly unlikely due to the arid conditions at the site and the fact that the facility will not accept liquid rates. However, it is presented as a theoretical upper bound to the calculations although it is not physically likely to occur. The following procedures and equations were used during the alternative model calculations.

1. Estimate the water content of the Lower Dockum. Water content was assumed to vary from residual saturation (assumed value of 0.1) to full saturation (assumed value of 0.3). Three calculations were used to characterize the full range of conditions (water contents of 0.1, 0.2 and 0.3) although fully saturated conditions are considered highly unlikely.

2. Calculate unsaturated hydraulic conductivity using Equation 1. A simplified equation similar to the Brooks-Corey model was used. (Note: the simplified model is conservative and calculates higher conductivity values for unsaturated flow than Brooks-Corey).

$$K(\theta) = K_s \left(\frac{\theta}{\theta_s} \right)^3 \qquad \text{(Equation 1)}$$

Where theta is the water content and theta-s is the saturated water content (porosity).

3. Calculate the darcy flux and the interstitial velocity. The darcy flux was obtained by multiplying the hydraulic conductivity by the gradient (assumed to be unity) and the interstitial velocity was determined by dividing the darcy flux by the water content as shown in Equation 2.

$$v = \frac{q}{\theta} = \frac{K_s(\theta)}{\theta} \frac{\partial h}{\partial l} \qquad \text{(Equation 2)}$$

Where v is the interstitial velocity, q is the darcy flux, K(θ) is the unsaturated hydraulic conductivity and dh/dl is the hydraulic gradient (assumed to be one).

4. Calculate the travel time through the Lower Dockum using the calculated velocity and assuming a total thickness of 600 feet.

The results from these simulations are shown below in Table 5.2.

TABLE 5.2
SIMULATION RESULTS

Water Content	Travel time (years)
0.1	15,646
0.2	3911
0.3	1738

5.2.3 Discussion of Modeling Results

Two different approaches have been presented for evaluating the potential for releases from the landfill to impact groundwater. Both of these evaluations have concluded that it would require an extremely long time for potential leaks to reach groundwater (on the order of thousands to

millions of years). Extremely conservative assumptions were used in the most recent evaluation of transport time to groundwater and these assumptions are not likely to occur during the lifetime of the facility or the extended future (greater than 1,000 years). The factors contributing to the long periods of time required for potential releases from the facility to reach the Santa Rosa Formation include the low permeability of the Lower Dockum, the thickness of the unit (600 feet) and arid conditions at the site. These conditions combine to make the Gandy Marley facility an ideal location for the proposed landfill activities.

5.3 VADOSE ZONE MONITORING SYSTEM

Due to the extremely long travel times in the Lower Dockum, groundwater monitoring data from the Santa Rosa formation will not provide meaningful information concerning potential releases from the proposed facility. It is therefore recommended that a Vadose Zone Monitoring System (VZMS) be used to detect potential releases from the facility. The VZMS will provide the most effective method for detecting potential releases from the facility in a timely manner. Before potential contaminants can reach the uppermost aquifer, these systems can detect leaks and help to initiate corrective actions for preventing impacts to the environment.

6.0 SUMMARY AND CONCLUSIONS

Site drilling has established the basal sand of the Lower Dockum (Santa Rosa Sandstone equivalent) to be the uppermost aquifer for the proposed Triassic Park Disposal Facility. Within a four-mile radius of the Facility, there is no water currently being produced from this unit. Water quality from this aquifer is considered to be poor, with water analyses at the site showing Total Dissolved Solids to be 18,800 mg/l.

Overlying this aquifer are 600-650 feet of unsaturated, low-permeability mudstones. Analyses of site core samples indicate that the average permeability of these mudstones are 5.7×10^{-8} cm/s. The base of the hazardous waste landfill is designed to rest on the top of this thick mudstone sequence. The low-permeability mudstone provides over 600 feet of excellent protection against potential transport of leakage from the facility to groundwater. The combination of the thick mudstone sequence and the lack of potable water resources make the proposed facility an excellent location for the safe disposal of hazardous waste. Conservative unsaturated transport modeling indicate that it would take thousands to millions of years for contaminants to travel from the base of the landfill to this aquifer.

The Gandy Marley Corporation considers the monitoring of the Lower Dockum aquifer not to be protective of human health and the environment and requests a waiver from these monitoring requirements for the following reasons:

- A VZMS will be implemented to detect potential leaks more effectively and in a more timely manner than monitoring wells installed in the Lower Dockum Formation
- The thick sequence (600-650 feet) of unsaturated, low permeability Lower Dockum mudstones provide an excellent geologic barrier to the downward migration of contaminants.
- The installation of monitoring wells in the Lower Dockum aquifer would potentially violate the integrity of geologic barrier provided by the thick sequence of mudstones and possibly create an avenue for contaminant migration.
- The Lower Dockum aquifer has artesian characteristics as demonstrated through a site specific investigation.
- A commitment exists from Gandy Marley to construct hazardous waste management units (HWMU) with leachate and release monitoring and retrieval systems.

This groundwater monitoring wavier has been prepared by qualified individuals and the proper certification will be included in the final waiver.

