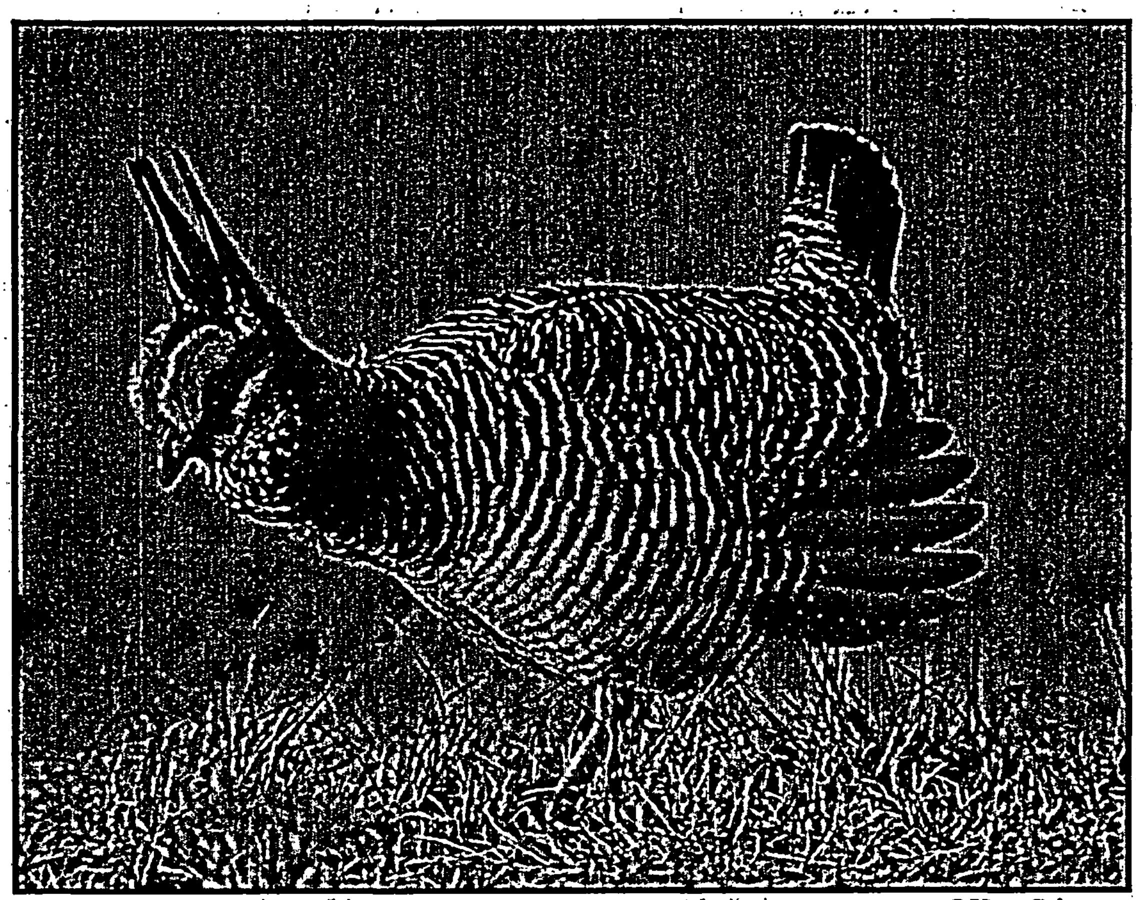
Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*)

Area of Critical Environmental Concern (ACEC)

A petition to the New Mexico BLM



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Petitioners

Forest Guardians
Dr. Jim Bailey
Audubon New Mexico
New Mexico Audubon Council
Animal Protection of New Mexico
Chihuahuan Desert Conservation Alliance
REP Environmental Education Foundation
New Mexico Chapter of Republicans for Environmental Protections
Southwest Environmental Center
Defenders of Wildlife
T & E, Inc.

FOREST GUARDIANS

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Special thanks to T & E, Inc., without whom
this petition would not have been possible.

LESSER PRAIRIE-CHICKEN AREA OF CRITICAL ENVIRONMENTAL CONCERN

Justification for Nomination

Nomination

Pursuant to the Federal Land and Policy Management Act (FLPMA) of 1972, 43 U.S.C. '1701, *et seq.*, petitioners hereby petitions the Bureau of Land Management (BLM) to designate the below described BLM administered public lands as an Area of Critical Environmental Concern (ACEC) for the critically imperiled Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*). Petitioners respectfully submit this nomination as an interested party, pursuant to BLM Manual '1617.81B (2000) and section 553(e) and 555(e) of the Administrative Procedures Act, 5 U.S.C. §§ 553(e) et seq., which grants members of the public the right to nominate areas of BLM-administered lands for ACEC designation. The petitioners have identified this area, which we refer to as the proposed Lesser Prairie-Chicken ACEC, as a potential ACEC based on the relevance and importance criteria as outlined in BLM manual 1613. As will be shown, the critically imperiled status of this species requires that the BLM authorize an amendment to the current programmatic land use plan to allow for the designation of the proposed Lesser Prairie-Chicken ACEC.

Introduction

The Federal Land Policy and Management Act (FLPMA) mandates that the BLM manage public lands in a manner that protects environmental quality, including important wildlife habitat, water resources and other ecological values (43 U.S.C. '1701). FLPMA also mandates that, in developing and revising land use plans, the BLM must give priority to the designation and protection of ACECs (43 U.S.C. '1701). In the New Mexico BLM Standards for Livestock Grazing, finalized in January of 2000, the Lesser Prairie-Chicken was given priority as a special status species. In addition, in response to a 1995 petition to list the Lesser Prairie-Chicken under the Endangered Species Act (ESA) the U.S. Fish and Wildlife Service (USFWS) found that the species was warranted for listing as a threatened species under the ESA, but that the species listing was precluded by the need to list other higher-priority species. The "warranted, but precluded" finding established the Lesser Prairie-Chicken as a "candidate species" under the ESA. The USFWS has continued to find the Lesser Prairie-Chicken's listing to be warranted but precluded in every year since the 1998 petition finding. Additionally, in 1999 the director of the New Mexico Department of Game and Fish (NMDGF) made a recommendation to the New Mexico State Game Commission (NMSGC) to list the Lesser Prairie-Chicken as "threatened" under the New Mexico Wildlife Conservation Act. The director's recommendation was never acted upon. Finally, the U.S. Forest Service in Region II lists the Lesser Prairie-Chicken as "sensitive", and the species is listed as "threatened" by the Colorado Division of Wildlife. Therefore, designation of the proposed Lesser Prairie-Chicken ACEC would be a significant partial requirement toward fulfilling the BLM's mandate under FLPMA, as well as under the BLM's policy requirements (BLM Manual '6840.06) to conserve special status species.

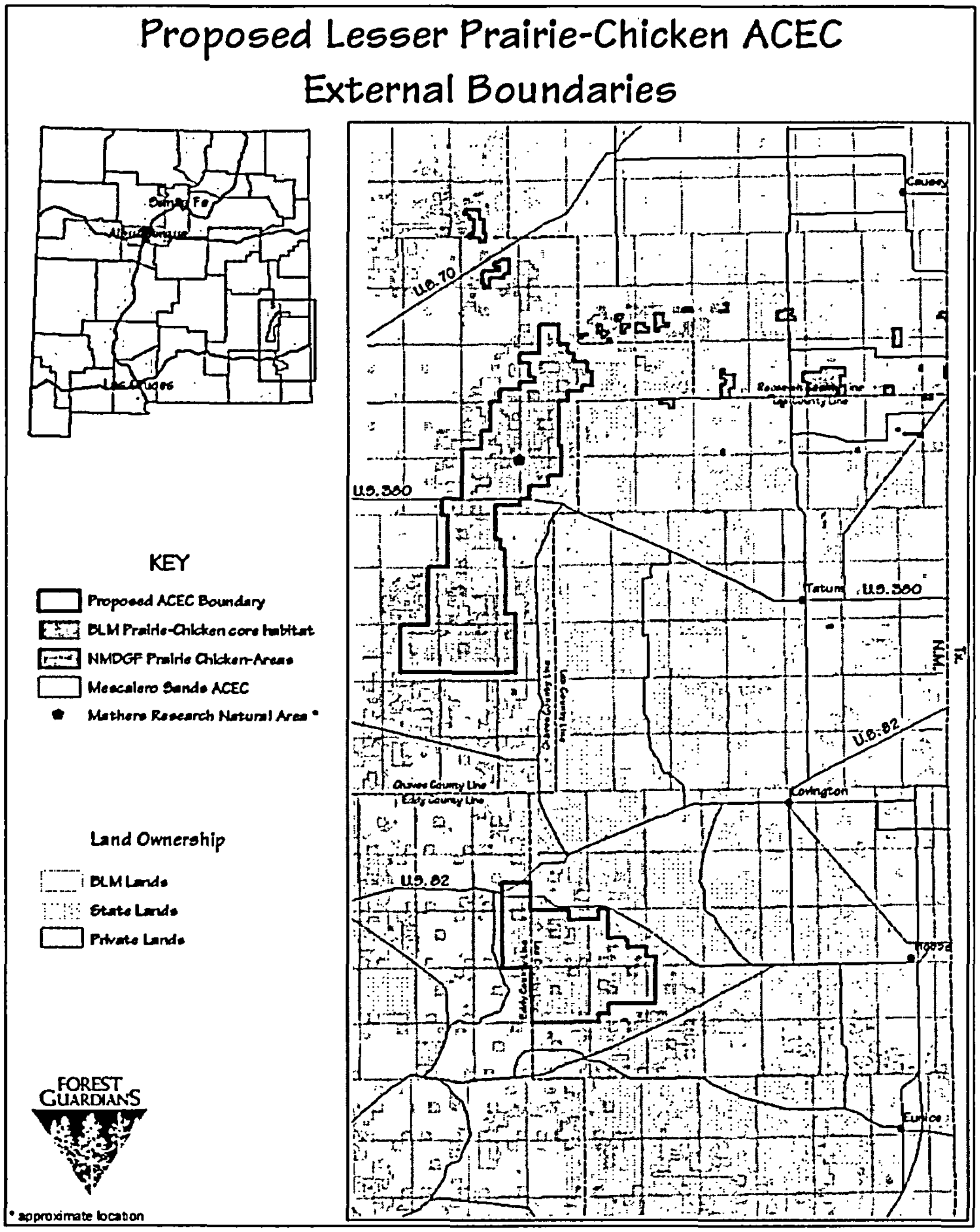

Figure 1. Exterior Boundaries of the proposed Lesser Prairie-Chicken ACEC. The proposed Lesser Prairie-Chicken ACEC includes 935 km^2 of BLM lands within the indicated boundaries. The proposed ACEC correspond to BLM designated core habitat for the Prairie-Chicken, vegetation and habitat community types and known Prairie-Chicken populations.

Location and Site Description

The proposed Lesser Prairie-Chicken ACEC is located in a series of adjacent parcels north and south of highway U.S. 82. The southern parcel is in an area administered by the BLM's Carlsbad Field Office and begins just below the 4th Standard Parallel (approximately 33° 24' N), straddling the Eddy and Lea county lines. This area encompasses approximately 388.5 km^2, 87% of which is BLM Land, with an additional 48.6 km^2 of State and private land. The northern parcels are administered by the BLM's Roswell Field Office, extend northward to the 1st Standard Parallel (approximately 33° 48' N), and are contained entirely within Chaves County. The northern parcels consist of one large area bisected by U.S. 380 and two small areas to the north adjacent to U.S. 70. These areas together encompass approximately 740.6 km^2, 74% of which is BLM land, with another 194.2 km^2 of State and private land. The proposed ACEC would consist only of the BLM Land within the boundaries (Figure 1).

The boundaries of the proposed ACEC are delineated by BLM designated "Core Habitat Areas" for the Lesser Prairie-Chicken, known lek sites and vegetation and habitat composition. The sites are composed of a diversity of habitats required to support stable populations of Lesser Prairie-Chickens, including lekking grounds, nesting habitat, brood rearing habitat and wintering habitat. The principal community type occurring within the boundaries of the proposed ACEC is the shinnery-oak-grassland type, recognized by the U.S. Forest Service as "a rich wildlife habitat" compared to the surrounding vegetation communities, that is in need of study and protection due to the clearing of oak as a land management practice (Peterson and Boyd 1998). The northern parcels of the proposed Lesser Prairie-Chicken ACEC contain the relatively small Mescalero Sands ACEC, a 32 km^2 area characterized by the BLM as a "drifting sands, endemic plant and wildlife community" that itself contains 7.3 km^2 of State Lands and 1.3 km^2 of private land suitable for acquisition (BLM 1997: 2-80). The northern parcels also include the 1.0 km^2 Mathers Research Natural Area (RNA), an area managed so that only "natural ecological changes and limited management activities are allowed", Visual Resource Management (VRM) class I (BLM 1997: 2-66).

The northern parcels of the proposed Lesser Prairie-Chicken ACEC contain some of the highest densities of known active lek sites within New Mexico (Morrissey 1995, BLM 1997, Peterson and Boyd 1998). The northern parcels of the proposed Lesser Prairie-Chicken ACEC are within the core of the remaining Prairie-Chicken habitat in New Mexico (Bailey and Williams 2000, Bailey 2002). The southern parcel of the proposed ACEC contains the remaining majority of the species habitat on public land, as well as a large portion of historical lek sites on public lands in New Mexico (Morrissey 1995, BLM 1997, Peterson and Boyd 1998, Bailey 1999 and 2000). Extirpation within the southern portion of the Lesser Prairie-Chicken range, including the southern parcel of the proposed ACEC, is imminent (Johnson et al. 1999). Given these urgent circumstances, the BLM has an opportunity and a duty under FLPMA to conserve and restore the Lesser Prairie-Chicken within both of these parcels by immediate designation and protection of this habitat as an ACEC.

Land Ownership Percentages within exterior boundaries of Proposed Lesser Prairie-Chicken ACEC

Northern Parcels *Southern Parcel*

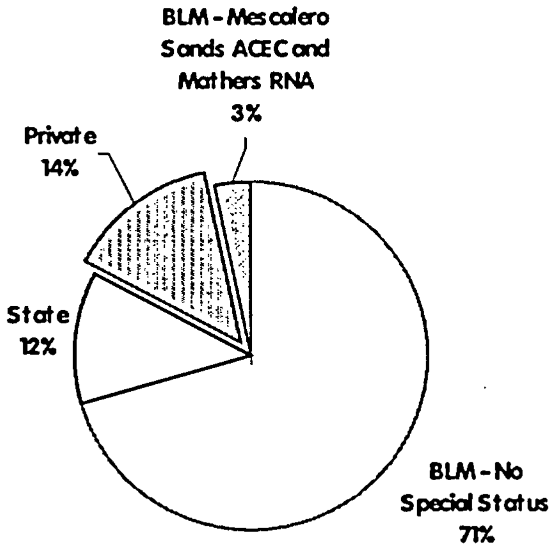

Figure 2. Land ownership of the proposed Lesser Prairie-Chicken ACEC. The majority of BLM Lands within the core of Lesser Prairie-Chicken habitat currently have no special protections. Within the proposed ACEC's northern parcels only 3% of BLM lands have any special status, and management prescriptions remain contrary to the requirements of Prairie-Chickens. Within the proposed ACEC's southern parcel, no special status lands have been designated. While there are private and state lands within the exterior boundary of the ACEC, only BLM land would be included in the ACEC designation.

Petitioners

Primary petitioner Forest Guardians is a non-profit conservation organization located in the southwestern United States. Forest Guardians seeks to preserve and restore native wildlands and wildlife in the American Southwest through fundamental reform of public policies and practices. The organization has approximately 2,000 members, most of who reside in New Mexico and Arizona.

Members engage in wildlife viewing, outdoor recreation, and other activities throughout the Southwest and are particularly concerned with the management of public lands that are essential to the recovery of the Lesser Prairie-Chicken. The health and integrity of ecosystems throughout Western public lands is an important to these members' aesthetic, scientific, and recreational enjoyment of public lands. Forest Guardians and its members are particularly concerned with the conservation of the Lesser Prairie-Chicken and the native ecosystems that it depends upon for survival.

Petition author Jon-Paul Oliva is a conservation biologist and graduate (M.S. Evolution & Ecology, 2001) of the University of New Mexico, Albuquerque and has expertise in plant and community ecology. Jon-Paul has over four years of professional experience in researching and studying a variety of threatened, endangered and sensitive plant and animal species. Jon-Paul is also a Geographic Information Systems (GIS) analyst and uses this tool to model habitat and understand landscape level phenomena affecting endangered, threatened and sensitive species.

Jim Bailey, Ph.D. – Jim Bailey is a private citizen and expert biologist on Lesser Prairie-Chickens with an interest in promoting the conservation and recovery of New Mexico's populations of Lesser Prairie-Chickens.

New Mexico Audubon Council - The New Mexico Audubon Council is an independent non-profit organization representing five local Chapters of the National Audubon Society in New Mexico whose mission is to conserve and restore natural ecosystems, focusing on birds, other wildlife, and their habitats. The New Mexico Audubon Council represents more than 4,000 members in New Mexico. In 1997, the New Mexico Audubon Council led the effort to petition the New Mexico State Department of Game and Fish to study the status of the Lesser Prairie-chicken for possible listing under the New Mexico Wildlife conservation Act. That study resulted in a recommendation that the State Game Commission list the Lesser Prairie-chicken as threatened in New Mexico.

Audubon New Mexico- Audubon New Mexico currently represents 4500 members and 4 local chapters in New Mexico. The mission of Audubon New Mexico is to promote the conservation and restoration of ecosystems, focusing on birds and other wildlife through advocacy, education, stewardship and Chapter support, for the benefit of New Mexico citizens of today and tomorrow. Audubon New Mexico is organized to be a State Field

Office of the National Audubon Society in New Mexico. Audubon New Mexico is an organization of members that use education and advocacy to further our interest in providing wildlife conservation in New Mexico. For over 18 years we have worked with Federal, State and Local resource agencies and councils to further our interest in providing protection and conservation of New Mexico's rich wildlife heritage.

Animal Protection of New Mexico - Animal Protection of New Mexico, Inc. (APNM) is a statewide nonprofit organization that advocates the rights of animals by affecting systemic change that results in their humane treatment.

Chihuahuan Desert Conservation Alliance – The Chihuahuan Desert Conservation Alliance (CDCA) was originally started in 1986 as the Carlsbad Concerned Citizens for Responsible Land Management and the name was changed to CDCA in 1995. CDCA is involved in a wide variety of activities including outdoor and public education, tree-planting and soil conservation projects, construction of nesting platforms for herons, monitoring of wild populations of birds and other animals, bird-banding activities, and other conservation activities. CDCA also takes a stand and gets involved on a wide variety of environmental and environmental justice issues.

New Mexico Chapter of Republicans for Environmental Protection (NM-REPAmerica) – NM- REPAmerica consists of New Mexicans from across the state who are committed to restoring the Republican Party to its proud heritage of conservation and care for the environment.

Republicans for Environmental Protections Environmental Education Foundation - The REP Foundation is a tax-exempt charitable institution dedicated to educating and building a conservative constituency for environmental protection.

Southwest Environmental Center - The Southwest Environmental Center is a non-profit organization dedicated to protecting the environment in southern New Mexico and neighboring areas through grassroots education and activism. SWEC's mission is to foster understanding and concern for the Southwest's natural heritage, and promote action for its protection and restoration.

Defenders of Wildlife - Defenders of Wildlife is dedicated to the protection of all native wild animals and plants in their natural communities. Defenders programs' focus on what scientists consider two of the most serious environmental threats to the planet: the accelerating rate of extinction of species and the associated loss of biological diversity, and habitat alteration and destruction.

T & E, Inc. – T & E, Inc. is a not for profit, private foundation dedicated to the appreciation and preservation of our native flora and fauna. T & E, Inc. has funded in the past and continues to fund research projects devoted to the Lesser Prairie-Chicken and believes there are many other valuable resources that will also benefit from ACEC designation.

Biology of the Lesser Prairie-Chicken

Habitat and Habitat Use

Current habitat of Lesser Prairie-Chickens in New Mexico is almost entirely contained within the shinnery-oak-grassland community type. This community type is characterized by the shinnery-oak (*Quercus havardii*), which can co-dominate with sand sagebrush (*Artemisia filifolia*) and is mixed with mid and tall grasses that are usually taller than the shinnery-oak itself (Peterson and Boyd 1998). Within the community type the major sub-types in New Mexico consist of; 1) shinnery-oak with sand bluestem and little bluestem, 2) Shinnery-oak lacking bluestem but rich in gramas, dropseed and three-awn grasses and, 3) sandhills, dominated by shinnery-oak with sparse grass cover (Peterson and Boyd 1998). The shinnery-oak communities of eastern New Mexico are found in sandy soils with low amounts of clay, a high soil permeability and very low rates of water erosion. Shinnery-oak is rarely taller than 2 ft. high, but has a disproportionately large underground stem system that serves a vital function in sand and soil stabilization (Peterson and Boyd 1998). The root system of shinnery-oak are usually horizontal within a few feet of the surface, but roots have been reported up to 30 ft. deep where shifting dunes have repeatedly buried and exposed plants, forcing the formation of new roots and shoots (Peterson and Boyd 1998). Shinnery-oak is also a long-lived species, with individual shoots having lifespans of 5-12 years and clones reaching sizes of up to 7,000 m^2. Shinnery-oak commonly attain ages of hundreds and probably thousands of years (Peterson and Boyd 1998). The longevity of individual clones of shinnery-oak help explain its slow means of reproduction. Plants are almost never known to reproduce by seed, instead relying almost entirely on clonal reproduction. The lateral movement of shinnery-oak into adjacent areas is exceedingly slow, with plants failing to encroach on old fields surrounded by shinnery-oak and left fallow for over 50 years. In the rare cases of shinnery-oak expansion into abandoned fields, the rate of expansion is slow, up to 30 ft. over a period of 50 years (Peterson and Boyd 1998). Although the shinnery-oaks do not reproduce sexually, they do produce large acorn crops. The buds of the shinnery-oak swell in early to late March and the leaves open in April and May. If drought conditions are severe, plants may fail to leaf out in the spring, but may leaf out later in the season if moisture becomes available (Peterson and Boyd 1998). Shinnery oak produce acorn crops approximately every 3 out of 10 years locally, with crops occurring somewhere every year but not more than twice in five years in a given location (Peterson and Boyd 1998).

Habitat of the Lesser Prairie-Chicken consists of four seasonally used components: lek sites (late February- early May), nesting sites (late April- mid June), brood rearing sites (late May-late July) and wintering sites (Taylor and Guthery 1980b, Davis 1981, Riley et al.1993b, Riley and Davis 1993, USFWS 1998, Giesen 1998, Bailey and Klingel 1998, Applegate and Riley 1998, NRCS 1999).

Lek sites are traditional and are used annually, although sites can be occasionally relocated in response to disturbances such as fire or conversion to agricultural areas (Giesen 1998). Lek sites are used for display purposes and as such are typically found on a locally high area such as a hill or ridge, or a grass flat , Copelin 1963, Taylor and Guthery 1980b, USFWS 1998, Giesen 1998). Lek sites are characterized by a limited amount of low, sparse vegetation, usually grasses (Davis et al. 1981). Probably because of these characteristics, Lesser Prairie-Chicken leks are known to be associated with prairie dog towns, as well as other disturbed areas such as roads or abandoned oil and gas well pads (Davis et al. 1981, Morrissey 1995). Habitat surveys have shown that good

Lesser Prairie-Chicken habitat can support approximately 1-2 lek sites per square mile (Morrissey 1995, Bailey 1999).

Males gather on lek sites in early spring, typically in the early morning and at dusk, with display activity peaking in early April (Giesen 1998, USFWS 1998). Males are also known to gather on lek sites during the fall, usually in lower density than during the spring, and breeding has not been reported (Taylor and Guthery 1980b, Giesen 1998). Males utilize vocalizations, called "booming" and posturing to attract females, who may visit lek sites 2-3 days prior to the initiation of mating (Giesen 1998). Food sources during this period of time are primarily plant based and include seeds, leaves, flowers and buds with shinnery-oak leaf galls, catkins leaves and acorns provide 60-70% of the food supply for the birds (Davis et al. 1980, Taylor and Guthery 1980b, Riley et al. 1992, Giesen 1998, Peterson and Boyd 1998, USFWS 1998).

The shinnery-oak-grassland community characterizes nesting habitat within New Mexico, and studies have repeatedly shown that female Lesser Prairie-Chickens prefer nesting habitat where rangeland health is excellent (Copelin 1963, Davis et al. 1979, USFWS 1998, Bailey 1999, Bailey et al. 2000). Successful nests are usually within bluestem clumps, primarily where residual vegetation cover is dense and where bluestem comprises greater than 25% of the vegetative cover (Davis et al. 1981, Giesen 1994). Vegetation height also strongly influences nesting success, with the most successful nests having a range of cover heights of 43-81 cm. with an average of 67 cm. (Riley et al. 1992, Giesen 1994,USFWS 1998). Vegetation density is always greater at nesting sites than in the surrounding rangeland, and is always greater at successful nests than at unsuccessful nests (Riley et al. 1992, Giesen 1994). The basal area of bluestem clumps is also important to nesting success, with successful nests having thicker and wider basal areas than unsuccessful nests (Riley et al. 1992). The regular distribution of suitable bluestem clumps is also important, as isolated patches of suitable nesting habitat provide a reliable target for predators and are correlated with decreasing nest success (USFWS 1998). Additionally, when grass cover is less abundant, Prairie-Chickens may become more dependent on shrub and forb cover for nest sites, resulting in decreased nesting success (Morissey 1995).

Lesser Prairie-Chickens select a nesting site within approximately 1.8 miles of the lek site (Giesen 1994). Because nesting occurs in early spring before the seasonal growth of bluestem, Prairie-Chickens are highly dependent on the persistence of residual grasses from the previous years for nesting cover and protection from predators (Davis et al. 1979 and 1981, Taylor and Guthery 1980b, Riley et al. 1992, USFWS 1998). Once a nesting site is selected, hens lay an average clutch of 10-12 eggs and the incubation period lasts from 24-26 days after the last egg is laid (Giesen 1998). Food sources during nesting are again primarily seeds, leaves, flowers and buds with shinnery-oak leaf galls, catkins, leaves and acorns providing the majority of the bird's food supply (Davis et al. 1980, Taylor and Guthery 1980b, Riley et al. 1992, Giesen 1998, Peterson and Boyd 1998, USFWS 1998).

Brood rearing habitat within New Mexico is also within the shinnery-oak-grassland community (Davis et al. 1979, Taylor and Guthery 1980b, Giesen 1998, Peterson and Boyd 1998). Brood rearing habitat is characterized by a greater cover of shinnery-oak and forbs than the surrounding areas. Areas of bare ground that provide enough space for the chicks to move freely are essential for successful brood rearing. Hens prefer areas of taller shrub cover than do birds without broods, and the density of grasses is lower and the height of grasses shorter than at nesting sites (Davis et al.1979, Riley et al. 1992, Riley and Davis 1993). Active sand dunes with shinnery-oak cover are common in brood habitat (Bailey 2000). Prairie-Chickens are more tolerant of mild to moderate disturbance levels, such as fire and grazing, within brood habitat than within nesting habitat (Davis et al. 1979). Good quality brood habitat also provides an abundant supply of insects, which are the main food source for chicks during the summer season (Davis et al 1980, Taylor and Guthery 1980b, Riley and Davis 1993). The insects consumed by Prairie-Chicken broods are primarily grasshoppers (Acrididae and Tettigoniidae) and treehoppers (Membracidae) which comprise up 60-90% and 30% of the diet, respectively (Davis et al 1980, Riley and Davis 1993). For adults, insect utilization can approach 55% (Davis et al. 1980). The reliance on green vegetation as a food source decreases during this period to approximately 23%, but the relative proportion of shinnery-oak acorns increases to approximately 21% (Davis et al. 1980).

Autumn and winter habitat within New Mexico is also within the shinnery-oak-grassland community, with agricultural fields supplementing the habitat (Giesen 1998, Bailey 1999). Beginning in the autumn, birds of different broods assemble into flocks where they roost in the shinnery-oak-grassland communities (Taylor and Guthery 1980a). Bailey (1999) speculated that although Prairie-Chickens are known to utilize waste grain fields as a supplemental food source, fields far from shinnery-oak cover might attract predators and enhance predation during the autumn-winter season. Reliance on shinnery-oak as a food source is high during this period, with leaves, catkins acorns and insect galls providing the primary constituents of the diet. In the autumn, use of shinnery-oak constitutes between 36-50% of the Prairie-Chicken diet, primarily acorns and insect galls (Crawford and Bolen 1976, Riley et al. 1993). The primary animal component of the Lesser Prairie-Chicken's autumn diet consists of short-horned grasshoppers (Acrididae), which makes up approximately 15% of the food source (Riley et al. 1993). Importantly, Crawford and Bolen's study found that even though waste grain fields were present, autumn food utilization was still primarily shinnery-oak acorns and insect galls, suggesting that Prairie-Chicken utilization of waste grains is minimal, except in the absence of suitable shinnery-oak grassland communities (Crawford and Bolen 1976).

The winter diet of the Lesser Prairie-Chicken is characterized by a decreased utilization of insect food sources and an increased reliance on vegetative food stuffs. Use of shinnery-oak acorns increases dramatically, with one study reporting that acorns comprised 69% of the winter diet (Davis et al. 1979, Riley et al. 1993). Prairie-Chickens also rely on wild buckwheat (*Eriogonum annuum*) as a food source during the winter season, with Riley et al. (1993b) reporting that the grain comprised 15% of the bird's winter diet.

The Lesser Prairie-Chicken relies on a mosaic of varied landscape and community sub-types within the shinnery-oak grassland community as habitat throughout the year (Riley et al. 1993, Bailey 1999). The bird's close association with the shinnery-oak-grassland community type in New Mexico is because this vegetation is critical for both food and cover. The lekking behavior of the Prairie-Chicken is dependent upon the exposed knolls and ridges that characterize lek sites. Nesting and brood rearing phases of Lesser Prairie-Chicken reproduction are particularly sensitive to plant community composition, with nesting success being highly correlated with the density and height of bluestem (*Andropogon* spp.) for nest concealment, and brood rearing success with the health of shinnery-oak dominated areas for concealment and as a source of insect food stuffs. It should be noted that Prairie-Chickens are not dependent on free water during any phase of the life cycle, but instead appear to meet their moisture requirements from insects, vegetation and dew formation (Morrissey 1995, Giesen 1998).

Geographic Distribution and Abundance

Historical

Historical reports suggest that Lesser Prairie-Chickens were locally abundant throughout eastern New-Mexico, the Texas panhandle, western Oklahoma, southwestern Kansas and southeastern Colorado, with small populations possibly existing in northeastern Colorado and extreme northwestern Nebraska (Colvin 1914, Ligon 1927, Bailey 1928, Taylor and Guthery 1980b, USFWS 1998). The approximate total area of this historic distribution was reported to be 358,000 km^2 (Taylor and Guthery 1980b, USFWS 1998).

The historic distribution of the Lesser Prairie-Chicken in eastern New Mexico was widespread and included all or parts of Union, Colfax, Harding, Quay, Guadalupe, De Baca, Curry, Roosevelt, Lea, Chaves and Eddy Counties (Ligon 1927, Bailey 1928). Ligon (1961) reported an 'ancestral' distribution lying east of the Pecos River Valley in a north-south band approximately 75 miles wide. The approximate total area of this historic distribution was reported to be 9864 mi^2 (Bailey and Williams 2000).

The pre-twentieth century abundance of Lesser Prairie-Chickens within their historical range is not precisely known. Estimates varied widely, with one estimate of over two million birds in Texas alone (Litton 1978, U.S.F.W.S. 1995). Bailey and Williams (2000) estimate, perhaps more reliably, that during an undefined period when the maximum historic range was occupied, the total population was roughly 125,000 birds.

While these numbers range widely, the general consensus in the literature is that pre-twentieth century abundance was relatively high but declined considerably after 1920 (Taylor and Guthery 1980b, Applegate and Riley 1998, Giesen 1998, Peterson and Boyd 1998, USFWS 1998, Bailey 1999, Bailey and Williams 1999, NRCS 1999,Giesen 2000, Sullivan et al. 2000, among others). Within New Mexico, population estimates for the years 1949 and 1961 were approximately 40-50,000 birds, and had declined to 8,000-10,000 birds by 1968 (Sands 1968, USFWS 1998). Crawford (1980) estimated the New Mexico population of Lesser Prairie-Chickens in 1979 to be approximately 10,000 birds.

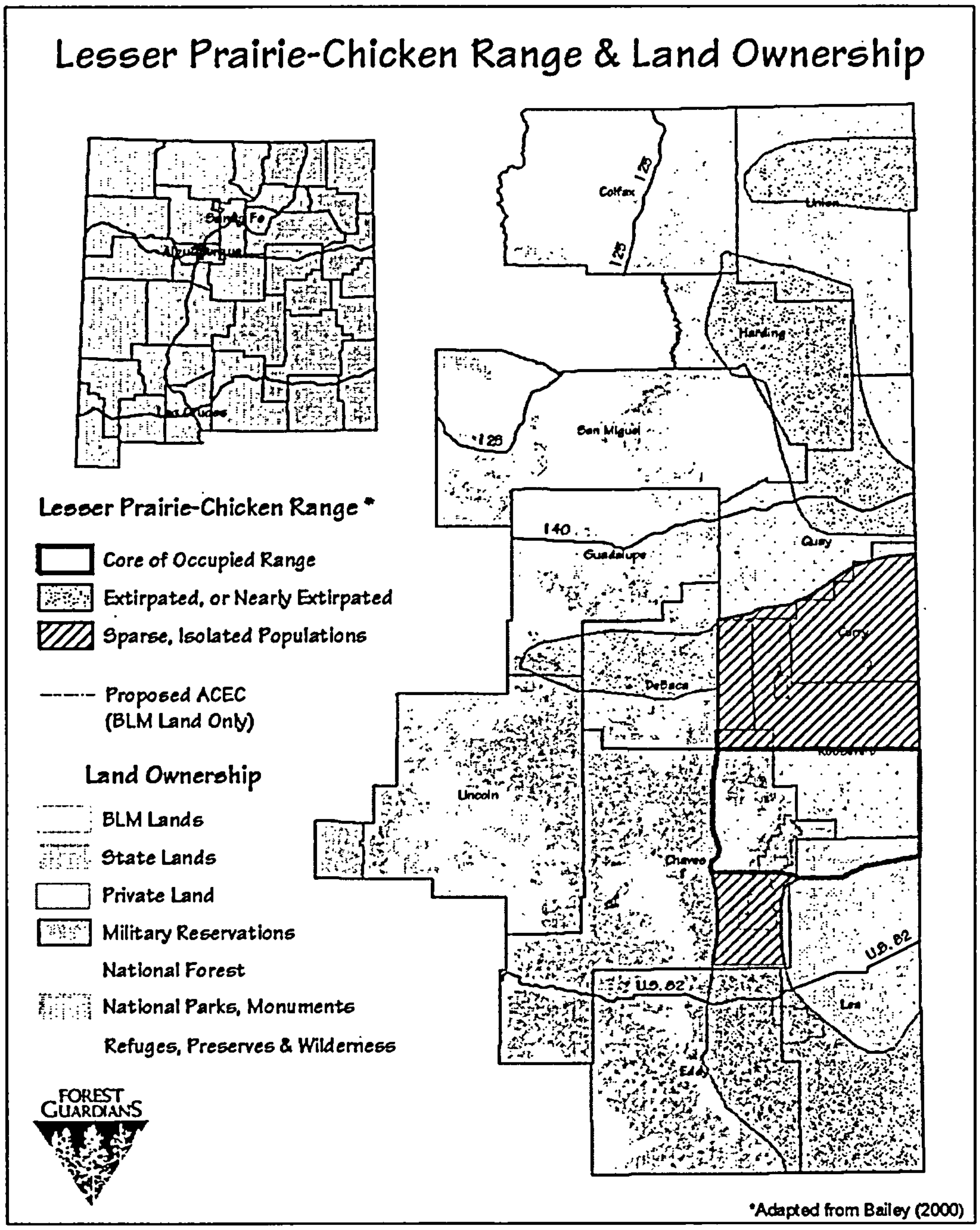

Figure 3. Historic and current range of the Lesser Prairie-Chicken. Once abundant throughout their range in eastern New Mexico, the Lesser Prairie-Chicken is extirpated from 56% of its former range and persists only as sparse and scattered populations in another 28% of that range. The core of the remaining populations is only 16% of its former range (Bailey and Williams 2000, Bailey 2002).

Current

The distribution of Lesser Prairie-Chickens has been greatly reduced since about 1920, and recent estimates suggest that the species occupies only 8-10% (28,640-35,800 km^2) of its historic range (Taylor and Guthery 1980b, USFWS 1998, Bailey and Williams 1999, Bailey 2002). Lesser Prairie-Chickens exist today in southeastern Colorado, south-central Kansas, western Oklahoma, southeastern New Mexico and the Texas panhandle (USFWS 1998). In Colorado, Lesser Prairie-Chickens have been extirpated from three of the six counties that they are once thought to have inhabited, and today are found only in Baca, Prowers and Kiowa Counties. In Kansas, Lesser Prairie-Chickens once occupied 38 counties and today occupy 34. In Oklahoma, Lesser Prairie-Chickens once occupied an estimated range of 10,143 km^2 and today occupy approximately 1,162 km^2, corresponding to an 89% decrease from historic range size. In Texas, Lesser Prairie-Chickens once occupied an estimated 13,663 km^2 and today occupy approximately 5,732 km^2, corresponding to a 58% decrease from historic range size (USFWS 1998).

Within New Mexico, Lesser Prairie-Chickens once occupied an estimated 38,085 km^2 and today occupy approximately 16,757 km^2, corresponding to a 56% decrease from its historic range size (Bailey and Williams 2000). The species is widely considered to be extirpated from the northeastern portion of its historic range, including all of Union, Harding and Quay Counties (USFWS 1998, Bailey and Williams 2000, Bailey 2002). The last confirmed sightings in these areas were from a NMDGF employee in 1993, and a 1998 NMDGF and U.S. Forest Service (USFS) survey of 190 miles of public road in Union County detected no active Prairie-Chicken leks (Bailey 2000). The most recent survey in this area was conducted by the USFS in 2002, with negative results (J. Bailey, personal communication).

The central portion of the Lesser Prairie-Chicken's historic range is home to the remaining "core" populations of Prairie-Chickens in the state (Figure 3). The first comprehensive survey of these areas was conducted in 1998 and 1999 by NMDGF biologists over 17,716 km^2, with 5,618 km^2 of historic range excluded because of either unsuitable habitat, a lack of basic habitat characteristics or a lack of access (Bailey and

Williams 2000). The survey results showed that Prairie-Chicken leks were not detected on 14 of 28 route-transects, in either year (Bailey and Williams 2002). Thirteen of these routes were above 34° N, suggesting these populations in DeBaca and Guadalupe counties are probably nearing extirpation (Bailey and Williams 2000). In contrast, survey data collected by NMDGF north of Highway 380 but south of 34°N have yielded stable numbers in recent years, with 9 out of 11 routes surveyed having at least one active lek in both 2000 and 2001. This area contains the "core" of present day Lesser Prairie-Chicken populations, and corresponds to just 16% of its historical range (Bailey 2002).

NMDGF survey data indicate that Lesser Prairie-Chickens are nearing extirpation south of Highway 380 in southeast Chaves County. Of the two routes in this area, no leks were detected in 2000 and only one lek on one route was detected in 2001 (Bailey 2002). Similarly, Best (2001) detected no leks in this region on ten routes in 2000 and 2001. BLM surveys of historical lek sites south of Highway 380 have yielded qualitatively similar data, with only 18% of leks surveyed categorized as active, versus 27% active leks north of Highway 380 (Bailey 2002). These data support the conclusion of Bailey and Williams (2000) that Lesser Prairie-Chickens are nearing extirpation south of highway 380 in southeast Chaves County (Bailey 2002).

A significant portion of the unoccupied range lies below 33° N latitude, in the extreme southeastern portion of New Mexico including the Querecho Plains. The Carlsbad Field Office of the BLM has approximately 30 historical leks within the Plains. The 1998 NMDGF survey located only one active Prairie-Chicken lek and a subsequent New Mexico Natural Heritage Program (NMNHP) survey found no active leks, as did a 2001 survey (Bailey 1999, Best 2001, Bailey 2002). These populations of the Lesser Prairie-Chicken south of 33°N are very close to being extirpated entirely from their historic range (Johnson et al. 1998, Bailey 1999 and 2002).

Today, the Lesser Prairie-Chicken survives in relative abundance in only 16% of its former range in New Mexico (Bailey and Williams 2000). Small and scattered populations persist south of Highway 380 and in parts of DeBaca and Guadalupe counties and comprise another 28% of the species former range (Bailey and Williams 2000). The

Lesser Prairie-Chicken is gone from 56% of its historical range in New Mexico (Bailey and Williams 2000). Prairie-Chicken populations of southeastern Chaves County have become sparsely distributed, and may also be in danger of extirpation, as may be the populations above 34° N in DeBaca and Guadalupe counties (Bailey 2002). The current distribution of the "core" Lesser Prairie-Chicken population is concentrated in southern Roosevelt, northern Lea and east-central Chaves counties (Figure 3, Bailey 2002).

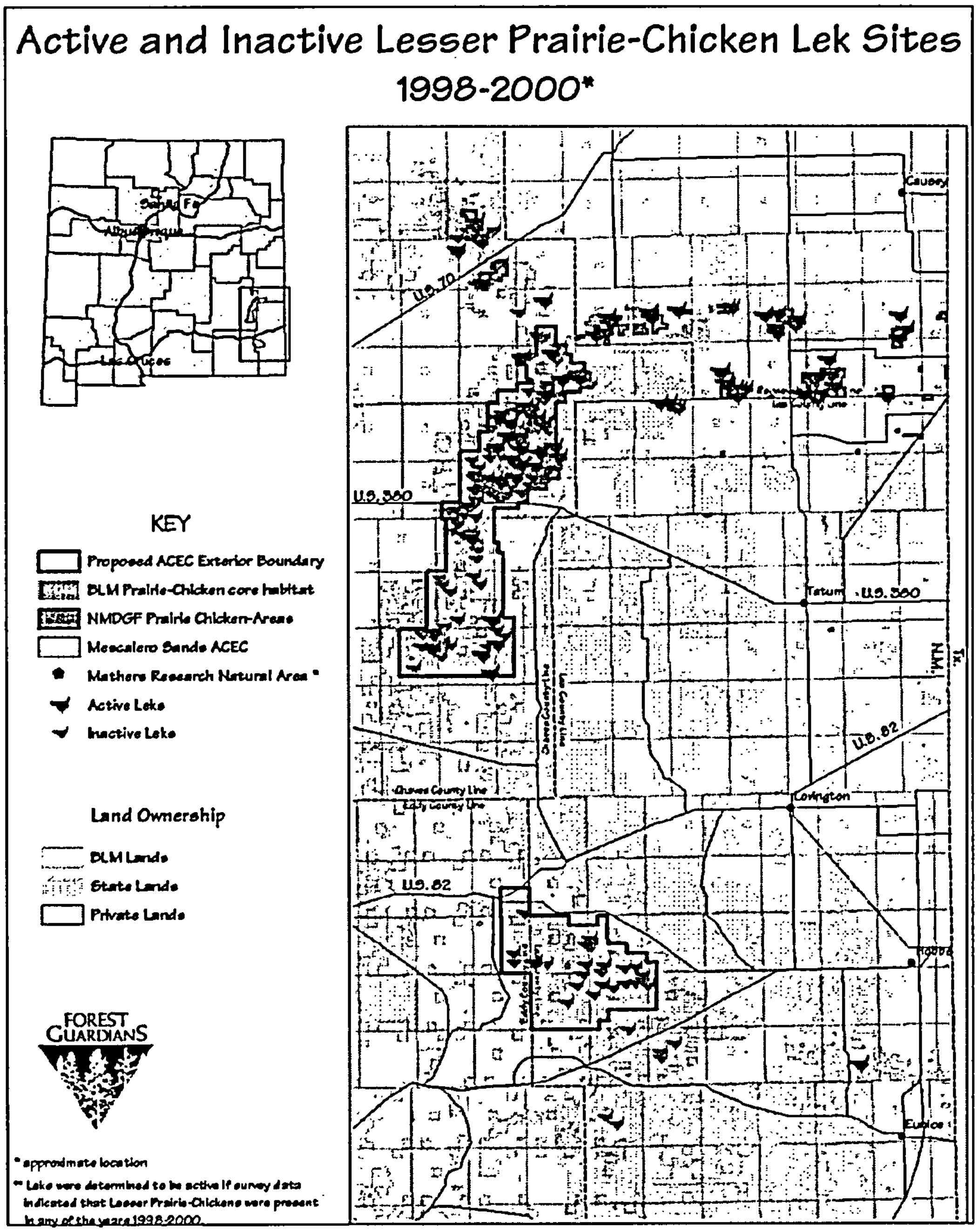

Figure 4. Active and Inactive Lek Sites, 1998-2000. The number of active lek sites in east-central and southeastern New Mexico has declined throughout the 1990s to all-time lows, particularly in the areas south of U.S. 380.

The New Mexico populations of Lesser Prairie-Chickens are thought to have increased in numbers during the 1980s, before declining to all time lows in the 1990s (Bailey 1998, Bailey and Williams 2000). The NMDGF surveyed hunters to estimate the numbers of birds harvested from 1983-1993 and found that the number of harvested birds declined sharply from a high of 4000 in 1988 to a low of 244 birds in 1993 (Morrissey 1995, Bailey and Williams 2000). Survey results from the BLM Caprock Wildlife Area by both BLM and NMNHP biologists have shown that Prairie-Chicken numbers in this management area have declined from population counts recorded in the 1971-1981 period. Morrissey reported that the estimated population within the Caprock Wildlife Area declined from 2600 in 1983 to 935 by 1995 (Morrissey 1995). Recent data collected within the Caprock Wildlife Area north of Highway 380 indicate that the populations in this area may have stabilized, with active leks/lek site visited being 0.18 in 2000, 0.25 in 2001 and 0.26 in 2002 (J. Bailey, personal communication). Data from the Roswell field office for 2002 also supports this conclusion. BLM personnel surveyed 34 active leks with an estimated 365 birds, with the number of active leks in the period 1999-2002 increasing from 16-34 (Davis 2002). This trend of population stabilization is encouraging, but the numbers are still far below the population levels of the 1970's, a period with comparable moisture.

Additional survey data from BLM biologists collected in west-central Lea County on lands managed by the Carlsbad Field Office (CFO) during the period 1985-1998 have shown even more dramatic declines in Prairie-Chicken populations. These surveys reported a high of 160 birds on 20 leks in 1987, a figure which by 1998 had declined to only six birds on one active lek (Figure 5) and by 2001 had declined to only two birds on one active lek (Bailey 2002). CFO personnel reported one active lek in 2002 with seven males, northeast of Eunice (Davis 2002). The CFO personnel also audibly detected Lesser Prairie-Chickens near an historic lek site in 2002 (Davis 2002).

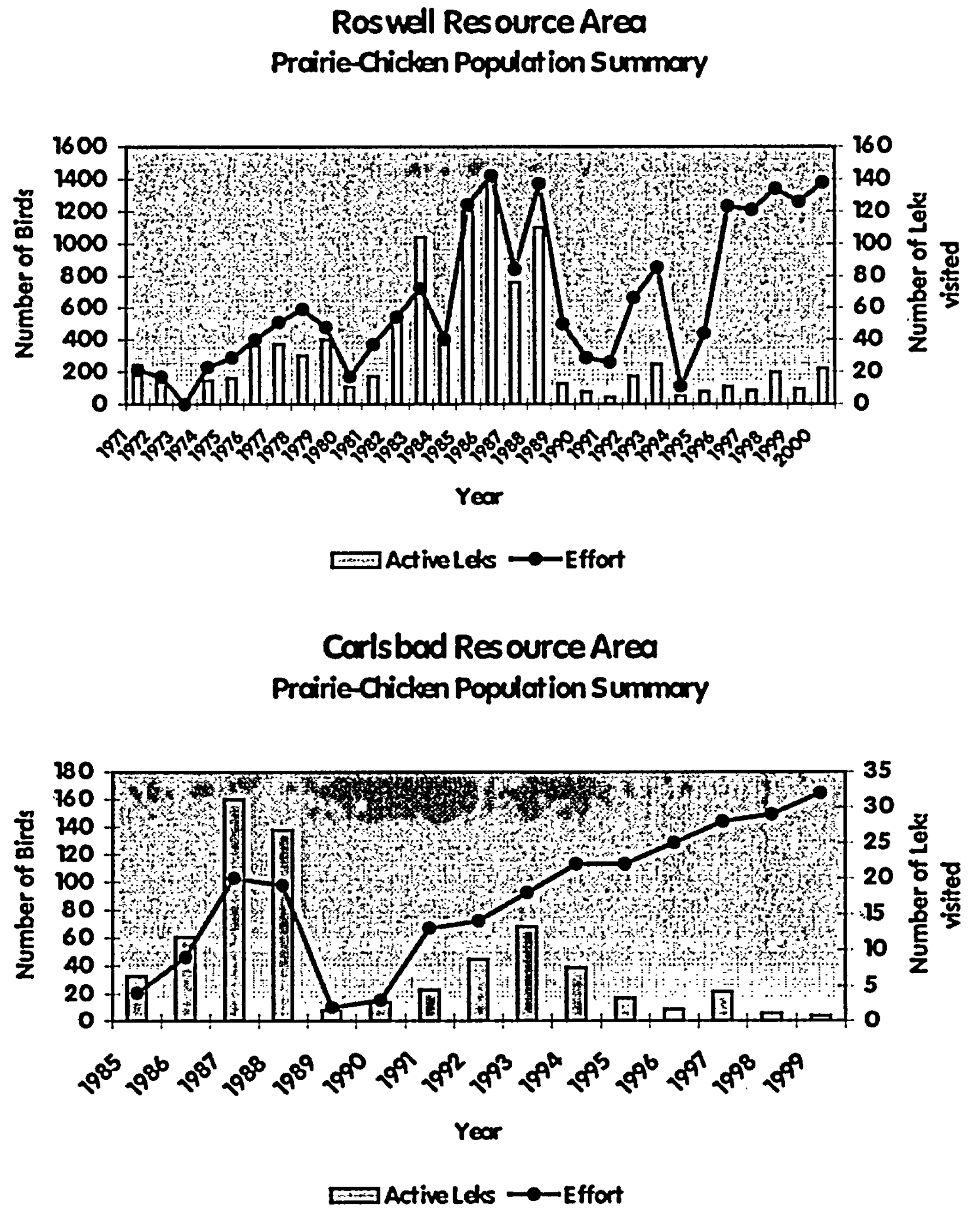

Figure 5. Population trends of BLM Lesser Prairie-Chickens. Populations of Lesser Prairie-Chickens, as estimated by lek surveys, have been steadily declining. Populations of both the Roswell and Carlsbad Resource areas have hit unprecedented lows in the 1990s and early 2000s, despite the fact that survey effort was higher than ever. From Smith et al. 1998.

Data reporting reproductive success supports the conclusions of survey data suggesting that Lesser Prairie-Chicken population trends are declining. Age ratios (juveniles/hen) for the period 1958-1968 averaged 3.7 juveniles/hen, but had declined to an average of 0.65 juveniles/hen in 1989 and 0.59 juveniles/hen in 1995 (Bailey 1999).

Current data indicate that Prairie-Chicken abundance is most stable on Prairie-Chicken Areas (PCAs) managed by the NMDGF. Surveys of 10 of these sites have reported low but stable or increasing population numbers for the years 1996-1998. Active numbers of leks in these areas increased from 11 in 1996 to 32 in 1998, as did the estimated number of birds (29 in 1996 and 181 in 1998) (Johnson et al. 1998). The most recent data from the PCAs show this trend continuing. Survey data from 2002 found a total of 132 active leks, with an estimated 533 birds (Davis 2002). In contrast, NMDGF surveys on randomly located roadside routes in east-central New Mexico during 1998-2002 suggest declining overall populations, although the trend is not statistically significant (Davis 2002). This evidence suggests the effectiveness of grazing exclosures in affecting the recovery of Lesser Prairie-Chicken populations. However, the PCAs in this area are small and isolated patches of habitat totaling just 87.9 km^2 (figure 1).

Based on these data, Lesser Prairie-Chickens have been extirpated from their historic range in northern New Mexico and nearly extirpated from their historic range south of 33° N. They persist in sparse and isolated populations in Curry and north Roosevelt County and in southeast Chaves County. Thus the remaining "core" populations of Lesser Prairie-Chickens in New Mexico occupy only 16% of the species historic range, and are found within south Roosevelt and north Lea counties as well as east-central Chaves County, on private lands, BLM lands including part of the Caprock Wildlife Area, and NMDGF PCAs (Bailey 2002).

Threats

The Lesser Prairie-Chicken populations in east-central and southeastern New Mexico face a variety of both natural and human caused threats. The major threats to Prairie-Chicken populations include drought, degradation of habitat caused by livestock grazing, habitat loss and habitat fragmentation, oil and gas development, control of shinnery oak through the use of herbicides, rangeland conversion for other uses, and a lack of adequate protections. The majority of the threats to the Lesser Prairie-Chicken intensify as the local populations become smaller and more isolated. Likewise, the effects of drought are multiplicative when occurring simultaneously with those of livestock grazing and other habitat degradation. The following narrative will outline the major impacts of these threats, as well as their interactive effects, on Lesser Prairie-Chicken populations.

Drought

Drought is a recurring phenomenon within the geographic range of the Lesser Prairie-Chicken in New Mexico. Even normal precipitation events are sporadic and typically localized. Periods of below average precipitation can have even more severe impacts when interacting with the effects of livestock grazing and other human disturbances. There have been periods of major drought recorded in these areas during the 1930s, 1950s and 1990s (Merchant 1982, Morrissey 1995, Bailey 1999). Bailey (1999) summarized the effects of the most recent drought of the 1990s on the prognosis for survival of the Lesser Prairie-Chickens. Using data from precipitation records, he concluded that the 1990s droughts were not as severe as those of the earlier twentieth century. The dramatic declines seen in Prairie-Chicken population numbers were the result of an interaction of drought with other factors, primarily habitat fragmentation, habitat degradation and livestock grazing. In east-central and southeastern New Mexico, within the current range of the Lesser Prairie-Chicken, forage demand is high, and grazing pressure continues to be high, even during periods of drought. As habitat fragmentation and population isolation increases, the impact of stochastic events like drought on the survival of Lesser Prairie-Chickens becomes more severe (Merchant 1982). Such negative interactive phenomena are well known from population biology studies of wide-ranging organisms (Brussard and Gilpin 1989, Soule et al. 1992, Bolger et al. 1997). Since drought affects the growth of vegetation, and spring and summer droughts can reduce the amount of grass cover, drought has the potential to result in decreased nesting success and increased predation on Lesser Prairie-Chickens. Because Prairie-Chickens depend on residual vegetative cover for nesting habitat, the effects of drought will be most severe in the following year to two years, during the nesting period. In fact, Bailey (1999) reported a weak correlation between precipitation occurring 16-28 months prior to nesting surveys and measured Prairie-Chicken abundance (lek surveys), as did Smith and Johnson (1998). Merchant (1982) also found similar depressive effects of drought on factors affecting Lesser Prairie-Chicken survival, including decreased number of nesting attempts, decreased nesting success, lower brood sizes and greatly reduced spring-summer survival rates of adult female Lesser Prairie-Chickens.

Livestock grazing

When periods of drought coincide with intense livestock grazing, grass cover may be reduced substantially for a period of years, resulting in increased predation and mortality, and decreased nesting success as compared to the effects of drought alone (Merchant 1982). In addition, grazing results in the decrease of Prairie-Chicken food plants and modification of the plant communities away from grasses and towards forbs and shrubs and short grass rangeland pioneering communities (Litton et al. 1994). Lesser Prairie-Chickens have either disappeared or have been reduced severely in numbers where Prairie-Chicken habitat has been excessively grazed (USFWS 1998). Jackson and DeArment (1963) found that the interactive effect of drought and livestock grazing was the single most important factor affecting the recovery of Lesser Prairie-Chicken populations in west Texas following periods of drought. The dependence of Lesser Prairie-Chickens on the narrowly occurring shinnery-oak-grassland community makes the species particularly sensitive to over utilization of the grass component of the community by livestock (USFWS 1998). Effects of grazing intensity on the soil permeability and soil moisture content have been documented (Crawley 1997, Taddese et al. 2002). Soil productivity is inversely related to grazing pressure in arid ecosystems, with ungrazed areas retaining soil moisture longer, resulting in higher grass production than in heavily grazed areas (Crawley 1997, Brown and Archer 1999). This effect is expected to intensify during periods of drought when grazing pressure remains constant (USFWS 1998). In addition, the over-utilization of grass cover by livestock reduces both grass height and the homogeneity of clump distribution on the landscape, factors which have been repeatedly shown to affect nesting success, presumably through increased predation (Taylor and Guthery 1980b, Riley et al. 1992, USFWS 1998, Bailey 1999). Recent research on grazed pasture areas in Lesser Prairie-Chicken habitat has documented the absence of senescent grasses that provide optimal nest sites (Johnson et al. 1998). The importance of these findings cannot be understated. The reliance of Lesser Prairie-Chickens on residual tall grasses for quality nesting cover means that grasses grown in July through mid-September need to survive ungrazed and untrampled for 9-10 months to provide the necessary quality nesting habitat. Grazing during this period, even relatively light intensity grazing, is likely to adversely affect the Lesser Prairie-Chicken's nesting success and should be avoided wherever Prairie-Chickens are important fauna (J. Bailey, personal communication). The 1997 Roswell Resource Area Proposed Management Plan/Final Environmental Impact Statement, approved in the October 1997 Record of Decision, while expressly authorizing livestock grazing within the Mescalero Sands ACEC, recognizes that "this (livestock grazing) could negatively influence or impair natural ecological processes meant to be protected..." (BLM 1997). In addition, the NRCS continues to subsidize fence and water development costs on private lands in the adjacent areas to promote livestock grazing. This practice results in the degradation of Lesser Prairie-Chicken habitat on private lands, and increases the importance of BLM Land as a habitat refuge for the Lesser Prairie-Chicken (J. Bailey, personal communication).

Habitat Loss and Landscape fragmentation

Several factors have contributed to loss of Prairie-Chicken habitat and habitat fragmentation, including conversion of rangeland to agricultural fields, loss of open rangeland to land development and oil and gas exploration and drilling activities, livestock grazing and tebuthiuron application. The initial conversion of rangeland to crop lands in the later nineteenth and early twentieth centuries did not apparently negatively impact Lesser Prairie-Chicken population numbers, and the widely spaced fields were a small enough component of the habitat that they actually increased food supplies for the species (Crawford 1980, Bailey 1999). After this early period, continuing conversion of rangeland to other uses began to detrimentally affect Prairie-Chicken populations (Copelin 1963, Jackson and DeArment 1963, Crawford 1974, Crawford and Bolen 1976). Today, Prairie-Chickens are entirely gone from areas where more than 37% of the rangeland has been converted to other uses, and have declined from areas where more than 20% of the land has been converted (Copelin 1963, Crawford 1974). While much of the rangeland within the historic range of the Lesser Prairie-Chicken in New Mexico has not been converted to cropland, these figures are important because 59% of the historic Prairie-Chicken range is privately owned and, as such, has little or no federal or state protections (Bailey 1999).

The BLM reported on the amount of habitat disturbed or lost solely to right-of-way activities, primarily roads, within five townships managed by the Carlsbad Field Office. The minimum loss of habitat was 1.2 km^2 over a total of 99.4 km and the maximum was 3.75 km^2 over a total of 322.5 km., with an average of 2.5 km^2 of habitat lost over an average 220.5 km. per township (BLM 1994: 3-31). It is important to note that this average loss of almost 3% of the remaining habitat includes only 5 of the approximately 30 townships that contain the BLM's "core Prairie-Chicken habitat", and *does not* include habitat loss due to oil and gas well pads, land conversion, use of tebuthiuron or livestock grazing. The report concluded:

"The cumulative loss of habitat within occupied Lesser Prairie-Chicken range is a major limiting factor in the management of the population and to their overall population dynamics..." (BLM 1994: 3-31).

Habitat fragmentation is a result of the same processes that produce habitat loss, but is accompanied by a separate set of effects on native species. Habitat fragmentation leads to the isolation of populations, a factor that limits genetic dispersal and increases the sensitivity of small populations to stochastic events such as drought and fire (Brussard and Gilpin 1989, Soule et al. 1992, Bolger et al. 1997). Small and isolated populations may suffer from inbreeding depression and genetic drift as a result of reduced genetic variability (Westemeier et al. 1998). In a related phenomenon, fragmentation of habitat also creates barriers to population dispersion and colonization, as well as restricting males' abilities to find mates, leading to a loss of reproductive potential (Morrissey 1995). Habitat fragmentation can also lead to the partitioning of habitat patches that are too small to contain an individual's home range (USFWS 1998). Such small patches may not contain the full range of habitat sub-types necessary to support Lesser Prairie-

Chicken mating, nesting, brood rearing and over-wintering requirements. Based on Crawford and Bolen (1976) and Copelin (1963), Bailey (1999) reported that a minimum area of 31 km^2, with at least 63% rangeland is necessary to support a stable Lesser Prairie-Chicken population. Average individual female non-nesting home range size is 2.31 km^2, and the average individual female nesting home range size is 0.92 km^2 (Riley et al.1994).

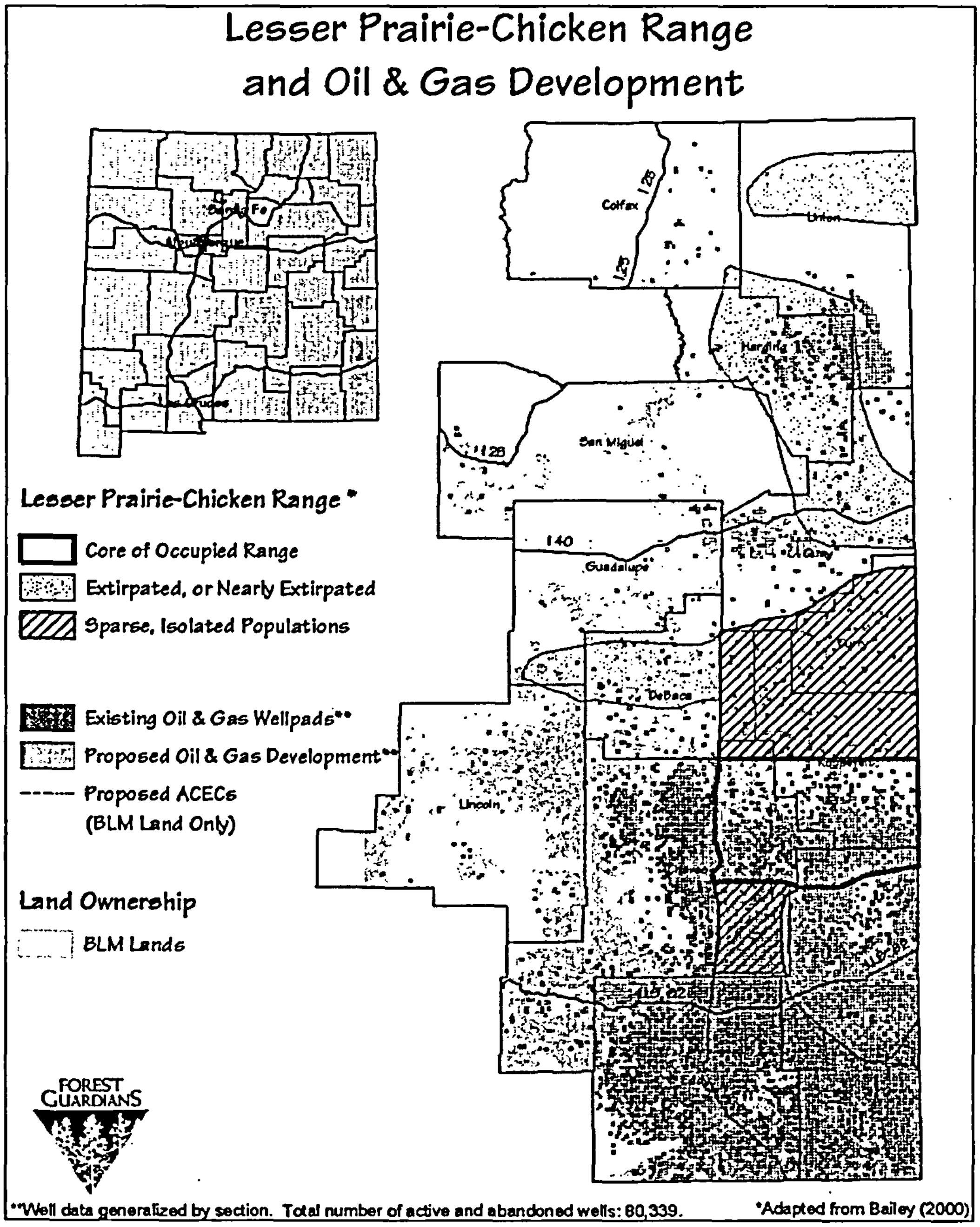

Figure 6. Distribution of Oil and Gas well pads and infrastructure. Lesser Prairie-Chicken habitat in the east-central and south-eastern portions of the bird's range in New Mexico has been disturbed by over 80,000 oil and gas well pads and accompanying infrastructure.

Oil & Gas Development

One widespread land conversion phenomenon that has been taking place on public lands since the second half of the nineteenth century is the conversion of rangeland for oil and gas well pads and associated facilities, roads and pipelines (Figure 5). Bailey reported an average of 16,187 m^2 of land required for an oil or gas well pad, although the number varied widely (1999). The roads created for oil and gas activities are known to attract off road vehicle users, a factor which may lead to further habitat degradation (Bailey 1999). An extensive network of above ground power lines and other support structures has also been erected to provide power to the well pad machinery (Figure 5). The effect of this infrastructure development has been to provide nesting, roosting and foraging sites to ravens (nest predators) and other predatory birds (e.g. Red-tailed Hawk, Great Horned Owl) that would not commonly occur in the shinnery-oak-grassland community (Smith, personal communication). In addition to the effect of oil and gas development on habitat loss and predator populations, there is strong anecdotal evidence that the noise from these activities disrupts Prairie-Chicken lekking behavior, further affecting reproduction success and decreasing usable habitat (Smith et al. 1998). In one study, in the extreme southeastern portion of the historic New Mexico range, only one of 29 historic leks was found to be active, with oil pump noise being moderate to high at 45% of the sites and low at 28% of the sites (Smith et al. 1998). The authors concluded that significant noise pollution from oil and gas well pad operations may be playing a role in extirpating the Lesser Prairie-Chickens from areas south of 33°N through interference with the male vocalizations and attraction of mates during the lekking season. A recent report by researcher Best (2001) recommended the removal of restrictions on oil and gas development in the Carlsbad Resource Area, in part based on the misconception that Lesser Prairie-Chickens never consistently occupied the area south of highway 380. The report contains a number of faulty assumptions too lengthy to review here, but the purpose of the report is clearly to endorse the position of the petroleum industry, that areas where Lesser Prairie-Chickens have been extirpated should be opened to oil and gas activities. This critique has been supported by a number of independent reviewers, including reviewers from the New Mexico Natural Heritage Program and the Wildlife Management Institute (Johnson 2001 unpublished, Carpenter and Riley 2001 unpublished). The study fails to recommend sound habitat management procedures that would allow for the recovery and re-colonization of birds back into areas of historical occupancy. A few important critiques of the document include; 1) a failure to review the majority of Lesser Prairie-Chicken grey literature, a significant source of information for this species, 2) a failure to consult recognized historical reports from widely cited ornithologists, including F.M. Bailey and J. Ligon 3) an erroneous assertion that Prairie-Chickens never permanently occupied areas south of highway 380 and, 4) incorrect reporting on historical lek activity, including the number of active leks south of highway 380 discovered by BLM biologists in the years 1998-2001, historical lek records between US 82 and the Eddy-Chaves County line, and historical lek records south of US 62-180 (Johnson 2001, unpublished). In recognition of the negative impacts of oil and gas development on the Lesser Prairie-Chicken, the BLM does not currently allow new drilling within 200 m. of a lek site, with certain exceptions. However, the Fish and Wildlife Service (2001) has reported that current restrictions on new oil and gas drilling within 200 m. of a lek site are inadequate to protect the species nesting habitat, because Prairie-Chickens are known to nest within a 3 km. radius of leks.

Applications of Tebuthiuron

In addition to the detrimental effects of grazing noted above, a significant additional adverse effect is the application of tebuthiuron to remove shinnery-oak (Morrissey 1995, Peterson and Boyd 1998, Bailey 1999). This form of land conversion has been widely used by the livestock industry, as well as federal and state land managers to convert shinnery-oak rangelands to grasslands for use by cattle. Jackson and DeArment (1963) found that the application of herbicides was a primary factor limiting the recovery of Prairie-Chicken populations. The authors documented a decrease in Prairie-Chicken numbers the year following application of herbicides, concomitant with a 25% decrease in shinnery-oak cover and a total cessation of acorn production for two years following the application. The importance of shinnery-oak for cover and as a food source has already been described in detail above. In addition, the sandy soils in which Shinnery-oak are found are subject to very high rates of wind erosion. The soil stabilization characteristics of shinnery-oak make it important in natural erosion control, a factor that alone should preclude its widespread removal (R. Peterson, personal communication). Shinnery-oak rarely reproduces sexually, relying primarily on vegetative reproduction to persist (Peterson and Boyd 1998). Historical reports document the failure of shinnery-oak to expand into old fields, even after fifty years and even when the fields are surrounded by mature stands of shinnery-oak (Peterson and Boyd 1998). Therefore, the application of tebuthiuron in shinnery-oak-grassland communities is particularly detrimental to Prairie-Chickens because shinnery-oak removal is virtually permanent (Peterson and Boyd 1998). Peterson reported that the BLM has applied tebuthiuron to over 404.7 km^2 in east-central and south-eastern New Mexico. Although the BLM halted application of herbicides on the Caprock Management Area beginning at its inception in the 1960s, brush control with tebuthiuron resumed prior to 1984, despite the fact that the BLM's Roswell Area Biologist expressed concern that the use of tebuthiuron may be harming Lesser Prairie-Chicken populations (Morrissey 1995).

A recent BLM proposal to use Tebuthiuron on the Bogle-Vest Camp Allotment in Chaves County, ostensibly for the benefit of the Lesser Prairie-Chicken, shows that the BLM still fails to acknowledge the detrimental effects of Tebuthiuron application on the shinnery-oak-grassland community and the Lesser Prairie-Chicken. The proposed Tebuthiuron application would impact 18.6 km^2 of the total 40.5 km^2 of shinnery (46%) within the allotment. Thus, almost half of the existing community will be affected. The application area is based on the existing BLM guidelines that call for tebuthiuron treatment in areas where the relative density of shinnery oak is greater than 40%, a methodology that is flawed. Because the absolute density of oak is not specified, an area may have very little vegetation at all, but if oak comprises greater than 40% of the relative density of the vegetation, tebuthiuron may be applied (Bailey 1999). The effect of even 'light' tebuthiuron application in halting acorn production in subsequent years has already been addressed. The Environmental Assessment (EA) for the proposed project takes for granted that the proposed action is needed to enhance wildlife habitat, but fails to demonstrate how the proposed action will do so.

Predation

Prairie-chickens are known to have a variety of natural predators within their range in New Mexico. Known Prairie-Chicken predators include coyote, fox, raccoon, snakes and raptors. Because of their large clutch sizes and ground nesting habits, Prairie-Chickens are especially vulnerable to nest predation. The impacts of predators upon Lesser Prairie-Chicken numbers depend on the predator / prey ratio and also on the quality of Prairie-Chicken habitat as it relates to escape cover (Bailey 1999). As habitat becomes degraded by factors such as grazing and brush eradication with tebuthiuron, escape cover quality is also degraded and Prairie-Chickens become more susceptible to predation.

Lack of Adequate Protections

Within New Mexico, the Lesser Prairie-Chicken has state protected status in name only. The Lesser Prairie-Chicken is listed in the state Game Code as a 'protected species' and currently the hunting season on the bird is closed. U.S. Forest Service managed land in New Mexico does not afford the Lesser Prairie-Chicken any special protective status (Morrissey 1995). The U.S. Fish and Wildlife Service has declined statutory protection of this species under the ESA, although the agency admits it warrants listing (USFWS 1998). The New Mexico State Land Office (SLO) holds 21% of the historic range lands of the Lesser Prairie-Chicken. Although the SLO is currently undergoing an internal restructuring to allow for the integration of land management for native flora and fauna, its primary mandate is to generate revenue for state beneficiary institutions (Bailey 1999). As such, the SLO provides no current protections for the Lesser Prairie-Chicken. The New Mexico Department of Game and Fish manages over 85 km^2 on 29 PCAs in Roosevelt, De Baca and Lea Counties. Bailey reported that habitat on at least two of the PCAs has been degraded by careless oil and gas development, and that several of the areas are not completely fenced to exclude livestock and trespass cattle and fence repair continues to be a problem (1999, J.Bailey, personal communication). Additionally, these small managed areas are probably not adequate to maintain diverse populations of Lesser Prairie-Chickens in the face of the continued threats to the species throughout its range.

The BLM in New Mexico has done extensive monitoring of Lesser Prairie-Chickens in recent decades (Bailey 1999). The BLM's response to threats facing the Lesser Prairie-Chicken cannot be underestimated, as it controls 19% of the overall historic range and 53% of the historic range of the species in southeastern New Mexico (Bailey 1999). The BLM Roswell Field Office Management Plan / EIS (RMP) restricts oil and gas activities during the mating season in recognition of the probable detrimental effects of oil and gas noise on Prairie-Chicken mating success (RMP AP3-5). Additionally, the BLM will not allow new drilling within 200 m. of a lek site, with certain exceptions. However, the Fish and Wildlife Service (2001) has reported that current restrictions on new oil and gas drilling within 200 m. of a lek are inadequate to protect the species nesting habitat, because Prairie-Chickens are known to nest within a 3 km. radius of leks.

The RMP also commits to avoiding core Prairie-Chicken areas when locating rights-of-way and recognizes Prairie-Chicken needs in defining the BLM's objectives for shinnery-oak-dune communities, RMP 2-71 and RMP 2-47, respectively (Bailey 1999). Unfortunately, BLM guidelines for application of tebuthiuron are still inadequate. The RMP calls for chemical control of shinnery-oak only in areas where oak is greater than 40% of the vegetative community. However, the minimum size area that may be measured for treatment is not specified and neither is the absolute density of oak having greater than 40% of the vegetative composition. Therefore, an area may have very little vegetation at all, but if oak comprises greater than 40% of the relative density of the vegetation, tebuthiuron may be applied (Bailey 1999).

In 1979 the BLM committed to constructing 21 exclosures of 0.08-0.6 km^2 each to provide nesting habitat for the Lesser Prairie-Chicken, a commitment that was never acted upon and finally rescinded in 1984 (Bailey 1999). The BLM also supported the treatment of 404.7 km^2 of shinnery-oak with tebuthiuron during the period 1984-1993 despite objections raised by the NMDGF. Finally, the BLM was to have initiated a study of Prairie-Chicken populations in 1995, but the study was canceled due to budget cuts (Morrissey 1995). The BLM established standards for livestock grazing in January of 2000 and a final Record of Decision was released in 2001, listing the Lesser Prairie-Chicken as a special status species and outlining the prescription for management.

However, the management prescription does not recognize the necessity of residual vegetation as wildlife cover, or as nesting cover for the Lesser Prairie-Chicken (BLM 2000, BLM 2001).

Importantly, re-introductions of Prairie-Chickens have been tried over a dozen times, with no success (Giesen 1998 and 2000). Wild Lesser Prairie-Chickens have been translocated in New Mexico and Colorado to areas of the species' historical range where it had been extirpated. Although the normal movements of birds are confined to 3-4 km. of lek sites, with occasional reports of flocks traveling as far as 40 km., translocated birds have traveled hundreds of km. to return to their points of capture (Taylor and Guthery 1980a).

ACEC Criteria

To be nominated, potential ACECs must meet relevance and importance criteria as outlined in BLM manual 1613. The following narrative will detail the relevance and importance of the proposed Lesser Prairie-Chicken ACEC.

Relevance

The proposed Lesser Prairie-Chicken ACEC meets, at a minimum, three of the relevance criteria as outlined in the BLM Manual 1613 (Criteria 1, 2, and 3). First, the area contains "a significant historical, cultural or scenic value" (Criterion 1). The proposed Lesser Prairie-Chicken ACEC contains a significant historical value in that it is home to a once wide-ranging bird species that has co-evolved with the shinnery-oak-grassland ecosystem of eastern New Mexico. Ample historical evidence exists to document the impact of these once abundant birds and their habitat on the historical communities of east-central and southeastern New Mexico (Ligon 1927, Colvin 1914, Ligon 1927, Peterson and Boyd 1998). Colvin (1914) reported that "flocks of 500 or more" birds gathered to feed on the waste grains of the earliest agricultural fields that were converted from the native shrub-grasslands. Writing of the shinnery-oak-grassland community type, Josiah Gregg remarked in 1844:

There was not a drop of water to be found... An immense sand-plain... being entirely barren of vegetation in some places, while others were completely converted with a extraordinary diminutive growth which has been called *shin-oak*... heavily laden with acorns... (from Peterson and Boyd 1998).

Today, both the once ubiquitous Lesser Prairie-Chicken and the shinnery-oak-grasslands they inhabit are dwindling due to land conversion, brush control, livestock grazing and oil and gas development (Copelin 1963, Jackson and DeArment 1963, Crawford 1974, Crawford and Bolen 1976, Taylor and Guthery 1980b, Riley et al. 1992, USFWS 1998, Bailey 1999). The establishment of the proposed Lesser Prairie-Chicken ACEC would help to ensure the preservation of this historical and culturally valuable component of the short-grass prairie of east-central and southeastern New Mexico.

Second, the proposed Lesser Prairie-Chicken ACEC is "a fish and wildlife resource" (Criterion 2). The area includes habitat for many threatened, endangered and sensitive species of wildlife including the Black-tailed Prairie Dog and the Sand Dune Lizard, each of which currently merit listing under the ESA (Table 1). A complete list of shinnery-oak-grassland community associates is included in Appendix A.

Table 1. Sensitive species, in addition to the Lesser Prairie-Chicken, within the proposed ACEC. Source: NMNHP NHIS database.

S1 – Critically Imperiled
S2 – Imperiled
S4 – Apparently Secure
B – Breeding
N – Non-breeding

G2- Imperiled
G3- Vulnerable
G4- Apparently Secure
G5- Secure
TU- Subspecies Unrankable

FWS – U.S. Fish and Wildlife Service
USFS – U.S. Forest Service

Species	Federal Listing?	State Listing?	ABI State Rank?	ABI Global Rank?	Sensitive?
Baird's Sparrow (*Ammodramus bairdii*)	N	Threatened	S2N	G4	FWS
Ferruginous Hawk (*Buteo regalis*)	N	N	S2B,S4N	G4	FWS
Western Burrowing Owl (*Athene cunicularia* hypugea)	N	N	S4B,S4N	G4TU	FWS
Swift Fox (*Vulpes velox*)	N	N	S2	G3	USFS
Arizona Black Tailed Prairie Dog (*Cynomys ludovicianus* arizonensis)*	Candidate	N	S2	G4	N
Sand Dune Lizard (*Sceloporus arenicolus*)	Candidate	Threatened	S1	G2	FWS USFS
Texas Horned Lizard (*Phrynosoma cornutum*)	N	N	S4	G4G5	FWS
White-tailed Deer *Odocoileus virginianus* texana	N	Sensitive	S4	G5	N

* Some question still exists about the possible subspecific status of certain populations, especially that in the Tularosa Basin of southern New Mexico (Hubbard 1992). However, the full species is itself a candidate for ESA listing (67 Fed. Reg. 40657-40679 (June 13, 2002)).

Baird's Sparrow – The Baird's Sparrow is an endemic species of the northern Great Plains that winters in southern New Mexico, south-eastern Arizona, western Texas and Northern Mexico (http://mountain-prairie.fws.gov/bairdssparrow/facts.htm). The Baird's Sparrow prefers taller to mixed grass prairie habitat. The bird exhibits little site fidelity from season to season, being found primarily where rangeland conditions are very good to excellent. Baird's sparrow populations have declined throughout the species range due to habitat loss from livestock grazing of grasslands and the conversion of native prairie and grasslands to agricultural lands (http://mountain-prairie.fws.gov/bairdssparrow/facts.htm). The nomadic nature of the Baird's Sparrow suggests that the species will become increasingly more rare in southeastern New Mexico as long as the shinnery-oak-grassland community continues to be degraded by livestock grazing and conversion to other uses.

Ferruginous Hawk – The ferruginous hawk is found in open habitats such as grasslands, shrubsteppes, shrublands, deserts, and the outer edges of pinyon-pine forests throughout western North America (http://arnica.csustan.edu/esrpp/fh.htm). The birds are common in New Mexico, including the shinnery-oak-grassland community of south-central and southeastern New Mexico throughout the winter months. Ferruginous hawks depend on only a few prey species, including cottontails, black-tailed jackrabbit, ground squirrels, and pocket gophers (http://arnica.csustan.edu/esrpp/fh.htm). Ferruginous hawk populations continue to decline throughout the species range, principally due to habitat loss through conversion to agriculture and other land uses, livestock grazing of rangelands and population control of the small mammals that serve as the species food source (http://arnica.csustan.edu/esrpp/fh.htm).

Western Burrowing Owl – The burrowing owl is found in the open desert grasslands and shrublands of the American west from Canada to Mexico (http://arnica.csustan.edu/esrpp/burowl.htm). The burrowing owl is capable of digging its own nest sites, but often nests within the abandoned dens of other animals, including prairie dogs. The burrowing owl is an opportunistic feeder, and the many insects of the shinnery-oak-grasslands make up a large part of its diet, as do small ground dwelling mammals such as mice, rats, gophers and squirrels (http://arnica.csustan.edu/esrpp/burowl.htm).

Swift Fox – The Swift Fox occurs within widely scattered and isolated pockets of remnant short and mid-grass prairie throughout the western United States. Swift Fox utilize dens throughout the year, either digging their own or enlarging the burrows of other animals (USFWS 2000). The Swift Fox are opportunistic feeders, and will eat small mammals, birds, insects, fruits and carrion. The Swift Fox has decreased southward from its historical distribution, which was once from Canada to Mexico. Today the species is extirpated from Canada, Montana and the Dakotas, and is found in smaller numbers in Wyoming, eastern Colorado and Kansas, but is found throughout most of its historic range in Oklahoma and New Mexico (USFWS 2000). Swift Fox populations are threatened primarily by conversion of rangeland for agricultural purposes, hunting and the widespread use of strychnine used to kill wolves and coyotes (USFWS 2000).

Arizona Black-tailed Prairie Dog – Prairie dogs are not commonly found within the shinnery-oak-grassland community type and are not found at all in areas where tall grasses are abundant (Peterson and Boyd 1998). Evidence suggests that the presence of prairie dogs in the shinnery-oak-grasslands is the result of livestock grazing of tall grasses, and the destruction of prairie dog predators (Peterson and Boyd 1998). Despite their historical absence from the shinnery-oak-grassland community, prairie dogs have played an important role in the ecology of Lesser Prairie-Chickens in recent times, as their colonies have been known to be associated with lek sites (Davis et al. 1981, Morrissey 1995, Bailey 1999).

Sand Dune Lizard – The sand dune lizard is the only reptile species restricted to the shinnery-oak-grassland community, and within New Mexico the lizard is limited to the south-eastern portion of the state (Peterson and Boyd 1998). The sand dune lizard occurs mainly in deep sand areas, but forages under the shinnery oak and is usually found within 4-6 ft. of an oak (Peterson and Boyd 1998). Treatment of shinnery oak with tebuthiuron is prohibited within the known habitat of the sand dune lizard, but continued livestock grazing as well as oil and gas development threatens the long term survival of the species (Bailey and Painter 1994).

Texas Horned Lizard – The Texas horned lizard is found throughout large parts of Texas, Oklahoma, Kansas and New Mexico in the arid and semi-arid grassland and shrubland communities. The lizards live primarily in sparsely vegetated, sandy areas with nearby colonizes of harvester (*Pogonomyrmex* spp.) ants http://www.tpwd.state.tx.us/nature/wild/reptiles/thlizard.htm). The lizards are ant specialist feeders and eat primarily harvester ants, but will feed on other insects such as grasshoppers, isopods and beetles (http://animaldiversity.ummz.umich.edu/accounts/phrynosoma/p._cornutum$narrative.html). Texas horned lizard populations have declined recently, principally due to the invasion of the imported fire ant, *Solenopsis invicta,* loss of habitat through land conversion processes, and the use of pesticides on harvester ants (http://animaldiversity.ummz.umich.edu/accounts/phrynosoma/p._cornutum$narrative.html).

White-tailed Deer - The white-tailed deer is thought to be restricted to the shinnery-oak-grasslands within New Mexico, and the shinnery-oak-grassland is the principal community type that harbors this subspecies throughout its range in the southern Great Plains (Peterson and Boyd 1998). The acorns of shinnery oak are a principal food source for the White-tailed Deer, along with forbs and other plants of the shinnery-oak-grasslands. There is some confusion as to the subspecies present in the shinnery-oak-grasslands of New Mexico. Bailey (1905) and Ligon (1927) ascribed the white-tailed deer to its own seperate subspecies, while modern sources typically describe the species as a member of the subspecies *texanus* (NMNHP database, unpublished).

The continuing degradation of the shinnery-oak-grassland community type, considered together with the fact that the New Mexico BLM controls almost 75% of the remaining Prairie-Chicken habitat in public ownership makes the proposed Lesser Prairie-Chicken ACEC invaluable for maintaining biodiversity within the shinnery-oak-grassland ecosystem of east-central and southeastern New Mexico and in promoting the recovery and continued existence of the Lesser Prairie-Chicken as well as the additional sensitive species described above.

Finally, the proposed Lesser Prairie-Chicken ACEC is important as "a natural process or ecosystem" (Criterion 3). The area contains the majority of the remaining shinnery-oak-grassland habitat on public lands that the Lesser Prairie-Chicken requires for survival within its range in New Mexico. This habitat is becoming increasingly degraded through brush control, land conversion, livestock grazing and oil and gas development (Bailey 2000, USFWS 1998, Riley et al. 1992, Taylor and Guthery 1980b, Copelin 1963, Jackson and DeArment 1963, Crawford and Bolen 1976, Crawford 1974). Because the vast majority of this ecosystem exists on private lands that are largely unregulated, the proposed Lesser Prairie-Chicken ACEC is critical in maintaining and restoring the historical quality and health of the shinnery-oak-grassland ecosystem, and preserving this habitat for both the survival of the Lesser Prairie-Chicken and as a reservoir of biodiversity for this threatened ecosystem.

Importance

The proposed Lesser Prairie-Chicken ACEC meets, at a minimum, two of the importance criteria as outlined in the BLM Manual 1613 (Criteria 1 and 2). First, the area contains "more than locally significant qualities which give it special worth, consequence, meaning, distinctiveness, or cause for concern, especially compared to any similar resource" (Criterion 1). The Lesser Prairie-Chicken's original range encompassed 358,000 km^2 throughout eastern New-Mexico, the Texas panhandle, western Oklahoma, southwestern Kansas and southeastern Colorado, with small populations possibly existing in northeastern Colorado and extreme northwestern Nebraska (Colvin 1914, Ligon 1927, Bailey 1928, Taylor and Guthery 1980b, Morrissey 1995). Today, its known range has been reduced by 92%, and of the species remaining range, only 5% remains in public ownership. Significantly, of the remaining lands in public ownership, the New Mexico BLM controls almost 75%, thereby making the proposed Lesser Prairie-Chicken ACEC regionally important as both a habitat reserve and "genetic bank" vital to the survival and recovery of the species over its entire current and former range (Taylor and Guthery 1980b). Additionally, the continued degradation of this public rangeland through livestock grazing, brush control, oil and gas development and land conversion makes the area an immediate cause for concern. Finally, as the remaining BLM lands represent the majority of Prairie-Chicken habitat on public lands, the proposed Lesser Prairie-Chicken ACEC clearly has special worth compared to similar resources, the majority of which exist on private lands. The area is already, and continues to be of major interest to birdwatchers worldwide, who visit the Caprock Wildlife Area from around the world (Dr. Kris Johnson, personal communication).

Second, the area "has qualities or circumstances that make it fragile, sensitive, rare, irreplaceable, exemplary, unique, endangered, threatened, or vulnerable to adverse change" (Criterion 2). The Fish and Wildlife Service, in reviewing the 1995 petition to list the Lesser Prairie-Chicken as endangered or threatened, gave the petition a "warranted, but precluded" ruling, and continues to find the species imperiled, acknowledging:

> "based on all currently available information, we find that the threats to the Lesser Prairie-Chicken, as outlined in the 12-month finding, remain unchanged and Lesser Prairie-Chickens continue to warrant federal listing as threatened" (Fish and Wildlife Service 2001).

The proposed Lesser Prairie-Chicken ACEC contains the majority of the remaining shinnery-oak-grassland habitat on public lands that the species requires for survival within its range in New Mexico. This habitat is increasingly subject to eradication through the use of tebuthiuron for conversion to grasslands for cattle grazing, both on public and private lands. The continued degradation of this area through brush control, livestock grazing and oil and gas development clearly makes it both "fragile" and "vulnerable to adverse change", as has been repeatedly documented (Copelin 1963, Jackson and DeArment 1963, Crawford 1974, Crawford and Bolen 1976, Taylor and Guthery 1980b, Riley et al. 1992, USFWS 1998). Finally, the well- documented failure of shinnery-oak to revegetate areas that have been converted to other land uses clearly makes the shinnery-oak-grassland habitat within the proposed Lesser Prairie-Chicken ACEC "irreplaceable" (Peterson and Boyd 1998).

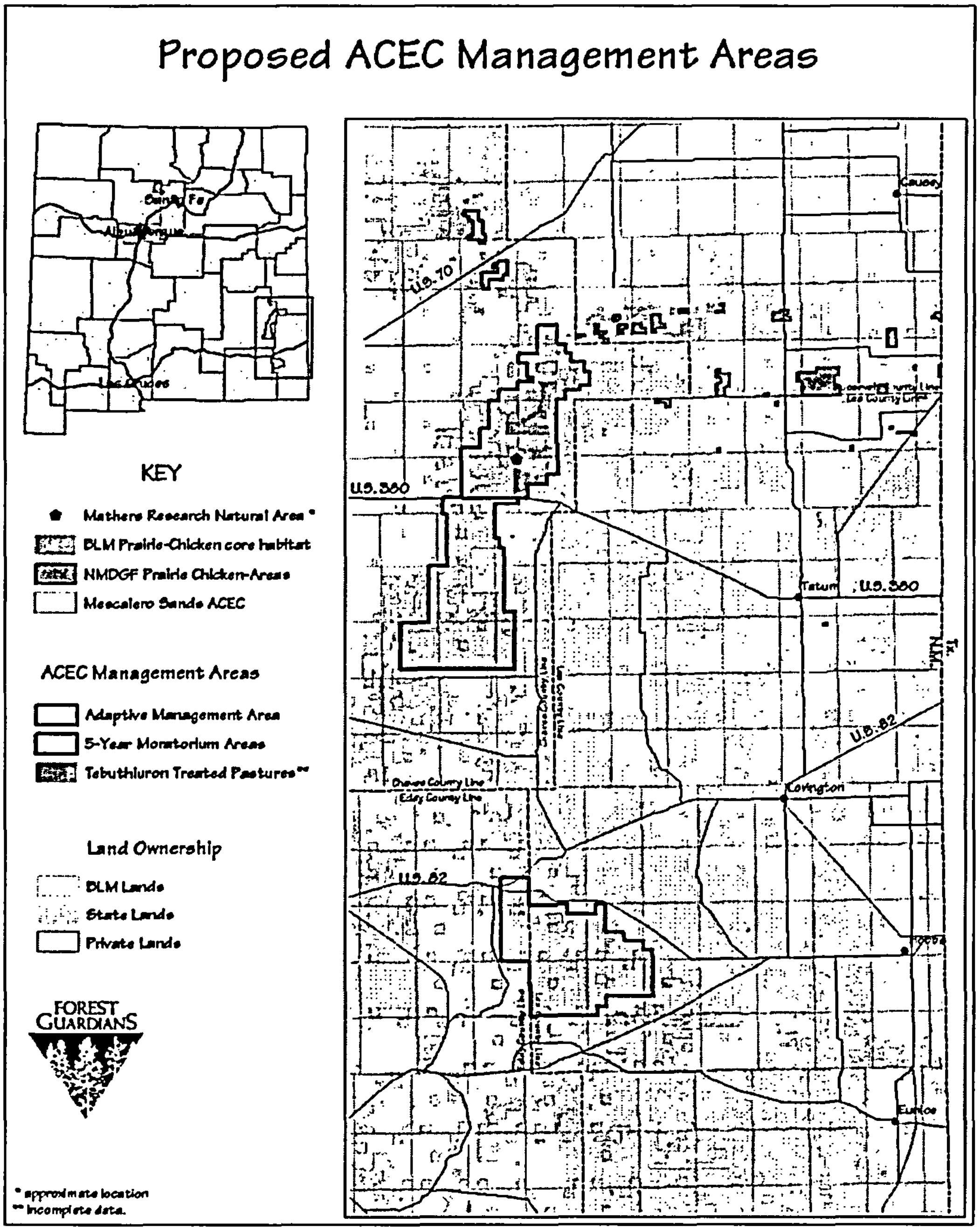

Figure 7. Management areas for BLM Lands within the proposed Lesser Prairie-Chicken ACEC. Two different management areas are proposed by the petitioners. The Adaptive Management Area contains stable populations and is designed to develop a management plan for the ACEC. The 5-year moratorium areas target populations where conditions are critical and emergency protections are needed.

Suggestions for Special Management

The petitioners propose the following management recommendations for the proposed Lesser Prairie-Chicken ACEC. The petitioners believe that in order to ensure proper management, a committee of state, federal and academic wildlife specialists should be convened to draft a comprehensive adaptive management plan for the shinnery-oak-grassland ecosystem and Lesser Prairie-Chicken habitat within the proposed Lesser Prairie-Chicken ACEC. The primary and overriding purpose of all management actions undertaken by this committee or by the agency within the ACEC boundaries must be to recover and sustain Lesser Prairie-Chicken populations. The committee should also re-convene on a regular basis to systematically review the results of the management plan and implement any necessary changes.

The petitioners propose that the committee should develop and implement an adaptive management strategy for the Lesser Prairie-Chicken ACEC, with the following guidelines. In light of the continuing decline of Prairie-Chicken population numbers and habitat conditions, the petitioners have delineated areas of critical importance, where populations are sparse and disconnected and/or extirpation is imminent (Moritorium Areas, Figure 7). These areas include the populations south of highway 380 and north of 33°N, the Querecho Plains populations and adjacent historic habitat, and the isolated northern populations adjacent to U.S. 70. Within these areas, the petitioners propose a 5-year moratorium on livestock grazing, as well as new oil and gas activity to allow for an emergency habitat recovery period. Monitoring of habitat conditions and Lesser Prairie-Chicken leks should be used to test the hypothesis that conditions for the species will improve during the 5-year moratorium.

The remaining portion of the proposed Lesser Prairie-Chicken ACEC contains the "core" populations of the Lesser Prairie-Chicken, and consists mainly of the Caprock Wildlife Area (Figure 7). Lesser Prairie-Chicken populations in this area are more stable and in less imminent danger, therefore the petitioners propose that this area be used to test adaptive management methodologies for enhancing and sustaining Lesser Prairie-Chicken habitat. These methodologies may include conservative livestock grazing, as well as herbicide applications, so long as the activities promote the recovery and stability of Lesser Prairie-Chicken populations. All management strategies implemented by the committee within the Adaptive Management Area should be applied with rigorous experimental design. It is the belief of the petitioners that this Adaptive Management Area can be used to develop sound criteria for recovering Lesser Prairie-Chickens, and that these criteria can then be applied to the other parts of the proposed Lesser Prairie-Chicken ACEC, once the emergency moratorium has ended. The Petitioners respectfully furnish the following list of suggestions for testing within the Adaptive Management Area based on eliminating the previously mentioned threats to the Lesser Prairie-Chicken:

1. Experimental reductions in livestock grazing within the Adaptive Management Area of the proposed Lesser Prairie-Chicken ACEC. Active lek sites should be used as experimental unit; with treatments applied to randomly selected, geographically independent lek sites. A minimum of five lek sites should be used for each grazing treatment. Treatments should include no grazing on at least 2.6 km^2 within 2.4 km. of lek sites and light intensity grazing (after June 30) on at least 2.6 km^2 within 2.4 km. of lek sites.
2. A permanent ban on the use of Tebuthiuron. The lethality of the herbicide tebuthiuron on shinnery oak precludes its safe application. If herbicides are deemed useful by the management team to retard growth of shinnery oak and promote grass cover, other less lethal herbicides should be used in place of tebuthiuron.
3. An expansion of the restrictions on certain oil and gas related activities during the lekking season. Based on the USFWS 2001 report, current restrictions on new oil and gas drilling within 200 m. of a lek are inadequate to protect the species, which is known to nest within 3 km. of a lek. These restrictions should be extended to areas within a minimum of 1.5 km. of an active lek.
4. Special management of the corridor areas that link the known east-central and southeast populations of Lesser Prairie-Chicken to facilitate migration and genetic exchange between these increasingly fragmented populations.

5. Encourage the use of the Conservation Reserve Program for any qualifying adjacent state and private lands within the external boundaries of the proposed Lesser Prairie-Chicken ACEC, to facilitate recovery of healthy shinnery-oak-grassland community conditions on non-public land.
6. Pursue the acquisition of private lands from willing sellers, as well as land exchanges with the New Mexico State Land Office within the boundaries of the proposed Lesser Prairie-Chicken ACEC.

The Adaptive Management Area also contains a number of large, tebuthiuron treated pastures where high concentrations of the herbicide were applied (Figure 7). These areas have been treated to enhance conditions for livestock grazing and surveyors have repeatedly failed to locate birds nesting or raising broods within the treated pastures (K. Johnson, personal communication). Therefore, the petitioners suggest that these areas be exempt from the livestock management recommendations discussed here, and that livestock grazing simply comply with all applicable federal law in these areas.

In addition to the recommendations above, the petitioners also respectfully submit the following recommendations to apply to BLM lands within the whole of the proposed Lesser Prairie-Chicken ACEC:

1. All of the area within the proposed Lesser Prairie-Chicken ACEC should be withdrawn from "locatable mineral" entry, non-energy mineral leasing and salable mineral entry.
2. Collection of plant material should be prohibited unless authorized by special permit, and then only for educational or scientific applications.
3. Vehicular traffic should be restricted to "designated" roads only, all other roads should be closed to all but administrative uses.
4. Recreational activity and access to the proposed Lesser Prairie-Chicken ACEC should be limited during the lekking season by special permit.
5. Management for recreational purposes should be limited to primitive recreational opportunities only.

6. No authorizations for new rights of way within 1.5 km of an active lek should be allowed.
7. The intentional introduction of any exotic plants or animals should be prohibited.

Conclusion

The protection of habitat on a large enough scale to protect ecosystem processes and allow for the continuation of stable community structures with a minimum of outside intervention is increasingly recognized as critical for the long-term survival of at-risk species (Soule and Simberloff 1986, Soule et al. 1992). The Lesser Prairie-Chicken populations of east-central and southeastern New Mexico occupy the largest remaining area of relatively intact shinnery-oak-grassland habitat on public lands (USFWS 1998, Bailey 1999). The majority of existing Prairie-Chicken habitat occurs on private land. Due to the limited feasibility of regulating activities on private lands, the prospects for recovering the species in these areas are less hopeful than on public land. This further elevates the relative importance of public lands for recovering the species. The New Mexico BLM controls almost 75% of the species' remaining habitat that is in public ownership, making the proposed Lesser Prairie-Chicken ACEC one essential component to the recovery of the species over its entire current and former range (Taylor and Guthery 1980b). The petitioners believe that the proposed Lesser Prairie-Chicken ACEC is on a scale large enough to provide for the recovery and maintenance of stable Lesser Prairie-Chicken populations in a fully functioning ecosystem. The unique combination of factors affecting the survival of the Lesser Prairie-Chicken presents an outstanding opportunity for the BLM to take the lead in conserving and recovering this species and for protecting the shinnery-oak-grassland ecosystem it inhabits.

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Appendix A. Wildlife Species of Chaves, Eddy and Lea Counties, NM; Shinnery-oak-grassland associates

Source: Biota Information System of NM (http://fwie.fw.vt.edu/states/nm.htm)

Species Common Name	Species Scientific Name
Tiger Salamander	*Ambystoma tigrinum*
Couch's Spadefoot	*Scaphiopus couchii*
Plains Spadefoot	*Spea bombifrons*
New Mexico Spadefoot	*Spea multiplicata*
Ornate Box Turtle	*Terrapene ornata*
Collared Lizard	*Crotaphytus collaris*
Longnose Leopard Lizard	*Gambelia wislizenii*
Greater Earless Lizard	*Cophosaurus texanus*
Lesser Earless Lizard	*Holbrookia maculata*
Texas Horned Lizard	*Phrynosoma cornutum*
Roundtail Horned Lizard	*Phrynosoma modestum*
Sand Dune Lizard	*Sceloporus arenicolus*
Eastern Fence Lizard	*Sceloporus undulatus*
Side-blotched Lizard	*Uta stansburiana*
Chihuahuan Spotted Whiptail	*Cnemidophorus exsanguis*
Prairie Racerunner	*Cnemidophorus sexlineatus* viridis
Great Plains Skink	*Eumeces obsoletus*
Texas Blind Snake	*Leptotyphlops dulcis* dissectus
Glossy Snake	*Arizona elegans*
Ringneck Snake	*Diadophis punctatus*
W. Hognose Snake	*Heterodon nasicus*
Night Snake	*Hypsiglena torquata*
Desert Kingsnake	*Lampropeltis getula* splendida
Milk Snake	*Lampropeltis triangulum*
Coachwhip	*Masticophis flagellum*
Gopher Snake	*Pituophis melanoleucus*
Texas Longnose Snake	*Rhinocheilus lecontei*
Ground Snake	*Sonora semiannulata*
Plains Blackhead Snake	*Tantilla nigriceps*
W. Diamondback Rattlesnake	*Crotalus atrox*
Western Rattlesnake	*Crotalus viridis*
Desert Massasauga	*Sistrurus catenatus* edwardsii
Turkey Vulture	*Cathartes aura*
Swainson's Hawk	*Buteo swainsoni*
Red-tailed Hawk	*Buteo jamaicensis*
Ferruginous Hawk	*Buteo regalis*
Golden Eagle	*Aquila chrysaetos* canadensis
Merlin	*Falco columbarius*
Lesser Prairie-Chicken	*Tympanuchus pallidicinctus*
Great-horned Owl	*Bubo virginianus*
Northern Flicker	*Colaptes auratus*

Appendix A. Wildlife Species of Chaves, Eddy and Lea Counties, NM; Shinnery-oak-grassland associates. Source: Biota Information System of NM (http://fwie.fw.vt.edu/states/nm.htm)

Species Common Name	Species Scientific Name
Scissor-tailed Flycatcher	*Tyrannus forficatus*
Dark-eyed Junco	*Junco hyemalis*
Brown-headed Cowbird	*Molothrus ater*
Desert Cottontail Rabbit	*Sylvilagus audubonii*
Thirteen-lined Ground Squirrel	*Spermophilus tridecemlineatus*
Ord's Kangaroo Rat	*Dipodomys ordii*
N. Grasshopper Mouse	*Onychomys leucogaster*
Coyote	*Canis latrans*
Kit Fox	*Vulpes macrotis*
Swift Fox	*Vulpes velox*
Common Gray Fox	*Urocyon cinereoargenteus* scottii
American Badger	*Taxidea taxus berlandieri*
Mule Deer	*Odocoileus hemionus*
White-tailed Deer	*Odocoileus virginianus* texana
Jerusalem Cricket	*Stenopelmatus mescaleroensis*

LESSER PRAIRIE-CHICKEN SURVEYS

ON THE NATIONAL ENRICHMENT FACILITY

PROPOSED PROJECT SITE

Prepared for:

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Rio Rancho, NM 87124

Prepared by:

Eagle Environmental, Inc.

30 Fonda Rd.
Santa Fe, NM 87508
(505) 247-9632

May 5, 2004

Purpose of Work

The purpose of this project was to conduct a baseline survey for Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) in the proposed National Enrichment Facility (NEF) site near Eunice, New Mexico (T21S, R38E, Section 32).

Methods

Lesser Prairie Chicken (LPCH) surveys were conducted at six listening stations. Stations were placed in and around the NEF site and spaced 0.5 to 1.0 miles apart (Figure 1; Table 1). Station locations were marked with a Garmin geographic positioning system (GPS) in differential correction mode.

Surveys were designed to identify the sounds of courting males on leks during the lekking period. Between ½ hour before sunrise and 2 hours after sunrise, each station was surveyed for up to 20-minutes. The close spacing of points and long survey duration maximized the ability to detect LPCHs. The stations were surveyed in the opposite order on the first and second mornings. Field data sheets are attached to the end of this document. All bird species detected in the survey area were recorded and are listed in the Appendix.

Vegetation in the survey area was evaluated for potential to provide LPCH habitat. Vegetation transect surveys conducted in 2003 were reviewed, and a general assessment of potential habitat in the area was made.

Table 1. Survey station latitude and longitude in decimal degrees (WGS 84 datum).

Survey Station	Latitude	Longitude
LP1	32.4311557	-103.0645315
LP2	32.4328675	-103.0825277
LP3	32.4410576	-103.0824883
LP4	32.4464499	-103.0923249
LP5	32.4427806	-103.073244
LP6	32.432821	-103.0993294

Results

No LPCHs were detected during the surveys and no visual sightings or aural detections were made (Table 2). The closest known LPCH lek to the NEF site is in the northern part of the same township (T21S, R38E). We are unable to disclose the location of this lek in this document.

Vegetation sampling conducted in 2003 indicated the predominant vegetation community on the NEF site is Plains sand scrub (GL Environmental, Inc. 2003). In this community, shinoak (*Quercus havardii*) is the dominant plant species. A variety of other shrubs and grasses adapted to sandy soils occur in the project area (GL Environmental, Inc. 2003). Additional plant communities in the survey area include grassland and mesquite woodland (Figures 2-7).

Overall, the potential LPCH habitat on the site is of moderate quality and minimal area. Along the north-south gravel road in the center of section 32, and northwest of the NEF site in the southeast quarter of section 30, Plains sand scrub provides the best potential habitat for LPCH in the survey area (Figures 3 and 6). Although this habitat type may be important to LPCH (Massey 2001), three vegetation characteristics on the NEF site may make the habitat of low suitability to LPCH. These characteristics include relatively low grass and shrub canopy cover (16.7% and 9.6%, respectively; GL Environmental 2003), scattered-to-dense honey mesquite (*Prosopis glandulosa*) stands, and relatively short grass height.

The eastern portion of section 32 harbors dense mesquite and provides no suitable LPCH habitat. In addition, just west of section 32 the shinoak-grassland communities merge into shortgrass prairie and provide no suitable LPCH habitat.

Through the life cycle of the facility, the habitat is expected to become less suitable to LPCH because of the reduction in Plains sand scrub vegetation due to construction and the addition of structures and disturbances that will likely discourage use of the site by LPCH.

Table 2. Summary of surveys conducted and weather conditions

Survey Date		Time	Temperature (°F)	Mean Wind Speed (mph)	Comments
5 April, 2004					No LPCHs detected
	Start	06:39	47	6	Light, intermittent sprinkles
	End	08:52	53	5	Rain lessened
6 April, 2004					No LPCHs detected
	Start	6:04	48	3	Clear and cool
	End	8:29	52	5	Clear and cool

In the project area, potential LPCH predators include the Swainson's hawk (*Buteo swainsoni*). A pair of Swainson's hawks appeared likely to nest in the north-central part of section 32. An adult hawk was observed making undulating courtship display flights during the 6 April visit. A second Swainson's Hawk pair was observed making courtship displays southwest of section 32. Along a private road in section 33, power lines provide ample raptor perches.

The potential for human disturbance in the area is high. A waste disposal site, gravel quarry, and county landfill are located within approximately one mile of the center of Section 32. There also is a contaminated soils cleanup facility located approximately two miles west of Section 32. Railroad tracks run east-west through the northern part of Section 32 (Figure 6).

Potential Impacts

In the project area, potential negative impacts to LPCH are limited. No LPCHs were detected and there is little potential habitat in the survey area. In addition, high human disturbance and predator potential in the area make it unlikely that LPCHs will colonize the area.

Cumulative regional impacts to LPCH are predicted to be low because of limited habitat availability in the immediate project area, the absence of LPCH on the site, and the apparently small number of known LPCH areas near the site. Although the cumulative effects of losing small habitat patches is a real concern for the viability of LPCH populations, the effect of losing isolated sub-optimal habitat patches currently not used by LPCH may be small. This project will likely remove approximately 1-3 km^2 of potential habitat from the potential LPCH range, which is small relative to the currently occupied range of LPCH in New Mexico (estimated at 16,757 km^2 as of 1999 by Bailey and Williams 2000).

Literature Cited

Bailey, J.A., and S. Williams III. 2000. Status of the Lesser Prairie-Chicken in New Mexico, 1999. Prairie Naturalist 32:157-168.

GL Environmental, Inc. 2003. Vegetation survey report: National Enrichment Facility, Lea County, New Mexico. Typescript.

Massey, M. 2001. Long-range plan for the management of Lesser Prairie Chickens in New Mexico 2002-2006. New Mexico Department of Game and Fish Report, July 2001.

Figure 1. Map of the survey area showing survey stations LP1-LP6 in and around the NEF project site (T21S, R38E, section 32). From USGS 7.5 minute quad Eunice, N. Mex.

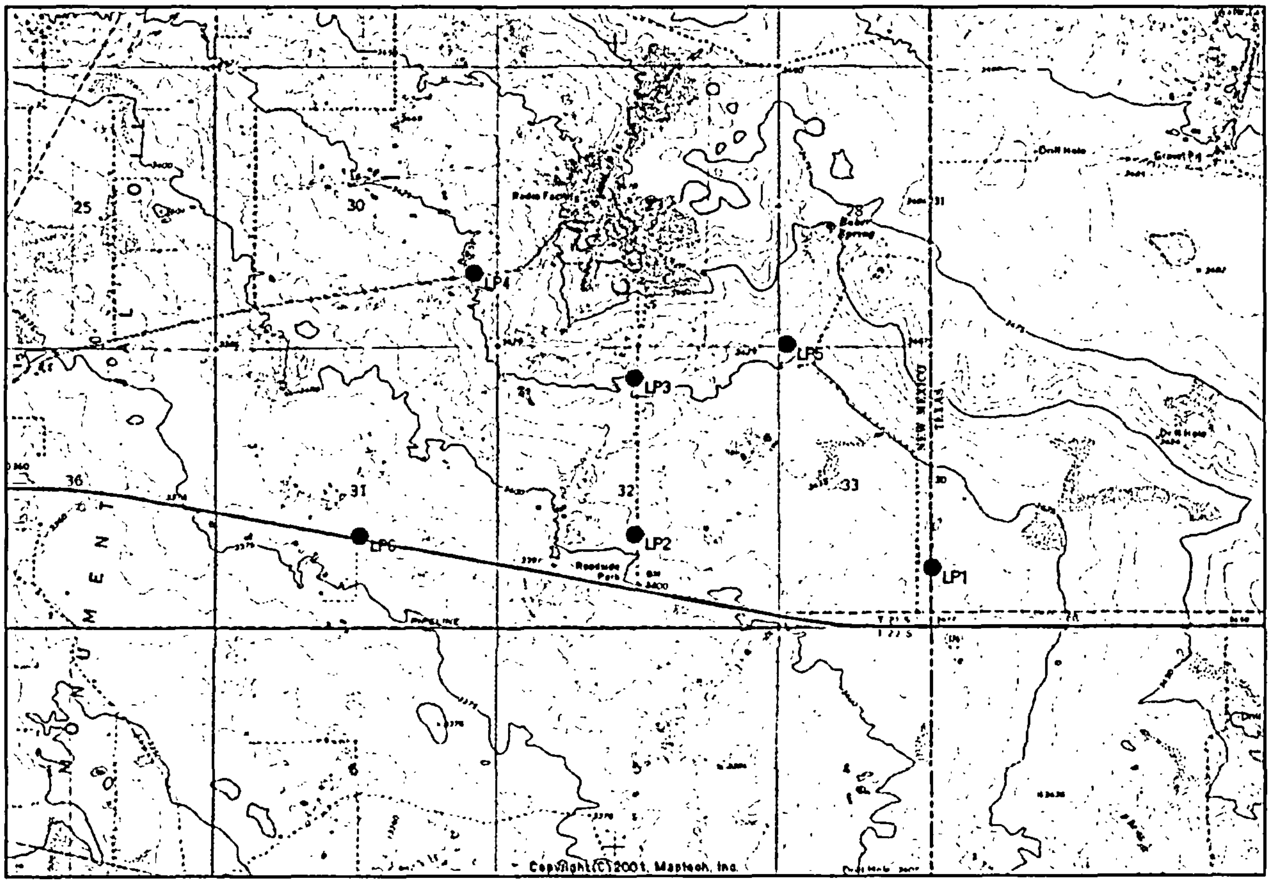


Figure 2. Habitat at survey station LP1 (north aspect)

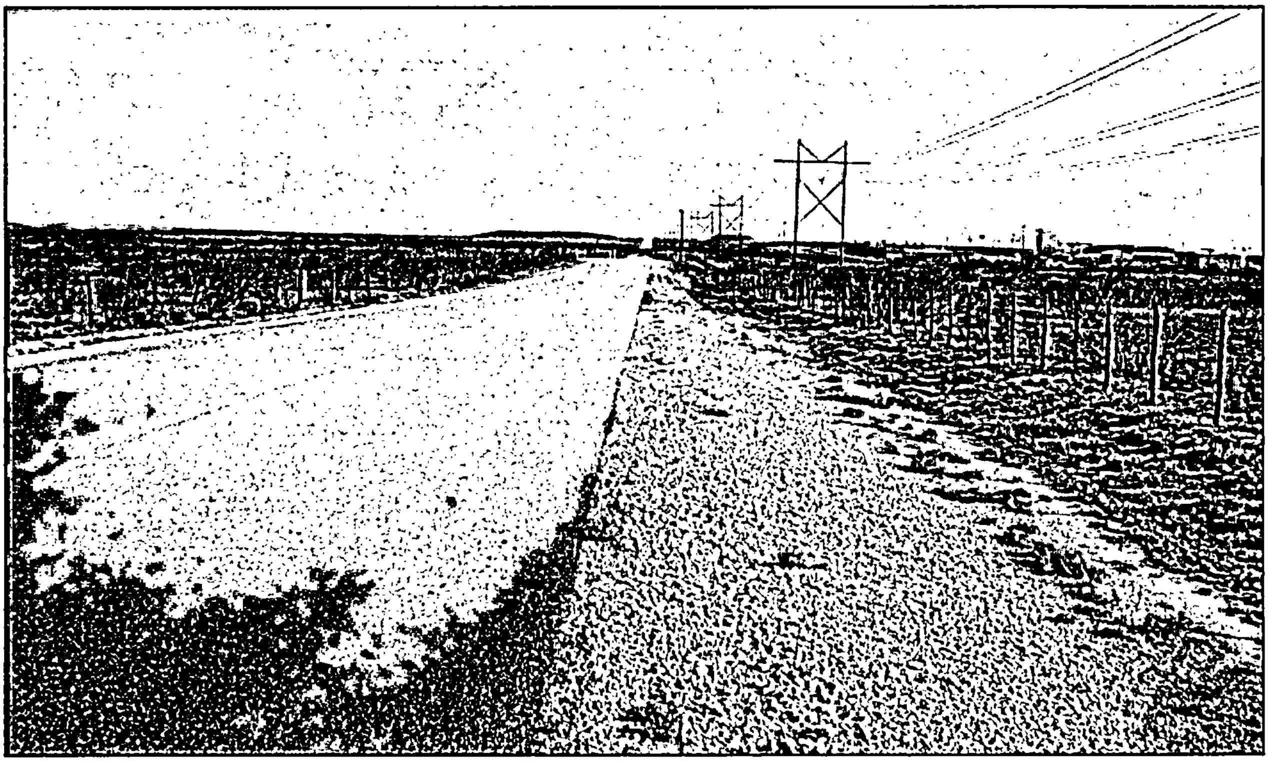


Figure 3. Habitat at survey station LP2 (north aspect)

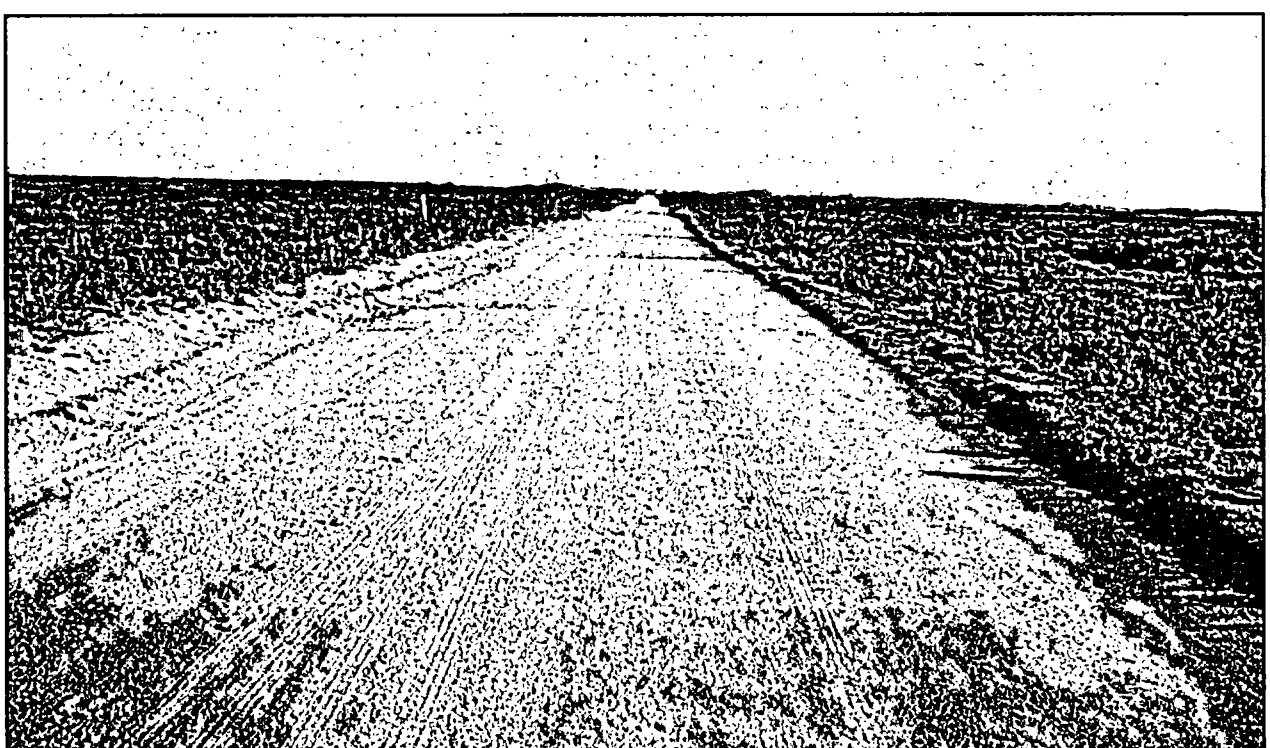


Figure 4. Habitat at survey station LP3 (south aspect)

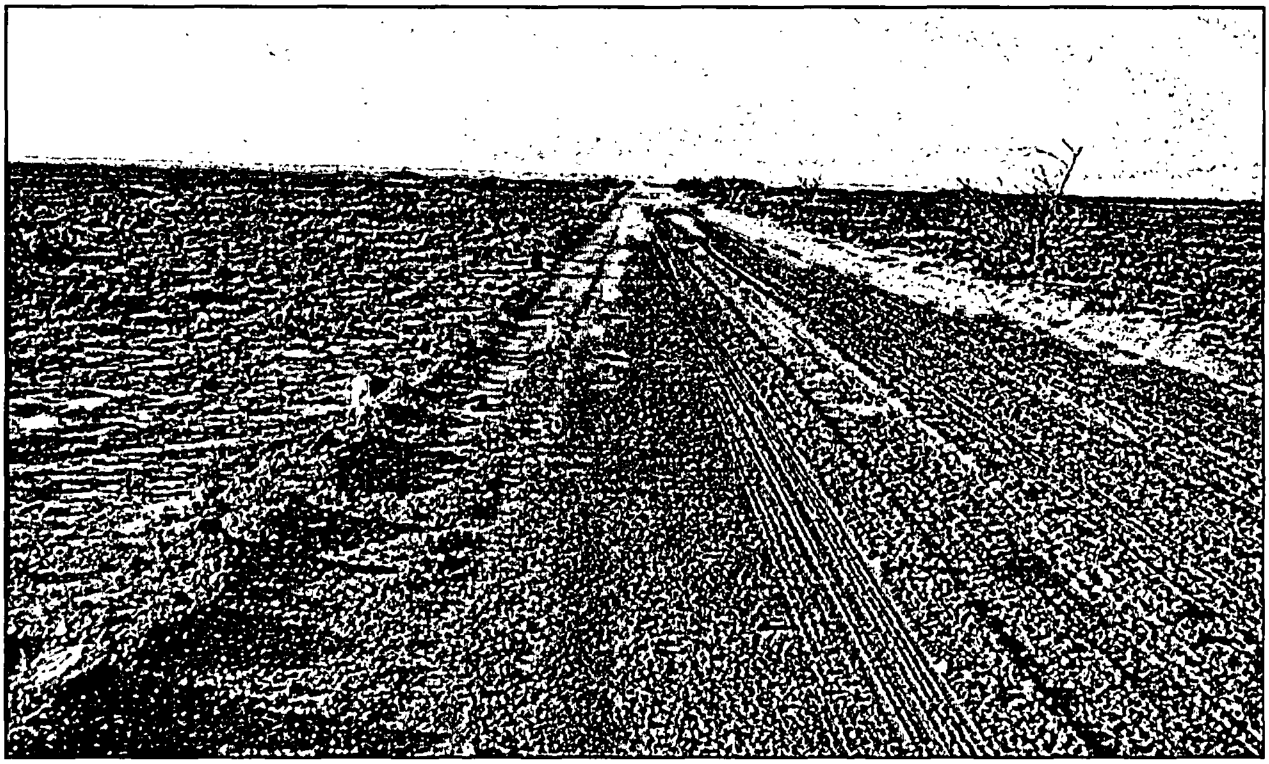


Figure 5. Habitat at survey station LP4 (south aspect)

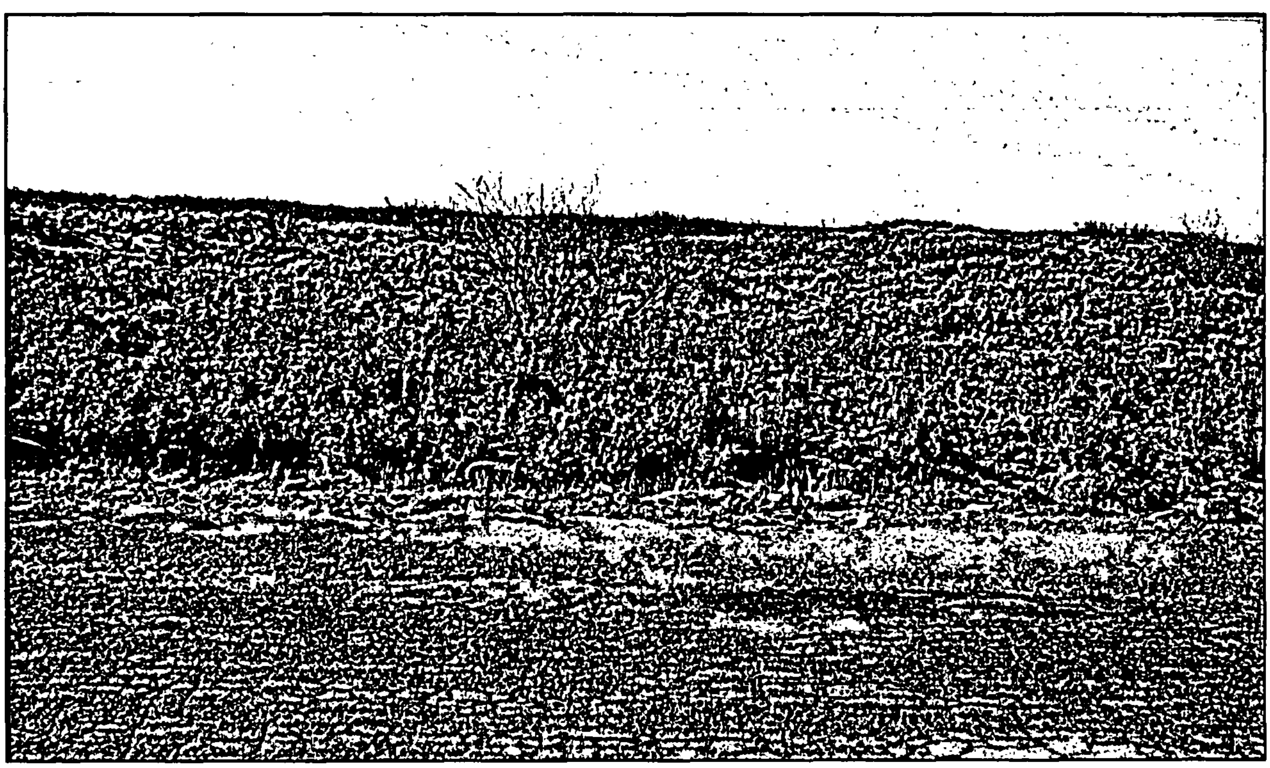


Figure 6. Habitat at survey station LP5 (north aspect)

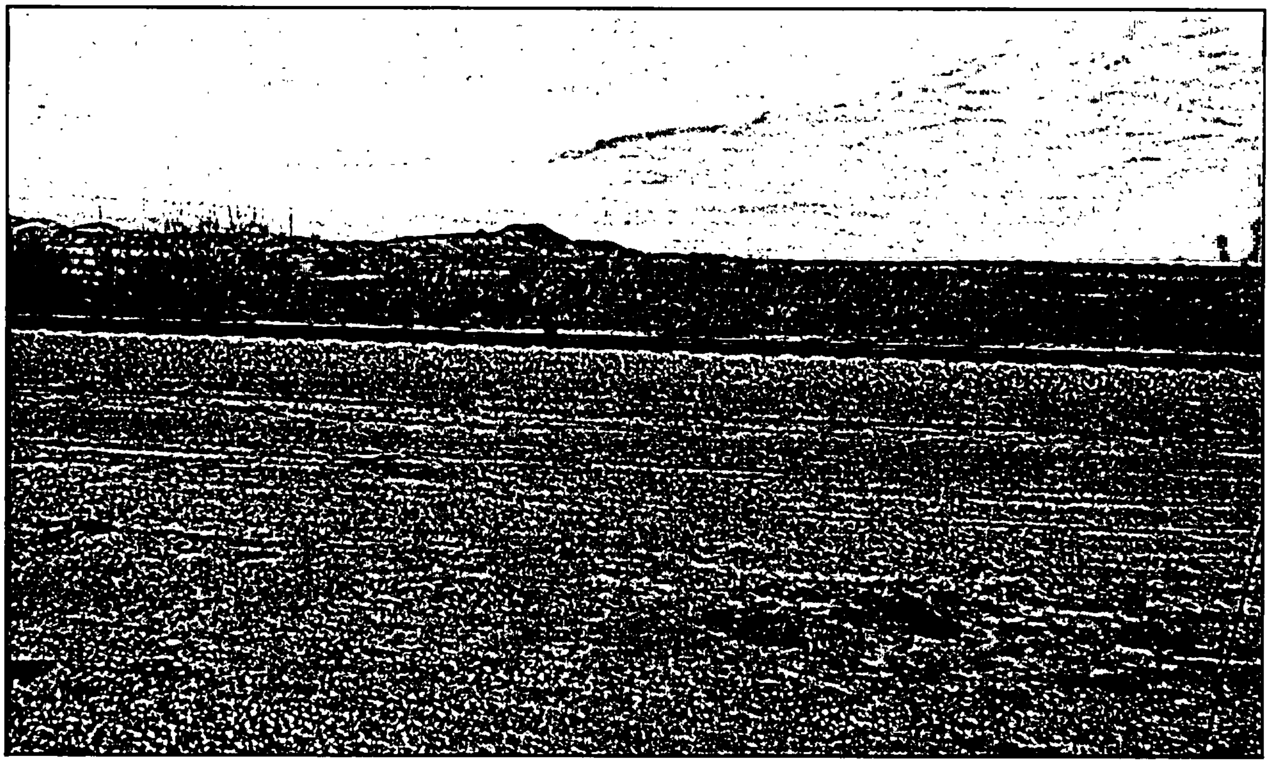
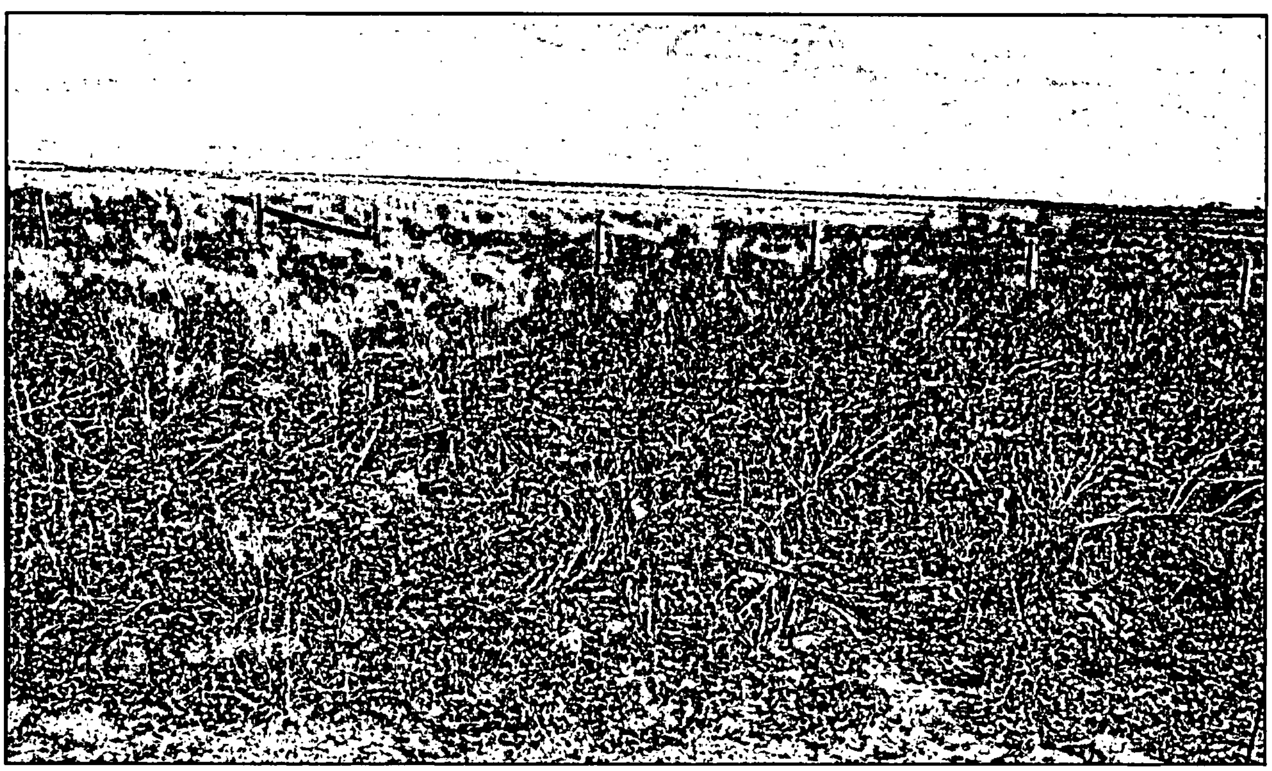


Figure 7. Habitat at survey station LP6 (north aspect)



Appendix. Common and scientific names of bird species detected in the survey area.

Common Name	*Scientific Name*
Swainson's Hawk	*Buteo swainsoni*
American Kestrel	*Falco sparverius*
Scaled Quail	*Callipepla squamata*
Killdeer	*Charadrius vociferus*
Mourning Dove	*Zenaida macroura*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Loggerhead Shrike	*Lanius ludovicianus*
Chihuahuan Raven	*Corvus cryptoleucus*
Cactus Wren	*Campylorhynchus brunneicapillus*
Bewick's Wren	*Thyromanes bewickii*
Northern Mockingbird	*Minimus polyglottos*
European Starling	*Sturnus vulgaris*
Vesper Sparrow	*Pooecetes gramineus*
Lark Bunting	*Calamospiza melanocorys*
Red-winged Blackbird	*Agelaius phoeniceus*
Eastern Meadowlark	*Sturnella magna*
Great-tailed Grackle	*Quiscalus mexicanus*
House Finch	*Carpodacus mexicanus*

9541-0093

(LOCATION: T21S, R38E, SEC 30, 31, 32, 33) SEE REPORT FOR POINT COORDINATES

New Mexico Lesser Prairie-chicken PCA Survey

1. Prairie-chicken Area: NOT ASSIGNED - NEF SITE
2. Date: 04 / 05 / 2004 (Month / Day / Year)
3. Observer: JOHN P. DELONG
4. Local Sunrise (from chart): 6:34 AM FROM LPS UNIT ☐ Mountain Standard ☒ Mountain Daylight

5.

	Start	Stop
Time	6:39	8:52
Wind Velocity	B-2	B-2
Temp	47 °F	53 °F

CAUTION: Any information collected from private lands is confidential and subject to the state game commission reg. 19 NMAC 33.4. DO NOT make copies of completed original. DO NOT share locations of leks with others.

Stop # or Listening Pt #	6. Time of Stop	7. # Leks Heard	8. Compass Bearing to Lek	9. # Leks Seen	10. # of Chickens Seen per Lek	11. Noise	12. Lek Location & Land Status (Unknown=Blank) UTM or Twnshp, Range, Sec, 1/4
LP1 (1)	6:39					☒ Moderate	☒ Priv
LP2 (2)	7:05					☒ Moderate	☒ State
LP3 (3)	7:32					☒ Moderate	☒ State
LP4 (4)	7:53					☒ Moderate	☒ Priv
LP5 (5)	8:16					☒ Low	☒ Priv
LP6 (6)	8:37					☒ High	☒ Priv
(7)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(8)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(9)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(10)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(11)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(12)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(13)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(14)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
(15)	:					☐ None ☐ Low ☐ Moderate ☐ High	☐ Priv ☐ BLM ☐ State ☐ PCA
14. Totals		Ø		Ø	Ø		

Write comments on rear

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954-0093

(LOCATION: T21S, R38E, SEC 30, 31, 32, 33) SEE REPORT FOR POINT COORDINATES

New Mexico Lesser Prairie-chicken PCA Survey

1. Prairie-chicken Area: NOT ASSIGNED - NEF SITE
2. Date: 04 / 06 / 2004 (Month / Day / Year)
3. Observer: JOHN P. DELONG
4. Local Sunrise (from chart): 6:34 AM FROM GPS UNIT ☐ Mountain Standard ☒ Mountain Daylight
5. Start — Time: 6:04; Wind Velocity: B-1; Temp: 48 °F
   Stop — Time: 8:29; Wind Velocity: B-2; Temp: 52 °F

CAUTION: Any information collected from private lands is confidential and subject to the state game commission reg. 19 NMAC 33.4. DO NOT make copies of completed original. DO NOT share locations of leks with others.

Stop # or Listening Pt #	6. Time of Stop	7. # Leks Heard	8. Compass Bearing to Lek	9. # Leks Seen	10. # of Chickens Seen per Lek	11. Noise	12. Lek Location & Land Status (Unknown=Blank) UTM or Twnshp, Range, Sec, 1/4
LP6 (1)	6:04					☒ High	☒ Priv
LP4 (2)	6:31					☒ Low	☒ Priv
LP5 (3)	6:57					☒ Low	☒ Priv
LP3 (4)	7:21					☒ Low	☒ State
LP2 (5)	7:44					☒ Moderate	☒ State
LP1 (6)	8:09					☒ Moderate	☒ Priv
(7)	:						
(8)	:						
(9)	:						
(10)	:						
(11)	:						
(12)	:						
(13)	:						
(14)	:						
(15)	:						
14. Totals		Ø		Ø	Ø		

Write comments on rear

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RCRA
PERMIT APPLICATION
FOR A HAZARDOUS WASTE
STORAGE, TREATMENT AND DISPOSAL FACILITY
ANDREWS COUNTY, TEXAS

SECTION VI. GEOLOGY REPORT

Prepared for:

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Terra Dynamics Incorporated
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Project No. 92-152
March 1993

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VI. Introduction

Waste Control Specialists, Inc. (WCS) proposes to permit a Class I hazardous waste landfill pursuant to 40 CFR Part 270, 31 TAC Chapter 305 (C) and (D) and 31 TAC Chapter 335. This report, which addresses the geologic aspects of the Resource Conservation and Recovery Act (RCRA) Part B Permit Application, has two companion reports which focus on the various engineering and geotechnical considerations of the Part B Permit Application. These two companion reports, provided under separate cover, were prepared by AM Environmental, Inc. (AME) of Austin, Texas (engineering design) and Jack H. Holt and Associates, Inc. (JHA) also of Austin, Texas (geotechnical evaluation). Where engineering design and/or geotechnical aspects of the geologic report are addressed by one of the other two reports, this fact is noted in the geologic report table of contents as well as noted within the geologic report text.

The proposed WCS landfill site is located in northwest Andrews County, Texas, approximately 30 miles northwest of the City of Andrews (Figure VI.A.1). This site rests on a gently sloping plain with a natural slope of approximately 0.5 degrees. The site is underlain by Quaternary windblown sands, the Tertiary Ogallala Formation, and the Triassic Dockum Group.

Portions of the Ogallala Formation serve as the regional aquifer for the Southern High Plains. However, the proposed WCS landfill site is located on the western edge of the Caprock Escarpment where the Ogallala Formation has been mostly eroded away and appears to be locally dry.

Regionally, the erosional remnants of the Ogallala Formation are typically cemented with caliche and produce water only in relatively low topographic areas, following wet weather periods. However, the vertical downward migration of groundwater from the Ogallala Formation appears to be locally impeded by many feet of low hydraulic conductivity claystones, siltstones, and interbedded silty sandstones which comprise the upper portion of the Dockum Group.

A summary of the regional and local topography, physiography and geology is presented in Section VI.A. of this report. Section A.1. contains a discussion regarding the active geologic processes, including: fault identification; seismicity; surface lineations; and land surface subsidence. The potential for erosion is discussed in a separate report provided by AME.

A regional and local physiographic and topographic discussion is provided in Section A.2. A discussion regarding the regional geology, including surface geology and stratigraphy, is contained in Section A.3. The regional discussion addresses the conditions that exist in the area of West Texas and Southeast New Mexico.

Results of the site subsurface soils investigation are presented in Section A.4. The subsurface structure, stratigraphic complexity, and the general hydrogeologic framework of the proposed WCS landfill site are discussed in this section. The subsurface investigation procedures and geotechnical properties of the subsurface soils are discussed in a separate report provided by JHA.

Section VI.B. of this report provides a detailed discussion of the regional and local groundwater conditions. This discussion includes a review of regional aquifers (Section B.1.) as well as a presentation of local groundwater conditions and the underground sources of drinking water (USDW) (Section B.2.). The detection monitoring system is discussed in a separate report provided by AME.

Section VI.C. of this report pertains to groundwater monitoring exemption, while Section VI.D. focuses on unsaturated zone monitoring. Records regarding local oil and gas wells are provided in Appendix A. Soil boring and well completion logs are provided in Appendix B. Shallow geophysical logs are provided in Appendix C.

VI.A. Geology and Topography

A.1. Active Geologic Processes

Active geologic processes consist of faulting, seismicity, surface lineations, land surface subsidence and the potential for surface erosion. These processes are discussed in the following section, except the potential for surface erosion. This is discussed in the companion engineering design report prepared by AME.

A.1.1. Identification of Faults

Regional Tectonic Processes

The proposed WCS landfill site is located within the Permian Basin region of West Texas. The Permian Basin derives its name from the fact that it is underlain by extensive deposits of Permian sediments.

The proposed landfill site is situated over the north central portion of a prominent structural feature known as the Central Basin Platform (Figure VI.A.2). The Central Basin Platform is a deep-seated horst-like structure that extends northwest to southeast from Southeast New Mexico to eastern Pecos County, Texas. The Central Basin Platform is flanked by two prominent structural depressions known as the Delaware Basin and the Midland Basin.

From the Cambrian to late Mississippian, West Texas and Southeast New Mexico experienced only mild structural deformation that produced broad regional arches and shallow depressions (Wright, 1979). The Central Basin Platform served intermittently as a slightly positive feature during the early Paleozoic (Galley, 1958). During the Mississippian and Pennsylvanian, the Central Basin Platform uplifted along ancient lines of weakness (Hills, 1985). The Delaware, Midland, and Val Verde Basins began to form out of the previously existing broad limestone shelf and shale basin.

Late Mississippian tectonic events uplifted and folded the platform and were followed by more intense late Pennsylvanian and early Permian deformation that compressed and faulted the area (Hills, 1963). Highly deformed local structures formed ranges of mountains oriented generally parallel to the main axis of the platform (Wright, 1979). The overall structural configuration of the Permian Basin was essentially completed by the end of Wolfcampian time (early Permian) (Stone and Webster, 1983).

This period of intense, late Paleozoic deformation was followed by a long period of gradual subsidence and erosion that stripped the Central Basin Platform and other structures to near base-level (Wright, 1979). The expanding sea gradually encroached over broad eroded surfaces and truncated edges of previously deposited sedimentary strata. These strata included new layers of arkose, sand, chert pebble conglomerate and shale deposits, which accumulated as erosional products along the edges and on the flanks of both regional and local structures. Throughout the remainder of Permian, the Permian Basin slowly filled with several thousand feet of evaporites, carbonates, and shales (Stone and Webster, 1983).

From the end of the Permian until late Cretaceous, there was relatively little tectonic activity except for periods of slight regional uplifting and downwarping (Stone and Webster, 1983). During the early Triassic, the region was slowly uplifted and slightly eroded. These conditions continued until the late Triassic, when gentle downwarping formed a large land-locked basin in which the terrigenous deposits of the Dockum Group accumulated in alluvial flood plains and as deltaic and lacustrine deposits (McGowen, et. al., 1979).

The late Cretaceous to early Tertiary marked the beginning of the Laramide Orogeny, which formed the Cordilleran Range to the west of the Permian Basin. This orogeny uplifted the region to essentially its present position, supplying sediments for the Pliocene Ogallala Formation and initiating the present hydrologic regime (Stone and Webster, 1983). There have been no major tectonic events within the Permian Basin since that time, except for a period of minor volcanism during the late Tertiary in northeastern New Mexico (Stone and Webster, 1983). Slight Tertiary movement along Precambrian lines of weakness may have opened joint channels which allowed the circulation of groundwater into Permian evaporite layers (Hills, 1985). The near-surface regional structure may be locally modified by differential subsidence related to groundwater dissolution of Permian salt deposits (Gustavson et. al., 1980).

Regional Faulting

Two types of faulting were associated with early Permian deformation. Most of the faults were long, high-angle reverse faults with several hundred feet of vertical displacement that often involved the Precambrian basement rocks (Hills, 1985). The traces of these faults are shown on the Precambrian structure map provided in Figure VI.A.3. The second type of faulting is found along the western margin of the platform where long strike-slip faults, with displacements of tens of miles, are found (Harrington, 1963) (Figure VI.A.4).

The large structural features of the Permian basin are reflected only indirectly in the Mesozoic and Cenozoic rocks, as there has been virtually no tectonic movement within the basin since the Permian (Nicholson and Clebsch, 1961). The east-west and north-south regional cross-sections provided in Figures VI.A.5 and VI.A.6 illustrate this relationship. Figure VI.A.5 reveals the draping of the Permian and Triassic sediments over the Central Basin Platform structure, located approximately 7,000 feet beneath the present land surface. The faults that uplifted the platform do not appear to displace the younger Permian sediments. The northernmost fault on Figure VI.A.6, located at the Matador Uplift, terminates in lower Wolfcamp sediments.

A further comparison of the structure of the Devonian Woodford Formation (Figure VI.A.7) to the structure of the younger Upper Guadalupe Whitehorse Group (Permian) (Figure VI.A.8) indicates that the structure of the younger strata is intimately related to the older structure. However, structural mapping of the younger strata does not indicate the upward continuation of this faulting into the overlying, shallow section. Therefore, the regional information does not indicate the presence of post-Permian faulting within the regional study area. In addition, the local information does not indicate Holocene displacement of faults within 3,000 feet of the proposed WCS landfill site. This local information is discussed fully in Section A.4.2.

Seismicity

The Central Basin Platform is an area of moderate, low intensity seismic activity, based on observational data obtained from the National Geophysical Data Center of the National Oceanic and Atmospheric Administration (NOAA, 1992). A computer search for all recorded seismic activity within a 250 km (155 mile) radius of the proposed WCS landfill site (32.433N, 103.05W) provided a list of 84 seismic events (152 total, 68 suspected duplicates) during the period from 1931 to 1992 (Table VI.A.1, Figure VI.A.9). Seismic activity within the regional area has been reported as recently as 1992 (Table VI.A.1). However, all documented seismic events are located at distances which exceed the required search distance of 3,000 feet from the proposed WCS landfill site.

The proposed WCS landfill site is located within an earthquake risk area zone of (1), which represents an area where only minor damage is expected as a result of earthquake activity (Algermissen, 1969) (Figure VI.A.10). This is due, in part, to the relatively low level of tectonic activity occurring within the regional study area. While data are insufficient to equate any seismic activity with specific tectonic structures or to indicate the tectonic stress levels and direction, the seismic activity that has occurred within the region is postulated to be associated with salt dissolution or movement along faults near oil and gas secondary recovery operations (Davis et. al., 1989). A search of Texas Railroad Commission (TRC) and New Mexico Oil Conservation Commission (OCC) records conducted by Geosource, Inc., Austin, Texas, revealed no secondary recovery operations within a three-mile radius of the proposed WCS landfill site.

<u>Surface Lineations</u>

Surface lineations are straight physiographic features. Surface lineations are typically identified based on a review of surface geologic maps, surface topography maps, LANDSAT images and/or high altitude aerial photographs (Finley and Gustavson, 1981). In the Southern High Plains, surface lineations typically fall into a combination of six categories: 1) linear stream segments; 2) drainage lines along linear valleys; 3) prominent topographic breaks (scarps); 4) alignment of playa lakes; 5) geologic contacts; and 6) anomalous ground surface color tones based on aerial photographic data. More than 4,600 surface lineations have been identified in the area of the Southern High Plains, ranging in length from 1.2 miles up to 40 miles (Finley and Gustavson, 1981).

Surface lineations are often associated with subsurface joint patterns and faults (Finley and Gustavson, 1981). Fractures form in geologic material along planes of weakness where cohesion has been lost (Dennis, 1972). Joints, unlike faults, are defined as fractures along which movement has been negligible or absent (Dennis, 1972). The development of joints is an indication of the brittle behavior of rock, and is most evident in the Triassic and Permian sandstones within the area of the Southern High Plains (Finley and Gustavson, 1981). The poorly consolidated sediments of the Ogallala Formation do not exhibit well-developed jointing patterns. The caliche caprock material often exhibits an irregular, nearly orthogonal jointing pattern. Since few surface faults have been recognized and mapped in the Southern High Plains, it is the jointing of the geologic material that exerts the greatest control over regional surface lineation patterns (Finley and Gustavson, 1981).

Several mechanisms can account for the relationship between surface lineations and subsurface jointing. Joints form preferential planes that can be exploited by surficial and subsurface weathering processes. Consequently, drainage systems in the Southern High Plains are often classified as surface lineations, since their linear orientation is controlled by the joint systems that they exploit (Finley and Gustavson, 1981). In addition, joints can be propagated upward into geologically younger sediments, by the differential compaction and dissolution of underlying materials (Stone and Webster, 1983; Finley and Gustavson, 1981).

In the Southern High Plains, the orientation of subsurface joints and their associated surface lineations is controlled primarily by historical tectonic and structural trends (Finley and Gustavson, 1981). As shown in Figure VI.A.11, the dominant direction of orientation for surface lineations in the Southern High Plains is northwest to southeast, with a secondary orientation direction of northeast to southwest. Figure VI.A.11 shows a surface lineation with a northwest-southeast alignment in the approximate vicinity of Monument Draw. This feature is located in northern Andrews County about 14 miles from the proposed WCS landfill site. This is the closest lineament to the proposed landfill site observed by Finley and Gustavson (1981). Their data do not indicate the presence of surface lineations at the site.

Surface lineations were identified in the vicinity of the proposed WCS landfill site, based on an analysis of NASA color-infrared aerial photographs (Figure VI.A.12).

These lineations, including one that is inferred through the proposed WCS landfill site, correspond to linear drainage features and ground surface color tone anomalies.

The lineation inferred through the proposed WCS landfill site appears as an anomaly in the ground surface color tone on a NASA color-infrared aerial photograph (Figure VI.A.12). This anomaly may be caused by shadows, changes in soil moisture and vegetation etc. (Finley and Gustavson, 1981) and appears to be linked to relatively abrupt topographic variations.

A.1.2. Land Surface Subsidence

Land surface subsidence can be induced by fluid withdrawal or can be naturally occurring. Most commonly, fluid withdrawal is associated with groundwater pumpage and oil and gas production activities.

Subsidence Associated with Fluid Withdrawal

The water-bearing zones of the Ogallala Aquifer consist of poorly consolidated to unconsolidated sands and gravels at a depth greater than 300 feet below the ground surface (Knowles et. al., 1984). The aquifer is typically under water table conditions. Despite the potential withdrawal of groundwater in the general vicinity of the proposed WCS landfill site, pressure declines associated with groundwater pumpage are probably insufficient to induce significant subsidence.

Oil production is occurring in the area from consolidated sediments at depths greater than 3,000 feet. Therefore, no subsidence is expected to occur from the withdrawal of brine or oil and gas. No evidence of subsidence related to fluid withdrawal was found in the reviewed literature (Section VI.E.).

Naturally Occurring Subsidence

Subsidence can also be naturally occurring and result from sediment compaction and/or subsurface dissolution of soluble strata. As discussed previously, joint/lineament systems can be associated with sediment compaction and dissolution (Finley and Gustavson, 1981).

A zone of active salt dissolution and subsidence has been noted by Gustavson et. al. (1980, 1981) in Permian strata of the Northern Texas Panhandle. Collapse features are evidence of such subsidence. However, no salt dissolution collapse features are noted within the study area based on a search of the available literature. Shallow depressions are noted in the study area. However, these depressions can be attributed to eolian deflation, caliche caprock solution and compaction, animal activity, and differential compaction (Collins, 1990).

A.1.3. Potential for Erosion

The potential for erosion is discussed in the companion engineering design report provided by AME.

A.2. Physiography and Topography

A.2.1. Physiographic Setting and Climate

Physiographic Setting

The proposed WCS landfill site is located in West Texas, which lies within the southern portion of the North American Great Plains Physiographic Province (Stone and Webster, 1983). The site is situated in northwest Andrews County, Texas on the southwestern edge of the Southern High Plains (Llano Estacado) (Figure VI.A.13).

The Llano Estacado is an elevated area of low relief undulating plains encompassing a large area of West Texas and Eastern New Mexico. It is bounded by the Western Caprock Escarpment along the Pecos River Valley to the west and the Eastern Caprock Escarpment developed by the headward tributaries of the Colorado, Brazos, and Red Rivers to the east (Stone and Webster, 1983) (Figure VI.A.13). The Basin and Range Physiographic Province lies to the west of the Southern High Plains. The Rolling Plains Physiographic Province lies to the east and the Edwards Plateau lies to the south of the Southern High Plains. Cities on the approximate boundary of the Llano Estacado include Amarillo, Texas to the north, Big Spring, Texas to the east, Midland/Odessa, Texas to the south, and Roswell, New Mexico to the west.

Climate

The proposed WCS landfill site lies within an area of temperate, arid climate. The average annual precipitation is approximately 14.5 inches (Figure VI.A.14), with more than 70 percent of the precipitation occurring between early May and late October (TNRIS, 1992). The mean annual maximum temperature is 77.4°F and the mean annual minimum temperature is 49.4°F. The maximum average daily temperature of 95.5°F occurs in July and the minimum average daily temperature of 29.5°F occurs in January. The average annual wind speed is 10.4 miles per hour with the prevailing direction being southwesterly in the winter and south to southeasterly in the summer. The average free water evaporation exceeds precipitation by about 58 inches per year (Conner et. al., 1974).

A.2.2. Topographic Features, Soil and Land Use

Regional Topography

The proposed WCS landfill site is located on a gently sloping plain. The regional slope is toward the southeast at 8 to 10 feet per mile (Reeves, 1966), with the local slope oriented toward the southwest at 25 feet per mile (Plate VI.A.1). Regional topographic features include the Pecos River Plain to the south and west, the Mescalero Ridge to the northwest, Monument Draw and Rattlesnake Ridge to the west, and the Llano Estacado to the north and east (Nicholson and Clebsch, 1961) (Figure VI.A.13 and Plate VI.A.2).

The Southern High Plains can be characterized by relatively flat topography, cut by regional surface drainage features and punctuated by playa lakes (Stone and Webster, 1983). Drainage is not well defined and consists of ephemeral streams that channel runoff into the playas.

The Mescalero Ridge defines the western edge of the Llano Estacado. It is a nearly perpendicular cliff, facing west to southwest. The ridge has a relief of nearly 150 feet in western Lea County, New Mexico, but displays very little relief in eastern Lea County or western Andrews County due to a heavy cover of dune sand. The south to southeast sloping Pecos River Plain, to the west, is covered with dune sand resulting in a low-relief undulating topography.

The only major regional drainage feature is Monument Draw, which is located to the southwest of the site, in Lea County, New Mexico (Plate VI.A.2). Monument Draw runs between the proposed WCS landfill site and Eunice, New Mexico. The draw begins with a southeasterly course to a point north of Eunice where it turns south and becomes a well defined cut approximately 30 feet in depth and 1,800 to 2,000 feet in width. The draw does not have through-going drainage and is partially filled with dune sand and alluvium (note: a second Monument Draw is shown on Plate VI.A.2 in northern Andrews County; this draw is a separate feature not to be confused with the draw in Lea County, New Mexico). East of Monument Draw is a north-south trending topographic high known locally as Rattlesnake Ridge. This poorly defined ridge parallels the Texas - New Mexico State line and crests about 125 feet higher than Monument Draw (Nicholson and Clebsch, 1961).

Large-Scale Local Topography Within the Boundary of the Proposed Landfill Site

The ground surface elevation within the boundary of the proposed WCS landfill site ranges from a high of 3,487.56 feet relative to mean sea level (MSL) in the extreme north central section to a low of 3,422.74 feet MSL in the southwest corner over a linear distance of approximately 4,600 feet (Plate VI.A.3). A relatively abrupt topographic slope break occurs along the central portion of the proposed WCS landfill site, south of a line from surveyed grid locations 10-F, 8-F, 6-D, 4-D and 2-D.

Small-Scale Local Topography Within the Boundary of the Proposed Landfill Site

Small-scale topographic features within the boundary of the proposed WCS landfill site include two highs, five closed depressions (locally referred to as "buffalo wallows") and a subtle surface water drainage feature (Plate VI.A.3).

A total of three of the local topographic depressions are located in close proximity to each along the southwestern margin of the proposed WCS landfill cell (Plate VI.A.3). The largest of these depressions (located at grid location 8-E) is about 400 feet by 300 feet with approximately one to two feet of vertical relief. The next largest of the three depressions (located near grid location 8-F) is nearly circular with a diameter of 300 feet and approximately three to four feet of vertical relief. The smallest of the three depressions (located between grid location 7-D and 7-E) is about 300 feet by 200 feet in size with approximately one to two feet of vertical relief.

A subtle surface water drainage feature is headed in the area immediately to the west of the three topographic depressions discussed above. This drainage feature accounts for approximately 12 feet of topographic incising over a run of approximately 500 feet. Field observations of this surface water feature indicate channel flow in the upper reach, with a rapid transition to sheet flow at its terminal end to the south.

A fourth topographic depression is located near grid location 2-D, along the eastern boundary of the proposed WCS landfill cell. This depression has dimensions of 200 feet by 100 feet and approximately four feet of topographic relief.

A fifth topographic depression is located near grid location 10-A, along the northwest corner of the proposed WCS landfill site. This depression has dimensions of around 125 feet by 200 feet and approximately one to two feet of topographic relief.

Local topographic highs are located along the southwest margin of the proposed WCS landfill cell. The largest high (located between grid 10-E and 10-F) is crescent-shaped with the long axis measuring approximately 600 feet and the short axis measuring about 300 feet. This topographic high has a vertical relief of one to two feet. The other topographic high (located between grid 8-E and 9-E) measures about 100 feet by 200 feet with less than two feet of vertical relief.

<u>Local Topography Outside the Boundary of the Proposed Landfill Site</u>

Local topographic features outside the boundary of the proposed WCS landfill site include three depressions to the west, a spring to the west and three highs to the north (Plate VI.A.3). Baker Spring is located 1,925 feet west and 360 feet south of the northwest corner of the proposed WCS landfill site, in Lea County, New Mexico. The water surface elevation at Baker Spring was surveyed at 3,440.82 feet MSL on February 2, 1993. Reports by local residents indicate that this spring is no longer active, and that the loss of spring activity may be linked to blasting activities at a nearby rock quarry (Vance, 1993). Site observations suggest that the historical source of Baker Spring may be attributed to seasonal seepage from the base of a surface outcropping of Ogallala Formation sediments. Field observations regarding the topography surrounding Baker Spring indicate evidence of historical quarrying activity.

Area Soils

The soils at the proposed WCS landfill site consist of dune sand mixed with organic material overlying weakly to strongly cemented caliche (Conner et. al., 1974; Turner et. al., 1974). The top soil depth ranges from 2 to 24 inches. The shallow caliche consists primarily of cemented dune sand and cemented Ogallala Formation sediments.

Area Land Use

The proposed WCS landfill site is located on land owned by the Flying "W" Diamond Ranch. This property, and the property immediately surrounding the proposed WCS landfill site is presently used as rangeland for cattle, requiring approximately 60 acres to sustain each head (Vance, 1993)

Other uses of land within the vicinity of the proposed WCS landfill site include: drill sites for oil and gas wells (a producing oil well is located near the southwest corner of the property); quarrying operations; and the surface recovery of oil field wastes. Surface quarrying of sand and gravel is conducted approximately one mile to the west of the proposed WCS landfill site, in New Mexico. The oil field waste recovery facility is adjacent to this rock quarry.

A.3. Regional Geology

A.3.1 Regional Surface Sediments

The geologic formations that outcrop within the region range from Quaternary through Triassic in age and include: Quaternary Alluvium (Holocene), Windblown cover sand (Pleistocene), and the Tahoka Formation (Pleistocene); the Tertiary Ogallala Formation (Pliocene); the Cretaceous Fort Terrett Formation; and the Triassic Dockum Group (Chinle Formation). The Hobbs Sheet of the Geologic Atlas of Texas showing the area surrounding the proposed WCS landfill site is provided on Plate VI.A.2.

Alluvium, Windblown Cover Sand, and Tahoka Formation

Floodplain deposits of fluvial origin outcrop at the surface to the west and southwest of the proposed WCS landfill site. These sediments are Holocene and possibly Pleistocene in age and were deposited along the course of Monument Draw in New Mexico (Plate VI.A.2).

Windblown cover sand of Pleistocene age is found immediately north of the proposed WCS landfill site, to the east along Highway 176, and at numerous other locations in Andrews, Gaines and other counties in Texas shown on Plate VI.A.2. This windblown cover sand ranges up to 10 feet in thickness and is calcareous, grayish red, fine to medium-grained quartz with silt and caliche nodules common (Barnes, 1976).

The Tahoka Formation is of Pleistocene age and consists of lacustrine clay, silt, sand, and gravel (Barnes, 1976). The clay and silt is sandy, indistinctly bedded to massive, and consists of various shades of light gray and bluish gray. The sand is gray, fine to coarse-grained quartz, friable, and grades to gravel at the margins of the deposits. These sediments occur approximately four miles east of the proposed WCS landfill site, near a topographic depression located north of Highway 176. The Tahoka Formation also outcrops at Whalen Lake and Shafter Lake in Andrews County, at San Simon Sink in New Mexico, and at a few other locations as shown on the Plate VI.A.2.

Ogallala Formation

The Pliocene Ogallala Formation consists of fluviatile sand, silt, clay, and gravel capped by caliche (Barnes, 1976). The sand deposits of the Ogallala Formation consist of fine to medium-grained quartz grains, which are silty and calcareous. Bed forms range from indistinctly bedded to massive, crossbedded, unconsolidated to weakly cohesive with 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. The capping caliche is hard, sandy, pisolitic at the top, and produces caprock along Mescalero Ridge. Development of the local caliche horizon probably occurred relatively recently, after the deposition of the Pliocene Ogallala Formation.

Within the southern region of the Llano Estacado, the Ogallala Formation lies unconformably above either Triassic or Cretaceous rocks, and occurs as an apron of coalescing alluvial fan lobes which extend eastward from the Rocky Mountains. This alluvial outwash plain was dominated by braided streams and extends from South Dakota to the Texas Panhandle (Seni, 1980).

The headward erosion of the major rivers, such as the Pecos River in New Mexico and the Canadian, Colorado, and Brazos Rivers in Texas, and their various tributaries has regionally modified the surface expression of the Ogallala Formation (Figure VI.A.13). Consequently, portions of the Ogallala Formation have been erosionally removed, exposing deeper, older stratigraphic units. In addition, winds and streams have locally eroded the Ogallala Formation, exposing Cretaceous rocks around some saline lakes in the southern part of the Southern High Plains (Plate VI.A.2). The Ogallala Formation, in the regional area shown on Plate VI.A.2, ranges from 0 to 100 feet in thickness (Barnes, 1976).

Fort Terrett Formation

A very isolated occurrence of the Fort Terrett Formation is exposed in a rock quarry approximately one mile west of the proposed WCS landfill site (Plate VI.A.2). This formation consists of limestone and shale deposited in a marine environment. Fort Terrett limestones are light gray to grayish yellow in color and are mostly fine grained, argillaceous, thin to thick bedded and massive. The shales are calcareous and thinly laminated and occur in shades of dusky yellow, yellowish gray, light olive-gray, and dark gray (Barnes, 1976).

The possibility exists that the Fort Terrett Formation sediments mapped at the rock quarry east of the proposed WCS landfill site (Plate VI.A.2) may actually be caliche. This is based on the fact that no Fort Terrett Formation sediments were observed (during on-site field activities) at an outcrop at Baker Spring, which is immediately east of the quarry. An exposure of highly cemented, concretionary and pisolitic caliche was observed at Baker Spring, which could be confused as a Cretaceous marine limestone.

However, the silt, sand and gravel content of the limestone material at Baker Spring indicates that it is caliche, and it is suggested that this caliche material may be the same material that was mapped by Barnes (1976) as the Fort Terrett Formation at the adjacent rock quarry.

Dockum Group - Chinle Formation

The Chinle Formation is the uppermost unit of the Triassic Dockum Group in eastern New Mexico and western Texas (Nicholson and Clebsch, 1961). The Chinle Formation consists of red and greenish micaceous claystone, thinly interbedded with fine-grained sandstone (Barnes, 1976). The Chinle Formation is exposed in a rock quarry in New Mexico approximately one mile west of the site (Plate VI.A.2).

In Texas, the Dockum Group consists of shale, sandstone, siltstone, limestone, and gravel. These shale sediments are typically micaceous, thinly bedded, and variegated. The Dockum Group lies immediately beneath the Ogallala Formation at the proposed WCS landfill site and ranges up to 1,400 feet in thickness within the region.

A.3.2 Regional Stratigraphy

Groundwater resources are commonly referred to as underground sources of drinking water (USDWs). The base of the Dockum Group (Santa Rosa Formation) is considered to be the base of the lowermost aquifer capable of providing usable groundwater to the land surface in the regional study area (Nicholson and Clebsch, 1961). This formation lies unconformably on top of the Permian Dewey Lake Formation, with the base of the Dockum Group at a depth of approximately 1,400 feet beneath the proposed WCS landfill site.

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. The stratigraphic column for the Central Basin Platform area is shown in Figure VI.A.15. Included on the column are all stratigraphic units from the Precambrian to Recent time. However, for the purpose of this regional discussion, only the Permian Ochoan units through the Recent units will be reviewed.

To better understand how the local geology relates to the regional stratigraphy, information was obtained from oil and gas operations in Andrews County, Texas and Lea County, New Mexico. A search of the oil and gas well records within a one-mile radius of the proposed WCS landfill site was conducted by Geosource, Inc., Austin, Texas, in November 1992.

Geosource, Inc. utilized public and private sources of data to identify producing and abandoned oil and gas wells or well tests located in the area. Table VI.A.2 lists the sources of information reviewed and briefly describes the information which can be obtained from each source. There are 12 operating or plugged wells located within a one-mile radius of the site. A map showing the location of oil and gas artificial penetrations within the area is included as Figure VI.A.16. A tabulation of the oil and gas wells is included as Table VI.A.3. Records of these wells are provided in Appendix A.

A detailed analysis of the regional and local subsurface stratigraphy was conducted based on a review of the drilling records and/or electric, nuclear, and lithologic logs from 17 individual locations. The data set consists of all available log data for the area on file with Petroleum Information (PI) within the boundaries of Figure VI.A.17. A total of two regional stratigraphic cross-sections were constructed using these data and are shown as Plates VI.A.4 and VI.A.5. These cross-sections depict the major stratigraphic units that occur within 2,000 feet below ground level (BGL) in the vicinity of the site. Review of these cross-sections does not indicate the presence of local faulting. The locations of the cross-sections are shown in Figure VI.A.17. The individual well logs used to prepare the cross-sections have been named and numbered for cross-referencing purposes.

Permian Units

The Permian sediments consist of the Wolfcamp, Leonard, Guadalupe, and Ochoa Series (Figure VI.A.15). The Ochoan sediments are important to this discussion because they are immediately below the USDW. In addition, the Ochoan stratigraphy provides information pertaining to the deeper structure beneath the site.

The Ochoa Series section represents the top of the Permian strata, and in the Central Basin Platform area consists primarily of the: Salado Formation; the Rustler Formation; and the Dewey Lake Formation (WTGS, 1976). The Salado Formation, which rests unconformably on the Tansill Formation, consists of a thick, regionally extensive evaporite unit composed dominantly of salt and lesser amounts of anhydrite and minor amounts of mudstone (McGillis and Presley, 1981). The Salado Formation ranges in thickness from approximately 750 feet in the area of the Central Basin Platform to over 2,000 feet in the Delaware Basin.

The Rustler Formation consists of a maximum of 375 feet of dolomite and anhydrite with an irregular basal zone of red sand, conglomerate, and variegated shale (Jones, 1953). The Rustler Formation represents the youngest anhydrite in the Permian Basin.

The Dewey Lake Formation lies conformably on the Rustler Formation and consists mainly of fine-grained red sandstone and siltstone with some anhydrite, but no salt. It ranges in thickness from 250 to 300 feet in Andrews County (WTGS, 1961). Although there is an unconformity found at the top of the Dewey Lake Formation, which separates it from Triassic deposits, in many places the nature of this contact is not clear (Stone and Webster, 1983). The Ochoan units have a combined thickness of over 3,000 feet and indicate a similar structural trend as the lower Permian units.

A portion of the Ochoan stratigraphic sequence (i.e., Salado Formation, Rustler Formation, and Dewey Lake Formation) is shown on Cross-sections A-A' and B-B' (Plates VI.A.4 and VI.A.5). The upper contact of the Salado Formation, in the area of the proposed WCS landfill site, is at a depth of approximately 1,595 feet BGL at location #13 and 1,828 feet BGL at location #15.

The Rustler Formation top occurs at a depth of approximately 1,356 feet BGL at location #13 and 1,615 feet BGL at location #15. The total thickness of the Rustler Formation ranges from 210 feet at location #4 to 237 feet thick at location #12.

The erosional surface of the Dewey Lake Formation slopes regionally to the southeast (Nativ, 1988). The upper contact of the Dewey Lake Formation in the area of the proposed WCS landfill site is at a depth of approximately 1,217 feet BGL at location #13 and 1,382 feet BGL at location #9.

Triassic Units

The Triassic Dockum Group disconformably overlies the Permian stratigraphic sequence within the regional study area (Figure VI.A.15). The Dockum Group is comprised of a series of fluvial and lacustrine mudstone, siltstone, sandstone, and silty dolomite deposits (McGowen et. al., 1979) which range up to approximately 1,400 feet thick in the area of the Central Basin Platform. 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 (McGowen et. al., 1979).

Figure VI.A.18 shows the inferred paleogeographic setting that existed during the deposition of the Dockum Group. The terrigenous clastics deposited in the Permian Basin area were mainly derived from older sedimentary rocks that accumulated in Texas and New Mexico. The maximum preserved thickness of Triassic rocks (2,000 feet) occurs in the Midland Basin (Nativ, 1988).

The Tecovas Formation represents the lowermost lithologic cycle of the Triassic System. It consists primarily of claystone and siltstone. However, the Tecovas Formation is absent throughout portions of the Central Basin Platform.

The Trujillo Formation (i.e., Santa Rosa Formation of New Mexico) represents the middle lithologic cycle of Dockum Group deposition. The Trujillo (Santa Rosa) Formation is characterized by a sandy lower interval that becomes increasingly muddy in the upper section. The upper lithologic cycle of the Triassic System, or Chinle Formation, exhibits similar overall upward fining, except in the area of the northwestern Midland Basin, where sand from an eastern source was deposited during the upper Triassic cycle (McGowen et. al., 1979). Figure VI.A.19 presents an isopach (i.e., thickness) map of the upper Dockum Group.

The stratigraphic sequence of the Triassic Dockum Group (i.e., Santa Rosa Formation and Chinle Formation) is shown on Cross-sections A-A' and B-B' (Plates VI.A.4 and

VI.A.5). The upper contact of the Santa Rosa Formation in the area of the proposed WCS landfill site is at a depth of approximately 965 feet BGL at location #13 and 1,202 feet BGL at location #14. The geophysical log characteristic shows the Santa Rosa Formation to be a massive sandstone body. The total thickness of the Santa Rosa ranges from 230 feet at locations #15 and #17 to 305 feet thick at location #12.

The upper Dockum Group (Chinle Formation) top occurs at a depth of approximately 48 feet BGL at location #9 (immediately south of the proposed landfill site) and 93 feet BGL at location #14. The total thickness of the upper Dockum Group ranges from 955 feet at location #13 to 1,125 feet thick at location #4. The cross-sections show the fluvial nature of the upper Dockum Group with interbedded sandstone, siltstone, and clay lenses. The erosional surface of the Triassic Dockum Group is also quite evident. The Dockum Group is overlain in some areas of the Southern High Plains by Cretaceous rocks and in other areas by the Ogallala Formation.

Cretaceous Units

The Jurassic stratigraphic sequence is not found in the Permian Basin (Figure VI.A.15). Therefore, the Cretaceous (Comanchean Series) sediments rest disconformably upon the Triassic Dockum Group. These sediments are found in southeast-dipping isolated erosional remnants (Figure VI.A.20) as much as 100 feet thick (Cronin and Wells, 1963). Note that the subcrop map shows that Cretaceous rocks have been eroded away beneath the proposed WCS landfill site. Therefore, while Cretaceous rocks are found in the region, no Cretaceous units are shown on the accompanying stratigraphic cross-sections (Plates VI.A.4 and VI.A.5).

Cretaceous rocks were deposited in an epineritic and littoral environment on a slowly subsiding shelf (Nativ, 1988). The base of the Cretaceous System in the Southern High Plains is composed of basal sands of the Trinity Group. These light gray to reddish gray sediments consist of nearly pure quartz sands with scattered lenses of gravel (Stone and Webster, 1983). They are poorly consolidated and form a blanket-like deposit that is 10 to 25 feet thick in the southeastern High Plains area.

The sediments of the Fredericksburg Group rest unconformably on top of the Trinity Group deposits and consist predominately of calcareous rocks. These strata consist of light-gray argillaceous limestone interbedded with shale at the base, becoming more massive marly limestone near the middle and grading into interbedded dolomite, shale, and sandstone at the top (Stone and Webster, 1983).

Tertiary Units

Within the regional study area, the Ogallala Formation (Pliocene) rests disconformably upon either the Triassic Dockum Group or the Cretaceous sediments. Figure VI.A.21 presents the structure of the base of the Ogallala Formation, which corresponds to the erosional surface of the underlying Cretaceous and Triassic units. The Ogallala Formation contains both coarse fluvial conglomerate and sandstone and fine-grained eolian siltstone and clay (Nativ, 1988).

Seni (1980) believed that the depositional environment of the Ogallala Formation and the overlying Quaternary deposits produced a series of overlapping, humid-type alluvial fans. Three fan lobes were identified (Figure VI.A.22) whose grain size varies as a function of the distance from the major channel system. After further investigation, it was noted that the grain size of the Ogallala Formation clastics is controlled by the topography of the underlying mid-Tertiary erosional surface (Gustavson and Winkler, 1988). Coarse fluvial clastics were deposited in paleovalleys, while finer eolian sediments covered upland areas (Nativ, 1988). Eolian clastics also overlie the fluvial sediments in the paleovalleys as sand and silt sheets. The Ogallala Formation typically ranges from 0 to 200 feet thick in the south portion of the Southern High Plains. The thickness of the Ogallala Formation reflects the underlying paleotopography.

A resistant calcite layer called the caprock caliche lies at or near the top of the Ogallala Formation (Nativ, 1988). Caliche develops as an authigenic accumulation of calcium carbonate that results from soil-forming processes, precipitation from groundwater, or some combination of both (Stone, 1985). The processes governing the development of caliche are discussed fully in Section A.4.3.

The Ogallala Formation and Dockum Group are easily discernible on electric logs from nearby oil and gas wells and are shown on Plates VI.A.4 and VI.A.5. Because the top of the Dockum Group is an erosional surface, the elevation of the contact between these two formations varies significantly over relatively short distances. The thickness of the

Ogallala Formation in the area shown by the cross-sections ranges from 48 feet at location #9 (immediately south of the proposed landfill site) to 93 feet at location #14 (approximately three miles north of the site). This thickness determination assumes that all material overlying the Dockum Group consists of Ogallala Formation sediments. This is based on geophysical log signature, and includes some amount of surficial deposits and caliche cemented surficial deposits.

A.4. Site Subsurface Soils Investigation

A.4.1. Investigation Procedures

Site operations were conducted from November, 1992 through February, 1993. These operations included: the drilling of continuous cores and soil borings; geophysical logging; and the installation of piezometers and monitoring wells. All soil borings were described using the Unified Soil Classification System (USCS). A summary of soil boring, well completion and selected geologic data is provided in Table VI.A.4. Soil boring and well completion logs are provided in Appendix B. Geophysical logs are provided in Appendix C. A detailed discussion of the site subsurface investigation procedures is provided in the companion geotechnical report provided by JHA.

A.4.2. Subsurface Structure

A discussion of the regional subsurface structure is provided in Section A.1 and A.3. This analysis of faulting, seismicity and the overall regional subsurface structure is based on a review of the available published literature, and is based on the construction of two deep geologic cross-sections (Plate VI.A.4 and V.I.A.5). These two cross-sections were developed from available oil and gas industry data.

The site subsurface structural analysis is based on data resulting from the site investigation: 55 continuous cores; eight geophysical logs; and four shallow exploration borings (Table VI.A.4). The structural interpretation derived from this information is summarized in ten shallow geologic cross-sections A-A' through J-J'. A cross-section location map is provided as Figure VI.A.23. The 10 shallow cross-sections are provided as Figure VI.A.24 through VI.A.33. A structure map on top of the Dockum Group is provided as Figure VI.A.34. In addition, two orthographic projections of the Dockum Group surface are provided as Figure VI.A.35 and VI.A.36, and a depth to the top of the Dockum Group map is provided as Figure VI.A.37.

The regional subsurface structural data indicates no evidence of post-Permian faulting or warping within the local study area. The site subsurface data supports this regional analysis. The local geologic cross-sections (Figure VI.A.24 through VI.A.33) indicate horizontally configured intervals of primarily silty claystone, siltstone and sandstone within the shallow Dockum Group (Chinle Formation) sediments. While individual lithologic intervals range from isolated to laterally extensive, the local depositional framework within the Dockum Group indicates no evidence of faulting or warping.

Paleotopographic Surface of the Dockum Group

The buried surface of the local Dockum Group indicates a paleotopographic expression, which is consistent with published information (Reeves, 1966; McGowen et. al., 1979; Dutton and Simpkins, 1986). As shown in Figures VI.A.34, VI.A.35 and VI.A.36, an apparent ridge runs in a roughly northwest/southeast direction through the middle of the local study area. The "D" survey line, or local cross-section G-G' (Figure VI.A.30) runs along the approximate axis of this structural feature.

This ridge has the general appearance of a east/southeast plunging anticline when viewed from above (Figure VI.A.34). However, local cross-sections A-A', B-B', C-C' and D-D' (Figure VI.A.24, VI.A.25, VI.A.26 and VI.A.27, respectively), which cut profile views across this apparent structural ridge, do not indicate a similar anticlinal warping of the underlying stratigraphic intervals. Rather, these cross-sections indicate a generally horizontal configuration of shallow Dockum Group sediments.

The Dockum Group sediments are locally overlain by nine to 54 feet of top soil, windblown silt and sand, caliche, and the gravel, sand, silt and clay deposits of the Pliocene Ogallala Formation. A disconformable contact exists between the underlying Dockum Group and the overlying Ogallala Formation (Gawloski, 1983). The depositional record of most of the Tertiary System (Miocene through Paleocene), as well as the entire Cretaceous and Jurassic Systems, is not present in the local study area. This represents a missing time-rock interval of approximately 169 million years. Erosion of this time-rock interval, including a portion of the Triassic Dockum Group, occurred prior to the deposition of Ogallala Formation sediments (Gawloski, 1983; McGowen et. al., 1979; Dutton and Simpkins, 1986). It is this erosional activity, combined with some amount of scouring associated with the transportation of Ogallala Formation sediments which has locally shaped the surface of the Dockum Group, giving it the paleotopographic appearance indicated in Figures VI.A.34, VI.A.35 and VI.A.36.

General Relationship Between Local Surface Topography and Dockum Structure

The local surface topography is partially dependant on the structure of the underlying Dockum Group. The surface of the Dockum Group slopes rapidly to the south and north, off of the axis of the Dockum Group ridge (Figure VI.A.34). The local ground surface topography slopes rapidly to the south off of the axis of the underlying Dockum Group ridge and flattens along the southern margin of the study area (Plate VI.A.3). This is in strong similarity to the underlying Dockum Group structure. However, the ground surface topography continues to gently climb toward the north of the underlying Dockum Group ridge, despite the fact that the Dockum Group structure drops off toward the north.

The thickness of sediment overlying the Dockum Group is related to Dockum Group structure and ground surface topography. The difference between ground surface elevation and underlying Dockum Group structure elevation can be expressed in the form of the depth (below ground level) to the top of the Dockum Group, which is referred to here as overburden thickness. As shown in Figure VI.A.37, the overburden sequence within the local study area is thinnest along an arcuate band extending approximately from location 9-H to location 1-E. A comparison of the overburden thickness trend (Figure VI.A.37) to the Dockum Group structure (Figure VI.A.34) and local topography (Plate VI.A.3) shows that this band of thinnest overburden corresponds to the area where the local topography rapidly drops-off, in effect coming closest to reaching the surface of the underlying Dockum Group. However, south of this band of thinnest overburden, the ground surface topography flattens-out to a slope of approximately 0.5 degrees, while the underlying Dockum Group structure continues to drop-off toward the south at a slope of approximately three degrees (six times greater than topography). As a result, the overburden thickness increases along the southern portion of the study area.

To the north of the band of thinnest overburden, the topography rises at a gentle rate while the structure of the underlying Dockum Group begins to drop-off on the northern flank of the local Dockum Group ridge. Consequently, the overburden thickness increases in the northern portion of the local study area.

<u>Small-Scale Dockum Group Structural Features and Buffalo Wallow Development</u>
Localized drainage depressions such as playa lakes and buffalo wallows characterize much of the topographic surface of the High Plains, and are attributed to a variety of causes, including: differential compaction; eolian deflation; the transportation of sediment by animal activity (thus the name buffalo wallow); the dissolution and subsidence of the underlying caliche cap; as well as the dissolution and subsidence of underlying Cretaceous limestone and Permian evaporite sediments (Nicholson and Clebsch, 1961; Reeves, 1966; Gustavson and Finley, 1985; Collins, 1990). Within the local study area, a relationship may exist between the formation of buffalo wallows and the existence of underlying structural depressions in the surface of the Dockum Group.

Small-scale features are apparent on the surface of the local Dockum Group. Figures VI.A.34, VI.A.35 and VI.A.36 show that the Dockum Group ridge, which extends through the center of the local study area, is pock-marked with low-relief (i.e., approximately four to nine feet deep) structural depressions. One such depression was explored by a series of four shallow borings (less than 31 feet deep) and one deeper continuous core (depth of 100 feet) near location 2-D. At this location, a bowl shaped structural depression in the surface of the Dockum Group corresponds to an overlying topographic depression, locally referred to as a buffalo wallow.

Both the depression in the surface of the Dockum Group, and the overlying buffalo wallow, have a relief of approximately four feet. However, cross-section D-D' (Figure VI.A.27), which passes beneath this topographic depression, does not indicate a similar down-warping of sedimentary intervals beneath the depression. Instead, cross-section D-D' indicates horizontally configured stratigraphic intervals beneath location 2-D. Therefore, it is unlikely that the structural depression beneath 2-D is due to the dissolution and slumping of underlying Dockum Group or deeper Permian evaporite layers. The structural depression in the surface of the Dockum Group is probably a reflection of a small-scale paleotopographic depression scoured into the surface of the Dockum Group prior to the local deposition of Ogallala Formation sediments.

The results of the coring and soil boring activity at location 2-D suggest that partial dissolution of the shallow caliche cap may have contributed to the development of the buffalo wallow. The continuous core drilled within the buffalo wallow (location 2-D) encountered only six feet of caliche cap, consisting primarily of calcium carbonate cemented silt and sand. However, four exploration soil borings drilled along the outer rim of the buffalo wallow (location 2-D(A), 2-D(B), 2-D(C) and 2-D(D)) encountered a thickness of caliche cap ranging from 5.7 feet to 15.6 feet, with an average thickness of approximately 10.2 feet. This suggests that a portion of the caliche cap material may have been dissolved at the surface or beneath the buffalo wallow at 2-D. Surficial dissolution of caliche cementation and subsequent removal by deflation may explain the development of buffalo wallows (Nicholson and Clebesch, 1961). In addition, dissolution of the deeper portion of the caliche, and subsequent slumping of the overlying caliche cap, may have initiated the topographic expression of the buffalo wallow or simply propagated a pre-existing topographic surface depression.

The drilling results at location 2-D indicate sediment depletion within the buffalo wallow. The depth from ground surface to the top of the Dockum Group is given in Figure VI.A.37. The thickness of material overlying the Dockum Group locally thins in the vicinity of 2-D. This can be explained by the removal of surficial material near location 2-D by eolian deflation or by the transportation of soil from the depression by animal activity. The buffalo wallow is presently covered with a thick carpet of vegetation, which would be expected to greatly diminish the effect of eolian deflation. However, this buffalo wallow presently appears to be frequented by livestock, resulting in possible sediment removal on their hooves and fur. This pattern of current livestock activity at the buffalo wallow may be indicative of the historic use of the site by North American Bison (i.e., buffalo).

The topographic and structural depression at location 2-D may establish a surface water and ground water relationship which has been integral in the development of the buffalo wallow. The buffalo wallow probably serves as a seasonal collection point for surface water. The coring and soil boring process at location 2-D indicated that the buffalo wallow contains approximately two feet of organic-rich soil, compared to less than 0.4 feet of soil along the rim of the buffalo wallow. In addition, the significantly increased density and length of grass and shrub growth within the buffalo wallow suggests increased available moisture.

This potential surface water and groundwater relationship is supported by the fact that the coring activity within the buffalo wallow encountered saturated conditions within the shallow sand and gravel immediately overlying the Dockum Group. However, cores and soil borings surrounding location 2-D did not produce water. This suggests that ponded surface water within the buffalo wallow is able to infiltrate into the subsurface, but is forced to pond beneath the buffalo wallow, possibly due to the structural depression in the underlying Dockum Group. This infiltrating surface water may increase the rate of caliche dissolution beneath the buffalo wallow and, therefore, may help to propagate the growth of the 2-D buffalo wallow. A complete discussion of the site groundwater conditions is provided in Section B.2.

If a local relationship exists between buffalo wallow formation and Dockum Group structure, then it is likely that buffalo wallows would be more abundant overlying Dockum Group structural highs. It is here where structural depressions are most likely to be closed (i.e., bowl-shaped) and, therefore, capable of ponding shallow groundwater. Such a relationship may be suggested by the abundance of buffalo wallows within the local area roughly bounded by survey locations 7-D and 7-E through 11-D and 10-F (Plate VI.A.3). This area directly overlies a broad structural high in the surface of the Dockum Group (Figure VI.A.34).

A.4.3. Subsurface Stratigraphic Complexity

The local subsurface stratigraphic framework is presented in ten shallow geologic cross-sections (Figures VI.A.24 through VI.A.33). These cross-sections are based on the results of the site coring, soil boring and geophysical logging program. A total of 59 soil boring logs are presented in Appendix B. A total of eight geophysical logs are provided in Appendix C. A percent siltstone and sandstone isopach map, which delineates the local sediment distribution pattern in the shallow Dockum Group, is provided as Figure VI.A.38. A stratigraphic column is provided as Figure VI.A.15.

<u>Surficial Materials</u>

The site is overlain by a thin veneer of two feet or less of organic-rich top soil. The top soil consists of moist, brown silty sand which contains abundant vegetation debris and roots. The top soil commonly contains well rounded, white, black, red, pink and opaque quartzitic gravel and gravel fragments, as well as caliche fragments. These gravel and caliche fragments appear to have weathered out of underlying caliche-cemented Ogallala Formation sediments.

<u>Caliche</u>

Within the local study area, the top soil horizon is underlain by a variable sequence of calcium carbonate cemented, calcrete duracrust capping material (i.e., caliche). Caliche is common throughout the Southern High Plains or Llano Estacado, and forms the resistant beds of the Caprock Escarpment along the western and eastern margins of the Southern High Plains (Gustavson and Finley, 1985). Caliche typically forms in arid to semi-arid climates, where seasonal precipitation dissolves and vertically transports low magnesium calcite from the surface soils into the deeper soil, where it is precipitated in the vadose zone of the C soil horizon (Leeder, 1982), or at the vadose zone/phreatic zone interface (Braithwaite, 1983).

Thick sequences of caliche such as those encountered within the local study area, are probably remnants from the Pleistocene, and may record episodic accumulations of carbonate in response to Pliocene-Pleistocene climatic fluctuations (Leeder, 1982). Common sources of calcium in the shallow subsurface include weathered rock products and organic sources such as lichen, fungi, algae and bacteria (James and Choquette, 1984). The primary factors controlling caliche formation include: meteoric precipitation rate; carbon dioxide content of meteoric water and carbon dioxide donation by organic material (increased carbon dioxide concentrations increase the rate of calcium carbonate dissolution); and temperature (increased temperature promotes calcium carbonate precipitation) (James and Choquette, 1984).

A local surface exposure of caliche, Ogallala Formation and Dockum Group sediments was observed at Baker Spring (Plate VI.A.3). At this location, the caliche cap consists of: approximately six feet of white, highly fractured calcium carbonate cemented feldspathic and quartzitic silt and very fine grained sand; overlying approximately 12 feet of white and pinkish white, massive caliche with extensive concretionary nodule growths (i.e., pisolites) and feldspathic and quartzitic silt and very fine grained sand; resting on top of approximately six feet of pinkish white, calcium carbonate cemented feldspathic and quartzitic silt, sand and gravel which becomes less cemented with depth. This lower six feet of caliche material appears to be calcium carbonate cemented Ogallala Formation sediments. This caliche altered Ogallala Formation material has an irregular basal contact and indicates a gradational transition into primarily uncemented Ogallala Formation sands and gravels below.

Caliche was encountered during the drilling program and was observed to be laterally extensive throughout the local study area, ranging up to 47 feet thick at location 7-A (Figure VI.A.24 through VI.A.33). As seen in the cross-sections, the local caliche cap thickens toward the north and south margins of the study area, similar to the overall thickness trend of the combined overburden sequence (Figure VI.A.37).

The caliche encountered during the drilling program is similar to the caliche exposed at Baker Spring. Matrix color ranges from white to pinkish white, with varying degrees of cementation, hardness, fracturing and pisolitic concretions. The caliche horizon contained varying amounts of feldspathic and quartzitic silt, sand and gravel fragments with a general trend of decreased cementation and increased silt, sand and gravel content with depth. In many areas, the caliche cap material included altered eolian silts and sands, as well as cemented Ogallala Formation sediments. Open fractures and vugs were observed within the caliche horizon.

<u>Ogallala Formation</u>

As discussed in Section A.3.2, the Ogallala Formation records a period of fluvial deposition during the Pliocene (3 to 11 million years ago). The Ogallala Formation had a source area in the Rocky Mountains, and was deposited as an eastern-thinning apron of coalescing alluvial fans (Seni, 1980).

A local surface exposure of caliche, Ogallala Formation and Dockum Group sediments was observed at Baker Spring (Plate VI.A.3). The Ogallala Formation sediments consist of approximately six feet of caliche cemented feldspathic and quartzitic silt, sand and gravel, resting on top of approximately 15 feet of planar crossbedded and trough crossbedded sand and gravel, which is indicative of a high energy fluvial system (Seni, 1980). Sediment color ranges from pinkish tan to dark brown with red, pink, white, black and opaque quartzitic gravel clasts and granitic cobbles. The base of the Ogallala Formation has a sharp and irregular contact with the underlying dusky red siltstone and claystone of the Dockum Group.

Ogallala Formation sediments were encountered in numerous soil borings throughout the local study area (Figure VI.A.24 through VI.A.33). These sediments consist of feldspathic and quartzitic sand and gravel with silt and clay, and appeared consistent with the surface exposure at Baker Spring. For the purpose of general classification and cross-section preparation, that portion of the Ogallala Formation that has been cemented as part of the overlying caliche cap, is represented in the cross-sections as caliche. However, it should be noted that a significant portion of the caliche cap within the local study area consists of altered Ogallala Formation sediments. The following discussion focuses on the uncemented portion of the Ogallala Formation, below the base of the caliche cap.

Caliche alteration of the Ogallala Formation, combined with incomplete recovery of caliche-cemented and uncemented Ogallala Formation samples during the coring program, hampered the accurate recognition and classification of the Ogallala Formation sediments. Therefore, an accurate thickness (i.e., isopach) map of the Ogallala Formation could not be prepared as part of the geologic investigation. However, the geologic cross-sections (Figure VI.A.24 through VI.A.33) provide a general means for determining the local thickness trend of Ogallala Formation.

The local thickness trend of the Ogallala Formation is partially related to the structure of the underlying Dockum Group. As shown in the local cross-sections A-A', B-B', C-C', D-D' and J-J' (Figure VI.A.24, VI.A.25, VI.A.26, VI.A.27 and VI.A.33, respectively), the thickness of the Ogallala Formation generally increases off of the northern and southern flanks of the underlying Dockum Group ridge (Figure VI.A.34).

In addition, small-scale structural lows in the surface of the Dockum Group generally contain an increased thickness of Ogallala Formation. This is particularly evident on cross-sections G-G' (Figure VI.A.30), where Ogallala Formation sediments appear thickest in structural lows between locations 9-D and 7-D, and between locations 5-D and 2-D. This general thickness trend is due to the fact that the Ogallala Formation occurs as an erosional remnant throughout much of the Southern High Plains area (Seni, 1980). As a result, thicker sequences of Ogallala Formation sediments often correspond to structural lows in the underlying formations. It is in these structural lows where the Ogallala Formation is partially protected from erosional activity. In addition, it is within these structural lows where a portion of the Ogallala Formation rests below the base of caliche cementation and is, therefore, clearly recognizable as the Ogallala Formation.

Ground surface topography also determines the local thickness trend of the Ogallala Formation. As discussed in Section VI.A.4.2, the overburden is thinnest where the ground surface has been eroded closest to the surface of the underlying Dockum Group. Since much of the local Ogallala Formation is tied up as cemented caliche, the thickness of the Ogallala Formation has a similar thickness trend as the entire overburden sequence. This general relationship is illustrated in Figure VI.A.37.

Dockum Group

As discussed in Section VI.A.3.2, the Dockum Group records a period of fluvial-deltaic and lacustrine deposition within a restricted continental basin during the Triassic (180 to 260 million years ago). The source areas for the Dockum Group included: the Llano Uplift area to the east; the Amarillo Uplift, Wichita Mountain Uplift and Arbuckle Mountain Uplift to the north and northeast; the Sierra Grande Arch and Sangre De Cristo Uplift to the northwest; the Sacramento Uplift to the west; and the Diablo Platform to the south (Figure VI.A.18) (McGowen et. al., 1979).

In Texas, the Dockum Group is stratigraphically divided into three formations: the basal Tecovas Formation (siltstone and claystone); the middle Trujillo Formation (sandstone and siltstone); and the upper Chinle Formation (claystone and siltstone) (Gawloski, 1983). The Trujillo Formation of West Texas is analogous to the Santa

Rosa Formation of New Mexico. The portion of the Dockum Group encountered at the site is classified as part of the Chinle Formation.

A thin surface outcrop of Dockum Group sediments exists at Baker Spring (Plate VI.A.3). At this location, approximately five feet of dusky red colored siltstone and claystone is exposed at the base of a highwall of caliche and Ogallala Formation sediments. The upper surface of the Dockum Group is irregular and indicates an eroded, disconformable contact with the overlying Ogallala Formation.

The Dockum Group was penetrated to a maximum depth of 300 feet below ground level (location 9-G) during the on-site soil boring program. Continuous cores, drill cuttings and geophysical logs were used to characterize this shallow portion of the Dockum Group at the site. This information is presented in 10 hydrogeologic cross-sections (Figure VI.A.24 through VI.A.33). In addition, the general distribution of Dockum Group silt and sand is presented in Figure VI.A.38.

Based on the results of the on-site drilling program, the Dockum Group consists primarily of reddish brown, maroon and purple siltstone and claystone with intervals of reddish tan and greenish gray siltstone and sandstone. However, as shown in the cross-sections, a number of cycles of predominantly mudstone and siltstone/sandstone deposition indicate the variable depositional history and complexity of the local Dockum Group.

The portion of the Dockum Group encountered during the on-site drilling program can be divided into three major depositional cycles: 1) a lower interval consisting of siltstone with some claystone, below an approximate elevation of 3,250 feet MSL; 2) an intermediate interval of primarily claystone with some siltstone and sandstone, within an approximate elevation range from 3,250 to 3,325 feet MSL; and 3) an upper interval consisting of siltstone and sandstone with some claystone above an approximate elevation of 3,325 feet MSL. These three depositional cycles are particularly well defined in cross-sections A-A' and J-J' (Figure VI.A.24 and VI.A.33, respectively).

The upper and lower depositional cycles represent periods of increased depositional activity. Reddish brown, massive to parallel-laminated claystones typically indicate lacustrine or prodelta sedimentation, while greenish gray and reddish brown, parallel-laminated and cross-laminated siltstones and very fine grained sandstones indicate delta-front deposition (McGowen et. al., 1979). A predominant greenish gray coloration of the siltstones and sandstones indicates deposition during periods of high lake levels (i.e., high stand), which corresponds to periods of relatively high rainfall rates. During these periods, the fluvial system is actively transporting material to the basin from distant source areas. This sediment is rich in lighter colored granitic minerals and often contains flakes of mica and biotite. A predominant reddish brown coloration of the siltstones and sandstones indicates deposition during periods of low lake level (i.e., low stand). This is when rainfall rates are relatively low, and the fluvial system is no longer transporting sediment into the basin from distant source areas. The primary sediment source consists of pre-existing Triassic strata located along the margin of the lacustrine basin.

The middle depositional cycle represents a period of relatively quite lacustrine deposition. This interval consists primarily of reddish brown, maroon and purple claystone with some siltstone and sandstone. The claystone intervals record periods of both high stand and low stand lacustrine deposition. However, a predominance of maroon and purple, worm-burrowed claystone is indicative of high stand lacustrine deposition. A dominantly reddish brown and purple claystone, mottled with greenish gray, is indicative of high stand mud flat deposition. Mud flat sediments also exhibit clay and mineral infilling of fractures (i.e., mud cracks) and contain disseminated calcium carbonate cementation and caliche nodules. Siltstone and sandstone intervals that do not exhibit observable grain size sorting trends are typically the result of fan delta deposition associated with low stand braided stream systems. Massive, reddish brown claystones which exhibit abundant worm burrows and slickensides are associated with low stand lacustrine and mud flat deposition (McGowen et. al., 1979).

The local distribution pattern of Dockum Group sandstone and siltstone indicates a sediment transportation network which is oriented in a general west to east direction. A percent sandstone and siltstone map was generated for the uppermost depositional cycle (Figure VI.A.38). The sandstone and siltstone within the upper depositional cycle exhibits a sinuous to dendritic distribution pattern, with a distribution axis running through the middle portion of the local study area. This configuration is consistent with the regional distribution pattern which indicates an east to northeast progradation of Dockum Group sands extending from a source area in the Diablo Platform to the west/southwest (Figure VI.A.39).

A sandstone and siltstone distribution map for the lower depositional cycle was not generated due the minimal number of borings which penetrate this interval. However, a geophysical logging program was conducted at eight deep locations at the proposed WCS landfill site, which provides information regarding the lateral continuity of the lower depositional cycle. These logs, combined with the results from the continuous coring/soil boring program, indicate a laterally continuous sandy silt interval within the lower depositional cycle, at an approximate subsurface elevation of 3,225 feet to 3,250 feet MSL (Figure VI.A.24 and VI.A.33).

The geophysical log signature observed in Figure VI.A.24 and VI.A.33 can also be seen on the two deep cross-sections (Plate VI.A.4 and VI.A.5) within the same approximate subsurface elevation range. As shown on the two deep cross-sections, the long axis of this sandy silt interval is oriented in a generally southwest to northeast direction. This interval is shown on Plate VI.A.5 extending over four miles from location #12 to location #15. As shown on Plate VI.A.4, the short axis of this sandy silt unit extends a minimum distance of 1.3 miles from location #4 to location #9. The southwest to northeast distribution pattern of this lower cycle sandy silt interval is consistent with the distribution pattern of the upper cycle (Figure VI.A.38) and is consistent with the regional Dockum Group sand distribution pattern (Figure VI.A.39).

A.4.4. Hydrogeologic Framework

The local hydrogeologic framework consists of unsaturated caliche and Ogallala Formation deposits overlying Dockum Group sediments which appear to be under both confined and water table conditions. Saturated conditions were encountered in the Ogallala Formation beneath the buffalo wallow at location 2-D. However, the Ogallala Formation did not yield water from any of the borings surrounding the buffalo wallow, or at any of the other locations at the proposed WCS landfill site.

This isolated occurrence of shallow groundwater in the Ogallala Formation is attributed to the localized perching of groundwater within a shallow depression in the paleotopographic surface of the Dockum Group immediately beneath the buffalo wallow. Based on the results of the site-wide drilling program, this isolated occurrence of shallow Ogallala Formation groundwater does not constitute an aquifer. See Section VI.A.4.2 for a complete discussion of local Dockum Group structure and its relationship to the 2-D buffalo wallow. A complete discussion of the local hydrogeologic system is provided in Section B.2.