APPENDIX A
WATER QUALITY DATA

UNITED STATES DEPARTMENT OF INTERIOR – GEOLOG MULTIPLE STATION ANALYSES			
Local Identifier	**Station Number**	**Date**	**Time**
09S.29E.22. Bozart Well	333132103574701	07/15/40	--09S.29E.22.
09S.29E.22. Jess Beadle	333133103574801	06/19/40	--09S.29E.22.
09S.29E.35. Winsor Well	332857103564501	07/15/40	--09S.29E.35.
09S.29E.36. J Beadle WL	332857103554301	03/11/40	--09S.29E.36.
09S.30E.36. J Beadle	332858103554401	07/13/38	--09S.30E.36 J
09S.31E.26. Camino Well	333014103442201	08/13/82	1415 09S.31E.26.
09S.31E.26.440	333000103442401	05/25/70	1400 09S.31E.26.4
12S.30E.07. Culp Ranch	331705103574801	08/13/82	1015 12S.30E.07.
12S.30E.31. Culp Ranch Well	331803103542101	08/46/82	1210 12S.30E.31.C

UNITED STATES DEPARTMENT OF INTERIOR – GEOLOG MULTIPLE STATION ANALYSES						
Local Identifier	**Date**	**Site**	**Geological Unit**	**Tempera ture Water (Deg C) (00010)**	**Agency Collecting Sample (Code Number) (00027)**	**Agency Analyzing Sample (Code Number) (00028)**
09S.29E.22. Bozart	07/15/40	GW	--	--	1028	1028
09S.29E.22. Jess B	06/19/40	GW	231DCKM	--	1028	1028
09S.29E.35 Winsor	07/15/40	GW	231DCKM	--	1028	1028
09S.29E.36. J Beadle	03/11/40	GW	--	--	1028	1028
09S.30E.36. J Beadle	07/13/38	GW	--	--	1028	1028
09S.31E.26. Camino	08/13/82	GW	--	19.0	80020	80020
09S.31E.26.440	05/25/70	GW	231SNRS	--	--	--
12S.30E.07. Culp Ranch	08/13/82	GW	--	20.0	80020	80020
12S.30E.31. Culp Ranch Well	08/13/82	GW	--	18.5	80020	80020

UNITED STATES DEPARTMENT OF INTERIOR – GEOLOG MULTIPLE STATION ANALYSES						
Local Identifier	**Date**	**PH Water Whole Lab (Standard Units) (00403)**	**Carbon Dioxide Dissolved (MG/L as CO2) (00405)**	**ANC Water Unfltrd Fet Field MG/L as CACO3 (00410)**	**ANC Water Unfltrd Fet Field MG/L as HCO3 (00440)**	**ANC Unfltrd Carb. Fet Field MG/L as CO3 (00445)**
09S.29E.22. Bozart	07/15/40	--	--	--	880	28
09S.29E.22. Jess Beadle	06/19/40	--	--	--	160	0
09S.29E.35 Winsor	07/15/40	--	--	--	220	0
09S.29E.36. J Beadle	03/11/40	--	--	--	300	27
09S.30E.36 J Beadle	07/13/38	--	--	--	370	104
09S.31E.26. Camino	08/13/82	8.5	5.7	--	--	--
09S.31E.26.440	05/25/70	--	2.3	189	230	0
12S.30E.07. Culp Ranch	08/13/82	8.1	12	--	--	--
12S.30E.31. Culp Ranch Well	08/13/82	8.3	8.6	--	--	--

UNITED STATES DEPARTMENT OF INTERIOR – GEOLOG MULTIPLE STATION ANALYSES						
Local Identifier	Date	Calcium Dissolved (MG/L as CA (00915)	Magnesium Dissolved (MG/L as MG) (00925)	Sodium Dissolved (MG/L as NA) (00930)	Sodium Adsorption Ratio (00931)	Sodium Percent
09S.29E.22. Bozart	07/15/40	61	145	--	--	--
09S.29E.22. Jess Beadle	0619/40	1500	625	--	--	--
09S.29E.35. Winsor	07/15/40	480	519	--	--	--
09S.29E.36. J Beadle	03/11/40	360	808	--	--	--
09S.30E.36. J Beadle	07/13/38	200	840	--	--	--
09S.31E.26. Camino	08/13/82	23	5.9	140	7	78
09S.31E.26.440	05/25/70	23	5.5	--	7	--
12S.30E.07. Culp Ranch	08/13/82	77	28	120	3	46
12S.30E.31. Culp Ranch Well	08/13/82	50	8.9	13	.5	15

UNITED STATES DEPARTMENT OF INTERIOR – GEOLOG MULTIPLE STATION ANALYSES						
Local Identifier	Date	Sulfate Dissolved (MG/L as SO4) (00945)	Fluoride Dissolved (MG/L as F) (00950)	Silica Dissolved MG/L as SI02) (00955))	Arsenic Dissolved (UG/L as AS) (01000)	Barium Dissolved (UG/L as BA) (01005)
09S.29E.22. Bozart	07/15/40	2400	--	--	--	--
09S.29E.22. Jess Beadle	0619/40	3600	--	--	--	--
09S.29E.35. Winsor	07/15/40	7400	--	--	--	--
09S.29E.36. J Beadle	03/11/40	11000	--	--	--	--
09S.30E.36. J Beadle	07/13/38	17000	--	--	--	--
09S.31E.26. Camino	08/13/82	110	.90	18	6	24
09S.31E.26.440	05/25/70	110	1.1	18	--	--
12S.30E.07. Culp Ranch	08/13/82	200	1.3	28	2	67
12S.30E.31. Culp Ranch Well	08/13/82	26	.30	31	5	140

UNITED STATES DEPARTMENT OF INTERIOR – GEOLOG MULIPLE STATION ANALYSES						
Local Identifier	Date	Iron Dissolved (UG/L as FE) (01046)	Lead Dissolved (UG/L as PB) (01049)	Manganese Dissolved (UG/L as AG) (01075)	Silver Dissolved (UG/L as AG) (01075)	Zinc Dissolved (UG/L as ZN) (01090)
09S.29E.22. Bozart	07/15/40	--	--	--	--	--
09S.29E.22. Jess Beadle	0619/40	--	--	--	--	--
09S.29E.35. Winsor	07/15/40	--	--	--	--	--
09S.29E.36. J Beadle	03/11/40	--	--	--	--	--
09S.30E.36. J Beadle	07/13/38	--	--	--	--	--
09S.31E.26. Camino	08/13/82	7.0	<1.0	1.0	<1.0	13
09S.31E.26.440	05/25/70	.0	--	--	--	--
12S.30E.07. Culp Ranch	08/13/82	8.0	<1.0	9.0	<1.0	240
12S.30E.31. Culp Ranch Well	08/13/82	19	<1.0	3.0	<1.0	150