A.4.5. Geotechnical Properties of the Subsurface Soils

A discussion of the subsurface soil geotechnical properties is provided in the companion report provided by JHA. Selected data based on laboratory permeameter testing are used in the discussion of local groundwater conditions contained in Section VI.B.2.

VI.B. Facility Groundwater

B.1. Regional Aquifers

The High Plains Aquifer of West Texas consists of water bearing units within: Quaternary alluvial deposits; the Pliocene Ogallala Formation; and Createceous rocks (Nativ and Gutierrez, 1988). Regionally, the Ogallala Formation is the primary component of the High Plains Aquifer (Dutton and Simpkins, 1986). The High Plains Aquifer is viewed as one, hydraulically connected aquifer system, and groundwater typically exists under both unconfined and confined conditions.

B.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 (Cronin, 1969). The general characteristics of the Ogallala Formation, which have been discussed previously in Sections A.3.1, A.3.2 and A.4.3 indicate the fluvial origin of the Ogallala Formation. There is complex vertical and lateral variability found within the Ogallala Formation.

Regionally, the Ogallala Formation thickens to the north and west. The saturated thickness of the Ogallala Aquifer ranges from a few feet to approximately 300 feet in the Southern High Plains (Nativ, 1988). Groundwater within the Ogallala Aquifer is typically under water table conditions, with a regional hydraulic gradient toward the southeast (Figure VI.B.1) ranging from approximately 10 feet/mile (Stone and Webster, 1983) to 15 feet/mile (Knowles et. al., 1984). The average hydraulic conductivity of the Ogallala Aquifer ranges from 1 foot/day (Knowles et. al., 1984) to 27 feet/day (Stone and Webster, 1983).

The Ogallala Aquifer is recharged primarily through the infiltration of precipitation. The rate of recharge is believed to be less than 1 inch/year (Stone and Webster, 1983). Groundwater discharge from the Ogallala Aquifer occurs naturally through springs, underflow, evaporation and transpiration, but is also removed artificially through pumpage and catchment. Currently, the rate of withdrawal exceeds the rate of recharge for much of the Ogallala Aquifer (Stone and Webster, 1983).

Water quality data for three Ogallala Aquifer wells, located within two miles of the site, resulted from a review of Texas and New Mexico state records for western Andrews County, Texas and eastern Lea County, New Mexico. These water well locations are tabulated in Table VI.B.1.a, and water quality data for these wells are presented in Table VI.B.1.b. The well locations are spotted on Plate VI.A.1.

Review of the water quality data indicates that the local Ogallala Aquifer contains fresh to slightly saline water (TDS $\leq$ 3,000 mg/L). The TDS value for well 26-40-201 (1,070 mg/L) is slightly above the Recommended Secondary Constituent Level of 1,000 mg/L (25 TAC Chapter 337). However, the Ogallala Formation does not appear to be water bearing at the proposed WCS landfill site.

Tertiary-Quaternary Aquifer

The Tertiary-Quaternary Aquifer is a minor regional aquifer and is not present at the proposed WCS landfill site. Quaternary-age alluvium occurs as channel deposits composed of alternating thickly bedded calcareous silt, fine sand, and clay that overlie Ogallala Formation and Chinle Formation sediments along Monument Draw (Nicholson and Clebsch, 1961). From the north end of Monument Draw southward, groundwater moves through both the Quaternary alluvium and through the large outliers of the Ogallala Formation underlying the Eunice Plain area. The sediments along Monument Draw and under the Eunice Plain to the west of the draw have an average saturated thickness of about 30 feet (Nicholson and Clebsch, 1961). The bulk of the water in the Tertiary-Quaternary Aquifer is derived by underground flow from the Laguna Valley area to the north-northwest, as local recharge by precipitation is probably negligible. East of Monument Draw, the buried Triassic strata form a north-trending barrier which is reflected topographically by Rattlesnake Ridge (Nicholson and Clebsch, 1961). Groundwater flow is diverted southward by this barrier. In the Rattlesnake Ridge area, the base of the Ogallala Formation is generally above the water table.

B.1.2. Cretaceous Aquifer

The Cretaceous Aquifer of the Southern High Plains is typically considered as part of the High Plains Aquifer (Nativ and Gutierrez, 1988). Recharge to the Cretaceous Aquifer is provided by overlying Quaternary and Ogallala Formation sediments in Texas, and by upward leakage from the underlying Dockum Group in eastern New Mexico. The regional hydraulic gradient of the Cretaceous Aquifer is toward the southeast (Figure VI.B.2).

The Cretaceous Aquifer in the Southern High Plains consists of: a basal unit - Trinity Formation sandstone; an intermediate unit - Edwards Formation limestone; and an upper unit - Kiamichi/Duck Creek Formation sandstone and limestone. Where present in the subsurface, the Cretaceous Aquifer is used in the Southern High Plains as a primary source of groundwater (Nativ and Gutierrez, 1988). However, within Andrews County, the Cretaceous Aquifer is only present in the extreme southeastern portion of the county. Therefore, the Cretaceous Aquifer is not considered to be of importance to this report and is not discussed further in this section.

B.1.3. Dockum Group Aquifer

The Dockum Group regionally consists of Triassic fluvial and lacustrine clay, shale, siltstone, sandstone and conglomerate. The Dockum Group is divided into three stratigraphic units (bottom section to top section): the Tecovas Formation; Trujillo Formation (analogous to the Santa Rosa Formation) and Chinle Formation. The Tecovas Formation is not present within the regional or local study area. Water from the Dockum Aquifer is used as a replacement for, or in combination with the Ogallala Aquifer as a regional source for irrigation, stock and municipal water (Dutton and Simpkins, 1986).

<u>Lower Dockum Aquifer</u>

Topographically controlled groundwater basin divides were developed during the Pleistocene, by the erosion of the Pecos and Canadian River valleys (Figure VI.B.3). Prior to the development of these groundwater basin divides, the lower Dockum Aquifer was recharged by precipitation on its outcrop area in eastern New Mexico (Figure VI.B.3, view a and b). However, since the development of the Pecos and

Canadian River valleys, the lower Dockum Aquifer in Texas has been cut-off from its recharge area. Without recharge, the lower Dockum Aquifer experiences a net loss of groundwater from withdrawal by wells and by seepage (Figure VI.B.3, view c and d) (Dutton and Simpkins, 1986).

Hydraulic head levels, hydrochemical facies analyses and groundwater oxygen isotope values for the Dockum Aquifer, compared to the High Plains Aquifer, indicate that the confined Dockum Aquifer is separated from the overlying High Plains Aquifer by the thick confining claystones of the upper Dockum Group (Dutton and Simpkins, 1986). Groundwater oxygen isotope values indicate that the confined Dockum Aquifer was recharged in eastern New Mexico during a cool climate, at elevations above approximately 5,900 feet MSL (Dutton and Simpkins, 1986). However, due to the Pleistocene cut-off of the lower Dockum recharge area, current recharge is negligible (Figure VI.B.3). Therefore, groundwater within the lower, confined Dockum Aquifer is "old" (up to 3 million years old) and storage is irrevocably depleted by pumpage.

The regional hydraulic gradient of the lower Dockum Aquifer, which is toward the southeast, is presented in Figure VI.B.4. It can be inferred from this map that the potentiometric surface of the water bearing zones within the lower Dockum Group is located at an approximate elevation of 3,100 feet MSL (350 feet BGL) in the area of the proposed WCS landfill site.

<u>Upper Dockum Aquifer</u>

The upper portion of the Dockum Group (Chinle Formation) serves as an aquitard in the regional and local study area (Nicholson and Clebsch, 1961; Dutton and Simpkins, 1986). This is supported by the fact that the hydraulic head of the lower Dockum Aquifer is significantly lower than that of the overlying Ogallala Aquifer throughout much of the regional study area (Figure VI.B.5). This relative head difference, approximately 200 to 300 feet in western Andrews County, suggests that the lower Dockum Aquifer is receiving essentially no recharge (Nativ, 1988). The primary limiting factors on recharge include: the aquitard characteristic of the upper Dockum Group; and the cut-off, by the Pecos River Valley, of historical recharge areas in eastern New Mexico (Figure VI.B.3).

Permeable zones do exist within the upper Dockum Group which produce low quantities of good to poor quality water. Recharge to the upper Dockum Aquifer is provided by vertical infiltration of precipitation from the overlying units of the Quaternary-Tertiary Aquifer and High Plains Aquifer. This occurs where relatively permeable zones within the Dockum Aquifer are in contact with the overlying aquifer units (Nicholson and Clebsch, 1961). Within the regional study area, the flow direction in the upper Dockum Aquifer system is toward the east, away from outcrop areas to the west (Dutton and Simpkins, 1986).

B.2. Local Groundwater Conditions

The local groundwater system consists of unsaturated caliche and Ogallala Formation deposits resting on top of Dockum Group sediments which appear to be under both confined and water table conditions. Saturated conditions were encountered in the Ogallala Formation beneath the buffalo wallow at location 2-D. However, the Ogallala Formation did not yield water from any of the borings surrounding the buffalo wallow, or at any other locations within the local study area, and therefore does not constitute an aquifer. This isolated occurrence of Ogallala Formation groundwater is attributed to the localized perching of groundwater within a shallow depression in the paleotopographic surface of the Dockum Group immediately beneath the buffalo wallow (see Section VI.A.4.2 for a complete discussion of local Dockum Group structure and its relationship to the 2-D buffalo wallow). Water bearing units within the shallow Dockum Group consist of isolated to laterally extensive prodelta and delta-front siltstones and sandstones.

B.2.1. Uppermost Aquifer

The uppermost aquifer at the site consists of the saturated portion of the Dockum Group. Insufficient data are currently available to conclusively determine the character of the uppermost aquifer. This is due to the fact that the water levels in many of the 12 groundwater monitoring wells and piezometers, which were installed as part of the field investigation, have not yet equilibrated. In some cases, this water level equilibration period currently exceeds 90 days (Table VI.B.2). However, four of the piezometers installed have approximately reached stabilization, and form the basis for the following discussion. Regardless of which portion of the local Dockum Group is ultimately defined as the uppermost aquifer, the results of the on-site drilling program and deep cross-section preparation indicate an interval of underlying clay that is in excess of 30 feet in thickness (Figure VI.A.24 through VI.A.33; Plate VI.A.4 and VI.A.5).

Hydraulic Gradient

Water level elevations at four on-site piezometers have approximately reached static conditions. The water elevations at these locations range from 3,322.11 feet MSL (150.23 feet BGL) at location 11-D, to 3,257.45 feet MSL (181.10 feet BGL) at location 2-G (Table VI.B.2). Based on this preliminary information, a east/southeast gradient of approximately 75 feet per mile (0.014 feet per foot) is inferred for the local Dockum Group (Figure VI.B.5). This information corresponds well with the regional potentiometric surface map (Figure VI.B.4), which indicates a southeast hydraulic gradient for lower Dockum Group. The regional potentiometric surface map (Figure VI.B.4) also indicates a potentiometric surface for the lower Dockum Group of approximately 3,100 feet MSL in western Andrews County.

Aquifer System

As shown in the cross-sections at locations 2-G, 7-G and 11-D (Figure VI.A.24 and VI.A.33), the present hydraulic head level in these piezometers extends well above the top of the completion interval. This suggests that the water bearing intervals at these locations are under confined conditions. However, the water levels in the supplemental wells installed in the claystone above these water bearing intervals have not yet equilibrated. Therefore, it can not be confirmed at this time whether the head levels in piezometers 2-G, 7-G and 11-D, indicate confined conditions or simply reflect the uppermost zone of saturation within the surrounding claystones (i.e., water table conditions).

The water level at piezometer 4-C has equilibrated, and is within the completion interval (Figure VI.A.29). This indicates that the Dockum Group sandstone in which piezometer 4-C is completed, is under water table conditions.

Nested wells have been installed at three locations at the site (4-G, 6-B and 9-G), to obtain data regarding vertical hydraulic gradients. Once water levels reach static conditions, a more complete understanding of the local hydrogeologic system will be gained.

Groundwater Seepage Velocity

As discussed above, the analysis of the preliminary water level data from four of the on-site piezometers, indicates a hydraulic gradient of approximately 75 feet per mile (0.014 feet per foot) towards the southeast (Figure VI.B.6). Since water levels at the site have not reached static conditions, no field testing (i.e., slug testing or aquifer pump testing) has been performed to this point to evaluate in-situ hydraulic conductivity values. The fact that most wells at the site require many weeks for their water levels to reach static conditions, provides a qualitative indication of relatively low hydraulic conductivities for the local Dockum Aquifer.

Since in-situ pumping or slug test data are not currently available, hydraulic conductivity values based on laboratory permeameter testing results were used. These hydraulic conductivity values were derived from the testing of subsurface soil samples obtained during the on-site drilling program. Porosity values are based on assumptions from Walton (1991). A discussion of the permeameter testing, and other geotechnical testing programs, is provided in the companion report prepared by JHA.

Groundwater seepage velocities were calculated for three types of lithologic material: claystone, siltstone and sandstone. The highest measured hydraulic conductivity values available, derived from laboratory permeameter testing, were used to calculate the seepage velocity for each of the three lithology types. In addition, the assumed porosity value for each lithology was selected from the low end of the published range (Walton, 1991), to maximize the calculated seepage velocity. Groundwater seepage velocities were calculated using Darcy's Law as follows:

$$v = (K/n)(dh/dl)$$ (Freeze and Cherry, 1979, p 71)

where:

v = seepage velocity
K = hydraulic conductivity
n = porosity
dh/dl = hydraulic gradient

The results of these calculations are summarized as follows:

Lithology	K (cm/sec)	n (0.20 =20%)	(dh/dl)	V (ft/day)	V (ft/year)
claystone	1.76×10^{-8}	0.10	0.014	7.0×10^{-6}	0.003
siltstone	3.20×10^{-6}	0.25	0.014	5.2×10^{-4}	0.2
sandstone	2.58×10^{-6}	0.25	0.014	4.3×10^{-4}	0.2

Groundwater Quality Data

Water quality samples have not been obtained from wells at the site. This is due to the fact that the wells have not equilibrated and have not been developed. However, a search of available state water quality data for Texas and New Mexico provided a groundwater analysis of a Dockum Aquifer well within two miles of the proposed landfill site (Table VI.B.1.b and Plate VI.A.1). This well is used as a groundwater monitoring well (MW-79) at the nearby Parabo, Inc. facility. The chemical analysis indicates slightly saline water (1,000 $\leq$ TDS $\leq$ 3,000 mg/L). The TDS (2,386 mg/L), sulfate (359 mg/L) and chloride (723 mg/L) values are above the Recommended Secondary Constituent Levels (25 TAC Chapter 337) of 1,000 mg/L, 300 mg/L and 300 mg/L, respectively.

B.2.2. Aquiclude

As discussed in Section VI.B.1.3, the Chinle Formation of the Dockum Group serves as a regional aquitard (Dutton and Simpkins, 1986). The portion of the Dockum Group encountered during the on-site drilling program consists of a complex assemblage of Chinle Formation claystone, siltstone and sandstone. As discussed in Section VI.B.2.1, laboratory-measured maximum hydraulic conductivities for site-specific Chinle Formation samples range from 1.76×10^{-8} cm/sec for claystone, to 3.20×10^{-6} cm/sec for siltstone and 2.58×10^{-6} for sandstone. These hydraulic conductivity values, combined with the massive to horizontally bedded character of local Chinle Formation, indicate that it will serve as an effective aquitard or aquiclude.

B.2.3. Underground Sources of Drinking Water (USDW)

An inventory of water wells within a 2-mile radius of the proposed landfill site was performed, based on existing state agency records. This information is summarized in

Table VI.B.1.a, and the well locations are posted on Plate VI.A.1. The 2-mile search area was initiated when no wells were found to be located within one mile of the site. A summary of groundwater quality analyses for these wells is provided in Table VI.B.1.b.

Based on geophysical log response and limited water chemistry data (Table VI.B.1.b), the Dockum Group appears to contain moderately saline water (TDS $\leq$ 10,000 mg/L). The underlying Permian units contain salt deposits and are not locally used as a water supply. Therefore, the base of the local USDW is determined to be at the base of the Dockum Group (i.e., approximately 1,400 feet BGL).

As discussed in Section B.1.1, the primary source of potable groundwater within the regional area is the Ogallala Aquifer. However, as discussed in this section, the base of the local USDW is considered to include water bearing zones within the lower Dockum Group. The local groundwater system will be insulated from proposed landfill activities at the WCS facility by the aquitard characteristics of the upper Dockum Group, and by the proposed landfill design and engineering controls. The proposed landfill design and engineering controls are discussed in the companion report provided by AME.

B.3. Detection Monitoring System

The detection monitoring system, including proposed well system (Section VI.B.3.1) and sampling parameters (Section VI.B.3.2), is discussed in the companion report provided by AME.

VI.C. Exemption from Groundwater Monitoring for an Entire Facility

WCS does not, at this time, wish to request an exemption from groundwater monitoring for the proposed landfill facility.

VI.D. Unsaturated Zone Monitoring

This section does not apply to this Part B Permit Application, because the proposed WCS facility is not a land treatment unit and is not associated with any Corrective Action.

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REPORT OF
PRELIMINARY SUBSURFACE EXPLORATION

PROPOSED NATIONAL ENRICHMENT FACILITY
LEA COUNTY, NEW MEXICO

Prepared for:

LOCKWOOD GREENE

Spartanburg, South Carolina

Prepared By:

MACTEC ENGINEERING AND CONSULTING, INC.

Knoxville, Tennessee

MACTEC Project 3043031049/0001

October 17, 2003

MACTEC

MACTEC

October 17, 2003

Mr. Philip Clarkson
Lockwood Greene
1500 International Drive
Spartanburg, SC 29304

Subject: **Report of Preliminary Subsurface Exploration**
Proposed National Enrichment Facility
Lea County, New Mexico
MACTEC Project 3043031049/0001

Dear Mr. Clarkson:

We at MACTEC Engineering and Consulting, Inc., (MACTEC) are pleased to submit this Report of Preliminary Subsurface Exploration for your project. Our services, as authorized by you, were provided in general accordance with our proposal number Prop03Knox/404, Revision 2, dated September 2, 2002.

The purpose of this preliminary exploration was to develop information about the site and subsurface conditions that could be used for assistance in determining the feasibility of constructing the proposed facilities at the site. This report describes the work performed, and presents the results obtained and our preliminary geotechnical exploration.

The preliminary exploration does not provide the necessary information to complete the design of the facilities. When specific project details concerning building and pavement locations and the foundation loads and site grades are developed, subsequent and more detailed exploration and analysis will be necessary to provide the final geotechnical design parameters.

Thank you for the opportunity to provide our professional geotechnical services during this phase of your project. We will be pleased to discuss our recommendations with you and would welcome the opportunity to provide the geotechnical engineering services needed to successfully complete your project.

Sincerely,

MACTEC ENGINEERING AND CONSULTING, INC.

Matthew B. Haston
Senior Professional

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REPORT OF PRELIMINARY SUBSURFACE EXPLORATION

PROPOSED NATIONAL ENRICHMENT FACILITY
LEA COUNTY, NEW MEXICO

Prepared for:

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Spartanburg, South Carolina

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MACTEC Project 3043031049/0001

October 17, 2003

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EXECUTIVE SUMMARY

We were selected by Lockwood Greene to perform a preliminary geotechnical exploration for the proposed National Enrichment Facility. The proposed project site is located north of New Mexico Highway 234 in the western portion of Lea County, New Mexico. The objectives of our preliminary exploration were to develop information about the site and subsurface conditions that could be used for assistance in determining the feasibility of constructing the proposed facilities at the site.

The exploration consisted of drilling five test borings in the proposed building area to depths of 40 to 100 feet. The major findings and recommendations of our subsurface exploration are as follows:

- Underlying an approximately two-foot veneer of loose eolian sands, the soil test borings encountered Quaternary age firm to very dense silty sands. Zones of rocklike calcium carbonate cemented soils (caliche) were encountered at varying intervals within this zone. Underlying the upper sandy soils, Triassic age very hard clays were encountered at depths of 35 to 40 feet. Each of the borings terminated in the clay soils at their predetermined depths.

- Ground water was not encountered in the borings performed for this exploration at the time of drilling. Based upon information from other explorations at this site and adjacent sites, we do not expect ground water to present difficulty during construction considering the preliminary maximum excavation depths.

- Shallow spread foundations bearing in the firm and better sandy soils such as those encountered in the soil test borings may be preliminarily designed using the allowable bearing pressure of 7,000 pounds per square foot.

- The upper loose eolian sands are not likely suitable for direct shallow foundation support or for the subgrade support of new engineered fills, pavements, or grade slabs. Therefore, we recommend that where encountered within building areas, these upper loose sands be stripped from the site during mass grading.

This summary is only an overview and should not be used as a separate document or in place of reading the entire report, including the appendices. Further, this is a preliminary exploration and does not provide the information for the final design of the proposed facilities. Additional field exploration, engineering analysis, laboratory and field testing may be required to develop the final geotechnical design parameters. We recommend the owner retain MACTEC to provide these services based on our familiarity with the project, the subsurface conditions, the intent of the preliminary recommendations, and our experience in this area.

1.0 OBJECTIVES OF EXPLORATION

The objective of this preliminary exploration was to develop information about the site and subsurface conditions that could be used for assistance in determining the feasibility of constructing the proposed facilities at the site and to aid in the development of a construction cost estimate and design basis. The preliminary exploration does not provide the necessary information to complete the design of the facilities. When specific project details concerning building, pavement, and railroad spur locations and the foundation loads and site grades are developed, subsequent and more detailed exploration and analysis will be necessary provide the final geotechnical design parameters. An assessment of site environmental conditions or an assessment for the presence of pollutants in the soil, rock, surface water, or ground water of the site was beyond the proposed scope of this exploration.

2.0 SCOPE OF EXPLORATION

The scope of services for this preliminary exploration has included a site reconnaissance, drilling the five requested soil test borings at the locations selected by Lockwood Greene within the proposed project area, and visually classifying the soil samples obtained from the standard penetration testing.

We collected two undisturbed and six bulk samples in conjunction with the drilling for laboratory testing. California bearing ratio (CBR), compaction, Atterberg limits, grain size, and moisture content laboratory tests were conducted on selected bulk samples to evaluate their suitability for use as engineered fill and to determine a representative CBR value for preliminary design purposes. Resistivity, pH, Atterberg limits, grain size, and moisture content laboratory tests were conducted on selected samples obtained during the standard penetration testing to evaluate the index properties of the site soils, aid in the classification of the soil type, and to assist in the evaluation of the corrosion potential of the site soils.

3.0 PROJECT INFORMATION AND SITE CONDITIONS

Project information was provided in a "Request for Proposal" (RFP) from Mr. Philip Clarkson of Lockwood Greene, dated August 18, 2003. Also provided was a drawing entitled "Conceptual Site Plan" (Drawing SKC-006), by Lockwood Greene, dated September 2, 2003. The drawing shows the preliminary location of the proposed facilities in relation to existing site features and existing topography. Lockwood Greene also provided a copy of a geotechnical exploration performed by others at a nearby site for informational purposes.

The proposed project is to consist of the construction of a National Enrichment Facility (NEF) north of Highway 234 just west of the New Mexico-Texas state line, near Eunice, New Mexico. The NEF is to be comprised of several building modules which will cover a combined total area in excess of 1,000,000 square feet. The individual building modules are to be of reinforced concrete frame construction with precast concrete exterior wall panels. The walls will act as shear walls providing lateral support for the structure. Based upon the provided drawing, several individual concrete storage pads are to be constructed to the north of the building area. These concrete pads cover an area having plan dimensions of approximately 1,000 by 2,000 feet. Also proposed for construction as part of the NEF are various paved access drives and parking areas, above ground storage tanks, cooling towers, and ancillary security and visitor center structures.

Maximum individual total column foundation loads are reportedly in the range of 400 to 1,300 kips. We understand much of the total column load is dead load. The project is in the preliminary planning phases at this time and information regarding finished grade elevations of the proposed facility has not been provided. Based upon the provided information, the finished floor is to be at about Elev.3414 feet. Site grades within the proposed project grading area range from Elev. 3402 to 3424 feet. We understand the proposed construction will not include basements or subsurface pits of more than five feet in depth.

Based upon a review of the provided topographic drawing, site grades range from about Elev. 3455 feet in the northeast corner of Section 33 down to about Elev. 3380 feet in the southwest corner of Section 32. The site is covered by sparse vegetation consisting of grasses, brush, and cacti. Surficial soils are loose sands. An existing unimproved road crosses the central portion of the site in a north-south orientation. A subsurface pipeline crosses the site in a northwest-southeast orientation.

4.0 AREA AND SITE GEOLOGY

4.1 PHYSICAL SETTING

The topography in southeastern New Mexico generally consists of broad plains and gently rolling hills with locally some bluffs and shallow river valleys. The geologic structure is relatively simple, generally consisting of flat-lying to gently warped sedimentary rocks ranging in age from Permian to Pliocene.

The site is located in the Great Plains physiographic province. In the project area, the Great Plains province is divided into two sections, the Pecos Valley section and the Southern High Plains section (Doleman, 1997). Mescalero Ridge, an escarpment (steep cliff) located about ½ mile to the northeast of the project site, is considered the boundary between the two sections. The primary difference between the two sections is the topography: the topographically lower Pecos Valley section is characterized by an irregular erosional surface while the topographically higher Southern High Plains section is a large flat mesa that slopes very gently to the southeast (Doleman, 1997).

The site is located in the Pecos Valley section of the Great Plains. Topography in this area was formed by erosion of the Tertiary age fluvial deposits and localized exposure of the underlying Mesozoic and Paleozoic rocks (Doleman, 1997). In the project area, the topography slopes gently to the southwest (at a gradient of approximately 15 feet per mile) and the surface geology is characterized by Quaternary age eolian (wind blown) deposits that mantle the underlying Quaternary and Tertiary age sediments. Local variations in local topography are reflective of the thickness and distribution of the eolian deposits.

4.2 REGIONAL GEOLOGY

The southeastern portion of New Mexico (and adjacent West Texas) is located in a geologically stable area known as the Permian Basin. This large subsurface structural basin, named for the geologic period in which it was formed, is a broad, down-warped area filled in with thick sequences of sedimentary rocks. During the late Cretaceous to early Tertiary time, tectonic uplift (mountain-building processes) to the west of the Permian Basin resulted in a structural high in the area that is now the Rocky Mountains and the southern extension of the Rocky Mountains (including the mountain ranges to the west of the project area). Erosion of this structural high provided the source area for sediments that now make up the younger Tertiary and Quaternary age formations that are locally exposed in the site vicinity.

4.3 LOCAL GEOLOGIC CONDITIONS

4.3.1 General

In the project area, the bedrock is relatively shallow (within 40 feet of the ground surface) and consists of sedimentary rocks of the Triassic age Chinle Formation. The Chinle Formation bedrock consists of a thick sequence of massive, unsaturated red, reddish purple or green claystone and siltstone with some localized fine-grained sandstone interbeds. The bedrock is overlain by approximately 35 to 40 feet of Quaternary age alluvial sediments. Based on published geologic maps and geotechnical reports for other projects in the area, the Quaternary age materials are part of the Gatuna Formation and consist of moderately cemented sand and gravel. The Gatuna Formation materials are mantled with a thin veneer of eolian (wind blown sand).

4.3.2 Geologic Materials

The materials encountered in our geotechnical borings at the site consist of Quaternary age eolian sand (wind-blown dune deposits) that is predominantly dry reddish brown silty sand. The upper loose eolian deposits were generally encountered to depths of up to two feet below existing ground surface in the exploratory borings. However, in areas where sand dunes have formed, the actual depth of the eolian soils is likely more than 2 feet.

Quaternary age alluvial deposits of the Gatuna Formation underlie the eolian deposits. As encountered in our borings, these alluvial deposits consist of dry, light yellow to reddish yellow, dense to very dense sand and silty sand. The sand is fine- to medium-grained, slightly to moderately cemented, and locally contains subangular to rounded gravel and caliche.

Dark red and purple, very hard high plasticity clay (claystone) of the Triassic age Chinle Formation uncomformably underlies the dense Gatuna Formation materials. As encountered in our borings, the Chinle Formation bedrock is at a depth of about 35 feet at the location of Boring B-2 and at a depth of about 40 feet at the location of Borings B-1, B-3, B-4, and B-5. In Boring B-3, drilled to a depth of approximately 100 feet beneath the existing ground surface, the very hard high plasticity clay was encountered from a depth of 40 feet to the maximum depth drilled (100.5 feet).

4.3.3 Ground-Water Conditions

Ground water was not encountered in the borings drilled at the site as part of our investigation. Also, ground-water wells being drilled in the eastern portion of the site by others (at the same time of our field investigation at the site) did not encounter water to a depth of about 220 feet (maximum depth drilled at the time of our investigation).

Based on the information from geotechnical investigations for other projects in the immediate area, the depth to ground water is greater than 150 feet in the general site vicinity. Ground water was not encountered in exploratory borings drilled as part of an investigation east of the site (between the site and the Texas border) within the 250-foot total depth explored (Weaver Boos & Gordon, Inc., 1998). Also, piezometers installed for a project in Andrews County Texas (located approximately ½-mile east of the site) indicate that the depth to ground water ranged from approximately 150 feet to 188 feet beneath the existing ground surface in January 1993 (Jack H. Holt, Ph.D. & Associates Inc., 1993).

4.4 TECTONIC SETTING

4.4.1 General

The tectonic regions in the project area (and in the state of New Mexico) can be defined based on historic seismicity and tectonic (structural) history. The project site is located within the seismically stable Permian Basin. The Permian Basin is defined by a broad subsurface structural feature composed of a series of Paleozoic age (greater than 250 million years before present) sedimentary basins whose last episodes of large-scale subsidence occurred during late Permian time (about 250 million years before present). The structural relief of these basins now exists as subsurface features buried beneath a thick sequence of younger, relatively undeformed sediments. Relative structural stability has been maintained since Permian time within this region as indicated by a lack of deep-seated, active faults within the post-Permian strata.

A prominent subsurface structural feature within the Permian Basin is the Central Basin Platform (CBP). The project site is located in the CBP where the top of the Permian deposits are approximately 1,400 feet below the ground surface, where outside the limits of the CBP, the Permian deposits are much deeper (Weaver Boos Consultants, Inc., 1998). The Permian deposits are primarily limestone and constitute the main reservoir rocks for the oil and gas fields in the general area.

The Permian Basin is bounded on the west by a seismically active area known as the Rio Grande Rift. The Rio Grande Rift is a major continental rift extending north-south through the state of New Mexico from north of Taos to south of Las Cruces. The overwhelming majority of active faults in New Mexico are located within the boundaries of the Rio Grande Rift.

The seismically active Basin and Range province borders the western margin of the Rio Grande Rift. This province is characterized by fault block mountain ranges commonly bounded by range front normal faults separated by intervening valleys. The valleys are typically formed on structural grabens overlain by valley fill sediments derived from the adjacent mountain blocks. Major development of basin and range structures occurred from late Tertiary (5 million years before present) to Pleistocene time (11,000 years before present) and continue into the present time. A number of fault offsets of late Tertiary age along the western flanks of the Guadalupe, Delaware, Sacramento and San Andres Mountains are observed within the Basin and Range physiographic province in Trans-Pecos, Texas.

Leveling surveys between El Paso, Texas and Carlsbad, New Mexico and the historic seismic record for the New Mexico and West Texas regions support the interpretation that current tectonic activity is occurring in the Rio Grande Rift and the Basin and Range province while the Permian Basin (in which the site is located) remains stable and tectonically or seismically quiet.

4.4.2 Faults

The majority of Quaternary age faults within New Mexico are mapped along the north-south trending Rio Grande Rift located approximately 180 miles west of the site.

According to Machette et al. (1998), Quaternary age faults are not identified in New Mexico within 100 miles of the site. Quaternary age faults within 150 miles of the site include the Guadalupe fault, located approximately 115 miles west of the site in New Mexico, and in Texas, the West Delaware Mountains fault zone, East Sierra Diablo fault, East Flat Top Mountain fault, and the East Baylor Mountain-Carrizo Mountain fault located 110 miles southwest, 120 miles southwest, 120 miles west-southwest, and 120 miles southwest of the site, respectively.

4.4.3 Seismicity

Current research indicates that the Rio Grande Rift and the adjacent Basin and Range tectonic province are seismically active and the Permian Basin (in which the site is located) is considered to be seismically quiet or inactive. As previously indicated, the overwhelming majority of active faults in New Mexico are located within the boundaries of the Rio Grande Rift. The majority of seismic activity reported in New Mexico for the period 1869 to 1998 is concentrated along the rift (Sanford, Lin, Tsai, and Jaksha, 2002). However, even though the Permian Basin is considered seismically inactive, there is a documented cluster of seismic activity in the Central Basin Platform area since the mid-1960s (U. S. Department of Energy, 2003). In this area, the spatial distribution of epicenters correlate with known locations of oil and natural gas fields and is believed to be induced by production, secondary recovery, or waste injection activities within this natural gas and petroleum province, rather than seismic sources (Sanford, Lin, Tsai, and Jaksha, 2002; U. S. Department of Energy, 2003).

5.0 SUBSURFACE CONDITIONS

Subsurface conditions were explored with five widely spaced borings drilled in general accordance with the procedures presented in Appendix A. The boring locations were selected by Lockwood Greene and boring depths were selected by MACTEC. The borings locations and elevations shown on the Boring Location Plan (Figure 2) and the Soil Test Boring Records were surveyed by others prior to the field exploration.

Subsurface conditions encountered at the boring locations are shown on the Soil Test Boring Records in Appendix B. These Soil Test Boring Records represent our interpretation of the subsurface conditions, based on the field logs and visual examination of the field samples by one of our engineers. The lines designating the interfaces between various strata on the Soil Test Boring Records represent the approximate interface locations.

The soil test borings drilled at this site typically encountered Quaternary age eolian and alluvial silty sands underlain by Triassic age clays. A discussion of the origin of these materials is presented in Section 4.0 of this report.

The upper eolian silty sand soils were encountered to a maximum depth of about two feet at the soil test boring locations. These sandy soils were observed to be loose. It should be noted that in areas where these soils have accumulated and formed dunes, the thickness of the eolian sands will be more than two feet. Dunes having estimated heights of up to about eight feet were observed during the field exploration. The upper approximately one foot of the eolian sands were observed to have fine roots and various organic materials.

Silty sand soils of Quartenary age were encountered underlying the surficial eolian deposits. These soils were classified as firm to very dense based upon their Standard Penetration Test (SPT) resistance values which ranged from 20 to in excess of 100 blows per foot. Calcium carbonated cementation was noted within this zone to a varying degree, with zones of caliche encountered at irregular intervals. Fine gravel was observed in some of the split-spoon samples from the soils within this zone.

Triassic age high plasticity clays were encountered underlying the Quaternary age sands at depths of 35 to 40 feet. These materials were classified as very hard based upon SPT resistance values which ranged from 53 to in excess of 100 blows per foot. Each of the soil test borings drilled as part of this project were terminated in the Triassic age clays at the predetermined depths.

6.0 GROUND-WATER CONDITIONS

Ground water was not observed in the test borings at the time of drilling. Also, it was reported that ground water was not encountered in borings drilled at the site by others for water well development to depths of 220 feet. For safety reasons, the borings drilled as part of MACTEC's scope of work were backfilled promptly after drilling; consequently, long-term measurements for the presence or absence of ground water were not obtained.

Fluctuations in the ground-water level occur because of variations in rainfall, evaporation, construction activity, surface run-off, and other site-specific factors. Given the proposed preliminary excavation depths, we expect ground water will not present significant construction problems for this project. The selected contractor should, however, be prepared to promptly remove surface waters which could impact construction activities.

7.0 PRELIMINARY FOUNDATION RECOMMENDATIONS

As previously noted, this exploration was for assistance in preliminary planning and design for the proposed NEF facility. Five borings, with an average spacing of 1,700 feet, across the proposed site for a project of this size are not sufficient to adequately define subsurface conditions for final design purposes. While these borings do, in our professional opinion, provide a sound basis for assistance in judging the feasibility of developing the site, there is insufficient information for developing specific, final recommendations for site preparation and foundation type or types and design parameters. The following information, therefore, should be considered as preliminary recommendations, subject to refinement when additional project details are available so that a more detailed program of borings and field or laboratory testing can be performed.

Assuming subsurface conditions encountered at the boring locations are representative of subsurface conditions elsewhere on the site, subsurface conditions generally appear to be suitable for the proposed construction supported on a system of shallow foundations. Footings bearing in the firm and dense sandy soils below the upper loose eolian (wind deposited) soils may be preliminarily designed for an allowable bearing pressure of 7,000 pounds per square foot (psf).

The upper loose eolian deposits were generally encountered to depths of up to two feet below existing ground surface in the soil test borings. However, in areas where sand dunes have formed, the actual depth of the eolian soils is likely more than two feet. If the eolian deposits are not removed as a part of mass site grading, it will be necessary to extend the foundation excavations into the underlying firm or better sandy soils to achieve the recommended preliminary allowable bearing pressure and reduce the likelihood of excessive differential settlements; therefore, we recommend that the upper eolian soils be removed during mass grading in structural areas.

The preliminary geotechnical and structural data available at this stage precludes performing rigorous settlement analyses. However, based upon the available data, our preliminary analyses indicate that spread footings bearing in the firm or better sands below the upper eolian soils as described above may be preliminarily assumed to be subject to maximum total settlements of up to about one inch for column loads of up to 1,300 kips. Under these circumstances, differential settlements may range up to ½ of an inch between similarly loaded columns. Settlements between differentially loaded or closely spaced columns would likely be more than the aforementioned values.

The behavior of a shallow foundation with respect to settlement is dependent upon a variety of factors. The information provided herein is intended to demonstrate the feasibility of shallow foundation support. Excessive differential settlement between adjacent columns, while uncommon in the firm or better soils such as those encountered in the borings, can cause structural and architectural damage. A more thorough exploration and analysis will be required to accurately estimate the range of expected total and differential settlements which may be expected when project specifics have been developed.

8.0 PRELIMINARY SITE PREPARATION RECOMMENDATIONS

Existing vegetation, surficial organic containing soils and loose eolian sands should be stripped and removed from the construction area. Typically, the upper approximately one foot of the site soils were observed to contain fine roots and limited organic materials. The eolian sands were encountered to depths of about two feet at the soil test boring locations; however, sand dunes were observed across the proposed building locations during the field exploration. These sand dunes are likely composed of loose sands and should therefore be stripped from the site as part of mass grading. Based upon our observations, sand dunes of up to eight feet in height will likely be encountered during grading. We recommend that prior to the preparation of the final bid documents, additional geotechnical exploration be performed to evaluate the depth to which the upper loose eolian sands may be encountered, especially with regard to the dune areas.

Information regarding the use of the upper loose sands for use as new fill is presented in the Engineered Fill section of this report.

After stripping the site and before placing new fill, we recommend the exposed subgrade in the building and pavement areas be proofrolled to detect unsuitable soil conditions. Proofrolling should be done after a suitable period of dry weather to avoid degrading an otherwise acceptable subgrade. Proofrolling should be performed with a heavily-loaded dump truck or with similar approved construction equipment. The proofrolling equipment should make at least four passes over each section, with the last two passes perpendicular to the first two.

We recommend the exposed subgrade and proofrolling operation be observed and documented by our personnel. If unstable conditions are encountered at the subgrade level, our geotechnical engineer will make appropriate recommendations to the owner's representative for dealing with the conditions.

Earth moving, selective borrowing and soil compaction will be required to achieve the final grades proposed for this project. Contractors bidding on this work should be supplied with this preliminary geotechnical information as well as supplemental exploration results because bids based on such data are generally more competitive, time schedules are more accurate and potential cost overruns are smaller as a result. Typical information required for grading operations would require further refinement of the items listed below in relationship to the selected site surface elevations:

- Classification tests to identify soil type
- Existing soil moisture contents to plan moisture content control measures
- Additional compaction tests to determine the maximum dry density and optimum moisture content for verifying the adequacy of compaction operations
- Evaluation of the compaction test results and recommendations of proper compaction procedures such as lift thickness, proper equipment types, moisture content control measures, etc.
- Further delineation of the stratification of materials to be excavated

9.0 DIFFICULT EXCAVATION

Construction of the proposed NEF will require excavation of the existing site soils to get within the range of the preliminary finished floor at about Elev. 3,414 feet. Based upon the limited number of borings performed for the preliminary exploration, much of these materials may be removed using conventional earthmoving equipment. However, zones of very dense soils and caliche were encountered above the proposed finished floor elevation. Therefore, such materials will likely be encountered during site grading. Heavy excavating equipment with ripping tools could be required to remove much of these materials. Materials sufficiently hard to cause refusal to the power auger equipment used to drill the borings were not encountered during the preliminary exploration.

Typically, there is no sharp transition between uncemented and cemented soils in geologic settings such as this site. The caliche encountered during this exploration could be penetrated by the mechanical auger used to drill the borings and can likely be excavated without blasting. It is, however, often difficult to excavate these materials without the use of specialized equipment or blasting, especially if harder or more extensive zones of caliche are encountered during site grading. The excavation of very dense soils or caliche in confined excavations, such as for shallow foundations or utilities, is often extremely difficult. The ease of excavation depends on the quality of the grading equipment, skill of the equipment operators, and geologic structure of the material to be excavated. Materials that cannot be penetrated by the mechanical auger often require blasting prior to removal.

10.0 PRELIMINARY SEISMIC CONSIDERATIONS

10.1 SITE COEFFICIENT AND SEISMIC ZONATION

The site coefficient, S, for seismic design of the proposed buildings can be determined as established in the Earthquake Regulations under Section 1629 of the Uniform Building Code (UBC) 1997 edition. Based on Figure 16-2 of the 1997 UBC, the site is located within Seismic Zone 1. In addition, based on our review of the site soil conditions as encountered in our borings and local geology, the Soil Profile Type may be assumed to be Type S_C as defined in Table 16-J of the 1997 UBC.

10.2 LIQUEFACTION

Liquefaction potential is greatest where the ground-water level is shallow, and submerged loose, fine sands occur within a depth of about 50 feet or less. Liquefaction potential decreases as grain size and clay and gravel content increase. As ground acceleration and shaking duration increase during an earthquake, liquefaction potential increases.

Ground water was not encountered in our borings drilled to a maximum depth of 100 feet below the ground surface. In addition, it was reported that a boring on the site drilled for water well development did not encounter water at a depth of 220 feet. Also, the soils at the site were dense to very dense. The absence of ground water near the surface would make the potential for liquefaction remote.

11.0 COMPACTED FILL RECOMMENDATIONS

We recommend compacted fill be constructed by spreading acceptable soil in loose layers not more than 8 inches thick. The soils used within the proposed construction areas should be compacted in lifts to at least 95 percent of the modified Proctor maximum dry density (ASTM D 1557). The upper 24 inches of fill beneath pavements and upper 12 inches beneath grade slabs should be compacted to at least 98 percent of the modified Proctor maximum dry density.

As a general rule, the moisture content of the fill soils compacted to 95 percent of the modified Proctor density should be maintained within +3 to -3 percentage points of the optimum moisture content as determined from the compaction test. This provision may require the contractor to dry soils during periods of wet weather or to wet soils during warm or dry periods. The fill soils should have a plasticity index (PI) of less than 15, and a maximum dry density of no less than 90 pounds per cubic foot (pcf).

A sample of potential borrow material was collected from Borings B-3 and B-4 and tested to determine the maximum dry density, optimum moisture content, natural moisture content, and PI. These tests are used to determine if the soil is suitable for use as engineered fill.

The laboratory test data indicate potential on-site borrow soils are typically dryer than the optimum moisture content. Since some of the natural moistures are substantially less than optimum moisture content, the contractor should anticipate wetting of the borrow soils will likely be required to achieve adequate compaction. Our laboratory test data also indicate the potential on-site borrow soils have maximum dry densities and PI values within the recommended ranges. In our opinion, the laboratory data indicate the potential on-site borrow soils are suitable for use as compacted fill. Additional testing should be performed to verify the suitability of the proposed borrow materials prior to final design or the initiation of site grading. The results of the laboratory tests along with a description of the test procedures are provided in Appendix C.

If calcium carbonate cemented soils (caliche) are to be used as engineered fill, it is imperative this material be reduced to particles having a maximum dimension of six inches by the excavation and compaction equipment. Sufficient quantities of soil should be mixed with these materials such that voids do not result between the pieces of caliche and so that the fill meets compaction requirements.

The upper eolian sands removed as part of site stripping are likely suitable for use as engineered fill provided the organic content of these materials is within an acceptable range. It is our preliminary recommendation that soils having an organic content of less than two percent, when subject to organic loss on ignition testing, are suitable for use as engineered fill. The upper approximately one foot of the eolian sands were observed to contain fine roots and organic materials. The upper eolian sands are likely to have in-situ moisture contents well below the materials optimum moisture content and the addition of water will be necessary to achieve the recommended degree of compaction.

12.0 CORROSION POTENTIAL

Corrosion is a major factor in reducing the service life of metal and concrete structures within the soil. Therefore, measuring the corrosion potential of soils is an important consideration when designing or selecting protective measures for buried structures or potions of structures.

There are several measurable soil properties which may be used to estimate the potential corrosiveness of a soil. These properties include resistivity, pH, chloride concentration, and sulfide content. Resistivity and pH are the two soil properties which have the greatest influence on underground corrosion and are relatively easily measured.

The electrical resistivity of a soil is measured in the laboratory by immersing the probe of a conductivity meter into a prepared slurry of soil sample and deionized water. Split-spoon samples from the depths of 5 and 10 feet were combined and tested from Borings B-2 and B-4. The measured resistivity of these samples was 7,400 and 2,100 ohm-centimeters for the samples from Borings B-2 and B-4, respectively.

The pH of a soil is a measure of the hydrogen-ion concentration and indicates the intensity of acidity or alkalinity of a soil. A pH value of 7 indicates neutrality; higher values, alkalinity; lower values, acidity. Soil pH values were determined by immersing the probe of a pH meter into a prepared slurry of soil sample and deionized water. The pH values were 7.99 and 7.93 for the samples from Borings B-2 and B-4, respectively.

Based upon published information, the measured pH and resistivity values place the site soils in the non-corrosive to questionable range for corrosion potential.

As the sample from Boring B-4 fell within the questionable range, we recommend further evaluation of the potential for corrosion. This evaluation will likely include additional pH and resistivity tests, as well as testing of the soil's sulfide and chloride concentration. Measures such as special coatings or cathodic protection for buried steel structures or the use of admixtures or chemically resistant cement for concrete protection may be required depending upon the results of such testing.

13.0 PRELIMINARY PERCOLATION RATE

Percolation testing was conducted at the proposed NEF site in general accordance with the procedures presented in Title 20, Chapter 7, Part 3 of the New Mexico Administrative Code (NMAC). Percolation testing was performed at locations approximately 25 and 75 feet east of soil test Boring B-4. The test holes were each drilled to depths of about 10 feet below existing ground surface in the silty sand soils such as those encountered in the upper portion of the subsurface profile across the site. Each hole was filled with water to a depth of about 1½ feet below existing ground surface; therefore, the upper loose eolian sands are not represented in the percolation test results.

The measured percolation rates for the two test locations were 6.7 and 10.0 minutes per inch. Averaging the two test results, as is suggested in the NMAC, the percolation rate of 8.4 minutes per inch is recommended for the preliminary design of systems leaching into materials similar to those tested. Additional percolation testing should be performed once information concerning specific drain field locations and elevations has been developed.

14.0 PRELIMINARY CALIFORNIA BEARING RATIO INFORMATION

Two remolded CBR tests were performed on bulk soil samples collected from auger cuttings. The samples were obtained from the depths of 5 to 10 feet in Boring B-3 and from ground surface to 15 feet in Boring B-4. Since the as-molded densities and moisture contents differed somewhat from the targeted values, interpolation and extrapolation of the CBR data were required to estimate the CBR values at 95 percent of the modified Proctor maximum dry density at optimum moisture content. The CBR test results are attached in Appendix C.

The CBR values corresponding to 95 percent of the modified Proctor maximum dry density at optimum moisture were estimated to be 34.4 and 10.5 for the samples from B-3 and B-4, respectively. We recommend the lower CBR value of 10.5 for use in preliminary design purposes.

Additional testing should be performed to evaluate the CBR values of proposed fill soils prior to the completion of the final design.

15.0 RECOMMENDED ADDITIONAL GEOTECHNICAL EXPLORATION

This exploration is preliminary in nature and should be used for general site planning and feasibility evaluation only. Due to the relatively limited information available at this preliminary stage of the project, preparation of a complete report of geotechnical study with specific recommendations for foundation design and site preparation will require significant supplemental exploration and analysis. Project details and performance criteria should, however, be initially further developed. As project details are developed, additional exploration, field and laboratory testing, and engineering analysis will be required. Additional field testing may include items such as more soil test borings, the collection of relatively undisturbed and disturbed samples, and possibly in-situ testing. Additional laboratory testing may include triaxial shear tests, consolidation tests, direct shear tests, grain size testing, unit weight, Atterberg limits, moisture content and compaction tests. Field resistivity testing may be used in conjunction with laboratory pH, chloride content, and sulfate tests to further evaluate the corrosion potential of the site soils. The geotechnical engineer should be retained to consult with the designer during design development, design and construction phases to be sure that the recommendations are properly interpreted and further developed as necessary.

16.0 BASIS OF RECOMMENDATIONS

The preliminary recommendations provided herein are based on the subsurface conditions and on project information provided to us; they apply only to the specific project and site discussed in this report. If the project information section in this report contains incorrect information or if additional information becomes available, you should convey the corrected or additional information to us and retain us to review our recommendations. We will then modify them if the new information has rendered them inappropriate for the proposed project. As mentioned previously, additional exploration and analysis along with interaction of the design team will be required to develop final recommendations for foundation design and site preparation.

Our exploration services include storing the collected samples and making them available for inspection for a period of 30 days. The samples are then discarded unless you request otherwise.

17.0 REFERENCES

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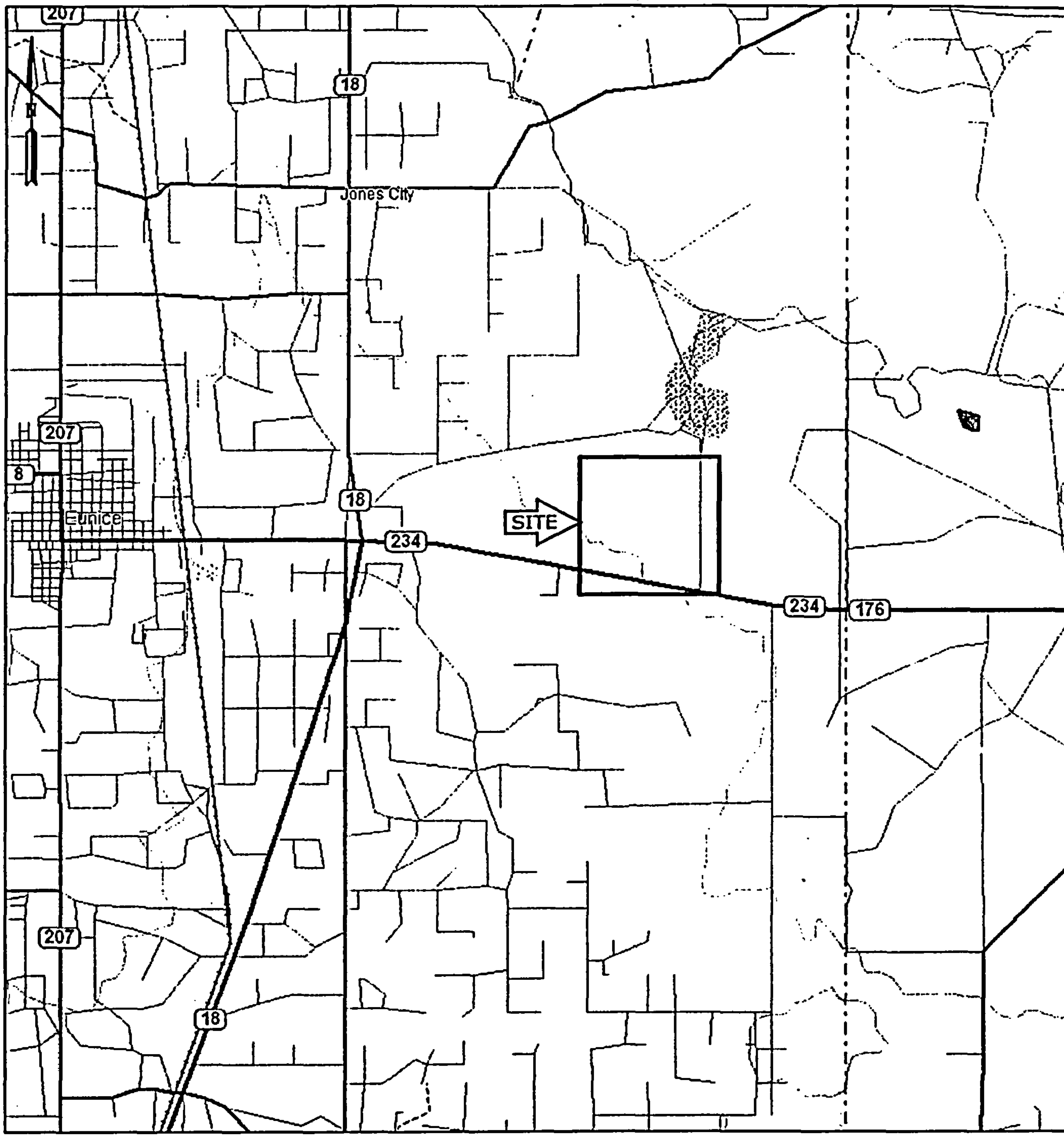
FIGURES



SOURCE: DELORME MAPPING AND OBSERVATIONS BY MACTEC PERSONNEL

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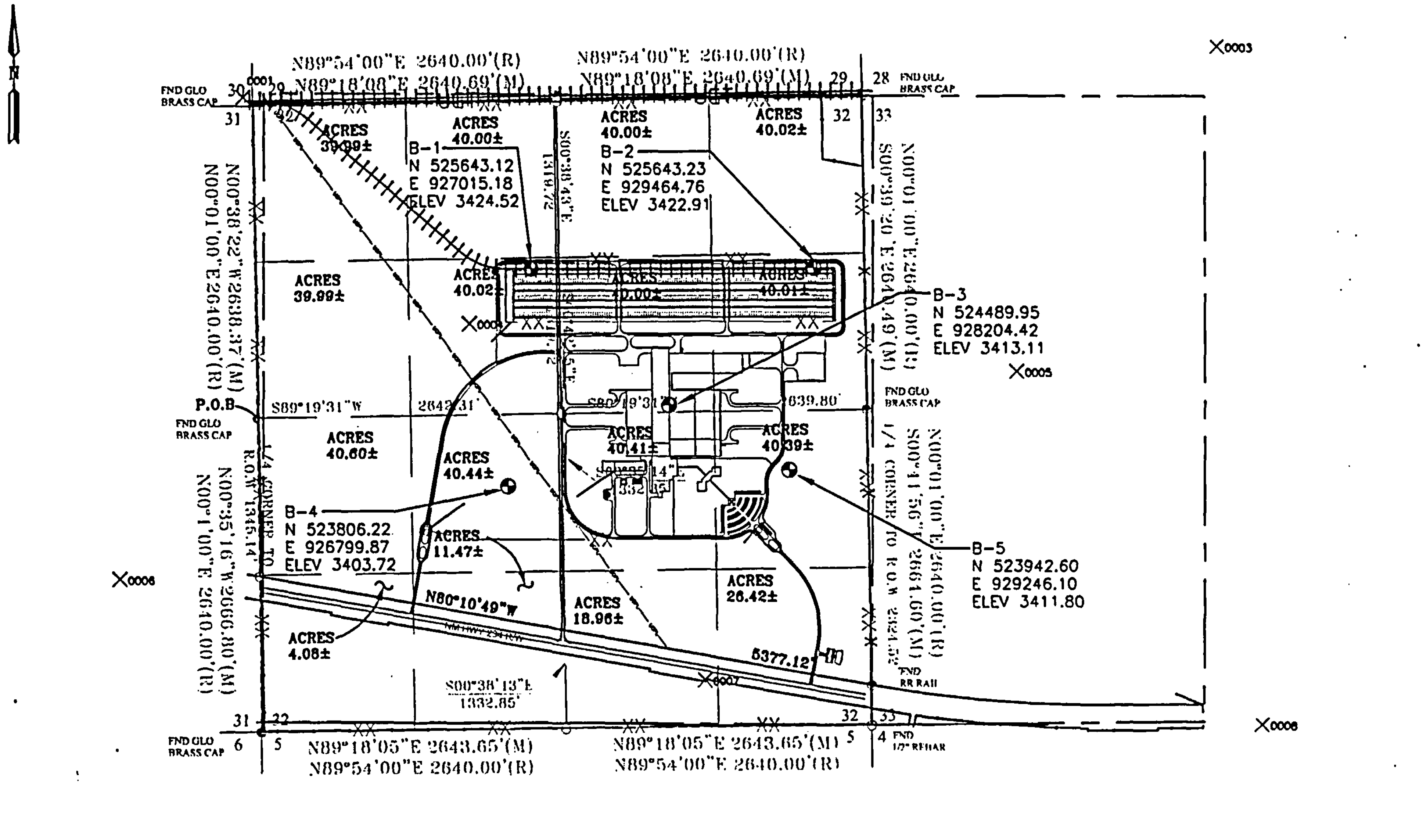
Knoxville, Tennessee 37921-5904
865-588-8544 • Fax: 865-588-8026

FIGURE 1: SITE LOCATION PLAN
NATIONAL ENRICHMENT FACILITY
LEA COUNTY, NEW MEXICO

DRAFTING BY:	PREPARED BY: mBH	CHECKED BY: JMS
JOB NUMBER: 3043031049/0001	DATE: OCTOBER 2, 2003	SCALE: 0 6250'

COORDINATES: N XX°XX'XX" W XX°XX'XX"



SOURCE: THIS DRAWING WAS ADAPTED FROM A CONCEPTUAL SITE PLAN SOIL BORING LAYOUT DATED SEPTEMBER 2, 2003 AND PROVIDED BY LOCKWOOD GREENE.

LEGEND

B-1 BORING LOCATION AND IDENTIFICATION

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Knoxville, Tennessee 37921-5904
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FIGURE 2: BORING LOCATION PLAN
NATIONAL ENRICHMENT FACILITY
LEA COUNTY, NEW MEXICO

DRAFTING BY:	PREPARED BY: MBH	CHECKED BY: JMS
JOB NUMBER: 3043031049/0001	DATE: OCTOBER 2, 2003	SCALE: 0 1000'

COORDINATES: N XX°XX'XX" W XX°XX'XX"

APPENDIX A

FIELD EXPLORATORY PROCEDURES

FIELD EXPLORATORY PROCEDURES

Soil Test Boring (Hollow Stem)

Soil test borings and sampling operations were conducted in general accordance with ASTM D 1586. The borings were advanced by mechanically turning continuous steel hollow-stem auger flights into the ground. At regular intervals, soil samples were obtained with a standard 1.4-inch I.D., 2-inch O.D., split-tube sampler. The sampler was first seated 6 inches to penetrate any loose cuttings and then driven an additional foot with blows of a 140-pound hammer falling 30 inches. The number of hammer blows required to drive the sampler the final foot of penetration was recorded and is designated the "standard penetration test (SPT) resistance." Proper evaluation of the penetration resistance provides an index to the soil's strength, density, and ability to support foundations.

Representative portions of the soil samples obtained from the split-tube sampler were examined by our engineer to assign manual soil classifications. Representative portions of the split-spoon samples were then placed in containers and shipped to our laboratory. Test Boring Records are attached, graphically showing the soil descriptions and penetration resistances.

Boring Backfill

The borings were backfilled shortly after drilling for safety purposes. We backfilled the borings with auger cuttings to the ground surface.

You are advised that, even with this backfill technique, there is the possibility of future borehole subsidence depending on actual subsurface conditions, surface drainage, etc. The property owner should monitor the boring locations over time to discover subsidence and make any necessary repairs.

Bulk Samples

Bulk samples of several soil types obtained at various elevations were collected for testing to determine the suitability of soil for reuse as engineered fill, its maximum dry density and CBR value.

Undisturbed Sampling

The relatively undisturbed samples were obtained by pushing a section of 3-inch O.D., 16-gauge steel tubing into the soil at the desired sampling level. The sampling procedure is described by ASTM D-1587. The tube, together with the encased soils, was carefully removed from the ground, made airtight, and transported to our laboratory.

APPENDIX B

KEY TO SYMBOLS AND DESCRIPTIONS

SOIL TEST BORING RECORDS

GROUP SYMBOLS	TYPICAL NAMES	GROUP SYMBOLS	TYPICAL NAMES
	TOPSOIL		**CONCRETE**
	ASPHALT		**DOLOMITE**
	GRAVEL		**LIMESTONE**
	FILL		**SHALE**
	SUBSOIL		**LIMESTONE/SHALE** - Limestone with shale interbeds
	ALLUVIUM		**SANDSTONE**
	COLLUVIUM		**SILTSTONE**
	RESIDUUM - Soft to firm		**AUGER BORING**
	RESIDUUM - Stiff to very hard		**UNDISTURBED SAMPLE ATTEMPT**

	Undisturbed Sample 1.5-2.0 = Recovered (ft) / Pushed (ft)		
	Split Spoon Sample		Auger Cuttings
	Rock Core 60-100 = RQD / Recovery		Dilatometer
	No Sample		Crandall Sampler
	Rotary Drill		Pressure Meter
∇	Water Table at time of drilling	○	No Recovery
		▼	Water Table after 24 hours

Correlation of Penetration Resistance with Relative Density and Consistency

SAND & GRAVEL		SILT & CLAY	
No. of Blows	Relative Density	No. of Blows	Consistency
0 - 4	Very Loose	0 - 2	Very Soft
5 - 10	Loose	3 - 4	Soft
11 - 20	Firm	5 - 8	Firm
21 - 30	Very Firm	9 - 15	Stiff
31 - 50	Dense	16 - 30	Very Stiff
Over 50	Very Dense	31 - 50	Hard
		Over 50	Very Hard

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

SILT OR CLAY	SAND			GRAVEL		Cobbles	Boulders
	Fine	Medium	Coarse	Fine	Coarse		

No.200 No.40 No.10 No.4 3/4" 3" 12"

U.S. STANDARD SIEVE SIZE

Reference: The Unified Soil Classification System, Corps of Engineers, U.S. Army Technical Memorandum No. 3-357, Vol. 1, March, 1953 (Revised April, 1960)

KEY TO SYMBOLS AND DESCRIPTIONS

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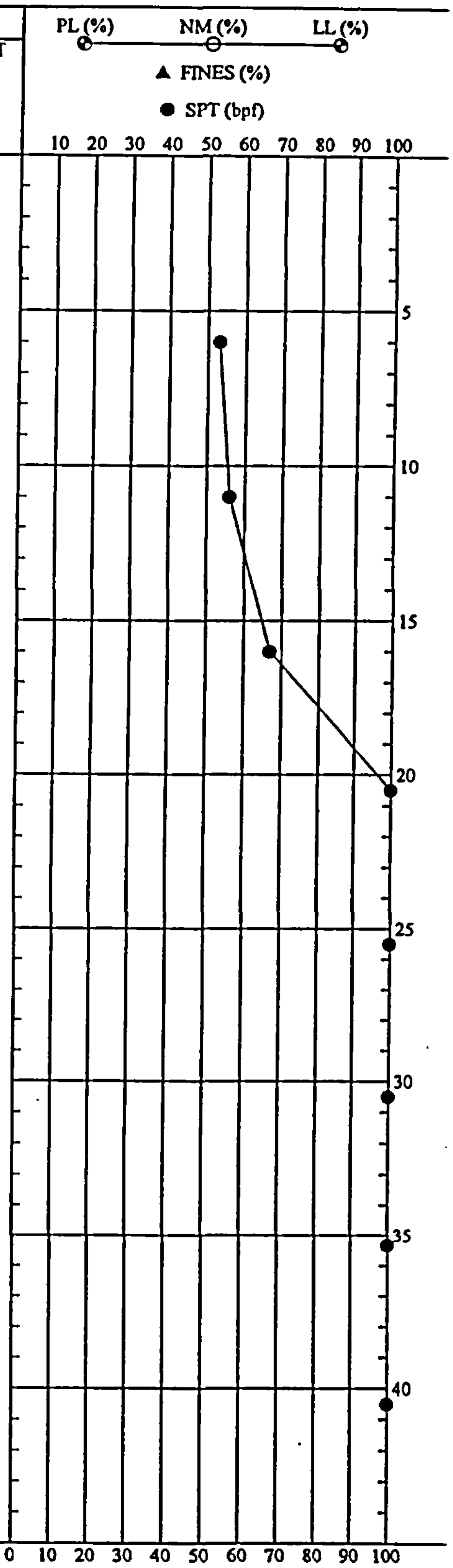
DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.	ELEV (ft)	SAMPLES IDENT	N-COUNT (1st 6" - 2nd 6" - 3rd 6")
0	REDDISH BROWN, DRY, SILTY FINE SAND WITH SOME FINE ROOTS - EOLIAN	3423.4		
	VERY DENSE, REDDISH BROWN, DRY, SILTY FINE TO MEDIUM SAND			
5		3418.4	SPT-1	15-25-28
10		3413.4	SPT-2	21-30-26
15	VERY DENSE, DARK RED, DRY, FINE TO MEDIUM SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND	3408.4	SPT-3	15-30-37
20	VERY DENSE, LIGHT REDDISH YELLOW, DRY, SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND	3403.4	SPT-4	50/6"
			UD-1	1.0-2.0
25		3398.4	SPT-5	50/6"
30		3393.4	SPT-6	50/6"
35	VERY DENSE, LIGHT REDDISH YELLOW, SILTY FINE TO COARSE SAND WITH SOME SUBANGULAR TO ROUNDED FINE GRAVEL	3388.4	SPT-7	50/4"
40	VERY HARD, DARK RED, DRY, HIGH PLASTICITY CLAY BORING TERMINATED 40.5'	3383.4	SPT-8	50/6"
45		3378.4		



REMARKS: STANDARD PENETRATION RESISTANCE TESTING PERFORMED USING A SAFETY HAMMER. NO GROUND WATER ENCOUNTERED AT TIME OF EXPLORATION. BACK FILLED ON 9/9/2003.

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 9, 2003 **BORING NO.:** B-1

PROJ. NO.: 3043031049/0001 **PAGE 1 OF 1**

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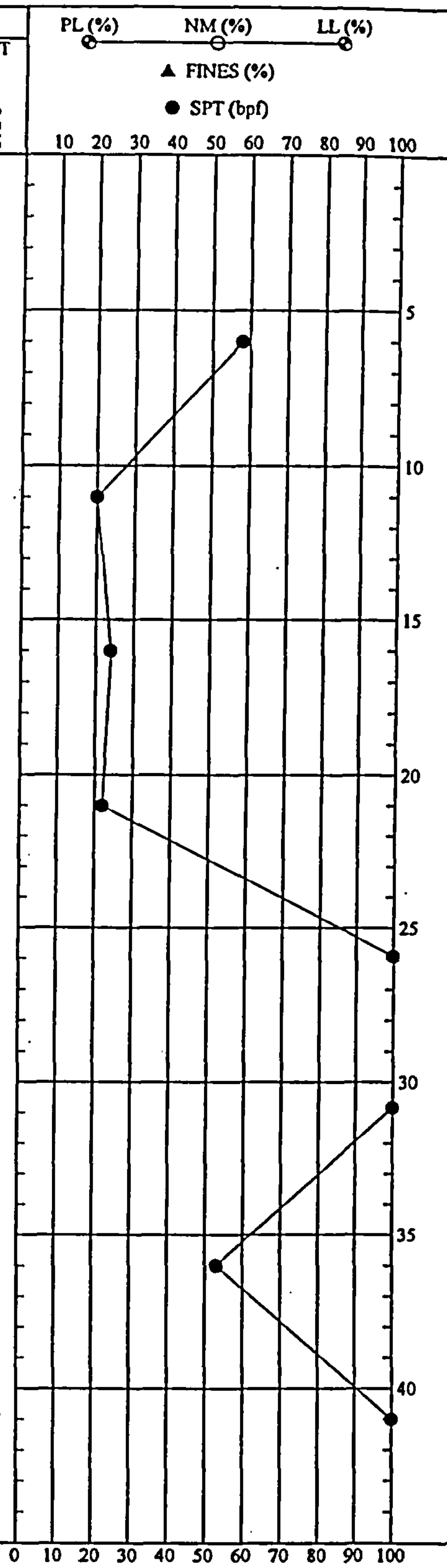
SOIL 3045031049 01.GPJ LAW GIBB.GDT 10/3/03

DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.	LEGEND	ELEV (ft)	SAMPLES IDENT	TYPE	N-COUNT (1st 6" 2nd 6" 3rd 6")
0	REDDISH BROWN, DRY, SILTY, FINE SAND WITH SOME FINE ROOTS - EOLIAN		3422.2			
	VERY DENSE, LIGHT YELLOW, DRY, FINE SILTY SAND WITH CLASTS OF CEMENTED SAND - CALICHE FROM 6.0' - 7.5'					
5			3417.2	SPT-1		13-29-29
10	FIRM TO VERY FIRM, LIGHT YELLOW, DRY, SILTY FINE TO MEDIUM SAND		3412.2	SPT-3		11-10-10
15			3407.2	SPT-4		9-12-12
20	VERY FIRM TO VERY DENSE, LIGHT YELLOW, SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND FROM 25.0' TO 35.0'		3402.2	SPT-5		13-10-12
25			3397.2	SPT-6		15-50/5"
30			3392.2	SPT-7		50/1"
35	VERY HARD, DARK RED AND PURPLE, MOIST, HIGH PLASTICITY CLAY		3387.2	SPT-8		14-23-30
40			3382.2	SPT-9		12-33-50/5"
	BORING TERMINATED AT 41.4'					
45			3377.2			



SOIL 3043031049 01.GPJ LAW GIBB.GDT 10/3/03

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SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 9, 2003 **BORING NO.:** B-2

PROJ. NO.: 3043031049/0001 **PAGE 1 OF 1**

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DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS (SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.)	ELEV (ft)	SAMPLES IDENT	N-COUNT (1st 6" 2nd 6" 3rd 6")	SPT (bpf)
0	REDDISH BROWN, DRY, SILTY FINE SANDY WITH SOME ROOTS - EOLIAN	3412.5			
	VERY DENSE, REDDISH BROWN, DRY, SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND				
5		3407.5	SPT-1	30-50/5"	
10		3402.5	SPT-2	33-50/6"	
15	VERY DENSE, LIGHT YELLOW, DRY SILTY FINE TO MEDIUM SAND - CALICHE	3397.5	SPT-3	50/1"	
20	VERY DENSE, REDDISH YELLOW, DRY SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND AND SOME FINE SUBANGULAR TO ROUNDED GRAVEL	3392.5	SPT-4	22-40-50/3"	
25	VERY DENSE, LIGHT YELLOW, DRY SILTY FINE TO MEDIUM CEMENTED SAND - CALICHE	3387.5	SPT-5	50/2"	
30		3382.5	SPT-6	50/2"	
35	VERY DENSE, REDDISH BROWN, DRY, SILTY FINE TO MEDIUM SAND	3377.5	SPT-7	50/3"	
40	VERY HARD, DARK RED, DRY, HIGH PLASTICITY CLAY	3372.5	SPT-8	23-50/6"	
45		3367.5			

PL (%) — NM (%) — LL (%)

▲ FINES (%)

● SPT (bpf)

0 10 20 30 40 50 60 70 80 90 100

REMARKS: STANDARD PENETRATION RESISTANCE TESTING PERFORMED USING A SAFETY HAMMER. NO GROUND WATER ENCOUNTERED AT TIME OF EXPLORATION. BACK FILLED ON 9/10/2003.

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SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 10, 2003 **BORING NO.:** B-3

PROJ. NO.: 3043031049/0001 **PAGE 1 OF 3**

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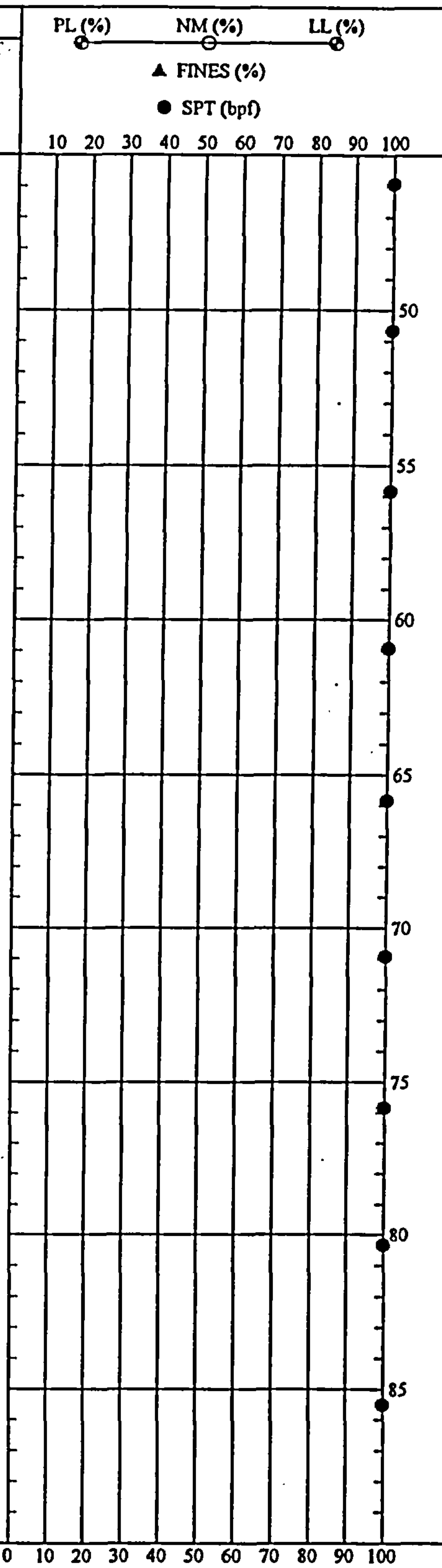
SOIL 3043031049 01.GPJ LAW GIBB.GDT 10/3/03

DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS (SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.)	LEGEND	ELEV (ft)	SAMPLES IDENT	TYPE	N-COUNT (1st 6" / 2nd 6" / 3rd 6")
45	VERY HARD, DARK RED, DRY, HIGH PLASTICITY CLAY		3367.5	SPT-9		27-50/5"
50			3362.5	SPT-10		39-50/2"
55	VERY HARD, DARK RED AND PURPLE, DRY, HIGH PLASTICITY CLAY		3357.5	SPT-11		35-50/4"
60			3352.5	SPT-12		31-50/5"
65			3347.5	SPT-13		32-50/4"
70			3342.5	SPT-14		22-50/5"
75			3337.5	SPT-15		39-50/4"
80	VERY HARD, DARK RED AND PURPLE, DRY, HIGH PLASTICITY CLAY WITH OCCASIONAL THIN CEMENTED LAYERS OF GREENISH GRAY		3332.5	SPT-16		50/4"
85	VERY HARD, REDDISH PURPLE WITH GRAY MOTTLING, DRY HIGH PLASTICITY CLAY		3327.5	SPT-17		50/6"
90			3322.5			



SOIL 3045031049 01.GPJ LAW GIBB.GDT 10/3/03

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SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 10, 2003 **BORING NO.:** B-3

PROJ. NO.: 3043031049/0001 **PAGE 2 OF 3**

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SOIL 3045031049_01.GPJ LAW_GIBB.GDT 10/3/03

DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS (SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.)	ELEV (ft)	SAMPLES IDENT	N-COUNT (1st 6" / 2nd 6" / 3rd 6")	SPT (bpf)
90	VERY HARD, RED AND PURPLE, DRY, HIGH PLASTICITY CLAY	3322.5	SPT-18	50/5"	100
95		3317.5	SPT-19	50/6"	100
100		3312.5	SPT-20	50/6"	100
100.5	BORING TERMINATED AT 100.5'				
105		3307.5			
110		3302.5			
115		3297.5			
120		3292.5			
125		3287.5			
130		3282.5			
135		3277.5			

PL (%) — NM (%) — LL (%)
▲ FINES (%)
● SPT (bpf)

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SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 10, 2003 **BORING NO.:** B-3

PROJ. NO.: 3043031049/0001 **PAGE 3 OF 3**

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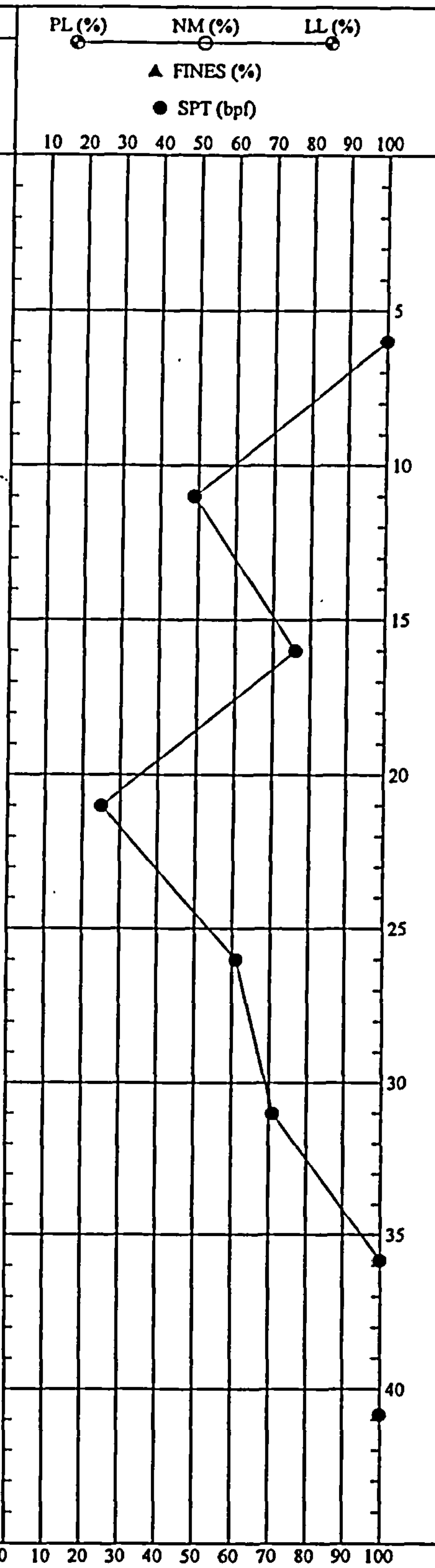
DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS (SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.)	ELEV (ft)	SAMPLES IDENT	N-COUNT (1st 6" / 2nd 6" / 3rd 6")
0	REDDISH BROWN, DRY, SILTY FINE SAND WITH SOME ROOTS - EOLIAN	3403.5		
	VERY DENSE, REDDISH BROWN, DRY, SILTY FINE SAND			
5		3398.5	SPT-1	26-50/6"
10	DENSE TO VERY DENSE, LIGHT RED, DRY, SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND	3393.5	SPT-2	17-26-23
15		3388.5	SPT-3	20-39-37
20	VERY FIRM TO VERY DENSE, LIGHT RED, DRY, SILTY FINE SAND WITH CEMENTED ZONES FROM 25.0' TO 30.0'	3383.5	SPT-4	7-13-12
			UD-2	1.0-2.0
25		3378.5	SPT-5	16-34-27
30	VERY DENSE, LIGHT REDDISH BROWN, DRY FINE SILTY FINE TO MEDIUM SAND	3373.5	SPT-6	16-30-41
35		3368.5	SPT-7	39-50/4"
40	VERY HARD, DARK RED, DRY, HIGH PLASTICITY CLAY	3363.5	SPT-8	35-50/4"
	BORING TERMINATED AT 40.8'			
45		3358.5		



SOIL 3043031049 01.GPJ LAW GIBB.GDT 10/3/03

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SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 9, 2003 **BORING NO.:** B-4

PROJ. NO.: 3043031049/0001 **PAGE 1 OF 1**

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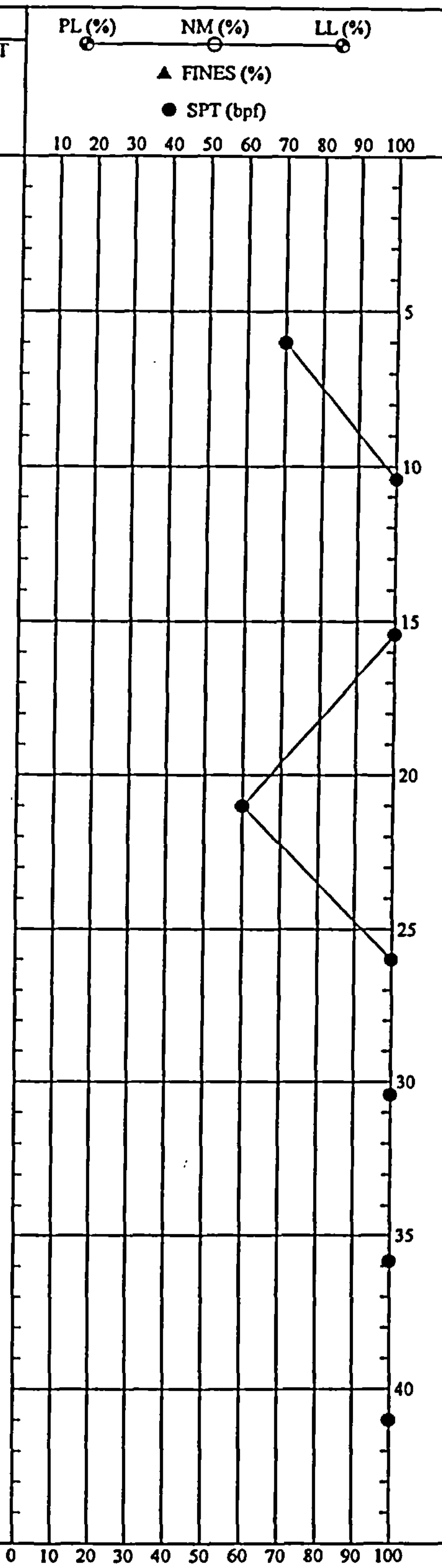
DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.	ELEV (ft)
0	REDDISH BROWN, DRY, SILTY FINE SAND WITH SOME FINE ROOTS - EOLIAN	3411.2
	VERY DENSE, REDDISH YELLOW, DRY SILTY FINE TO MEDIUM SAND	
5		3406.2
10	VERY DENSE, LIGHT YELLOW, DRY, SILTY FINE TO MEDIUM CEMENTED SAND - CALICHE	3401.2
15		3396.2
20	VERY DENSE, LIGHT YELLOW, DRY SILTY FINE TO MEDIUM SAND WITH CLASTS OF CEMENTED SAND	3391.2
25		3386.2
30	VERY DENSE, REDDISH YELLOW, DRY, SILTY FINE TO MEDIUM SAND WITH SOME FINE SUBANGULAR TO ROUNDED GRAVEL	3381.2
35		3376.2
40	VERY HARD, REDDISH PURPLE, DRY, HIGH PLASTICITY CLAY	3371.2
	BORING TERMINATED AT 41.0'	
45		3366.2

SAMPLES

IDENT	N-COUNT (1st 6" - 2nd 6" - 3rd 6")
SPT-1	25-35-35
SPT-2	50/5"
SPT-3	50/5"
SPT-4	15-24-36
SPT-5	9-38-50/4"
SPT-6	50/5"
SPT-7	30-50/4"
SPT-8	18-50/6"



SOIL 3045031049 01.GPJ LAW GIBB.GDT 10/3/03

REMARKS: STANDARD PENETRATION RESISTANCE TESTING PERFORMED USING A SAFETY HAMMER. NO GROUND WATER ENCOUNTERED AT TIME OF EXPLORATION. BACK FILLED ON 9/10/2003.

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT: NEF - Lea County, New Mexico

DRILLED: September 10, 2003 **BORING NO.:** B-5

PROJ. NO.: 3043031049/0001 **PAGE 1 OF 1**

MACTEC

APPENDIX C

LABORATORY TEST PROCEDURES

LABORATORY TEST RESULTS

LABORATORY TEST PROCEDURES

Atterberg Limits

Originally, the Atterberg Limits consisted of seven "limits of consistency" of fine-grained soils. In current engineering usage, the term usually refers only to the liquid limit (LL) and plastic limit (PL). The LL (between the liquid and plastic states) is the water content at which a trapezoidal groove of specified shape, cut in moist soil held in a special cup, is closed after 25 taps on a hard rubber plate. The PL (between plastic and semi-solid states) is the water content at which the soil crumbles when rolled into threads of 1/8 inch in diameter.

The LL has been found to be proportional to the compressibility of the normally consolidated soil. The PI is the calculated difference in water contents between the LL and the PL. Together the LL and PI are used to classify silts and clays according to the Unified Soil Classification System (ASTM D 2487). The PI is used to predict the potential for volume changes in confined soils beneath foundations or grade slabs. The LL, PL, and PI are determined in accordance with ASTM D 4318.

Moisture Content

The moisture content in a given mass of soil is the ratio, expressed as a percentage, of the weight of the water to the weight of the solid particles. This test was conducted in accordance with ASTM D 2216.

Grain Size Distribution

Grain Size Tests are performed to aid in determining the soil classification and the grain size distribution. The soil samples are prepared for testing according to ASTM D 421 (dry preparation) or ASTM D 2217 (wet preparation). If only the grain size distribution of soils coarser than a number 200 sieve (0.074-mm opening) is desired, the grain size distribution is determined by washing the sample over a number 200 sieve and, after drying, passing the samples through a standard set of nested sieves. If the grain size distribution of the soils finer than the number 200 sieve is also desired, the grain size distribution of the soils coarser than the number 10 sieve is determined by passing the sample through a set of nested sieves. Materials passing the number 10 sieve are dispersed with a dispersing agent and suspended in water, and the grain size distribution calculated from the measured settlement rate of the particles. These tests are conducted in accordance with ASTM D 422.

Compaction Tests (Moisture-Density Relationship)

Compaction tests are performed on representative soil samples to determine the maximum dry density and optimum moisture content. The results of the tests are used in conjunction with other tests to determine engineering properties relating to settlement, bearing capacity, shear strength, and permeability. The results may also be used as a standard to determine the percent compaction of any soil embankment.

The two most commonly used compaction tests are the standard Proctor test and the modified Proctor test. They are performed in accordance with ASTM D 698 and D 1557, respectively. Generally, the standard Proctor compaction test is run on samples from building areas and areas where moderate loads are anticipated. The modified Proctor compaction test is generally used for analyses of highways and other areas where large building loads are expected. Both tests have three procedures, depending upon soil particle size:

Test	Procedure	Hammer Weight	Hammer Fall	Mold Diameter	Screen Size (Material Finer Than)	Number of Layers	Number of Blows per Layer
Standard (D 698)	A	5.5 lb.	12"	4"	No. 4 sieve	3	25
	B	5.5 lb.	12"	4"	No. 3/8" sieve	3	25
	C	5.5 lb.	12"	6"	3/4" sieve	3	56
Modified (D 1557)	A	10 lb.	18"	4"	No. 4 sieve	5	25
	B	10 lb.	18"	4"	No. 3/8" sieve	5	25
	C	10 lb.	18"	6"	3/4" sieve	5	56

Test results are presented as a curve depicting dry unit weight versus moisture content. The compaction method used and any deviations from the recommended procedures are noted in the report.

Laboratory California Bearing Ratio Tests

The results of the compaction test are utilized in compacting the test sample to the desired density and moisture content for the laboratory California Bearing Ratio test. The California Bearing Ratio, generally abbreviated CBR, is a punching shear test and is a comparative measure of the shearing resistance of a soil. It provides data that is a semi-empirical index of the strength and deflection characteristics of a soil that has been correlated with pavement performance to establish design curves. The CBR is used with empirical curves to design pavement structures.

A laboratory CBR test is conducted according to ASTM D 1883. A representative sample is compacted to a specified density at a specified moisture content. The test is performed on a 6-inch diameter, 4.585-inch-thick disc of compacted soil that is confined in a steel cylindrical mold. The sample is compacted in accordance with Method B or D of ASTM D 698 or D 1557. These compaction procedures are outlined in this report in the section on compaction tests.

CBR tests may be run on the compacted samples in either soaked or unsoaked conditions. During testing, a piston approximately 2 inches in diameter is forced into the soil sample at the rate of 0.05 inches per minute to a depth of 0.5 inches to determine the resistance to penetration. The CBR is the percentage of the load it takes to penetrate the soil to a 0.1-inch depth compared to the load it takes to penetrate a standard crushed stone to the same depth.

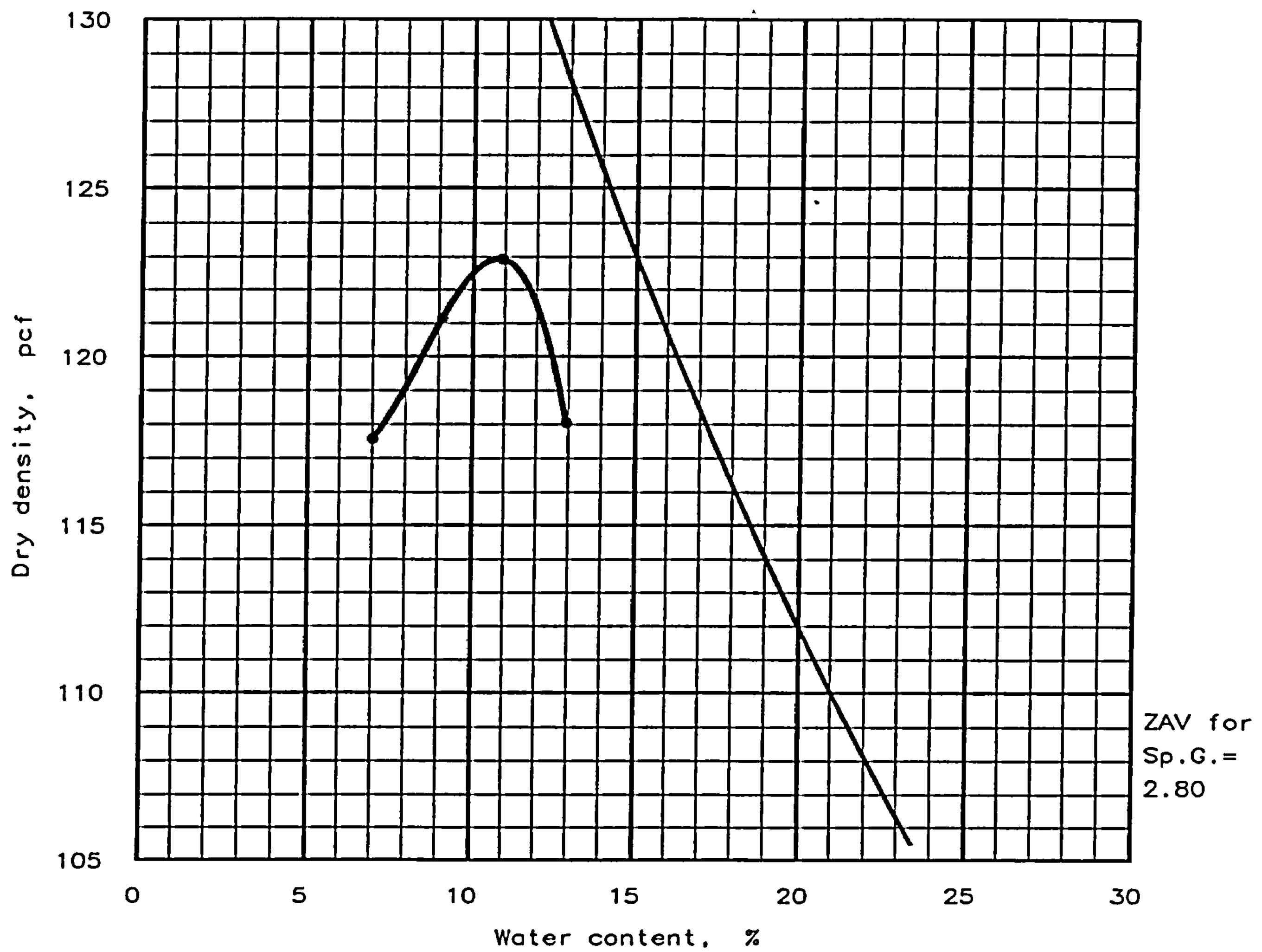
Table C.1
Soil Data Summary
Index and Compaction Properties

Boring Number	Sample Type	Sample Depth (Feet)	Maximum Dry Density, pcf (ASTM D 1557)	Optimum Moisture Content, % (ASTM D 1557)	Natural Moisture Content, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Percent Finer Than #200 Sieve	pH	Resistivity (Ohm-cm)
B-2	SS	5			4.1			NP	16.7		
B-2	SS	25			3.9			NP	18.9		
B-2	SS	5								7.99	7,400
B-2	SS	10									
B-3	SS	5			7.5	26	17	9	31.0		
B-3	SS	10									
B-3	BULK	5 - 10	122.9	10.8	4.3			NP	24.8		
B-3	SS	45			11.4	60	23	37	91.9		
B-3	SS	50									
B-3	SS	70			13.7	50	18	32	96.1		
B-3	SS	75									
B-4	SS	5								7.93	2,100
B-4	SS	10									
B-4	BULK	0 - 15	122.8	9.6	3.2			NP	22.8		
B-5	SS	5			2.8			NP	21.6		
B-5	SS	10									

Bulk - Bulk Sample
SS - Standard Penetration Test Sample
NP - Non-Plastic

Prepared By MBH Date 10-15-03 Checked By [signature] Date 10-15-03

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 1557-02 Procedure B, Modified

Elev/ Depth	Classification USCS	Classification AASHTO	Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in	% < No.200
5-10'	SM	A-2-4(0)	4.3 %	NT	NV	NP	0.0 %	31.2 %

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 122.9 pcf Optimum moisture = 10.8 %	Brown silty sand

Project No.: 3043031049.0001
Project: NEF Lea County, New Mexico
Location: Boring B-3 Bulk

Date: October 13, 2003

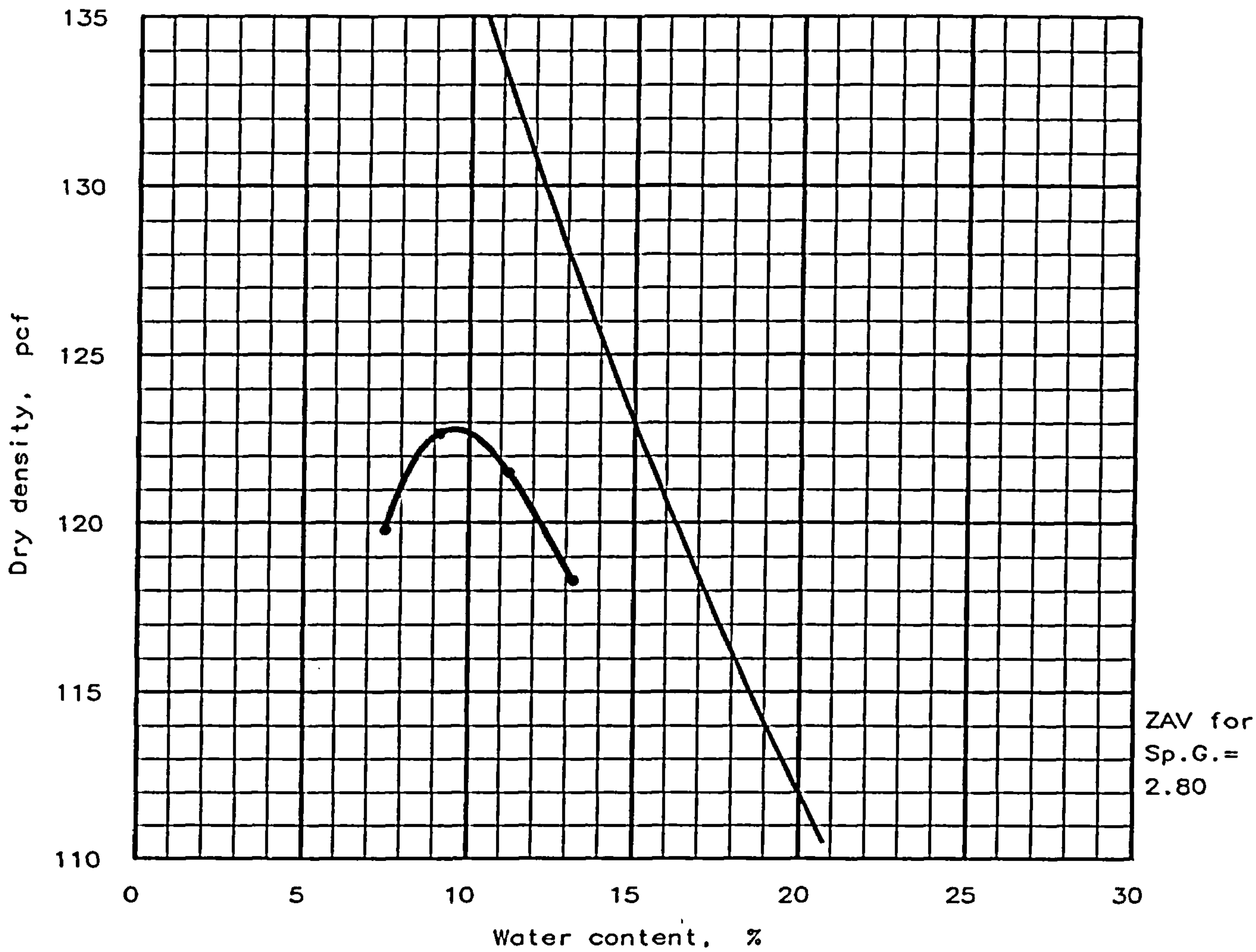
MOISTURE-DENSITY RELATIONSHIP TEST

LAW ENGINEERING AND ENVIRONMENTAL SERVICES, INC.

Remarks:
Sample Number 2837
NT- No Test
DNS- Data Not Submitted

Fig. No. 2837

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 1557-02 Procedure B, Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in	% < No.200
	USCS	AASHTO						
0-15'	SM	A-2-4(0)	3-8% %	NT	NP	NP	0.0 %	22.7 %

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 122.8 pcf Optimum moisture = 9.6 %	Tan silty sand

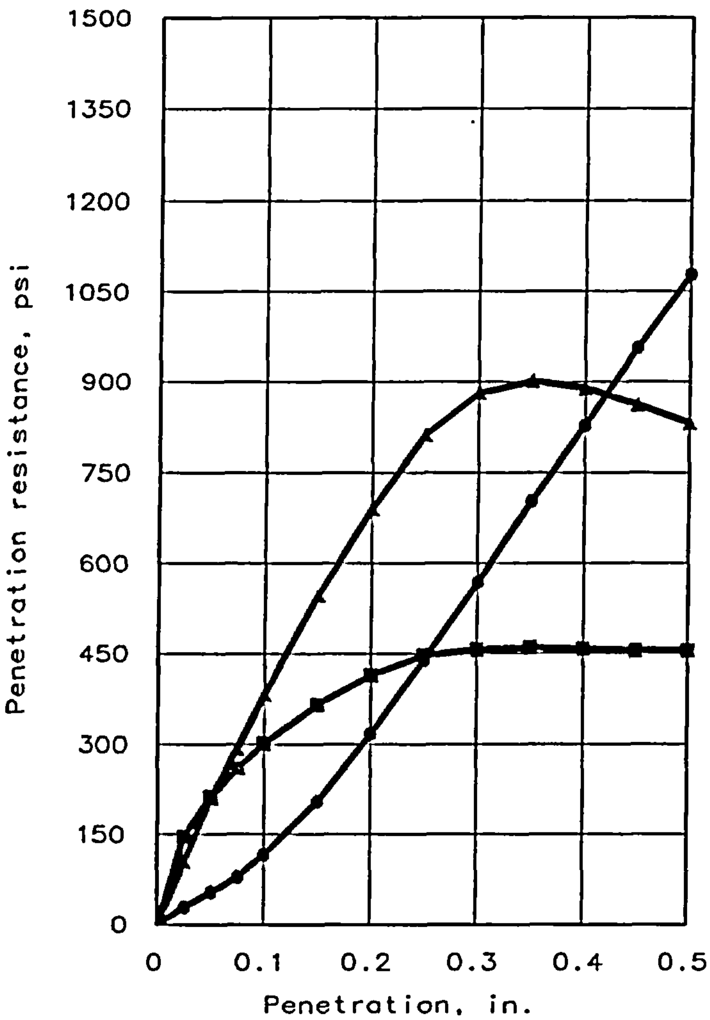
Project No.: 3043031049.0001
Project: NEF Lea County, New Mexico
Location: Boring B-4 , 0-7' and 7-15' combined
Bulk Sample
Date: October 13, 2003

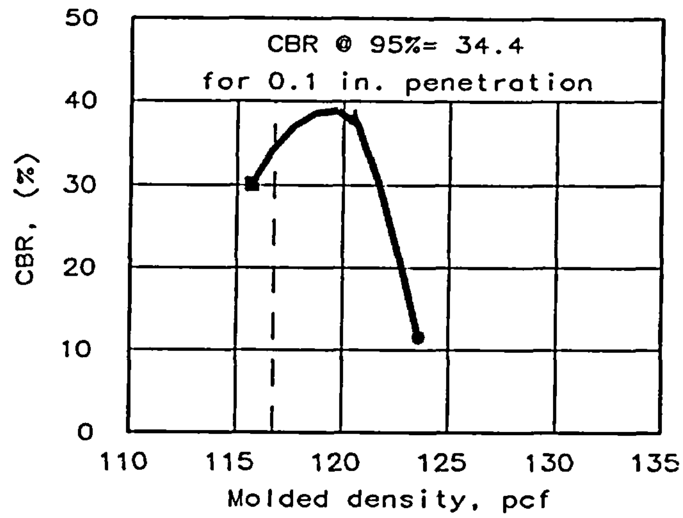
Remarks:
Sample Number 2836
NT- No Test
DNS- Data Not Submitted

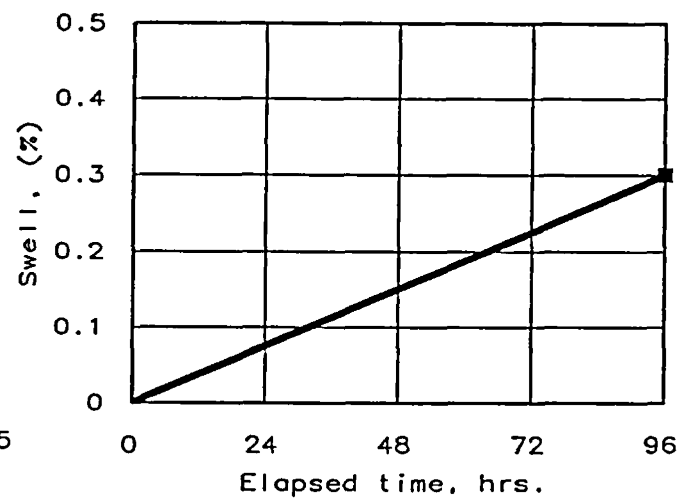
MOISTURE-DENSITY RELATIONSHIP TEST
LAW ENGINEERING AND ENVIRONMENTAL SERVICES, INC.

Fig. No. 2836

BEARING RATIO TEST REPORT







	Molded			Soaked			CBR, (%)		Lin.	Pen.	Swell
	Dens.	% max	moist	Dens.	% max	moist	0.1"	0.2"	Cor.	Sur.	%
1 ●	123.6	100.6	11.2%	123.2	100.2	13.1%	11.6	21.1	0	10.0	0.3
2 ▲	120.5	98.0	11.2%	120.1	97.7	12.7%	38.1	46.0	0	10.0	0.3
3 ■	115.7	94.1	11.1%	115.4	93.9	13.9%	30.1	27.5	0	10.0	0.3

MATERIAL DESCRIPTION	USCS	Max. dens.	Opt. w.c.	LL	PI
Brown silty sand	SM	122.9	10.8	NV	NP

Project No: 3043031049.0001
Project: NEF - Lea County, New Mexico
Location: Boring B-3, 5-10' Bulk

Date: October 13,2003

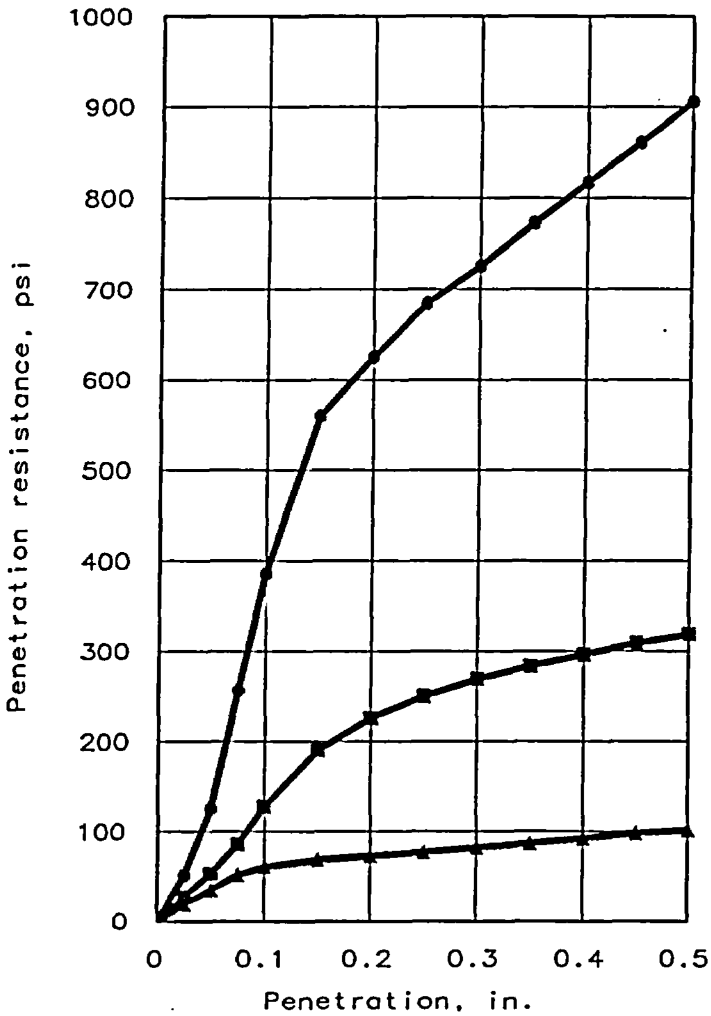
BEARING RATIO TEST REPORT

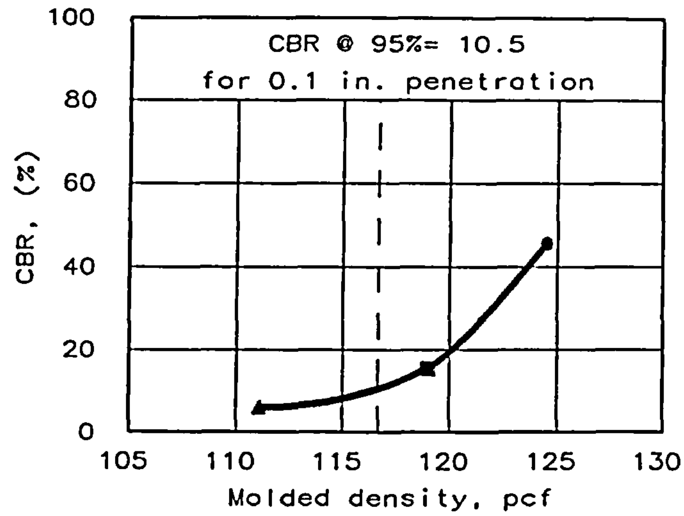
LAW ENGINEERING AND ENVIRONMENTAL SERVICES, INC.

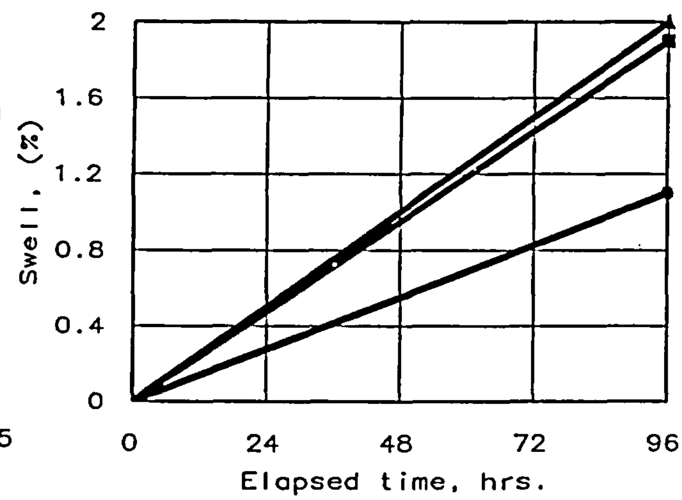
Test Descr./Remarks:
ASTM D1883-99 C.B.R.
ASTM D 1557-02 B /
Sample Number 2837
Penetration on
soaked samples.

Fig. No.: 2837

BEARING RATIO TEST REPORT







	Molded			Soaked			CBR, (%)		Lin.	Pen.	Swell
	Dens.	% max	moist	Dens.	% max	moist	0.1"	0.2"	Cor.	Sur.	%
1 ●	124.5	101.4	9.5%	123.1	100.2	14.0%	45.5	43.3	0.020	10.0	1.1
2 ▲	111.1	90.5	9.7%	108.9	88.7	18.5%	6.0	4.8	0	10.0	2.0
3 ■	119.0	96.9	9.7%	116.8	95.1	16.3%	15.3	15.7	0.020	10.0	1.9

MATERIAL DESCRIPTION	USCS	Max. dens.	Opt. w.c.	LL	PI
Tan silty sand	SM	122.8	9.6	NV	NP

Project No: 3043031049.0001

Project: NEF - Lea County, New Mexico

Location: Boring B-4, 0-7' & 7-15' combined Bulk

Date: October 13,2003

Test Descr./Remarks:

ASTM D1883-99 C.B.R.

ASTM D 1557-02 B /

Sample Number 2836

Penetration on

soaked samples.

BEARING RATIO TEST REPORT

LAW ENGINEERING AND ENVIRONMENTAL SERVICES, INC.

Fig. No.: 2836

COOK-JOYCE INC.
ENGINEERING AND CONSULTING
812 WEST ELEVENTH
AUSTIN, TEXAS 78701-2000
(512) 474-9097 FAX (512) 474-8463

WASTE CONTROL SPECIALISTS
2002 ANNUAL GROUNDWATER MONITORING REPORT

JANUARY 25, 2003

Prepared for:

Waste Control Specialists, LLC
9998 Highway 176
Andrews, Texas

WCS\FINAL\01098.02\2002 REPORT\
R010327_GW MONITORING.DOC

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1.0 INTRODUCTION

Provision VI.Q. of Permit No. HW-50358 requires, among other things, the submittal of a *summary of all background ground-water quality values, ground-water monitoring analyses, ground-water flow rates, and statistical calculations.* In addition, Provision III.J.6. states: *The permittee shall determine the ground-water flow rate and direction in the uppermost aquifer for upgradient, downgradient and supplemental detection monitoring wells required by this permit at least semi-annually. The documentation shall include a calculation of ground-water flow rate and direction, and a contour map of piezometric water levels in the uppermost aquifer based, at a minimum, upon concurrent measurements in all monitoring wells. The results and documentation shall be included in the annual report required by Provision VI.X* [*sic*]. This report is submitted to fulfill the cited permit requirements for report year 2002.

In addition to the presentation of the required information, a discussion of the status of the current detection monitoring program is provided. Technical issues and concerns regarding the current program are identified and action items for addressing these issues and concerns are presented.

2.0 BACKGROUND INFORMATION

The permit, as originally issued, required the installation and sampling of both upgradient and downgradient monitoring wells near the landfill. The locations of the detection monitor wells are shown on Figure 2-1. During the first year of groundwater monitoring WCS was to collect and analyze samples from the upgradient monitoring wells on a quarterly basis to determine the background concentrations of specified monitoring parameters in the groundwater. Each downgradient monitoring well was to be sampled semi-annually after the first year of monitoring. For each sampling event, four separate samples from each downgradient well were to be collected and analyzed for the specified monitoring parameters. The semi-annual data for the downgradient wells were to be compared to the background values using the Analysis of Variance (ANOVA) statistical procedure.

For many of the constituents, the reporting limits that were available during the first year of monitoring (1997) were higher than those available in subsequent years. For numerous parameters, primarily metals, statistically significant increases were determined and it was suggested that a more appropriate statistical method might be employed. In addition, it was suggested that rather than performing interwell comparisons of downgradient to upgradient, the more appropriate comparison might be intrawell comparisons, comparison of the constituent concentration in each well to the previous constituent concentrations in that well. A permit modification request was submitted to the TNRCC by letter dated April 30, 1999 and was subsequently approved on October 28, 1999, which among other things allowed the use of intrawell comparisons using the Fischer's Exact Test statistical method. In addition, the modification allowed for arsenic, barium and vanadium to only be monitored and reported until the first semi-annual sampling event in 2000, at which time the statistical analyses for these parameters were to be resumed with a new baseline data set.

The following action items (shown in italics) were proposed in the 2001 Annual Groundwater Monitoring Report for resolution of technical concerns and issues identified with the detection monitoring program. The status of each item is indicated following the item.

1. *Applicable characteristics of the uppermost aquifer, including hydraulic conductivity, effective porosity, and hydraulic gradient will be evaluated to determine the most appropriate interval of time between sample events to ensure that independent*

samples of groundwater are obtained to the greatest extent technically feasible. An initial evaluation of the appropriate sampling interval has been completed and discussed in this report.

2. *Alternative procedures for collecting samples representative of the groundwater quality at the point of compliance will be investigated to identify the least intrusive and most effective method for sample collection.* Sample collection procedures have been assessed and recommended modifications are included in this report.

3. *Leachate samples will be collected from individual leachate collection system risers and analyzed separately for priority pollutant volatile organics, semi-volatile organics, metals, and PCBs.* Samples were collected and analyzed. Complete analytical results will be submitted with a permit modification request to change the current detection monitoring parameters.

4. *Significant constituents in the leachate will be evaluated to identify those constituents that are anticipated to be the most mobile constituents in the groundwater.* Analytical results for the leachate samples have been reviewed to identify more appropriate detection monitoring parameters. Documentation will be submitted with the permit modification request to change the current detection monitoring parameters.

5. *To the extent that groundwater data is available for the leachate constituents identified in Item 4., the distribution of the data will be evaluated and potentially viable statistical evaluation methodologies will be identified and assessed.* This activity is underway and the results of the evaluation will be submitted with the permit modification request to change the current detection monitoring parameters.

6. *Statistical evaluation methodologies for constituents that have not typically been detected or are not anticipated to be naturally-occurring in the groundwater will be researched and candidate methods identified.* This activity is underway and the results of the evaluation will be submitted with the permit modification request to change the current detection monitoring parameters.

7. *An application for modification of the permit will be prepared to provide the results of the action item's listed above and request appropriate changes in the permit and the*

sampling and analysis plan. A Class 1[1] permit modification request to change the sampling methodology is being submitted in concert with this report. A Class 2 permit modification request to revise the analytical parameters and statistical procedures will be submitted by May 2003.

During 2002, numerous activities relating to refinement of the detection monitoring system were performed. These activities included surveying the locations and top of casing elevations for all of the wells and piezometers that were identified as potentially completed in the water bearing zone of interest; monthly measurement of depth to groundwater and determination of water level elevations in those wells and piezometers; alteration of purging and sampling procedures for the DW and MW wells as agreed with the TCEQ staff; and participation in several meetings and other communications to inform members of the staff of the TCEQ about the status of these activities and their results. This report presents the data and the findings of the activities performed relative to the detection monitoring system in 2002. Sections 3.0 and 4.0 provide information on the groundwater gradient and velocity evaluations. Section 5.0 discusses the analytical results and the conclusions from evaluation of those results. Section 6.0 presents conclusions and proposed activities for 2003 to further refine the understanding of the complex hydrogeology of the site and develop a more appropriate detection monitoring system.

3.0 2002 GROUNDWATER GRADIENT EVALUATION ACTIVITIES

Provision III.J.6 requires at least semi-annual groundwater elevation measurements in the upgradient and downgradient groundwater monitoring wells and determination of rate and direction of groundwater flow. The 2002 groundwater gradient and flow rate were determined based on the methods and recommendations of the 18 December 2001 Groundwater Gradient Monitoring Report, a copy of which was included as an appendix to the 2001 Annual Groundwater Monitoring Report. The determination of the 2002 groundwater gradient and flow rate is discussed in Section 4 of this report.

The general purpose of the 2001 Groundwater Gradient Monitor Report was to present the results of a review of data from the site's upgradient and downgradient wells, supplemented with existing data from other areas of the site, to more accurately generate an groundwater gradient map and determine flow rate of the water bearing zone of interest, so that the collected information could be as a tool to evaluate and update the groundwater monitoring program based on site-specific conditions. The 2001 Gradient Report recommended several activities to be conducted during 2002 in order to improve the quality of available data to be used to refine the determination of the groundwater gradient and flow rate at the site. The activities identified to be completed in 2002 included:

- Identification of existing monitor wells and piezometers that may be useful in developing a site wide groundwater gradient map;
- Performance of a top of casing survey for each of these existing monitor wells and piezometers;
- Conduct hydrogeologic analyses of the identified monitor wells and piezometers to determine if the identified monitor wells and piezometers have been completed in a zone that reflects the hydrologic head of the water bearing zone of interest;
- Measure groundwater levels during the year and determine which of the monitor wells and piezometers constructed in the water bearing zone of interest have static water levels and are not continuing to be affected by purging and sampling activities; and

- Select monitor wells and piezometers that accurately reflect the static hydrologic head of the water bearing zone of interest that can be utilized to construct the groundwater gradient maps.

The activities recommended for 2002 have been completed and the results are presented in the following subsections. In addition, responses to TCEQ comments, as outlined in Items 4 and 5 of a 2 May 2002 letter, are addressed.

3.1 SITE MONITOR WELLS AND PIEZOMETERS

The monitor wells and piezometers which were identified as being those most likely screened in the water bearing zone of interest consist of:

Downgradient Wells	Upgradient Wells	Supplemental Wells	Supplemental Piezometers
DW-32A	MW-1A	2-G	TP-0001
DW-32B	MW-1B	4-G2	TP-0002
DW-33A	MW-2A	4-G3	TP-0003
DW-33B	MW-2B	7-G	TP-0004
DW-34A	MW-3A	6B-2	TP-0005
DW-34B	MW-3B	A-22	PM-0003
DW-35A	MW-4A	A-24	PM-0006
DW-35B	MW-4B	NMB-23	PM-0009
DW-36A		NMB-24	PM-0012
DW-36B			

3.2 SURVEY DATA

Surveying of the site monitor wells and piezometers was conducted by West Texas Consultants, Inc. Surveying of the TP and PM series piezometers was conducted in October 2001, and the remaining identified monitor wells were surveyed in March 2002. Piezometer and monitor well location coordinates and top of casing elevations are summarized in Table 3-1.

The survey resulted in an adjustment in the top of casing elevations of all of supplemental wells and to many of the upgradient and downgradient wells. The 2002 survey indicated that the top of casing elevations of the supplemental wells are approximately 9 feet lower than previously surveyed. The new survey resulted in only minor adjustments for the upgradient and downgradient wells. The adjusted survey results have been incorporated into the reported groundwater gauging data for the 2002 reporting period.

3.3 HYDROGEOLOGIC DESCRIPTION OF THE SITE

The boring logs and well completion diagrams for each of the identified wells and piezometers were analyzed to determine if the wells and piezometers were completed in the water bearing zone of interest. The analyses of the data included construction of geologic cross sections, groundwater gradient maps based on groundwater elevations from validated wells and piezometers, and a structure map of the top of the water bearing zone of interest.

The two geologic cross sections are depicted in Figures 3-1 and 3-2. Section A-A' and B-B' are generally orientated east-west. Section A-A' is located north of the landfill and is approximately 8,000 feet in length. Section B-B' is located through the landfill area and is approximately 9,000 feet in length. Boring logs and well completion diagrams for the identified wells and piezometers are presented in Appendix A. As depicted on the geologic cross sections, surface caprock is continuous across the site and varies in thickness. Underling the caprock, interbedded clays and claystones with transmissive zones of siltstone and sandstone are found.

The first transmissive zone is described as a sandstone to silt and is encountered at elevations ranging from 3,393 to 3,359 feet msl. This zone appears to be laterally continuous across the site. While the strata was not shown in NMB-23, this well is not within the permitted facility boundary. Further, the log for this boring is very general, so the strata may be actually be present but not identified. Groundwater has never been encountered in this zone. In the area of the landfill, there are five monitor wells (SW series) completed in this zone; none of these wells has ever yielded any groundwater. To the east of the landfill, piezometer TP-0002 is also screened in this zone and has been dry since construction in August of 2001.

The second transmissive zone is a sandstone to siltstone. This zone appears to be discontinuous across the site. Where absent, it grades into a silty clay. Where present, it is encountered at elevations ranging from 3,307 to 3,273 feet msl. Piezometer PM-0012 is screened into this zone and has been dry since construction in August of 2001. Piezometers

PM-0009 and TP-0003 are also completed in lenses of the second transmissive zone and have encountered groundwater.

The third transmissive zone is the water bearing zone of interest in which the landfill's upgradient and downgradient monitor wells are screened. This zone is laterally continuous across the site and is encountered at elevations ranging from 3,280 to 3,225 feet msl. This zone is generally described as a sandstone and silt. Wells and piezometers screened in this zone indicate it is saturated and confined, with hydraulic heads (distance above top of transmissive zone) ranging from approximately 40 feet to 130 feet.

3.4 STATIC CONDITION OF WELLS AND PIEZOMETERS

Due to the low hydraulic conductivity of the water bearing zone of interest, the static groundwater elevations of wells disturbed by sampling activities do not fully recover between sampling events and have not fully recovered to date. Therefore, the groundwater elevations that were recorded during the year are not reflective of the actual static groundwater elevation of the water bearing zone of interest. To determine which wells and piezometers have not recovered from past sampling activities, hydrographs of the groundwater elevations during 2002 have been constructed for each of the wells and piezometers. The hydrographs are included in Appendix B as Hydrograph Plots 3-1 through 3-36.

The hydrographs indicate the upgradient (MW series) and downgradient (DW series) wells did not equilibrate during 2002 from past groundwater sampling activities.

The 2002 hydrograph for Monitor Well NMB-23 indicates that the well is recharging. A review of the hydrograph from 2001 for NMB-23 (Hydrograph Plot 3-15) also indicated that the well was recharging. A review of the facility records indicates this well was installed for groundwater gradient purposes in September 1998 and has never been sampled. Gauging data during 2002 indicates an increase in the groundwater elevation of approximately 14.5 feet (1.2 feet per month). Gauging data from July through December 2001 indicates an increase in the groundwater elevation of approximately 5.75 feet (1.15 feet per month). The total thickness of the groundwater in the well by the end of 2002 was approximately 139 feet. With the well being constructed in September 1998, 51 months ago, the well has recharged at an average rate of 2.72 feet per month since construction.

3.5 EVALUATION OF WELLS AND PIEZOMETERS FOR GRADIENT MONITORING

The monitor wells and piezometers which were identified as being those most likely screened in the water bearing zone of interest are listed in Section 3.1. A tabulation of these identified monitor wells and piezometers and the circumstances that either support or do not allow for the use of these data points in developing the final groundwater gradient map are shown on Table 3-2.

An additional review of the identified wells and piezometers listed in Section 3.1 was also conducted by comparing the groundwater elevation measurements from these points to one another in the form of groundwater gradient maps. Groundwater gauging events occurred monthly throughout 2002 for the identified wells and piezometers.

The list of the identified wells and piezometers that was transmitted to site personnel to be gauged during 2002 erroneously excluded well 4G-2. As was suggested in the TCEQ letter dated 2 May 2002 (Item 4), the water level shown on Figure 5-17 for well 4G-3 was inconsistent with the water level reported in Tables 4-1 and 5-1 of the 18 December 2001 Gradient Report. The water level shown for well 4G-3 on Figure 5-17 of the Gradient Report was actually the water level for 4G-2, as shown on Tables 4-1 and 5-1 of the Gradient Report. (With regard to the other comment in Item 4 of the 2 May 2002 TCEQ letter, the correct groundwater elevation for well G2 was 3298.73. The elevation of 3298.23 shown on Figure 5-17 was an error.) As noted in Item 5 of the 2 May 2002 letter, based on the cross-section shown in Figure 3-2, it does appear that well 4G-2 is the well that is completed in the water bearing zone of interest and that well 4G-3 is completed in a thin and essentially dry siltstone zone below the water bearing zone of interest.

After completion and evaluation of the cross-sections, site personnel were requested to gauge well 4G-2, and on 24 January 2003, the well was gauged. The January 2003 elevation was compared to the 2001 data for 4G-2 and the level was within 0.5 feet. Therefore, the groundwater elevation appears to be stable through 2002 and the groundwater elevation recorded on 24 January 2003 was used in the evaluation of the groundwater gradient for the water bearing zone of interest.

Piezometers TP-0002 and PM-0012 were included in the points identified in Section 3.1 as potential sources for groundwater elevation data representative of the water bearing zone of interest. These piezometers have been determined from the cross-sections to be completed in the first and second transmissive zones and are dry; therefore, they were not used to construct the final 2002 groundwater contour maps for the water bearing zone of interest.

Figure 3-3 is a groundwater contour map utilizing all wells determined to be completed in the water bearing zone of interest, as identified in Section 3.1. If a specific well or piezometer caused an anomaly in the contouring, such as a significant depression or mounding of the groundwater, that point was evaluated to determine the possible cause and the resultant usefulness in characterizing the groundwater gradient of the water bearing zone of interest. These anomalies are identified and discussed below.

The groundwater gradient map depicted in Figure 3-3, in concert with the hydrographs discussed previously, indicates that the groundwater elevation in the wells downgradient of the landfill (DW series) are depressed due to past sampling events. Consequently, these wells cannot be relied on at this time as accurately reflecting the static water level elevation of the water bearing zone of interest.

Piezometer TP-0003 has an anomalously low groundwater elevation resulting in as apparent depression of the groundwater contours in the area of the piezometer. A review of the cross section (Figure 3-2) indicates that TP-0003 is completed in the discontinuous siltstone lens located above the water bearing zone of interest. Therefore, groundwater elevation data from this point was not considered representative of the water bearing zone of interest and was not used in the development of the final site gradient maps (see Section 4).

Piezometer PM-0009 has a groundwater elevation that results in an apparent mounding of groundwater in the area of the piezometer. A review of the completion record for this piezometer indicates that the bottom of PM-0009 is at an elevation of 3269.65 feet msl. Based on the structure map of the top of the water bearing zone of interest (Figure 3-4), the elevation of this zone in the area of PM-0009 is approximately 3255 feet msl. As a result, it is believed that this piezometer is not screened in the water bearing zone of interest and therefore was not used in the development of the final site gradient maps discussed in Section 4.1.

4.0 GROUNDWATER RATE AND DIRECTION

Based on the groundwater elevations (Table 4-1) from the identified wells and piezometers that have been determined to be properly screened and have stabilized groundwater levels, groundwater gradient maps have been constructed from semi-annual gauging events recorded in May 2002 and September 2002 (Table 4-1).

4.1 GROUNDWATER GRADIENT

Figures 4-1 and 4-2 are the groundwater gradient maps which result after considering the above discussions in Section 3.5. These two figures represent the groundwater elevation data collected during the Spring and Fall 2002 groundwater monitoring events, and also include the groundwater elevation for well 4G-2, which was collected in January 2003. As discussed above, the January 2003 groundwater elevation for well 4G-2 is within 0.5 feet of the water level elevations measured for this well in 2001, and it has not been sampled or purged since 2001. The groundwater elevation at this well, however, is not consistent with the groundwater elevations for the other wells determined to be suitable for gradient determination. Given the apparent anomalous water elevation at well 4G-2, a separate set of groundwater gradient maps for the Spring and Fall 2003, excluding the groundwater elevation data for well 4G-2, were constructed and are shown in Figures 4-3 and 4-4.

The reason for the anomalous water level in well 4G-2 in unclear. Given that well 4G-3 is completed in a lower, thin siltstone that is believed to be essentially dry, and that well 4G-3 is very near well 4G-2, it is possible that there is leakage from the water bearing zone of interest into the lower siltstone formation, thus depressing the water level in 4G-2 somewhat. This is inconclusive and bears further evaluation to determine the use of 4G-2 in the future groundwater gradient determinations. For now, both sets of groundwater gradient contours are being presented, although the gradient calculated without well 4G-2 is used in the determination of the groundwater flow rate below.

The groundwater gradient maps for Spring and Fall 2002 are similar in both the indicated direction and gradient. The groundwater flow direction is to the south-southwest at an average gradient of 0.017 feet per foot across the site.

Future equilibration of the groundwater in the upgradient MW series wells and in NMB-23 will allow for additional control north of the landfill. It is estimated that groundwater recharge to NMB-23, based on its current recharge rate 14.5 feet per year and an anticipated decrease in the recharge rate as it near equilibration, will be fully recharged by early to mid of 2004. It is estimated that to fully recover DW-32A will have to reach an elevation of approximately 3315 feet msl. Currently, the well will require approximate recharge of 65 feet to fully recover. At the current recharge rate of approximately 30 feet per year, it is estimated that DW-32A will require more than 2 years to fully recover. Potential modification of the sampling frequency of the downgradient DW-35 and DW-36 series monitor wells may provide sufficient time for these wells to equilibrate between monitoring events, thereby providing additional control along the southern perimeter of the landfill. Nonetheless, an additional piezometer is proposed to be constructed to the southwest of the landfill to supply an additional control point in the area to the south and west of the landfill.

4.2 GROUNDWATER VELOCITY

The velocity of the groundwater in the water bearing zone of interest has been calculated based on the groundwater gradient, the hydraulic conductivity, and the porosity using the following expression:

$$\text{Groundwater velocity} = \frac{Ki}{\theta}$$

The hydraulic conductivity of the water-bearing zone of interest at the WCS facility has been calculated by evaluating groundwater recharge data as a rising head slug test, using the Hvorslev method. Groundwater elevation data were collected from recharge of monitor well DW-36A following the purging and sampling activities in September 2001. Data from DW-36A were chosen for the evaluation because, based on past experience, recharge rates in the 36-series wells are greater than in the other DW wells. Use of the more rapid recharge data will result in a more conservative or higher hydraulic conductivity than from wells with slower recharge. The hydraulic conductivity calculations are included in Appendix C. The calculation based on site-specific conditions resulted in a hydraulic conductivity of 6.13E-08 cm/sec.

The hydraulic gradient in the water-bearing zone of interest is approximately 0.017 ft/ft based on the 2002 groundwater gradient maps previously presented. A porosity of 15% was used for calculation of velocity, based on published literature. The literature review included porosity ranges as stated in *Groundwater and Wells*; F.G. Driscoll, Ph.D., *Applied Hydrologeology*, C.W. Fetter, Jr., *Groundwater Hydrology*, H. Bouwer, and *Groundwater*, Freeze and Cherry. Generally, the porosity of consolidated sandstone ranges from 3% to 30%.

Therefore, the calculation of the groundwater velocity is:

$$\text{Groundwater velocity} = \frac{Ki}{\theta}$$

Hydraulic conductivity (K)	=	6.13E-08 cm/s
Hydraulic gradient (i)	=	0.017
Porosity (θ)	=	0.15

$$= \frac{6.13\text{E}-08\text{cm/sec} \times 0.017\ \text{ft/ft} \times 86{,}400\text{sec/day} \times 365\text{day/yr} \times 1\text{ft}/30.48\text{cm}}{0.15}$$

= 0.0072 ft/year, or 0.0006 ft/month

If we assume a porosity of 0.30, the velocity would be 0.0036 ft/year, and if we assume a porosity of 0.05, the velocity will be 0.022 ft/year.

4.3 DISCUSSION OF GROUNDWATER SAMPLE COLLECTION

An evaluation of groundwater recharge data and the groundwater gradient in the water bearing zone of interest at the WCS site has been performed. The purpose of the evaluation was to estimate the amount of time necessary for "new" groundwater to be available for sampling based on site-specific conditions. "New" groundwater is desired to be sampled at each monitoring event so that independent samples are collected for data evaluation purposes, as required by applicable regulations.

The sampling procedure, including purging the well dry before sample collection and the sample volume itself, removes an approximate volume of 3.8 ft^3, as calculated below.

Water column height	= 40 ft
Unit volume within the well bore for a 4" well	= 0.087 ft^3/ft depth
Sample volume required for current monitoring parameters (one sample set only)	= 3 gal = 0.401 ft^3

Total volume (V) of water removed for sampling

$$V = (40 \text{ ft} \times 0.087 \text{ ft}^3/\text{ft}) + 0.401 \text{ ft}^3$$

$$V = 3.8 \text{ ft}^3$$

This volume does not consider the volume of water that is drained from the sand pack when bailing the well to dryness, which results in a conservative calculation of the volume of water removed, relative to the actual amount of water that has to recharge the well for sampling.

The radius of influence of this volume of removed water in the water-bearing zone of interest is estimated at 0.733 ft, as calculated below.

Volume (V) of water removed	=	3.8 ft^3
Water-bearing zone of interest screen length (h)	=	15 ft
Water-bearing zone of interest porosity (θ)	=	15 percent

$$= \frac{\sqrt{V}}{\sqrt{\pi \theta h}}$$

$$= \frac{\sqrt{3.8 \text{ ft}^3}}{\sqrt{\pi x 0.15 x 15 ft}}$$

radius = 0.733 ft

Using the same range of potential porosities as described above, the radius of influence for a porosity of 0.30 would be 0.52 ft, and the radius of influence for a porosity of 0.05 would be 1.27 ft.

In order for "new" and "independent" groundwater for a sampling event to occupy a well after a sampling event, groundwater must flow under natural conditions from the upgradient end of the radius of influence to the downgradient end, i.e., a total distance of 2 x 0.733 ft, or 1.466 ft. Another way to say this is that although one would expect water to refill the well from 360 degrees, only the water from upgradient is new water, or water that has not been sampled previously. Therefore, it takes water that moves twice the distance of the radius of influence to be new water.

The minimum time taken for "new" groundwater to occupy the sampling volume and provide an "independent" sample is about 2,443 months (1.466 ft divided by 0.0006 ft/month) for a porosity of 0.15, 3467 months for a porosity of 0.30, and 1385 months for a porosity of 0.05.

If the wells are not purged prior to sampling, the volume of water removed from each of the wells to collect one sample set will be approximately 3 gallons, or 0.401 ft^3, for analysis of the current monitoring parameters. The radius of influence from removal of this volume of groundwater would be 0.476 feet assuming the average case of 15% porosity. Based on this radius of influence, it would require approximately 793 months for "new" groundwater to migrate past the well to provide an independent sample at a hydraulic conductivity of 6.0E-8 cm/sec. WCS is preparing a permit modification request to eliminate purging of the detection monitoring wells prior to sampling, since they are still recharging after a six-month monitoring interval, and therefore the groundwater present in the wells is as "fresh" as it would be if purging occurred.

These calculations approximating site-specific conditions of the water-bearing zone of interest demonstrate that the interval between sampling events must be much longer than six months in order to collect independent samples from the monitoring wells at each sampling event.

5.0 GROUNDWATER SAMPLING AND ANALYSIS

Groundwater samples were collected from the third transmissive zone on a semi-annual basis, in general accordance with the provisions of Permit No. HW-50358-001. Some adjustments to the sample collection procedures were made in 2002, in consultation with the TCEQ permits staff. Sampling and analytical procedures are described below.

Downgradient monitoring wells were purged for the first semi-annual event in late January/early February to allow the groundwater to recharge approximately 60 days prior to sample collection in April and May of 2002. Purging was accomplished by evacuating all water within the well casing using a bailer. Purging of the wells in prior years was conducted using an electric pump. The upgradient wells were not purged for the Spring 2002 monitoring event.

In the Spring 2002 monitoring event, four sample sets were collected from all downgradient monitoring wells in accordance with permit requirements, with the exception of wells DW-32A and DW-33A. In these two wells, the groundwater did not recharge enough to supply sufficient water for the collection of four sample sets. Samples from the downgradient wells were analyzed for all parameters currently specified by the permit. A single sample was collected from upgradient wells MW-3A, MW-3B, MW-4A, and MW-4B during the Spring 2002 monitoring event. Each of these samples was analyzed for the metal parameters identified in the permit.

As agreed in a meeting with TCEQ staff on 29 August 2002, downgradient well pairs DW-32 through DW-34 were not going to be purged prior to the Fall 2002 monitoring event. However, site personnel had completed purging of well pairs DW-34 through DW-36 on 25 August 2002, so well pairs DW-32 and DW-33 were not purged prior to this event. Purging was again accomplished by evacuating all water within the well casing using a bailer. The upgradient wells were not purged.

In the Fall 2002 monitoring event, four sample sets were collected from all downgradient monitoring wells in accordance with permit requirements. Samples from the downgradient wells were analyzed for all parameters currently specified by the permit. A single sample was collected from upgradient wells MW-3A, MW-3B, MW-4A, and MW-4B. Each of these samples was analyzed for the metal parameters identified in the permit.

As discussed in the semi-annual report documenting the Fall 2001 sampling event, included in the Annual Report for 2001, metal pieces from an electric line used to gauge the water level in DW-36A separated from the e-line and dropped to the bottom of the well. All metal objects, other than the stainless steel nipple and a magnet encased within stainless steel (lost when trying to recover the e-line parts), were recovered from this well prior to the Fall 2002 sampling event, but after the well was purged.

Groundwater samples were analyzed by Severn Trent Laboratory in Denver, Colorado. Summary tables of the 2002 and previous analytical data are contained in Appendix D. CJI prepared these tables by adding the 2002 data to the tables prepared last year for the 2001 Annual Report. Last year's tables were developed by review of previously assembled tables prepared by others and verification of the 2001 and 2000 data, with a combination of complete reviews for parameters with significant detected values and spot checks for data that were reported as non-detects. The consolidated laboratory reports for the Spring and Fall 2002 events are provided as Appendices G and H, respectively.

5.1 STATISTICAL DATA EVALUATION OVERVIEW

In accordance with Permit Provision III.J.4., the monitoring data for each downgradient monitoring well were statistically evaluated using Fisher's Exact Test and the previously-established background database. In addition, the metals data from the upgradient wells collected for the Spring and Fall 2002 monitoring event were also evaluated statistically, using the same procedure. Results of the statistical evaluations of all parameters that were detected in either the Spring or Fall 2002 monitoring event are tabulated in Appendix E. Of the 28 monitoring parameters that are statistically evaluated, the only parameters that were detected at quantifiable levels in the Spring and/or Fall 2002 monitoring events were: barium, chromium, cobalt, copper, lead, nickel, silver, vanadium, and zinc. Results of the statistical evaluations that were determined to be significant through application of the Fisher's Exact Test to the background data are summarized in Table 5-1. Parameters that were indicated as significant detections in one or both of the monitoring events are barium, chromium, cobalt, lead, nickel, and copper.

The current analytical laboratory's reporting limits constitute quantification levels. Estimated concentrations of analytes are reported when the analytical results indicate the presence of an analyte at levels below the quantification level. Since the current statistical procedure is based on the number of detections, regardless of concentration, the estimated concentrations reported below the quantification limit are not considered to be detectable values for the purposes of statistical evaluation. Each of the parameters with apparent statistically significant detections is discussed further in Section 5.3.

5.2 QUALITATIVE EVALUATION

A qualitative evaluation was conducted of the cumulative data for the parameters that were identified as having statistically significant increases in one or more of the DW wells. As part of this evaluation, the data for these parameters in the DW wells were plotted over time. The data plots are provided in Appendix F. Results of this evaluation are discussed below.

<u>Barium</u>

The data for barium in the DW wells are shown graphically in Plots 5-1A through 5-1J in Appendix F. Detections of barium were first reported in Fall 1998, after detection limits lowered to 0.01 mg/L from the previous value of 0.4 mg/L or greater. Barium is detected in both the upgradient and downgradient wells. Historically, quantified detections were most frequently reported in the range of 0.01 mg/L (which is the reporting limit) to 0.03 mg/L, although occasional values on the order of 0.04 to 0.09 mg/L have been reported.

The background dataset for barium was allowed to be re-established under a permit modification approved in October 1999, due to the elevated reporting limit of 0.4 mg/L or greater during the initial background period. Barium was detected at this lower reporting limit during the new background period (Fall 1998 through Fall 1999) in all DW wells. However, barium detections were reported in one or both of the first two semi-annual events of the background period and the third semi-annual event in well pairs DW-32 through DW-34, but only in the third semi-annual event of the background period in well pairs DW-35 and DW-36. The reason for this difference is not known. DW-35 and DW-36 were sampled three times, two at the lower reporting limit, before barium was routinely detected, whereas DW-32 through DW-34 were sampled quarterly for a year and for one semi-annual event before the barium detection limit dropped and barium was detected.

Subsequent to the collection of the new background dataset, barium detections have increased in frequency. Barium has been detected at quantifiable levels in virtually all wells, including the MW wells, in all monitoring events since the Fall 2000 event. This increase in frequency of quantifiable barium concentrations may reflect the fact that these wells did not yield sufficient water at construction for proper development and removal of sediment fines from the drilling process.

In the 2002 data, the barium results from the sample sets collected from the downgradient wells generally exhibited greater variability than in prior years. (Since only one sample was collected from upgradient well pairs MW-4 and MW-5, the potential variability at upgradient wells in 2002 cannot be assessed.) In most cases, a marked increase in reported concentrations is observed from the initial sample set through the subsequent sample sets. Initial concentrations are consistent with historical concentration ranges, while the higher concentrations are frequently an order of magnitude greater than historical concentrations. The variation in reported concentration of the sample sets is believed to be associated with the amount of entrained sediment in the samples, since total metals are analyzed. In general, the amount of sediment increases as the sample sets are collected and groundwater nearer to the bottom of the well casing is sampled. Naturally occurring metallic elements in the sediment, which are not mobile in the groundwater, will be dissolved by the acid digestion step in the analytical procedure, resulting in higher detected concentrations as the amount of sediment increases. The increased sediment that was apparently encountered in the 2002 groundwater samples may reflect the fact that these wells did not yield sufficient water at construction for proper development and removal of sediment fines from the drilling process, and/or may be influenced by changes in the well sampling procedures.

Chromium

The data for chromium in the DW wells are shown graphically in Plots 5-2A through 5-2J in Appendix F. Prior to Fall 1999, chromium was not detected in the DW wells, with detection limits ranging from 0.01 to 0.10 mg/L. In Fall of 1999, detection limits lowered to 0.005 mg/L and chromium detections were reported Chromium has historically been detected in both the upgradient and downgradient wells, with quantified detections most frequently reported in the range of 0.005 mg/L (the reporting limit) to 0.010 mg/L, although occasional values on the order of 0.012 to 0.015 mg/L have been reported.

The statistical tables in Appendix E were originally developed by others, and subsequently reformatted and revised by CJI to reflect 2001 and 2002 detections. Review of the tabulated data for chromium in Appendix D and the source file for the statistical tables in Appendix E indicates that the source file used the chromium data for Spring 1999 through Spring 2000 as the background dataset. These data are more appropriate for use as the background dataset for chromium, given the elevated reporting limits that were embodied in the original background periods; however, it does not appear that re-establishment of the background dataset for chromium was expressly authorized by the October 1999 permit modification.

Subsequent to the collection of the new background dataset, chromium detections have increased in frequency, although quantifiable concentrations are not reported as routinely for chromium as they are for barium. Chromium has been detected at quantifiable levels in one or more monitoring events since the Fall 2000 event in all wells, including the MW wells. Given the hydrogeologic characteristics of the transmissive zone as discussed in Sections 4.1 and 4.2, this increase in frequency of quantifiable chromium concentrations is believed to reflect the transition of more nearly "new" water to the well in the more recent data.

In the 2002 data, the chromium results from the sample sets collected from the downgradient wells generally exhibited greater variability than in prior years. (Since only one sample was collected from upgradient well pairs MW-4 and MW-5, the potential variability at upgradient wells in 2002 cannot be assessed.) In most cases, a marked increase in reported concentrations is observed from the initial sample set through the subsequent sample sets. Initial concentrations are generally consistent with historical concentration ranges, while the higher concentrations are two to ten times greater than historical concentrations. The variation in reported concentration of the sample sets is believed to be associated with the amount of entrained sediment in the samples, as discussed for barium.

Lead

The data for lead in the DW wells are shown graphically in Plots 5-3A through 5-3J in Appendix F. Early monitoring data for 1997 and 1998 indicated lead was typically not detected at reporting limits varying from 0.004 to 0.02 mg/L. However, a number of detections at concentrations ranging from 0.02 mg/L to 0.33 mg/L were reported in both the upgradient and downgradient wells during this time period, based on data previously tabulated by others. Lead results for 2001 and 2002 are most typically not detectable at a reporting limit of 0.003 mg/L or estimated concentrations below that reporting limit.

In the 2002 data, the lead results from the sample sets collected from the downgradient wells generally exhibited greater variability than in prior years, although not to extent exhibited by the barium and chromium data. (Since only one sample was collected from upgradient well pairs MW-4 and MW-5, the potential variability at upgradient wells in 2002 cannot be assessed.) In some cases, a marked increase in reported concentrations is observed from the initial sample set through the subsequent sample sets. Initial concentrations are generally consistent with historical concentration ranges, while the higher concentrations are typically two to ten times greater than historical concentrations. A singular, anomalously high lead concentration (0.079 mg/L) was reported for the third (and final) sample set collected from DW-33A in Spring 2002. The variation in reported concentration of the sample sets is believed to be associated with the amount of entrained sediment in the samples, as discussed for barium.

Nickel

The data for nickel in the DW wells are shown graphically in Plots 5-4A through 5-4J in Appendix F. Prior to Fall 2000, nickel was not detected in the DW wells, with detection limits generally ranging from 0.01 to 0.10 mg/L. In Fall of 2000, detection limits lowered to 0.005 mg/L, and quantifiable nickel concentrations have been reported in at least one sample from each of the DW wells since that time. Nickel was also detected in upgradient wells MW-1A, MW-1B, MW-2AA, MW-2B, and MW-3A in the Fall 2000 event, one of two monitoring events for which all MW wells were analyzed for nickel at a reporting limit of 0.005 mg/L. The nickel data from Fall 2000 forward contain a substantial fraction of non-detect or estimated concentrations below the reporting limit of 0.005 mg/L. Quantified detections are most frequently reported in the range of 0.005 mg/L (the reporting limit) to 0.020 mg/L.

In the 2002 data, the nickel results from the sample sets collected from the downgradient wells generally exhibited greater variability than in prior years. (Since only one sample was collected from upgradient well pairs MW-4 and MW-5, the potential variability at upgradient wells in 2002 cannot be assessed.) In most cases, a marked increase in reported concentrations is observed from the initial sample set through the subsequent sample sets. Initial concentrations are generally consistent with historical concentration ranges, while the higher concentrations are two to ten times greater than historical concentrations. The variation in reported concentration of the sample sets is believed to be associated with the amount of entrained sediment in the samples, as discussed for barium.

Copper

The data for copper in the DW wells are shown graphically in Plots 5-5A through 5-5J in Appendix F. Early monitoring data for 1997 and 1998 indicated copper was typically not detected at reporting limits varying from 0.02 to 0.03 mg/L. However, a number of detections at concentrations ranging from 0.02 mg/L to 0.087 mg/L were reported in one or more samples from MW-4A, DW-32A, DW-32B, DW-33A, and DW-33B during this time period, based on data previously tabulated by others. Copper results for 2001 and 2002 contain a substantial number of non-detectable or estimated concentrations at a reporting limit of 0.005 mg/L, but also contain a substantial number of quantifiable concentrations generally ranging between 0.005 and 0.01 mg/L.

In the 2002 data, the copper results from the sample sets collected from the downgradient wells tended to exhibit a somewhat greater variability than in prior years, although the variability was much less pronounced in comparison to that exhibited by the previously discussed metals. (Since only one sample was collected from upgradient well pairs MW-4 and MW-5, the potential variability at upgradient wells in 2002 cannot be assessed.) An increase in reported concentrations from the initial sample set through one or more of the subsequent sample sets is observed in some cases, while others are relatively stable or do not display a consistent pattern. Reported copper concentrations even in wells with increasing copper concentrations trends were generally consistent with historically observed concentrations. The lesser variation in reported copper concentrations for the sample sets indicates that the copper content of the entrained sediment is not as significant as the previously discussed metals.

Cobalt

Cobalt concentrations for 2001 and 2002 were typically not detectable or estimated concentrations below the reporting limit of 0.01 mg/L. However, quantifiable concentrations of cobalt were reported in well DW-33A. In Spring of 2002, one of the three samples from DW-33A was reported to contain cobalt at 0.025 mg/L, and two of the four samples collected from DW-33A in Fall 2002 were reported to contain cobalt at 0.012 and 0.016 mg/L. Detection limits for prior years varied between 0.01 and 0.05 mg/L. Relatively isolated detections of cobalt were reported in the historical data tabulation for both upgradient and downgradient wells, ranging from 0.025 to 0.065 mg/L. Plot 5-6A in Appendix F depicts the cobalt concentration record for DW-33A.

5.3 DISCUSSION OF APPARENT SIGNIFICANT DETECTIONS

The apparent significant detections of certain metals that occur naturally in soils and groundwater clearly represent false positive results given the construction of the landfill, the climate of the region, and the hydrogeology of the site. The landfill is a state-of-the-art design with a double liner system, a leachate collection system over the upper liner, and a leak detection system between the liners. The upper transmissive zone, in which the SW wells are completed, has been and remains consistently dry based on semi-annual gauging of the SW wells. While numeric evaluation of the potential for a release to reach the groundwater has not been performed, qualitative evaluation indicates this potential to be remote. Further, even if a release could have occurred and could have reached the groundwater, the results of the gradient evaluation (see Appendix C) demonstrates that the rate of groundwater movement is so slow that it would take on the order of 10,000 years for the groundwater to move from the downgradient limit of the landfill unit to the nearest downgradient well, using conservative assumptions about the properties of the saturated transmissive zone.

The apparent significant detections are discussed in more detail below.

Barium and Chromium

The initial background datasets for barium and chromium were replaced with subsequent data collected at appropriate detection limits. However, the very slow rate of groundwater movement makes the collection of a valid background dataset, merely comprised of near-independent observations in lieu of truly independent observations, virtually impossible. Initial calculations of the potential time to obtain "new" water between monitoring events indicate that many years, if not decades, would have to transpire between sampling events to ensure truly independent measurements. The more recent data with significantly greater frequencies of detection than in previous years with the same analytical reporting limits reflects a gradual transition in groundwater chemistry over time, consistent with the very slow rate of groundwater movement. Barium and chromium concentrations in the initial sample sets are consistent with the concentration ranges in the background dataset; increasing concentrations in the subsequent sample sets are associated with the presence of increasing amounts of entrained sediment.

Copper, Lead and Nickel

The background data for copper, nickel and lead are all comprised of a significant portion of non-detect results at reporting limits that are substantially greater than current reporting limits. As a result, the current statistical test yields apparent statistically significant increases based on low level detections that are well within the typical concentration ranges observed for these parameters. Concentrations of lead and nickel in the initial sample sets are consistent with the concentration ranges in the background dataset; increasing concentrations in the subsequent sample sets are associated with the presence of increasing amounts of entrained sediment. Reported concentrations of copper even in wells with increasing concentration trends over the sample sets were generally consistent with historically observed ranges.

Cobalt

The reported concentrations for cobalt in 2002 are less than previously observed values. The apparent statistically significant increases for cobalt in DW-33A are a result of the non-detect results for cobalt in the background data at a reporting limit that is substantially greater than the current reporting limit.

6.0 CONCLUSIONS AND 2003 ACTIVITIES

6.1 Water Bearing Zone of Interest

Sections 3.0 and 4.0 presented data, information and results of various evaluations of the water bearing zone of interest. From this it has been determined that the water bearing zone of interest is not uniform in hydraulic conductivity characteristics.

New Mexico Well NMB-23, which is reported to never have been purged or sampled, has yet to equilibrate since it was first completed in October 1998. It recharged during 2002 at a rate of approximately 14.5 feet per year. It is estimated that the groundwater will reach equilibration by early to mid 2004, based on the estimate that the groundwater will stabilize at an elevation approximately 5 feet above its current level and that the rate of recharge to the well will decrease as it nears equilibration. Contrasted with NMB-23, New Mexico Well NMB-24, which is approximately 1600 feet south of NMB-23 and was also installed in October 1998, reached equilibrium prior to October 2000. As evidenced by the information presented in Section 3.0, the detection monitoring wells do not recover between the semi-annual monitoring events when the wells are purged and four "replicate" samples (i.e., four sample sets) are collected.

Because of the previous lack of recovery of the detection monitoring wells, particularly at DW-32 which is located near the southwest corner of the landfill, there is inadequate undisturbed groundwater elevation control in the vicinity of the southwest corner of the landfill. To address this issue, three additional activities will be undertaken to increase groundwater elevation control in this area. First, in concert with this report, a Class 1[1] permit modification request is being submitted to the TCEQ to change sampling procedures to eliminate purging and require collection of only one sample set, rather than four "replicates". This will significantly reduce the amount of water removed a each monitoring event, thereby decreasing the time required for groundwater levels to recover. Second, a letter will be submitted to the TCEQ requesting that the DW-32 wells not be sampled as part of the Spring 2003 sampling event, which is currently scheduled to be conducted during April 2003. As discussed in Section 4.1, if the DW-32 wells are not sampled in the spring, and the wells are not purged and only one sample set is collected from the wells in subsequent sampling events, it is anticipated that it will take more than two years for the DW-32 well pair to fully recover to provide valid groundwater elevation data. In order to more timely fill the data gap for the groundwater elevation in the vicinity of the southwest corner of the landfill, WCS will install a piezometer completed in the water bearing zone of interest, at the location shown on Figure 6-1, for the sole purpose of determining groundwater elevations in the future.

Given that the nature of the water bearing zone of interest is highly variable, and based on observed development characteristics after completion of the new piezometer, alternate development techniques may be implemented in order to facilitate well development and groundwater equilibrium. If the groundwater recharge rate of the proposed piezometer responds in the same manner as NMB-23, then natural development and gradient equilibrium will take several years. NMB-23 is currently developing at a rate of approximately 14 feet per year and the well is estimated to be relatively near to reaching equilibrium. If it becomes evident, after measuring the water level frequently for two months, that the proposed piezometer is not developing such that equilibrium will be achieved within six months, then it is planned to add water to the well to a level near the anticipated equilibrium elevation. Such action may result in more timely data collection from the piezometer to fill the gradient data gap near the southwest corner of the landfill.

6.2 Detection Monitoring Program

As noted above, a Class 1[1] permit modification request is being submitted in concert with this report. This permit modification request seeks revision of permit provision III.H.1 to allow groundwater sample collection without first purging the wells, as is currently required by provision III.H.1. This is requested because the monitor wells do not fully recover between sampling events (see Section 4.1) and therefore the groundwater available for sampling in the wells is equally as "fresh" or representative of groundwater from the formation as it would be if purging were continued.

The Class 1[1] permit modification request also seeks authorization to implement an alternate sampling procedure to that which is currently required by permit provision III.J.1.b. and 30 TAC §335.163(7)(A), as provided under 30 TAC §335.163(7)(B). The purpose of this request is to allow collection of only one set of samples for each well for each detection monitoring event. Section 4.3 presents information that demonstrates that independent samples cannot be collected during one sampling event. Groundwater velocity is so slow that "new" water does not move into the well so as to be able to collect an independent sample even at a six-month sampling interval. This Class 1[1] permit modification request is being submitted in order to implement the no purging and alternate sampling with the Spring 2003 sampling event, which will be conducted in April.

An additional permit modification request will be submitted to the TCEQ by May 2003 to authorize different analytical parameters for the detection monitoring program and more appropriate statistical evaluation methodologies. It is anticipated that this Class 2 permit modification request will be acted upon prior to October 2003, when the fall groundwater monitoring event is scheduled.

6.3 2003 Activities

The additional piezometer will be installed by no later than the time of the Spring 2003 sampling event. Appropriate geological logging will be performed of the boring in order to collect additional geologic data in the area of the new piezometer.

Water level measurements will be collected for the previously selected wells and piezometers, installed in the water bearing zone of interest, every other month. Well 4G-2 will be added to the list for the continuing water level measurements. Well 4G-2 will be further evaluated to try to determine if the well is representative of the static water level of the water bearing zone of interest.

A plan will be developed for additional transmissive zone characterizations, which may include but are not limited to: identification and selection of appropriate historical boring cores for further evaluation and testing, additional historical boring geophysical log comparison and evaluations, and slug testing of selected wells/piezometers. The plan will be transmitted to the TCEQ for review and comment prior to the Spring 2003 sampling event.

TABLES

TABLE 3-1
WASTE CONTROL SPECIALISTS
MONITOR WELL TOP OF CASING ELEVATIONS

Well ID	2002 Survey TOC Elevation (ft)	Previous Survey TOC Elevation (ft)	Survey Discrepancy	2002 Survey Northing	2002 Survey Easting
DW32A	3461.52	3461.520	0	6873779.82	561178.95
DW32B	3461.46	3461.440	-0.02	6873775.51	561187.80
DW33A	3464.99	3465.000	0.01	6873728.26	561321.08
DW33B	3465.12	3465.150	0.03	6873724.02	561329.87
DW34A	3468.70	3468.650	-0.05	6873673.92	561463.85
DW34B	3468.94	3468.910	-0.03	6873669.60	561472.83
DW35A	3467.86	3467.770	-0.09	6873621.74	561583.27
DW35B	3467.95	3467.870	-0.08	6873618.32	561592.62
DW36A	3467.59	3467.520	-0.07	6873577.70	561708.27
DW36B	3467.93	3467.790	-0.14	6873574.37	561717.37
NMB-23	3467.85	3476.830	8.980	6876221.09	559328.28
NMB-24	3439.15	3448.110	8.960	6874754.32	559238.66
MW1A	3480.79	3489.670	8.880	6875849.83	561434.11
MW1B	3480.61	3489.627	9.017	6875855.32	561442.62
MW2A	3481.72	3490.728	9.008	6875934.44	561558.00
MW2B	3481.93	3490.919	8.989	6875939.12	561567.30
MW3A	3483.04	3491.953	8.913	6876011.00	561687.05
MW3B	3483.10	3492.020	8.920	6876015.93	561696.15
MW4A	3484.70	3493.637	8.937	6876099.58	561805.86
MW4B	3484.74	3493.720	8.980	6876104.92	561814.61
A-22-99	3460.00	3468.940	8.940	6870486.35	566186.58
A-24-99	3464.20	3473.160	8.960	6870962.73	567389.93
2G	3440.76	3449.650	8.890	6871955.32	564367.73
4G-2	3440.22	3449.180	8.960	6872424.69	563497.51
4G-3	3439.88	3449.112	9.232	6872426.30	563467.22
6B-2	3487.07	3496.050	8.980	6875082.71	563755.97
7G	3448.57	3457.560	8.99	6873076.60	562123.75
TP-0001	3485.38	NA	NA	6875530.62	567764.77
TP-0002	3463.14	NA	NA	6872824.80	565091.45
TP-0003	3487.98	NA	NA	6872640.64	568169.40
TP-0004	3489.05	NA	NA	6874473.10	566186.43
TP-0005	3488.35	NA	NA	6874805.18	567481.73
PM-0003	3487.99	NA	NA	6874858.36	567445.80
PM-0006	3489.59	NA	NA	6874526.98	566142.11
PM-0009	3483.03	NA	NA	6872792.74	567459.53
PM-0012	3474.66	NA	NA	6872795.55	566424.24

TABLE 3-2
STABILIZED GROUNDWATER/SCREENED INTERVALS

Monitor Points	Stabilized Groundwater	Properly Screened	Groundwater Data
DW-32A	NO	YES	NO
DW-32B	NO	YES	NO
DW-33A	NO	YES	NO
DW-33B	NO	YES	NO
DW-34A	NO	YES	NO
DW-34B	NO	YES	NO
DW-35A	NO	YES	NO
DW-35B	NO	YES	NO
DW-36A	NO	YES	NO
DW-36B	NO	YES	NO
MW-1A	NO	YES	NO
MW-1B	NO	YES	NO
MW-2A	NO	YES	NO
MW-2B	NO	YES	NO
MW-3A	NO	YES	NO
MW-3B	NO	YES	NO
MW-4A	NO	YES	NO
MW-4B	NO	YES	NO
2-G	YES	YES	YES
4-G2	YES	YES	YES
4-G3	YES	NO	NO
7-G	YES	YES	YES
6B-2	YES	YES	YES
A-22	YES	YES	YES
A-24	YES	YES	YES
NMB-23	NO	YES	NO
NMB-24	YES	YES	YES
TP-0001	YES	YES	YES
TP-0002	NO	NO	NO
TP-0003	NO	NO	NO
TP-0004	YES	YES	YES
TP-0005	YES	YES	YES
PM-0003	YES	YES	YES
PM-0006	YES	YES	YES
PM-0009	NO	NO	NO
PM-0012	NO	NO	NO

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52	1/22/02	1305	215.49	231.90	3246.03	2/25/02	1324	211.18	231.90	3250.34					
DW32B	3461.46	1/22/02	1309	200.11	248.80	3261.35	2/25/02	1329	195.19	248.80	3266.27					
DW33A	3464.99	1/22/02	1314	222.57	234.64	3242.42	2/25/02	1335	219.99	234.64	3245.00					
DW33B	3465.12	1/22/02	1318	211.41	247.15	3253.71	2/25/02	1339	207.48	247.15	3257.64					
DW34A	3468.70	1/22/02	1322	198.62	238.40	3270.08	2/25/02	1344	195.51	238.40	3273.19					
DW34B	3468.94	1/22/02	1324	201.52	252.94	3267.42	2/25/02	1348	197.65	252.94	3271.29					
DW35A	3467.86	1/22/02	1329	191.54	235.82	3276.32	2/25/02	1352	189.91	235.82	3277.95	2/28/02	1409	190.33	235.82	3277.53
DW35B	3467.95	1/22/02	1331	191.49	250.59	3276.46	2/25/02	1357	189.88	250.59	3278.07	2/28/02	1029	189.77	250.59	3278.18
DW36A	3467.59	1/22/02	1334	190.86	241.00	3276.73	2/25/02	1402	189.12	241.00	3278.47					
DW36B	3467.93	1/22/02	1336	190.98	255.52	3276.95	2/25/02	1409	189.27	255.52	3278.66	2/27/02	1355	189.19	255.52	3278.74
NMB-23	3467.85	1/21/02	1428	139.97	264.06	3327.88	2/22/02	1153	138.79	264.06	3329.06					
NMB-24	3439.15	1/21/02	1434	116.19	232.87	3322.96	2/22/02	1139	116.16	232.87	3322.99					
MW1A	3480.79	1/21/02	1444	151.11	260.47	3329.68	2/22/02	1147	148.48	260.47	3332.31					
MW1B	3480.61	1/21/02	1446	142.02	274.84	3338.59	2/22/02	1152	140.89	274.84	3339.72					
MW2A	3481.72	1/21/02	1449	158.58	264.25	3323.14	2/22/02	1156	156.50	264.25	3325.22					
MW2B	3481.93	1/21/02	1451	190.58	277.55	3291.35	2/22/02	1159	185.22	277.55	3296.71					
MW3A	3483.04	1/21/02	1455	154.56	268.00	3328.48	2/22/02	1203	152.98	268.00	3330.06					
MW3B	3483.10	1/21/02	1456	153.81	283.15	3329.29	2/22/02	1206	152.26	283.15	3330.84					
MW4A	3484.70	1/21/02	1458	139.78	271.45	3344.92	2/22/02	1209	139.05	271.45	3345.65					
MW4B	3484.74	1/21/02	1500	139.63	286.50	3345.11	2/22/02	1212	138.94	286.50	3345.80					
A-22-99	3460.00	1/21/02	1537	168.69	255.00	3291.31	2/22/02	1325	167.91	255.00	3292.09					
A-24-99	3464.20	1/21/02	1532	158.09	267.00	3306.11	2/22/02	1318	159.26	267.00	3304.94					
2G	3440.76	1/21/02	1523	151.69	250.00	3289.07	2/22/02	1308	150.80	250.00	3289.96					
**4G-2	3440.22			157.64	200.00	3282.58			157.64	200.00	3282.58					
4G-3	3439.88	1/21/02	1517	238.27	246.26	3201.61	2/22/02	1301	238.20	246.26	3201.68					
6B-2	3487.07	1/21/02	1506	137.61	272.00	3349.46	2/22/02	1217	136.43	272.00	3350.64					
7G	3448.57	1/21/02	1621	138.35	215.00	3310.22	2/22/02	1500	138.04	215.00	3310.53					
TP-0001	3485.38	1/22/02	1422	98.5	242.30	3386.88	2/22/02	1348	98.50	242.30	3386.88					
TP-0002	3436.14	1/22/02	1349	122.62	122.94	3313.52	2/22/02	1434	122.62	122.94	3313.52					
TP-0003	3487.98	1/22/02	1408	225.81	230.40	3262.17	2/22/02	1333	223.78	230.40	3264.20					
TP-0004	3489.05	1/22/02	1502	133.85	230.55	3355.20	2/22/02	1356	134.07	230.55	3354.98					
TP-0005	3488.35	1/22/02	1450	119.72	233.30	3368.63	2/22/02	1340	119.62	233.30	3368.73					
PM-0003	3487.99	1/22/02	1435	119.73	212.33	3368.26	2/22/02	1344	119.77	212.33	3368.22					
PM-0006	3489.59	1/28/02	1637	134.08	134.60	3355.51	2/22/02	1353	134.26	134.60	3355.33					
PM-0009	3483.03	1/28/02	1646	117.35	213.38	3365.68	2/22/02	1446	100.82	213.38	3382.21					
PM-0012	3474.66	1/28/02	1606	184.06	184.25	3290.60	2/22/02	1441	dry	184.25						

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52	3/11/02	1414	209.43	231.90	3252.09	3/26/02	1218	227.28	231.90	3234.24
DW32B	3461.46	3/11/02	1101	193.45	248.80	3268.01	3/26/02	1222	235.37	248.80	3226.09
DW33A	3464.99	3/8/02	1400	218.67	234.64	3246.32	3/26/02	1227	230.34	234.64	3234.65
DW33B	3465.12	3/8/02	1047	207.61	247.15	3257.51	3/26/02	1231	239.11	247.15	3226.01
DW34A	3468.70	3/8/02	858	194.87	238.40	3273.83	3/26/02	1235	222.94	238.40	3245.76
DW34B	3468.94	3/7/02	1323	196.71	252.94	3272.23	3/26/02	1238	238.67	252.94	3230.27
DW35A	3467.86						3/26/02	1240	205.04	235.82	3262.82
DW35B	3467.95						3/26/02	1242	204.11	250.59	3263.84
DW36A	3467.59	3/13/02	1227	201.52	241.00	3266.07	3/26/02	1245	205.36	241.00	3262.23
DW36B	3467.93						3/26/02	1247	204.41	255.52	3263.52
NMB-23	3467.85						3/26/02	1130	137.72	264.06	3330.13
NMB-24	3439.15						3/26/02	1134	116.13	232.87	3323.02
MW1A	3480.79						3/26/02	1143	146.25	260.47	3334.54
MW1B	3480.61						3/26/02	1147	139.81	274.84	3340.80
MW2A	3481.72						3/26/02	1149	154.62	264.25	3327.10
MW2B	3481.93						3/26/02	1151	180.40	277.55	3301.53
MW3A	3483.04						3/26/02	1155	151.50	268.00	3331.54
MW3B	3483.10						3/26/02	1158	150.81	283.15	3332.29
MW4A	3484.70						3/26/02	1200	138.35	271.45	3346.35
MW4B	3484.74						3/26/02	1202	138.22	286.50	3346.52
A-22-99	3460.00						3/26/02	1334	167.56	255.00	3292.44
A-24-99	3464.20						3/26/02	1329	159.61	267.00	3304.59
2G	3440.76						3/26/02	1320	150.38	250.00	3290.38
**4G-2	3440.22								157.6	200.00	3282.58
4G-3	3439.88						3/26/02	1315	238.07	246.26	3201.81
6B-2	3487.07						3/26/02	1306	135.90	272.00	3351.17
7G	3448.57						3/26/02	1251	137.61	215.00	3310.96
TP-0001	3485.38						3/26/02	1357	98.31	242.30	3387.07
TP-0002	3436.14						3/26/02	1414	122.63	122.94	3313.51
TP-0003	3487.98						3/26/02	1343	221.58	230.40	3266.40
TP-0004	3489.05						3/26/02	1404	134.04	230.55	3355.01
TP-0005	3488.35						3/26/02	1350	119.51	233.30	3368.84
PM-0003	3487.99						3/26/02	1353	119.63	212.33	3368.36
PM-0006	3489.59						3/26/02	1401	134.27	134.60	3355.32
PM-0009	3483.03						3/26/02	1340	90.77	213.38	3392.26
PM-0012	3474.66						3/26/02	1408	dry	184.25	

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52	4/10/02		227.71	231.90	3233.81	4/19/02		224.86	231.90	3236.66					
DW32B	3461.46						4/19/02		228.07	248.80	3233.39					
DW33A	3464.99	4/10/02		229.35	234.64	3235.64	4/19/02		228.78	234.64	3236.21					
DW33B	3465.12						4/19/02		229.91	247.15	3235.21					
DW34A	3468.70						4/19/02		214.52	238.40	3254.18					
DW34B	3468.94						4/19/02		225.91	252.94	3243.03					
DW35A	3467.86						4/19/02		198.37	235.82	3269.49	4/30/02	1410	197.1	235.82	3270.80
DW35B	3467.95						4/19/02		198.13	250.59	3269.82	4/30/02	1035	196.7	250.59	3271.27
DW36A	3467.59						4/19/02		198.10	241.00	3269.49	4/30/02	815	198.6	241.00	3269.00
DW36B	3467.93						4/19/02		198.00	255.52	3269.93	4/29/02	1410	196.7	255.52	3271.26
NMB-23	3467.85															
NMB-24	3439.15															
MW1A	3480.79															
MW1B	3480.61															
MW2A	3481.72															
MW2B	3481.93															
MW3A	3483.04															
MW3B	3483.10															
MW4A	3484.70															
MW4B	3484.74															
A-22-99	3460.00															
A-24-99	3464.20															
2G	3440.76															
**4G-2	3440.22															
4G-3	3439.88															
6B-2	3487.07															
7G	3448.57															
TP-0001	3485.38															
TP-0002	3436.14															
TP-0003	3487.98															
TP-0004	3489.05															
TP-0005	3488.35															
PM-0003	3487.99															
PM-0006	3489.59															
PM-0009	3483.03															
PM-0012	3474.66															

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52	5/1/02	1040	223.75	231.90	3237.77	5/29/02	1417	225.52	231.90	3236.00
DW32B	3461.46	5/1/02	1043	224.98	248.80	3236.48	5/29/02	1421	226.72	248.80	3234.74
DW33A	3464.99	5/1/02	1027	227.92	234.64	3237.07	5/29/02	1428	230.56	234.64	3234.43
DW33B	3465.12	5/1/02	1023	225.68	247.15	3239.44	5/29/02	1434	228.92	247.15	3236.20
DW34A	3468.70						5/29/02	1437	215.93	238.40	3252.77
DW34B	3468.94	5/1/02	855	220.85	252.94	3248.09	5/29/02	1440	224.37	252.94	3244.57
DW35A	3467.86						5/29/02	1446	199.11	235.82	3268.75
DW35B	3467.95						5/29/02	1449	198.91	250.59	3269.04
DW36A	3467.59						5/29/02	1452	199.50	241.00	3268.09
DW36B	3467.93						5/29/02	1456	199.39	255.52	3268.54
NMB-23	3467.85	5/6/02	1309	136.37	264.06	3331.48	5/28/02	1430	135.65	264.06	3332.20
NMB-24	3439.15	5/6/02	1313	116.13	232.87	3323.02	5/28/02	1436	115.92	232.87	3323.23
MW1A	3480.79	5/6/02	1320	143.8	260.47	3336.99	5/28/02	1444	142.62	260.47	3338.17
MW1B	3480.61	5/6/02	1323	138.48	274.84	3342.13	5/28/02	1448	137.94	274.84	3342.67
MW2A	3481.72	5/6/02	1325	152.38	264.25	3329.34	5/28/02	1453	151.26	264.25	3330.46
MW2B	3481.93	5/6/02	1327	174.86	277.55	3307.07	5/28/02	1457	172.11	277.55	3309.82
MW3A	3483.04	5/2/02	1455	149.72	268.00	3333.32	5/28/02	1501	149.58	268.00	3333.46
MW3B	3483.10	5/2/02	1505	149.22	283.15	3333.88	5/28/02	1504	148.89	283.15	3334.21
MW4A	3484.70	5/2/02	1510	137.57	271.45	3347.13	5/28/02	1510	137.43	271.45	3347.27
MW4B	3484.74	5/2/02	1520	137.46	286.50	3347.28	5/28/02	1513	137.30	286.50	3347.44
A-22-99	3460.00	5/6/02	1355	167.7	255.00	3292.30	5/30/02	1010	169.00	255.00	3291.00
A-24-99	3464.20	5/6/02	1359	159.61	267.00	3304.59	5/30/02	1015	160.56	267.00	3303.64
2G	3440.76	5/6/02	1338	149.94	250.00	3290.82	5/30/02	1036	151.38	250.00	3289.38
**4G-2	3440.22			157.64	200.00	3282.58			157.64	200.00	3282.58
4G-3	3439.88	5/6/02	1343	237.89	246.26	3201.99	5/30/02	1026	237.72	246.26	3202.16
6B-2	3487.07	5/6/02	1333	135.49	272.00	3351.58	5/29/02	1510	138.37	272.00	3348.70
7G	3448.57	5/6/02	1500	142.56	215.00	3306.01	5/29/02	1500	138.84	215.00	3309.73
TP-0001	3485.38	5/6/02	1418	98.16	242.30	3387.22	5/30/02	1401	98.18	242.30	3387.20
TP-0002	3436.14	5/6/02	1348	122.61	122.94	3313.53	5/30/02	1343	122.53	122.94	3313.61
TP-0003	3487.98	5/6/02	1404	218.66	230.40	3269.32	5/30/02	1410	216.77	230.40	3271.21
TP-0004	3489.05	5/6/02	1426	134.86	230.55	3354.19	5/30/02	1356	133.64	230.55	3355.41
TP-0005	3488.35	5/6/02	1412	119.32	233.30	3369.03	5/30/02	1407	119.31	233.30	3369.04
PM-0003	3487.99	5/6/02	1415	119.43	212.33	3368.56	5/30/02	1404	119.41	212.33	3368.58
PM-0006	3489.59	5/6/02	1423	134.27	134.60	3355.32	5/30/02	1353	134.20	134.60	3355.39
PM-0009	3483.03	5/6/02	1434	95.96	213.38	3387.07	5/30/02	1415	86.73	213.38	3396.30
PM-0012	3474.66	5/6/02	1443	dry	184.25		5/30/02	1349	DRY	184.25	

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52	6/25/02	1149	223.1	231.90	3238.42	7/30/02	1228	220.06	231.90	3241.46
DW32B	3461.46	6/25/02	1151	219.16	248.80	3242.30	7/30/02	1231	209.78	248.80	3251.68
DW33A	3464.99	6/25/02	1157	228.46	234.64	3236.53	7/30/02	1237	225.67	234.64	3239.32
DW33B	3465.12	6/25/02	1200	221.65	247.15	3243.47	7/30/02	1239	215.95	247.15	3249.17
DW34A	3468.70	6/25/02	1203	209.18	238.40	3259.52	7/30/02	1242	203.28	238.40	3265.42
DW34B	3468.94	6/25/02	1205	215.48	252.94	3253.46	7/30/02	1244	207.44	252.94	3261.50
DW35A	3467.86	6/25/02	1209	196.13	235.82	3271.73	7/30/02	1247	193.73	235.82	3274.13
DW35B	3467.95	6/25/02	1211	196.02	250.59	3271.93	7/30/02	1249	193.71	250.59	3274.24
DW36A	3467.59	6/25/02	1216	195.92	241.00	3271.67	7/30/02	1252	193.16	241.00	3274.43
DW36B	3467.93	6/25/02	1218	195.98	255.52	3271.95	7/30/02	1255	193.26	255.52	3274.67
NMB-23	3467.85	6/24/02	1257	134.78	264.06	3333.07	7/29/02	1121	133.22	264.06	3334.63
NMB-24	3439.15	6/24/02	1302	115.81	232.87	3323.34	7/29/02	1126	115.54	232.87	3323.61
MW1A	3480.79	6/24/02	1308	141.46	260.47	3339.33	7/29/02	1131	140.21	260.47	3340.58
MW1B	3480.61	6/24/02	1311	137.42	274.84	3343.19	7/29/02	1134	136.90	274.84	3343.71
MW2A	3481.72	6/24/02	1315	150.14	264.25	3331.58	7/29/02	1139	148.86	264.25	3332.86
MW2B	3481.93	6/24/02	1317	169.13	277.55	3312.80	7/29/02	1141	165.08	277.55	3316.85
MW3A	3483.04	6/24/02	1320	148.46	268.00	3334.58	7/29/02	1144	147.37	268.00	3335.67
MW3B	3483.10	6/24/02	1322	147.82	283.15	3335.28	7/29/02	1147	146.77	283.15	3336.33
MW4A	3484.70	6/24/02	1326	136.93	271.45	3347.77	7/29/02	1149	136.42	271.45	3348.28
MW4B	3484.74	6/24/02	1328	136.86	286.50	3347.88	7/29/02	1151	136.43	286.50	3348.31
A-22-99	3460.00	6/24/02	1402	168.45	255.00	3291.55	7/30/02	1345	167.81	255.00	3292.19
A-24-99	3464.20	6/24/02	1357	159.47	267.00	3304.73	7/30/02	1341	158.81	267.00	3305.39
2G	3440.76	6/24/02	1346	150.63	250.00	3290.13	7/30/02	1357	150.22	250.00	3290.54
**4G-2	3440.22			157.64	200.00	3282.58			157.64	200.00	3282.58
4G-3	3439.88	6/24/02	1340	237.61	246.26	3202.27	7/30/02	1402	237.51	246.26	3202.37
6B-2	3487.07	6/24/02	1332	136.92	272.00	3350.15	7/30/02	1308	136.00	272.00	3351.07
7G	3448.57	6/25/02	1144	137.9	215.00	3310.67	7/30/02	1259	137.70	215.00	3310.87
TP-0001	3485.38	6/24/02	1424	98.66	242.30	3386.72	7/30/02	1319	98.32	242.30	3387.06
TP-0002	3436.14	6/24/02	1350	122.54	122.94	3313.60	7/30/02	1354	122.55	122.94	3313.59
TP-0003	3487.98	6/24/02	1409	214.78	230.40	3273.20	7/30/02	1330	211.38	230.40	3276.60
TP-0004	3489.05	6/24/02	1431	133.67	230.55	3355.38	7/30/02	1316	133.54	230.55	3355.51
TP-0005	3488.35	6/24/02	1418	119.34	233.30	3369.01	7/30/02	1325	119.45	233.30	3368.90
PM-0003	3487.99	6/24/02	1421	119.44	212.33	3368.55	7/30/02	1322	119.51	212.33	3368.48
PM-0006	3489.59	6/24/02	1428	134.22	134.60	3355.37	7/30/02	1314	134.23	134.60	3355.36
PM-0009	3483.03	6/24/02	1414	85.83	213.38	3397.20	7/30/02	1336	87.02	213.38	3396.01
PM-0012	3474.66	6/24/02	1436	DRY	184.25		7/30/02	1350	DRY	184.25	

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52						8/27/02	1444	216.59	231.90	3244.93
DW32B	3461.46						8/27/02	1448	203.85	248.80	3257.61
DW33A	3464.99						8/27/02	1453	223.44	234.64	3241.55
DW33B	3465.12						8/27/02	1456	212.69	247.15	3252.43
DW34A	3468.70	8/25/02	1300	199.93	238.40	3268.77	8/27/02		232.59	238.40	3236.11
DW34B	3468.94	8/25/02	900	203.16	252.94	3265.78	8/27/02		248.03	252.94	3220.91
DW35A	3467.86	8/22/02	818	200.79	235.82	3267.07	8/27/02		226.54	235.82	3241.32
DW35B	3467.95	8/21/02	1305	192.37	250.59	3275.58	8/27/02		217.99	250.59	3249.96
DW36A	3467.59	8/21/02	505	197.40	241.00	3270.19	8/27/02		222.3	241.00	3245.29
DW36B	3467.93	8/20/02	1330	191.85	255.52	3276.08	8/27/02		217.89	255.52	3250.04
NMB-23	3467.85						8/27/02	1308	131.18	264.06	3336.67
NMB-24	3439.15						8/27/02	1314	115.29	232.87	3323.86
MW1A	3480.79						8/27/02	1321	139.28	260.47	3341.51
MW1B	3480.61						8/27/02	1323	136.42	274.84	3344.19
MW2A	3481.72						8/27/02	1326	147.87	264.25	3333.85
MW2B	3481.93						8/27/02	1329	163.09	277.55	3318.84
MW3A	3483.04						8/27/02	1333	146.51	268.00	3336.53
MW3B	3483.10						8/27/02	1336	145.94	283.15	3337.16
MW4A	3484.70						8/27/02	1339	136.14	271.45	3348.56
MW4B	3484.74						8/27/02	1341	136.07	286.50	3348.67
A-22-99	3460.00										
A-24-99	3464.20										
2G	3440.76										
**4G-2	3440.22								157.64	200.00	3282.58
4G-3	3439.88										
6B-2	3487.07						8/27/02	1346	137.73	272.00	3349.34
7G	3448.57						8/27/02	1518	139.13	215.00	3309.44
TP-0001	3485.38										
TP-0002	3436.14										
TP-0003	3487.98										
TP-0004	3489.05										
TP-0005	3488.35										
PM-0003	3487.99										
PM-0006	3489.59										
PM-0009	3483.03										
PM-0012	3474.66										

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52										
DW32B	3461.46										
DW33A	3464.99										
DW33B	3465.12										
DW34A	3468.70	8/28/02		231.75	238.40	3236.95	8/30/02		230.5	238.40	3238.22
DW34B	3468.94	8/28/02		247.47	252.94	3221.47	8/30/02		246.5	252.94	3222.4
DW35A	3467.86	8/28/02		225.17	235.82	3242.69	8/30/02		222.9	235.82	3244.96
DW35B	3467.95	8/28/02		216.94	250.59	3251.01	8/30/02		215.5	250.59	3252.49
DW36A	3467.59	8/28/02		220.18	241.00	3247.41	8/30/02		217.1	241.00	3250.52
DW36B	3467.93	8/28/02		216.54	255.52	3251.39	8/30/02		214	255.52	3253.89
NMB-23	3467.85										
NMB-24	3439.15										
MW1A	3480.79										
MW1B	3480.61										
MW2A	3481.72										
MW2B	3481.93										
MW3A	3483.04										
MW3B	3483.10										
MW4A	3484.70										
MW4B	3484.74										
A-22-99	3460.00	8/28/02	1119	168.64	255.00	3291.36					
A-24-99	3464.20	8/28/02	1115	158.59	267.00	3305.61					
2G	3440.76	8/28/02	1059	151.12	250.00	3289.64					
**4G-2	3440.22			157.64	200.00	3282.58			157.64	200.00	3124.94
4G-3	3439.88	8/28/02	1053	237.41	246.26	3202.47					
6B-2	3487.07										
7G	3448.57										
TP-0001	3485.38	8/28/02	1135	98.32	242.30	3387.06					
TP-0002	3436.14	8/28/02	1102	122.57	122.94	3313.57					
TP-0003	3487.98	8/28/02	1125	208.46	230.40	3279.52					
TP-0004	3489.05	8/28/02	1140	133.51	230.55	3355.54					
TP-0005	3488.35	8/28/02	1130	119.35	233.30	3369.00					
PM-0003	3487.99	8/28/02	1132	119.45	212.33	3368.54					
PM-0006	3489.59	8/28/02	1138	134.24	134.60	3355.35					
PM-0009	3483.03	8/28/02	1110	88.68	213.38	3394.35					
PM-0012	3474.66	8/28/02	1106	DRY	184.25						

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52						9/12/02	1151	215.82	231.90	3245.70
DW32B	3461.46						9/12/02	1154	201.13	248.80	3260.33
DW33A	3464.99						9/12/02	1159	222.26	234.64	3242.73
DW33B	3465.12						9/12/02	1201	211.30	247.15	3253.82
DW34A	3468.70	9/3/02		227.96	238.40	3240.74	9/11/02	1533	224.64	238.40	3244.06
DW34B	3468.94	9/3/02		244.48	252.94	3224.46	9/11/02	1530	240.94	252.94	3228.00
DW35A	3467.86	9/3/02		216.66	235.82	3251.2	9/11/02	1506	209.22	235.82	3258.64
DW35B	3467.95	9/3/02		212.57	250.59	3255.38	9/11/02	1502	207.93	250.59	3260.02
DW36A	3467.59	9/3/02		211.97	241.00	3255.62	9/11/02	1459	206.85	241.00	3260.74
DW36B	3467.93	9/3/02		210.51	255.52	3257.42	9/11/02	1455	206.19	255.52	3261.74
NMB-23	3467.85						9/12/02	755	130.22	264.06	3337.63
NMB-24	3439.15						9/12/02	801	115.28	232.87	3323.87
MW1A	3480.79						9/12/02	807	138.91	260.47	3341.88
MW1B	3480.61						9/12/02	809	136.27	274.84	3344.34
MW2A	3481.72						9/12/02	812	147.41	264.25	3334.31
MW2B	3481.93						9/12/02	815	161.38	277.55	3320.55
MW3A	3483.04						9/12/02	819	146.19	268.00	3336.85
MW3B	3483.10						9/12/02	822	145.63	283.15	3337.47
MW4A	3484.70						9/12/02	824	136.07	271.45	3348.63
MW4B	3484.74						9/12/02	826	135.99	286.50	3348.75
A-22-99	3460.00						9/12/02	915	168.33	255.00	3291.67
A-24-99	3464.20						9/12/02	920	157.38	267.00	3306.82
2G	3440.76						9/12/02	902	150.68	250.00	3290.08
**4G-2	3440.22								157.64	200.00	3282.58
4G-3	3439.88						9/12/02	856	237.35	246.26	3202.53
6B-2	3487.07						9/12/02	830	137.02	272.00	3350.05
7G	3448.57						9/12/02	745	138.38	215.00	3310.19
TP-0001	3485.38						9/12/02	937	98.40	242.30	3386.98
TP-0002	3436.14						9/12/02	850	122.57	122.94	3313.57
TP-0003	3487.98						9/12/02	925	206.72	230.40	3281.26
TP-0004	3489.05						9/12/02	945	133.46	230.55	3355.59
TP-0005	3488.35						9/12/02	931	119.41	233.30	3368.94
PM-0003	3487.99						9/12/02	933	119.51	212.33	3368.48
PM-0006	3489.59						9/12/02	942	134.24	134.60	3355.35
PM-0009	3483.03						9/12/02	950	88.91	213.38	3394.12
PM-0012	3474.66						9/12/02	846	DRY	184.25	

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 4-1
WASTE CONTROL SPECIALISTS
JANUARY - FEBRUARY 2002
GROUNDWATER ELEVATIONS

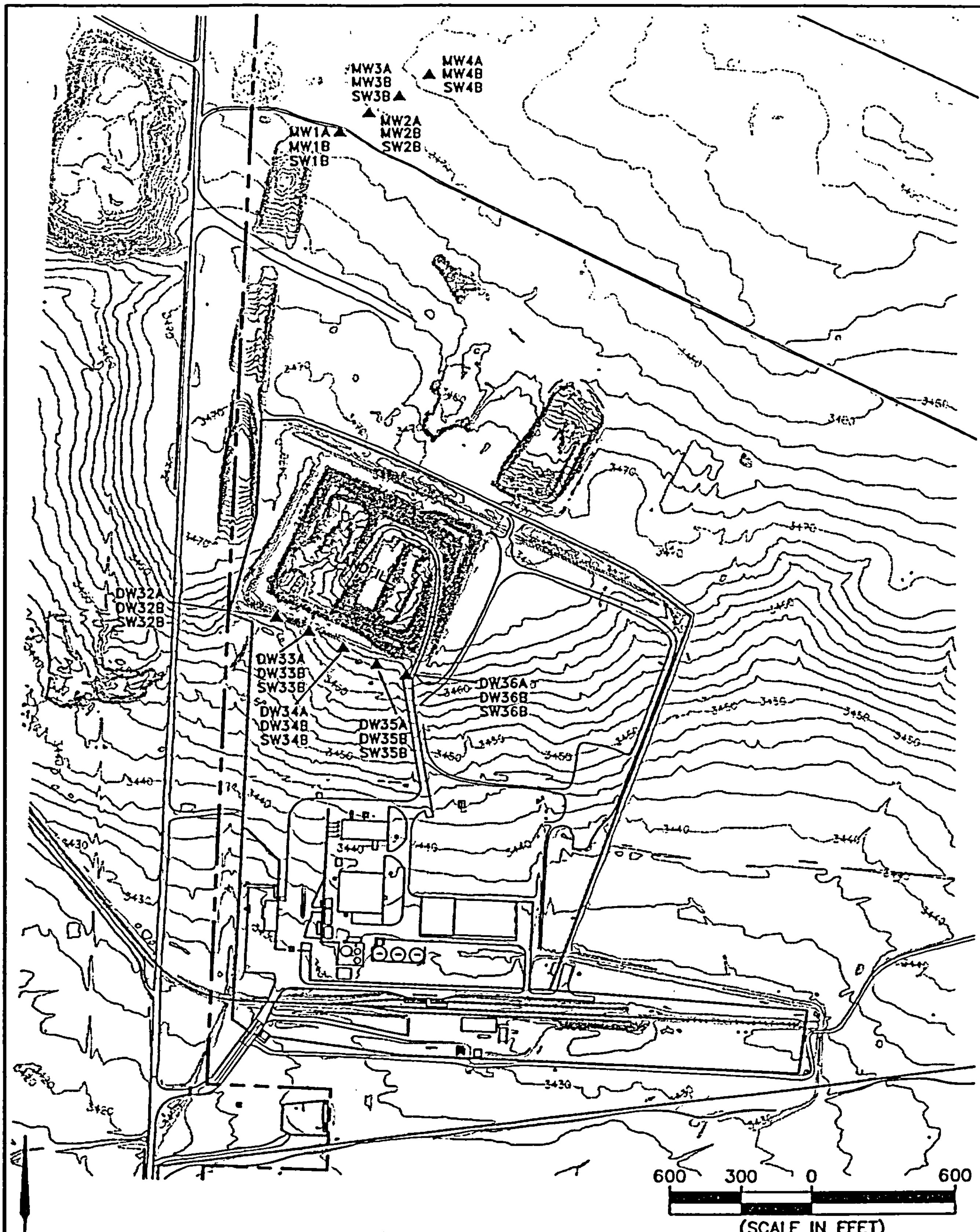
Well ID	TOC Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)	Date	Time	DtW (ft)	Total Depth (ft)	GW Elevation (ft)
DW32A	3461.52	10/29/02	1440	220.98	231.90	3240.54	11/25/02	1058	218.38	231.90	3243.14	12/20/02	1108	215.43	231.90	3246.09
DW32B	3461.46	10/29/02	1442	205.32	248.80	3256.14	11/25/02	1100	200.45	248.80	3261.01	12/20/02	1110	196.77	248.80	3264.69
DW33A	3464.99						11/25/02	1117	224.51	234.64	3240.48	12/20/02	1118	222.41	234.64	3242.58
DW33B	3465.12						11/25/02	1120	212.56	247.15	3252.56	12/20/02	1122	209.97	247.15	3255.15
DW34A	3468.70						11/25/02	1123	212.04	238.40	3256.66	12/20/02	1130	207.48	238.40	3261.22
DW34B	3468.94						11/25/02	1126	219.71	252.94	3249.23	12/20/02	1132	212.96	252.94	3255.98
DW35A	3467.86						11/25/02	1128	199.27	235.82	3268.59	12/20/02	1135	197.06	235.82	3270.8
DW35B	3467.95						11/25/02	1131	199.13	250.59	3268.82	12/20/02	1137	196.99	250.59	3270.96
DW36A	3467.59	10/29/02	1433	202.91	241.00	3264.68	11/25/02	1134	199.03	241.00	3268.56	12/20/02	1141	196.59	241.00	3271
DW36B	3467.93	10/29/02	1430	202.75	255.52	3265.18	11/25/02	1136	199.05	255.52	3268.88	12/20/02	1143	196.64	255.52	3271.29
NMB-23	3467.85	10/29/02	1045	127.62	264.06	3340.23	11/25/02	1312	126.32	264.06	3341.53	12/19/02	1254	125.29	264.06	3342.56
NMB-24	3439.15	10/29/02	1051	115.21	232.87	3323.94	11/25/02	1316	115.38	232.87	3323.77	12/19/02	1300	115.38	232.87	3323.77
MW1A	3480.79	10/29/02	1104	137.78	260.47	3343.01	11/25/02	1321	137.18	260.47	3343.61	12/19/02	1307	136.65	260.47	3344.14
MW1B	3480.61	10/29/02	1106	135.6	274.84	3345.01	11/25/02	1323	135.06	274.84	3345.55	12/19/02	1309	134.57	274.84	3346.04
MW2A	3481.72	10/29/02	1110	146.08	264.25	3335.64	11/25/02	1325	145.33	264.25	3336.39	12/19/02	1311	144.65	264.25	3337.07
MW2B	3481.93	10/29/02	1112	158.35	277.55	3323.58	11/25/02	1327	156.58	277.55	3325.35	12/19/02	1313	155.12	277.55	3326.81
MW3A	3483.04	10/29/02	1116	146.32	268.00	3336.72	11/25/02	1329	145.34	268.00	3337.7	12/19/02	1315	144.61	268.00	3338.43
MW3B	3483.10	10/29/02	1118	145.72	283.15	3337.38	11/25/02	1331	144.78	283.15	3338.32	12/19/02	1317	144.05	283.15	3339.05
MW4A	3484.70	10/29/02	1121	136.1	271.45	3348.60	11/25/02	1333	135.64	271.45	3349.06	12/19/02	1319	135.27	271.45	3349.43
MW4B	3484.74	10/29/02	1124	135.94	286.50	3348.80	11/25/02	1335	135.57	286.50	3349.17	12/19/02	1321	135.19	286.50	3349.55
A-22-99	3460.00	10/29/02	1337	168.02	255.00	3291.98	11/25/02	1424	169.71	255.00	3290.29	12/20/02	1008	168.97	255.00	3291.03
A-24-99	3464.20	10/29/02	1332	159.64	267.00	3304.56	11/25/02	1420	161.84	267.00	3302.36	12/20/02	1015	160.39	267.00	3303.81
2G	3440.76	10/29/02	1322	150.09	250.00	3290.67	11/25/02	1408	151.92	250.00	3288.84	12/20/02	1024	150.82	250.00	3289.94
**4G-2	3440.22			157.64	200.00	3282.58			157.64	200.00	3282.58			157.64	200.00	3282.58
4G-3	3439.88	10/29/02	1312	237.18	246.26	3202.7	11/25/02	1402	237.16	246.26	3202.72	12/20/02	1029	237.09	246.26	3202.79
6B-2	3487.07	10/29/02	1137	135.81	272.00	3351.26	11/25/02	1339	140.59	272.00	3346.48	12/19/02	1324	138.64	272.00	3348.43
7G	3448.57	10/29/02	1424	138.8	215.00	3309.77	11/25/02	1139	139.26	215.00	3309.31	12/20/02	1147	137.91	215.00	3310.66
TP-0001	3485.38	10/29/02	1357	98.32	242.30	3387.06	11/25/02	1441	98.38	242.30	3387	12/20/02	1407	98.31	242.3	3387.07
TP-0002	3436.14	10/29/02	1318	122.58	122.94	3313.56	11/25/02	1412	122.6	122.94	3313.54	12/20/02	1340	122.59	122.94	3313.55
TP-0003	3487.98	10/29/02	1344	200.04	230.40	3287.94	11/25/02	1430	193.87	230.40	3294.11	12/20/02	1355	188.35	230.4	3299.63
TP-0004	3489.05	10/29/02	1405	133.55	230.55	3355.5	11/25/02	1448	133.86	230.55	3355.19	12/20/02	1415	133.8	230.55	3355.25
TP-0005	3488.35	10/29/02	1351	119.34	233.30	3369.01	11/25/02	1436	119.45	233.30	3368.9	12/20/02	1401	119.39	233.3	3368.96
PM-0003	3487.99	10/29/02	1353	119.43	212.33	3368.56	11/25/02	1438	119.54	212.33	3368.45	12/20/02	1403	119.5	212.33	3368.49
PM-0006	3489.59	10/29/02	1403	134.26	134.60	3355.33	11/25/02	1446	134.29	134.60	3355.3	12/20/02	1412	134.29	134.6	3355.3
PM-0009	3483.03	10/29/02	1410	83.02	213.38	3400.01	11/25/02	1452	82.97	213.38	3400.06	12/20/02	1351	83.07	213.38	3399.96
PM-0012	3474.66	10/29/02	1414	dry	184.25		11/25/02	1457	dry	184.25		12/20/02	1346	dry	184.25	

**4G-2 groundwater elevation was recorded on 1/24/03.

TABLE 5-1
SIGNIFICANT DETECTIONS FOR 2002
BY SAMPLING EVENT AND CONSTITUENT

	BARIUM	CHROMIUM	COPPER	LEAD	NICKEL	COBALT
	DW-34A	DW-32A	DW-32B	DW-34A	DW-32B	
	DW-34B	DW-32B	DW-33B		DW-33A	
	DW-35A	DW-33A	DW-34A		DW-33B	
	DW-35B	DW-33B	DW-34B		DW-34A	
	DW-36A	DW-34A	DW-35A		DW-34B	
	DW-36B	DW-34B			DW-35A	
		DW-35A			DW-35B	
					DW-36A	
					DW-36B	
	DW-34A	DW-32A	DW-34A	DW-34A	DW-32A	DW-33A
	DW-34B	DW-32B	DW-34B	DW-34B	DW-32B	
	DW-35A	DW-33A	DW-35A	DW-35A	DW-33A	
	DW-35B	DW-33B	DW-35B	DW-35B	DW-33B	
	DW-36A	DW-34A	DW-36A	DW-36A	DW-34A	
	DW-36B	DW-34B			DW-34B	
		DW-36A			DW-35A	
					DW-35B	
					DW-36A	
					DW-36B	

FIGURES



REV.	DATE	DESCRIPTION	DR BY	APP BY

COOK-JOYCE INC.
ENGINEERING AND CONSULTING
812 WEST ELEVENTH 512-474-9097
AUSTIN, TEXAS 78701

PROJECT:
WASTE CONTROL SPECIALISTS, LLC
ANDREWS COUNTY, TEXAS

SHEET TITLE:
LOCATION OF DETECTION MONITORING SYSTEM WELLS

DES BY		SCALE: SEE BAR SCALE
DR BY	SDB	PROJECT NO. 01098.02
CHK BY	KLM	CJI NO. 01098022
APP BY	SLC	SHEET 1 OF 1 SHEETS
DATE ISSUED: 01-27-2003		FIGURE NO. 2-1
PURPOSE: TECQ REVIEW		

AVLIS

USEC
A Global Energy Company

New Mexico

Technical Appendices

Submitted By:

The State of New Mexico
Gary E. Johnson, Governor

WCS Waste Control Specialists, LLC

APPENDIX 45.50-7

JACK HOLT & ASSOCIATES REPORT

GEOTECHNICAL INVESTIGATION

AND

ENGINEERING ANALYSIS

FOR

WASTE CONTROL SPECIALISTS INC.

LANDFILL PROJECT

ANDREWS COUNTY, TEXAS

REPORT FOR:

AM ENVIRONMENTAL, INC.

2525 WALLINGWOOD, SUITE 701

AUSTIN, TEXAS 78746

FILE NO.: 10-25792

12 MARCH 1993

JACK H. HOLT Ph.D. & ASSOCIATES INC.
2220 BARTON SKYWAY
AUSTIN, TEXAS 78704
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GEOTECHNICAL INVESTIGATION

ENGINEERING ANALYSIS

FOR

WASTE CONTROL SPECIALISTS INC.