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOG MULTIPLE STATION ANALYSES						
Local Identifier	Date	Nitrogen Nitrate Dissolved (MG/L as N03) (71581)	Mercury Dissolved (UG/L as HG) (71890)	Elev. Of Land Surface Datum (Ft. Above NGVD) (72000)	Depth of Hole Total (Feet) (72001)	Depth Below Land Surface (Water Level) (Feet 72019)
09S.29E.22. Bozart	07/15/40	--	--	--	50	--
09S.29E.22. Jess Beadle	0619/40	--	--	--	258	--
09S.29E.35. Winsor	07/15/40	--	--	--	14	--
09S.29E.36. J Beadle	03/11/40	--	--	--	--	--
09S.30E.36. J Beadle	07/13/38	--	--	--	12	--
09S.31E.26. Camino	08/13/82	--	<.1	--	--	--
09S.31E.26.440	05/25/70	.00	--	--	271	115.00
12S.30E.07. Culp Ranch	08/13/82	--	<.1	3860	--	--
12S.30E.31. Culp Ranch Well	08/13/82	--	<.1	3970	--	--

APPENDIX B
PREVIOUS UNSATURATED FLOW MODELING RESULTS

B-1 Unsaturated Flow Modeling

Unsaturated flow modeling was performed to simulate potential leakage or infiltration from the proposed hazardous waste facilities. Site characterization data indicate unsaturated conditions in the strata underlying the proposed facilities. The unsaturated flow model developed by McKee and Bumb (1988) predicts the extent of wetting fronts emanating from leakage sources on the base of the landfill. Leakage rates were based on preliminary HELP (Hydrologic Evaluation of Landfill Performance) modeling results presented in Tables A-1, Triassic Park HELP Model Results Summary for Cell Floor and A-2, Triassic Park HELP Model Results Summary for Cell Slope. The modeling results help illustrate how the natural hydrological conditions at the site inhibit subsurface fluid flow. [Note: These HELP modeling results should not be confused with those presented in the engineering report in Volumes III and VI, which support the current landfill design.] The following simulation was performed to account for the heterogeneities at the site. The simulation predicts the soil moisture distribution in the Lower Dockum from leakage sources at the base of the landfill. The predicted wetting fronts led to the estimation of unsaturated hydraulic conductivities, darcy flux rates, interstitial water velocities and approximate contaminant travel times to the nearest aquifers. The primary modeling objectives include the following:

- prediction of the effective saturation distribution (wetting front) emanating from the landfill source; and,
- determination of the unsaturated hydraulic conductivity and advective transport rates.

TABLE B-1
TRIASSIC PARK HELP MODEL RESULT SUMMARY FOR CELL FLOOR

Time (years)	LCRS Operational Beyond 30 Years Post Closure			LCRS Not Operational Beyond 30 Years Post Closure		
	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)
0	1.3781	NA	0.1410	1.3781	NA	0.1410
20	0.9400	0.0454	0.1222	.9400	0.0454	0.1222
30	0.2735	0.0430	0.1181	0.2735	0.0430	0.1181
50	0.1927	0.0450	0.1125	3.4579	0.0450	0.1125
70	0.1329	0.0450	0.1087	8.0071	0.0450	0.1098
90	0.1007	0.0439	0.1059	9.1465	0.0439	0.1083
100	0.0775	0.0442	0.1049	8.5811	0.0442	0.1076
120	0.0744	0.0453	0.1029	8.8612	0.0453	0.1062
140	0.0629	0.0461	0.1013	8.6989	0.0461	0.1048
160	0.0547	0.0442	0.0999	8.5494	0.0442	0.1034
180	0.0482	0.0442	0.0987	8.4178	0.0442	0.1021
200	0.0431	0.0431	0.0976	8.2818	0.0442	0.1008

NA - Not Applicable
LCRS= Leakage collection and recovery system

TABLE B-2
TRIASSIC PARK HELP MODEL RESULT SUMMARY FOR CELL SLOPE[1]

Time (years)	LCRS Operational Beyond 30 Years Post Closure			LCRS Not Operational Beyond 30 Years Post Closure		
	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)
0	173.0000	NA	0.1410	173.0000	NA	0.1414
20	123.0000	0.0453	0.1221	123.0000	0.0453	0.1223
30	53.5373	0.0442	0.1182	53.5373	0.0442	0.1182
50	37.0011	0.0453	0.1152	37.0282	0.0453	0.1152
70	24.5001	0.0461	0.1087	24.5114	0.0452	0.1087
90	18.0529	0.0442	0.1059	18.0583	0.0449	0.1059
100	13.6143	0.0425	0.1049	13.6174	0.0430	0.1049
120	12.9000	0.0443	0.1029	12.9032	0.0450	0.1029
140	10.7627	0.0439	0.1013	10.7642	0.0450	0.1013
160	9.2002	0.0457	0.0999	9.2030	0.0439	0.0999
180	8.0161	0.0462	0.0987	8.0178	0.0457	0.0987
200	7.0994	0.0461	0.0976	7.1002	0.0462	0.0976

Notes: [1]Initial HELP Modeling Results were based on landfill liner system without double liner system on side slopes. These should not be confused with HELP results presented in the Engineering Report.
NA - Not Applicable
LCRS = Leakage collection and recovery system.

B-2 Modeling Methodology

Unsaturated flow modeling was performed using the exact steady state solution developed by McKee and Bumb (1988) and Bump and McKee et al. (1988). The steady state solution derived from the Richards equation (1931) of unsaturated flow provides more conservative results in lieu of transient based solutions. The McKee and Bumb (1988) and Bumb and McKee et al. (1988) steady state solution for a continuous point source in an infinite isotropic medium is governed by the following equations.

$$\Delta\eta_{\infty} = \frac{Q^{\exp\left[\frac{\alpha}{2}\left(z-z'-\sqrt{r^2+(z-z')^2}\right)\right]}}{4\pi\sqrt{r^2+(z-z')^2}} \qquad \text{(EQ. 1)}$$

where

$$r = \sqrt{(x-x')-(y-y')^2} \qquad \text{(EQ. 2)}$$

$\Delta\eta$ = hydraulic potential

$$S = S_r + (S_m - S_r)(\alpha\eta / K_o)^{1/n} \qquad \text{(EQ. 3)}$$

or

$$S_e = (a\eta / K_o)^{1/n} \qquad \text{(EQ. 4)}$$

At the Facility site, the evapotranspiration rate is high with respect to precipitation (Stoller, 1994). According to McKee and Bumb (1988), the soils in semi-arid regions of the western United States are at or below residual saturation (Sr). Therefore, the observed initial moisture contents are probably at or near the residual moisture content. Generally, fluid flow is inhibited at soil moisture contents at or below the residual moisture content. The amount of saturation above the residual moisture content is referred to as the effective saturation. Unsaturated hydraulic conductivity is a function of the effective saturation and is expressed in the following equation (McKee and Bumb, 1988; Bumb and McKee et al., 1988):

$$K(\theta) = K_0 S_e^n \qquad \text{(EQ. 5)}$$

Brooks and Corey (1964) correlated the n exponent with the pore size distribution index α. McKee and Bumb (1988) by confirmation of theoretical derivations by Irmay (1954) suggest an optimal value of 3 for η.

Under steady state conditions flow is driven by the force of gravity as the matric potential approaches unity (Hillel, 1980). Therefore, under steady state conditions the unsaturated hydraulic conductivity is equal to the darcy flux which in turn is multiplied by the unit area to obtain a leakage or discharge rate (Q). The following equations express these relationships:

$$q(\theta) = K(\theta); \qquad \text{(EQ. 6)}$$

$$Q = \frac{q(\theta)}{\mathrm{A}} \qquad \text{(EQ. 7)}$$

The average interstitial water velocity (v) was used to estimate advective transport rates of non-reactive conservative solutes. Approximate travel times to the nearest aquifers can be estimated from the interstitial water velocity using the following expression:

$$v = q / \theta \qquad \text{(EQ. 8)}$$

In summary, modeling assumptions include steady state unsaturated flow in an infinite domain, a continuous leakage source, flow through porous medium, complete saturation of the soil beneath the source, and initial uniform saturation of the medium. The modeling does not account for secondary permeability features such as faults, fractures and macropores.

B-3 Input Parameters

Input parameters and initial boundary conditions were based on observed field conditions, landfill design specification, and preliminary HELP modeling results [Note: These preliminary HELP modeling results were based on a landfill liner design which did not incorporate a double liner system on the side slope areas. These results should not be confused with the HELP modeling results presented in the engineering report in Volume III and VI. The results presented in the engineering report support the currently proposed landfill design which

incorporates a double liner in all areas and does not indicate any leakage from the landfill.] Average hydraulic parameters for the Lower Dockum and landfill design specifications are presented in this section. Input parameters used for the unsaturated flow modeling are presented in Table A-3, Input Parameters for Unsaturated Flow Modeling.

Modeled source coordinates correspond to the basal dimensions of the proposed landfill. Conservative average leakage rates from the preliminary HELP modeling were used as source terms

TABLE B-3
INPUT PARAMETERS FOR UNSATURATED FLOW MODELING

	β	Ko			Q		α	Source Coordinates (m)		
Unit	(m)	(m/day)	Sr	Sm	(m^3/day)	n	1/m	x[1]	y[1]	z[1]
Lower Dockum	0.373	4.90E-05	0.279	1	8.00E-05	3	8.042	0, 33, 66, 99, 132, 165, 193, 231, 264, 297, 330, 363, 396, 429, 462	0	0
Upper Dockum	0.2076	1.05E-02	0.161	1	3.80E-05	3	14.45	5.5, 11, 16.5, 22, 27.5, 33, 38.5, 44, 49.5, 55, 60.5, 66, 71.5, 77	0	24.5, 22.6, 20.72, 18.84, 16.96, 15.07, 13.19, 11.31, 9.42, 7.54, 5.65, 3.77, 1.88, 0
Clay Berm	0.37	8.64E-05	0.126[a]	1	3.80E-05	3	8.108	0, 5.5, 11	0	3.77, 1.88, 0
Quaternary Alluvium	0.0726[a]	8.64E-02	0.0458[a]	1	3.80E-05	3	41.32	0, 5.5, 11	0	3.77, 1.88, 0

Key:

β = bubbling pressure; typical values reported by Bumb and Mckee et al. (1988)
- Ko = saturated hydraulic conductivity; site-specific means values
- Sm = maximum saturation; assumed
- Sr = residual saturation; site-specific mean values
- Q = leakage rate; based on HELP modeling results
- n = curve fitting parameter based on pre size index (Mckee and Bumb, 1988)

α = n/β
- 1 = Typical values reported by Bumb and Mckee et al (1988)
- a = typical values reported by Bumb and Mckee et al. (1988)
- b = assumed values

along the base (8.58 gpd) of the landfill to provide conservative "worst case" estimate of unsaturated flow. The leakage rate for the floor of the landfill was based on HELP modeling simulations between 70 and 200 years. The initial leakage rates for the first 50 years of HELP modeling were excluded from the average because these rates were extremely low and probably not representative of steady state conditions. These simulated leakage rates are based on extreme conditions such as waste moisture content conditions which exceed the field capacity of the waste and a termination of leachate pumping following the 30-year post-closure period.