LANDFILL PROJECT

ANDREWS COUNTY, TEXAS

INTRODUCTION

A Geotechnical Investigation and Engineering Analysis for the above referenced project located in Andrews County, Texas was authorized by Mr. Allen Messenger of A.M. Environmental, Austin, Texas on 15 October 1992. The purpose of the investigation was to determine subsurface soil conditions and materials at the site and to obtain samples for laboratory testing. Based on our boring logs and laboratory tests an engineering analysis was performed to determine foundation stability, slope stability and soil permeability as well as other design parameters for the proposed hazardous waste landfill.

SCOPE

The scope of the project included the following:

1. Reconnaissance of the project site to observe physical features, vegetation and access to the property.

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2. Surveying grid system on the site on 500 foot intervals and obtaining elevations at each grid point. Topographic survey of entire site and areas outside the site for a distance of 1000 feet.

3. Mobilization and demobilization of office trailer, storage building, electrical service, equipment, van truck, logging trailers, water tank and drill rigs to the site.

4. Drilling, logging and sampling 55 soil borings using air rotary and air coring to depths of 100 feet to 300 feet.

5. Drilling, logging and sampling 12 soil borings to depths of 45 feet to obtain rock cores.

6. Wrapping and packaging core samples in core boxes and properly storing on site prior to shipping to laboratory. Transporting samples to the laboratory in Austin, Texas.

7. Laboratory testing including but not limited to Unified Soils Classifications, Moisture Contents, Unit Weights, Atterberg Limits, Unconfined Compression Tests, Permeabilities, Triaxial Tests, Consolidation Tests, Moisture/Density Relationships and Direct Shear Tests.

8. Installation of eight monitor wells (4 inch PVC) and six piezometers (2 inch PVC) and coordinating the installation of wells with Terra Dynamics, Inc.

9. Monitoring groundwater levels in open bore holes prior to plugging and in water wells and piezometers.

10. Plugging of all bore holes with cement bentonite slurry.

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11. Preparing a written engineering report with grid survey, topographic survey, boring location plan, soil boring logs, laboratory test results and water level data. Preparing engineering analyses including soil permeability, slope stability, foundation stability, settlement analyses and recommendations for landfill design.

LOCATION AND SITE DESCRIPTION

The proposed landfill site is located in Andrews County, Texas approximately 34 miles west of Andrews, Texas on State Highway 176 (see location on State Highway Map - Figure 1). The site is located approximately 0.5 miles north of the Highway on the Flying "W" Diamond Ranch. The initial grid survey area consists of approximately 485 acres of undeveloped ranch land. The landfill area will be 100 acres in size with approximate dimensions of 1100 feet by 4000 feet. The terrain consists of gently sloping grass covered ranch land with scattered small mesquite trees. The proposed landfill site is bordered by a gravel ranch road on the west that parallels the Texas-New Mexico state line. An oil well location exists approximately 2500 feet south of the landfill site. An overhead power line borders the site on the east. The site slopes gradually from north to south changing in surface elevation from approximately 3480 feet to 3440 feet above mean sea level.

Several surface depressions exist on the landfill site and are locally referred to as buffalo wallows. These depressions are believed to have been formed by the dissolution of the carbonaceous caliche deposits near the surface or from natural depressions in the Triassic red bed clay formation below.

SITE SURVEY AND GRID LAYOUT

The project site was selected by Mr. Allen Messenger after preliminary borings indicated shallow depths to red bed clay in the area. Grid layout with approximate size of 6000 feet by 4500 feet was surveyed by Mr. James E. Tompkins, (R.P.S.) Engineering and Surveying of Andrews, Texas. Grid points were staked on the site at 500 foot intervals. Grid points were lettered from north to south A through J and numbered from east to west 1 through 13. The Texas-New Mexico State line running north to south has a bearing of N 0° 0'0"W. The grid lines A through J have a bearing of S 65° 0' 0" E. The grid lines 1 through 13 have a bearing of S 25° 0'0" W.

Additional surveying was performed by Tompkins Engineering and Surveying to provide adequate topographical information both inside and outside the grid to depict surface physical features on a one foot contour interval. The benchmark for the project is located at the state line marker located 1600 feet north of State Highway 176 with an elevation of 3484.75 feet MSL. A Grid Survey and Topography Map is shown in Figure III.

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FIELD INVESTIGATION

The drilling and sampling was accomplished with a 1974 Model Midway 1300 and 1977 Model Midway 1500 owned and operated by Scarborough Drilling, Inc. from Lamesa, Texas. These truck mounted rigs are equipped with direct rotary table, 550 CFM air compressors, mud pump, 2 7/8 inch diameter drill stem, 3 1/2 inch drill stem, tri-cone roller bits, drag bits, 3 foot core barrel and 10 foot core barrels.

Initially all holes were continuously sampled by air coring with 4 3/4 inch O.D. Christian Core barrels producing 2 1/8 inch diameter core samples. Where bit wear was excessive in hard limestone or conglomerate then tri-cone roller bits were used until hard layers were penetrated. Where soft layers were encountered and recovery using air coring was poor, split spoon (1.4 inch diameter) samples were obtained using rig pull-down.

The investigation consisted of drilling, logging and sampling a total of 55 bore holes (see Generalized Boring Location Plan - Figure IV). Of the 55 holes a total of 14 holes were continuously air cored in the upper caliche (hard limestone and sandstone deposits) to depths ranging from 9 feet to 53 feet deep. The remaining holes were drilled with straight air rotary in the upper caliche layers and cuttings were continuously sampled, logged and visually classified. All 55 holes were continuously sampled (air coring) from the top of the red bed (Triassic) using both split spoon samples and 2 1/8 I.D.

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Christianson core barrels. Continuous coring intervals varied from lengths of 4 feet to 10 feet depending on the type of soils encountered.

The initial investigation consisted of drilling and continuous air coring all bore holes to depths of 100 feet with selected holes extended to depths of 200 feet. At six piezometers and three monitor well locations the bore holes were extended to depths ranging from 260 feet to 300 feet and either continuously cored or air rotary drilled and cuttings were logged to accurately describe the geology and classify the soils. These nine holes were also used for geophysical logging that was coordinated by Terra-Dynamics, Austin, Texas. The geophysical logs and core logs were then compared and correlated by Terra-Dynamics. A total of 12 holes were drilled with a CME 55 Rig equipped with a mud rotary NXB Christianson Wireline system (1.875 diameter core) for the purpose of obtaining rock cores from the upper limestone (caliche) formation. These holes varied in depth from 12 feet to 36 feet below the existing grade. The total recovery as well as Rock Quality Designation (RQD) is shown on the individual boring logs. All rock cores were visually classified and logged in the field and samples were wrapped with plastic and stored in wooden core boxes and transported to the lab. A table depicting boring numbers, grid locations, boring depth and date of boring is shown in the Soil Boring Summary in Appendix II.

All core samples were examined and visually classified, logged in the field prior to wrapping and placing in cardboard core boxes. Grab samples from air rotary cuttings were also visually classified and logged and placed in ziploc plastic bags and stored in cardboard boxes. All core boxes were properly labeled with boring number and grid location, date, sample intervals and transported to the laboratory of Jack H. Holt & Associates, Inc. in Austin, Texas for testing and storage.

LABORATORY TESTING

The laboratory testing program included tests to determine the engineering characteristics and properties of the soil and rock samples obtained from the drilling and sampling program. These tests include soil classification, shear strength, plasticity, density, moisture, grain size analysis, and permeability. All laboratory tests were run in strict accordance with ASTM Standards using up-to-date calibrated testing equipment and apparatus as required by those standards. The laboratory testing program was performed under the supervision and direction of Dr. Jack H. Holt, Ph.D., P.E. Listed below is a list of the specific laboratory tests and their appropriate ASTM Designation:

1. Classification of soils according to the "Unified Soil Classification System" (ASTM D2487-90).
2. Sieve Analysis of soils including Minus No. 200 Mesh Sieve and Hydrometer Analysis (ASTM D-422-63).

3. Moisture Content of Soils (ASTM D-2216-90).

4. Unit Weight Tests.

5. Atterberg Limits Tests including Liquid Limits, Plastic Limits (ASTM D-4318-84).

6. Unconfined Compressive Strength - clay soils (ASTM D-2166-91).

7. Unconfined Compression Tests - rock specimens (ASTM D-2938-68).

8. Triaxial Tests.

9. Permeability Tests using both flexible wall and rigid permeameters (ASTM D-5084-90).

10. Moisture-Density Relationship Tests using Modified Proctor (ASTM D-1557-91) and Standard Proctor (ASTM D-698-91).

11. Consolidation Tests.

The results of all laboratory tests can be found in Appendix I. Laboratory test results are also shown on the individual boring logs at the appropriate depth.

SUBSURFACE CONDITIONS

The subsurface soil conditions are described in more detail by the attached Logs of Borings found in Appendix II. In general the soil conditions consist of a thin (one foot or less) layer of brown organic sandy silt overlying a formation of white or tan caliche. The caliche consists of crumbly to very hard cemented sand, conglomerate limestone rock, sandy silt and gravel. At the base of the caliche strata lies a sand and gravel layer that varies in thickness from 0 feet to 20 feet. The depth of the caliche layer including the sand and gravel strata below ranges from approximately 9 feet to 53 feet across the investigated area.

Below the caliche lies a formation of reddish brown silty clay (red bed clay) that extends to termination of the borings at 100 feet to 300 feet below the existing grade. The red bed clay consists of a highly consolidated impervious mottled reddish brown-gray clay, purple-gray silty clay, and yellowish brown-gray silty clay. Siltstones and sandstones are found at various depths and thicknesses across the grid area and vary in color from red, tan, gray, pink and yellow. The depth to the top of the red bed (Triassic-Dockum Group) varies across the site from 9 feet (B-24) to 53 feet (B-1) and generally averages 12 feet to 30 feet deep through the center of the grid area between Grid Lines C and E.

The red, reddish brown or purple silty clay soils range in moisture content from 2.5% to 25% and generally average 8% to 12% in most of the borings.

Dry density of the clay soils range from 116 PCF to 145 PCF and average 132 PCF.

Liquid Limits of the clays range from 35% to 55%. Plasticity indices vary from 24 to 38. The clays vary in percent passing the #200 Mesh Sieve from 87% to 99.8%.

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A total of 36 vertical permeabilities and 6 horizontal permeabilities were run on the reddish brown silty clays, sandstones and siltstones. Vertical permeabilities range from <1.00x 10^{-9} cm/sec to 1.76 x 10^{-8} cm/sec for the clays. Horizontal permeabilities range from 1.63 x 10^{-9} cm/sec to 1.10 x 10^{-8} cm/sec. The siltstones and sandstones found at depths of 56 feet to 90 feet range in vertical permeability from 2.58 x 10^{-8} cm/sec to 1.93 x 10^{-6} cm/sec. The horizontal permeability averages 6.53 x 10^{-7} cm/sec. The siltstone at a depth of 208 feet has a permeability of 2.06 x10^{-8}. The permeability tests were run according to ASTM D-5084-90 using a flexible wall permeameter under a constant head. De-aired tap water and a .005N Ca SO_4 solution was used for the permeant liquid. The permeabilities were calculated on both the inflow and outflow and then averaged for the final result. The plot of Q x L vs T x A x H for selected tests are shown graphically in the Steady State Permeability Plots in Appendix I. Shown in each graph is the plot for both inflow and outflow through the sample. The slope of straight line is the permeability in cm/sec. A summary of permeability test results including boring number, grid location, soil classification, depth are shown in Permeability Test Results, Appendix I.

Unconfined compression test on the clay soils range from 13.9 TSF to 49.7 TSF with an average of 30 TSF.

GROUNDWATER

Water level measurements were made on open bore holes at 24 hours and 48 hours after completion. All borings were found to be dry with the exception of B-7, B-4, B-10, B-20, B-30, B-20, B-41 and B-41S. Groundwater was found at a shallow depths only in borings B-41 and B-41S at 26 feet and 32.4 feet respectively. Groundwater or damp sandstone/siltstone was encountered during the drilling operation only in Borings B-7, B-21 and B-48 at depths ranging from 200 feet to 220 feet below the existing grade.

Piezometers (2 inch PVC pipe) were installed at four locations (B-4, B-7, B-10 and B-20) with screened intervals ranging in depths from 170 feet to 257 feet below the existing grade. Water level measurements ranged from 149.8 feet to 187.8 feet below the existing grade on 14 January 1993.

Additional piezometers were installed at boring B-30 and boring B-39 . These holes were dry at the time of this report. Monitor wells were installed at grid locations 4-G, 9-G, and 6-B to better define saturated zones and obtain hydrological data for various zones. Details on construction of these wells are depicted in the State of Texas Well Reports in Appendix III. Water level measurements for all piezometers and wells are found in the Water Level Measurements, Appendix III. The groundwater hydrology is discussed in more detail in the Terra Dynamics Report.

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FOUNDATION STABILITY

The landfill floor elevation will be established at 3,400 feet. Maximum depth of the waste material will be 76 feet. A 16.5 foot thick cap is planned for the crest section which slopes at 3% grade back to the containment dike. The clay cap will be covered with a filter fabric and 2 feet of top soil. An 8 foot thick liner system will be placed between the waste material and the impervious clay formation. A typical landfill Section is shown below.

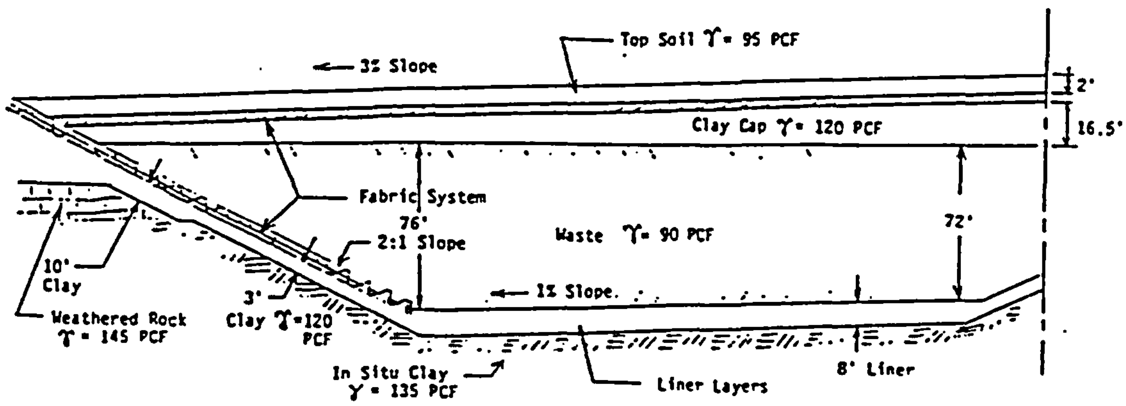

FIGURE VI

Typical Landfill Section

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Side walls of the slopes are lined with 10 feet of compacted clay where the sands, gravel and rock exists. The side wall is lined with 3 feet of compacted clay soil where cut into the existing red bed clay. The floor liner is 8 foot thick. Allowable bearing capacities for settlement and slope stability analysis are based on laboratory strength tests of the rock and in-situ clays, siltstones, sandstones and compacted clay liner. Allowable bearing capacities with each stratum are shown together with a corresponding Factor of Safety.

TABLE I

Stratum Description		Allowable Bearing Capacity, PSF	Factor Safety
1.	Compacted silty clay	10,100	2.3
2.	Weathered limestone with layers of rock & sands	35,000	3.5
3.	Natural bedded clay	14,600	3.0

Assuming a maximum waste height of 98.5 feet to include 16.5 feet of compacted clay at the crest and an 8 foot liner, the maximum pressure on the floor will be approximately 9,190 PSF. Considering these conditions, it is apparent the supporting soils have adequate strength to support the landfill with an acceptable margin of safety.

A. <u>Slope Stability</u> - The slope stability of the landfill containment section was analyzed for the periods during construction and after completion. An analysis was made considering a containment side slope of 2:1;

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1.5:1 and a slope of 1:1. Computations for stability were based on the following criteria developed from laboratory tests using conservative results.

SLOPE CRITERIA

DEPTHS (FT.)	σ'_3	σ'_1	$\frac{\sigma'_1 + \sigma^1_3}{2}$	$\frac{\sigma'_1 - \sigma'_3}{2}$
29 - 30	34.5	132.0	83.3	48.8
	51.0	208.0	129.5	78.5
23 - 25	34.5	154.0	94.3	59.8
	51.0	200.0	125.5	74.5

WHERE:
σ' = Normal Stress (PSI)
σ_3 = Confining Stress (PSI)

Design parameters:

1. Friction Angle (ϕ) = 36°

2. Unit Weight γ = 135 PCF

3. Effective Cohesive Shear Strength C′ = 260 PSF

The slope stability analysis was made using the computer program (PC STABL 5M) adopted by the Federal Public Road Administration. This program was developed by the University of Purdue under a federal grant program and is widely used throughout the U.S.A.

The computer analysis calculates the ten most critical failure circles based on the selected slope, friction angle ϕ, cohesion and whether or not a compacted clay liner is considered. The analysis computes the factor of safety for each

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failure circle. A graphical analysis depicting 10 failure circles for each of the failure planes at various slopes are shown in Appendix IV. The most critical condition is highlighted by arrows. Slope conditions were considered without the clay liner and omitting the effects of the cohesive strength of the clays. Listed below in Table II are the results of the analysis.

TABLE II

SUMMARY OF SLOPE STABILITY ANALYSIS

COMPUTER NO. RUN	SLOPE (H:V	ϕ	C' (PSF)	WITH LINER W/O LINER	MINIMUM FACTOR OF SAFETY
1	1:1	36°	260	With Liner	1.54
2	1.5:1	36°	260	W/O Liner	1.52
3	1.5:1	36°	260	With Liner	1.73
4	2:1	36°	No Cohesion	W/O Liner	1.47
5	2:1	36°	No Cohesion	With Liner	1.90
6	2:1	36°	260	W/O Liner	2.36

C' = Effective Cohesive Shear Strength

All of the computer analysis were run with an internal friction angle (ϕ) of 36°. This is considered to be a conservative figure based on laboratory tests of the insitu clays. The analysis clearly shows that a 2:1 slope with or without the compacted clay liner will provide a safe stable condition with a safety factor of 2.36. Computer run number 4 and 5 indicate even under saturated conditions the 2:1 slope would be stable.

B. Settlement Analysis - The groundwater table at the most shallow depth is 150 feet below existing ground surface (as of 2/15/93) and is not a consideration for calculation of settlement. Therefore only elastic settlement is considered and consolidation is not a factor. Since the waste repository is considered as a flexible foundation and therefore the elastic settlement is given by:

$$S_e = C_d\, qB\, (1 - \mu^2{}_s/E_s)$$

Where S_e = elastic settlement
C_d = a parameter accounting for the shape of the load area
q = distributed load
B = width of the foundation
μ_s = Poisson's ratio of the soil
E_s = Young's modulus of the soil

Based on the unit weights given in Figure VI, page 12, the maximum elastic settlement (Se) at the center of the waste repository when the complete landfill is loaded is calculated to be 2.45 inches (see Appendix IV for our calculations).

BORE HOLE GROUTING

All bore hoes were grouted with a cement/bentonite slurry. The bore holes were grouted after all water level measurement were made and drilling was completed on the site. Because of the hard dry clays and the absence of groundwater bore holes generally remained open and there was little or no problem with

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caving or sloughing. Each hole was measured prior to grouting to verify the depth was within one foot of the original drilling depth. If not, the holes were redrilled with air rotary and the bore hole was grouted immediately by pumping grout through a 2 inch PVC tremmie pipe from bottom to surface.

The grout mixture consisted of a ratio of 94 pounds portland cement per 5 pounds bentonite per 12 gallons of water. The grout was mixed at a local concrete redi-mix company within 2 miles of the site. The grout was poured into the open bore hole from the chute of the redi-mix truck. Where caving or sloughing of holes was a problem than centrifugal pump and tremmie line was used to ensure that grout was forced from bottom to top of the hole.

The original bore hole depth, the depth prior to grouting, date grouted, truck number and amount of cement/bentonite used was recorded by the technician.

REMARKS

This report has been prepared in order to aid in the evaluation of this property and to assist the architect and engineer in the design of the project. It is intended for use with regard to specific projects discussed in general herein and any substantial changes in locations or grades should be brought to our attention so that we may determine how this may affect our conclusions. If during the proposed construction, the soil strata are found to differ from that reported here, we should be

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notified immediately. This report contains soil boring logs which are for the purpose of arriving at foundation criteria and are not to be used by the excavation contractor in arriving at rock hardness or rock depth. The procedures, tests and recommendations of this investigation and report have been conducted and furnished in accordance with generally accepted professional engineering practices in the field of foundations, engineering soil mechanics and engineering geology. No other warranty is either expressed or implied.

STATE OF TEXAS
JACK HASTON HOLT
35732
REGISTERED PROFESSIONAL ENGINEER

Jack H.
Ph.D., P

JHH/mco

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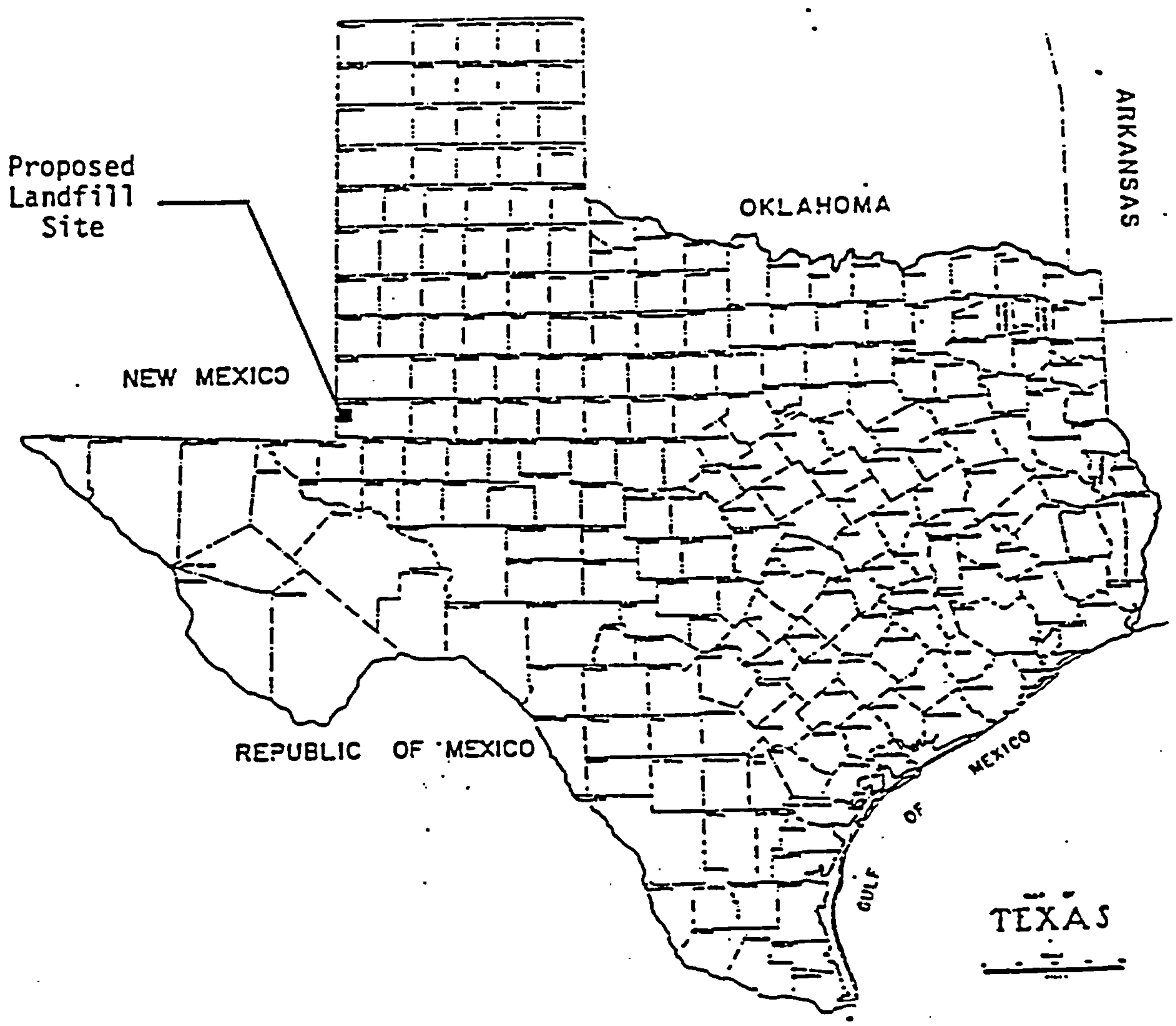
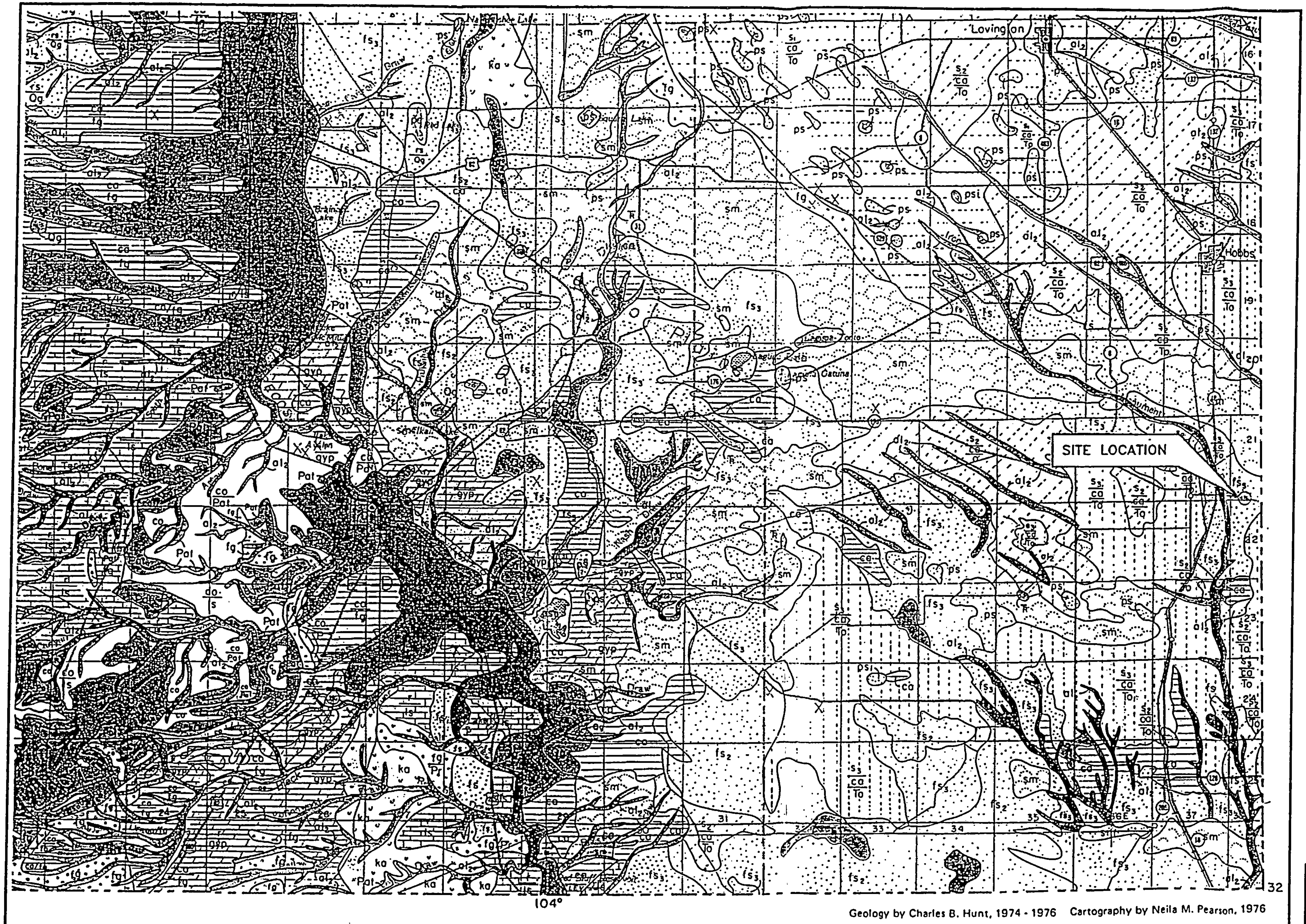


Proposed Andrews Landfill Site
on State of Texas Map
Andrews County, Texas

FIGURE I



fs — SAND FACIES — *Sandy alluvium with subordinate amounts of fine gravel, silt, and clay. Forms at least four kinds of ground: 1) On short, steep fans sloping from the mountains of granitic or gneissic rock (e.g., parts of the Florida Mountains), this facies may form a smooth sandy layer a few feet thick covering gravel below; slopes 5 to 20 percent; washes 1 to 10 ft deep may expose underlying gravel. 2) On other short fans, sand facies may form arcuate belt at toe of fan with slopes averaging 10 percent, commonly reworked into coppice dunes 3 to 7 ft high (sm). 3) Other belts of smooth sandy ground commonly slope 5 percent or less and consist of sand mounds approximately 1 ft high over caliche (fs_2). 4) Gypsiferous sand (fs_3), especially in the Jornada del Muerto, Tularosa Valley and east side of the Pecos Valley. Sand facies absent on the broad Las Palomas surface. Thin fan sand covering pediments is denoted by fs over subscript that identifies underlying formation. Boundary with residual sand, fan gravel, and fan silt is approximate*

sm — LOOSE SAND IN MOUNDS — *Coppice dunes, commonly 3 to 7 ft high and 25 to 50 ft in diameter; generally elongated north of east but a local exception lies east of Columbus where elongation is south of east. Age is Holocene. Boundaries fairly accurate*

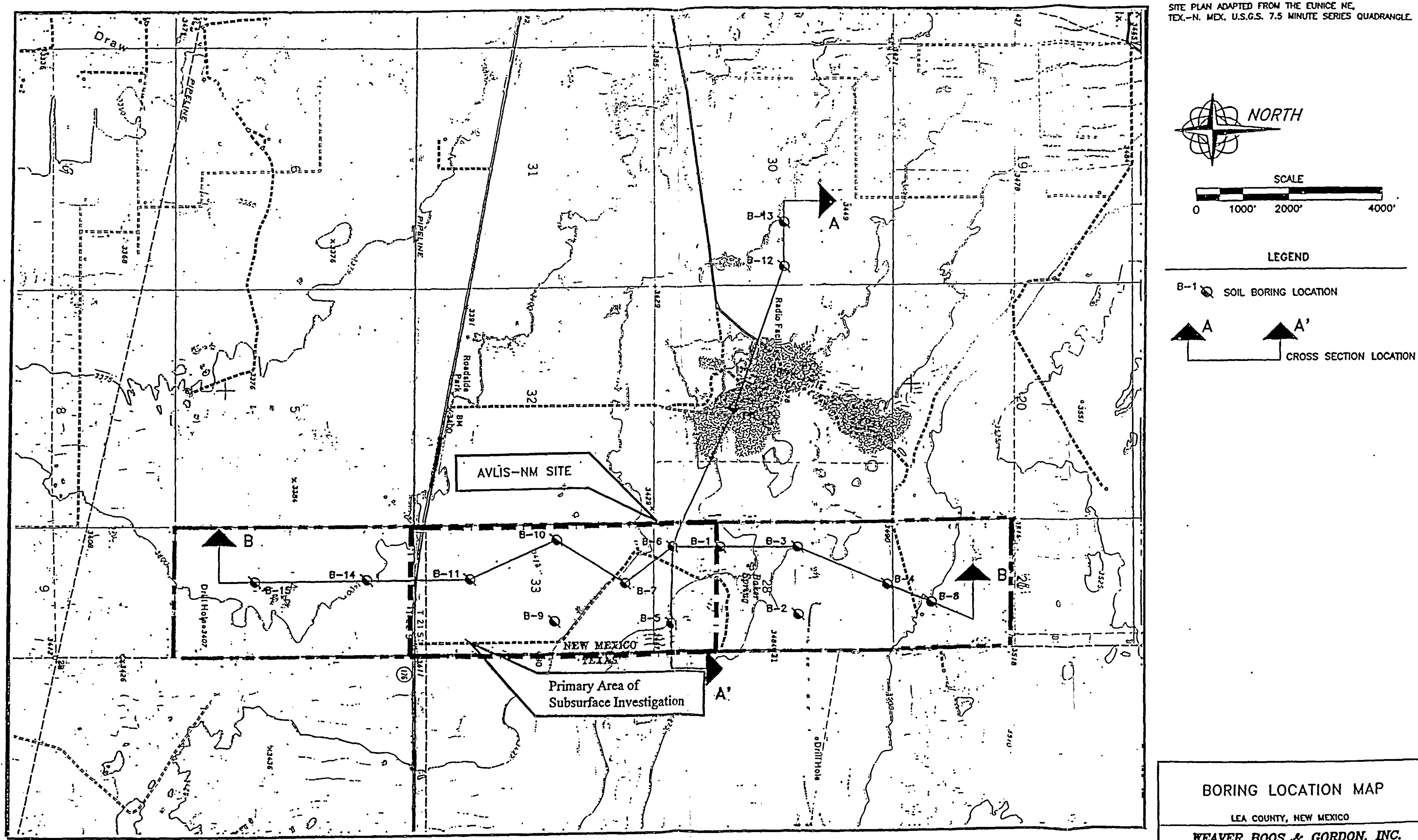
s_3/ca/To — THICK SAND ON CALICHE ON OGALLALA FORMATION — *Sand 3 to 5 ft thick. Local mounds. Brownish-red, fine sandy loam over reddish-brown, sandy clay loam; noncalcareous to depths of 3 ft; calcareous subsoil contains filaments of lime carbonate. Where farmed, ground is subject to wind erosion. Boundaries approximate*

SOURCE: NEW MEXICO BUREAU OF MINES & MINERAL RESOURCES, 1977.

SURFICIAL GEOLOGY OF LEA COUNTY, NEW MEXICO

WEAVER BOOS & GORDON, INC.

CHICAGO, IL (312) 922-1030	GRIFFITH, IN (219) 923-9609	ALBUQUERQUE, NM (505) 867-6990
PREPARED BY: SJS	DATE: 11/4/98	FILE: 0090-02-01
REVIEWED BY: TB	CAD: AVLIS4.DWG	FIGURE 5



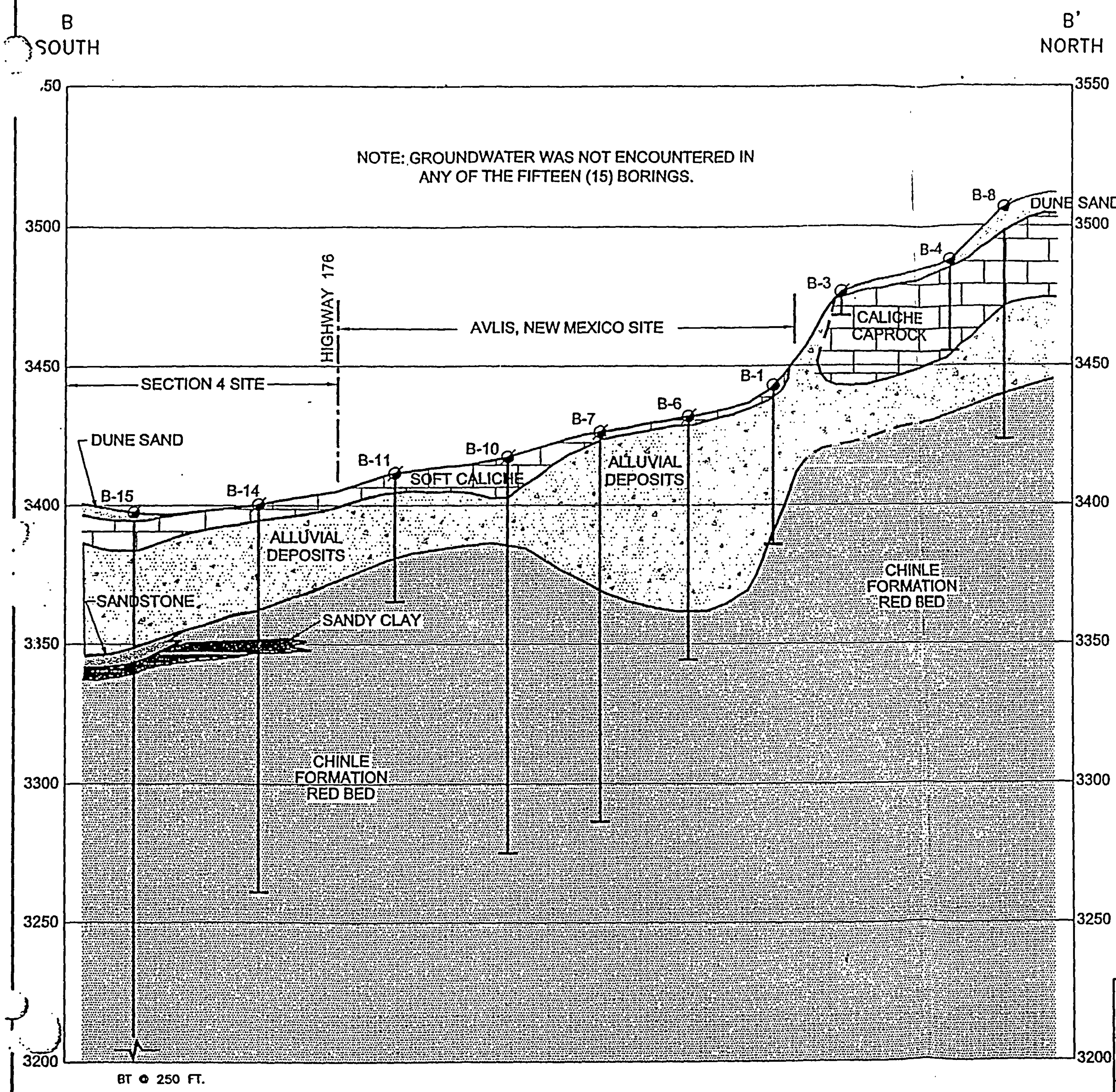
BORING LOCATION MAP

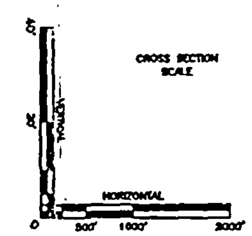
LEA COUNTY, NEW MEXICO

WEAVER BOOS & GORDON, INC.

CHICAGO, IL (312) 922-1030 | GRIFFITH, IN (219) 923-9609 | ALBUQUERQUE, NM (505) 867-6990

PREPARED BY: SJS	DATE: 11/4/98	FILE: 0090-02-01
REVIEWED BY: TB	CAD: AVLIS4.DWG	FIGURE 6





NOTES:

THE DEPTH AND THICKNESS OF THE SUBSURFACE INFORMATION INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE SOIL BORINGS TO PROVIDE A GENERAL OVERVIEW OF THE SUBSURFACE CONDITIONS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION AND ON THE DATE OF THE SOIL BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE SOIL BORINGS MAY VARY FROM THOSE INDICATED. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS. FOR MORE DETAILED INFORMATION REFER TO THE BORING LOGS AND LABORATORY TEST RESULTS.

☐ DRAFT
☐ PERMIT APPLICATION
☐ APPROVED FOR CONSTRUCTION
☐ CLIENT APPROVAL BY: ____________

DATE: 2/26/97
FILE: [illegible]
CAD: [illegible].DWG

DRAWN BY: JRS
DESIGN BY: [illegible]
REVIEWED BY: [illegible]

REVISIONS

NO.	DATE	DESCRIPTION

ISSUE OF DOCUMENTS

[illegible]

CROSS SECTION B–B'

PROPOSED AVLIS SITE
LEA COUNTY, NEW MEXICO

WEAVER BOOS CONSULTANTS, INC.

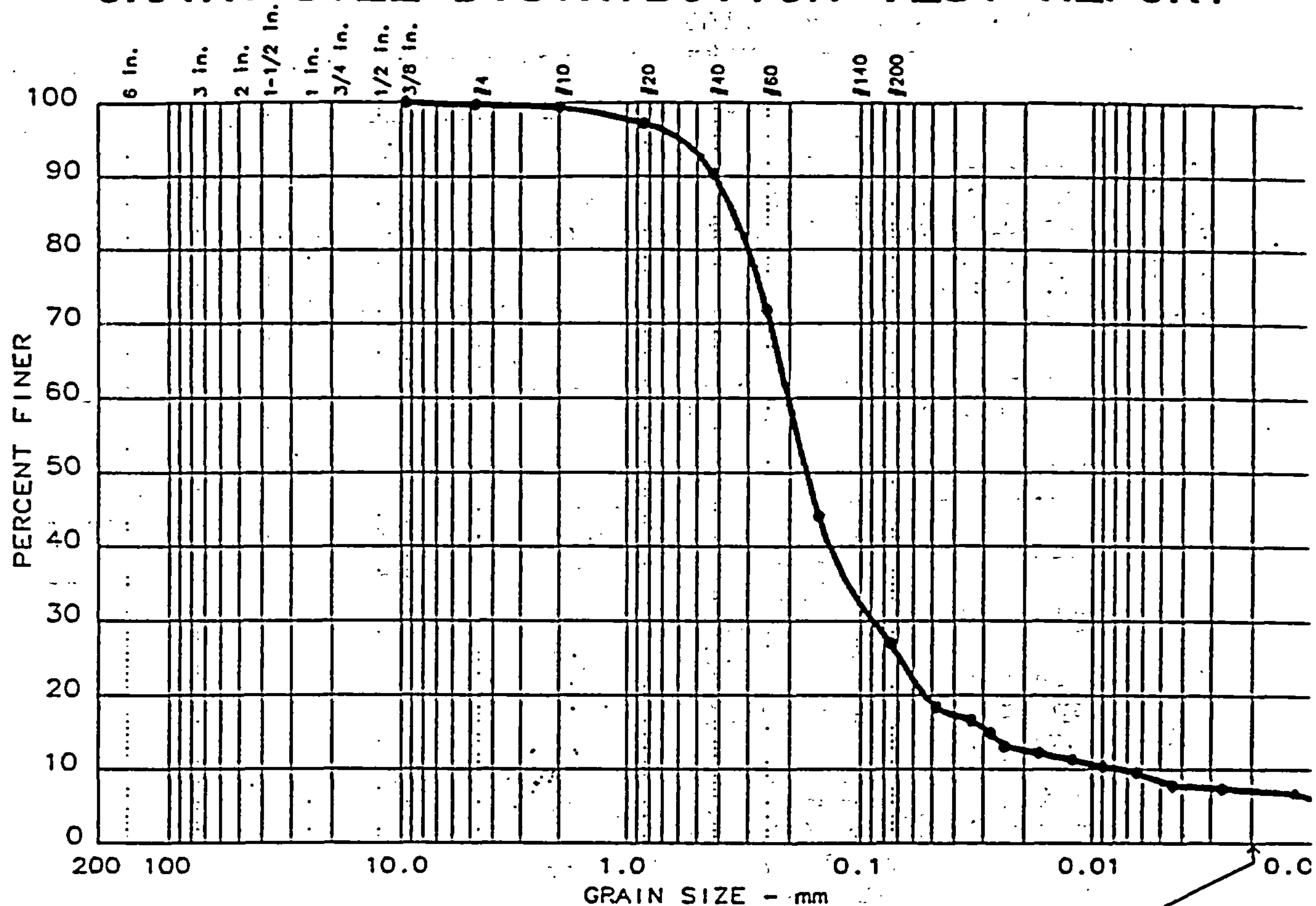
ALBUQUERQUE, NM (505) [illegible] · CHICAGO, IL (312) [illegible] · [illegible] (219) [illegible]

FIGURE 7

Attachment IV.5.B

Soil Laboratory Analysis

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	19	0.0	0.3	72.7	19.9	7.1

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.343	0.202	0.169	0.0878	0.0281	0.0071	5.35	28.3

MATERIAL DESCRIPTION	USCS	AASHTO
● RED F/C SAND, LITTLE SILT, TR CLAY	SM	A-2-4

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-7-98

Remarks:
BORING: B-101
DEPTH: 20.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 1-7-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED F/C SAND, LITTLE SILT, TR CLAY
USCS Class: SM Liquid limit: NA
AASHTO Class: A-2-4 Plasticity index: NA

Notes

Remarks: BORING: B-101 DEPTH: 20.0'

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 436.70
Tare = 0.00
Dry sample weight = 436.70
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	1.20	99.7
# 10	2.90	99.3
# 20	1.10	97.2
# 40	4.50	90.4
# 60	13.80	71.9
# 100	27.80	44.1
# 200	36.40	27.0

Hydrometer Analysis Data

Separation sieve is number 40
Percent -# 40 based on complete sample= 90.4
Weight of hydrometer sample: 50
Calculated biased weight= 55.31
Automatic temperature correction
Composite correction at 20 deg C =-4.5

Meniscus correction only= 1

Specific gravity correction factor= 0.978
Hydrometer type: 152H   Effective depth L= 16.294964 - 0.164 x Rm

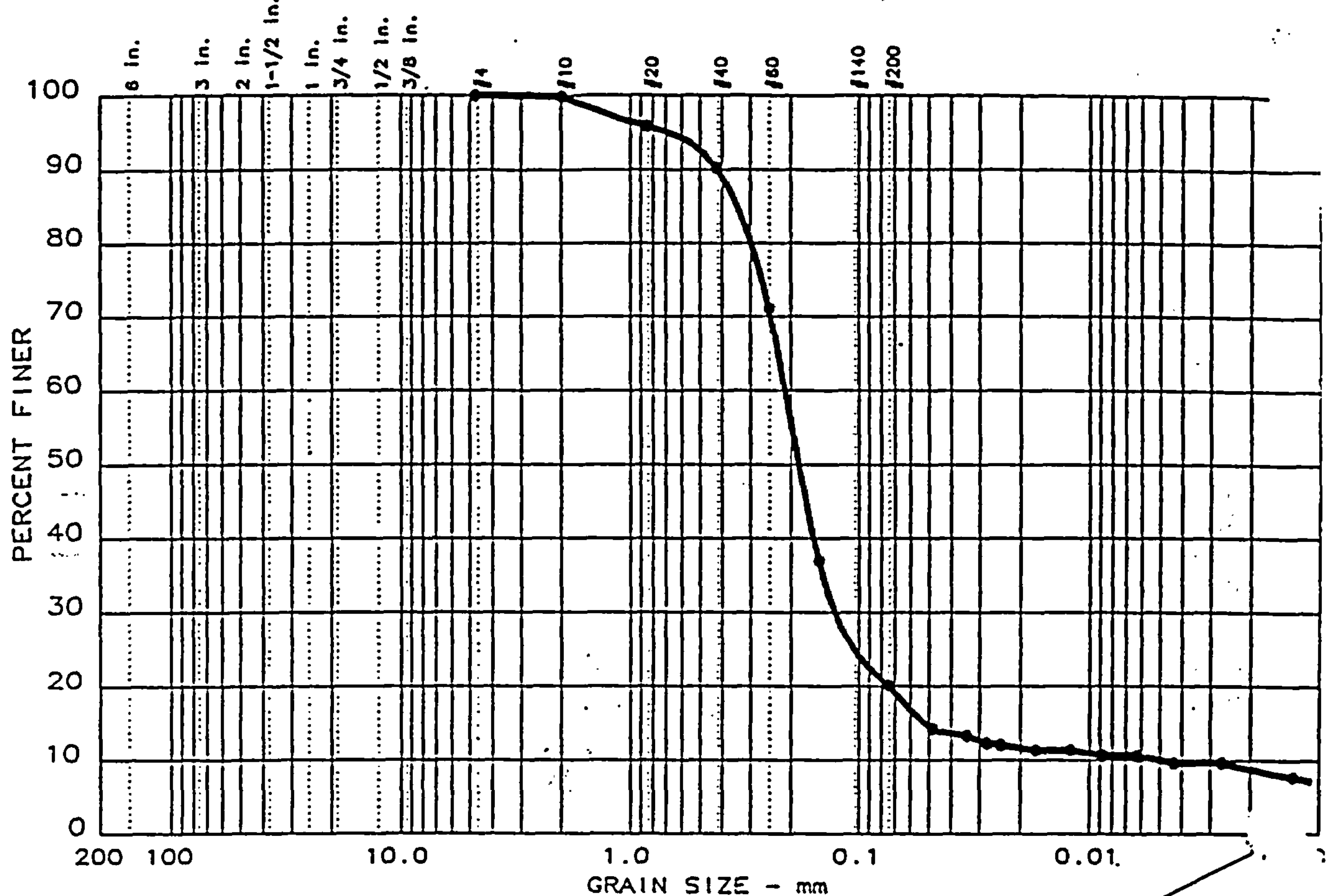
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	22.0	14.5	10.4	0.0129	15.5	13.8	0.0479	18.4
2.0	22.0	13.5	9.4	0.0129	14.5	13.9	0.0341	16.6
3.0	22.0	12.5	8.4	0.0129	13.5	14.1	0.0280	14.9
4.0	22.0	11.5	7.4	0.0129	12.5	14.2	0.0244	13.1
8.0	22.0	11.0	6.9	0.0129	12.0	14.3	0.0173	12.2
16.0	22.0	10.5	6.4	0.0129	11.5	14.4	0.0123	11.3
30.0	22.0	10.0	5.9	0.0129	11.0	14.5	0.0090	10.5
60.0	22.0	9.5	5.4	0.0129	10.5	14.6	0.0064	9.6
125.0	22.0	8.5	4.4	0.0129	9.5	14.7	0.0044	7.8
330.0	23.0	8.0	4.2	0.0128	9.0	14.8	0.0027	7.4
1410.0	23.5	7.5	3.8	0.0127	8.5	14.9	0.0013	6.7
2850.0	22.5	7.0	3.0	0.0128	8.0	15.0	0.0009	5.4

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0   % GRAVEL = 0.3   % SAND = 72.7
% SILT = 19.9   % CLAY = 7.1   (% CLAY COLLOIDS = 5.7)

D85= 0.34 D60= 0.202 D50= 0.169
D30= 0.0878 D15= 0.02809 D10= 0.00714
Cc = 5.3518 Cu = 28.2813

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	9	0.0	0.0	79.8	11.4	8.8

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.342	0.212	0.184	0.127	0.0519	0.0049	15.65	43.2

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SAND, LITTLE SILT, TR CLAY	SC	A-2-4

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-22-97

Remarks:
BORING: 102
DEPTH: 20.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-22-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SAND, LITTLE SILT, TR CLAY
USCS Class: SC Liquid limit: NA
AASHTO Class: A-2-4 Plasticity index: NA

Notes

Remarks: BORING: 102 DEPTH: 20.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	123.00
Tare =	0.00
Dry sample weight =	123.00

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
'e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.20	99.8
# 20	2.00	95.8
# 40	4.80	90.3
# 60	14.40	71.1
# 100	31.50	36.9
# 200	39.90	20.2

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 99.8
Weight of hydrometer sample: 50
Calculated biased weight= 50.08
Automatic temperature correction
Composite correction at 20 deg C =-3.5

Meniscus correction only= 1
Specific gravity of solids= 2.75

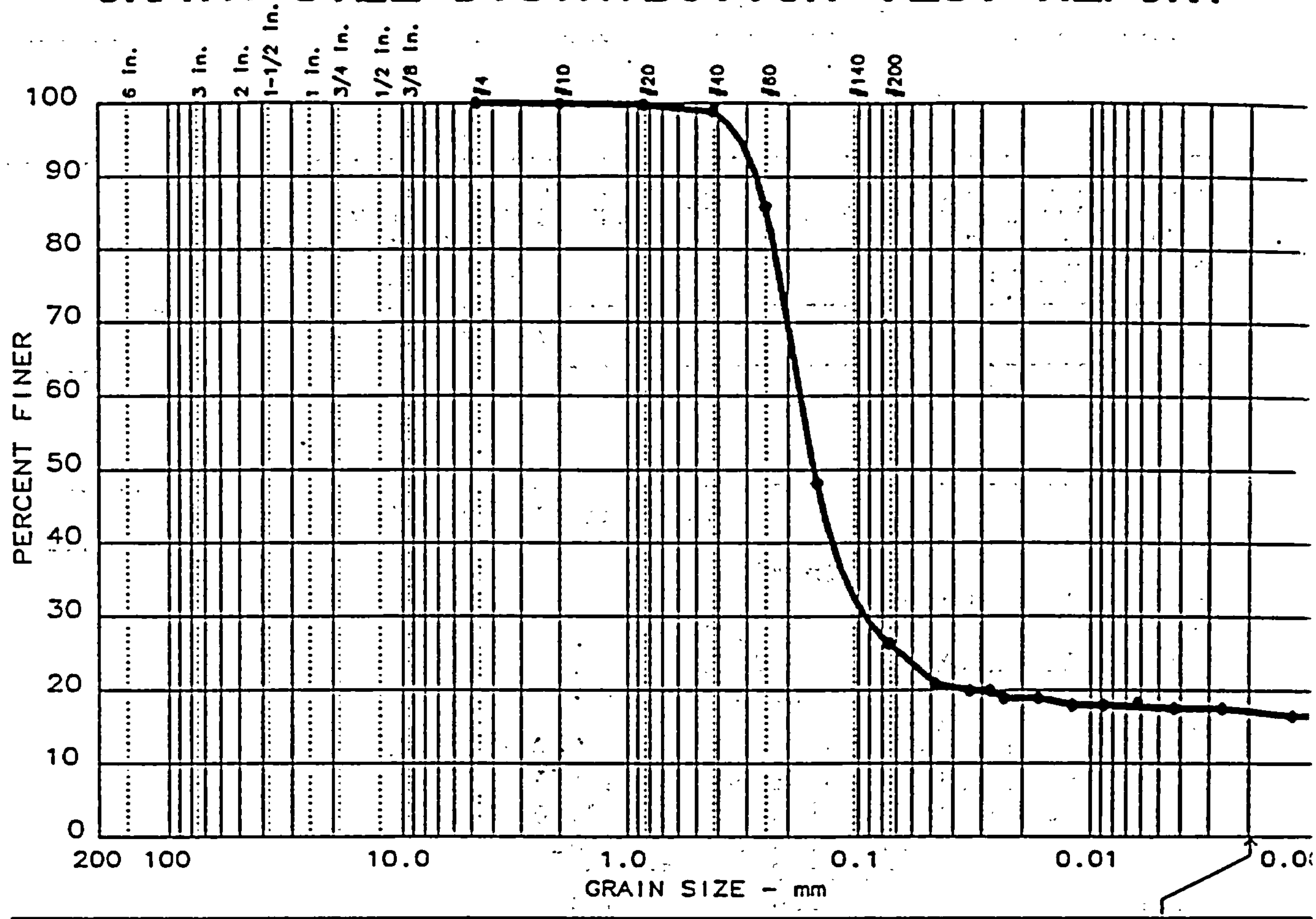
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.5	10.0	7.3	0.0127	11.0	14.5	0.0483	14.3
2.0	23.5	9.5	6.8	0.0127	10.5	14.6	0.0343	13.3
3.0	23.5	9.0	6.3	0.0127	10.0	14.7	0.0281	12.3
4.0	23.0	9.0	6.2	0.0128	10.0	14.7	0.0244	12.0
8.0	23.5	8.5	5.8	0.0127	9.5	14.7	0.0172	11.3
16.0	23.5	8.5	5.8	0.0127	9.5	14.7	0.0122	11.3
30.0	24.0	8.0	5.5	0.0126	9.0	14.8	0.0089	10.6
60.0	24.0	8.0	5.5	0.0126	9.0	14.8	0.0063	10.6
125.0	24.0	7.5	5.0	0.0126	8.5	14.9	0.0044	9.7
330.0	24.0	7.5	5.0	0.0126	8.5	14.9	0.0027	9.7
1410.0	24.0	6.5	4.0	0.0126	7.5	15.1	0.0013	7.7
2850.0	24.0	6.0	3.5	0.0126	7.0	15.1	0.0009	6.7

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 79.8
% SILT = 11.4 % CLAY = 8.8 (% CLAY COLLOIDS = 7.0)

D85= 0.34 D60= 0.212 D50= 0.184
D30= 0.1274 D15= 0.05188 D10= 0.00490
Cc = 15.6495 Cu = 43.2016

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	10	0.0	0.0	73.6	9.2	17.2

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.245	0.176	0.154	0.0929				

MATERIAL DESCRIPTION	USCS	AASHTO
● REDISH BRN SAND, LITTLE CLAY, TR SILT	SC	A-2-4

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-18-97

Remarks:
BORING: 103
DEPTH: 5.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-18-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: REDISH BRN SAND, LITTLE CLAY, TR SILT
USCS Class: SC Liquid limit: NA
AASHTO Class: A-2-4 Plasticity index: NA

Notes

Remarks: BORING: 103 DEPTH: 5.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	100.50
Tare =	0.00
Dry sample weight =	100.50

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
-e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.10	99.9
# 20	0.10	99.7
# 40	0.50	98.9
# 60	7.00	85.9
# 100	25.90	48.2
# 200	36.80	26.4

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 99.9
Weight of hydrometer sample: 50
Calculated biased weight= 50.05
Automatic temperature correction
Composite correction at 20 deg C =-3.5

Meniscus correction only= 1
Specific gravity of solids= 2.73

Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

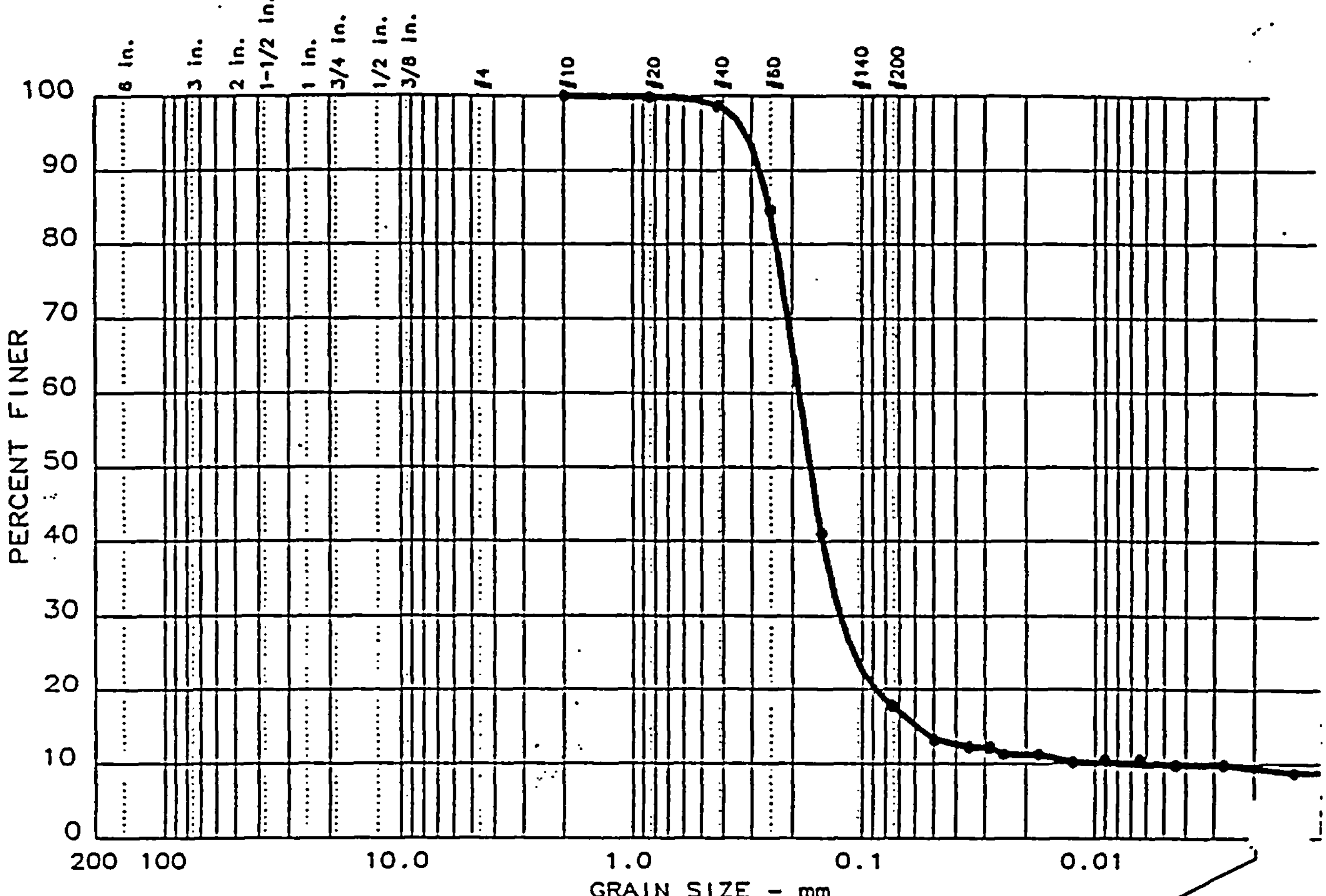
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	13.5	10.7	0.0128	14.5	13.9	0.0479	20.9
2.0	23.0	13.0	10.2	0.0128	14.0	14.0	0.0340	20.0
3.0	23.0	13.0	10.2	0.0128	14.0	14.0	0.0277	20.0
4.0	23.0	12.5	9.7	0.0128	13.5	14.1	0.0241	19.0
8.0	23.0	12.5	9.7	0.0128	13.5	14.1	0.0170	19.0
16.0	23.0	12.0	9.2	0.0128	13.0	14.2	0.0121	18.0
30.0	23.0	12.0	9.2	0.0128	13.0	14.2	0.0088	18.0
60.0	23.5	12.0	9.3	0.0128	13.0	14.2	0.0062	18.3
125.0	24.0	11.5	9.0	0.0127	12.5	14.2	0.0043	17.6
330.0	24.0	11.5	9.0	0.0127	12.5	14.2	0.0026	17.6
1410.0	24.0	11.0	8.5	0.0127	12.0	14.3	0.0013	16.6
2850.0	24.0	11.0	8.5	0.0127	12.0	14.3	0.0009	16.6

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 73.6
% SILT = 9.2 % CLAY = 17.2 (% CLAY COLLOIDS = 16.6)

D85= 0.25 D60= 0.176 D50= 0.154
D30= 0.0929

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	11	0.0	0.0	82.2	8.4	9.4

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.251	0.187	0.167	0.124	0.0580	0.0062	13.26	30.0

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SAND, TR SILT & CLAY	SC	A-2-4

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-18-97

Remarks:
BORING: 104
DEPTH: 4.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA

Test No.: 11

Date: 12-18-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SAND, TR SILT & CLAY
USCS Class: SC
Liquid limit: NA
AASHTO Class: A-2-4
Plasticity index: NA

Notes

Remarks: BORING: 104 DEPTH: 4.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	160.90
Tare =	0.00
Dry sample weight =	160.90

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.10	99.8
# 40	0.70	98.6
# 60	7.70	84.6
# 100	29.50	41.0
# 200	41.10	17.8

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-3.5

Meniscus correction only= 1
Specific gravity of solids= 2.68
Specific gravity correction factor= 0.993

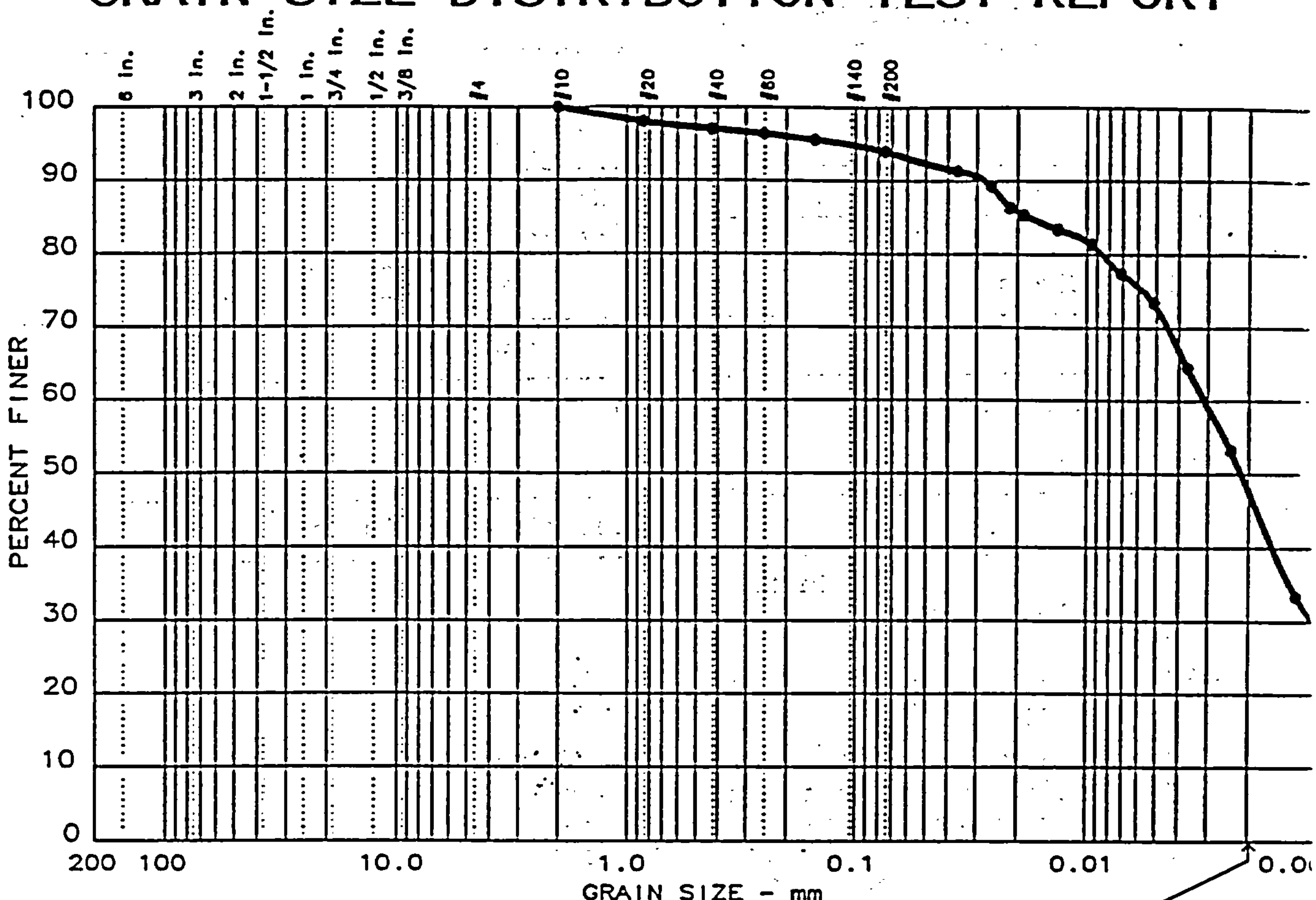
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	9.5	6.7	0.0130	10.5	14.6	0.0498	13.2
2.0	23.0	9.0	6.2	0.0130	10.0	14.7	0.0353	12.2
3.0	23.0	9.0	6.2	0.0130	10.0	14.7	0.0288	12.2
4.0	23.0	8.5	5.7	0.0130	9.5	14.7	0.0250	11.3
8.0	23.0	8.5	5.7	0.0130	9.5	14.7	0.0177	11.3
16.0	23.0	8.0	5.2	0.0130	9.0	14.8	0.0125	10.3
30.0	23.5	8.0	5.3	0.0130	9.0	14.8	0.0091	10.5
60.0	23.5	8.0	5.3	0.0130	9.0	14.8	0.0064	10.5
125.0	24.0	7.5	5.0	0.0129	8.5	14.9	0.0044	9.8
330.0	24.0	7.5	5.0	0.0129	8.5	14.9	0.0027	9.8
1410.0	24.0	7.0	4.5	0.0129	8.0	15.0	0.0013	8.8
2850.0	24.0	7.0	4.5	0.0129	8.0	15.0	0.0009	8.8

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 82.2
% SILT = 8.4 % CLAY = 9.4 (% CLAY COLLOIDS = 8.8)

D85= 0.25 D60= 0.187 D50= 0.167
D30= 0.1240 D15= 0.05801 D10= 0.00622
Cc = 13.2587 Cu = 30.0262

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	1	0.0	0.0	6.0	46.3	47.7

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0022	0.0010				

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-10-97

Remarks:
BORING: 104
DEPTH: 60.0'

GRAIN SIZE DISTRIBUTION TEST REPORT

WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-10-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL — Liquid limit: NA
AASHTO Class: — Plasticity index: NA

Notes

Remarks: BORING: 104 DEPTH: 60.0'

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 447.00
Tare = 0.00
Dry sample weight = 447.00
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	1.00	98.0
# 40	1.50	97.0
# 60	1.80	96.4
# 100	2.20	95.6
# 200	3.00	94.0

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-4.5

Meniscus correction only= 1
Specific gravity of solids= 2.7
Specific gravity correction factor= 0.989

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	50.0	46.2	0.0130	51.0	7.9	0.0365	91.3
2.0	23.0	49.0	45.2	0.0130	50.0	8.1	0.0261	89.3
3.0	23.0	47.5	43.7	0.0130	48.5	8.3	0.0216	86.4
4.0	23.0	47.0	43.2	0.0130	48.0	8.4	0.0188	85.4
8.0	23.0	46.0	42.2	0.0130	47.0	8.6	0.0134	83.4
16.0	23.0	45.0	41.2	0.0130	46.0	8.8	0.0096	81.4
30.0	23.0	43.0	39.2	0.0130	44.0	9.1	0.0071	77.5
60.0	23.0	41.0	37.2	0.0130	42.0	9.4	0.0051	73.5
125.0	23.0	36.5	32.7	0.0130	37.5	10.1	0.0037	64.6
330.0	22.0	31.0	26.9	0.0131	32.0	11.0	0.0024	53.2
1410.0	22.0	21.0	16.9	0.0131	22.0	12.7	0.0012	33.4
2850.0	23.0	17.5	13.7	0.0130	18.5	13.3	0.0009	27.0

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 6.0
% SILT = 46.3 % CLAY = 47.7 (% CLAY COLLOIDS = 29.1)

D85= 0.02 D60= 0.003 D50= 0.002
D30= 0.0010

PERMEABILITY TEST REPORT

TEST DATA:

Specimen Height (cm): 6.32
Specimen Diameter (cm): 6.39
Dry Unit Weight (pcf): 114.9
Moisture Before Test (%): 10.5
Moisture After Test (%): 17.5

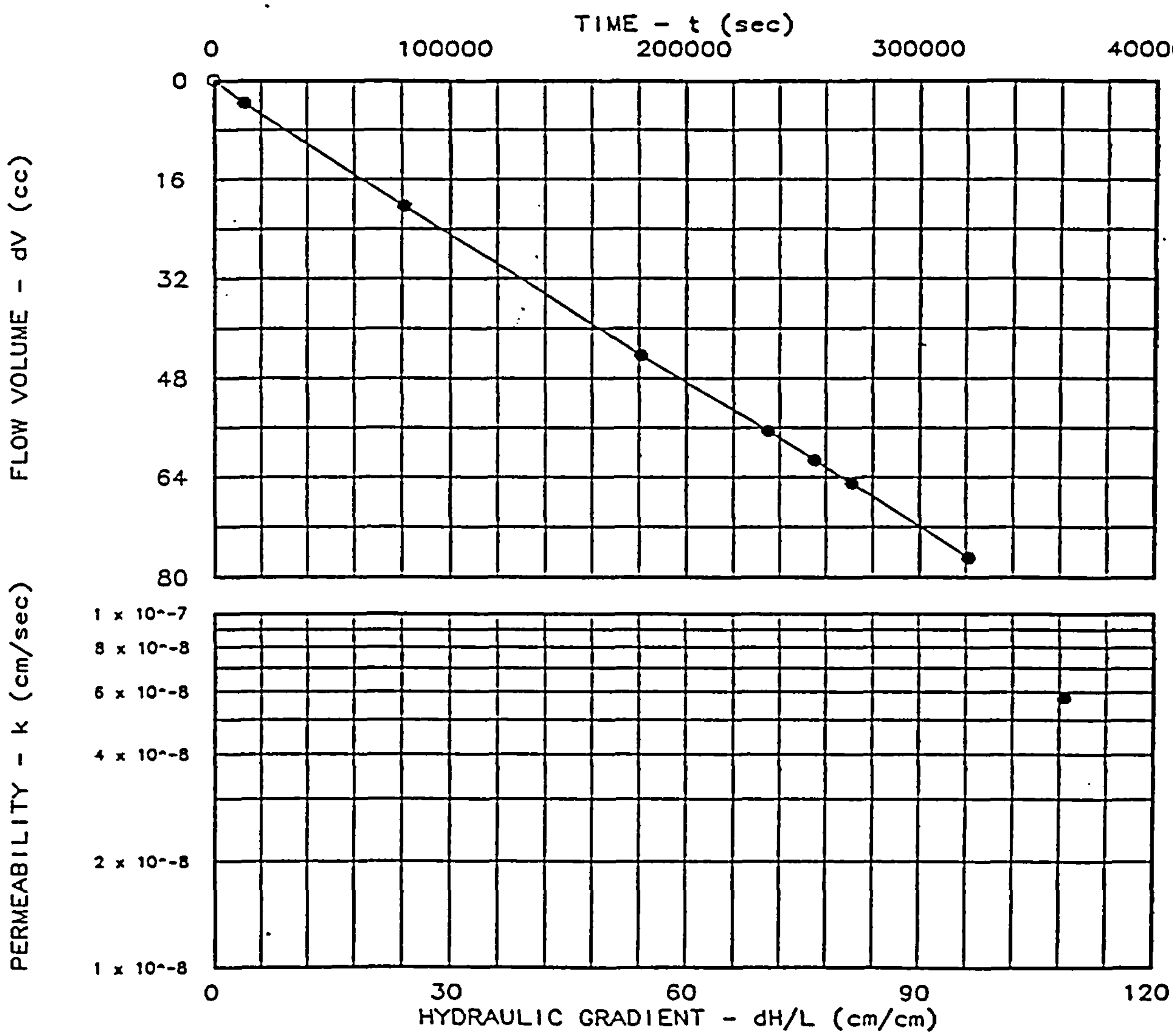
Run Number:	1 ●	2 ▲
Cell Pressure (psi):	30.0	
Test Pressure(psi):	27.0	
Back Pressure(psi):	17.2	
Diff. Head (psi):	9.8	
Flow Rate (cc/sec):	2.37 x 10^-4	
Perm. (cm/sec):	5.79 x 10^-8	

SAMPLE DATA:

Sample Identification: BORING: 104
DEPTH: 60.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-8-97

PERMEABILITY TEST REPORT

WEAVER BOOS CONSULTANTS, INC.

Project No.: 95042.10
File No.: 95042.10
Lab No.: 4
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name:	LEA COUNTY LANDFILL
e No.:	95042.10
oject Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 104 DEPTH: 60.0'
Lab No.:	4
Description:	RED SILTY CLAY, TR SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-8-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test:			After test:		
Diameter:	1	2		1	2	
Top:	in	in		in	in	
Middle:	2.515 in	in		2.506 in	in	
Bottom:	in	in		in	in	
Average:	2.52 in	6.39 cm		2.51 in	6.37 cm	
Length:	1	2	3	1	2	3
	2.488 in	in	in	2.498 in	in	in
Average:	2.49 in	6.32 cm		2.50 in	6.34 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.70	
Wet Wt. & Tare:	411.90	438.00
Dry Wt. & Tare:	372.70	372.70
Tare Wt.:	0.00	0.00
Moisture Content:	10.5 %	17.5 %
Dry Unit Weight:	114.9 pcf	115.2 pcf
Porosity:	0.3185	0.3163
Saturation:	60.8 %	102.2 %

Cell No.: 4 Panel No.: Positions:

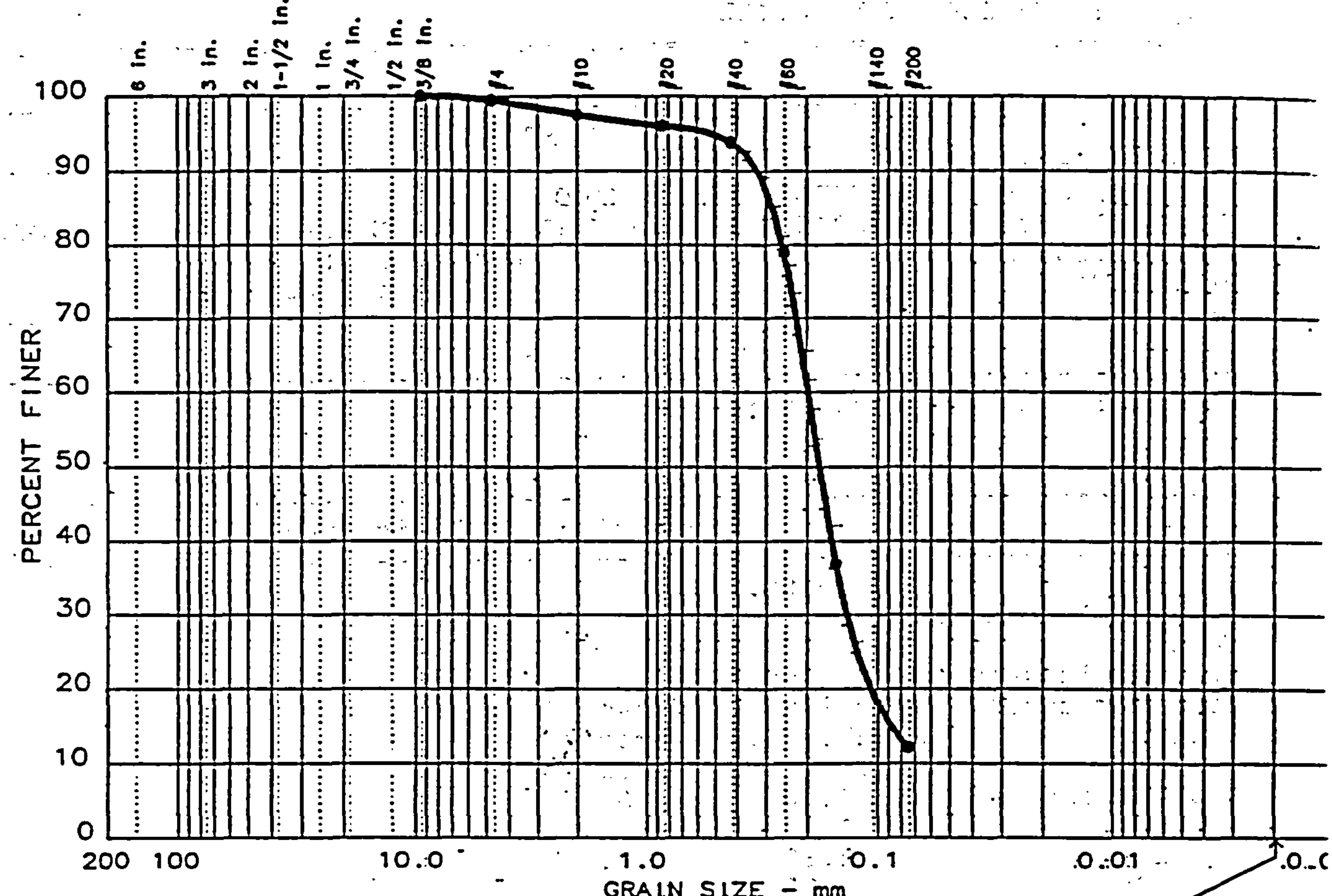
Run Number:	1	2
Cell Pressure:	30.0 psi	0.0 psi
Saturation Pressure:	30.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D X S R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S X	12/12/97	13:19:00	0	27.0	17.0	5.80	84.60	0.00
	12/12/97	16:55:00	12,960	27.0	17.0	9.50	81.00	3.65
	12/13/97	11:46:00	80,820	27.0	17.0	26.50	64.80	20.25
	12/14/97	15:33:00	180,840	27.0	17.0	50.90	41.20	44.25
	12/15/97	6:32:00	234,780	27.0	17.0	63.40	29.20	56.50
	12/15/97	12:12:00	255,180	27.0	17.0	68.10	24.40	61.25
	12/15/97	16:36:00	271,020	27.0	17.0	72.00	20.80	65.00
	12/16/97	6:29:00	321,000	27.0	17.0	84.00	9.00	76.90

t Pressure = 27.0 psi Differential Head = 9.8 psi, 686.2 cm H2O
Gradient = 1.086E 02 Flow rate = 2.370E-04 cc/sec R squared = 0.99990
Permeability, K27.0° = 6.810E-08 cm/sec, K20° = 5.791E-08 cm/sec

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	5	0.0	0.6	87.2	12.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.279	0.197	0.176	0.135	0.0869			

MATERIAL DESCRIPTION	USCS	AASHTO
● GRAYISH BRN F/C SAND, LITTLE SILT, TR FINE GRAVEL	SM	A-2-4

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-30-98

Remarks:
BORING: B-105
S-9

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA   Test No.: 5

Date: 1-30-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: GRAYISH BRN F/C SAND, LITTLE SILT, TR FINE GRAVEL
USCS Class: SM   Liquid limit: NA
AASHTO Class: A-2-4   Plasticity index: NA

Notes

Remarks: BORING: B-105 S-9

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 105.70
Tare = 0.00
Dry sample weight = 105.70
Tare for cumulative weight retained= 0

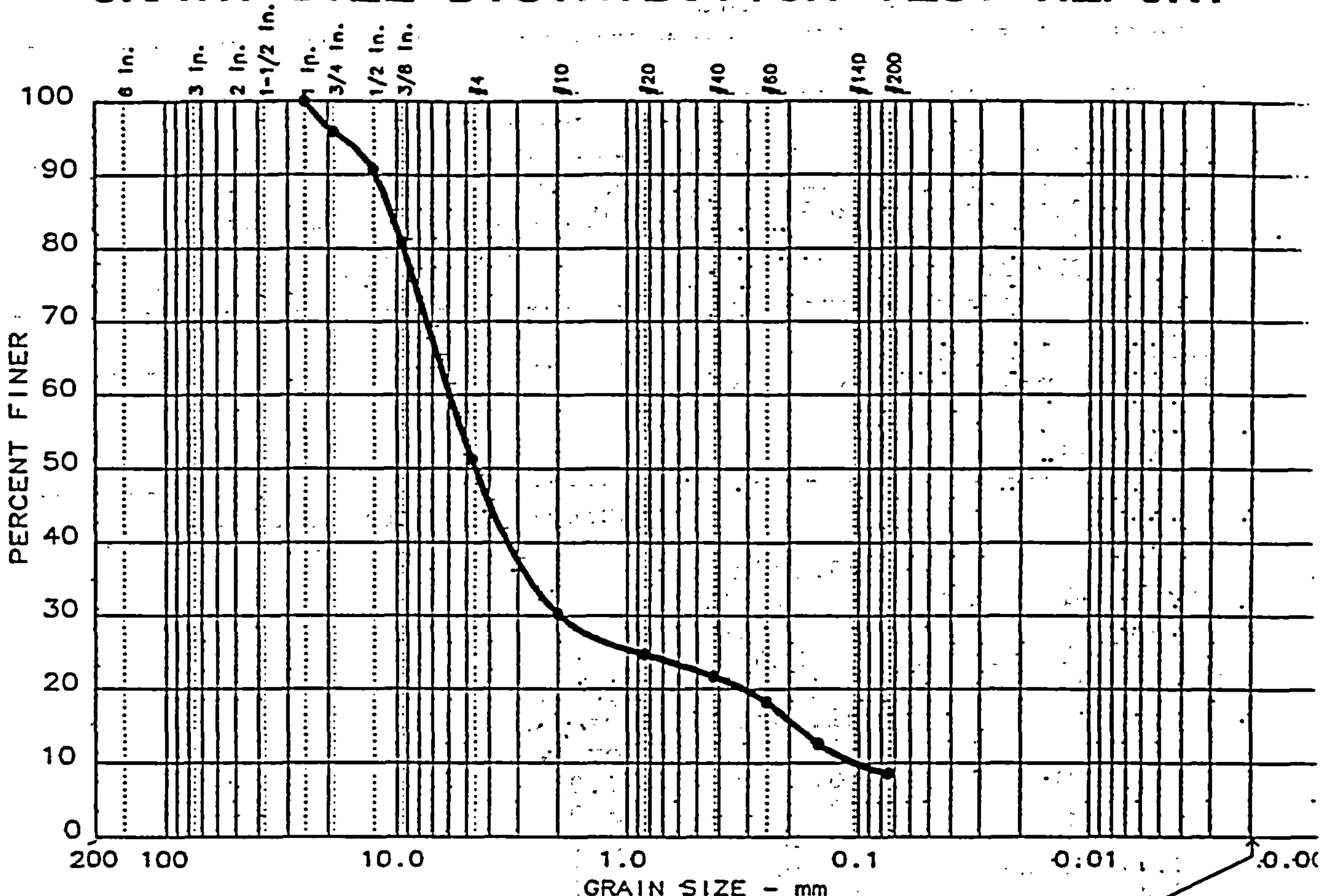
Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
4	0.60	99.4
# 10	2.60	97.5
# 20	4.20	96.0
# 40	6.50	93.9
# 60	22.20	79.0
# 100	66.70	36.9
# 200	92.80	12.2

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0   % GRAVEL = 0.6   % SAND = 87.2
% FINES = 12.2

D85= 0.28 D60= 0.197 D50= 0.176
D30= 0.1346 D15= 0.08690

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	6	0.0	48.8	42.6	8.6	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	10.6	5.90	4.58	1.95	0.186	0.102	6.31	57.5

MATERIAL DESCRIPTION	USCS	AASHTO
● ROSE & WHITE F/C GRAVEL & SAND, TR SILT	GP-GM	A-1-a

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-30-98

Remarks:
BORING: B-105
S-38

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 1-30-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: ROSE & WHITE F/C GRAVEL & SAND, TR SILT
USCS Class: GP-GM   Liquid limit: NA
AASHTO Class: A-1-a   Plasticity index: NA

Notes

Remarks: BORING: B-105 S-38

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	229.10
Tare =	0.00
Dry sample weight =	229.10

Tare for cumulative weight retained= 0

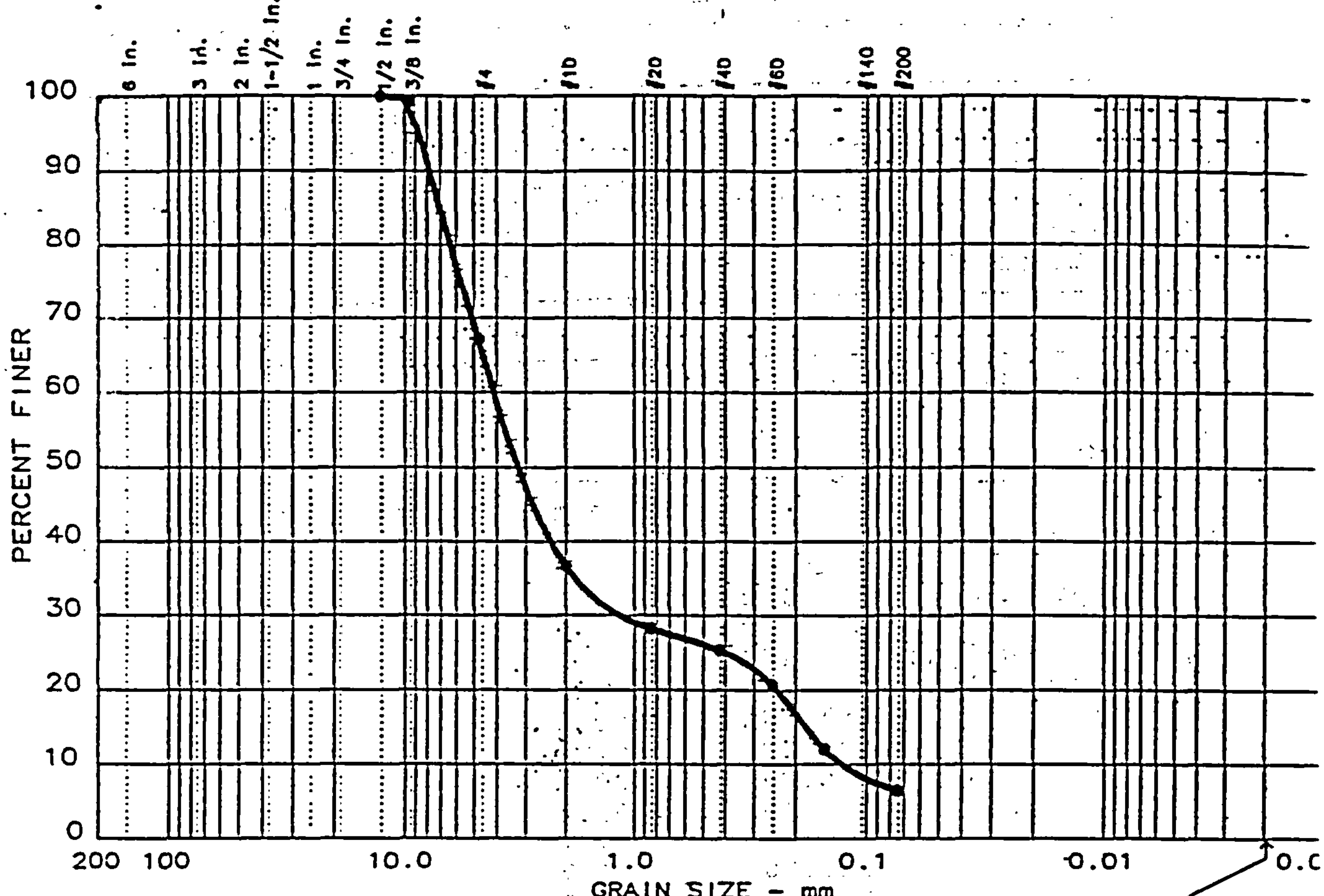
Sieve	Cumul. Wt. retained	Percent finer
1 inches	0.00	100.0
.75 inches	9.50	95.9
0.5 inches	21.20	90.7
0.375 inches	43.70	80.9
# 4	111.70	51.2
# 10	159.70	30.3
# 20	172.40	24.7
# 40	179.30	21.7
# 60	187.30	18.2
# 100	200.20	12.6
# 200	209.30	8.6

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0   % GRAVEL = 48.8   % SAND = 42.6
% FINES = 8.6

D85= 10.56 D60= 5.895 D50= 4.576
D30= 1.9521 D15= 0.18642 D10= 0.10245
Cc = 6.3096 Cu = 57.5440

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	4	0.0	32.9	60.6	6.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	7.00	4.12	3.23	1.16	0.178	0.126	2.60	32.7

MATERIAL DESCRIPTION	USCS	AASHTO
● ROSE & WHITE F/C SAND, SOME F/M GRAVEL, TR SILT	SW-SM	A-1-a

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-30-98

Remarks:
BORING: B-105
S-39

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 1-30-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: ROSE & WHITE F/C SAND, SOME F/M GRAVEL, TR SILT
USCS Class: SW-SM — Liquid limit: NA
AASHTO Class: A-1-a — Plasticity index: NA

Notes

Remarks: BORING: B-105 S-39

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	192.90
Tare =	0.00
Dry sample weight =	192.90

Tare for cumulative weight retained= 0

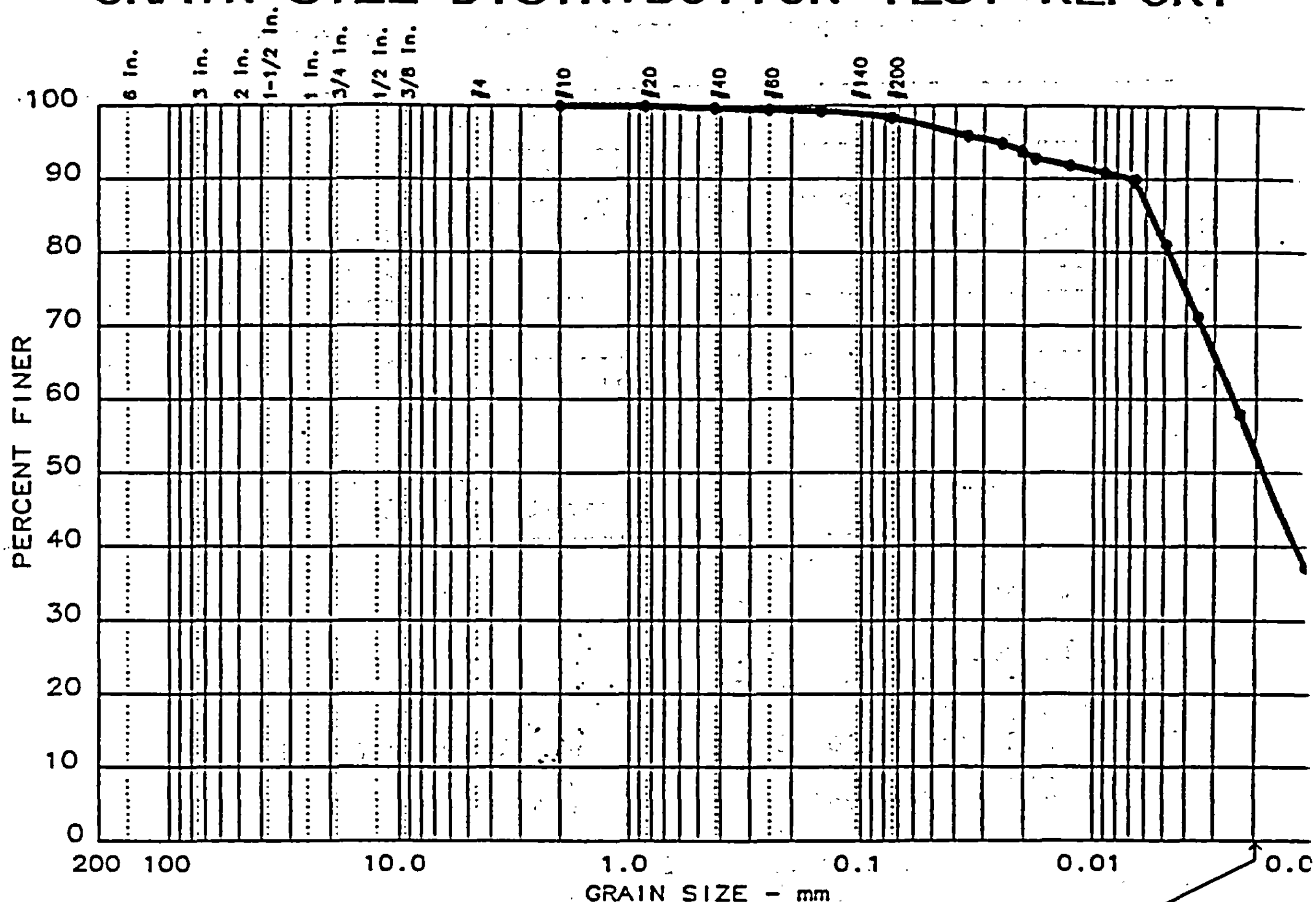
Sieve	Cumul. Wt. retained	Percent finer
0.5 inches	0.00	100.0
.375 inches	1.40	99.3
# 4	63.50	67.1
# 10	122.20	36.7
# 20	138.40	28.3
# 40	144.00	25.3
# 60	153.00	20.7
# 100	169.60	12.1
# 200	180.40	6.5

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 32.9 % SAND = 60.6
% FINES = 6.5

D85= 7.00 D60= 4.116 D50= 3.232
D30= 1.1601 D15= 0.17762 D10= 0.12575
Cc = 2.6002 Cu = 32.7341

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	2	0.0	0.0	1.6	45.8	52.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0018	0.0009				

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-10-97

Remarks:
BORING: 108
DEPTH: 60.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-10-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL   Liquid limit: NA
AASHTO Class: Plasticity index: NA

Notes

Remarks: BORING: 108 DEPTH: 60.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	293.70
Tare =	0.00
Dry sample weight =	293.70

Sample split on number 10 sieve
Split sample data:
  Sample and tare = 50 Tare = 0 Sample weight = 50
  Cumulative weight retained tare= 0
  e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.10	99.8
# 40	0.20	99.6
# 60	0.30	99.4
# 100	0.40	99.2
# 200	0.80	98.4

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
  Composite correction at 20 deg C =-4.5

Meniscus correction only= 1
Specific gravity of solids= 2.72
Specific gravity correction factor= 0.985

[illegible]

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	52.5	48.7	0.0129	53.5	7.5	0.0353	95.8
2.0	23.0	52.0	48.2	0.0129	53.0	7.6	0.0251	94.8
3.0	23.0	51.5	47.7	0.0129	52.5	7.7	0.0206	93.9
4.0	23.0	51.0	47.2	0.0129	52.0	7.8	0.0180	92.9
8.0	23.0	50.5	46.7	0.0129	51.5	7.8	0.0128	91.9
16.0	23.0	50.0	46.2	0.0129	51.0	7.9	0.0091	90.9
30.0	23.0	49.5	45.7	0.0129	50.5	8.0	0.0067	89.9
60.0	23.0	45.0	41.2	0.0129	46.0	8.8	0.0049	81.1
125.0	23.0	40.0	36.2	0.0129	41.0	9.6	0.0036	71.2
330.0	22.0	33.5	29.4	0.0130	34.5	10.6	0.0023	57.9
1410.0	22.0	23.0	18.9	0.0130	24.0	12.4	0.0012	37.2
2850.0	23.0	19.0	15.2	0.0129	20.0	13.0	0.0009	29.9

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0   % GRAVEL = 0.0   % SAND = 1.6
% SILT = 45.8   % CLAY = 52.6   (% CLAY COLLOIDS = 32.7)

D85= 0.01 D60= 0.002 D50= 0.002
D30= 0.0009

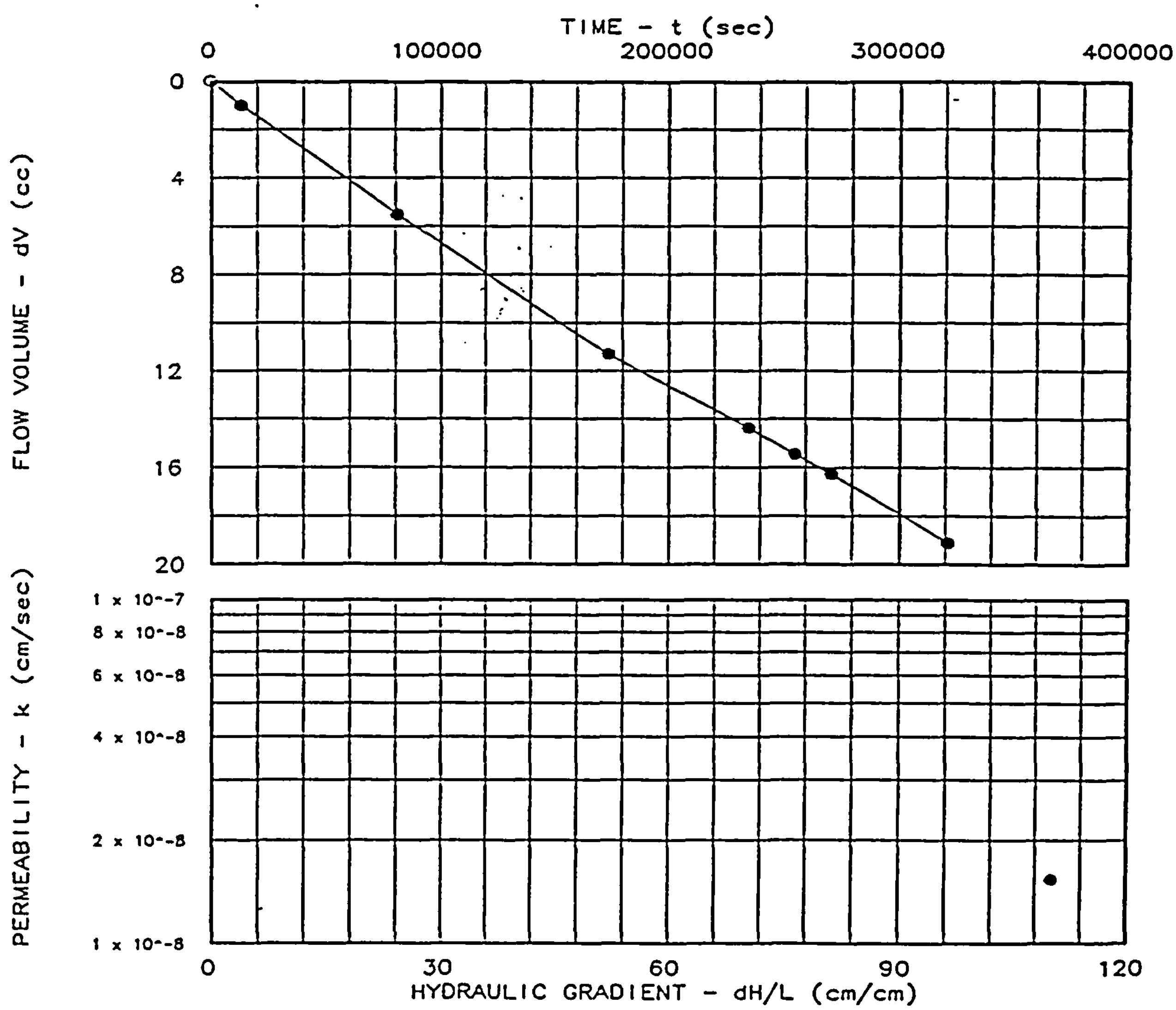
PERMEABILITY TEST REPORT

TEST DATA:
Specimen Height (cm): 6.97
Specimen Diameter (cm): 6.10
Dry Unit Weight (pcf): 137.7
Moisture Before Test (%): 4.7
Moisture After Test (%): 9.0
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 30.0
Test Pressure(psi): 27.0
Back Pressure(psi): 16.1
Diff. Head (psi): 10.9
Flow Rate (cc/sec): 5.82 x 10--5
Perm. (cm/sec): 1.54 x 10--8

SAMPLE DATA:
Sample Identification: BORING: 108
DEPTH: 60.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-8-97

PERMEABILITY TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Project No.: 95042.10
File No.: 95042.10
Lab No.: 2
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name: LEA COUNTY LANDFILL
e No.: 95042.10
.oject Location: HOBBS, NEW MEXICO
Project No.: 95042.10
Sample Identification: BORING: 108
DEPTH: 60.0'
Lab No.: 2
Description: RED SILTY CLAY,
TR SAND
Sample Type: CORE
Max. Dry Dens.:
Method (D1557/D698):
Opt. Water Content:
Date: 12-8-97
Remarks:

Permeameter Type: FLEXIBLE WALL
Tested by: JWM
Checked by: WSG
Test type: CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	Before test: 2	Before test: 3	After test: 1	After test: 2	After test: 3
.ameter:						
Top:	in	in		in	in	
Middle:	2.403 in	in		2.401 in	in	
Bottom:	in	in		in	in	
Average:	2.40 in	6.10 cm		2.40 in	6.10 cm	
Length:	2.745 in	in	in	2.786 in	in	i
Average:	2.75 in	6.97 cm		2.79 in	7.08 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.72	
Wet Wt. & Tare:	471.10	490.70
Dry Wt. & Tare:	450.10	450.10
Tare Wt.:	0.00	0.00
Moisture Content:	4.7 %	9.0 %
Dry Unit Weight:	137.7 pcf	135.9 pcf
Porosity:	0.1889	0.1995
Saturation:	54.5 %	98.5 %

Cell No.: 2 Panel No.: Positions:

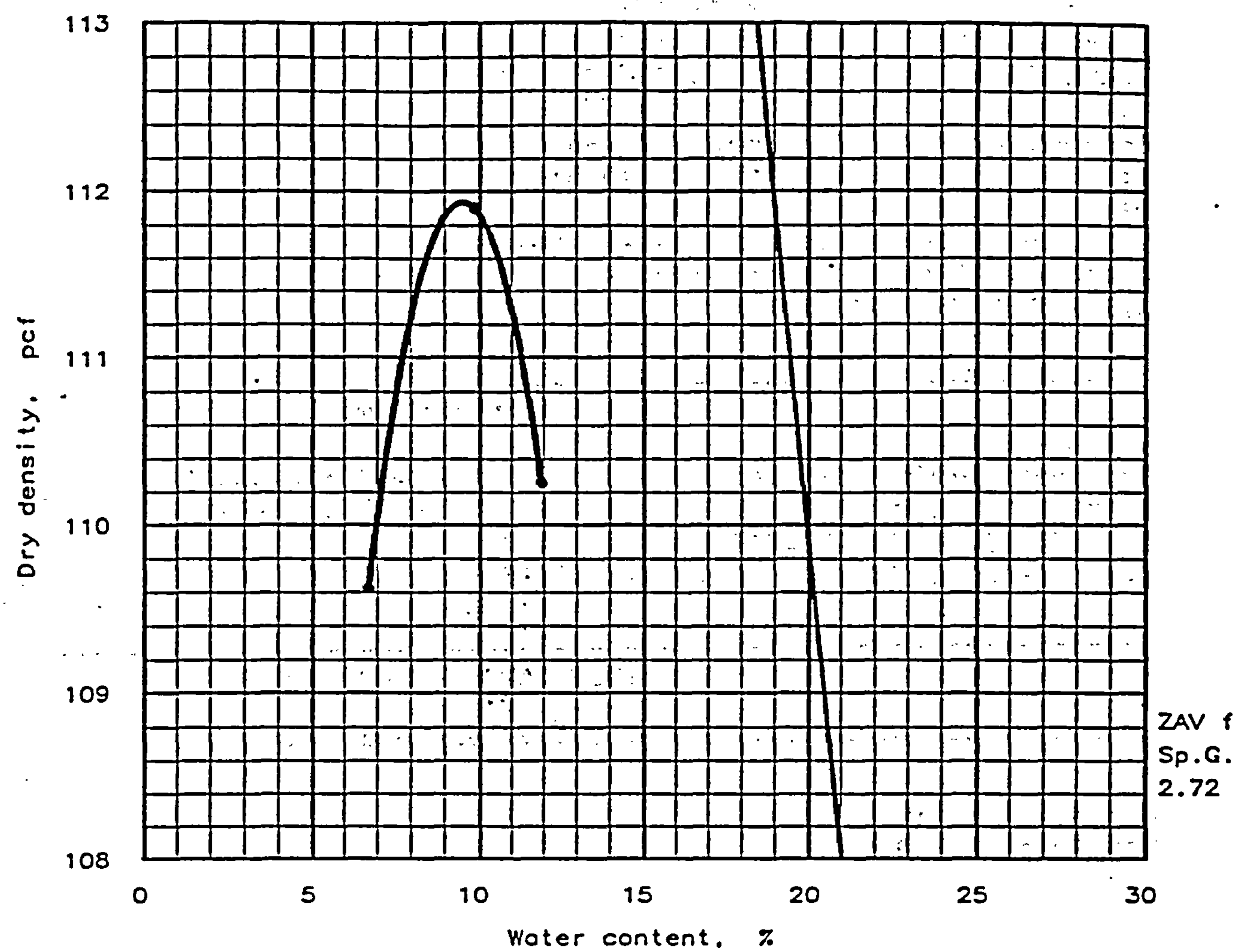
Run Number:	1	2
Cell Pressure:	30.0 psi	0.0 psi
Saturation Pressure:	30.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D S	X R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S	X	12/12/97	13:18:00	0	27.0	17.0	6.00	86.20	0.00
		12/12/97	16:54:00	12,960	27.0	17.0	7.00	85.20	1.00
		12/13/97	11:45:00	80,820	27.0	17.0	11.60	80.80	5.50
		12/14/97	13:32:00	173,640	27.0	17.0	17.70	75.30	11.30
		12/15/97	6:31:00	234,780	27.0	17.0	20.70	72.20	14.35
		12/15/97	12:11:00	255,180	27.0	17.0	21.80	71.10	15.45
		12/15/97	16:35:00	271,020	27.0	17.0	22.60	70.30	16.25
		12/16/97	6:28:00	321,000	27.0	17.0	25.40	67.40	19.10

T--t Pressure = 27.0 psi Differential Head = 10.9 psi, 767.3 cm H2O
_ .dient = 1.100E 02 Flow rate = 5.821E-05 cc/sec R squared = 0.99773
Permeability, K27.0° = 1.808E-08 cm/sec, K20° = 1.537E-08 cm/sec

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 698-91 Procedure A, Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.2
	USCS	AASHTO						
	CL			2.72			0.0 %	98.

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 111.9 pcf Optimum moisture = 9.5 %	RED SILTY CLAY, TR SAND

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO

Date: 12-16-97

Remarks:
BORING: 108
DEPTH: 60.0'

MOISTURE-DENSITY RELATIONSHIP TEST
WEAVER BOOS CONSULTANTS, INC.

Fig. No. ______

PROJECT DATA

Date: 12-16-97
Project no.: 95042.10
Project: LEA COUNTY LANDFILL
Location 1: HOBBS, NEW MEXICO
2:
Remarks 1: BORING: 108
2: DEPTH: 60.0'
3:
Material 1: RED SILTY CLAY,
description 2: TR SAND
Elevation or depth:
Fig no:

SPECIMEN DATA

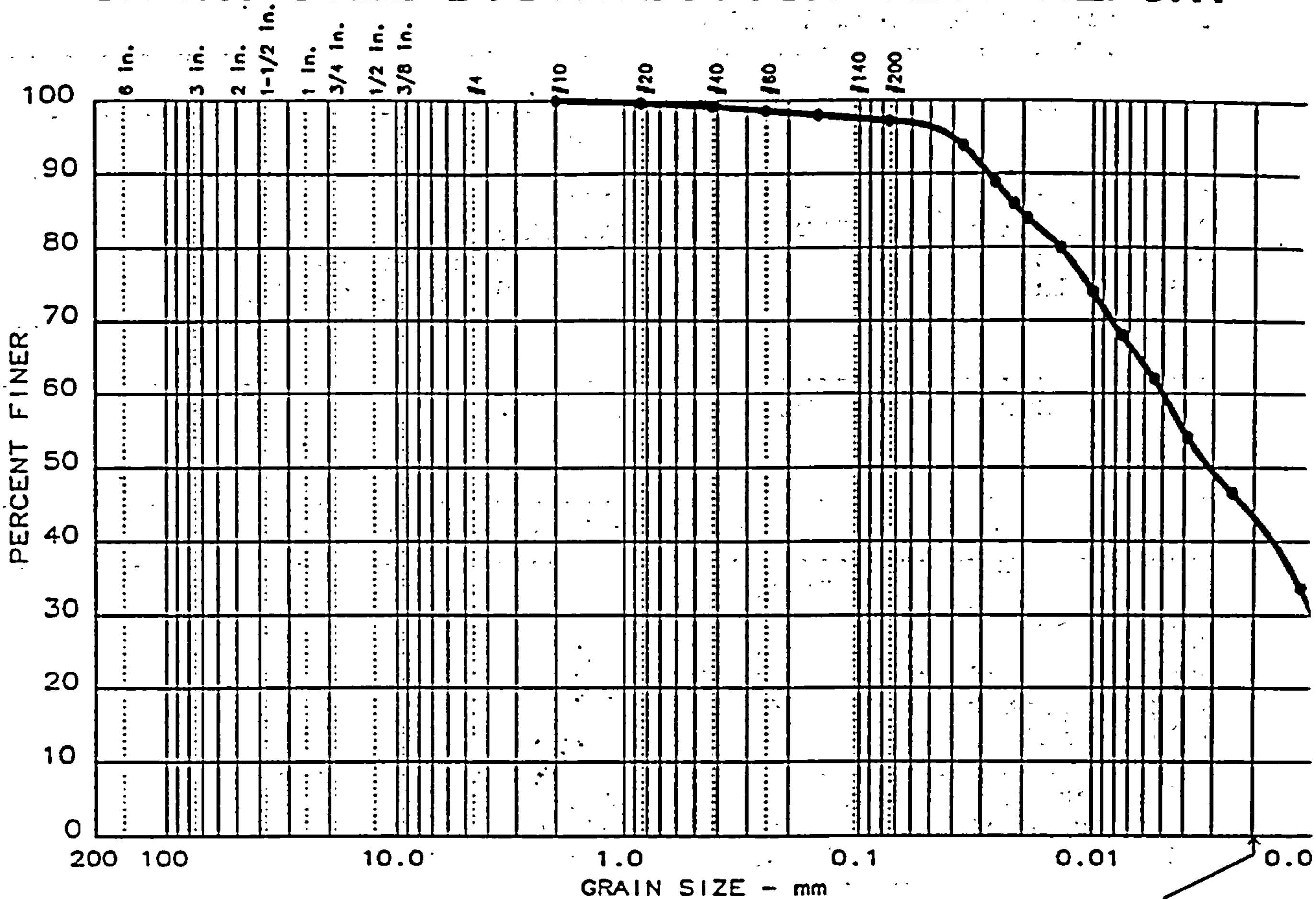
USCS classification: CL AASHTO classification:
Natural moisture: Specific gravity: 2.72
Percent retained on No.4 sieve: 0.0
Percent passing No. 200 sieve: 98.4
Liquid limit: Plastic limit: Plasticity index:

TEST DATA AND RESULTS

Type of test: Standard, ASTM D 698-91 Procedure A

Max dry den= 111.9 pcf
Opt moisture= 9.5 %

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	3	0.0	0.0	2.8	53.8	43.4

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0031	0.0011				

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-10-97

Remarks:
BORING: 109
DEPTH: 80.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-10-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL — Liquid limit: NA
AASHTO Class: — Plasticity index: NA

Notes

Remarks: BORING: 109 DEPTH: 80.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	336.20
Tare =	0.00
Dry sample weight =	336.20

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.20	99.6
# 40	0.40	99.2
# 60	0.70	98.6
# 100	1.00	98.0
# 200	1.40	97.2

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-4.5

Meniscus correction only= 1
Specific gravity of solids= 2.67
Specific gravity correction factor= 0.995

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	51.0	47.2	0.0131	52.0	7.8	0.0364	93.9
2.0	23.0	48.5	44.7	0.0131	49.5	8.2	0.0264	88.9
3.0	23.0	47.0	43.2	0.0131	48.0	8.4	0.0219	85.9
4.0	23.0	46.0	42.2	0.0131	47.0	8.6	0.0192	83.9
8.0	23.0	44.0	40.2	0.0131	45.0	8.9	0.0138	80.0
16.0	23.0	41.0	37.2	0.0131	42.0	9.4	0.0100	74.0
30.0	23.0	38.0	34.2	0.0131	39.0	9.9	0.0075	68.0
60.0	23.0	35.0	31.2	0.0131	36.0	10.4	0.0054	62.0
125.0	23.0	31.0	27.2	0.0131	32.0	11.0	0.0039	54.1
330.0	22.0	27.5	23.4	0.0132	28.5	11.6	0.0025	46.6
1410.0	22.0	21.0	16.9	0.0132	22.0	12.7	0.0013	33.7
2850.0	23.0	15.5	11.7	0.0131	16.5	13.6	0.0009	23.2

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 2.8
% SILT = 53.8 % CLAY = 43.4 (% CLAY COLLOIDS = 26.7)

D85= 0.02 D60= 0.005 D50= 0.003
D30= 0.0011

PERMEABILITY TEST REPORT

TEST DATA:

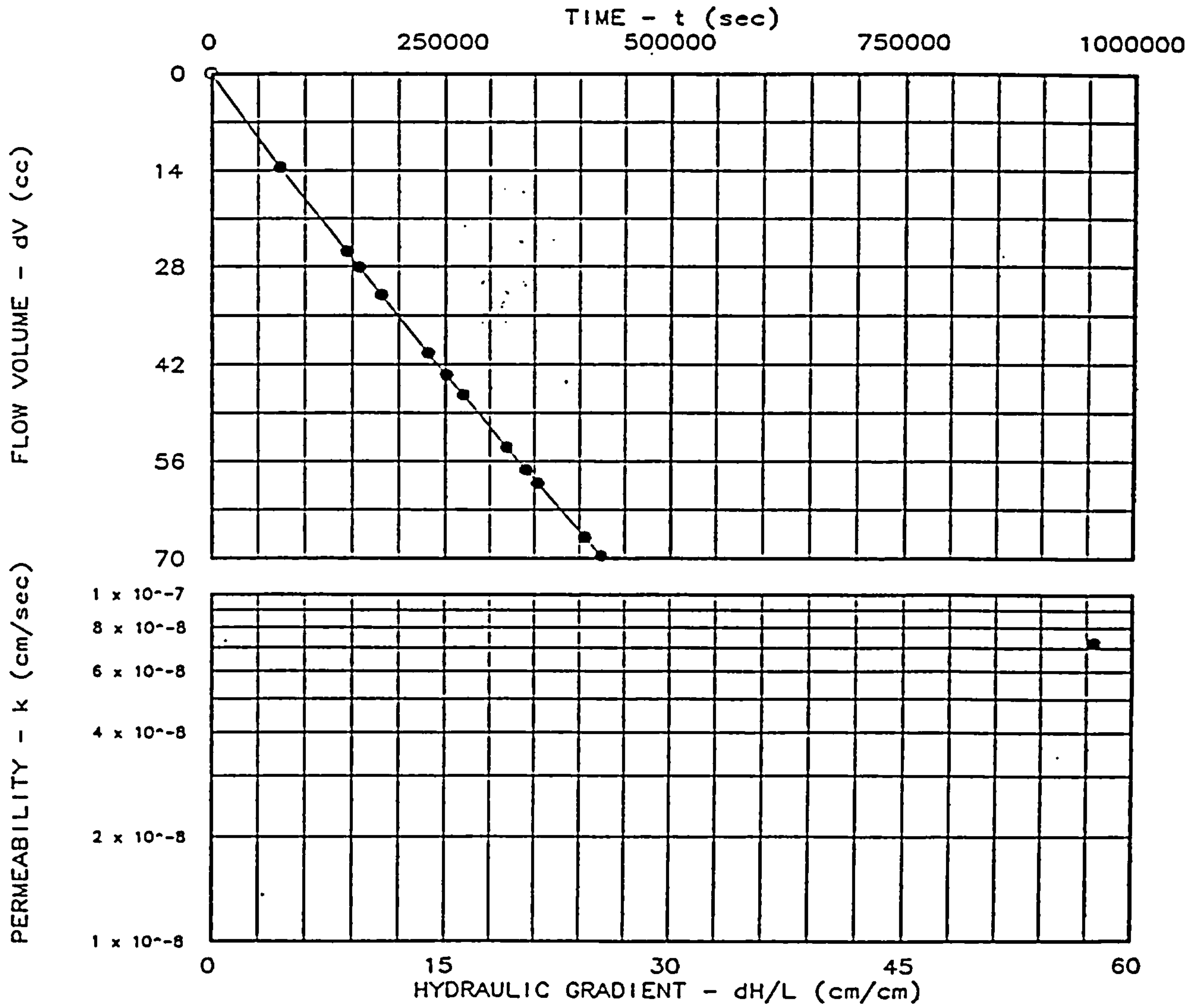
Specimen Height (cm): 5.72
Specimen Diameter (cm): 6.43
Dry Unit Weight (pcf): 107.3
Moisture Before Test (%): 12.3
Moisture After Test (%): 21.8
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 30.0
Test Pressure(psi): 25.0
Back Pressure(psi): 20.3
Diff. Head (psi): 4.7
Flow Rate (cc/sec): 1.59 x 10^-4
Perm. (cm/sec): 7.25 x 10^-8

SAMPLE DATA:

Sample Identification: BORING: 109
DEPTH: 80.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-3-97

PERMEABILITY TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Project No.: 95042.10
File No.: 95042.10
Lab No.: 1
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name:	LEA COUNTY LANDFILL
e No.:	95042.10
oject Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 109 DEPTH: 80.0'
Lab No.:	1
Description:	RED SILTY CLAY, TR SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-3-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	Before test: 2	Before test: 3	After test: 1	After test: 2	After test: 3
Diameter:	1	2		1	2	
Top:	in	in		in	in	
Middle:	2.531 in	in		2.508 in	in	
Bottom:	in	in		in	in	
Average:	2.53 in	6.43 cm		2.51 in	6.37 cm	
Length:	1	2	3	1	2	3
	2.253 in	in	in	2.301 in	in	in
Average:	2.25 in	5.72 cm		2.30 in	5.84 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.67	
Wet Wt. & Tare:	358.70	389.00
Dry Wt. & Tare:	319.40	319.40
Tare Wt.:	0.00	0.00
Moisture Content:	12.3 %	21.8 %
Dry Unit Weight:	107.3 pcf	107.0 pcf
Porosity:	0.3560	0.3578
Saturation:	59.4 %	104.4 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 1 Panel No.: Positions:

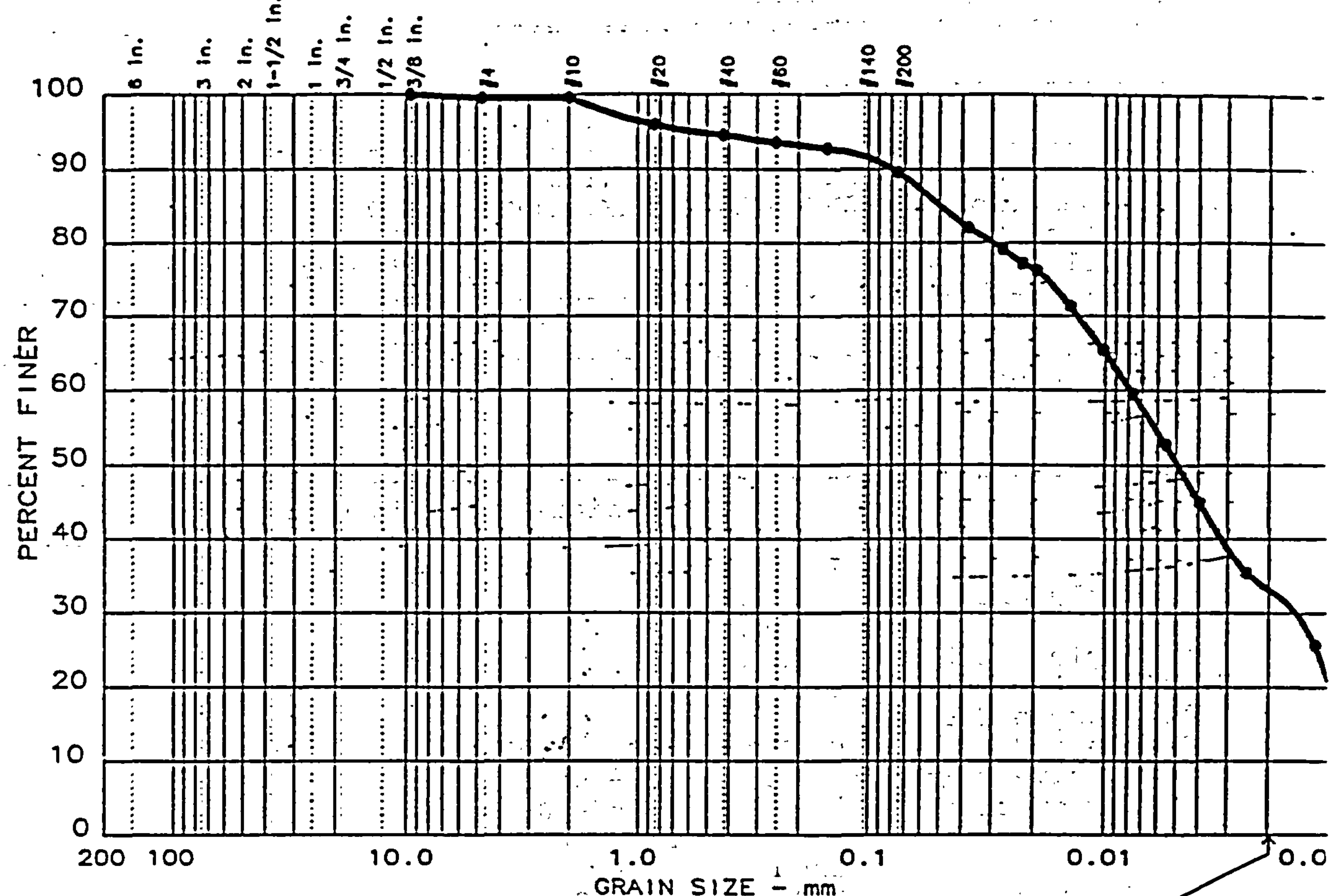
Run Number:	1	2
Cell Pressure:	30.0 psi	0.0 psi
Saturation Pressure:	30.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D S	X R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S	X	12/ 6/97	14:51:00	0	25.0	20.0	12.00	81.40	0.00
		12/ 7/97	11:10:00	73,140	25.0	20.0	26.30	68.70	13.50
		12/ 8/97	6:50:00	143,940	25.0	20.0	38.80	56.60	25.80
		12/ 8/97	10:34:00	157,380	25.0	20.0	41.20	54.40	28.10
		12/ 8/97	17:08:00	181,020	25.0	20.0	45.10	50.50	32.00
		12/ 9/97	7:15:00	231,840	25.0	20.0	53.40	42.20	40.30
		12/ 9/97	12:39:00	251,280	25.0	20.0	56.70	39.20	43.45
		12/ 9/97	17:48:00	269,820	25.0	20.0	59.70	36.40	46.35
		12/10/97	7:25:00	318,840	25.0	20.0	67.30	28.80	53.9
		12/10/97	13:25:00	340,440	25.0	20.0	70.60	25.60	57.2
		12/10/97	17:01:00	353,400	25.0	20.0	72.60	23.60	59.20
		12/11/97	7:32:00	405,660	25.0	20.0	80.50	16.00	66.95
		12/11/97	12:37:00	423,960	25.0	20.0	83.20	13.40	69.60

Test Pressure = 25.0 psi Differential Head = 4.7 psi, 328.8 cm H2O
Gradient = 5.746E 01 Flow rate = 1.590E-04 cc/sec R squared = 0.99911
Permeability, K27.0° = 8.523E-08 cm/sec, K20° = 7.247E-08 cm/sec

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	15	0.0	0.4	10.0	56.5	33.1

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0049	0.0015	0.0010			

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, LITTLE SAND	CL	A-4

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-23-97

Remarks:
BORING: 110
DEPTH: 90.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-23-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, LITTLE SAND
USCS Class: CL — Liquid limit: NA
AASHTO Class: A-4 — Plasticity index: NA

Notes

Remarks: BORING: 110 DEPTH: 90.0'

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 427.40
Tare = 0.00
Dry sample weight = 427.40
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
'e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	1.80	99.6
# 10	1.80	99.6
# 20	1.80	96.0
# 40	2.50	94.6
# 60	3.00	93.6
# 100	3.40	92.8
# 200	5.00	89.6

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 99.6
Weight of hydrometer sample: 50
Calculated biased weight= 50.21
Automatic temperature correction
Composite correction at 20 deg C =-4

Meniscus correction only= 1

Specific gravity of solids= 2.74
Specific gravity correction factor= 0.980
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	22.5	45.5	42.0	0.0129	46.5	8.7	0.0379	82.1
2.0	22.5	44.0	40.5	0.0129	45.0	8.9	0.0272	79.1
3.0	22.5	43.0	39.5	0.0129	44.0	9.1	0.0224	77.2
4.0	22.5	42.5	39.0	0.0129	43.5	9.2	0.0195	76.2
8.0	22.5	40.0	36.5	0.0129	41.0	9.6	0.0141	71.3
16.0	22.5	37.0	33.5	0.0129	38.0	10.1	0.0102	65.5
30.0	22.5	34.0	30.5	0.0129	35.0	10.6	0.0076	59.6
60.0	22.5	30.5	27.0	0.0129	31.5	11.1	0.0055	52.8
125.0	22.5	26.5	23.0	0.0129	27.5	11.8	0.0040	45.0
330.0	23.0	21.5	18.2	0.0128	22.5	12.6	0.0025	35.5
1410.0	23.0	16.5	13.2	0.0128	17.5	13.4	0.0012	25.7
2850.0	23.0	10.0	6.7	0.0128	11.0	14.5	0.0009	13.0

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.4 % SAND = 10.0
% SILT = 56.5 % CLAY = 33.1 (% CLAY COLLOIDS = 17.1)

D85= 0.05 D60= 0.008 D50= 0.005
D30= 0.0015 D15= 0.00095

PERMEABILITY TEST REPORT

TEST DATA:

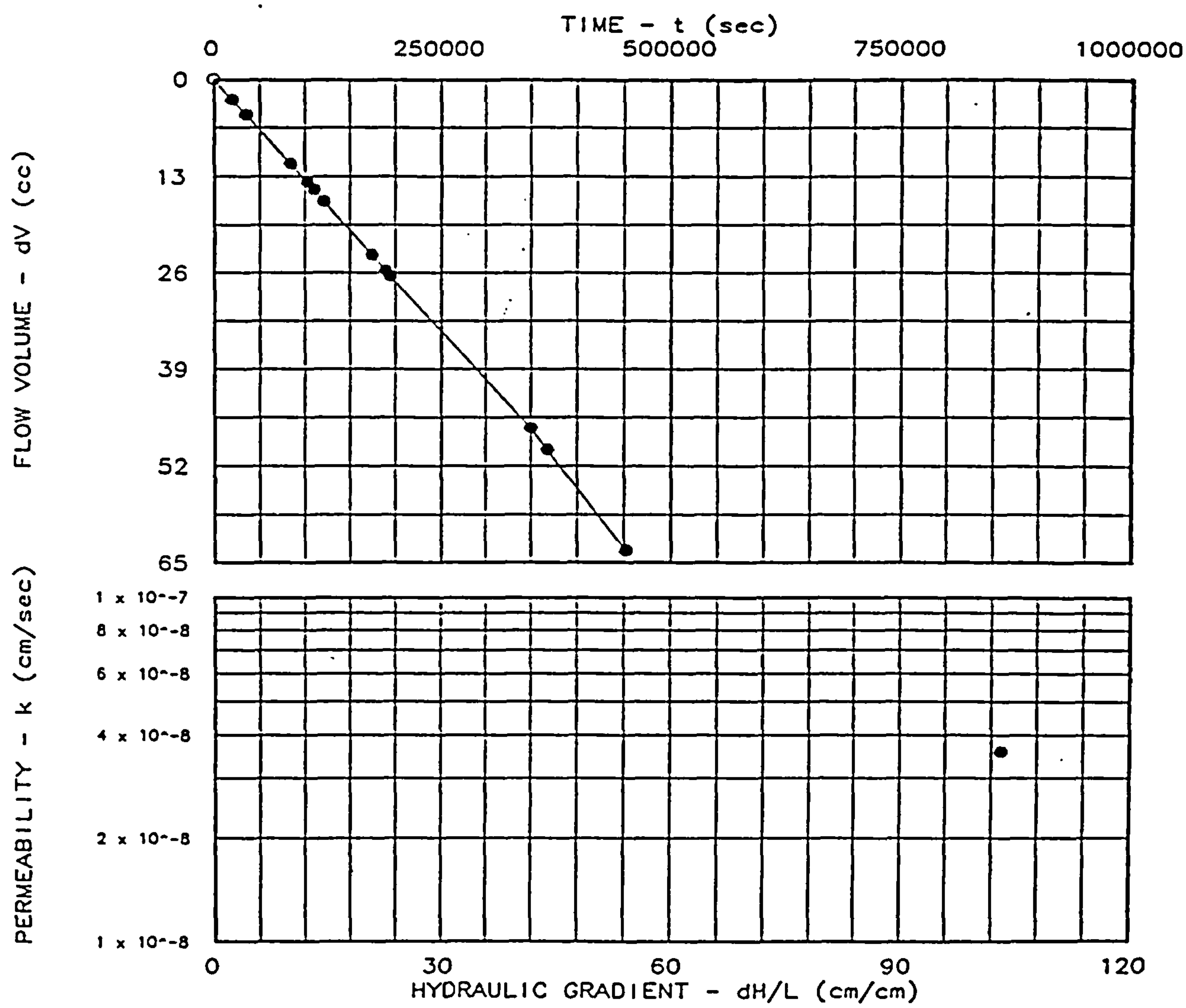
Specimen Height (cm): 7.10
Specimen Diameter (cm): 6.36
Dry Unit Weight (pcf): 103.0
Moisture Before Test (%): 13.8
Moisture After Test (%): 24.4
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 35.0
Test Pressure(psi): 27.0
Back Pressure(psi): 16.6
Diff. Head (psi): 10.4
Flow Rate (cc/sec): 1.38 x 10^-4
Perm. (cm/sec): 3.58 x 10^-8

SAMPLE DATA:

Sample Identification: BORING: 110
DEPTH: 90.0'
Visual Description: RED SILTY CLAY, LI'. SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL Location: HOBBS, NEW MEXICO Date: 12-18-97	Project No.: 95042.10 File No.: 95042.10 Lab No.: 1
PERMEABILITY TEST REPORT WEAVER BOOS CONSULTANTS, INC.	Tested by: JWM Checked by: WSG Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name:	LEA COUNTY LANDFILL
e No.:	95042.10
Project Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 110 DEPTH: 90.0'
Lab No.:	1
Description:	RED SILTY CLAY, LITTLE SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-18-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test:			After test:		
Diameter:	1	2		1	2	
Top:	in	in		in	in	
Middle:	2.502 in	in		2.505 in	in	
Bottom:	in	in		in	in	
Average:	2.50 in	6.36 cm		2.51 in	6.36 cm	
Length:	1	2	3	1	2	3
	2.795 in	in	in	2.802 in	in	in
Average:	2.80 in	7.10 cm		2.80 in	7.12 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.74	
Wet Wt. & Tare:	422.80	462.00
Dry Wt. & Tare:	371.50	371.50
Tare Wt.:	0.00	0.00
Moisture Content:	13.8 %	24.4 %
Dry Unit Weight:	103.0 pcf	102.5 pcf
Porosity:	0.3979	0.4009
Saturation:	57.3 %	99.8 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 1 Panel No.: Positions:

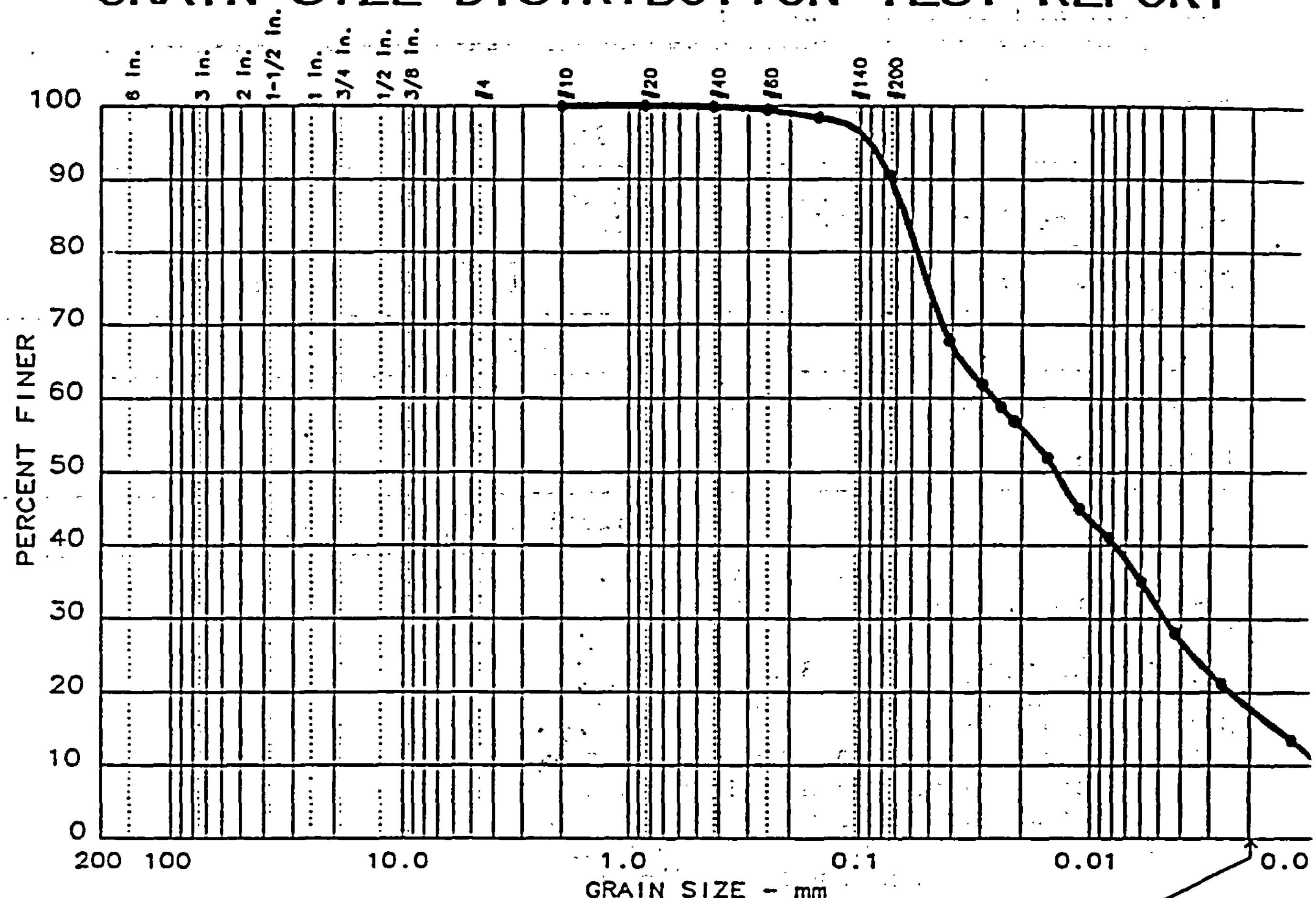
Run Number:	1	2
Cell Pressure:	35.0 psi	0.0 psi
Saturation Pressure:	35.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D X S R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	GAUGE PRESSURE-psi OUT	BURET READING-cc IN	BURET READING-cc OUT	FLOW VOLUME-cc AVERAGE
S X	12/22/97	7:32:00	0	27.0	17.0	4.40	80.60	0.00
	12/22/97	13:04:00	19,920	27.0	17.0	7.20	78.00	2.70
	12/22/97	17:15:00	34,980	27.0	17.0	9.20	76.00	4.70
	12/23/97	6:47:00	83,700	27.0	17.0	15.90	69.60	11.25
	12/23/97	11:57:00	102,300	27.0	17.0	18.40	67.20	13.70
	12/23/97	14:02:00	109,800	27.0	17.0	19.40	66.20	14.70
	12/23/97	17:03:00	120,660	27.0	17.0	21.00	64.70	16.25
	12/24/97	7:48:00	173,760	27.0	17.0	28.50	57.60	23.55
	12/24/97	12:10:00	189,480	27.0	17.0	30.60	55.40	25.70
	12/24/97	13:30:00	194,280	27.0	17.0	31.40	54.80	26.40
	12/26/97	8:38:00	349,560	27.0	17.0	52.60	35.00	46.90
	12/26/97	13:36:00	367,440	27.0	17.0	55.00	31.60	49.80
	12/27/97	13:08:00	452,160	27.0	17.0	69.60	19.20	63.30

Test Pressure = 27.0 psi Differential Head = 10.4 psi, 733.0 cm H2O
Gradient = 1.033E 02 Flow rate = 1.380E-04 cc/sec R squared = 0.99924
Permeability, K27.0° = 4.213E-08 cm/sec, K20° = 3.582E-08 cm/sec

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	5	0.0	0.0	9.4	72.7	17.9

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0141	0.0047	0.0015	0.0010	0.86	27.2

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-10-97

Remarks:
BORING: 110
DEPTH: 230.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-10-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL Liquid limit: NA
AASHTO Class: Plasticity index: NA

Notes

Remarks: BORING: 110 DEPTH: 230.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	335.30
Tare =	0.00
Dry sample weight =	335.30

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
-Cumulative weight retained tare= 0
e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.00	100.0
# 40	0.10	99.8
# 60	0.30	99.4
# 100	0.80	98.4
# 200	4.70	90.6

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-4

Meniscus correction only= 1
Specific gravity of solids= 2.68
Specific gravity correction factor= 0.993

Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	37.5	34.2	0.0130	38.5	10.0	0.0412	67.9
2.0	23.0	34.5	31.2	0.0130	35.5	10.5	0.0298	61.9
3.0	23.0	33.0	29.7	0.0130	34.0	10.7	0.0246	58.9
4.0	23.0	32.0	28.7	0.0130	33.0	10.9	0.0215	56.9
8.0	23.0	29.5	26.2	0.0130	30.5	11.3	0.0155	52.0
16.0	23.0	26.0	22.7	0.0130	27.0	11.9	0.0112	45.0
30.0	23.0	24.0	20.7	0.0130	25.0	12.2	0.0083	41.1
60.0	23.0	21.0	17.7	0.0130	22.0	12.7	0.0060	35.1
125.0	23.0	17.5	14.2	0.0130	18.5	13.3	0.0042	28.1
330.0	23.0	14.0	10.7	0.0130	15.0	13.8	0.0027	21.2
1410.0	23.5	10.0	6.8	0.0130	11.0	14.5	0.0013	13.5
2850.0	23.5	8.0	4.8	0.0130	9.0	14.8	0.0009	9.5

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 9.4
% SILT = 72.7 % CLAY = 17.9 (% CLAY COLLOIDS = 10.4)

D85= 0.06 D60= 0.026 D50= 0.014
D30= 0.0047 D15= 0.00150 D10= 0.00097
Cc = 0.8610 Cu = 27.2270

PERMEABILITY TEST REPORT

TEST DATA:

Specimen Height (cm): 4.82
Specimen Diameter (cm): 6.17
Dry Unit Weight (pcf): 118.6
Moisture Before Test (%): 9.6
Moisture After Test (%): 15.3

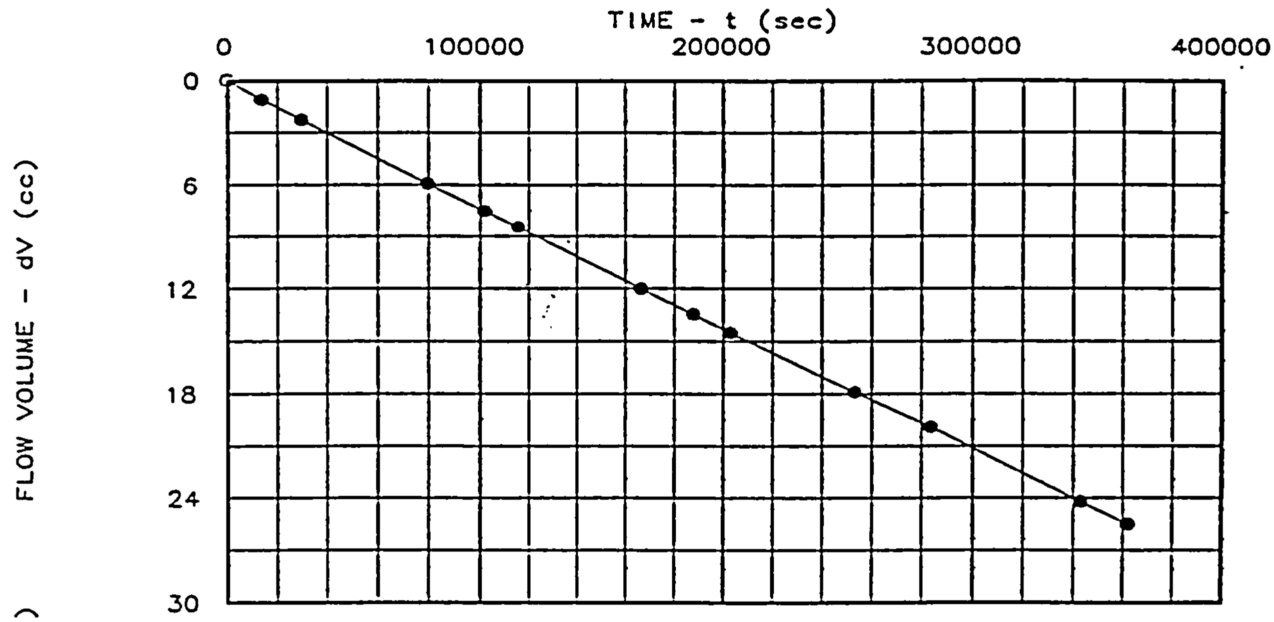
Run Number:	1 ●	2 ▲
Cell Pressure (psi):	30.0	
Test Pressure(psi):	27.0	
Back Pressure(psi):	16.1	
Diff. Head (psi):	10.9	
Flow Rate (cc/sec):	6.97 x 10^-5	
Perm. (cm/sec):	1.25 x 10^-8	

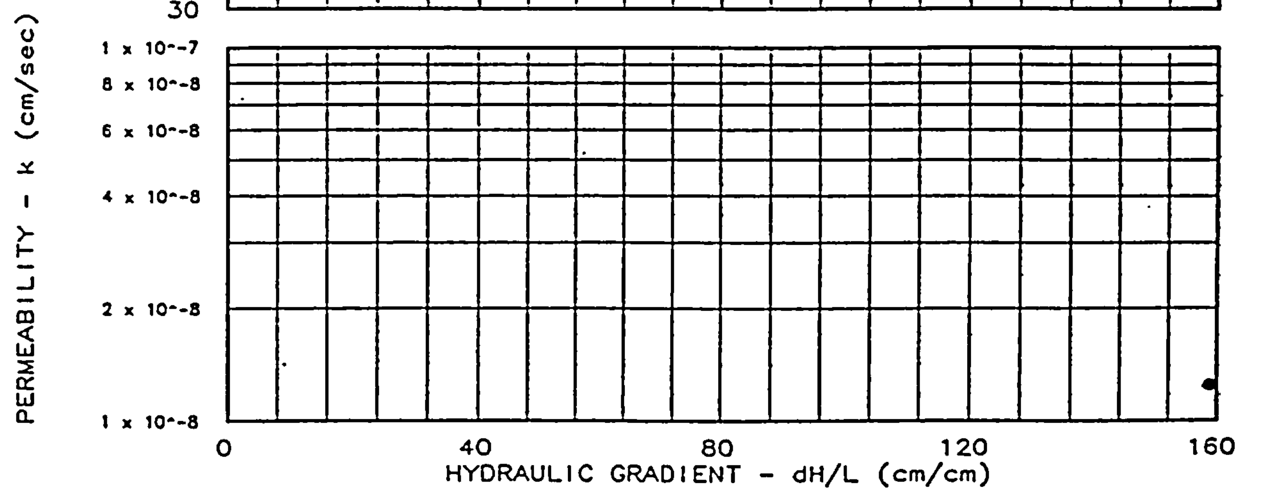
SAMPLE DATA:

Sample Identification: BORING: 110
DEPTH: 230.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE





Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-12-97

PERMEABILITY TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Project No.: 95042.10
File No.: 95042.10
Lab No.: 5
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

P--oject Name:	LEA COUNTY LANDFILL
e No.:	95042.10
.roject Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 110 DEPTH: 230.0'
Lab No.:	5
Description:	RED SILTY CLAY, TR SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-12-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	2	3	After test: 1	2	3
Diameter:						
Top:	in	in		in	in	
Middle:	2.431 in	in		2.456 in	in	
Bottom:	in	in		in	in	
Average:	2.43 in	6.17 cm		2.46 in	6.24 cm	
Length:	1.899 in	in	in	1.873 in	in	i:
Average:	1.90 in	4.82 cm		1.87 in	4.76 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.68	
Wet Wt. & Tare:	300.50	316.30
Dry Wt. & Tare:	274.30	274.30
Tare Wt.:	0.00	0.00
Moisture Content:	9.6 %	15.3 %
Dry Unit Weight:	118.6 pcf	117.8 pcf
Porosity:	0.2914	0.2961
Saturation:	62.2 %	97.5 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 5 Panel No.: Positions:

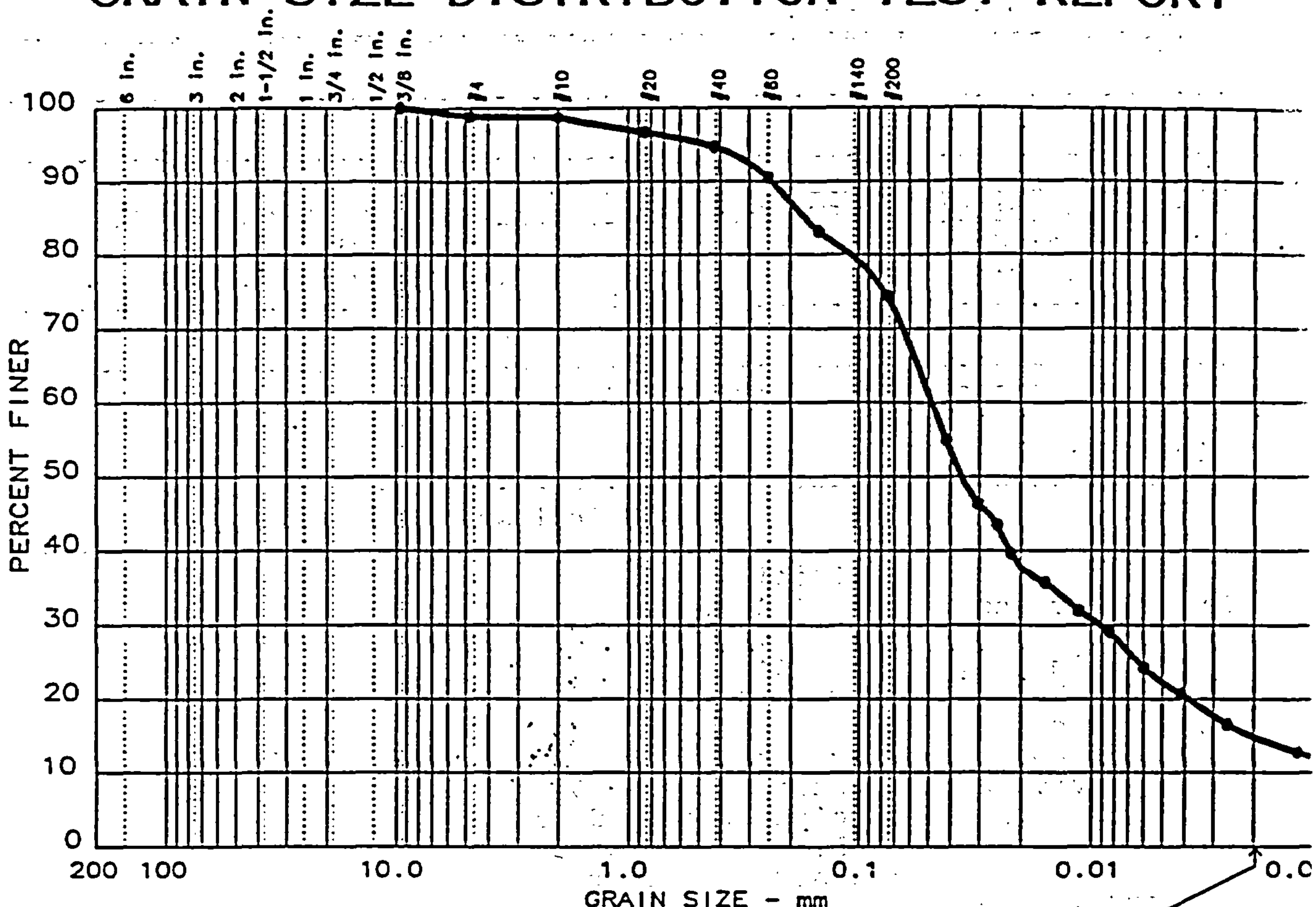
Run Number:	1	2
Cell Pressure:	30.0 psi	0.0 psi
Saturation Pressure:	30.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D S	X R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S	X	12/15/97	8:26:00	0	27.0	17.0	4.10	84.70	0.00
		12/15/97	12:13:00	13,620	27.0	17.0	5.30	83.70	1.10
		12/15/97	16:37:00	29,460	27.0	17.0	6.50	82.60	2.25
		12/16/97	6:30:00	79,440	27.0	17.0	10.30	79.10	5.90
		12/16/97	12:45:00	101,940	27.0	17.0	12.00	77.60	7.50
		12/16/97	16:27:00	115,260	27.0	17.0	13.00	76.70	8.45
		12/17/97	6:39:00	166,380	27.0	17.0	16.60	73.20	12.00
		12/17/97	12:34:00	187,680	27.0	17.0	18.10	71.80	13.45
		12/17/97	16:47:00	202,860	27.0	17.0	19.20	70.80	14.5[illegible]
		12/18/97	6:43:00	253,020	27.0	17.0	22.60	67.40	17.9[illegible]
		12/18/97	15:09:00	283,380	27.0	17.0	24.60	65.40	19.90
		12/19/97	7:41:00	342,900	27.0	17.0	29.00	61.20	24.20
		12/19/97	12:54:00	361,680	27.0	17.0	30.30	59.90	25.50

Test Pressure = 27.0 psi Differential Head = 10.9 psi, 765.7 cm H2O
Gradient = 1.588E 02 Flow rate = 6.970E-05 cc/sec R squared = 0.99986
Permeability, K27.0° = 1.466E-08 cm/sec, K20° = 1.247E-08 cm/sec

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	6	0.0	1.1	24.4	59.6	14.9

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.170		0.0357	0.0090	0.0020			

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, SOME SAND, TR FINE GRAVEL	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-15-97

Remarks:
BORING: 110
DEPTH: 350.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA

Test No.: 6

Date: 12-15-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, SOME SAND, TR FINE GRAVEL
USCS Class: CL
Liquid limit: NA
AASHTO Class:
Plasticity index: NA

Notes

Remarks: BORING: 110 DEPTH: 350.0'

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 444.50
Tare = 0.00
Dry sample weight = 444.50
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
# 4	5.00	98.9
# 10	5.20	98.8
# 20	1.10	96.7
# 40	2.10	94.7
# 60	4.20	90.5
# 100	7.90	83.2
# 200	12.30	74.5

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 98.8
Weight of hydrometer sample: 50
Calculated biased weight= 50.59
Automatic temperature correction
Composite correction at 20 deg C =-4

Meniscus correction only= 1

Specific gravity correction factor= 0.970
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	32.0	28.7	0.0126	33.0	10.9	0.0417	55.0
2.0	23.0	27.5	24.2	0.0126	28.5	11.6	0.0304	46.4
3.0	23.0	26.0	22.7	0.0126	27.0	11.9	0.0251	43.5
4.0	23.0	24.0	20.7	0.0126	25.0	12.2	0.0221	39.6
8.0	23.0	22.0	18.7	0.0126	23.0	12.5	0.0158	35.8
16.0	23.0	20.0	16.7	0.0126	21.0	12.9	0.0113	32.0
30.0	23.0	18.5	15.2	0.0126	19.5	13.1	0.0083	29.1
60.0	23.0	16.0	12.7	0.0126	17.0	13.5	0.0060	24.3
125.0	23.5	14.0	10.8	0.0126	15.0	13.8	0.0042	20.7
330.0	23.0	12.0	8.7	0.0126	13.0	14.2	0.0026	16.6
1410.0	23.0	10.0	6.7	0.0126	11.0	14.5	0.0013	12.8
2850.0	23.5	9.0	5.8	0.0126	10.0	14.7	0.0009	11.1

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 1.1 % SAND = 24.4
% SILT = 59.6 % CLAY = 14.9 (% CLAY COLLOIDS = 11.6)

D85= 0.17 D60= 0.048 D50= 0.036
D30= 0.0090 D15= 0.00203

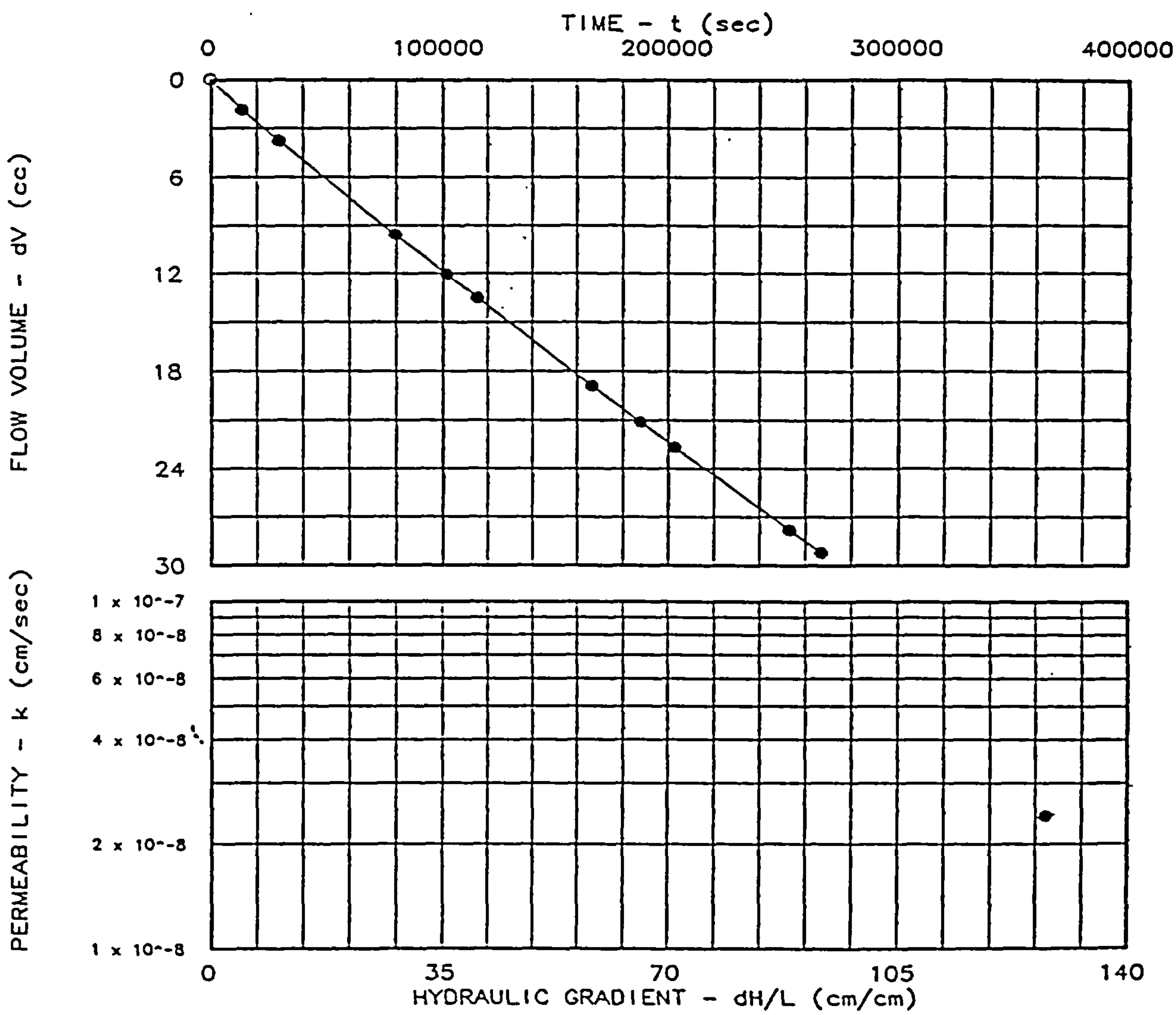
PERMEABILITY TEST REPORT

TEST DATA:
Specimen Height (cm): 5.93
Specimen Diameter (cm): 6.15
Dry Unit Weight (pcf): 106.8
Moisture Before Test (%): 13.4
Moisture After Test (%): 21.9
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 30.0
Test Pressure(psi): 27.0
Back Pressure(psi): 16.3
Diff. Head (psi): 10.7
Flow Rate (cc/sec): 1.07 x 10^-4
Perm. (cm/sec): 2.41 x 10^-8

SAMPLE DATA:
Sample Identification: BORING: 110
DEPTH: 350.0'
Visual Description: RED SILTY CLAY, SOM.
SAND, TR FINE GRAVEL
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-11-97

Project No.: 95042.10
File No.: 95042.10
Lab No.: 1
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST REPORT

WEAVER BOOS CONSULTANTS, INC.

PERMEABILITY TEST DATA

PROJECT DATA

Project Name:	LEA COUNTY LANDFILL
·e No.:	95042.10
Project Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 110 DEPTH: 350.0'
Lab No.:	1
Description:	RED SILTY CLAY, SOME SAND, TR FINE GRAVEL
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-11-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	2	3	After test: 1	2	3
Diameter:	1	2		1	2	
Top:	in	in		in	in	
Middle:	2.423 in	in		2.408 in	in	
Bottom:	in	in		in	in	
Average:	2.42 in	6.15 cm		2.41 in	6.12 cm	
Length:	1	2	3	1	2	3
	2.334 in	in	in	2.350 in	in	in
Average:	2.33 in	5.93 cm		2.35 in	5.97 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.79	
Wet Wt. & Tare:	342.00	367.50
Dry Wt. & Tare:	301.60	301.60
Tare Wt.:	0.00	0.00
Moisture Content:	13.4 %	21.9 %
Dry Unit Weight:	106.8 pcf	107.4 pcf
Porosity:	0.3870	0.3836
Saturation:	59.2 %	98.0 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 1 | Panel No.: | Positions:

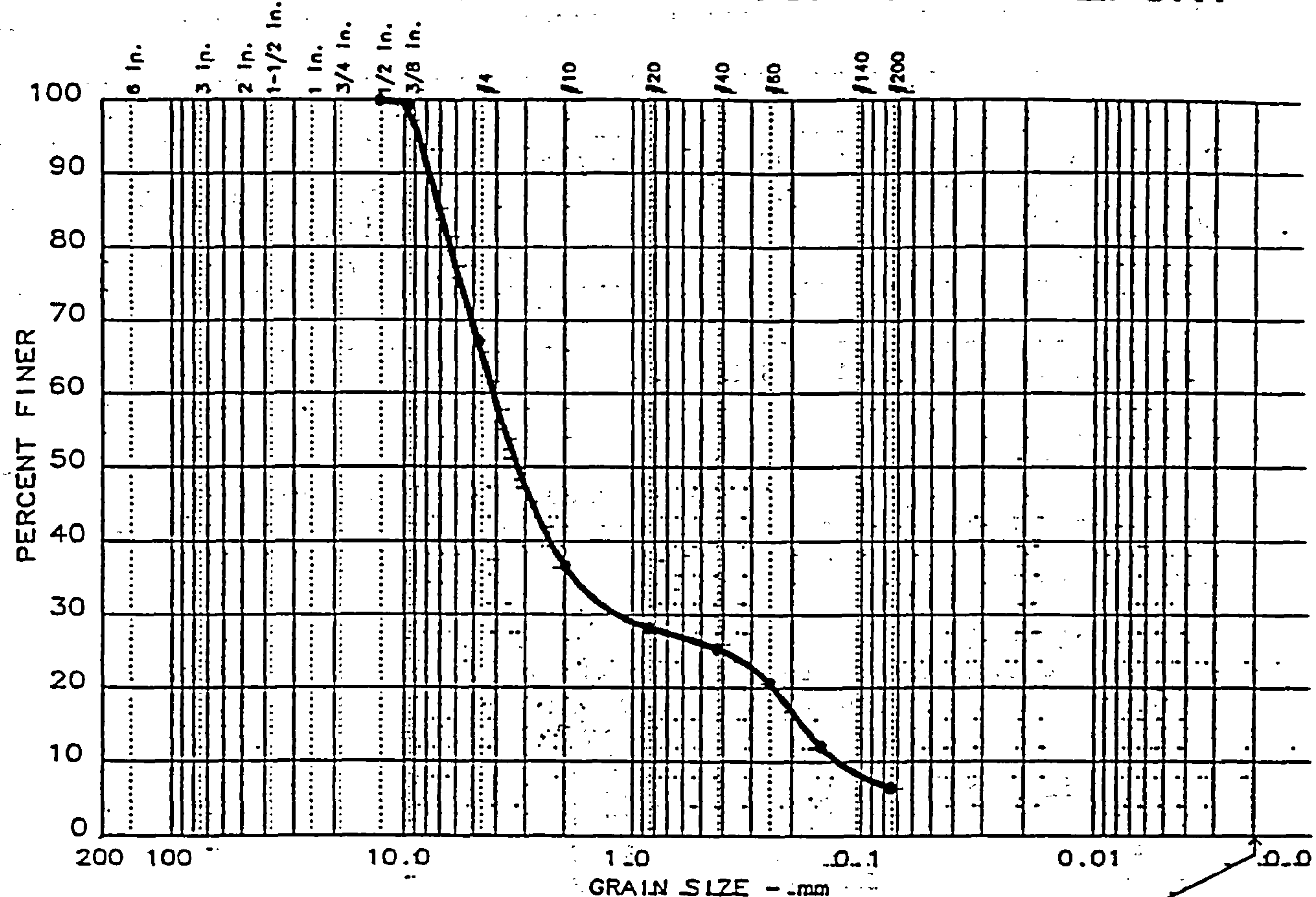
Run Number:	1	2
Cell Pressure:	30.0 psi	0.0 psi
Saturation Pressure:	30.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D X S R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S X	12/15/97	8:25:00	0	27.0	17.0	5.50	83.60	0.00
	12/15/97	12:11:00	13,560	27.0	17.0	7.50	81.90	1.85
	12/15/97	16:35:00	29,400	27.0	17.0	9.50	80.10	3.75
	12/16/97	6:28:00	79,380	27.0	17.0	15.40	74.40	9.55
	12/16/97	12:43:00	101,880	27.0	17.0	18.00	72.00	12.05
	12/16/97	16:25:00	115,200	27.0	17.0	19.50	70.60	13.50
	12/17/97	6:37:00	166,320	27.0	17.0	25.00	65.30	18.90
	12/17/97	12:32:00	187,620	27.0	17.0	27.20	63.10	21.10
	12/17/97	16:45:00	202,800	27.0	17.0	28.80	61.60	22.65
	12/18/97	6:41:00	252,960	27.0	17.0	34.00	56.50	27.80
	12/18/97	10:32:00	266,820	27.0	17.0	35.40	55.10	29.20

Test Pressure = 27.0 psi Differential Head = 10.7 psi, 755.4 cm H2O
Gradient = 1.274E 02 Flow rate = 1.075E-04 cc/sec R squared = 0.99922
Permeability, K27.0° = 2.836E-08 cm/sec, K20° = 2.411E-08 cm/sec

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	3	0.0	32.9	60.6	6.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	7.00	4.12	3.23	1.16	0.178	0.126	2.60	32.7

MATERIAL DESCRIPTION	USCS	AASHTO
● LIGHT PINK COARSE SAND, SOME FINE GRAVEL, TR SILT	SW-SM	A-1-a

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-30-98

Remarks:
BORING: B-111
S-35

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 3

Date: 1-30-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: LIGHT PINK COARSE SAND, SOME FINE GRAVEL, TR SILT
USCS Class: SW-SM Liquid limit: NA
AASHTO Class: A-1-a Plasticity index: NA

Notes

Remarks: BORING: B-111 S-35

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 192.90
Tare = 0.00
Dry sample weight = 192.90
Tare for cumulative weight retained= 0

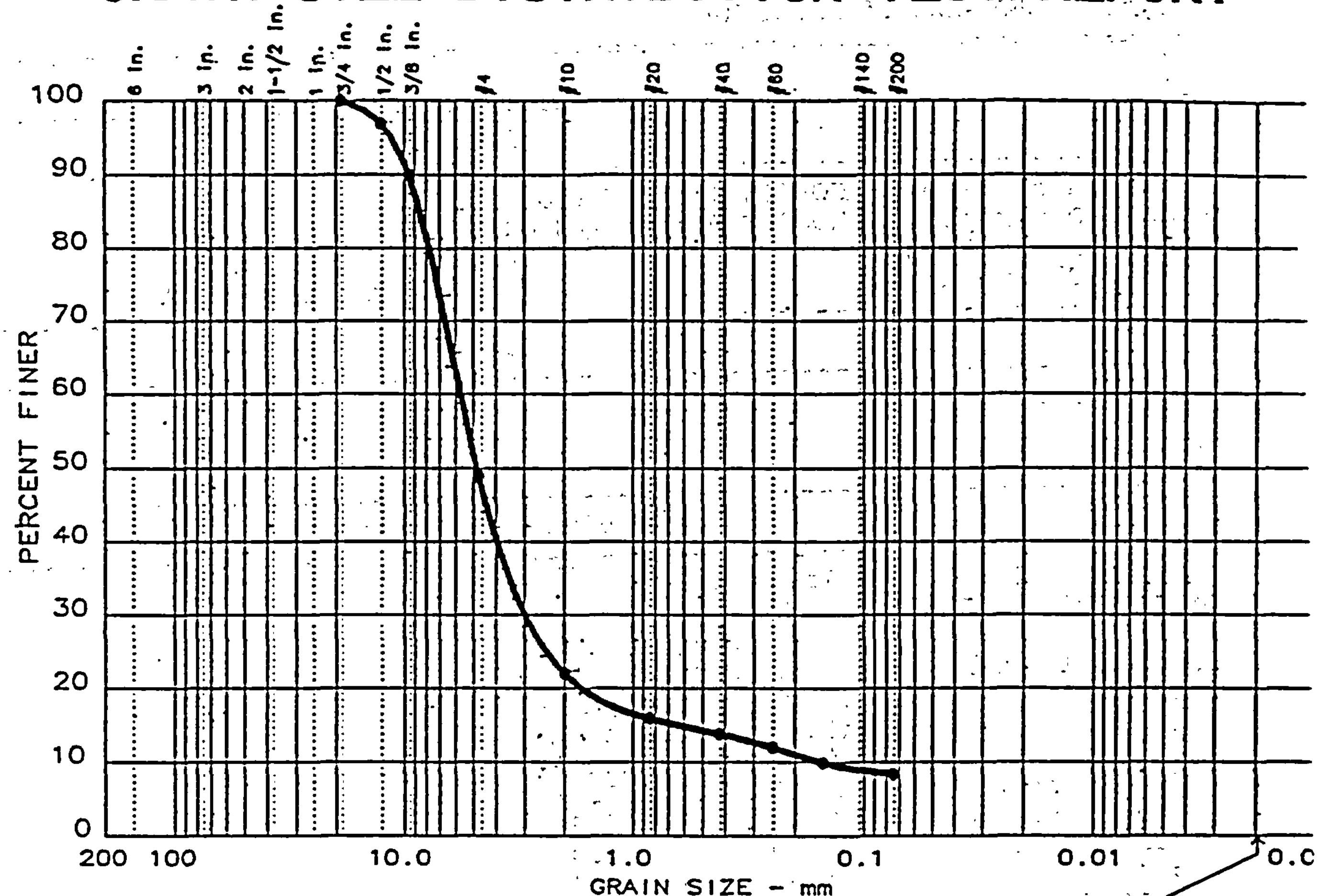
Sieve	Cumul. Wt. retained	Percent finer
0.5 inches	0.00	100.0
0.375 inches	1.40	99.3
# 4	63.50	67.1
# 10	122.20	36.7
# 20	138.40	28.3
# 40	144.00	25.3
# 60	153.00	20.7
# 100	169.60	12.1
# 200	180.40	6.5

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 32.9 % SAND = 60.6
% FINES = 6.5

D85= 7.00 D60= 4.116 D50= 3.232
D30= 1.1601 D15= 0.17762 D10= 0.12575
Cc = 2.6002 Cu = 32.7341

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	2	0.0	51.0	40.6	8.4	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	8.51	5.68	4.83	2.98	0.601	0.153	10.22	37.2

MATERIAL DESCRIPTION	USCS	AASHTO
● ROSE & WHITE F/M GRAVEL & SAND, TR SILT	GP-GM	A-1-a

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-30-98

Remarks:
BORING: B-111
S-39

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 2

Date: 1-30-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: ROSE & WHITE F/M GRAVEL & SAND, TR SILT
USCS Class: GP-GM Liquid limit: NA
AASHTO Class: A-1-a Plasticity index: NA

Notes

Remarks: BORING: B-111 S-39

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 212.70
Tare = 0.00
Dry sample weight = 212.70
Tare for cumulative weight retained= 0

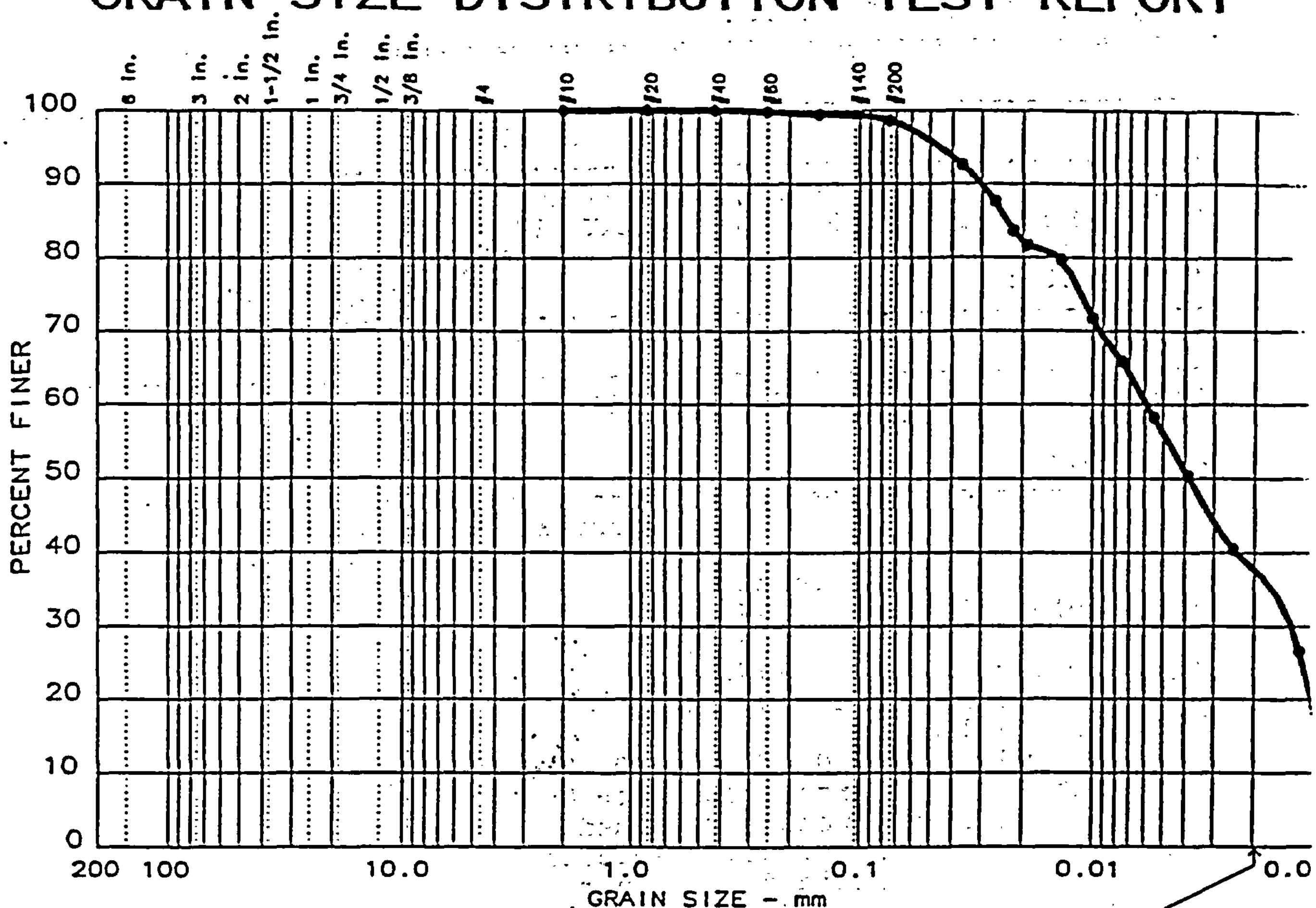
Sieve	Cumul. Wt. retained	Percent finer
0.75 inches	0.00	100.0
.5 inches	6.80	96.8
0.375 inches	21.30	90.0
# 4	108.50	49.0
# 10	165.90	22.0
# 20	178.80	15.9
# 40	183.20	13.9
# 60	187.10	12.0
# 100	191.60	9.9
# 200	194.90	8.4

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 51.0 % SAND = 40.6
% FINES = 8.4

D85= 8.51 D60= 5.682 D50= 4.831
D30= 2.9785 D15= 0.60117 D10= 0.15276
Cc = 10.2212 Cu = 37.1963

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	12	0.0	0.0	1.4	60.9	37.7

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0038	0.0014	0.0010	0.0009	0.34	6.2

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-18-97

Remarks:
BORING: 111
DEPTH: 80.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA

Test No.: 12

Date: 12-18-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL Liquid limit: NA
AASHTO Class: Plasticity index: NA

Notes

Remarks: BORING: 111 DEPTH: 80.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	396.10
Tare =	0.00
Dry sample weight =	396.10

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
-e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.00	100.0
# 40	0.00	100.0
# 60	0.10	99.8
# 100	0.30	99.4
# 200	0.70	98.6

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-3.5

Meniscus correction only= 1
Specific gravity of solids= 2.7
Specific gravity correction factor= 0.989

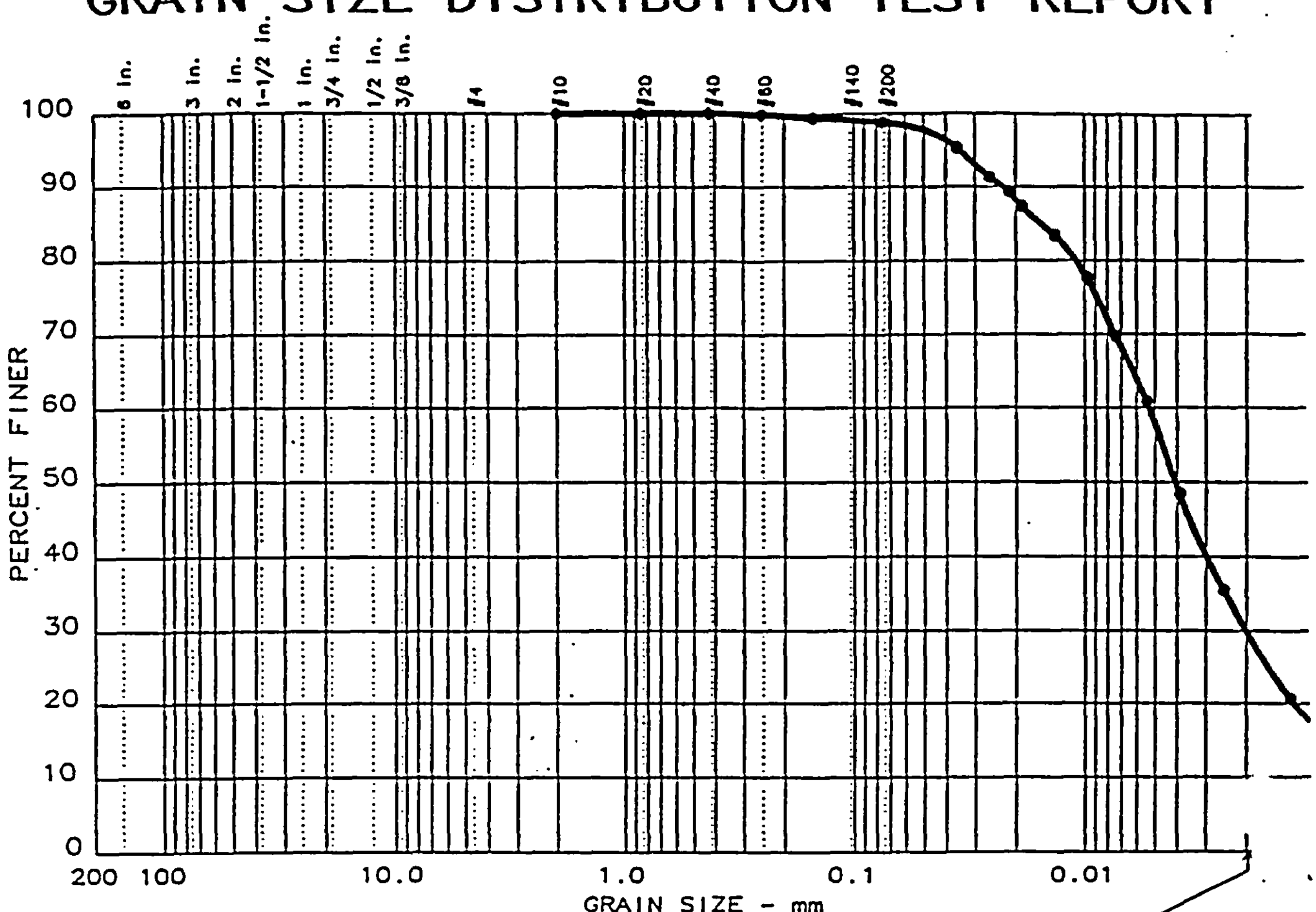
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.5	49.5	46.8	0.0129	50.5	8.0	0.0365	92.6
2.0	23.5	47.0	44.3	0.0129	48.0	8.4	0.0264	87.6
3.0	23.5	45.0	42.3	0.0129	46.0	8.8	0.0220	83.7
4.0	23.5	44.0	41.3	0.0129	45.0	8.9	0.0192	81.7
8.0	23.5	43.0	40.3	0.0129	44.0	9.1	0.0137	79.7
16.0	23.5	39.0	36.3	0.0129	40.0	9.7	0.0100	71.8
30.0	23.5	36.0	33.3	0.0129	37.0	10.2	0.0075	65.9
60.0	24.0	32.0	29.5	0.0128	33.0	10.9	0.0055	58.2
125.0	24.0	28.0	25.5	0.0128	29.0	11.5	0.0039	50.3
330.0	24.0	23.0	20.5	0.0128	24.0	12.4	0.0025	40.4
1410.0	24.0	16.0	13.5	0.0128	17.0	13.5	0.0013	26.6
2850.0	24.0	7.0	4.5	0.0128	8.0	15.0	0.0009	8.8

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 1.4
% SILT = 60.9 % CLAY = 37.7 (% CLAY COLLOIDS = 13.7)

D85= 0.02 D60= 0.006 D50= 0.004
D30= 0.0014 D15= 0.00102 D10= 0.00095
Cc = 0.3361 Cu = 6.1589

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	13	0.0	0.0	1.2	68.9	29.9

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0041	0.0020				

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-18-97

Remarks:
BORING: 111
DEPTH: 140.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 13

Date: 12-18-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL Liquid limit: NA
AASHTO Class: Plasticity index: NA

Notes

Remarks: BORING: 111 DEPTH: 140.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	456.80
Tare =	0.00
Dry sample weight =	456.80

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
:e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.00	100.0
# 40	0.00	100.0
# 60	0.10	99.8
# 100	0.30	99.4
# 200	0.60	98.8

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-3.5

Meniscus correction only= 1
Specific gravity of solids= 2.7
Specific gravity correction factor= 0.989

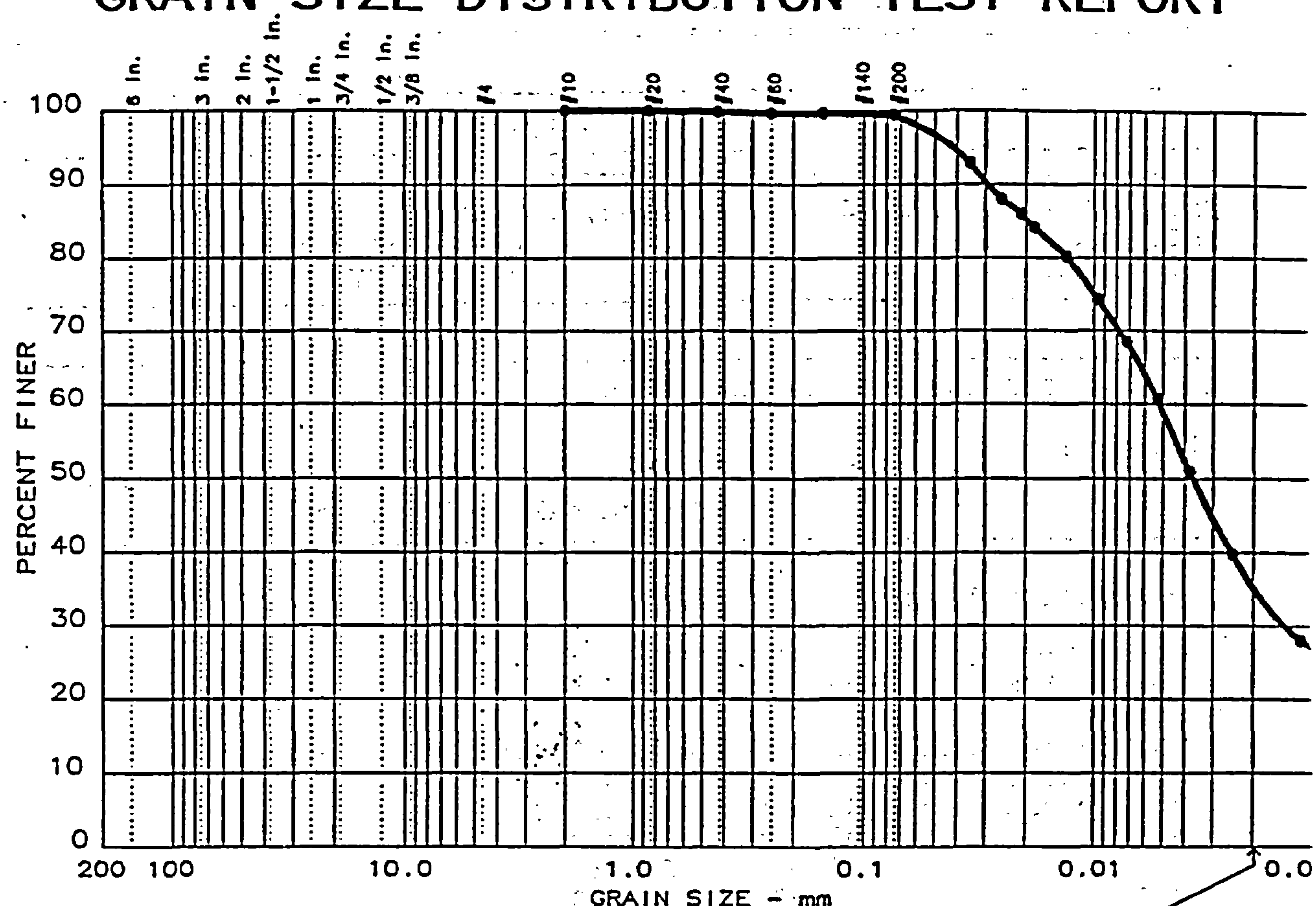
Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	51.0	48.2	0.0130	52.0	7.8	0.0361	95.3
2.0	23.0	49.0	46.2	0.0130	50.0	8.1	0.0261	91.3
3.0	23.0	48.0	45.2	0.0130	49.0	8.3	0.0215	89.3
4.0	23.0	47.0	44.2	0.0130	48.0	8.4	0.0188	87.3
8.0	23.0	45.0	42.2	0.0130	46.0	8.8	0.0136	83.4
16.0	23.5	42.0	39.3	0.0129	43.0	9.2	0.0098	77.7
30.0	23.5	38.0	35.3	0.0129	39.0	9.9	0.0074	69.8
60.0	23.5	33.5	30.8	0.0129	34.5	10.6	0.0054	60.9
125.0	24.0	27.0	24.5	0.0128	28.0	11.7	0.0039	48.4
330.0	24.0	20.5	18.0	0.0128	21.5	12.8	0.0025	35.5
1410.0	24.0	13.0	10.5	0.0128	14.0	14.0	0.0013	20.7
2850.0	24.0	10.5	8.0	0.0128	11.5	14.4	0.0009	15.7

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 1.2
% SILT = 68.9 % CLAY = 29.9 (% CLAY COLLOIDS = 17.0)

D85= 0.02 D60= 0.005 D50= 0.004
D30= 0.0020

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	7	0.0	0.0	0.6	64.1	35.3

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0037	0.0014				

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-4-97

Remarks:
BORING: 111
DEPTH: 200.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-4-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL — Liquid limit: NA
AASHTO Class: — Plasticity index: NA

Notes

Remarks: BORING: 111 DEPTH: 200.0'

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 372.50
Tare = 0.00
Dry sample weight = 372.50
Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
[illegible]e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
# 20	0.00	100.0
# 40	0.10	99.8
# 60	0.20	99.6
# 100	0.20	99.6
# 200	0.30	99.4

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.00
Automatic temperature correction
Composite correction at 20 deg C =-4.5

Meniscus correction only= 1
Specific gravity of solids= 2.77
Specific gravity correction factor= 0.974

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	51.5	47.7	0.0127	52.5	7.7	0.0352	92.9
2.0	23.0	49.0	45.2	0.0127	50.0	8.1	0.0256	88.0
3.0	23.0	48.0	44.2	0.0127	49.0	8.3	0.0211	86.1
4.0	23.0	47.0	43.2	0.0127	48.0	8.4	0.0184	84.1
8.0	23.0	45.0	41.2	0.0127	46.0	8.8	0.0133	80.2
16.0	23.0	42.0	38.2	0.0127	43.0	9.2	0.0097	74.4
30.0	23.0	39.0	35.2	0.0127	40.0	9.7	0.0072	68.5
60.0	23.0	35.0	31.2	0.0127	36.0	10.4	0.0053	60.7
125.0	23.0	30.0	26.2	0.0127	31.0	11.2	0.0038	51.0
330.0	22.0	24.5	20.4	0.0129	25.5	12.1	0.0025	39.8
1410.0	22.0	18.5	14.4	0.0129	19.5	13.1	0.0012	28.1
2850.0	23.0	17.0	13.2	0.0127	18.0	13.3	0.0009	25.7

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 0.6
% SILT = 64.1 % CLAY = 35.3 (% CLAY COLLOIDS = 26.4)

D85= 0.02 D60= 0.005 D50= 0.004
D30= 0.0014

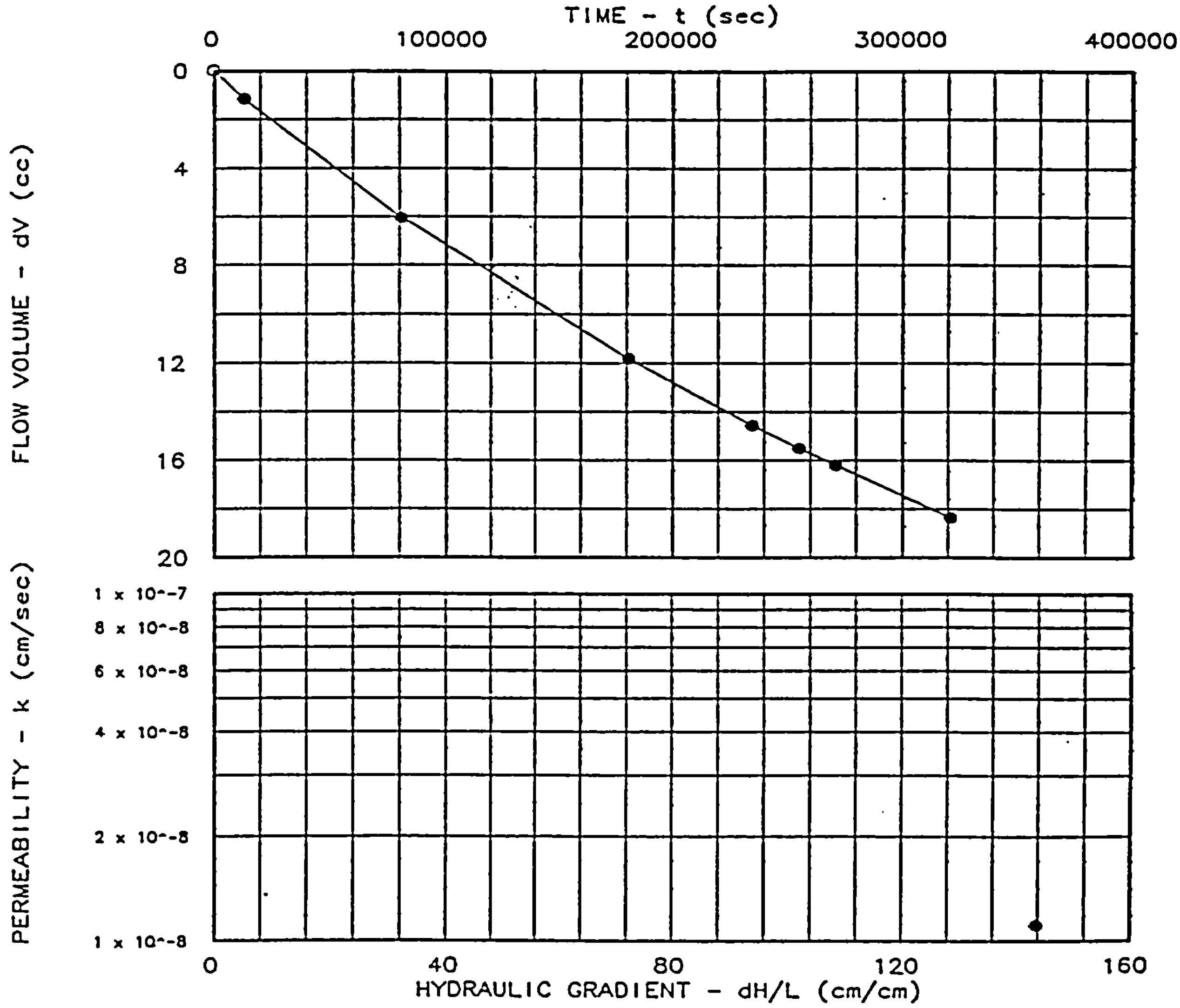
PERMEABILITY TEST REPORT

TEST DATA:
Specimen Height (cm): 5.32
Specimen Diameter (cm): 6.15
Dry Unit Weight (pcf): 115.6
Moisture Before Test (%): 9.7
Moisture After Test (%): 17.1
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 30.0
Test Pressure(psi): 27.0
Back Pressure(psi): 16.1
Diff. Head (psi): 10.9
Flow Rate (cc/sec): 5.58 x 10^-5
Perm. (cm/sec): 1.11 x 10^-8

SAMPLE DATA:
Sample Identification: BORING: 111
DEPTH: 200.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-8-97

PERMEABILITY TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Project No.: 95042.10
File No.: 95042.10
Lab No.: 3
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name: LEA COUNTY LANDFILL
[illegible]e No.: 95042.10
[illegible]oject Location: HOBBS, NEW MEXICO
Project No.: 95042.10
Sample Identification: BORING: 111
DEPTH: 200.0'
Lab No.: 3
Description: RED SILTY CLAY, TR SAND
Sample Type: CORE
Max. Dry Dens.:
Method (D1557/D698):
Opt. Water Content:
Date: 12-8-97
Remarks:

Permeameter Type: FLEXIBLE WALL
Tested by: JWM
Checked by: WSG
Test type: CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	Before test: 2	Before test: 3	After test: 1	After test: 2	After test: 3
[illegible]iameter: Top:	in	in		in	in	
Middle:	2.420 in	in		2.431 in	in	
Bottom:	in	in		in	in	
Average:	2.42 in	6.15 cm		2.43 in	6.17 cm	
Length:	2.094 in	in	in	2.073 in	in	in
Average:	2.09 in	5.32 cm		2.07 in	5.27 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.77	
Wet Wt. & Tare:	320.70	342.30
Dry Wt. & Tare:	292.30	292.30
Tare Wt.:	0.00	0.00
Moisture Content:	9.7 %	17.1 %
Dry Unit Weight:	115.6 pcf	115.7 pcf
Porosity:	0.3314	0.3307
Saturation:	54.3 %	95.9 %

Cell No.: 3 Panel No.: Positions:

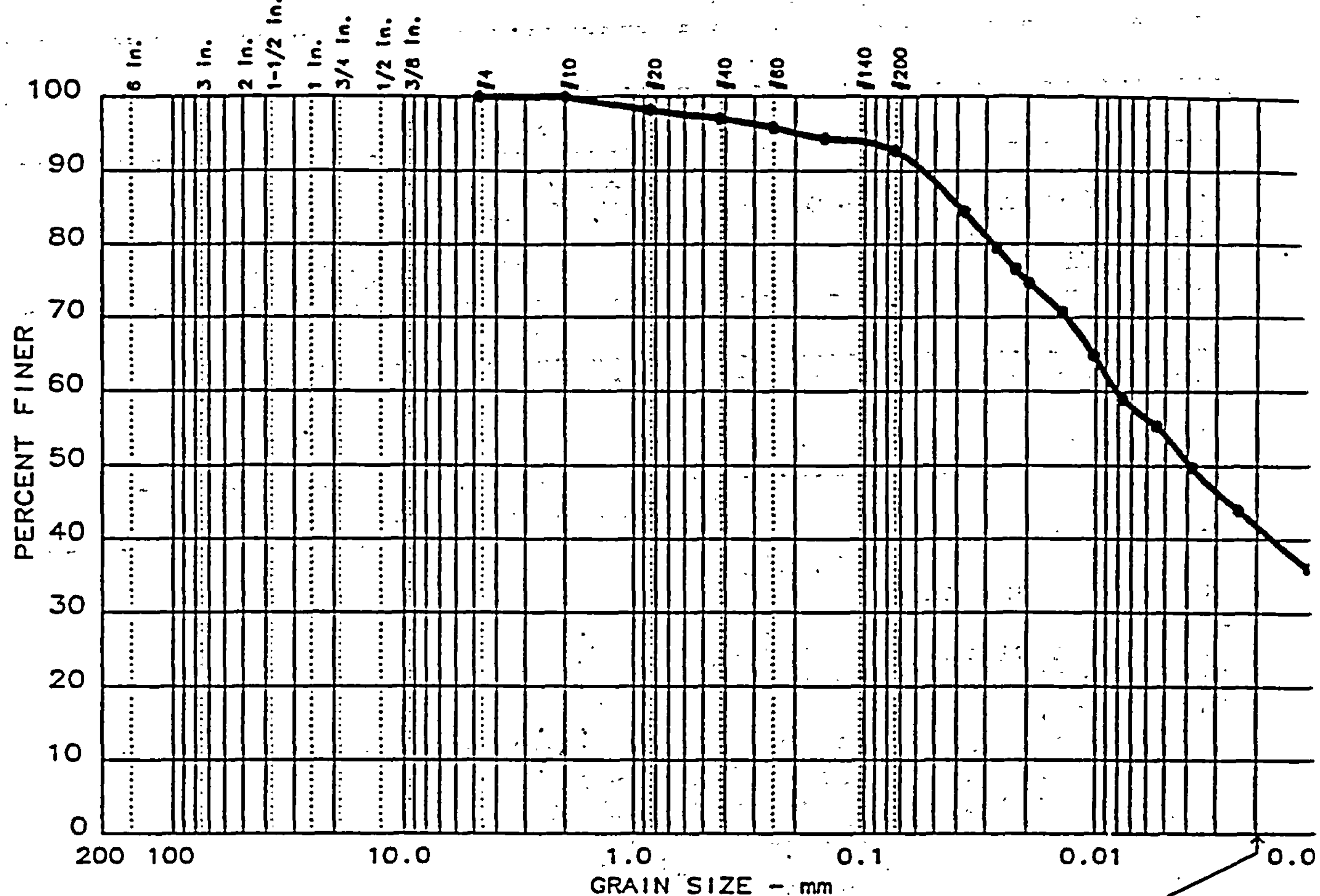
Run Number:	1	2
Cell Pressure:	30.0 psi	0.0 psi
Saturation Pressure:	30.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D X S R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S X	12/12/97	13:19:00	0	27.0	17.0	8.10	85.40	0.00
	12/12/97	16:55:00	12,960	27.0	17.0	9.20	84.20	1.15
	12/13/97	11:46:00	80,820	27.0	17.0	14.40	79.60	6.05
	12/14/97	15:33:00	180,840	27.0	17.0	20.40	74.10	11.80
	12/15/97	6:32:00	234,780	27.0	17.0	23.20	71.40	14.55
	12/15/97	12:12:00	255,180	27.0	17.0	24.20	70.50	15.50
	12/15/97	16:36:00	271,020	27.0	17.0	25.00	69.90	16.20
	12/16/97	6:29:00	321,000	27.0	17.0	27.20	67.80	18.35

Test Pressure = 27.0 psi Differential Head = 10.9 psi, 763.8 cm H2O
Gradient = 1.436E 02 Flow rate = 5.583E-05 cc/sec R squared = 0.99305
Permeability, K27.0° = 1.310E-08 cm/sec, K20° = 1.114E-08 cm/sec

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	14	0.0	0.0	7.2	51.0	41.8

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA			0.0038					

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SILTY CLAY, TR SAND	CL	

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 12-18-97

Remarks:
BORING: 111
DEPTH: 485.0'

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

Date: 12-18-97
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SILTY CLAY, TR SAND
USCS Class: CL   Liquid limit: NA
AASHTO Class: A-4   Plasticity index: NA

Notes

Remarks: BORING: 111 DEPTH: 485.0'

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	409.50
Tare =	0.00
Dry sample weight =	409.50

Sample split on number 10 sieve
Split sample data:
Sample and tare = 50 Tare = 0 Sample weight = 50
Cumulative weight retained tare= 0
'e for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
# 10	0.10	100.0
# 20	0.90	98.2
# 40	1.50	97.0
# 60	2.10	95.8
# 100	2.80	94.4
# 200	3.60	92.8