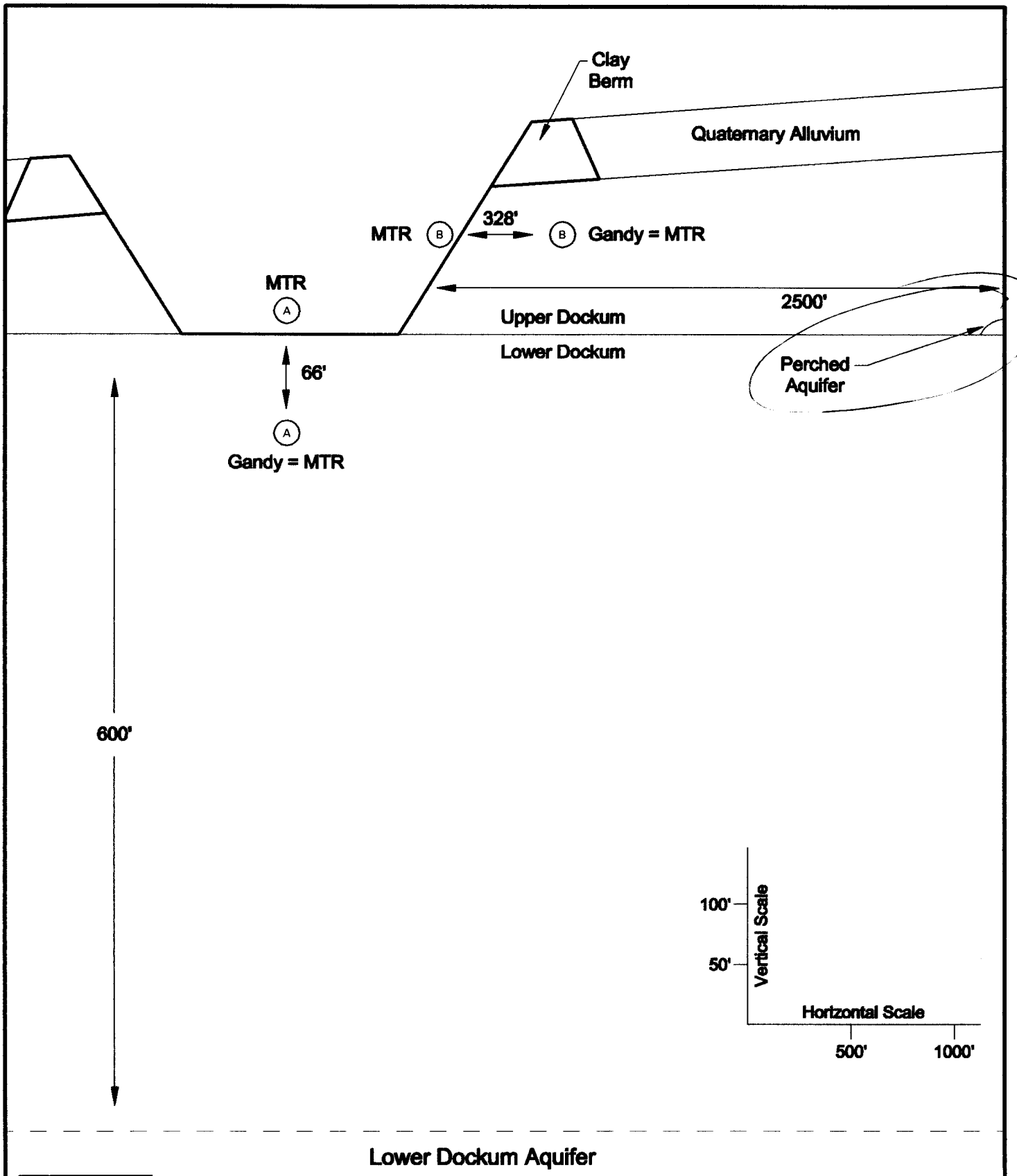
Average site-specific saturated hydraulic conductivity values for the Lower Dockum (5.68×10^{-8} cm/s) were used as initial conditions for the modeling simulations. The effective saturation values for the Lower Dockum simulation was based on site-specific average initial moisture contents (Stoller, 1994). The bubbling pressures for the Lower Dockum simulation was based on average values of similar types of geologic materials reported by Bumb and McKee et al. (1988). Initial boundary conditions are presented in Figure 5-1, which shows a schematic of the proposed landfill and surrounding hydrostratigraphy. As displayed in Figure 5-1, the Lower Dockum Aquifer is approximately 600 feet (200 meters) below the site.

B-4 Modeling Results

The steady state unsaturated flow modeling results are presented in Figures 5-2 through 5-5. The Lower Dockum results are presented as a function of depth from the source. The results of the modeling simulations are in reference to the landfill source.

Figure 5-2 displays the effective saturation at various distances from the source. As the wetting front disperses from the landfill source the chart shows abrupt decreases in saturation. Although the effective saturation dissipates less rapidly in the Lower Dockum, moisture contents decrease by nearly one order of magnitude at approximately 200 meters from the landfill source. The modeling results indicate that the Lower Dockum maintains saturation because fluid movement is driven primarily by gravitational forces; therefore fluid migration is greatest in the vertical direction.