Hydrometer Analysis Data

Separation sieve is number 10
Percent -# 10 based on complete sample= 100.0
Weight of hydrometer sample: 50
Calculated biased weight= 50.01
Automatic temperature correction
Composite correction at 20 deg C =-3.5

Meniscus correction only= 1
Specific gravity of solids= 2.75

Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	23.0	46.0	43.2	0.0128	47.0	8.6	0.0374	84.4
2.0	23.0	43.5	40.7	0.0128	44.5	9.0	0.0271	79.6
3.0	23.0	42.0	39.2	0.0128	43.0	9.2	0.0224	76.6
4.0	23.0	41.0	38.2	0.0128	42.0	9.4	0.0196	74.7
8.0	23.0	39.0	36.2	0.0128	40.0	9.7	0.0141	70.8
16.0	23.0	36.0	33.2	0.0128	37.0	10.2	0.0102	64.9
30.0	23.0	33.0	30.2	0.0128	34.0	10.7	0.0076	59.0
60.0	23.5	31.0	28.3	0.0127	32.0	11.0	0.0054	55.4
125.0	24.0	28.0	25.5	0.0126	29.0	11.5	0.0038	49.8
330.0	24.0	25.0	22.5	0.0126	26.0	12.0	0.0024	43.9
1410.0	24.0	21.0	18.5	0.0126	22.0	12.7	0.0012	36.1
2850.0	24.0	19.5	17.0	0.0126	20.5	12.9	0.0009	33.2

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 7.2
% SILT = 51.0 % CLAY = 41.8 (% CLAY COLLOIDS = 34.5)

D85= 0.04 D60= 0.008 D50= 0.004

WEAVER BOOS CONSULTANTS, INC.
ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS
520 N. Michigan Ave., Chicago, IL 60611 • (312) 670-0041
1944 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-9609

WATER CONTENT DETERMINATION

Project: LEA COUNTY LANDFILL Job No.: 95042.10
Location of Project: HOBBS, NEW MEXICO Date of Testing: 12-4-97 THROUGH 12-18-97
Description of Soil: ______ Date of Weighing: ______
Tested By: JM

Boring No.	108	108	104	108	109	102	101
Sample No.	215'	100'	60.0'	150.0'	120.0'	20.0'	20.0'
Container No. (cup)	SS	AA	AN	AA	AN	A-12	A-12
Wt. of cup + wet soil	88.9	78.0	92.3	89.5	104.5	143.0	469.1
Wt. of cup + dry soil	82.7	67.9	84.7	82.2	97.3	138.5	451.6
Wt. of cup	14.7	15.1	14.8	15.1	14.9	16.0	15.9
Wt. of dry soil	68.0	52.8	69.9	67.1	82.4	122.5	435.7
Wt. of water	6.2	10.1	7.6	7.3	7.2	4.5	17.5
Water content (w)*%	9.1	19.1	10.9	10.9	8.7	3.7	4.0

Boring No.							
Sample No.							
Container No. (cup)							
Wt. of cup + wet soil							
Wt. of cup + dry soil							
Wt. of cup							
Wt. of dry soil							
Wt. of water							
Water content (w)* %							

*w = (wt. of water/wt. of dry soil)*100

Remarks:

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ORGANIC AND WATER CONTENT DETERMINATIONS
ASTM D2974

Project: LEA COUNTY LANDFILL
Location of Project: HOBBS, NEW MEXICO
Description of Soil:
Tested By: JM & WSG

Job No.: 95042.10
Date of Testing: 12-16-97 THROUGH 12-18-97
Date of Weighing:
Oven Temperature: 60°C
Furnace Temperature: 440°C

MOISTURE CONTENT

Boring No.	111	103	104	111	110		
Sample No.	140.0'	5.0'	4.0'	485.0'	90.0'		
Container No. (cup)	45	106	222	TZ	45		
Wt. of cup + wet soil	127.8	94.5	118.9	98	188.1		
Wt. of cup + dry soil	121.6	92.9	117.8	89.3	175.1		
Wt. of cup	48.7	51.4	54.4	14.8	48.6		
Wt. of dry soil	72.9	41.5	63.4	74.5	126.5		
Wt. of water	6.2	1.6	1.1	8.7	13		
Water content (w)*%	8.5	3.9	1.7	11.7	10.3		

ORGANIC CONTENT

Boring No.	111	103	104	111	110		
Sample No.	140.0'	5.0'	4.0'	485.0'	90.0'		
Container No. (cup)	45	106	222	190	45		
Init. wt. of cup + oven dry soil	121.6	92.9	117.8	126.9	175.1		
Final wt. of cup + burnt soil	119.4	92.5	117.4	124.3	169.9		
Wt. of cup	48.7	51.4	54.4	52.4	48.6		
Wt. of oven dry soil	72.9	41.5	63.4	74.5	126.5		
Wt. Loss	2.2	0.4	0.4	2.6	5.2		
Organic content (LOI)**%	3.0	1.0	0.6	3.5	4.1		

*w = (wt. of water/wt. of dry soil)*100
**LOI = (wt. loss/wt. of dry soil)*100

Remarks:

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ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS
520 N. Michigan Ave., Chicago, IL 60611 • (312) 670-0041
1944 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-9609

ORGANIC AND WATER CONTENT DETERMINATIONS
ASTM D2974

Project: LEA COUNTY LANDFILL
Job No.: 95042.10
Location of Project: HOBBS, NEW MEXICO
Date of Testing: 12-3-97 THROUGH 12-16-97
Description of Soil:
Date of Weighing:
Tested By: JM & WSG
Oven Temperature: 60°C
Furnace Temperature: 440°C

MOISTURE CONTENT

Boring No.	109	108	111	110	110	111	
Sample No.	80.0'	60.0'	200.0'	350.0'	230.0'	80.0'	
Container No. (cup)	190	106	45	45	106	190	
Wt. of cup + wet soil	113.8	121.8	134.7	124.9	137.5	159.2	
Wt. of cup + dry soil	106.5	117.8	123.7	115.5	131.0	145.5	
Wt. of cup	52.4	51.4	48.7	48.7	51.4	52.4	
Wt. of dry soil	54.1	66.4	75.0	66.8	79.6	93.1	
Wt. of water	7.3	4.0	11.0	9.4	6.5	13.7	
Water content (w)*%	13.5	6.0	14.7	14.1	8.2	14.7	

ORGANIC CONTENT

Boring No.	109	108	111	110	110	111	
Sample No.	80.0'	60.0'	200.0'	350.0'	230.0'	80.0'	
Container No. (cup)	190	106	45	45	106	190	
Init. wt. of cup + oven dry soil	106.5	117.8	123.7	115.5	131.0	145.5	
Final wt. of cup + burnt soil	103.0	117.1	121.4	113.6	129.4	140.6	
Wt. of cup	52.4	51.4	48.7	48.7	51.4	52.4	
Wt. of oven dry soil	54.1	66.4	75.0	66.8	79.6	93.1	
Wt. Loss	3.5	0.7	2.3	1.9	1.6	4.9	
Organic content (LOI)**%	6.5	1.1	3.1	2.8	2.0	5.3	

*w = (wt. of water/wt. of dry soil)*100
**LOI = (wt. loss/wt. of dry soil)*100

Remarks:

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SPECIFIC GRAVITY TESTS
ASTM D854

Project: LEA COUNTY LANDFILL Job No.: 95042.10
Location of Project: HOBBS, NEW MEXICO Date of Testing: 12-8-97 THROUGH 12-22-
Description of Soil: ______ Date of Weighing: ______
Tested By: WSG

Jar No.	1	2	3	4	5	1	1
Boring No.	B-104	B-108	B-109	B-111	B-110	B-110	B-111
Depth	60.0'	60.0'	80.0'	200.0'	350.0'	230.0'	80.0'
Oven Dry Wt. (A) g	130.6	117.8	130.5	110.7	113.7	112.6	111.0
Wt. Pycn & Water (B) g	1440.0	1440.0	1440.0	1440.0	1440.0	1440.7	1440.1
Wt. Pycn, Water & Soil (C) g	1522.3	1514.5	1521.6	1510.8	1512.9	1511.3	1510
Temperature °C	23	23	23	23	23	19.0	23.5
Temp. Correction (D)	0.9993	0.9993	0.9993	0.9993	0.9993	1.0002	0.9992
Specific Gravity	2.70	2.72	2.68	2.77	2.79	2.68	2.70

Jar No.	2	3	4	5	1		
Boring No.	B-111	B-104	B-111	B-103	B-110		
Depth	140.0'	4.0'	485.0'	5.0'	90.0'		
Oven Dry Wt. (A) g	115.7	102.0	110.3	81.3	103.3		
Wt. Pycn & Water (B) g	1440.1	1440.1	1440.1	1440.1	1440.0		
Wt. Pycn, Water & Soil (C) g	1513.0	1504.0	1510.3	1491.6	1505.6		
Temperature °C	23.5	23.5	23.5	23.5	23.0		
Temp. Correction (D)	0.9992	0.9992	0.9992	0.9992	0.9993		
Specific Gravity	2.70	2.68	2.75	2.73	2.74		

$$\text{SPECIFIC GRAVITY}_{20^\circ} = \frac{A \times D}{A + B - C}$$

Remarks:

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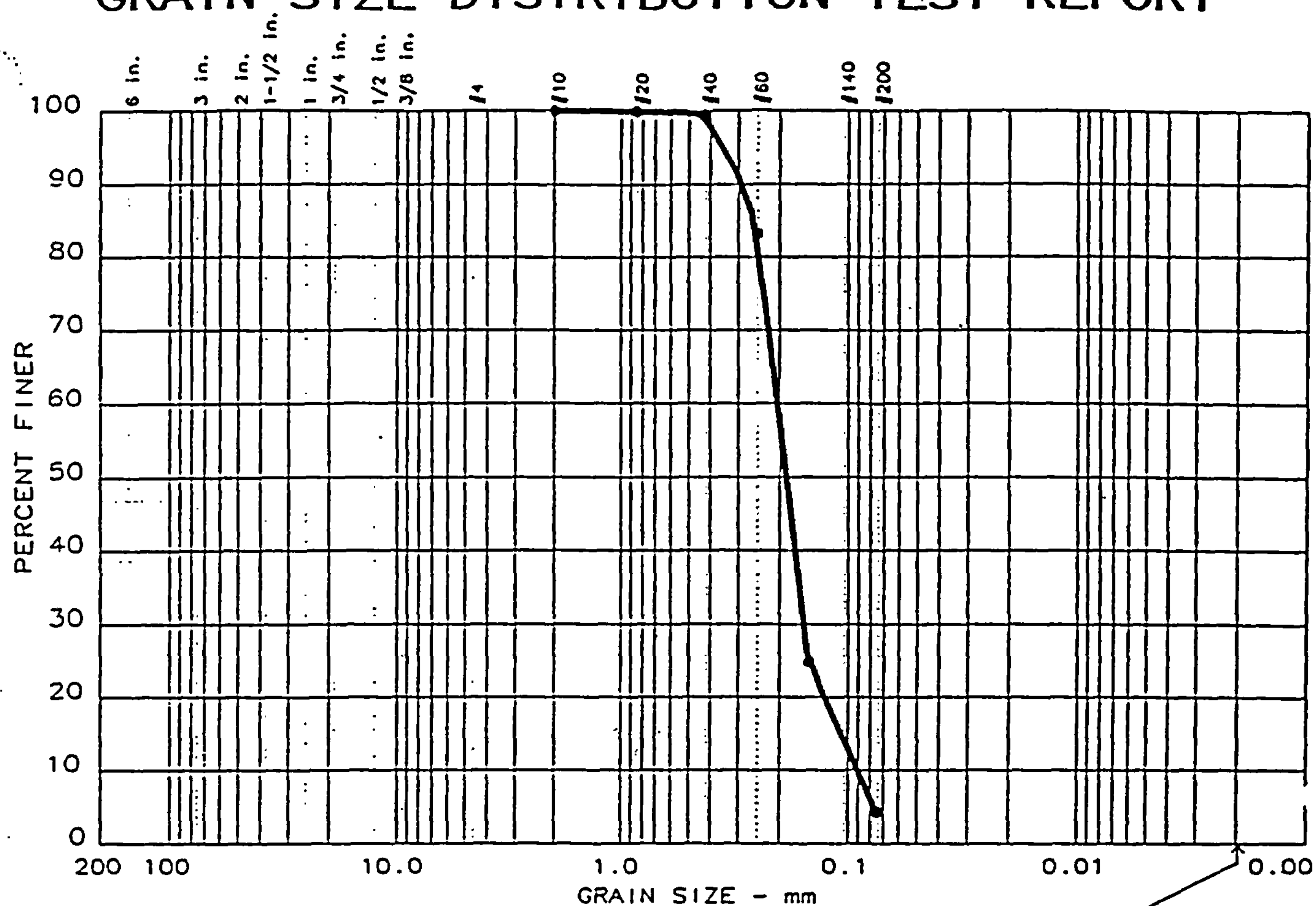
GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	18	0.0	0.0	95.7	4.3	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.258	0.204	0.187	0.157	0.107	0.0902	1.34	2.3

MATERIAL DESCRIPTION	USCS	AASHTO
● REDISH BROWN SAND	SP	A-3

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-7-98

Remarks:
SAND #1
3.0' BGS

GRAIN SIZE DISTRIBUTION TEST REPORT

WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA

Test No.: _

Date: 1-7-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: REDISH BROWN SAND
USCS Class: SP
AASHTO Class: A-3
Liquid limit: NA
Plasticity index: NA

Notes

Remarks: SAND #1 3.0' BGS

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	423.80
Tare =	0.00
Dry sample weight =	423.80

Tare for cumulative weight retained= 0

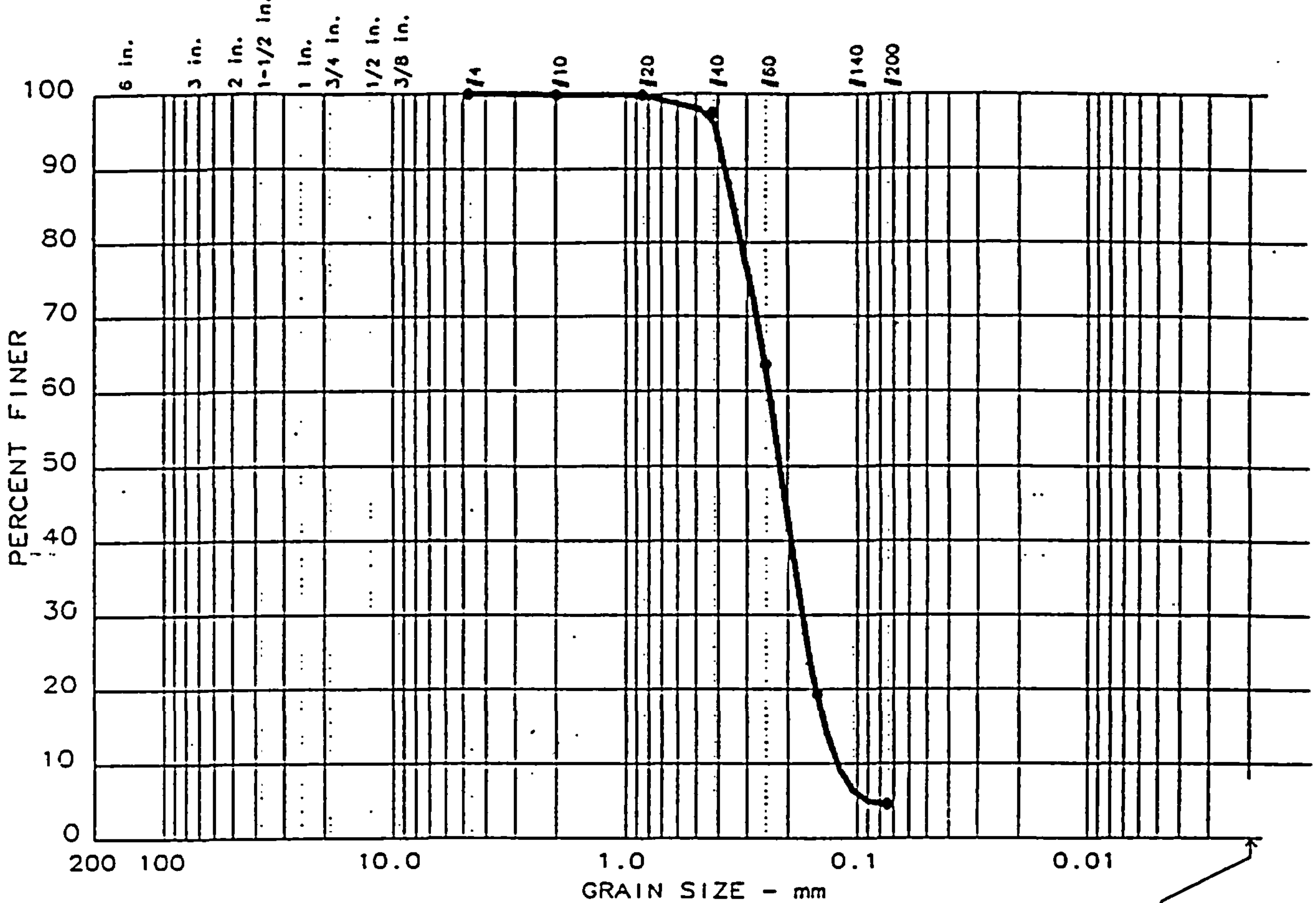
Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
20	0.30	99.9
40	2.60	99.4
# 60	71.20	83.2
# 100	318.10	24.9
# 200	405.40	4.3

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 95.7
% FINES = 4.3

D85= 0.26 D60= 0.204 D50= 0.187
D30= 0.1567 D15= 0.10715 D10= 0.09016
Cc = 1.3351 Cu = 2.2620

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	16	0.0	0.0	95.4	4.6	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.343	0.240	0.216	0.173	0.139	0.122	1.02	2.0

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SAND	SP	A-3

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-7-98

Remarks:
SAND #3
SURFACE

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 16

Date: 1-7-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SAND
USCS Class: SP
AASHTO Class: A-3
Liquid limit: NA
Plasticity index: NA

Notes

Remarks: SAND #3 SURFACE

Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 418.70
Tare = 0.00
Dry sample weight = 418.70
Tare for cumulative weight retained= 0

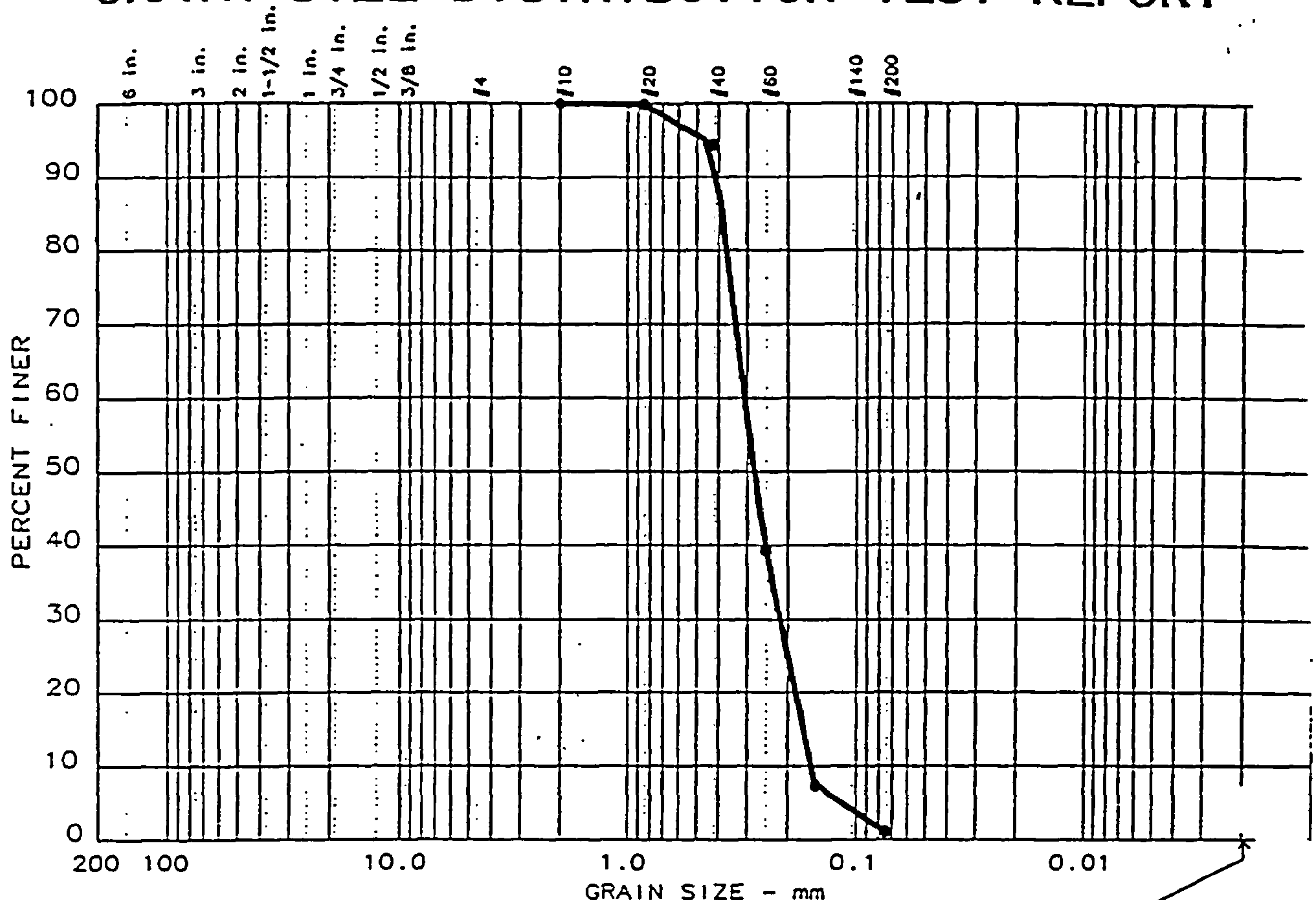
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
10	0.30	99.9
20	0.70	99.8
# 40	10.60	97.5
# 60	152.50	63.6
# 100	337.70	19.3
# 200	399.60	4.6

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 95.4
% FINES = 4.6

D85= 0.34 D60= 0.240 D50= 0.216
D30= 0.1732 D15= 0.13868 D10= 0.12218
Cc = 1.0233 Cu = 1.9634

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	17	0.0	0.0	98.9	1.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	NA	NA	0.389	0.308	0.280	0.215	0.169	0.156	0.96	2.0

MATERIAL DESCRIPTION	USCS	AASHTO
● RED SAND	SP	A-3

Project No.: 95042.10
Project: LEA COUNTY LANDFILL
● Location: HOBBS, NEW MEXICO

Date: 1-7-98

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Remarks:
SAND #5
SURFACE

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 17

Date: 1-7-98
Project No.: 95042.10
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: HOBBS, NEW MEXICO
Sample Description: RED SAND
USCS Class: SP Liquid limit: NA
AASHTO Class: A-3 Plasticity index: NA

Notes

Remarks: SAND #5 SURFACE

Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	438.70
Tare =	0.00
Dry sample weight =	438.70

Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
# 10	0.00	100.0
20	0.60	99.9
40	24.40	94.4
# 60	266.30	39.3
# 100	406.60	7.3
# 200	434.00	1.1

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 98.9
% FINES = 1.1

D85= 0.39 D60= 0.308 D50= 0.280
D30= 0.2153 D15= 0.16904 D10= 0.15649
Cc = 0.9605 Cu = 1.9702

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Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL

Location of Project: HOBBS, NM

Description of Soil: RED SAND

Job No.: 95042.10

Date of Testing: JAN. 6, 1998

Tested By.: WSG

Sample Number	Reading Number	Sample Information		Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
		Length, cm	Area, cm2								
SAND #1	1	11.0	81.07	1/6/98	99.70			540	190	4.79E-04	
3.0' BGS	2	11.0	81.07	1/6/98	99.70			660	210	4.33E-04	
	3	11.0	81.07	1/6/98	99.70			600	180	4.08E-04	
	Average										4.40E-04

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Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL
Job No.: 95042.10
Location of Project: HOBBS, NM
Date of Testing: JAN. 6, 1998
Description of Soil: RED SAND
Tested By.: WSG

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
SAND #3	1	10.0	81.07	1/6/98	99.70			300	110	4.54E-04	
SURFACE	2	10.0	81.07	1/6/98	99.70			300	90	3.71E-04	
	3	10.0	81.07	1/6/98	99.70			300	85	3.51E-04	
	Average										3.92E-04

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Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL
Location of Project: HOBBS, NM
Description of Soil: RED SAND

Job No.: 95042.10
Date of Testing: JAN. 6, 1998
Tested By.: JWM

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
SAND #5	1	10.0	81.07	1/6/98	99.70			540	180	4.12E-04	
SURFACE	2	10.0	81.07	1/6/98	99.70			540	170	3.89E-04	
	3	10.0	81.07	1/6/98	99.70			540	165	3.78E-04	
	Average										3.93E-04

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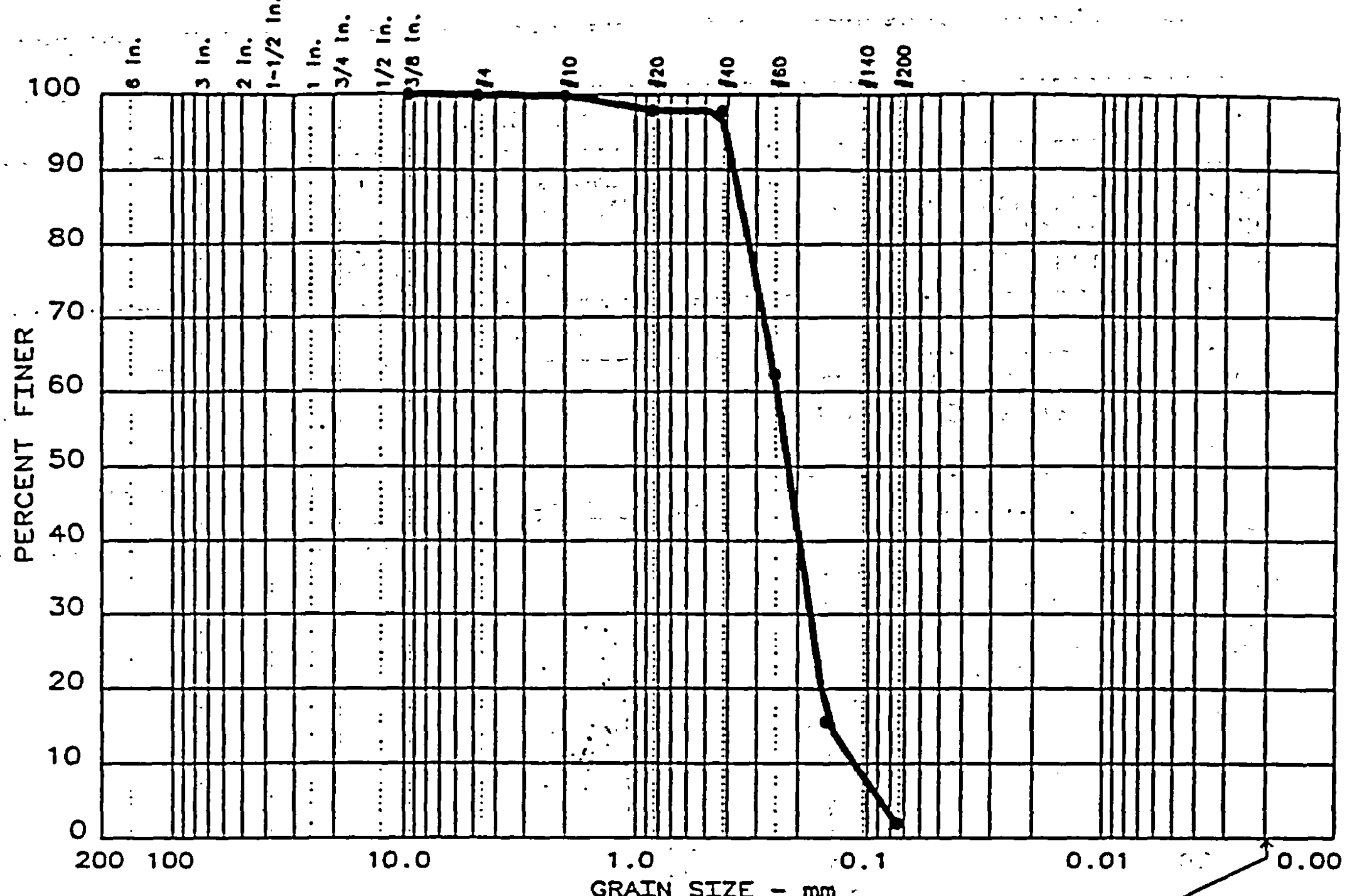
GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	5	0.0	0.0	98.0	2.0	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.349	0.244	0.218	0.175	0.144	0.112	1.13	2.2

MATERIAL DESCRIPTION	USCS	AASHTO
● REDDISH BRN SAND, TR SILT	SP	A-3

Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL
● Location: LEA COUNTY, ILLINOIS

Date: 7-21-98

GRAIN SIZE DISTRIBUTION TEST REPORT

WEAVER BOOS CONSULTANTS, INC.

Remarks:

SAMPLE: 1A

UNWASHED

BORING: 500S OW

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA — Test No.: 5

Date: 7-21-98
Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: LEA COUNTY, ILLINOIS
Sample Description: REDDISH BRN SAND, TR SILT
USCS Class: SP — Liquid limit:
AASHTO Class: A-3 — Plasticity index:

Notes

Remarks: SAMPLE: 1A UNWASHED
BORING: 500S 0W
Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	323.20
Tare =	0.00
Dry sample weight =	323.20

Tare for cumulative weight retained= 0

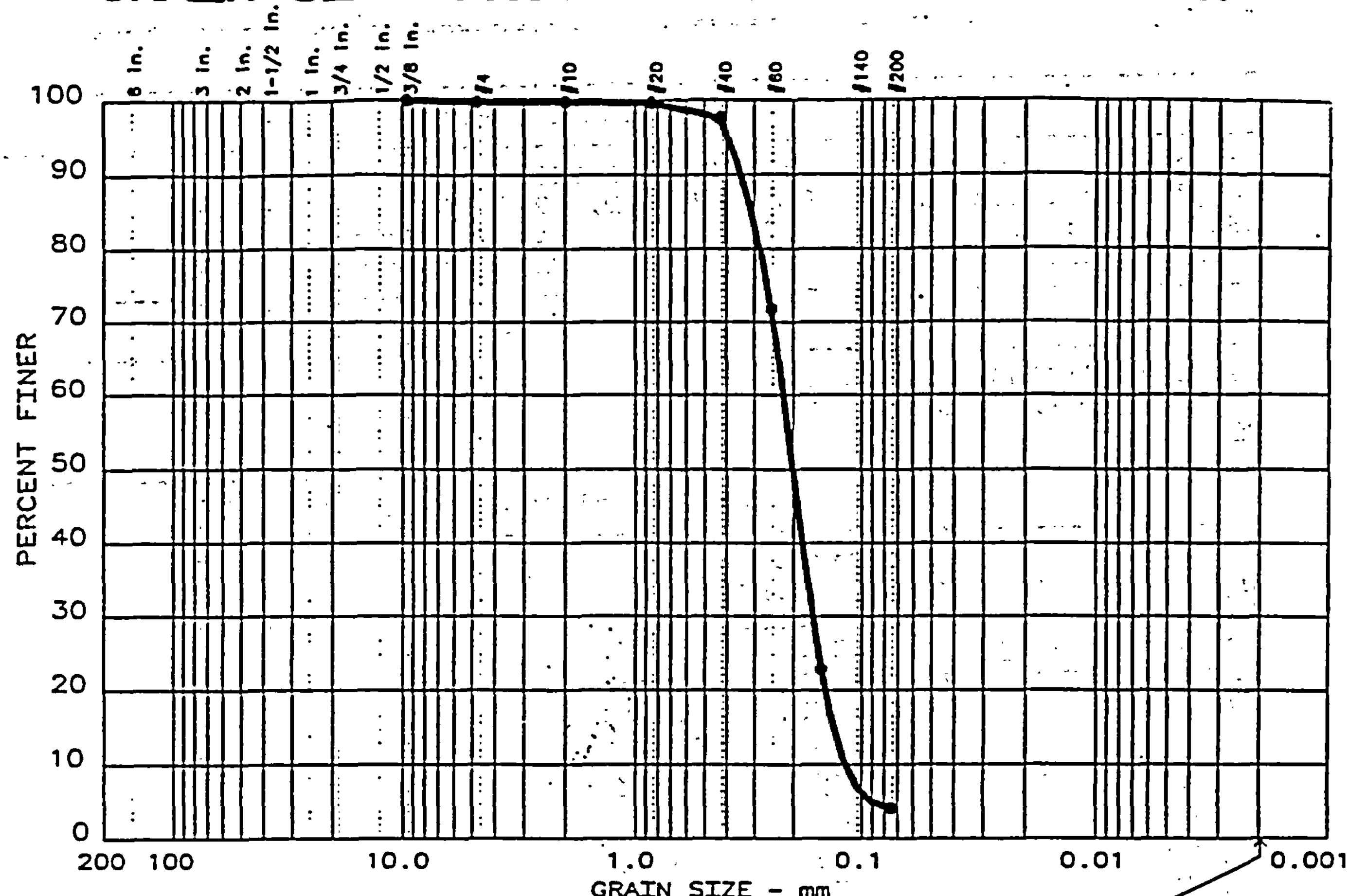
Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
4	0.10	100.0
10	0.30	99.9
# 20	6.80	97.9
# 40	7.20	97.8
# 60	121.50	62.4
# 100	272.50	15.7
# 200	316.80	2.0

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 98.0
% FINES = 2.0

D85= 0.35 D60= 0.244 D50= 0.218
D30= 0.1754 D15= 0.14421 D10= 0.11194
Cc = 1.1285 Cu = 2.1752

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	6	0.0	0.2	95.7	4.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.308	0.220	0.200	0.163	0.132	0.117	1.03	1.9

MATERIAL DESCRIPTION	USCS	AASHTO
● REDDISH BRN SAND, TR SILT	SP	A-3

Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL
● Location: LEA COUNTY, ILLINOIS

Date: 7-21-98

Remarks:
SAMPLE: 2A
UNWASHED
BORING: 500S 210W

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA

Test No.: 6

Date: 7-21-98
Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: LEA COUNTY, ILLINOIS
Sample Description: REDDISH BRN SAND, TR SILT
USCS Class: SP
AASHTO Class: A-3
Liquid limit:
Plasticity index:

Notes

Remarks: SAMPLE: 2A UNWASHED
BORING: 500S 210W
Fig. No.:

Mechanical Analysis Data

Initial
Dry sample and tare= 312.90
Tare = 0.00
Dry sample weight = 312.90
Tare for cumulative weight retained= 0

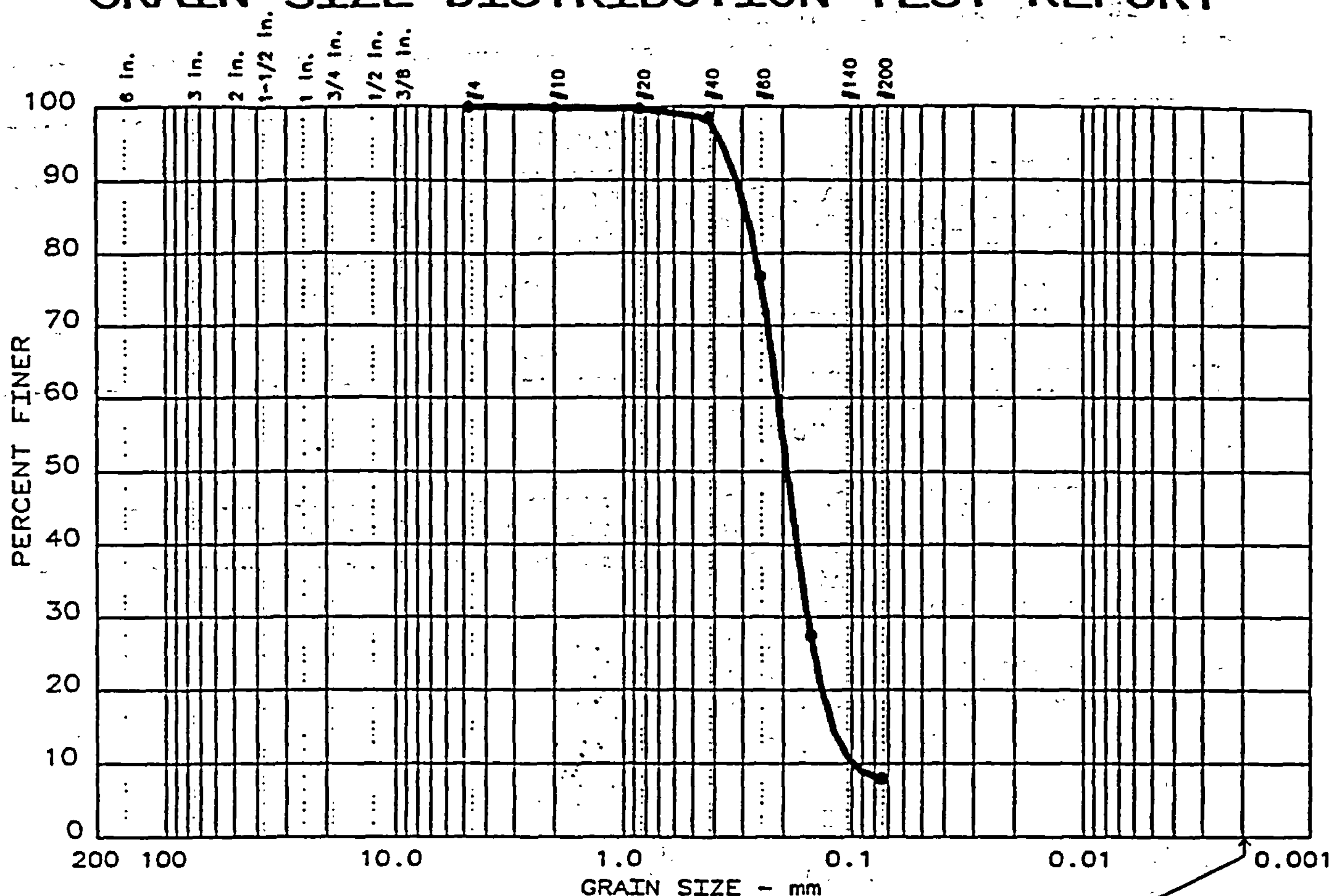
Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
4	0.50	99.8
10	0.70	99.8
# 20	1.30	99.6
# 40	7.50	97.6
# 60	88.20	71.8
# 100	241.30	22.9
# 200	300.10	4.1

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.2 % SAND = 95.7
% FINES = 4.1

D85= 0.31 D60= 0.220 D50= 0.200
D30= 0.1633 D15= 0.13213 D10= 0.11722
Cc = 1.0328 Cu = 1.8793

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	7	0.0	0.0	92.0	8.0	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.284	0.209	0.190	0.155	0.120	0.0986	1.16	2.1

MATERIAL DESCRIPTION	USCS	AASHTO
● REDDISH BRN SAND, TR SILT	SP-SM	A-3

Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL
● Location: LEA COUNTY, ILLINOIS

Date: 7-21-98

Remarks:
SAMPLE: 3A
UNWASHED
BORING: 500S 700W

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA   Test No.: 7

Date: 7-21-98
Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: LEA COUNTY, ILLINOIS
Sample Description: REDDISH BRN SAND, TR SILT
USCS Class: SP-SM   Liquid limit:
AASHTO Class: A-3   Plasticity index:

Notes

Remarks: SAMPLE: 3A UNWASHED
BORING: 500S 700W
Fig. No.:-

Mechanical Analysis Data

Initial
Dry sample and tare= 298.20
Tare = 0.00
Dry sample weight = 298.20
Tare for cumulative weight retained= 0

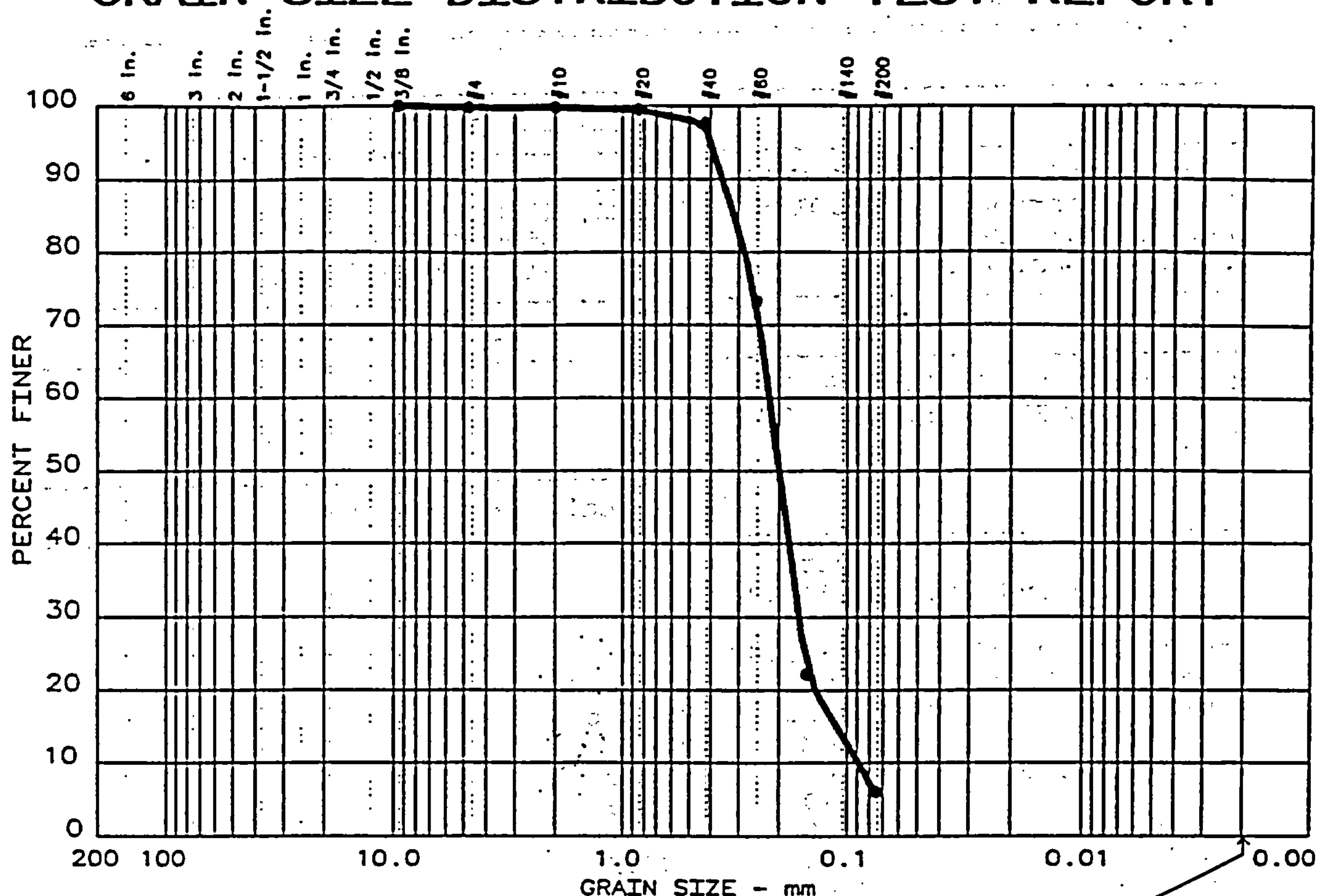
Sieve	Cumul. Wt. retained	Percent finer
# 4	0.00	100.0
10	0.50	99.8
20	0.90	99.7
# 40	4.70	98.4
# 60	69.20	76.8
# 100	216.40	27.4
# 200	274.30	8.0

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0   % GRAVEL = 0.0   % SAND = 92.0
% FINES = 8.0

D85= 0.28 D60= 0.209 D50= 0.190
D30= 0.1545 D15= 0.11995 D10= 0.09863
Cc = 1.1574 Cu = 2.1208

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	8	0.0	0.1	93.8	6.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.313	0.219	0.198	0.162	0.110	0.0880	1.36	2.5

MATERIAL DESCRIPTION	USCS	AASHTO
● REDDISH BRN SAND, TR SILT	SP-SM	A-3

Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL
● Location: LEA COUNTY, ILLINOIS

Date: 7-21-98

Remarks:
SAMPLE: 4A
UNWASHED
BORING: 500S 1200W

GRAIN SIZE DISTRIBUTION TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Figure No. ______

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 8

Date: 7-21-98
Project No.: 0016-02-05
Project: LEA COUNTY LANDFILL

Sample Data

Location of Sample: LEA COUNTY, ILLINOIS
Sample Description: REDDISH BRN SAND, TR SILT
USCS Class: SP-SM Liquid limit:
AASHTO Class: A-3 Plasticity index:

Notes

Remarks: SAMPLE: 4A UNWASHED
BORING: 500S 1200W
Fig. No.:

Mechanical Analysis Data

	Initial
Dry sample and tare=	319.40
Tare =	0.00
Dry sample weight =	319.40

Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	Percent finer
0.375 inches	0.00	100.0
4	0.40	99.9
10	0.70	99.8
# 20	1.70	99.5
# 40	7.60	97.6
# 60	85.40	73.3
# 100	248.40	22.2
# 200	300.00	6.1

Fractional Components

Gravel/Sand based on #4 sieve
Sand/Fines based on #200 sieve
% + 3 in. = 0.0 % GRAVEL = 0.1 % SAND = 93.8
% FINES = 6.1

D85= 0.31 D60= 0.219 D50= 0.198
D30= 0.1620 D15= 0.10952 D10= 0.08800
Cc = 1.3630 Cu = 2.4860

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Constant Head Permeability Test (ASTM D 2434)

Project: **Lea County Landfill**
Job No.: **0016-02-05**
Location of Project: **Lea County, Ilinois**
Date of Testing: **7-17-98**
Description of Soil: **Reddish Brn Sand, TR Silt**
Tested By.: **JWM**
Classification: **USCS: SP AASHTO: A-3**
Remarks: **Sample: 1 Washed**
Boring: 500S 0W

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
	1	7.0	20.27	7/17/98	119.00			300	690	6.67E-03	
	2	7.0	20.27	7/17/98	119.00			840	1570	5.42E-03	
	3	7.0	20.27	7/17/98	119.00			360	595	4.80E-03	
	4	7.0	20.70	7/17/98	119.00			420	650	4.40E-03	
	Average										5.32E-03

PERMEABILITY TEST REPORT

TEST DATA:

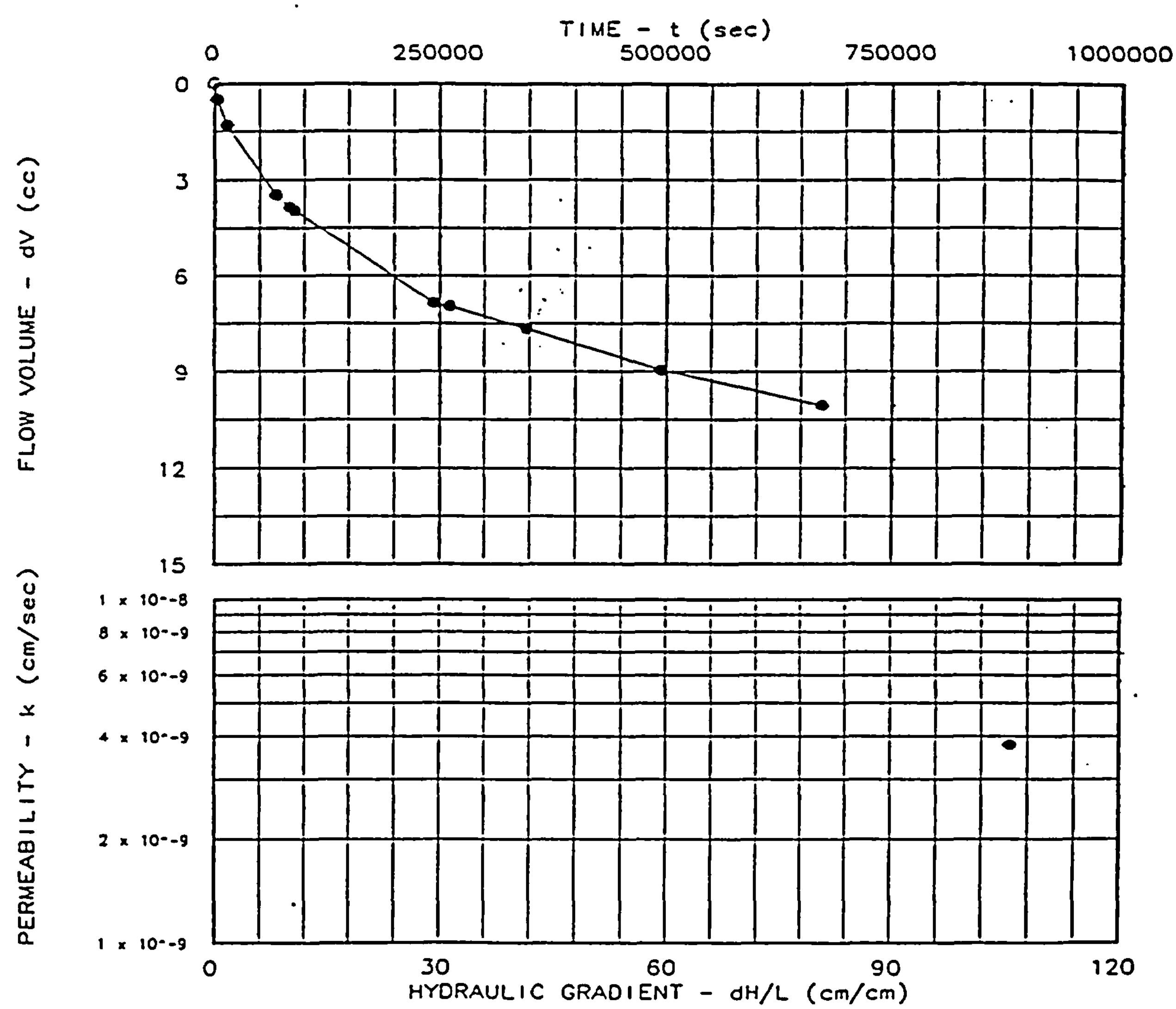
Specimen Height (cm): 7.29
Specimen Diameter (cm): 6.07
Dry Unit Weight (pcf): 114.7
Moisture Before Test (%): 15.9
Moisture After Test (%): 23.7
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 36.0
Test Pressure(psi): 27.0
Back Pressure(psi): 16.0
Diff. Head (psi): 11.0
Flow Rate (cc/sec): 1.36 x 10--5
Perm. (cm/sec): 3.78 x 10--9

SAMPLE DATA:

Sample Identification: BORING: 111
DEPTH: 80.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-16-97

Project No.: 95042.10
File No.: 95042.10
Lab No.: 2
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST REPORT

WEAVER BOOS CONSULTANTS, INC.

PERMEABILITY TEST DATA

PROJECT DATA

...ect Name:	LEA COUNTY LANDFILL
... No.:	95042.10
...ject Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 111 DEPTH: 80.0'
Lab No.:	2
Description:	RED SILTY CLAY, TR SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-16-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test:			After test:		
...ameter:	1	2		1	2	
Top:	in	in		in	in	
Middle:	2.389 in	in		2.510 in	in	
Bottom:	in	in		in	in	
Average:	2.39 in	6.07 cm		2.51 in	6.38 cm	
Length:	1	2	3	1	2	3
	2.870 in	in	in	2.898 in	in	in
Average:	2.87 in	7.29 cm		2.90 in	7.36 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.70	
Wet Wt. & Tare:	448.90	479.40
Dry Wt. & Tare:	387.40	387.40
Tare Wt.:	0.00	0.00
Moisture Content:	15.9 %	23.7 %
Dry Unit Weight:	114.7 pcf	102.9 pcf
Porosity:	0.3194	0.3894
Saturation:	91.3 %	100.5 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 2 Panel No.: Positions:

Run Number:	1	2
Cell Pressure:	36.0 psi	0.0 psi
Saturation Pressure:	35.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D X S R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	GAUGE PRESSURE-psi OUT	BURET READING-cc IN	BURET READING-cc OUT	FLOW VOLUME-cc AVERAGE
S X	12/23/97	13:03:00	0	27.0	17.0	7.80	77.50	0.00
	12/23/97	14:02:00	3,540	27.0	17.0	8.30	77.00	0.50
	12/23/97	17:03:00	14,400	27.0	17.0	9.20	76.30	1.30
	12/24/97	7:48:00	67,500	27.0	17.0	11.80	74.60	3.45
	12/24/97	12:10:00	83,220	27.0	17.0	12.20	74.20	3.85
	12/24/97	13:30:00	88,020	27.0	17.0	12.30	74.10	3.95
	12/26/97	8:39:00	243,360	27.0	17.0	15.80	71.80	6.85
	12/26/97	13:37:00	261,240	27.0	17.0	15.90	71.70	6.95
	12/27/97	13:08:00	345,900	27.0	17.0	16.60	71.00	7.65
	12/29/97	6:16:00	493,980	27.0	17.0	18.00	69.80	8.95
	12/31/97	8:03:00	673,200	27.0	17.0	19.20	68.80	10.05

Test Pressure = 27.0 psi Differential Head = 11.0 psi, 770.1 cm H2O
Gradient = 1.056E 02 Flow rate = 1.359E-05 cc/sec R squared = 0.88804
Permeability, K27.0° = 4.449E-09 cm/sec, K20° = 3.783E-09 cm/sec

PERMEABILITY TEST REPORT

TEST DATA:

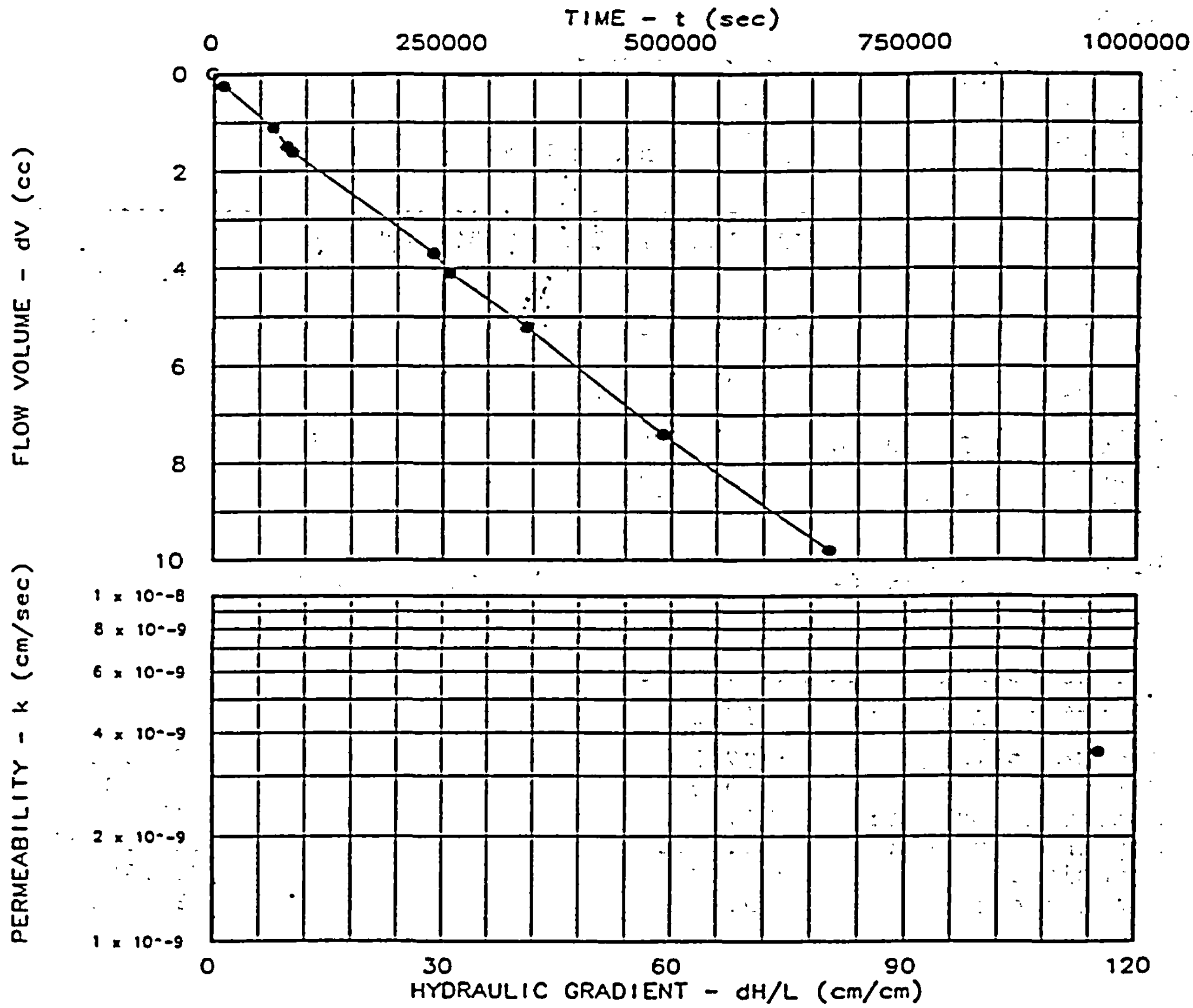
Specimen Height (cm): 6.79
Specimen Diameter (cm): 6.20
Dry Unit Weight (pcf): 118.0
Moisture Before Test (%): 11.0
Moisture After Test (%): 17.0
Run Number: 1 ● 2 ▲
Cell Pressure (psi): 38.0
Test Pressure(psi): 27.0
Back Pressure(psi): 15.9
Diff. Head (psi): 11.1
Flow Rate (cc/sec): 1.44 x 10--5
Perm. (cm/sec): 3.52 x 10--9

SAMPLE DATA:

Sample Identification: BORING: 111
DEPTH: 140.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL Location: HOBBS, NEW MEXICO Date: 12-16-97	Project No.: 95042.10 File No.: 95042.10 Lab No.: 3
PERMEABILITY TEST REPORT WEAVER BOOS CONSULTANTS, INC.	Tested by: JWM Checked by: WSG Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name:	LEA COUNTY LANDFILL
File No.:	95042.10
Project Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 111 DEPTH: 140.0'
Lab No.:	3
Description:	RED SILTY CLAY, TR SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-16-97
Remarks:	

Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	Before test: 2	Before test: 3	After test: 1	After test: 2	After test: 3
Diameter:						
Top:	in	in		in	in	
Middle:	2.440 in	in		2.463 in	in	
Bottom:	in	in		in	in	
Average:	2.44 in	6.20 cm		2.46 in	6.26 cm	
Length:	2.675 in	in	in	2.690 in	in	in
Average:	2.68 in	6.79 cm		2.69 in	6.83 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.70	
Wet Wt. & Tare:	430.00	453.20
Dry Wt. & Tare:	387.30	387.30
Tare Wt.:	0.00	0.00
Moisture Content:	11.0 %	17.0 %
Dry Unit Weight:	118.0 pcf	115.1 pcf
Porosity:	0.3002	0.3170
Saturation:	69.4 %	99.0 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 2 Panel No.: Positions:

Run Number:	1	2
Cell Pressure:	38.0 psi	0.0 psi
Saturation Pressure:	35.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D S	X R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S	X	12/23/97	14:03:00	0	27.0	17.0	5.70	83.10	0.00
		12/23/97	17:04:00	10,860	27.0	17.0	6.10	83.00	0.25
		12/24/97	7:49:00	63,960	27.0	17.0	7.00	82.20	1.10
		12/24/97	12:11:00	79,680	27.0	17.0	7.40	81.80	1.50
		12/24/97	13:31:00	84,480	27.0	17.0	7.50	81.70	1.60
		12/26/97	8:40:00	239,820	27.0	17.0	9.60	79.60	3.70
		12/26/97	13:38:00	257,700	27.0	17.0	10.00	79.20	4.10
		12/27/97	13:09:00	342,360	27.0	17.0	11.00	78.00	5.20
		12/29/97	6:17:00	490,440	27.0	17.0	13.00	75.60	7.40
		12/31/97	8:04:00	669,660	27.0	17.0	15.20	73.00	9.80

Test Pressure = 27.0 psi Differential Head = 11.1 psi, 782.3 cm H2O
Gradient = 1.151E 02 Flow rate = 1.439E-05 cc/sec R squared = 0.99888
Permeability, K27.0° = 4.143E-09 cm/sec, K20° = 3.523E-09 cm/sec

PERMEABILITY TEST REPORT

TEST DATA:

Specimen Height (cm): 7.43
Specimen Diameter (cm): 5.99
Dry Unit Weight (pcf): 108.6
Moisture Before Test (%): 14.6
Moisture After Test (%): 24.7

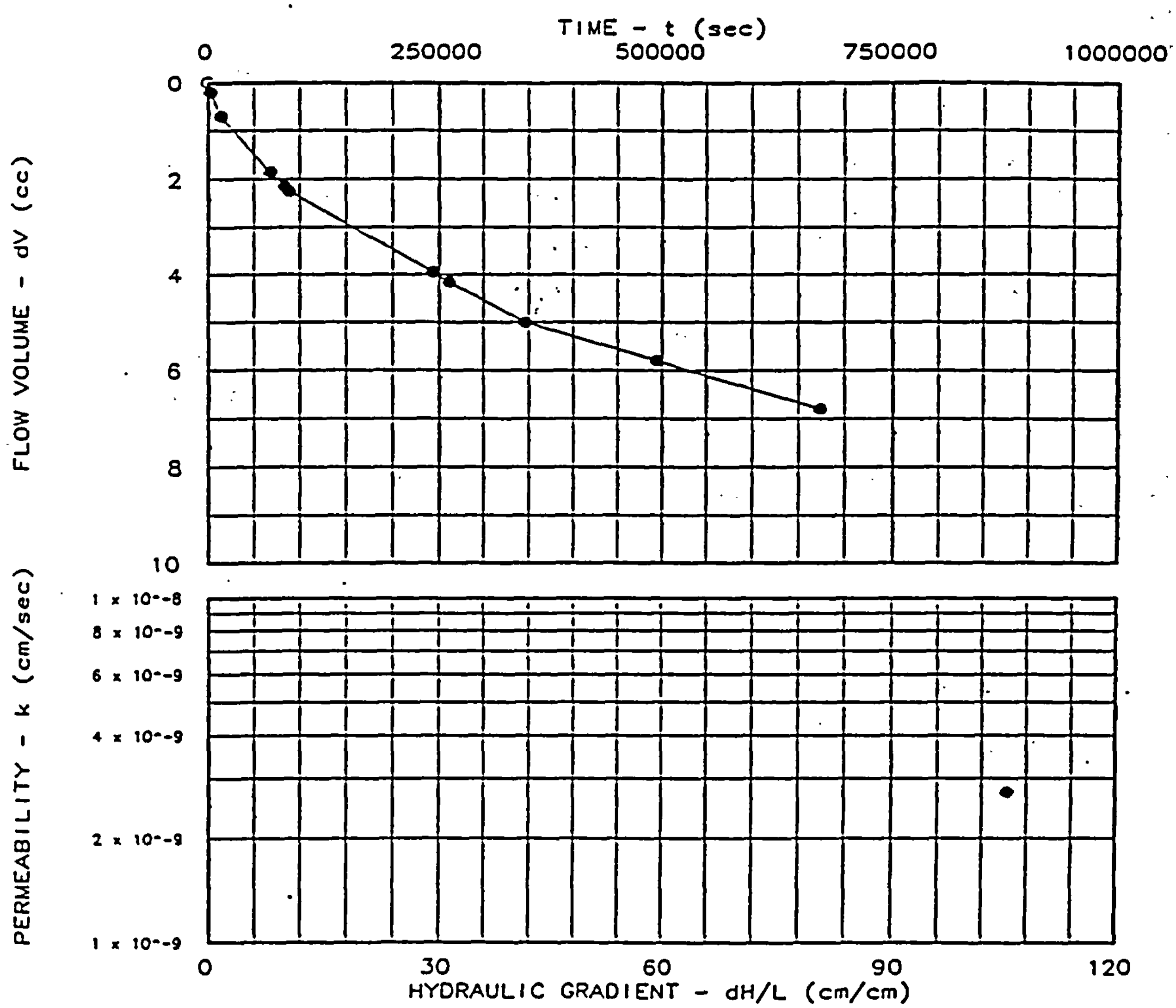
Run Number:	1 ●	2 ▲
Cell Pressure (psi):	39.0	
Test Pressure(psi):	27.0	
Back Pressure(psi):	15.9	
Diff. Head (psi):	11.1	
Flow Rate (cc/sec):	9.54 x 10^-6	
Perm. (cm/sec):	2.73 x 10^-9	

SAMPLE DATA:

Sample Identification: BORING: 111
DEPTH: 485.0'
Visual Description: RED SILTY CLAY, TR SAND
Remarks:

Maximum Dry Density (pcf):
Optimum Moisture Content (%):

Percent Compaction:
Permeameter type: FLEXIBLE WALL
Sample type: CORE



Project: LEA COUNTY LANDFILL
Location: HOBBS, NEW MEXICO
Date: 12-16-97

PERMEABILITY TEST REPORT
WEAVER BOOS CONSULTANTS, INC.

Project No.: 95042.10
File No.: 95042.10
Lab No.: 4
Tested by: JWM
Checked by: WSG
Test: CH - Constant head

PERMEABILITY TEST DATA

PROJECT DATA

Project Name:	LEA COUNTY LANDFILL
File No.:	95042.10
Project Location:	HOBBS, NEW MEXICO
Project No.:	95042.10
Sample Identification:	BORING: 111 DEPTH: 485.0'
Lab No.:	4
Description:	RED SILTY CLAY, TR SAND
Sample Type:	CORE
Max. Dry Dens.:	
Method (D1557/D698):	
Opt. Water Content:	
Date:	12-16-97
Remarks:	
Permeameter Type:	FLEXIBLE WALL
Tested by:	JWM
Checked by:	WSG
Test type:	CH - Constant head

PERMEABILITY TEST SPECIMEN DATA

	Before test: 1	2	3	After test: 1	2	3
Diameter:						
Top:	in	in		in	in	
Middle:	2.360 in	in		2.430 in	in	
Bottom:	in	in		in	in	
Average:	2.36 in	5.99 cm		2.43 in	6.17 cm	
Length:	2.925 in	in	in	2.922 in	in	in
Average:	2.93 in	7.43 cm		2.92 in	7.42 cm	

Moisture, Density and Sample Parameters:

	Before test	After test
Specific Gravity:	2.75	
Wet Wt. & Tare:	418.00	454.80
Dry Wt. & Tare:	364.70	364.70
Tare Wt.:	0.00	0.00
Moisture Content:	14.6 %	24.7 %
Dry Unit Weight:	108.6 pcf	102.5 pcf
Porosity:	0.3675	0.4028
Saturation:	69.2 %	100.7 %

CONSTANT HEAD PERMEABILITY TEST CONDITIONS DATA

Cell No.: 4 Panel No.: Positions:

Run Number:	1	2
Cell Pressure:	39.0 psi	0.0 psi
Saturation Pressure:	35.0 psi	0.0 psi
Inflow Corr. Factor:	1.00	1.00
Outflow Corr. Factor:	1.00	1.00
Test Temperature:	27.0 °C	0.0 °C

PERMEABILITY TEST READINGS DATA

CASE D S	X R	DATE	TIME (24 hr)	ELAPSED TIME-sec	GAUGE PRESSURE-psi IN	OUT	BURET READING-cc IN	OUT	FLOW VOLUME-cc AVERAGE
S	X	12/23/97	13:04:00	0	27.0	17.0	7.70	84.40	0.00
		12/23/97	14:03:00	3,540	27.0	17.0	7.90	84.20	0.20
		12/23/97	17:04:00	14,400	27.0	17.0	8.60	83.90	0.70
		12/24/97	7:49:00	67,500	27.0	17.0	10.00	83.00	1.85
		12/24/97	12:11:00	83,220	27.0	17.0	10.30	82.70	2.15
		12/24/97	13:31:00	88,020	27.0	17.0	10.40	82.60	2.25
		12/26/97	8:41:00	243,420	27.0	17.0	12.00	80.80	3.95
		12/26/97	13:39:00	261,300	27.0	17.0	12.20	80.60	4.15
		12/27/97	13:09:00	345,900	27.0	17.0	13.00	79.70	5.00
		12/29/97	6:18:00	494,040	27.0	17.0	13.80	78.90	5.80
		12/31/97	8:04:00	673,200	27.0	17.0	14.70	77.80	6.80

Test Pressure = 27.0 psi Differential Head = 11.1 psi, 782.7 cm H2O
Gradient = 1.054E 02 Flow rate = 9.538E-06 cc/sec R squared = 0.93547
Permeability, K27.0° = 3.208E-09 cm/sec, K20° = 2.728E-09 cm/sec

WEAVER BOOS CONSULTANTS, INC.
ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS
200 S. Michigan Ave., Chicago, IL 60604 • (312) 922-1030
14 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-9609

Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL
Job No.: 95042.10
Location of Project: HOBBS, NM
Date of Testing: JAN. 28, 1998
Description of Soil: ______
Tested By.: JWM
Boring No.: B105

Sample Number	Reading Number	Sample Information Length, cm	Sample Information Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
39	1	7.0	20.27	1/28/98	121.9			300	385	3.64E-03	
	2	7.0	20.27	1/28/98	121.9			420	410	2.77E-03	
	3	7.0	20.27	1/28/98	121.9			360	295	2.32E-03	
	Average										2.91E-03

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ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS
200 S. Michigan Ave., Chicago, IL 60604 • (312) 922-1030
14 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-8609

Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL
Location of Project: HOBBS, NM
Description of Soil: ______
Boring No.: B111

Job No.: 95042.10
Date of Testing: JAN. 28, 1998
Tested By.: JWM

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
39	1	7.0	20.27	1/28/98	121.9			660	410	1.76E-03	
	2	7.0	20.27	1/28/98	121.9			660	350	1.50E-03	
	3	7.0	20.27	1/28/98	121.9			720	325	1.28E-03	
	Average										1.51E-03

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ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS
200 S. Michigan Ave., Chicago, IL 60604 • (312) 922-1030
44 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-9609

Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL
Location of Project: HOBBS, NM
Description of Soil: ____
Boring No.: B111

Job No.: 95042.10
Date of Testing: JAN. 28, 1998
Tested By.: JWM

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
35	1	7.0	20.27	1/28/98	121.9			840	745	2.51E-03	
	2	7.0	20.27	1/28/98	121.9			600	460	2.17E-03	
	3	7.0	20.27	1/28/98	121.9			600	435	2.05E-03	
	Average										2.25E-03

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WEAVER BOOS CONSULTANTS, INC.

ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS

200 S. Michigan Ave., Chicago, IL 60604 • (312) 922-1030

4 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-9609

Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL

Job No.: 95042.10

Location of Project: HOBBS, NM

Date of Testing: JAN. 28, 1998

Description of Soil: ______

Tested By.: JWM

Boring No.: B105

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
38	1	7.0	20.27	1/28/98	121.9			840	50	1.69E-04	
	2	7.0	20.27	1/28/98	121.9			840	25	8.43E-05	
	Average										8.43E-05

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WEAVER BOOS CONSULTANTS, INC.
ENVIRONMENTAL AND GEOTECHNICAL ENGINEERS
200 S. Michigan Ave., Chicago, IL 60604 • (312) 922-1030
4 N. Griffith Blvd., Unit C, Griffith, IN 46319 • (219) 923-9600

Constant Head Permeability Test (ASTM D 2434)

Project: LEA COUNTY LANDFILL
Job No.: 95042.10
Location of Project: HOBBS, NM
Date of Testing: JAN. 28, 1998
Description of Soil:
Tested By.: JWM
Boring No.: B105

Sample Number	Reading Number	Sample Information Length, cm	Area, cm2	Date Tested	Head h, cm	Time Start	Time End	Total time t, sec	Total Flow Q, ml	K=(QL)/Aht cm/sec	Average K
9	1	7.0	20.27	1/28/98	121.9			600	395	1.87E-03	
	2	7.0	20.27	1/28/98	121.9			600	350	1.65E-03	
	3	7.0	20.27	1/28/98	121.9			660	345	1.48E-03	
	Average										1.67E-03

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Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/19/92	Boring No.: B-2	Grid No.: 7-C

Log By: A. WEEGAR	Drilling Method & Bit Sizes: 0'-38' MUD ROTARY; 38'-TD AIR ROTARY	Survey Data: Northing: 7650.8990; Easting: 12296.2097; Ground Surface Elev. (MSL): 3,479.43
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS; 2 1/8" CB	
Driller: LANE SCARBOROUGH	Total Depth: 215' BGL	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/11/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
Silty CLAY (CL): continued from previous page.	40	NR (GRAB)	0 / 2 — SS 40-42	
		NR	2.2 / 4 — CB 42-46	
	45			
		NR	3.7 / 6 — CB 46-52	
	50			
less plastic, more friable below 52'; sl. moist to dry.		NR (GRAB)	0 / 8 — CB 52-60	
	55			
	60	NR (GRAB)	0.6 / 6 — CB 60-66	
	65	NR (GRAB)	DRILLED OUT TO 73'	
	70			
		NR	0.9 / 2 — SS 73-75	
	75		0.6 / 5 — CB 75-80	
	80			

FILE NAME: A-LOG7C.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location:	Project No.:	Date Drilled:	Boring No.:	Grid No.:
ANDREWS CO. LANDFILL SITE	92-152	11/19/92	B-2	7-C

Log By: A. WEEGAR	Drilling Method & Bit Sizes: 0'-38' MUD ROTARY; 38'-TD AIR ROTARY	Survey Data: Northing: 7650.8990; Easting: 12296.2097; Ground Surface Elev. (MSL): 3,479.43
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS; 2 1/8" CB	
Driller: LANE SCARBOROUGH	Total Depth: 215' BGL	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/11/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)		Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	Silty CLAY (CL): continued from previous page.	80		1 / 2 — SS 80-82	
			NR		
		85		2 / 2 — 2" S/S 85-87	
			NR	0 / 3 — 3" C/B 87-90	
		90		2 / 2 — 2" S/S 90-92	
			NR	0 / 3 — 3" C/B 92-95	
		95		2 / 2 — 2" S/S 95-97	
? — ? — ?			NR	0 / 3 — 3" C/B 97-100	
97' - 105'	Silty CLAY (CL): claystone: mottled dk. red, brownish yellow and occasional inclusions of pale yellow; no longer laminated: appears as accreted clasts: rusty red dendritic pattern throughout - possible organic remnants; v. hard; dry; pale yellow inclusions are silty, isolated silty partings throughout.	100		2 / 2 — 2" S/S 100-102	
		105		3.8 / 4 — 3" C/B 102-106	
106' - 119'	Silty CLAY (CL): same as above; pale yellow silty inclusions are now stratified in occassional intervals of < 0.10' thick; crumbly due to increased silt in matrix; dry.	110		5.5 / 6 — 3" C/B 106-112	
			NR		
		115		2.5 / 6 — 3" C/B 112-118	
			NR		
119' - 140'	SEE COMMENTS NEXT PAGE	120		2.9 / 6 — 3" C/B 118-124	

FILE NAME: A-LOG7C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/19/92	Boring No.: B-2	Grid No.: 7-C

Log By: A. WEEGAR

Drilling Method & Bit Sizes: 0'-38' MUD ROTARY; 38'-TD AIR ROTARY

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Sample Method(s): 2" SS; 2 1/8" CB

Driller: LANE SCARBOROUGH

Total Depth: 215' BGL

Survey Data:
Northing: 7650.8990
Easting: 12296.2097
Ground Surface Elev. (MSL): 3,479.43

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/11/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
119' – 140'	SILTSTONE (ML): white; carbonate cemented silt; v/g biotite and mica flakes; v.hard; laminated and cross-bedded w/ yellow inclusions and yellow along bedding boundaries; mica and biotite flakes concentrated at bedding boundaries.
140' – 145'	Silty CLAY (CL): interbedded claystone reddish brown; light and dk. silt fragments throughout; hard; dry; light gray carbonate cemented layers throughout – these layers have irregular boundaries but do not disrupt prevailing bedding structure.
145' – 184'	CLAY (CL): claystone; reddish brown with apparent tubes filled with light gray claystone; hard; slight moisture; slightly slippery.

Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Sample	Stratigraphic Interval
120–123	NR	2.9 / 4	3" C/B 118–122	
123–131		8 / 8	3" C/B 132–140	
131–140	NR	2.5 / 8	3" C/B 132–140	
140–148	NR	7.5 / 8	3" C/B 140–148	
148–156	NR	3.6 / 8	148–156	
156–160	NR	3.4 / 8	156–164	

FILE NAME: A-LOG7C.DWG

Terra Dynamics Incorporated	SOIL BORING LO

Location:	Project No.:	Date Drilled:	Boring No.:	Grid No
ANDREWS CO. LANDFILL SITE	92-152	11/19/92	B-2	7-C

Log By: A. WEEGAR	Drilling Method & Bit Sizes: 0'-38' MUD ROTARY; 38'-TD AIR ROTARY	Survey Data: Northing: 7650.8990; Easting: 12296.2097; Ground Surface Elev. (MSL): 3,479.43
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS; 2 1/8" CB	
Driller: LANE SCARBOROUGH	Total Depth: 215' BGL	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/11/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
CLAY (CL): continued from previous page.	160	NR	3.4 / 8 — 3"C/B 156-164	
	165–170		7.8 / 8 — 3"C/B 164-172	
	175	NR	1.3 / 8 — 3"C/B 172-180	
	180		5.6 / 8 — 3"C/B 180-188	
184' - 192'' Silty SAND (SM): sandstone; v. pale brown; vfg sand; carb. cemented; vfg pink and dk. mineral frags.; vfg-fg mica flakes; hard; dry.	185	NR		
	190–195	NR	4.1 / 8 — 3"C/B 188-196	
196'' - 200' CLAY (CL): claystone; reddish brown; w/ tubes & layers of light gray claystone; hard; sl. moisture; sl. slippery.	200	NR	2 / 4 — 3"C/B 196-200	

FILE NAME: A-LOG7C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE

Project No.: 92-152

Date Drilled: 11/19/92

Boring No.: B-2

Grid No.: 7-C

Log By: A. WEEGAR

Drilling Method & Bit Sizes: 0'-38' MUD ROTARY; 38'-TD AIR ROTARY

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Sample Method(s): 2" SS; 2 1/8" CB

Driller: LANE SCARBOROUGH

Total Depth: 215' BGL

Survey Data:
Northing: 7650.8990
Easting: 12296.2097
Ground Surface Elev. (MSL): 3,479.43

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/11/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
200'-215' Silty CLAY (CL): v. dark maroon silty claystone, with occasional light greenish gray mottling and pink dendritic mottling; brittle; dry.	200		DRILL OUT TO 215' - LOG CUTTINGS	
	205			
Gradational color change to dusky red below 210'.	210			
TOTAL DEPTH=215'	215			
	220			
	225			
	230			
	235			
	240			

FILE NAME: A-LOG7C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/18/93	Boring No.: B-43	Grid No.: 7-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7197.7520 Easting: 12084.9454 Ground Surface Elev. (MSL): 3,471.23
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'–0.6'	TOP SOIL: brown; silty sand; organic material; moist.	0			
0.6'–19'	CALICHE: yellowish pink; calcium carbonate; cemented silt and vfg sand; gravel frags.; mod. hard; dry.	5			
	– hard streaks below 7.5'.	10		DRILL OUT TO 27'; LOG CUTTINGS	
		15			
19'–23'	CALICHE: yellowish white; calcium carbonate cemented sand and gravel; sand is fg quartz and feldspar; angular to subrounded; gravel is dark, pink and opaque quartzite and feldspar; angular to subrounded; mod. soft; dry.	20			
23'–26'	Gravelly SAND (SW): pinkish tan; vfg to cg quartz feldspar sand; subrounded to rounded; dark, pink and opaque quartz and feldspar gravel; subrounded to rounded; loose; dry.	25			OCALLALA
26'–31'	Silty CLAY (CL): maroon; silty claystone; blocky fracture; non plastic; dry.			1.5 / SS 27–28.5 / 1.5	TRIASSIC
		30		0 / CB 29–35 / 6	
31'–61'	Silty CLAY (CL): dusky red claystone with dendritic mottling of yellow, tan and gray; sl. soapy; blocky fracture; mod. dense; dry.		NR (GRAB)		
		35	NR	1 / CB 35–39 / 4	
			NR		
			NR		
		40	NR		

FILE NAME: A-LOG7D.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/18/93	Boring No.: B-43	Grid No.: 7-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7197.7520 Easting: 12084.9454 Ground Surface Elev. (MSL): 3,471.23
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON: CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
		40–45	NR	2.5 / 5 (CB 39-44)	
		45–50	NR	2 / 6 (CB 44-50)	
	– reduced purple color below 57'; possible vertical fracture with black mineralization along fracture plane at 57'; crumbly to 61'.	50–60	NR	4.4 / 10 (CB 50-60)	
61'–65'	Silty CLAY (CL): rusty red silty claystone with greenish gray inclusions increasing in content toward base; blocky fracture; dry.	60–66	NR	4.4 / 6 (CB 60-66)	
65'–69.8'	Silty CLAY (CL): purplish red with heavy mottling of greenish gray inclusions; crumbly; dry.	66–76		10 / 10 (CB 66-76)	
69.8'–96'	Very Silty CLAY (CL): rusty red v. silty claystone with subtle large mottling of yellow; greenish gray layers and inclusions of calcium carbonate rich material (from 71'–76'); trace dark inclusions; blocky fracture; dry.	70–80			

FILE NAME: A-LOG73.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/18/93	Boring No.: B-43	Grid No.: 7-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7197.7520 Easting: 12084.9454 Ground Surface Elev. (MSL): 3,471.23
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	80		10 / 10 CB 76-86	
– possible primary slickenside 84'.	85			
	90		10 / 10 CB 86-96	
– possible primary slickenside 95'.	95			
96'-100' CLAY (CL): purple with maroon mottling; sl. soapy; crumbly; dry.		NR	2 / 4 CB 96-100	
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG70.DWG

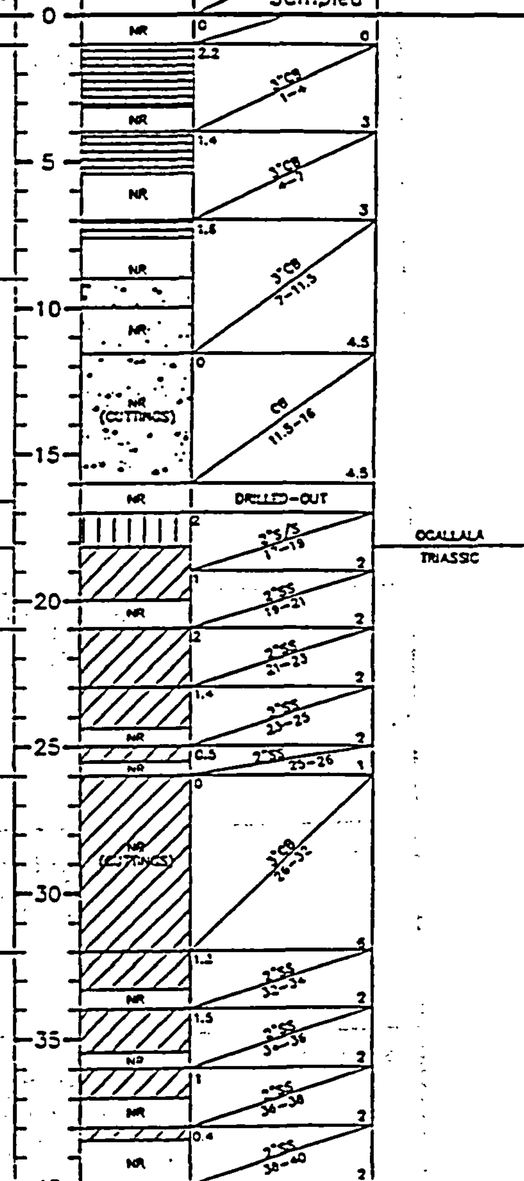
Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/19 – 11/20/92	Boring No.: B-3	Grid No.: 7-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: 0'–16' MUD ROTARY; 0'–TD AIR ROTARY	Survey Data: Northing: 6744.4660; Easting: 11873.6823
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2"SS & 3"CB	Ground Surface Elev. (MSL): 3,465.56
Driller: JOHN/LANE SCARBOROUGH	Total Depth: 100' BGL	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/9/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
0' – 1'	TOP SOIL
1' – 7'	CALICHE (SM): pinkish white carbonate cemented silt & sand; v. hard; chalky; sand grains are vfg – cg white, pink, opaque and black (granitic).
9' – 16.5'	Silty SAND AND GRAVEL (SM): v. pale brown; vfg – fg sand; white, pink and opaque grains (granitic); silt throughout; carbonate and quartzite gravel throughout; loose; dry. OGALLALA FM.; basal contact based on driller.
16.5' – 18.2'	Clayey SILT (ML): v. pale brown; loose w/ inclusions of caliche & gravel; dry.
18.2' – 20'	Silty CLAY (CL): mottled dk. red, brownish yellow, and occasional inclusions of pale yellow claystone; crumbly; dry.
21' – 25'	CLAY (CL): dusky red claystone; hard; stiff; sl. moist; v. dense, slippery, basal contact based on driller.
26' – 32'	Silty CLAY (CL): reddish brown; crumbly, horizontally oriented dk. frags throughout; dry, basal contact based on driller.
32' – 40'	CLAY (CL): mottled red-brown; hard; firm; v. dense; slippery, basal contact from driller.



FILE NAME: A-LOG7E.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/19 - 11/20/92	Boring No.: B-3	Grid No.: 7-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: 0'-16 MUD ROTARY; 0'-TD AIR ROTARY	Survey Data: Northing: 6744.4660 Easting: 11873.6823 Ground Surface Elev. (MSL): 3,465.56
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2"SS & 3"CB	
Driller: JOHN/LANE SCARBOROUGH	Total Depth: 100' BGL	

Remarks: MUD ROTARY BOREHOLE DRILLED IN 1/9/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
40' - 60'	Silty CLAY (CL): reddish brown; claystone w/ silt parting and inclusion; dendritic pattern common; silt partings and inclusions are light gray; black carbonated leaf fragment along parting; hard; crumbly; dry; basal contact from driller.
60' - 65.7''	Cleyey Silt (ML): gray and red siltstone with yellow claystone laminations; vfg mica frags. within siltstone; silt-sized dark frags. throughout; hard; mod. crumbly; increased clay content toward base; dry.
68' - 74''	Silty CLAY (CL): dusky red and mottied w/ weak red claystone interbedded w/ light reddish brown siltstone; mica frags. throughout siltstone; dk. frags. throughout; crumbly; mod. hard; lighter colors common along dendritic pattern within claystone; dry.
75' - 91.5''	Silty CLAY (CL): dusky red and mottled w/ weak red claystone interbedded w/ light reddish brown siltstone; mica frags. throughout siltstone; dk. grags. throughout; crumbly; mod. hard; lighter colors common along dendritic pattern within claystone; light gray claystone filled tubes below 55'; hard; mod. dense; dry; cross-bedded below 85'.

Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Sample	Stratigraphic Interval
40-44	CRAB	0 / 4	3"CB 40-44	
44-48	NR	1 / 4	3"CB 44-48	
48-51	NR	1.7 / 3	3"CB 48-51	
51-57	NR	2.5 / 6	3"CB 51-57	
57-61	NR; NR	1.2 / 4	3"CB 57-61	
61-62		0.7 / 0.9	2"SS/61-61.1; 3"CB/61.1-62	
62-65	NR	1 / 3	3"CB 62-65	
65-68	NR	0.7 / 3	3"CB 65-68	
68-71	NR (CRAB)	0 / 3	3"CB 68-71	
71-75	NR (CRAB)	0 / 4	3"CB 71-75	
75-81	NR	2.7 / 6	3"CB 75-81	

FILE NAME: A-LOG7E.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/19 - 11/20/92	Boring No.: B-3	Grid No.: 7-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: 0'-16' MUD ROTARY; 0'-TD AIR ROTARY	Survey Data: Northing: 6744.4660 Easting: 11873.6823 Ground Surface Elev. (MSL): 3,465.56
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2"SS & 3"CB	
Driller: JOHN/LANE SCARBOROUGH	Total Depth: 100' BGL	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/9/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
SILTY CLAY (CL): same as above.	80	NR	2.? / 6	
	81–87	NR	4.2 / 6 (3"CB 81-87)	
	87–93	NR	4.5 / 6 (3"CB 87-93)	
93" - 94.5" CLAY (CL): dk. reddish gray claystone; hard; v. dense; dry.	93–100	NR	1.5 / 7 (3"CB 93-100)	
TOTAL DEPTH AT 100'	100			

FILE NAME: A-LOG7E.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/20 – 11/22/92	Boring No.: B-4	Grid No.: 7-G

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2525 Easting: 11451.1737
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA TEXAS	Sample Method(s): 2" SS CONTINUOUS: 2½" CB	Ground Surface Elev. (MSL): 3,444.17
Driller:	Total Depth: 270' BGL	Top of PVC Casing Elev.: 3,446.21

Remarks: CORE FROM 0'–230'
DESCRIBED ON 11/27/92: GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE – LOG CUTTINGS FROM 230'–270'

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)

0'–1.9' TOP SOIL: reddish brown sandy silt: vfg mica frags.; root material; crumbly; dry.

1.9'–3.5' CALICHE: pinkish white; carb. cemented silt and sand; v. hard; chalky; vfg sand grains of white, pink, black & opaque (granitic) material; some quartzite gravel; dry.

5'–8' CALICHE: reddish brown & pale brown; same as above; dry; basal contact from driller.

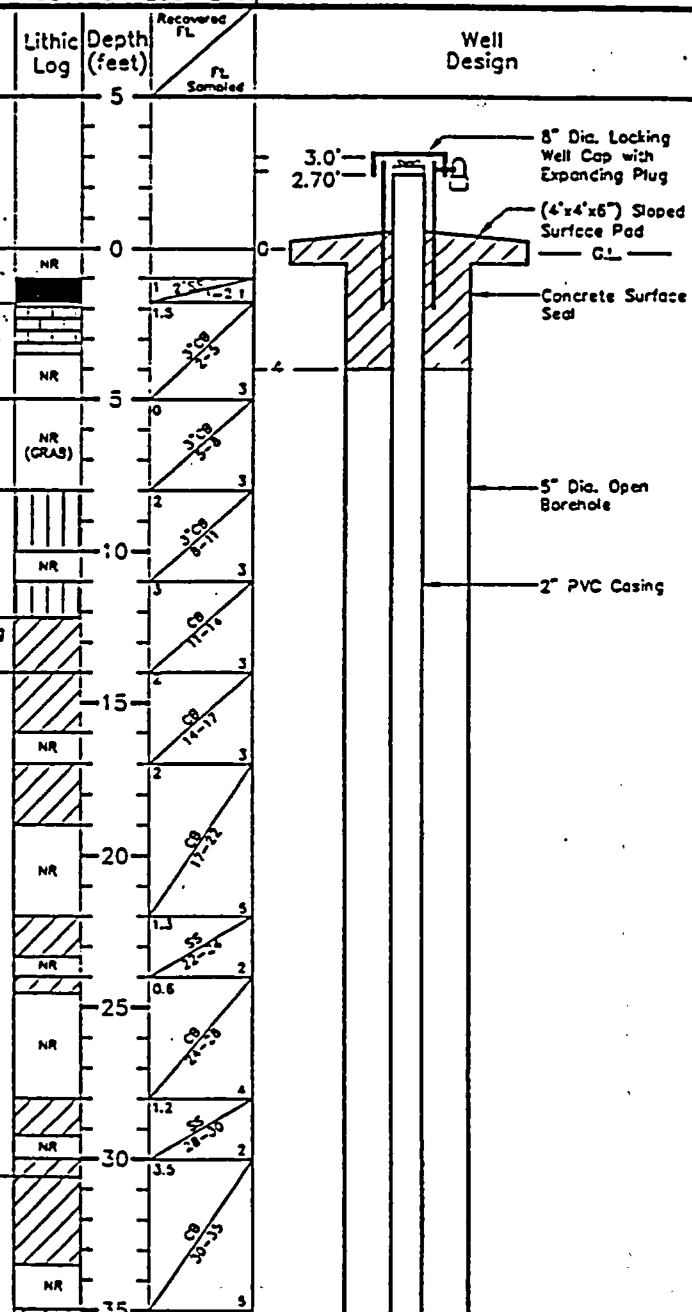
BASE OF OGALLALA – TRIASSIC TOP

8'–12.2' Clayey SILT (ML): laminated pink siltstone and weak red claystone; dk. silt frags. throughout; crumbly; dry.

12.2'–14' Silty CLAY (CL): weak red claystone: with siltstone along partings and as inclusions; mod. dense; sl. crumbly; hard; sl. slippery.

14'–30.7' Silty CLAY (CL): mottled reddish brown and white claystone; contorted and dendritic; siltstone as partings and inclusions; hard; dense; dry.

30.7' – 51.8' Silty CLAY (CL): weak red and pale red mottled siltstone; trace vfg mica frags.; carbonized leaf frags.; hard; mod. crumbly; blocky; soapy; dry.



FILE NAME: A-LOG7GA.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location:	Project No.:	Date Drilled:	Boring No.:	Grid No.:
ANDREWS CO. LANDFILL SITE	92-152	11/20 – 11/22/92	B-4	7-G

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2625 Easting: 11451.1737
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS CONTINUOUS: 2½" CS	Ground Surface Elev. (MSL): 3,444.17
Driller:	Total Depth: 270' BGL	Top of PVC Casing Elev.: 3,446.21

Remarks: CORE FROM 0'–230'. DESCRIBED ON 11/27/92; GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE – LOG CUTTINGS FROM 230'–270'

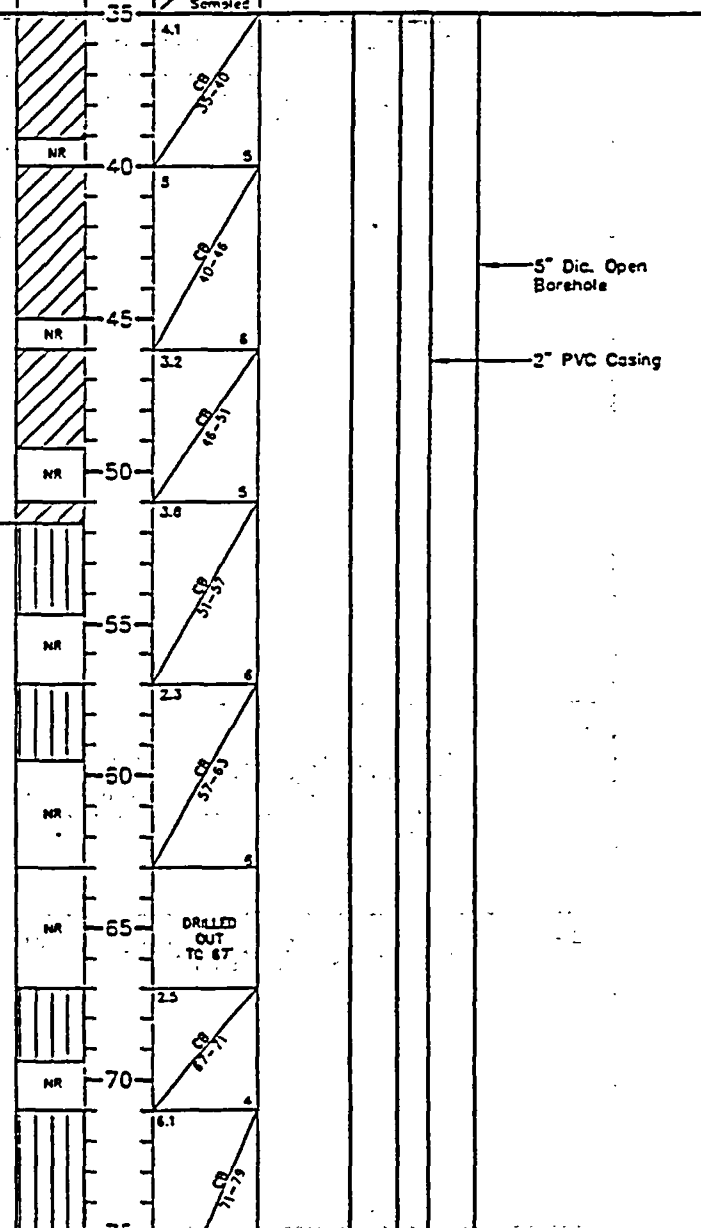
Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design

Silty CLAY (CL): same description as previous page.

dk reddish gray (purple) below 46' w/dendritic pattern and inclusions of brownish yellow.

51.8'–77' Clayey SILT (ML): light gray siltstone; laminated and cross-laminated w/ weak red; vfg mica frags.; mod. dense; hard; concoidal fracture to blocky and sl. fissile; dry.

sandy below 67'; vfg sand along cross-laminated partings; vfg – fg mica frags.; carb. plant remains and frags.