Figures 5-3 and 5-4 display the unsaturated hydraulic conductivity and interstitial water velocity results, respectively. Comparison of these data to the effective saturation distributions (Figure 5-2) show the high degree of correlation between unsaturated flow and soil moisture content. Figures 5-3 and 5-4 show abrupt decreases in unsaturated hydraulic conductivity and interstitial water velocity, respectively, at relatively short distances from the source. Although Figure 5-4 shows that the interstitial water velocities decrease exponentially over distance, gross travel times may be estimated. The simulated interstitial water velocities were used to compute the contaminant travel time for a non-reactive solute from the base of the landfill to the Lower Dockum Aquifer, located approximately 200 meters (600 feet) below the site, as at 4,084,674 years.

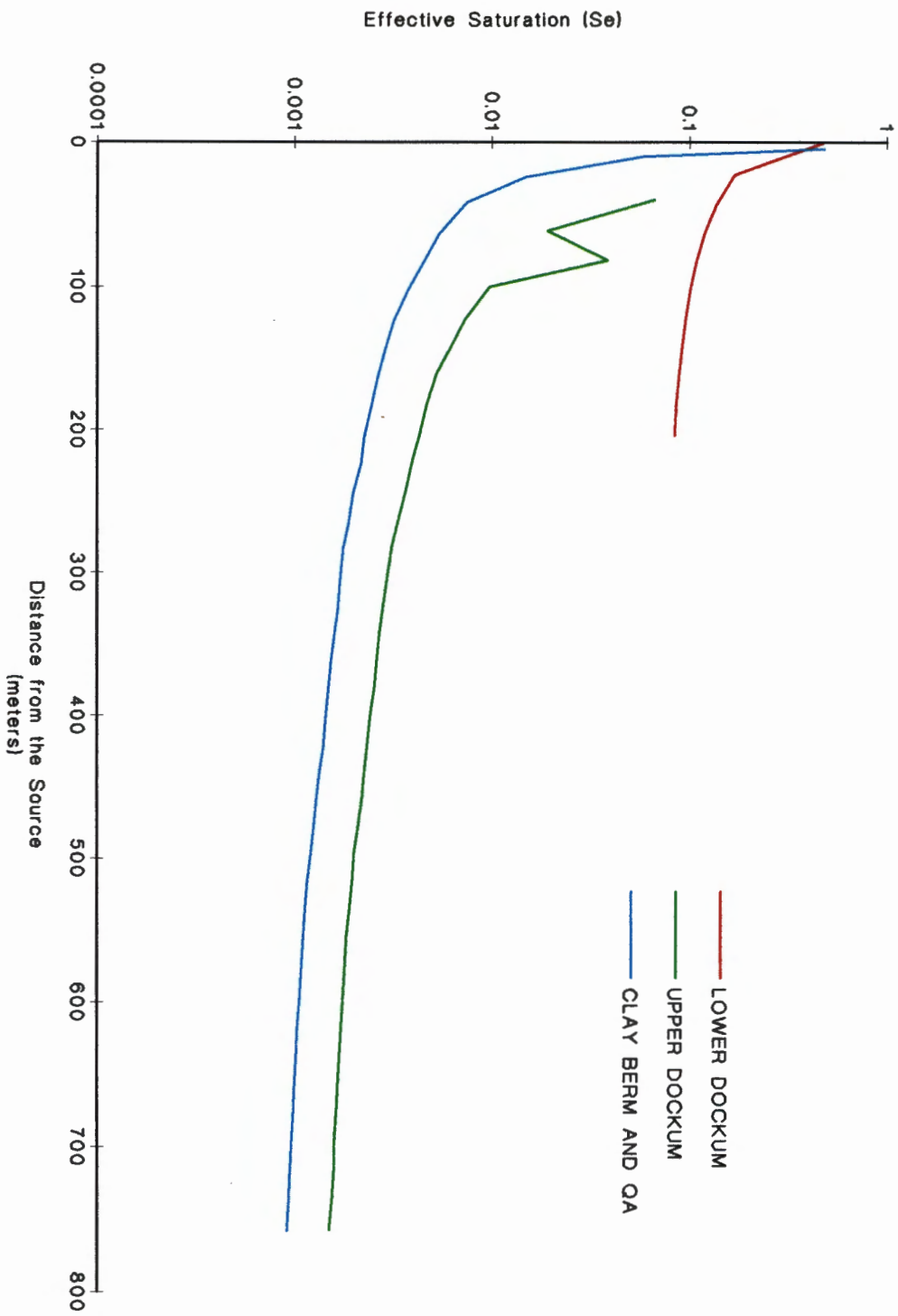


LANDFILL PROFILE

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure B-1

AutoCAD FILE: FIG3-19 C-F.DWG

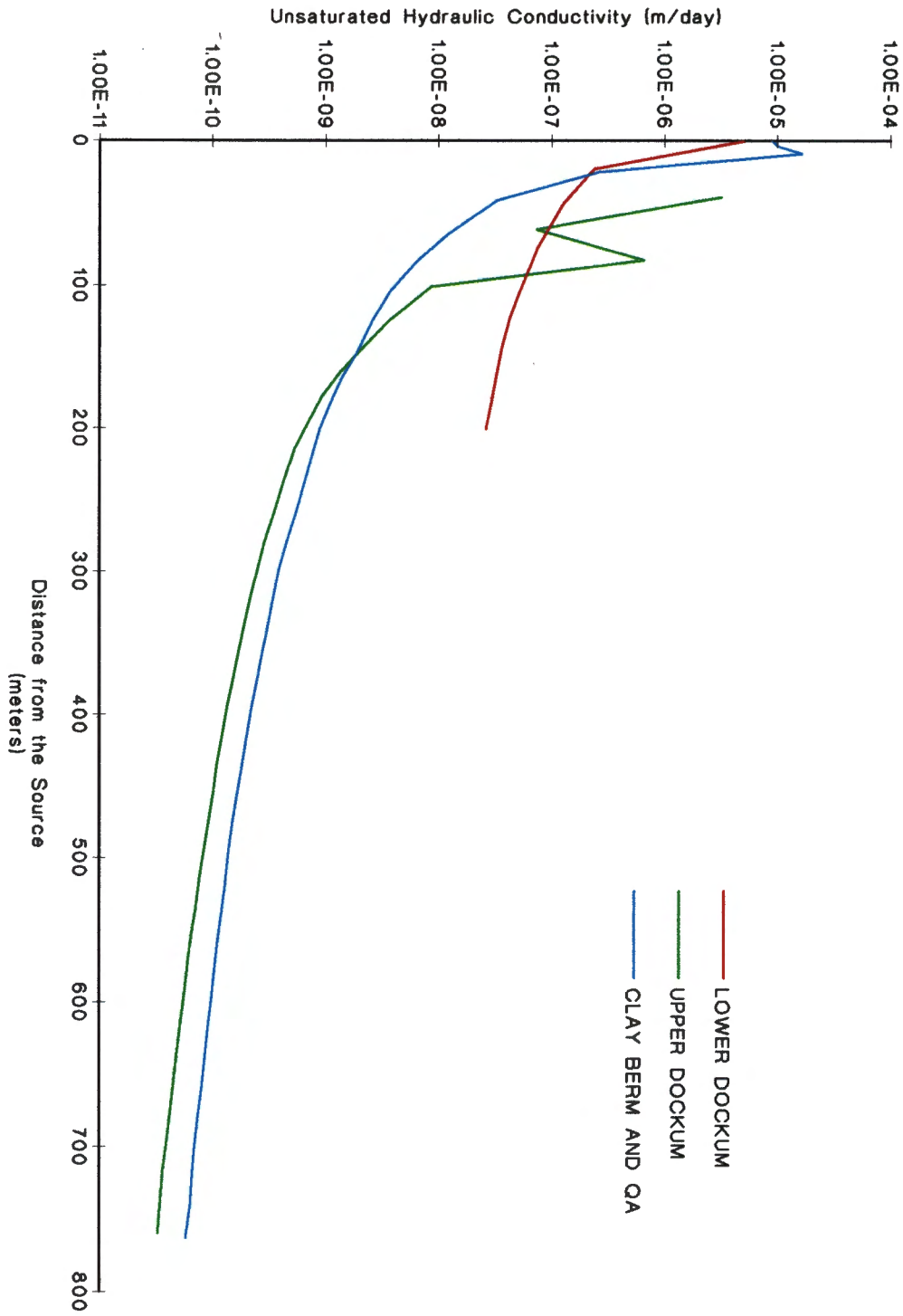


STEADY STATE EFFECTIVE SATURATION vs. DISTANCE FROM SOURCE

Figure B-2

TRIASSIC PARK WASTE DISPOSAL FACILITY

AutoCAD FILE: GANDY-FIG3-20

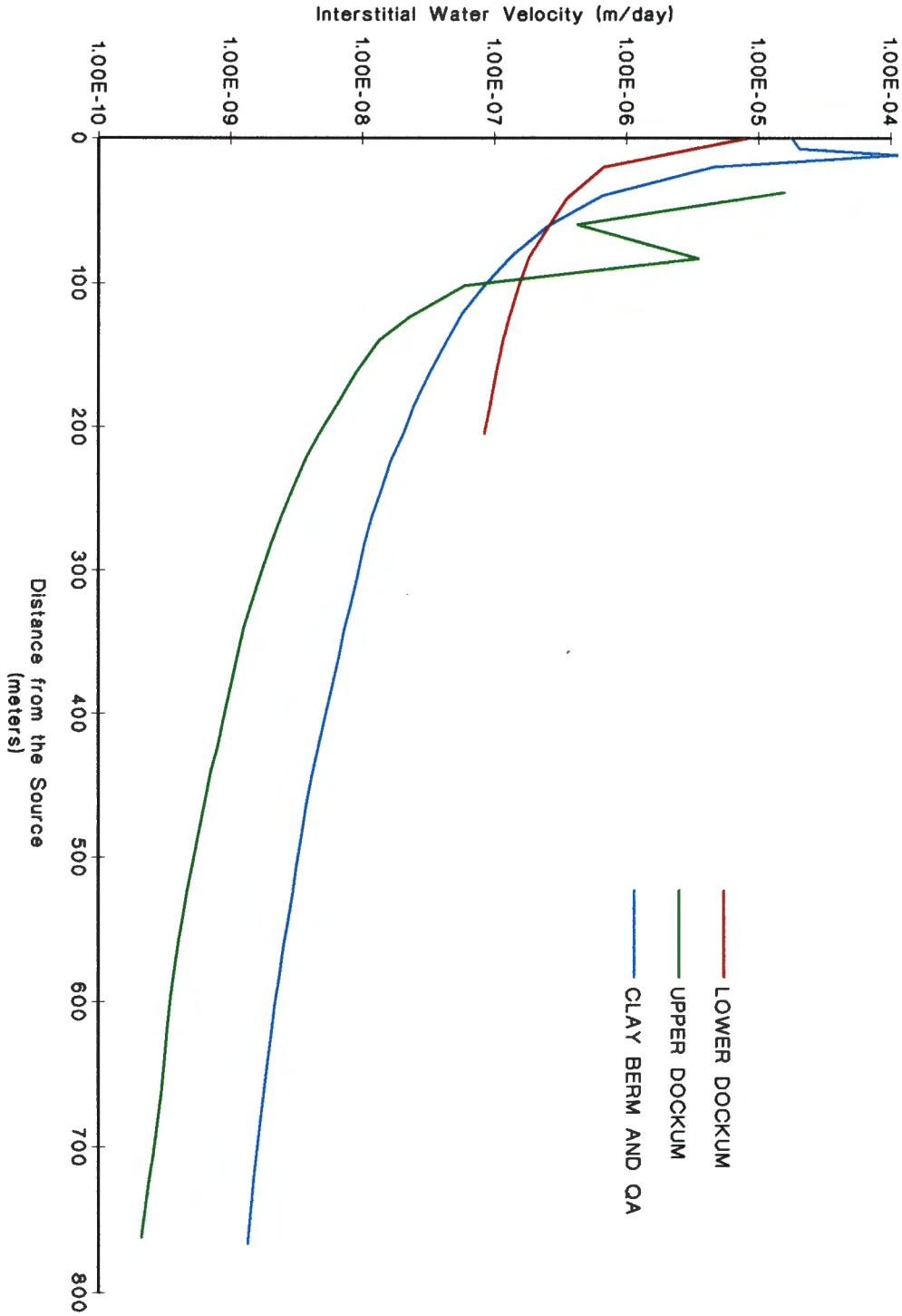


STEADY STATE UNSATURATED HYDRAULIC CONDUCTIVITY vs. DISTANCE FROM SOURCE

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure B-3

AutoCAD FILE GANDY-FIG3-21

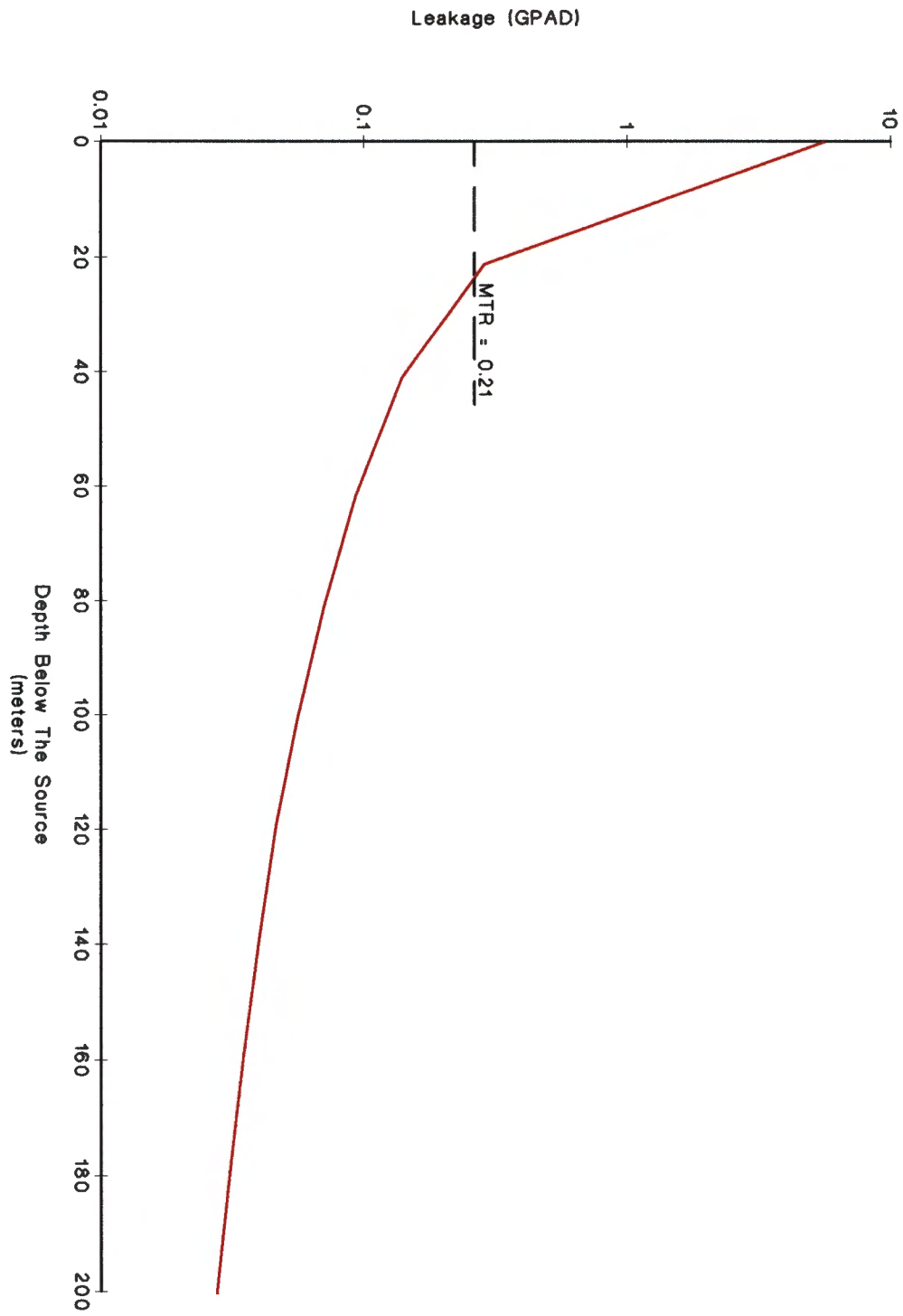


INTERSTITIAL WATER VELOCITY vs. DISTANCE FROM SOURCE

TRIASSIC PARK WASTE DISPOSAL FACILITY

Figure B-4

AutoCAD FILE GANDY-FIG3-22



STEADY STATE LEAKAGE INTO LOWER DOCKUM vs.DISTANCE FROM SOURCE

Figure B-5

TRIASSIC PARK WASTE DISPOSAL FACILITY

AutoCAD FILE GANDY-FIG3-23

TO VIEW THE MAP AND/OR MAPS WITH THIS DOCUMENT, PLEASE CALL THE HAZARDOUS WASTE BUREAU AT 505-476-6000 TO MAKE AN APPOINTMENT