FILE NAME: A-LOG7GA.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/20 - 11/22/92	Boring No.: B-4	Grid No.: 7-G

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2625 Easting: 11451.1737
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS CONTINUOUS: 2⅛" CB	Ground Surface Elev. (MSL): 3,444.17
Driller:	Total Depth: 270' BGL	Top of PVC Casing Elev.: 3,446.21

Remarks: CORE FROM 0'-230' DESCRIBED ON 11/27/92: GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE - LOG CUTTINGS FROM 230'-270'

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
Clayey SILT (ML): same as previous page.		75	CB 71-79; 8	
77'-98' Silty CLAY (CL): reddish brown; mod. hard; silty laminations w/vfg mica frags; sl. fissile; sl. crumbly; soapy; dry.	NR	80	1.7; CB 79-85; 6	5" Dia. Open Borehole
	NR	85	3.4; CB 85-91; 6	2" PVC Casing
	NR	90	5; CB 91-97; 6	
	NR	95	1.4; CB 97-103; 6	
98'-105' Clayey SILT (ML): reddish brown and grayish brown siltstone; dendritic and mottled coloration pattern; vfg mica and dk. min. frags. throughout; hard; crumbly; dry; color change to light gray below 103'.	NR	100	3.2; CB 103-111; 8	
105'-171' Silty CLAY (CL): dk. reddish gray siltstone w/light gray mottling and colored tubes; crumbly; mod. dense; mod. hard; soapy; dry.	NR	105		
	NR	110	1.5; CB 111-119	
		115		

FILE NAME: A-LOG7GA.DWG

Terra Dynamics Incorporated	SOIL BORING & WELL COMPLETION LOG

Location:	Project No.:	Date Drilled:	Boring No.:	Grid No.:
ANDREWS CO. LANDFILL SITE	92-152	11/20 - 11/22/92	B-4	7-G

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2525 Easting: 11451.1737 Ground Surface Elev. (MSL): 3,444.17 Top of PVC Casing Elev.: 3,446.21
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS CONTINUOUS: 2⅛" CB	
Driller:	Total Depth: 270' BGL	

Remarks: CORE FROM 0'-230' DESCRIBED ON 11/27/92: GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE - LOG CUTTINGS FROM 230'-270'

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
Silty CLAY (CL): same as previous page.	NR	115	1.5 / 8 CB 111-119	5" Dia. Open Borehole; 2" PVC Casing
	NR	120	1.2 / 6 CB 119-125	
	NR	125	2.1 / 6 CB 125-131	
	NR	130–135	2.5 / 6 CB 131-137	
	NR	140	0.9 / 8 CB 137-145	
	NR	145–150	1.2 / 6 CB 145-151	
	NR	155	2.5 CB 151-157	

FILE NAME: A-LOG7GA.DWG

Terra Dynamics Incorporated	SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/20 - 11/22/92	Boring No.: B-4	Grid No.: 7-G

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2625 Easting: 11451.1737 Ground Surface Elev. (MSL): 3,444.17 Top of PVC Casing Elev.: 3,446.21
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS; CONTINUOUS: 2⅛" CB	
Driller:	Total Depth: 270' BGL	

Remarks: CORE FROM 0'-230' DESCRIBED ON 11/27/92; GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE - LOG CUTTINGS FROM 230'-270'

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)		Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled
	Silty CLAY (CL): same as previous page.	NR	155	2.3 / 8 CB 151-157
		NR (GRAB)	160	0 / 8 CB 157-163
		NR (GRAB)	165, 170	0 / 8 CB 163-171
171'-175'	Silty CLAY (CL): mottled and dendritic light olive brown, grayish brown and weak red; crumbly; soapy; dry.			1.7 / 8 CB 171-179
175'-187'	Clayey SILT (ML): reddish brown with tubes, mottling and laminations of light gray; concoidal fracture to crumbly; mod. hard; mod. dense; sl. soapy; dry.	NR	175	
			180, 185	5 / 8 CB 179-187
		NR		
187'-203.5'	Sandy Clayey SILT (ML): grading from dk reddish brown to light gray below 191; hard; blocky fracture; cross-laminated; vfg sand frags. throughout; moist.		190, 195	2 / 8 CB 187-195
		NR		

Well Design:
- 5" Dia. Open Borehole
- 2" PVC Casing
- 173.5
- Bentonite Seal ½" Pellets
- 183.5
- 185
- Filter Sand (16-40)
- 2" Sch. 40 PVC Well Screen, .010 Slots

FILE NAME: A-LOG7G.DWG

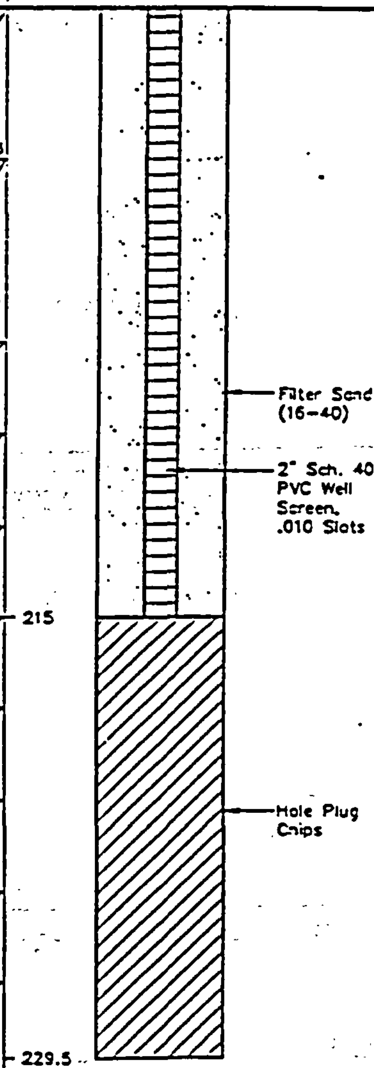
Terra Dynamics Incorporated	SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/20 – 11/22/92	Boring No.: B-4	Grid No.: 7-G
Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2625 Easting: 11451.1737		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS CONTINUOUS: 2⅛" CB	Ground Surface Elev. (MSL): 3,444.17		
Driller:	Total Depth: 270' BGL	Top of PVC Casing Elev.: 3,446.21		

Remarks: CORE FROM 0'–230'
DESCRIBED ON 11/27/92; GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE – LOG CUTTINGS FROM 230'–270'

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled
	Sandy Clayey SILT (ML): same as previous page.	NR	195–200	CB 175–200: 3.5 / 5
203.5'–206'	Clayey Silt (ML): red siltstone; mod. hard; crumbly; laminated; vfg mica and dk. min. frags.; dry.		200–206	CB 200–206: 6 / 6
206'–215'	Sandy SILT (ML): light gray siltstone; hard; blocky fracture; cross laminated; vfg sand; vfg pink & dk. min.frags.; moist.		206–215	CB 206–209: 3 / 3; CB 209–212: 3 / 3; CB 212–215: 3 / 3
215'–230'	Silty CLAY (CL): red claystone; mod. hard; crumbly; blocky to conchoidal fracture; sl. soapy; dry. color change to dusky red below 221'.	NR; NR	215–230	CB 215–218: 1.5 / 3; CB 218–221: 3 / 3; CB 221–224: 3 / 3; CB 224–227: 3 / 3; CB 227–230: 2.5 / 3
230'–250'	Clay (CL): maroon claystone; sl. soapy; crumbly; dry.		230–235	DRILL TO 270' – LOG CUTTINGS

Well Design



FILE NAME: A-LOG7GA.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 11/20 – 11/22/92	Boring No.: B-4	Grid No.: 7-G

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5838.2625 Easting: 11451.1737
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS CONTINUOUS: 2⅛" CB	Ground Surface Elev. (MSL): 3,444.17
Driller:	Total Depth: 270' BGL	Top of PVC Casing Elev.: 3,446.21

Remarks: CORE FROM 0'–230' DESCRIBED ON 11/27/92; GEOPHYSICAL LOG HOLE DRILLED ON 1/23/93 20' FROM 7-G CORE HOLE – LOG CUTTINGS FROM 230'270'.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
CLAY (CL): maroon claystone; sl. soapy; crumbly; dry.		235		
		240		
Heavy mottled w/ greenish gray, purple, mustard yellow.		245		
250'–265' Silty CLAY (CL): maroon silty claystone w/ heavy mottling of greenish gray, purple and mustard yellow; brittle and crumbly; dry.		250		
– less silt below 255'.		255		
		260		
265'–270' CLAY (CL): maroon claystone w/ mottling of greenish gray and mustard yellow; soapy; crumbly; dry.		265		
TOTAL DEPTH = 270'		270		
		275		

FILE NAME: A-LOG7GA.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location:	Project No.:	Date Drilled:	Boring No.:	Grid No.:
ANDREWS CO. LANDFILL SITE	92-152	12/18/92	B-23	7-1

Log By: A. WEEGAR

Drilling Method & Bit Sizes: AIR ROTARY

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Sample Method(s): 2" SS, 3" CB

Driller: JOHN SCARBOROUGH

Total Depth: 101'

Survey Data:
Northing: 4932.0522
Easting: 11028.4705

Ground Surface Elev. (MSL): 3,429.13

Remarks:

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
0' - 2'	TOP SOIL: brown silty sand; organic; moist.	0			
2' - 23'	CALICHE: pink; calc. carb. cemented silt with sand and gravel; gradual increase in gravel content with depth; soft; dry.	5, 10, 15, 20		DRILL OUT, LOG CUTTINGS	
23' - 25'	CALICHE: grayish white; gravel frags. throughout; hard; dry.	25			
25' - 37'	Silty Gravelly SAND (GM): pink and tan; vfg qtz sand and silty sand with red, pink, black and opaque quartzite gravel; sand and gravel is subrounded to well rounded; loose; dry.	30, 35			OGALLALA
37' - 54'	CLAY (CL): dk. brownish red; mod. hard; sl. soapy; blocky fracture; moist; basal contact from cuttings.	40		1.3 / 2 SS 37-39; 1.8 / 2 SS 39-41	TRIASSIC

FILE NAME: A-LOG71.DWG

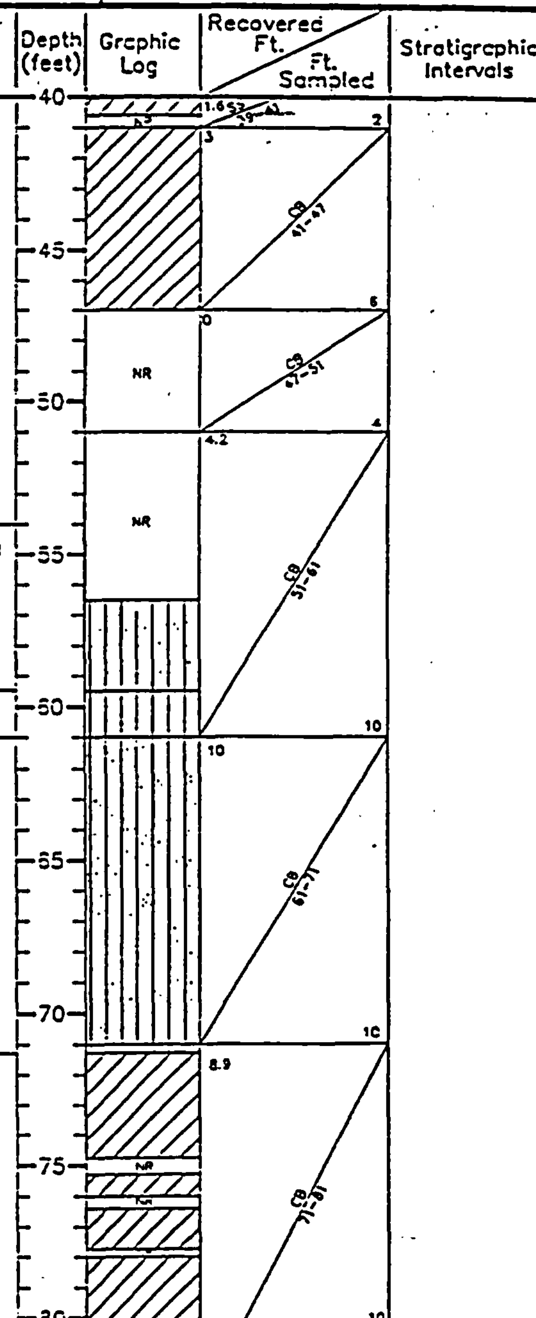
Terra Dynamics Incorporated

SOIL BORING LO

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/18/92	Boring No.: B-23	Grid No 7-I

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 4932.0522 Easting: 11028.4705 Ground Surface Elev. (MSL): 3,429.13
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS, 3" CB	
Driller: JOHN SCARBOROUGH	Total Depth: 101'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	
54' – 59.5'	Sandy Clayey SILT (ML): light greenish gray clayey siltstone with sand throughout; sand is vfg qtz; mica and biotite flakes throughout; small low-angle cross-bedding; thin interbeds of clay and rounded clay nodules; increased clay content toward base; mod. hard; chalky; blocky fracture; dry.
59.5' – 61'	Clayey SILT (ML): cross-bedded light greenish gray and dusky red clayey siltstone grading into dusky red clayey siltstone; trace small mica frags.; mod. hard; blocky fracture; dry.
61' – 71.2'	Silty SAND (SM): speckled appearance with white, olive and opaque vfg sand grains in greenish gray yellow and white silty matrix; calc. carb. cemented silty sandstone; small biotite and med. mica flakes throughout; low angle cross-bedding w/gray and dusky red silty clay rip-up clasts and layers throughout; mod. hard; dusty; blocky fracture; dry.
71.2' – 101'	Silty CLAY (CL): interbedded dusky red claystone and clayey siltstone; mica frags. within siltstone intervals; increasing clay content toward base; greenish gray infilled tubes and inclusions throughout; mod. hard; sl. soapy; blocky fracture with crumbly zones; dry.



FILE NAME: A-LOG71.DWG

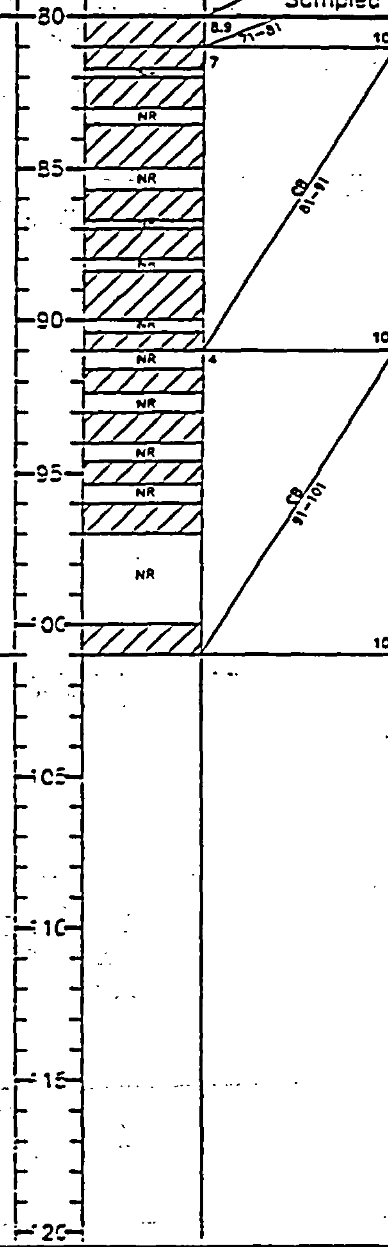
Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152
Date Drilled: 12/18/92	Boring No.: B-23
Grid No.: 7-1	
Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): 2" SS, 3" CB
Driller: JOHN SCARBOROUGH	Total Depth: 101'
Remarks:	

Survey Data:
Northing: 4932.0522
Easting: 11028.4705
Ground Surface Elev. (MSL):
3,429.13

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
SILTY CLAY (CL): same as above.	80			
TOTAL DEPTH = 101'				



FILE NAME: A-LOG71.DWG

Terra Dynamics Incorporated	**SOIL BORING LO[G]**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/23/93	Boring No.: B-49	Grid No.: 8-B

Log By: R.M^cGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8315.3752 Easting: 12054.4457 Ground Surface Elev. (MSL): 3,481.91
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'-0.8'	TOP SOIL: dk. brown, silt and sand, with organic material, loose, dry.	0		DRILL OUT TO 44'; LOG CUTTINGS	
0.8'-6.0'	CALICHE: lt. tan-calcitic cemented sand and silt, vfg-fg quartz sand, soft, dry.	5			
6.0'-29'	SILTY SAND (SM): reddish-tan, sand and silt, vfg quartz feldspar sand; loose; dry. - caliche cementing scattered 12'-28' - chert frags-pebblesized scattered 23'-26'	10, 15, 20, 25			
29'-36'	CALICHE: calcitic and micritic cemented sand and silt, concretion rings in micrite, sandstone lithoclasts in micritic matrix, sandstone lithoclasts have silica concretions, lt. gray, to tan, hard, dry.	30, 35			
36'-42.5'	SAND and GRAVEL (SW): lt. red brown, fg quartz sand, quartz pebbles rounded to subrounded to angular, soft, dry.	40			

FILE NAME: A-LOG3B.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location:	Project No.:	Date Drilled:	Boring No.:	Grid No.:
ANDREWS CO. LANDFILL SITE	92-152	01/23/93	B-49	8-B

Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Date: Northing: 8315.3752 Easting: 12054.4457 Ground Surface Elev. (MSL): 3,481.91
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
SAND and GRAVEL (SW): same as above.	40		DRLG	OGALLALA
42.5'–100' CLAY (CL): red with yellow mottling; dry, plastic.		NR	DRLG	TRIASSIC
	45		1 / SS 44–46 / 2	
			2 / SS 46–48 / 2	
– purple, red and yellow mottling; 48'–50'.			2 / SS 48–50 / 2	
	50		2 / SS 50–52 / 2	
			1 / SS 52–53 / 1	
– brittle; dry.	55	NR ? / NR ?	4 / CB 53–59 / 6	
– increase in purple coloring brittle, dry.	60	NR ? / NR ?	2.8 / CB 59–65 / 6	
	65	NR ? / NR ?	4.1 / CB 65–71 / 6	
– orange red color with red, yellow, greenish-white and purple mottling. appears to have mixed clay clasts.	70	NR ?		
		NR ?	6.5 / CB 71–81 / 10	
– orange red, red, yellow, purple mottled without clasts; brittle; dry.	75			
	80			

FILE NAME. A-LOG82.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/23/93	Boring No.: B-49	Grid No.: 8-3
Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8315.3752 Easting: 12054.4457 Ground Surface Elev. (MSL): 3,481.91		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL			
Driller:	Total Depth: 100'			
Remarks:				

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	80	NR ?	0.5 / CB 71-81 / 10	
		NR ?	7.5	
– vertically oriented fracs at approx. 84'–85'.	85	NR ?	CB 81-91	
	90		10	
		NR ?	7.6	
	95	NR ?	CB 91-100	
TOTAL DEPTH = 100' – healed fracture oriented 60° from vertical at approx. 99'.	100		9	
	105			
	110			
	115			
	120			

FILE NAME: A-LOGB3.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/13/93	Boring No.: B-37	Grid No.: 8-C

Log By: A. WEEGAR/R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7862.1723 Easting: 11843.1039 Ground Surface Elev. (MSL): 3,477.37
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 101'	
Remarks:		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
0'–0.5'	TOP SOIL: sandy silt; organic material; brown.	0			
0.5'–16'	CALICHE: white to lt. tan calcite cemented sand and silt; vfg qtz. sand; with lithoclasts of sandstone in calcite matrix; soft drilling.	5, 10, 15		DRILLED OUT WITH ROCK BIT TO 38' —LOG CUTTINGS	
16'–26'	CALICHE: gray to tan, micritic and calcitic cemented sand; silt to occasional gravel sandstone lithoclasts with silica concretions around them; lithoclasts cemented with probable dolomite; quartz and feldspar sand and pebbles; silica chips (concoidal).	20, 25			
26'–28'	SAND and GRAVEL (SW): river bed gravel with whitish sand and silt; graded; angular to rounded.				
28'–37'	SAND and GRAVEL (SW): river bed gravel with reddish sand and silt; graded; angular to rounded.	30, 35			OGALLALA / TRIASSIC
37'–61'	CLAY (CL): red clay with sand size calcite inclusions; soft; moist.	40		2 / SS 38–40 / 2	

FILE NAME: A-LOG80.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/13/93	Boring No.: B-37	Grid No.: 8-C

Log By: A. WEEGAR/R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data Northing: 7862.1723 Easting: 11843.1039 Ground Surface Elev. (MSL): 3,477.37
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 101'	
Remarks:		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
	- yellow mottling bottom 0.3' (41.7-42); less moist.	40		2 / SS 40-42 / 2	
				2 / SS 42-44 / 2	
	- gray/green clay nodules at 45' approx. 0.15'.	45		2 / SS 44-46 / 2	
				1.9 / SS 46-48 / 2	
			NR ? / NR ?	1 / CB 48-51 / 3	
		50			
		55	NR	0 / CB 51-57 / 6	
		60	NR	0 / CB 57-61 / 4	
61'-81'	CLAY (CL): yellowish pink, mottled green, yellow, red and gray clay; dry; brittle; almost talcish.			4 / CB 61-65 / 4	
		65	NR / NR	3.5 / CB 65-71 / 6	
	- red clay with slight yellow mottling; soft plastic; moist.	70	NR ? / NR ? / NR ?	5.2 / CB 71-81 / 10	
	- reddish orange with yellow mottling and gray/green nodules of clay gradually drying out, over dry (1.6' above base of recovery).	75			
	- "poker chip" clay with mica flakes.	80	NR		

FILE NAME: A-LOG8C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/13/93	Boring No.: B-37	Grid No.: 8-C

Log By: A. WEEGAR/R. McGOWEN

Drilling Method & Bit Sizes: AIR ROTARY

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Sample Method(s): CORE BARREL; SPLIT SPOON

Driller:

Total Depth: 101'

Survey Data
Northing: 7862.1723
Easting: 11843.1039
Ground Surface Elev. (MSL): 3,477.37

Remarks:

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
		80	NR	5.2 / 10 (CB ?1-81)	
81'-84'	SILTY CLAY (CL): red clay interbedded with whitish green siltstone.			10 / 10 (CB 81-91)	
84'-91'	CLAY (CL): red-orange with green clay nodules scattered; brittle with mica flakes.	85			
		90			
				10 / 10 (CB 91-101)	
		95			
TOTAL DEPTH = 101'		100			
		105			
		110			
		115			
		120			

FILE NAME: A-LOG8C.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/14-15/92	Boring No.: B-18	Grid No.: 8-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7409.0953 Easting: 11631.7184 Ground Surface Elev. (MSL): 3,471.98
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
0' - 1'	TOP SOIL: brown silty sand; organic plant material; dry.	0			
1' - 10.5'	CALICHE: pinkish white and greyish tan; calcium carbonate cemented; microcrystalline; v. hard; dry.	5			
10.5' - 12.25'	CALICHE: pinkish white; mod. soft; dry.	10			
12.25' - 17'	CALICHE: pinkish white and greyish tan calcium carbonate cemented; microcrystalline; v. hard; dry.	15		DRILL OUT LOG CUTTINGS	
17' - 22'	CALICHE: light pink calc. carb. cemented gravel; white; red, and dk. tan gravel; subrounded to rounded; mod. hard; dry.	20			
22' - 30'	Gravelly SAND (SW): pinkish tan; fg - cg qtz. sand; well rounded; subrounded to well rounded quartzite gravel; white, tan, pink and dk. clasts; loose; dry; basal contact with driller.	25			OGALLALA
30' - 45'	CLAY (CL): mottled dusky red, yellow, purple and light gray clay; mod. hard; sl. plastic; dense; moist. - increased purple coloration below 35'.	30 35 40	NR NR NR	C / CB 30-31 / 1 2.3 / CB 31-35 / 4 3.9 / CB 35-39 / 4 3.2	TRIASSIC

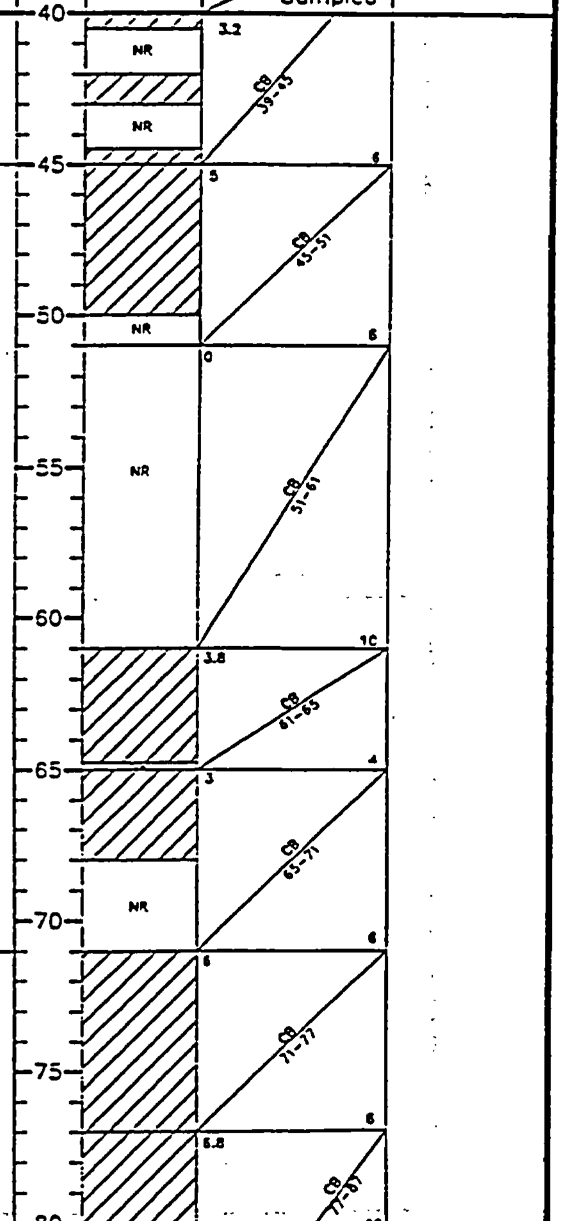
FILE NAME: A-LOG2D.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/14-15/92	Boring No.: B-18	Grid No.: 8-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7409.0953 Easting: 11631.7184 Ground Surface Elev. (MSL): 3,471.98
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals



CLAY (CL): maroon clay with slight mottling of light gray and purple; mod. hard; sl. plastic; dense; moist.

45' – 71". Slightly Silty CLAY (CL): heavily mottled dusky red, maroon, purple, yellow and gray; hard; blocky fracture; dry with occasional zones of dense, moist clay.

– switched out bits; used pilot bit.

– primarily dusky red with slight gray, tan and purple mottling.

71"–100' Silty CLAY (CL): mottled dusky red, light gray and purple; trace mica frags.; hard; sl. crumbly; blocky fracture; dry.

FILE NAME: A-LOG83.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/14-15/92	Boring No.: B-18	Grid No.: 8-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7409.0953 Easting: 11631.7184 Ground Surface Elev. (MSL): 3,471.98
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
Silty CLAY (CL): same as above.	80	(hatched)	6.8 / 10 (CB 77-87)	
	85	NR		
	90	(hatched)	4.5 / 5 (CB 87-92)	
- becoming increasingly crumbly below 92'	95	(hatched)	3.5 / 8 (CB 92-100)	
TOTAL DEPTH = 100'	100	NR (GRAB)		
	105			
	110			
	115			
	120			

FILE NAME: A-LOG8D.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/20/92	Boring No.: B-32	Grid No.: 8-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6955.8008 Easting: 11420.4446 Ground Surface Elev. (MSL): 3,465.58
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 134'	

Remarks:

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)		Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
		80		8.4 / 10 (CB 78-88)	
84.9'–93.4'	CLAY (CL): dark maroon claystone with mottling of pinkish gray and tubes of greenish gray; hard; sl. soapy; blocky fracture; dry.	85			
		90	NR	7.7 / 10 (CB 88-98)	
93.4'–96.8'	CLAY (CL): purple/grey with mottling of pinkish tan; crumbly; dry.	95			
96.8'–101.4'	Clayey SILTSTONE (ML): greenish gray clayey siltstone with dk. maroon claystone inclusions and thin layers; blocky and platey fracture; hard; sl. moist.	100	NR	9.4 / 10 (CB 98-108)	
101.4'–105'	Sandy SILT (ML): interbedded greenish gray siltstone and dusky red and pinkish yellow silty sandstone; sand is vfg quartz with vfg mica and biotite fragments; sandstone is calc. carb. cemented; hard; blocky fracture; with platey fracture in siltstone intervals; dry.				
105'–121.8'	Silty SAND (SM): white, pink and olive sand with greenish gray and pinkish tan silty matrix; sand is vfg with small to medium mica and biotite flakes; hard; blocky fracture; dry; basal contact.	105			
		110		10 / 10 (CB 108-118)	
		115			
		120		4.9 / 10 (CB 118-128)	

FILE NAME: A-LOG32.DWG

Terra Dynamics Incorporated			SOIL BORING LOG		
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152		Date Drilled: 12/20/92	Boring No.: B-32	Grid No.: 8-E
Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY		Survey Data: Northing: 6955.8008 Easting: 11420.4446 Ground Surface Elev. (MSL): 3,465.58		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL				
Driller: LANE SCARBOROUGH	Total Depth: 134'				
Remarks:					

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
		120		4.9 / 10 — CB 118–128	
121.8'–134'	Silty CLAY (CL): dusky red & maroon with grayish purple mottling; crumbly; dry.		NR (GRAB)		
		125			
		130		4.1 / 6 — CB 128–134	
TOTAL DEPTH = 134'			NR		
		135			
		140			
		145			
		150			
		155			
		160			

FILE NAME: A-LOGSE.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/22/92	Boring No.: B-33	Grid No.: 8-F

Log By: P. GRANT	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6502.8105 Easting: 11209.2032 Ground Surface Elev. (MSL): 3,466.96
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'–1'	TOP SOIL: brown; silty sand; moist.	0		– DRILL OUT TO 25' WITH ROCK BIT.	
1'–24'	CALICHE: white sandy silt; calcium carb. cement; hard; dry. – Ogallala gravels at 5' are white, pink, black quartzite; mod. hard. – more gravels below 10'; looser below 10'. – gravel and coarse sand strata at 18'; drills easily; light tan cuttings; sl. moist. – yellow silty clay in bottom foot of Ogallala with some small rounded gravels.	5, 10, 15, 20		– LITH. LOG FROM CUTTINGS.	OGALLALA
24'–34'	CLAY (CL): dark reddish-brown claystone; sl. plastic; crumbly; dense; sl. moist; yellow mottling; white burrow(?) infillings present; sl. reactive to HCl.	25, 30	NR (GRAB); NR (GRAB); NR	SS 25–27: 0 / 2 CB 27–30: 0 / 3 CB 30–33: 2.8 / 3	TRIASSIC
34'–42'	Silty CLAY (CL): reddish-brown silty claystone; green-gray, yellow & white mottling; crumbly; appears slightly bioturbated; not reactive with HCl; dense; dry; sl. soapy; hard.	35, 40	NR; NR	CB 33–38: 3.3 / 5 CB 38–48: 7 / 10	

FILE NAME: A-LOG8F.DWG

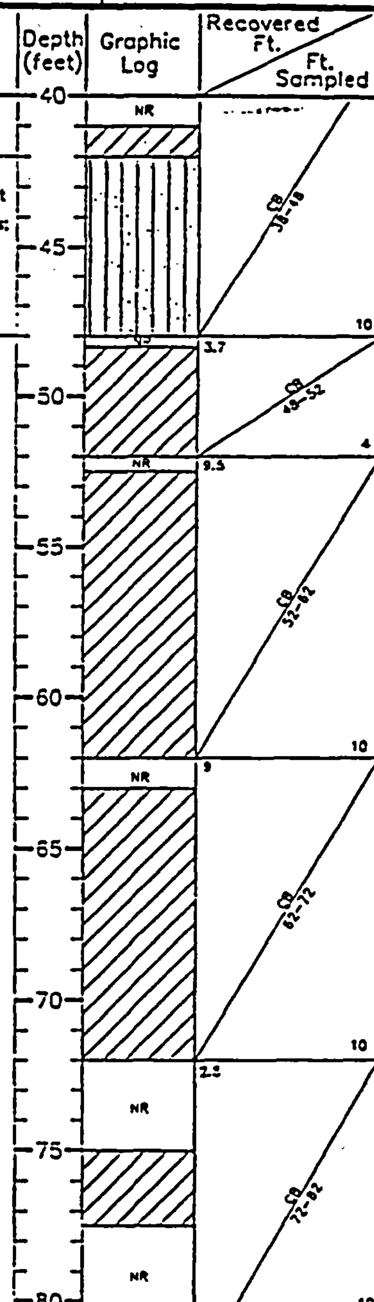
Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/22/92	Boring No.: B-33	Grid No.: 8-F

Log By: P. GRANT	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6502.8105 Easting: 11209.2032 Ground Surface Elev. (MSL): 3,466.96
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
	- gradational to silty sand at 42'.
42'-48'	<u>SILTY SAND (SM)</u>: brownish tan to white; mottled throughout with yellow, brown, gray; v. hard; blocky fract.; f.c. sand to silt with rounded to subangular clasts; calc. carb. cemented grains clear to white to pink; mica flakes; carb.(?) or biotite(?) grains; dry, bedding & cross-bedding present; iron(?) staining; possible borings.
48'-86'	<u>SILTY CLAY (CL)</u>: reddish brown claystone with silt disseminated; yellow & white mottling; dendritic pattern common; no reaction to HCl; hard; blocky fract.; dry.
	- little silt below 50'.
	- increasing silty interbeds below 66'; scattered clayey silts (green white); dry.
	- decreasing silt below 75'.



Stratigraphic Interval

FILE NAME: A-LOG8F.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/22/92	Boring No.: B-33	Grid N. 8-F

Log By: P. GRANT	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6502.8105 Easting: 11209.2032 Ground Surface Elev. (MSL): 3,466.96
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
		80	NR	CB 72-82; 10	
			NR	8	
	– less silt towards 86'.	85			
86'-100'	CLAY (CL): reddish purple; claystone; mod. hard; crumbly; dense; red & brown mottling; dry.			CB 82-92	
	– purple below 90'; sl. plastic.	90		10	
			NR	6.5	
		95		CB 92-100	
TOTAL DEPTH = 100'	– same description as above with slightly reddish purple color in places.	100		8	
		105			
		110			
		115			
		120			

FILE NAME: A-LOG8F.DWG

Terra Dynamics Incorporated	**SOIL BORING LO**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/18-19/92	Boring No.: B-22	Grid N 8-

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5596.6670 Easting: 10786.6818
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	Ground Surface Elev. (MSL): 3,437.08
Driller: LAZARO CASTILLO LANE SCARBOROUGH	Total Depth: 100'	

Remarks:

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigra Interva
		80		10 / CB 72-82 / 10	
			NR	6.2 / CB 82-92 / 10	
		85			
85.8'-89.1'	<u>Clayey Sandy SILT (ML)</u>: interbedded and cross bedded dk. reddish brown silty clay and light grayish red sandy silt with light greenish gray silty clay in basal 1'; mica frags. throughout; hard; blocky fracture; basal 1' is soapy; dry.				
89.1'-100'	<u>Slightly Silty CLAY (CL)</u>: dk. reddish brown with dendritic greenish gray mottling, inclusions and layers throughout; trace v/g mica frags.; carbonized plant material; blocky fracture; sl. soapy; dry.	90			
				6.4 / CB 82-100 / 8	
		95			
			NR		
TOTAL DEPTH = 100'		100			
		105			
		110			
		115			
		120			

FILE NAME: A-LOG8H.DWC

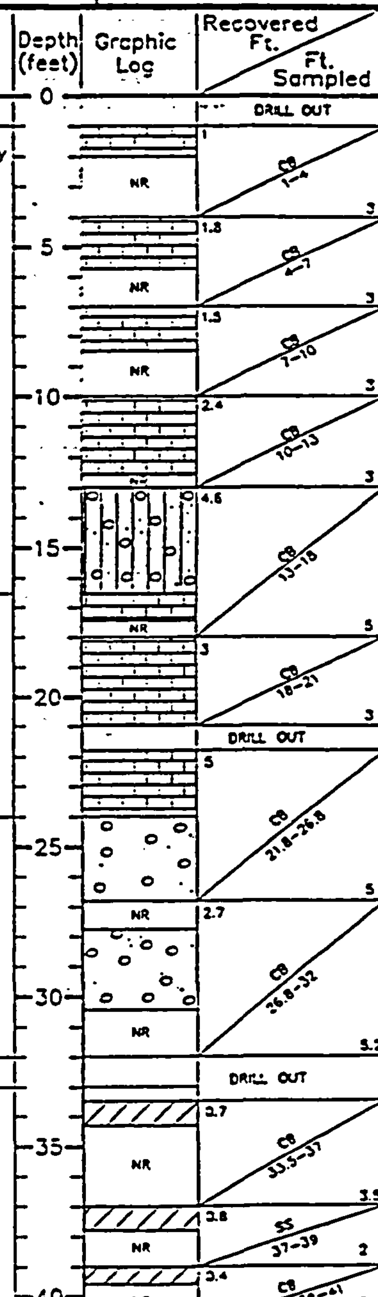
Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12-9-92	Boring No.: B-13	Grid No.: 9-C

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY: MUD ROTARY 21.8'-32'	Survey Data: Northing: 8073.4781 Easting: 11389.9571 Ground Surface Elev. (MSL): 3,476.22
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/8/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Stratigraphic Interval
0' - 1'	TOP SOIL: brown sandy silt; loose; root material; moist.	
1' - 16.5'	CALICHE: white and v. light gray calcium carb. cemented silty sand/sandy silt; trace vfg sand-sized pink min. frags. and fg sand and round gravel size dk. min. frags.; hard; crumbly; dry; nature. fractures. Increasing sand and dk. gravel content below 7'.	
16.5' - 28.5'	CALICHE: pink and gray calcium carb. cemented silt; v. hard; blocky fracture; concentric growth rings and apparent nodules; calcite crystal growth in vugs; trace subrounded dk. gravel clast; natural fractures; moist along fractures; basal contact from driller.	
24' - 32'	Gravelly SAND (SP); vfg to cg pink gravel w/ red, tan, olive and black/ brown gravel; loose; sand and gravel is subr. to round; gravel is quartzite; basal contact from driller.	OGALLALA
32' - 33'	CLAY (CL); gray; mod. soft; sl. plastic; soapy; moist.	TRIASSIC
33' - 80'	CLAY (CL); maroon clay; mod. plastic; sticky; soapy; very thin light grey, yellow and black laminations; moist to wet down to about 45'.	



FILE NAME: A-LOG3C.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12-9-92	Boring No.: B-13	Grid No.: 9-C

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY; MUD ROTARY 21.8'-32'	Survey Data: Northing: 8073.4781 Easting: 11389.9571 Ground Surface Elev. (MSL): 3,476.22
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/8/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

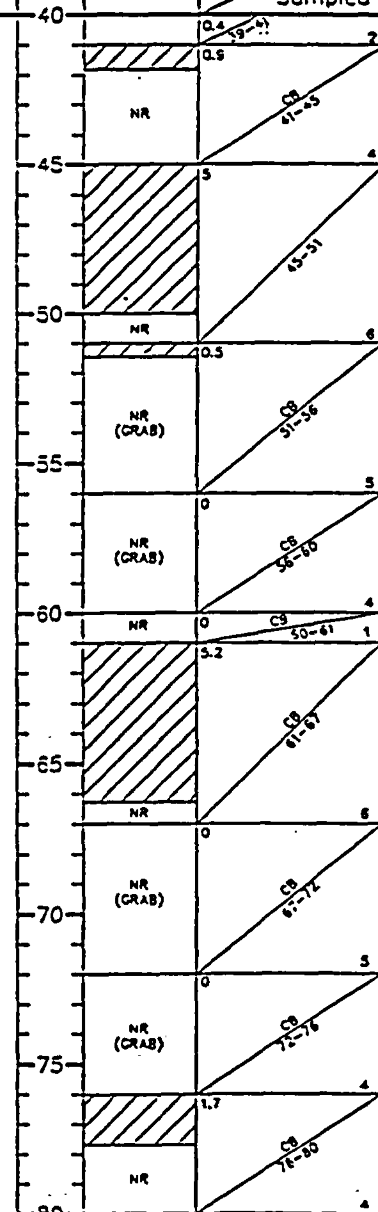
Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval

— Drier from 45' – 50'.

— Increased moisture & plasticity below 51'.

— Use clay bit from 58' – 60'.

— Use pilot bit w/ increase shoe separation below 60'.



FILE NAME: A-LOG9C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12-9-92	Boring No.: B-13	Grid No.: 9-C

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY; MUD ROTARY 21.8'-32'	Survey Data: Northing: 8073.4781 Easting: 11389.9571 Ground Surface Elev. (MSL): 3,476.22
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	

Remarks: MUD ROTARY BOREHOLE DRILLED ON 1/8/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
80–100' Silty CLAY (CL): purplish maroon w/ yellow & greenish gray mottling; platy fracture, sl. crumbly; sl. soapy; non-plastic; dry.	80		1.8 / 4 (CB 80-84)	
		NR		
	85		4 / 4 (CB 84-88)	
	90		8 / 8 (CB 88-96)	
	95			
TOTAL DEPTH AT 100'			3.8 / 4 (CB 96-100)	
	100			
	105			
	110			
	115			
	120			

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/20/92	Boring No.: B-27	Grid No.: 9-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7620.4057 Easting: 11178.6477 Ground Surface Elev. (MSL): 3,472.74
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBCROUGH LAZARO CASTILLO	Total Depth: 100'	

Remarks: MUD ROTARTY BOREHOLE DRILLED ON 1/3/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Stratigraphic Interval
0'-1'	TOP SOIL: brown silty sand; organic material; moist.	
1'-9'	CALICHE: pinkish, grayish white; calcium carb. cemented silt and vfg pink sand; v. hard; blocky fracture; dry.	
9'-11.5'	Silty Gravelly SAND (GM): pinkish white; vfg qtz. sand with white and dark gravel and partial caliche cementation; mod. loose; dry.	
11.5'-25'	CALICHE: pink and pinkish gray; microcrystalline calcium carb. cementation with trace vfg pink sand and dark gravel; concentric growth rings; v. hard; dry. — increased gravel content below 22'.	
25'-27.5'	Silty Gravelly SAND (GW): dark, white, pink, clear and opaque sand and gravel with pinkish tan silt matrix; sand is subr. to well rd. vfg-cg quartz; gravel is subr.; loose; dry.	OGALLALA
27.5'-51.3'	Silty CLAY (CL): dusky red to maroon silty clay with blue/gray mottling throughout; mod. dense; crumbly in upper 4'; sl. plastic & soapy below 31'; moist. — yellow mottling below 37'.	TRIASSIC

Depth (feet)	Sample	Recovered Ft. / Ft. Sampled
0-6	DRILL OUT WITH ROCK BIT	
6.0-11.5	CB (NR intervals)	2.4 / 5.5
11.5-16.5	CB	3.8 / 5.0
16.5-21.5	CB (NR at base)	4.0 / 5.0
21.5-25	CB (NR at base)	2.5 / 3.5
25-27.5	NR (GRAB); DRILL OUT WITH ROCK BIT	
28-30	SS	1.5 / 2
30-32	SS	1.7 / 2
32-34	SS	1.6 / 2
34-36	SS	1.8 / 2
36-38	SS	1.9 / 2
38-40	SS	1.8 / 2

FILE NAME: A-LOG9D.DWG

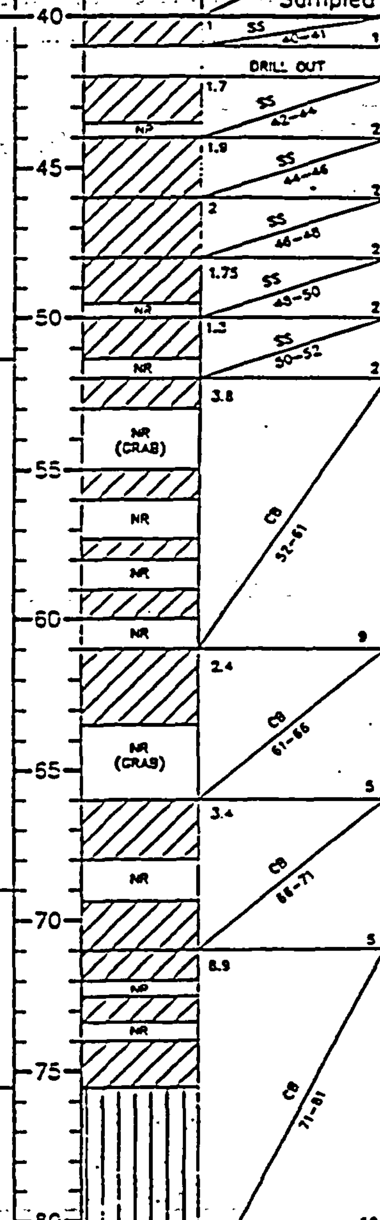
Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/20/92	Boring No.: B-27	Grid No.: 9-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7620.4057 Easting: 11178.6477
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	Ground Surface Elev. (MSL): 3,472.74
Driller: LAZARO CASTILLO LANE SCARBOROUGH	Total Depth: 100'	
Remarks: MUD ROTARTY BOREHOLE DRILLED ON 1/3/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
	Silty CLAY (CL): same as above.
51.3'–69'	Silty CLAY (CL): light dusky red silty claystone with light gray, yellow and purple/grey dendritic mottling; hard; blocky fracture; sl. crumbly; dry; basal contact from cuttings.
69'–75.5'	Silty CLAY (CL): heavily mottled purple/gray/green with dendritic coloration of dusky red; mod. hard claystone; blocky fracture; dry.
75.5'–83.8'	Sandy SILT (ML): dusky red sandy siltstone with greenish gray mottling in upper 1'; sand is vfg quartz with med. mica and biotite flakes; matrix material reacts with HCl; hard; blocky fracture, sl. chalky; dry.

Depth (feet) | Graphic Log | Recovered Ft. / Ft. Sampled | Stratigraphic Interval



FILE NAME: A-LOG9D.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/20/92	Boring No.: B-27	Grid No.: 9-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7620.4057 Easting: 11178.6477 Ground Surface Elev. (MSL): 3,472.74
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LAZARO CASTILLO LANE SCARBOROUGH	Total Depth: 100'	

Remarks: MUD ROTARTY BOREHOLE DRILLED ON 1/3/93 NEXT TO ORIGINAL BOREHOLE. LOG IS COMPOSITE OF BOTH BOREHOLES.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	80		5.9 / 10 (71-81)	
83.6'–100' Silty CLAY (CL): variegated dusky red, yellow, dark gray and purple silty claystone with siltstone layers; trace vfg mica frags. in siltstone intervals; blocky fracture; mod. hard; dry.	85	NR, NR, NR	8.3 / 10 (CR 81-91)	
	90			
	95		9 / 9 (CR 71-100)	
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG9D.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/20/93	Boring No.: B-46	Grid No.: 9-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7166.5723 Easting: 10968.3576 Ground Surface Elev. (MSL): 3,467.53
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 101'	
Remarks:		

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'-2.5'	TOP SOIL: dark brown; clayey sand; v. organic rich; loamy; moist.	NR (GRAB)	DRILL OUT; LOG CUTTINGS	
2.5'-13'	CALICHE: pinkish white calcium carbonate cemented silt and vfg sand; alternatingly hard and soft layers; hard layers are grayish tan micrite with silt and vfg pink sand; trace subrounded pink and opaque gravel; dry.	NR (GRAB)		
13'-18'	CALICHE: pinkish white calcium carbonate cemented silt and vfg sand; dark, black, opaque and red qtzite gravel frags. throughout; loose; dry.	NR (GRAB)		
18'-20.5'	Gravelly SAND (SP): pink vfg quartz sand; black, dark, red and opaque gravel; v. loose; moist.	(GRAB)		OCALLALA
20.5'-28'	CLAY (CL): maroon; sl. soapy; dense; sl. plastic; crumbly; trace calcium carbonate nodules; moist.	NR (GRAB)		TRIASSIC
			0 / SS 22-24 / 2	
			2 / SS 24-26 / 2	
			2 / SS 26-28 / 2	
28'-37'	CLAY (CL): heavily mottled yellow, bluish gray and purple; sl. soapy; dense; sl. plastic; crumbly; moist-dry.		2 / SS 28-30 / 2	
			2 / SS 30-32 / 2	
			2 / SS 32-34 / 2	
			2 / SS 34-36 / 2	
			2 / SS 36-38 / 2	
37'-40.9'	CLAY (CL): maroon with clasts and trace mottling of grayish purple and yellow; sl. soapy; dense; sl. plastic; crumbly to concoidal fracture; moist.		2 / SS 38-40 / 2	

Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40

FILE NAME: A-LOG3E.DWG

Terra Dynamics Incorporated

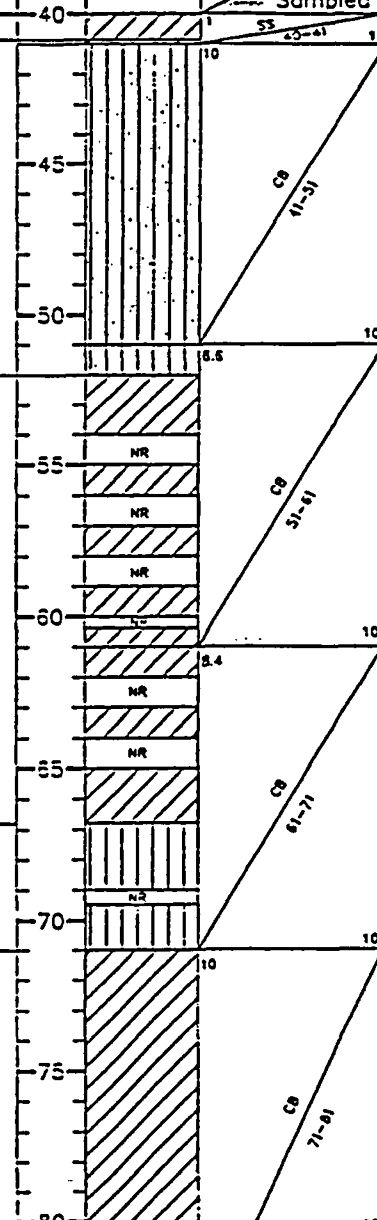
SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/20/93	Boring No.: B-46	Grid No.: 9-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7166.5723; Easting: 10968.3576; Ground Surface Elev. (MSL): 3,467.53
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 101'	
Remarks:		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
40.9'-52'	Silty Clayey SAND (SM): variegated tan, yellow, pink, gray and white siltstone and sandstone with clay laminae and clasts; interbedded and cross-bedded; sand is vfg white quartz and pink feldspar; vfg to cg mica and biotite frags. and flakes; increased sand content below 47'; hard; blocky fracture; calcium carbonate cementation; dry.
52'-66.9'	Silty CLAY (CL): dark reddish brown and reddish purple silty claystone; with slight purple grey dendritic mottling; greenish gray clasts and worm burrows; dense; blocky fracture to crumbly; dry; gradational change to light dusky red siltstone at base.
66.9'-71'	Clayey SILT (ML): light dusky red siltstone and claystone; calcite xl filled fractures; hard; blocky fracture; dry.
71'-101'	Slightly Silty CLAY (CL): reddish brown and yellowish tan slightly silty claystone with greenish gray layers and tubes; calcite filled (45°) diagonal fractures common.

Depth (feet) | Graphic Log | Recovered Ft. / Ft. Sampled | Stratigraphic Interval



FILE NAME: A-LOG9E.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/20/93	Boring No.: B-46	Grid No.: 9-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7166.5723 Easting: 10968.3576 Ground Surface Elev. (MSL): 3,467.53
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 101'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
Slightly Silty CLAY (CL): same as above.	80			
	81–91		7 / 10, CB 81-91	
	91–101		6.4 / 10, CB 91-101	
TOTAL DEPTH = 101'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG9E.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

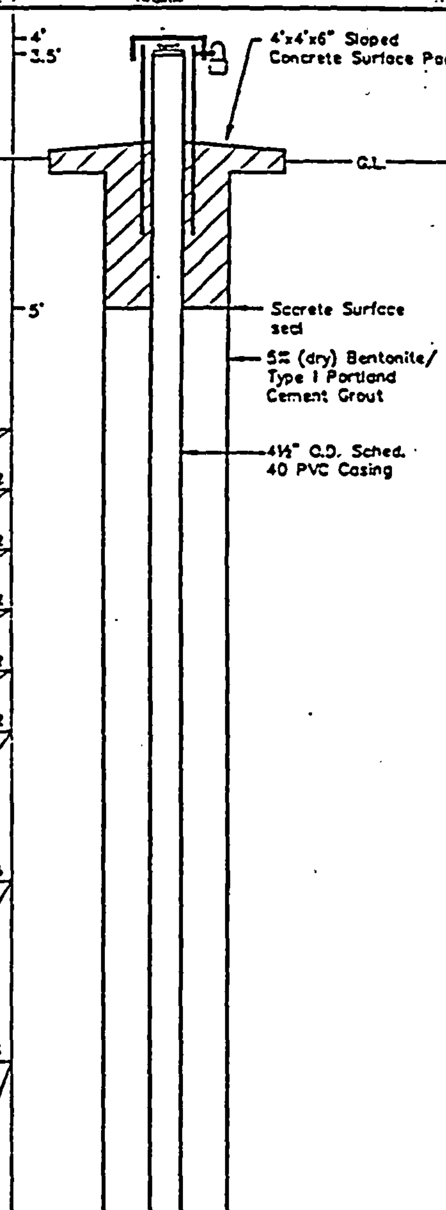
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid Well No.: 9-G(i)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/29/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903 Ground Surface Elev. (MSL): 3,454.55 Top of PVC Casing Elev.: 3,458.25
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 170'	

Sample Method(s): CONTINUOUS FROM 9' TO 170' USING SPLIT SPOON AND CORE BARREL.

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Sample (Recovered Ft. / Ft. Sampled)
0'–9'	CALICHE: white; some white silty clay, some white pebbles.	NR	
9'–11'	CALICHE BASE OF OGALLALA – TRIASSIC TOP	NR	SS 9–11: 0 / 2
11'–15.5'	Silty CLAY (CL): dusky red; hard; waxy; dry; some whitish-gray mottling.	NR	SS 11–13: .25 / 2; SS 13–15: 1.5 / 2
15.5'–23'	Slightly Silty CLAY (CL): maroon; hard; waxy; dry; some gray mottling.	NR	SS 15–17: 1.5 / 2; SS 17–19: 1.6 / 2; CB 19–24: 3 / 5
23'–25'	Slightly Silty SAND (SM): pinkish-red, well sorted vf-fg angular sand; some yellow and green mottling; HCl perm non-reactive; dry.		
25'–26'	CLAYEY SAND (SL): white, chalky; HCl reactive; vf sand grains; dry.		CB 24–30: 5.9 / 6
26'–30'	Slightly Silty SAND (SM): pinkish-red, vf-fg angular sand grains; HCl perm numerous gray rip-up clasts; some yellow, green mottling; dry; lighter color with depth.		
30'–42.5'	Slightly Silty SAND (SM): white, fine grained slightly angular sand; biotite and mica flakes; numerous rip-up white and gray clay clasts; slightly HCl reactive; permeable.		CB 30–40: 10

Well Design



FILE NAME: A-LOG9G1.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(1)

Log By: M. JOHNSON; A. WEEGAR

WELL COMPLETED ON: 1/29/93

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Drilling Method & Bit Sizes: AIR ROTARY

Total Depth: 170'

Sample Method(s): CONTINUOUS FROM 9' TO 170' USING SPLIT SPOON AND CORE BARREL

Survey Data:
Northing: 6260.8293
Easting: 10544.8903
Ground Surface Elev. (MSL): 3,454.55
Top of PVC Casing Elev.: 3,458.25

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Recovered Ft / Ft Sampled
	Slightly Silty SAND (SM): same as above.		35–40	30-40; 10
42.5'-50'	Silty CLAY (CL): dusky red; mod. hard; dry; numerous silty sand laminations with depth (slightly HCl reactive); some gray, white mottling.	NR (42–43)	40–50	8.1 / 10; CB 40-50
50'-60'	Silty CLAY (CL): dusky red; mod. hard; waxy; dry; white and gray mottling, some vf grained sand near top.	NR (50–52)	50–60	7.8 / 10; CB 50-60
60'-84'	Silty CLAY (CL): dusky red; hard; waxy; dry; white and gray mottling.	NR (60–61.5)	60–70	8.5 / 10; CB 60-70
		NR	70–75	3.4; CB 70-80

Well Design:
- 5% (dry) Bentonite/Type I Portland Cement Grout
- 4½" O.D. Sched. 40 PVC Casing

FILE NAME: A-LOGSG1.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LO(

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Gnd/Well No.: 9-G(i)
Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/29/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 170'	Top of PVC Casing Elev.: 3,458.25		
Sample Method(s): CONTINUOUS FROM 9' TO 170' USING SPLIT SPOON AND CORE BARREL.				

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log
	Silty CLAY (CL): same as above.	NR
		NR
84'–90'	Silty CLAY (SM): reddish-brown; hard; dry; brown coloring increasing with depth, some vf sand increasing with depth, some gray mottling; dry.	
90'–94'	Silty CLAY (CL): dusky red; hard; dry; some vf sand, gray mottling.	
94'–110'	Slightly Silty SAND (SM): grayish white, vf to fg sand, grains are angular; biotite and mica flakes; some yellow, pink and green color, bottom 1 (one) foot more yellow; HCl permeable; dry; v. slightly HCl reactive.	
	– Color becoming tan below 105 ft.; some brown/yellow streaking with depth; rip-up clay clasts (white).	
110'–117.5'	Slightly Silty SAND (SM): tan/yellow, fg sand, slightly angular grains; dry, numerous biotite and mica flakes; some gray, brown streaking; slightly HCl reactive; thin brown, yellow lamination.	

Depth (feet): 75, 80, 85, 90, 95, 100, 105, 110, 115

Recovered FL / FL Sampled: CB 70–80 (10); 6.2 CB 80–90 (10); 10 CB 90–100 (10); 10 CB 100–110 (10); 10 CB 110–120

Well Design:
- 5% (dry) Bentonite/Type I Portland Cement Grout
- 4½" O.D. Sched. 40 PVC Casing

FILE NAME: A-LOCSC1.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(1)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/29/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 170'	Top of PVC Casing Elev.: 3,458.25
Sample Method(s): CONTINUOUS FROM 9' TO 170' USING SPLIT SPOON AND CORE BARREL.		

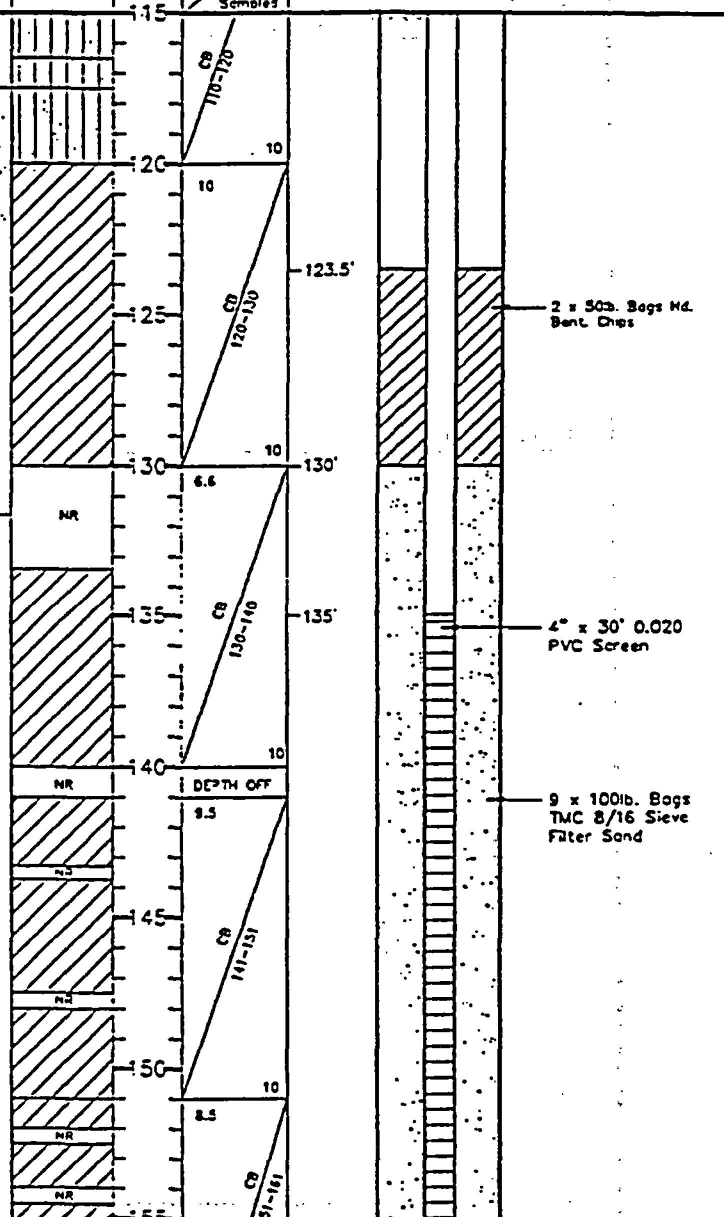
Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design

– Red, fg sand, from 116.5' to 17.5'.

117.5'–131.5' Slightly Silty SAND (SM): tan/yellow, fg sand, slightly angular grains; dry; numerous mica and biotite flakes; slightly HCl reactive; thin yellow lamination.

– Red, yellow and gray laminations. Bottom one foot is gray.

131.5'–170' Silty CLAY (CL): dusky red; numerous gray clay clasts (greenish–white) with occasional mustard yellow mottling; mod. hard; blocky fracture to sl. crumbly; dry.



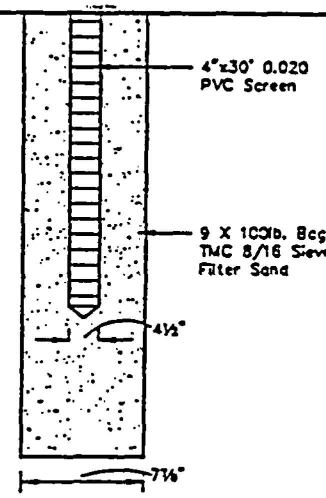
FILE NAME: A-LOG9G1.DWG

Terra Dynamics Incorporated	SOIL BORING & WELL COMPLETION LO

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(1)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/29/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903 Ground Surface Elev. (MSL): 3,454.55 Top of PVC Casing Elev.: 3,458.25
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 170'	
Sample Method(s): CONTINUOUS FROM 9' TO 170' USING SPLIT SPOON AND CORE BARREL.		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
Silty CLAY (CL): same as above.	NR	155–160	8.5 / 10 CB 151–161	
	NR, NR	160–170	9.3 / 10 CB 161–170	165' 165.5'
TOTAL DEPTH = 170'		170		
		175, 180, 185, 190, 195		



FILE NAME: A-LOG9G1.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/2/93	Boring No.: B-21	Grid/Well No.: 9-G(2)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 223'	Top of PVC Casing Elev.: 3,457.85

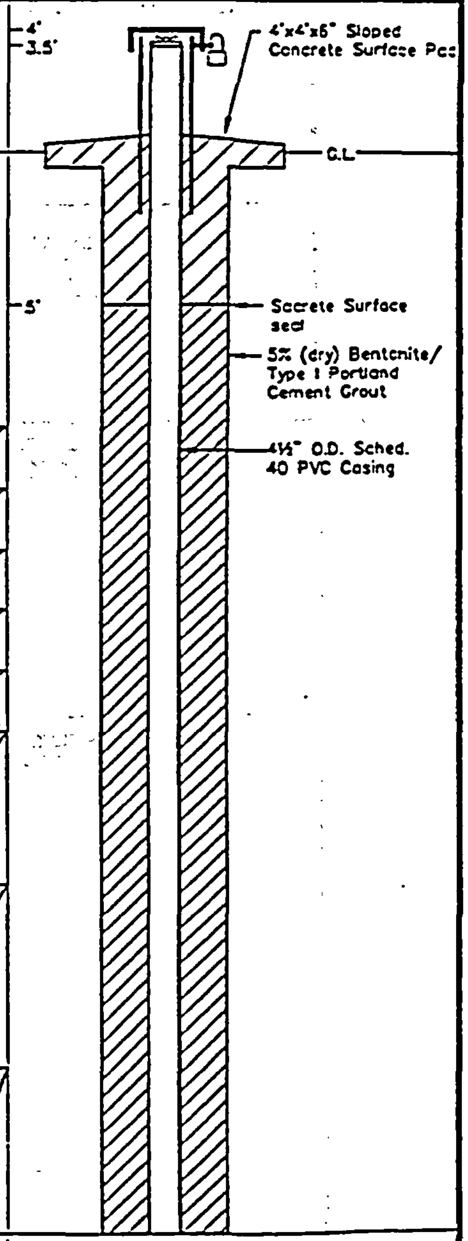
Sample Method(s): CONTINUOUS FROM 9' TO 223' USING SPLIT SPOON AND CORE BARREL

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
0'–9'	CALICHE: white; some white silty clay, some white pebbles.
9'–11'	CALICHE BASE OF OGALLALA – TRIASSIC TOP
11'–15.5'	Silty CLAY (CL): dusky red; hard; waxy; dry; some whitish–gray mottling.
15.5'–23'	Slightly Silty CLAY (CL): maroon; hard; waxy; dry; some gray mottling.
23'–25'	Slightly Silty SAND (SM): pinkish–red, well sorted vf–fg angular sand; some yellow and green mottling; HCl perm non–reactive; dry.
25'–26'	CLAYEY SAND (SL): white, chalky, HCl reactive; vf sand grains; dry.
26'–30'	Slightly Silty SAND (SM): pinkish–red, vf–fg angular sand grains; HCl perm numerous gray rip–up clasts; some yellow, green mottling; dry; lighter color with depth.
30'–42.5'	Slightly Silty SAND (SM): white, fine grained slightly angular sand; biotite and mica flakes; numerous rip–up white and gray clay clasts; slightly HCl reactive; permeable.

Sample	Recovered Ft.	Ft. Sampled	Graphic Log
			NR (0'–9')
SS 9–11	0	2	NR
SS 11–13	.25	2	NR
SS 13–15	1.5	2	NR
SS 15–17	1.5	2	NR
SS 17–19	1.6	2	
CB 19–24	3	5	NR
CB 24–30	5.9	6	
CB 30–40	10		

Depth (feet): 5, 0, 5, 10, 15, 20, 25, 30, 35

Well Design



FILE NAME: A-LOG9G2.DWG

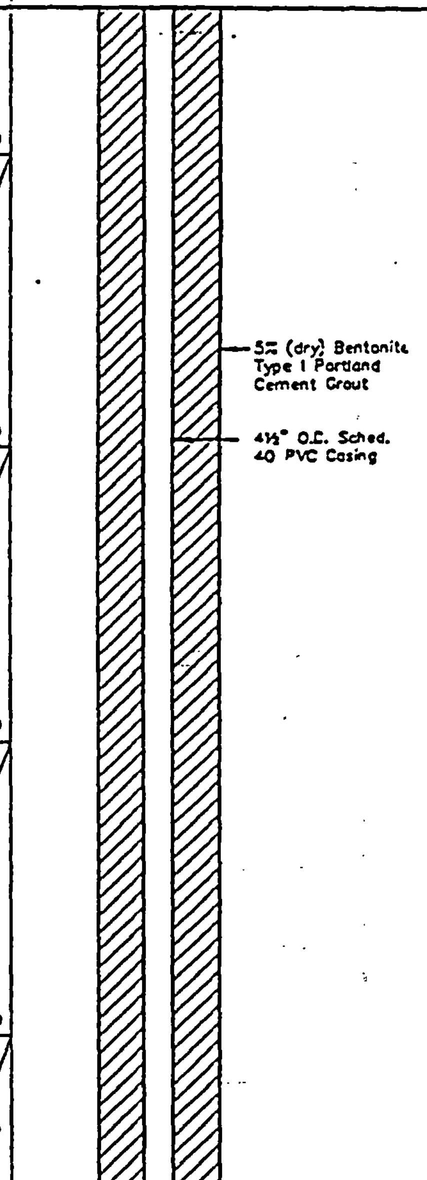
Terra Dynamics Incorporated	SOIL BORING & WELL COMPLETION LO'

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92: 1/2/93	Boring No.: B-21	Grid/Well No.: 9-G(2)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 223'	Top of PVC Casing Elev.: 3,457.85
Sample Method(s): CONTINUOUS FROM 9' TO 223' USING SPLIT SPOON AND CORE BARREL		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Ft. / Ft. Sampled
	Slightly Silty SAND (SM): same as above.		35–40	30–40; 10
		NR	40–50	8.1; CB 40–50; 10
42.5'–50'	Silty CLAY (CL): dusky red; mod. hard; dry; numerous silty sand laminations with depth (slightly HCl reactive); some gray, white mottling.			
50'–60'	Silty CLAY (CL): dusky red; mod. hard; waxy; dry; white and gray mottling, some vf grained sand near top.	NR	50–60	7.8; CB 50–60; 10
60'–84'	Silty CLAY (CL): dusky red; hard; waxy; dry; white and gray mottling.	NR	60–70	8.5; CB 60–70; 10
		NR	70–75	3.4; CB 70–80

Well Design



FILE NAME: A-LOC9G2.DWG

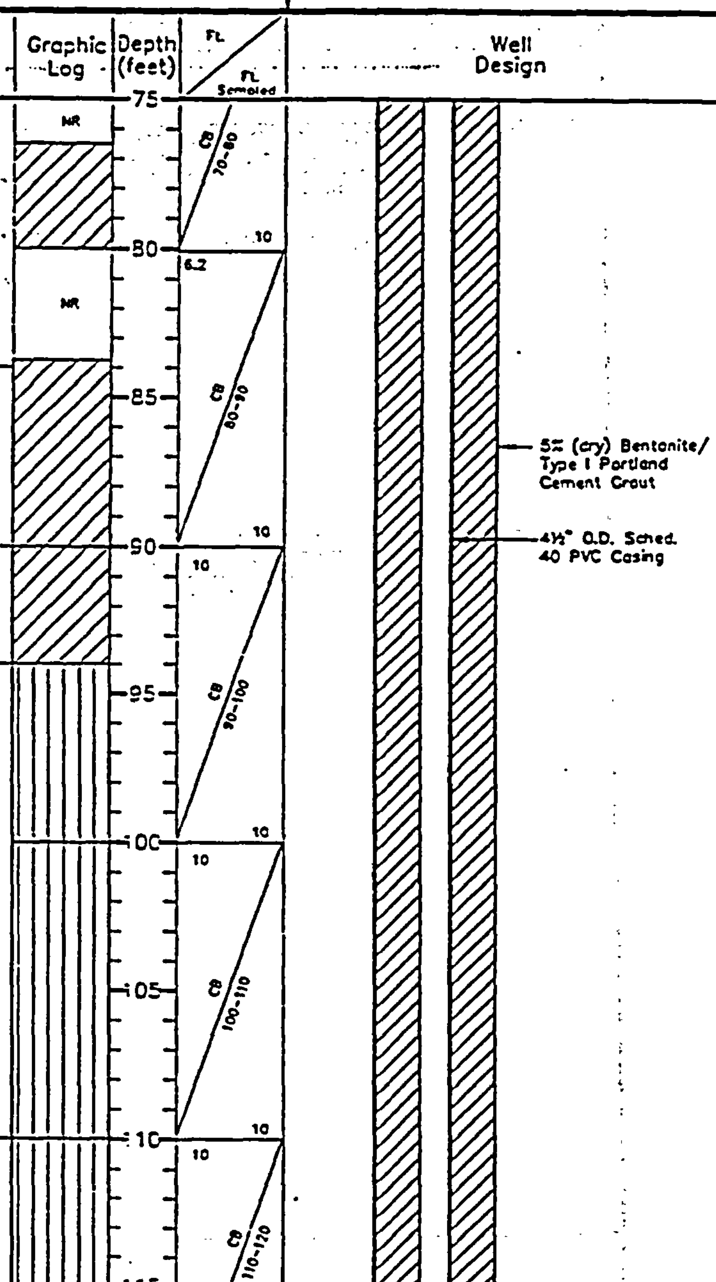
Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92: 1/2/93	Boring No.: B-21	Grid/Well No.: 9-G(2)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 223'	Top of PVC Casing Elev.: 3,457.85
Sample Method(s): CONTINUOUS FROM 9' TO 223' USING SPLIT SPOON AND CORE BARREL		

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
84'–90'	Silty CLAY (SM): reddish-brown; hard; dry; brown coloring increasing with depth, some vf sand increasing with depth, some gray mottling; dry.
90'–94'	Silty CLAY (CL): dusky red; hard; dry; some vf sand, gray mottling.
94'–110'	Slightly Silty SAND (SM): grayish white, vf to fg sand, grains are angular; biotite and mica flakes; some yellow, pink and green color, bottom 1 (one) foot more yellow; HCl permeable; dry. v. slightly HCl reactive.
	– Color becoming tan below 105 ft.; some brown/yellow streaking with depth; rip-up clay clasts (white).
110'–117.5'	Slightly Silty SAND (SM): tan/yellow, fg sand, slightly angular grains; dry, numerous biotite and mica flakes; some gray, brown streaking; slightly HCl reactive; thin brown, yellow lamination.

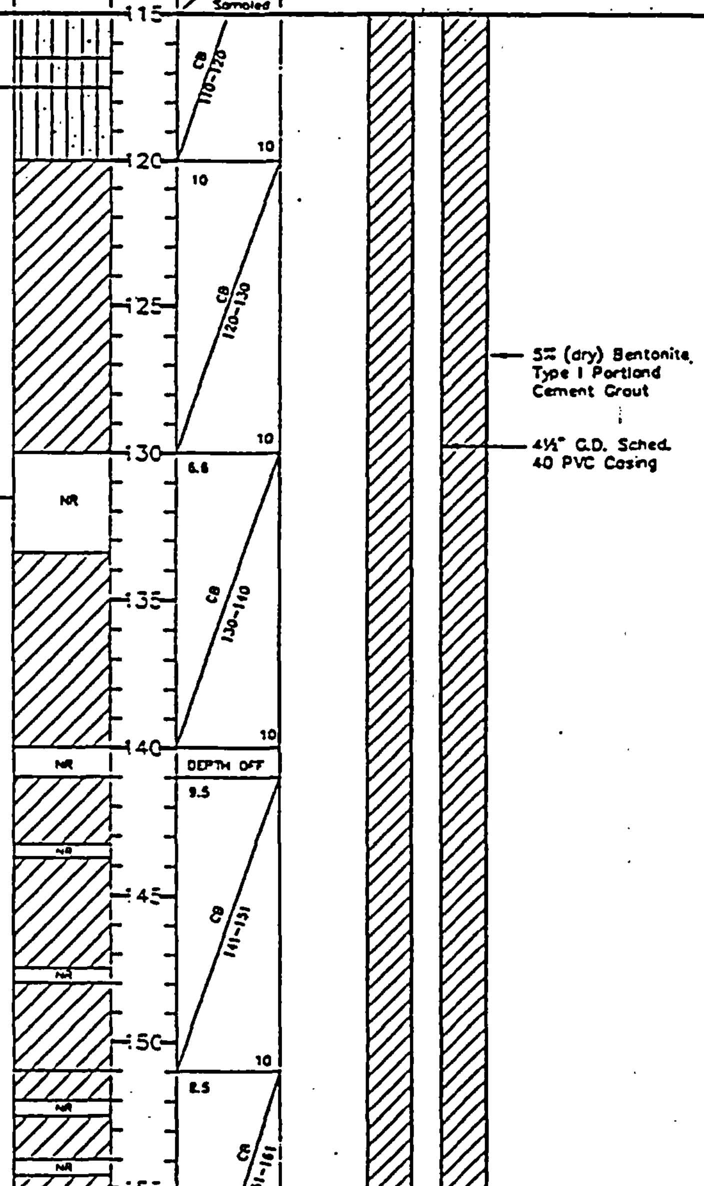


FILE NAME: A-LOG9G2.DWG

Terra Dynamics Incorporated	**SOIL BORING & WELL COMPLETION LOG**		
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/2/93	Boring No.: B-21; Gnd/Well No.: 9-G(2)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 223'	Top of PVC Casing Elev.: 3,457.85
Sample Method(s): CONTINUOUS FROM 9' TO 223' USING SPLIT SPOON AND CORE BARREL		

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
	– Red, fg sand, from 116.5' to 17.5'.
117.5'–131.5'	Slightly Silty SAND (SM): tan/yellow, fg sand, slightly angular grains; dry; numerous mica and biotite flakes; slightly HCl reactive; thin yellow lamination.
	– Red, yellow and gray laminations. Bottom one foot is gray.
131.5'–196'	Silty CLAY (CL): dusky red; numerous gray clay clasts (greenish–white) with occasional mustard yellow mottling; mod. hard; blocky fracture to sl. crumbly; dry.



FILE NAME: A-LOG9G2.DWG

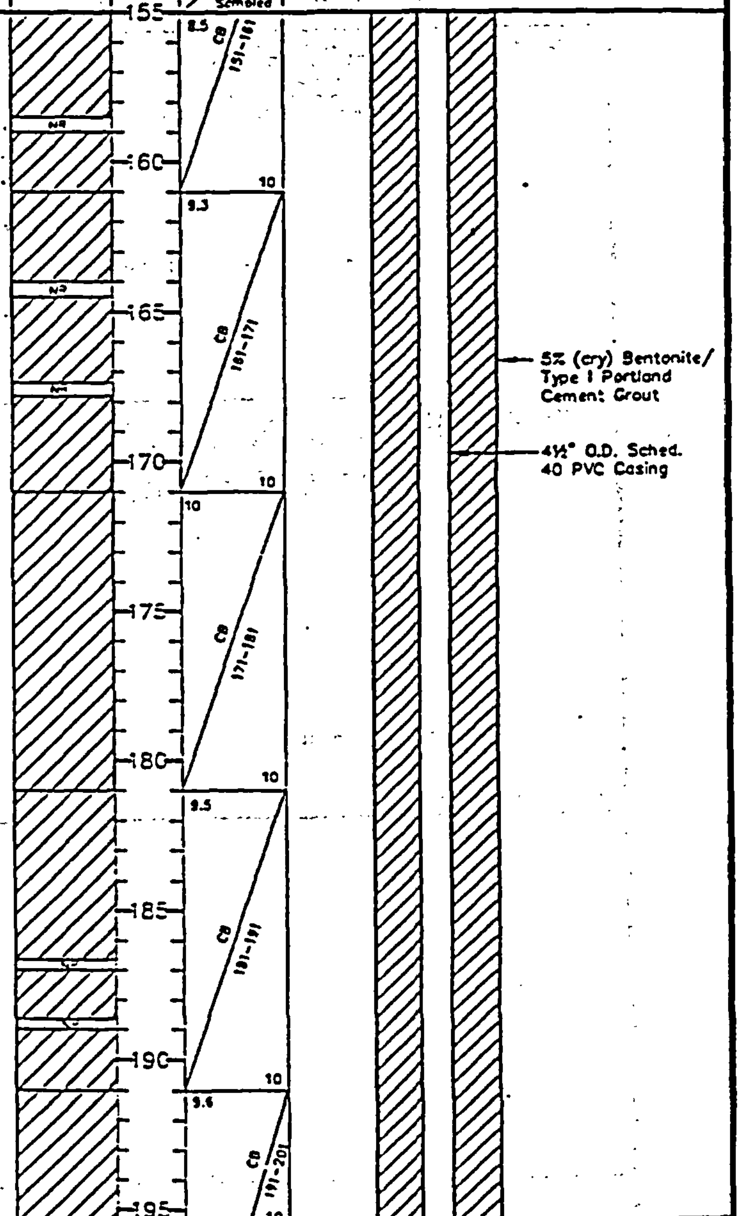
Terra Dynamics Incorporated			**SOIL BORING & WELL COMPLETION LOG**		
Location: ANDREWS CO. LANDFILL SITE		Project No.: 92-152	Date Drilled: 12/16/92: 1/2/93	Boring No.: B-21	Grid/Well No.: 9-G(2)
Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93		Survey Data: Northing: 6260.8293 Easting: 10544.8903		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS			Ground Surface Elev. (MSL): 3,454.55		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 223'		Top of PVC Casing Elev.: 3,457.85		
Sample Method(s): CONTINUOUS FROM 9' TO 223' USING SPLIT SPOON AND CORE BARREL					

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	FL / FL Sampled	Well Design

Silty CLAY (CL): same as above.

- Increased mustard yellow mottling below 180'.

- 45° slickenside at 186' with calcite crystalization along slip plane; increased greenish gray dendritic mottling below 186'; sl. increased crumbly texture below 186'.



FILE NAME: A-LOG9G2.DWG

Terra Dynamics Incorporated

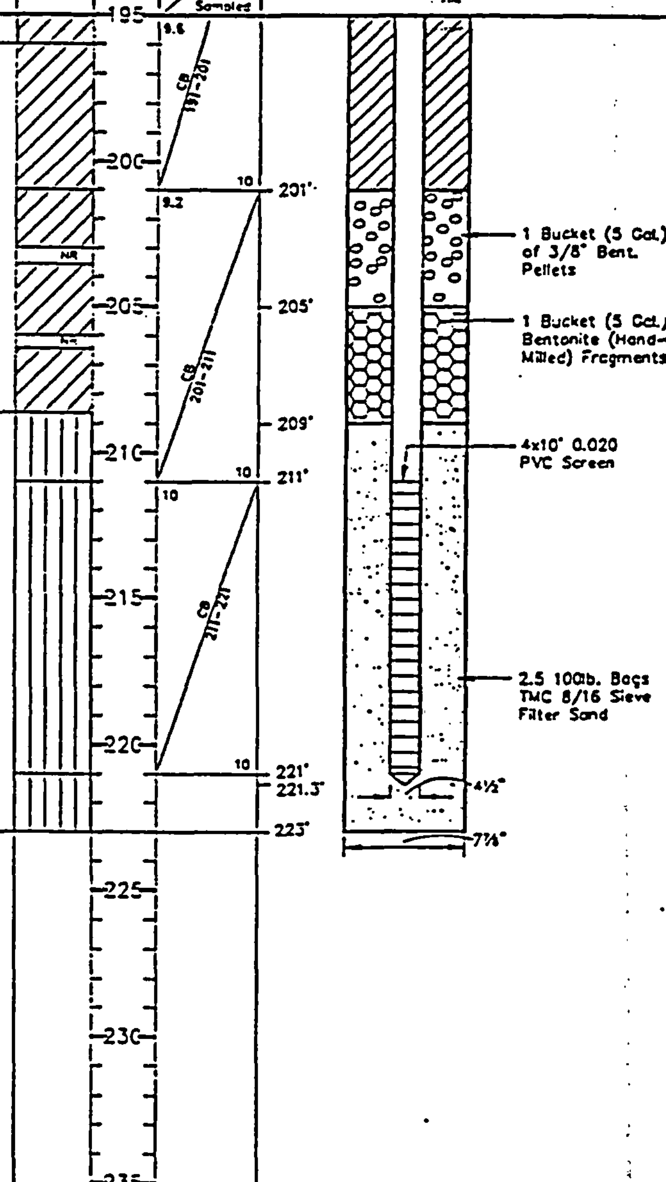
SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/15/92: 1/2/93	Boring No.: B-21	Grid/Well No.: 9-G(2)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 223'	Top of PVC Casing Elev.: 3,457.85

Sample Method(s): CONTINUOUS FROM 9' TO 223' USING SPLIT SPOON AND CORE BARREL

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)		Graphic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
196'-205.8'	Slightly Silty CLAY (CL): heavily mottled primarily greenish gray and purplish gray with dendritic coloring of reddish brown and mustard yellow; sl. soapy; blocky fracture and crumbly; dry.				
	- reduced greenish gray mottling below 201'.				
205.8'-223'	SILT(ML): greenish grey siltstone; trace vfg mica frags.; hard; blocky fracture; moist.				
	- reddish brown clayey siltstone layers; clasts and vertical seams from 213'-224'.				
	- faint cross-lamination below 220'.				
TOTAL DEPTH = 223'					



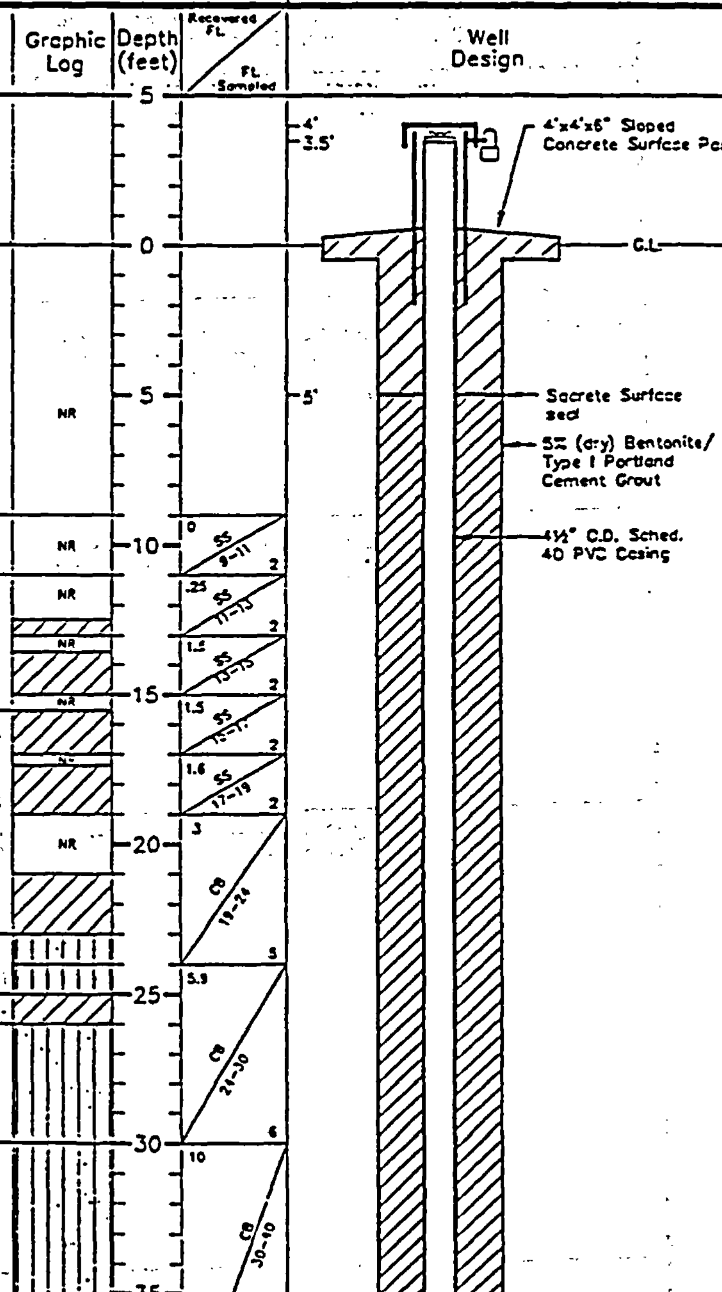
FILE NAME: A-LOG9G2.DWG

Terra Dynamics Incorporated	SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(3)
Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 300'	Top of PVC Casing Elev.: 3,457.65		

Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
0'–9'	CALICHE: white; some white silty clay, some white pebbles.
9'–11'	CALICHE BASE OF OGALLALA – TRIASSIC TOP
11'–15.5'	Silty CLAY (CL): dusky red; hard; waxy; dry; some whitish-grey mottling.
15.5'–23'	Slightly Silty CLAY (CL): maroon; hard; waxy; dry; some gray mottling.
23'–25'	Slightly Silty SAND (SM): pinkish-red, well sorted vf-fg angular sand; some yellow and green mottling; HCl perm non-reactive; dry.
25'–26'	CLAYEY SAND (SL): white, chalky; HCl reactive; vf sand grains; dry.
26'–30'	Slightly Silty SAND (SM): pinkish-red, vf-fg angular sand grains; HCl perm numerous gray rip-up clasts; some yellow, green mottling; dry, lighter color with depth.
30'–42.5'	Slightly Silty SAND (SM): white, fine grained slightly angular sand; biotite and mica flakes; numerous rip-up white and gray clay clasts; slightly HCl reactive; permeable.



FILE NAME: A-LOG9G.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location:	Project No.:	Date Drilled:	Boring No.:	Grid/Well No.:
ANDREWS CO. LANDFILL SITE	92-152	12/16/92: 1/23/93	B-21	9-G(3)

Log By: M. JOHNSON; A. WEEGAR

WELL COMPLETED ON: 1/26/93

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Drilling Method & Bit Sizes: AIR ROTARY

Total Depth: 300'

Survey Date:
Northing: 6260.8293
Easting: 10544.8903
Ground Surface Elev. (MSL): 3,454.55
Top of PVC Casing Elev.: 3,457.65

Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Recovered Ft. / Ft. Sampled
Slightly Silty SAND (SM): same as above.		35–40	CB 30-40; 10
	NR	40–50	8.1; CB 40-50; 10
42.5'-50' Silty CLAY (CL): dusky red; mod. hard; dry, numerous silty sand laminations with depth (slightly HCl reactive); some gray, white mottling.			
50'-60' Silty CLAY (CL): dusky red; mod. hard; waxy; dry; white and gray mottling, some vf grained sand near top.	NR	50–60	7.2; CB 50-60; 10
60'-84' Silty CLAY (CL): dusky red; hard; waxy; dry; white and gray mottling.	NR	60–70	8.5; CB 60-70; 10
	NR	70–75	3.4; CB 70-80

Well Design:
- 5% (dry) Bentonite/Type I Portland Cement Grout
- 4½" O.D. Sched. 40 PVC Casing

FILE NAME: A-LOG9G.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(3)

Log By: M. JOHNSON; A. WEEGAR

WELL COMPLETED ON: 1/26/93

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Drilling Method & Bit Sizes: AIR ROTARY

Total Depth: 300'

Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.

Survey Data:
Northing: 6260.8293
Easting: 10544.8903
Ground Surface Elev. (MSL): 3,454.55
Top of PVC Casing Elev.: 3,457.55

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Recovered Ft. / Ft. Sampled
Silty CLAY (CL): same as above.	NR	75–80	CB 70-80; 10
	NR	80–84	6.2
84'–90' Silty CLAY (SM): reddish-brown; hard; dry; brown coloring increasing with depth, some vf sand increasing with depth, some gray mottling; dry.		84–90	CB 80-90; 10
90'–94' Silty CLAY (CL): dusky red; hard; dry; some vf sand, grey mottling.		90–94	10
94'–110' Slightly Silty SAND (SM): grayish white, vf to fg sand, grains are angular; biotite and mica flakes; some yellow, pink and green color, bottom 1 (one) foot more yellow; HCl permeable; dry; v. slightly HCl reactive.		94–100	CB 90-100; 10
– Color becoming tan below 105 ft.; some brown/yellow streaking with depth; rip-up clay clasts (white).		100–110	10; CB 100-110; 10
110'–117.5' Slightly Silty SAND (SM): tan/yellow, fg sand, slightly angular grains; dry; numerous biotite and mica flakes; some gray, brown streaking; slightly HCl reactive; thin brown, yellow lamination.		110–115	10; CB 110-120

Well Design:
- 5% (dry) Bentonite/ Type I Portland Cement Grout
- 4½" O.D. Sched. 40 PVC Casing

FILE NAME: A-LOG9G.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LO[G]

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/25/93	Survey Date: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 300'	Top of PVC Casing Elev.: 3,457.65
Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.		

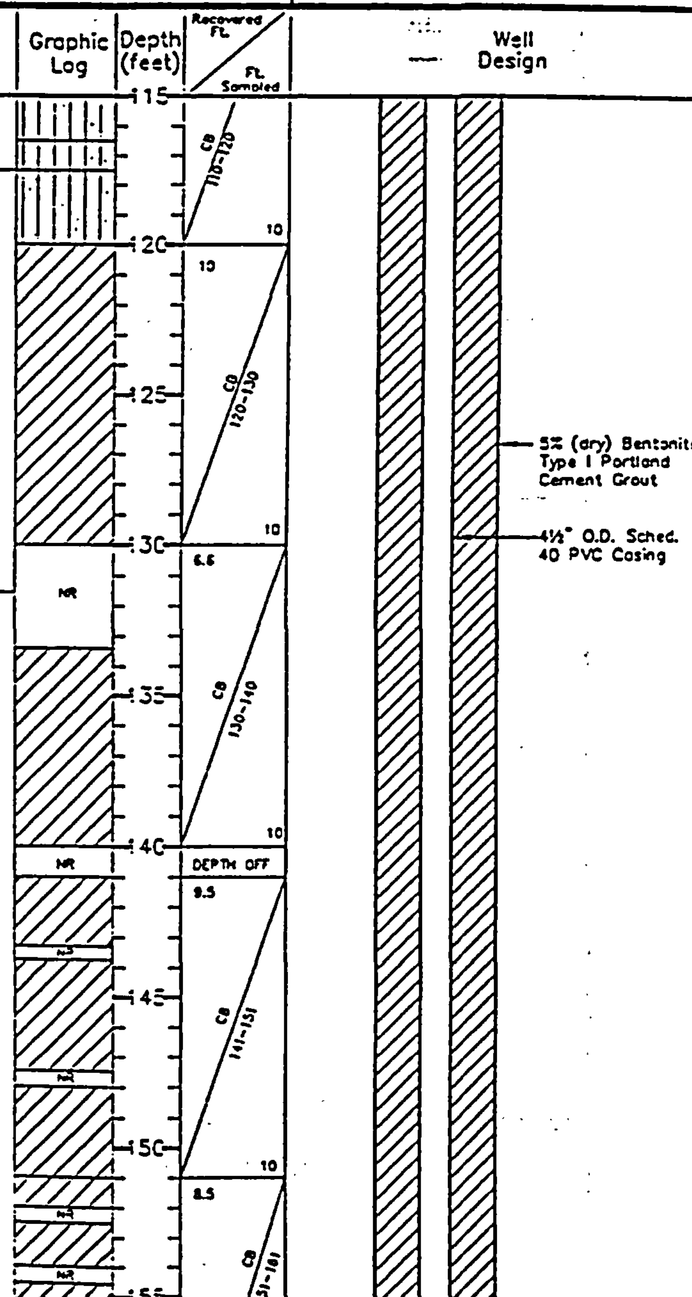
Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)

- Red, fg sand, from 116.5' to 17.5'.

117.5'–131.5' — Slightly Silty SAND (SM): tan/yellow, fg sand, slightly angular grains; dry; numerous mica and biotite flakes; slightly HCl reactive; thin yellow lamination.

- Red, yellow and gray laminations. Bottom one foot is gray.

131.5'–196' — Silty CLAY (CL): dusky red; numerous gray clay clasts (greenish-white) with occasional mustard yellow mottling; mod. hard; blocky fracture to sl. crumbly; dry.



FILE NAME. A-LOG9G.DWG

Terra Dynamics Incorporated	**SOIL BORING & WELL COMPLETION LOG**

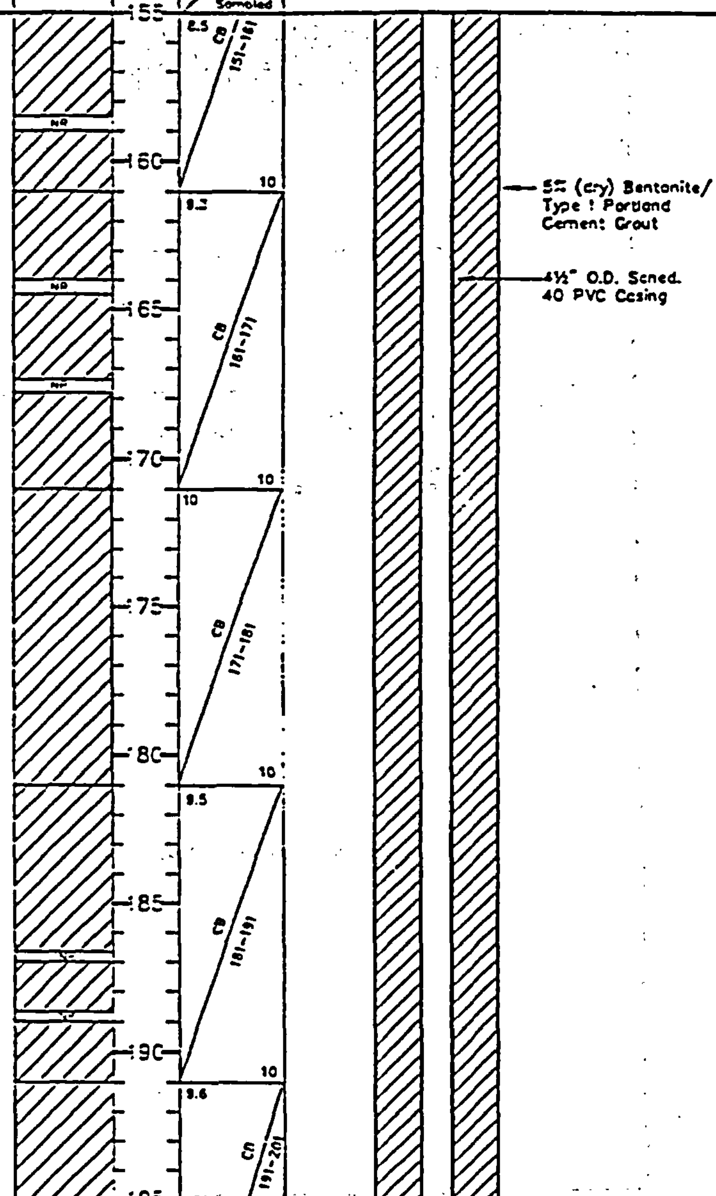
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92: 1/23/93	Boring No.: B-21	Gnd/Well No.: 9-G(3)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/26/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		Ground Surface Elev. (MSL): 3,454.55
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 300'	Top of PVC Casing Elev.: 3,457.65
Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Depth (feet)	Recovered FL / FL Sampled	Well Design

<u>Silty CLAY (CL)</u>: same as above.

- Increased mustard yellow mottling below 180'.
- 45° slickenside at 186' with calcite crystalization along slip plane; increased greenish gray dendritic mottling below 186'; sl. increased crumbly texture below 186'.



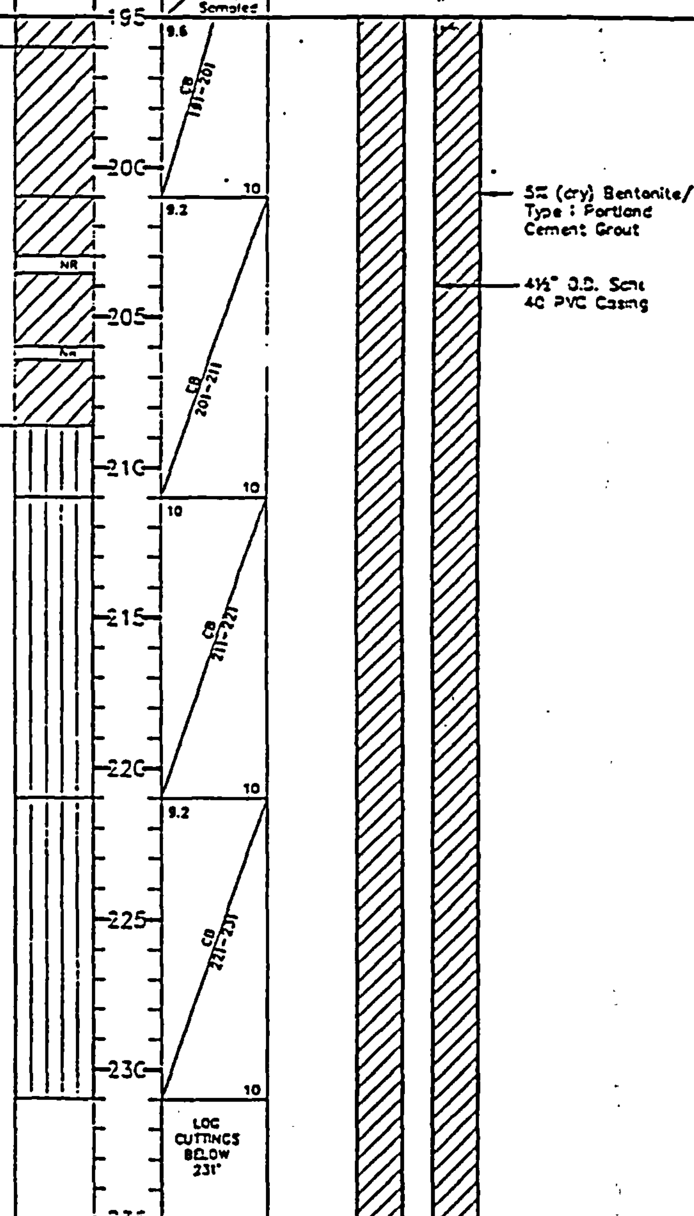
FILE NAME. A-LOG9C.DWG

Terra Dynamics Incorporated	**SOIL BORING & WELL COMPLETION LO**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(3)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/26/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903 Ground Surface Elev. (MSL): 3,454.55 Top of PVC Casing Elev.: 3,457.65
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 300'	
Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)		Graphic Log	Depth (feet)	Recovered Ft / Ft Sampled	Well Design
196'–208.8'	Slightly Silty CLAY (CL): heavily mottled primarily greenish gray and purplish gray with dendritic coloring of reddish brown and mustard yellow; sl. soapy; blocky fracture and crumbly; dry. – reduced greenish gray mottling below 201'.				
208.8'–238'	SILT(ML): greenish grey siltstone; trace vfg mica frags.; hard; blocky fracture; moist. – reddish brown clayey siltstone layers; clasts and vertical seams from 213'–224'. – faint cross-lamination below 220'.				



FILE NAME: A-LOG9G.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LOG

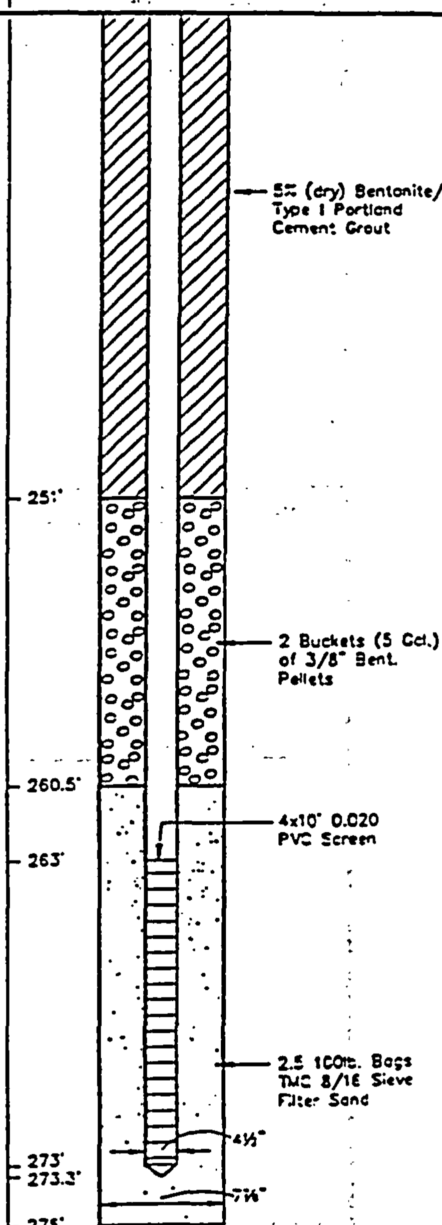
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92: 1/23/93	Boring No.: B-21	Grid/Well No.: 9-G(3)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/26/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903 Ground Surface Elev. (MSL): 3,454.55 Top of PVC Casing Elev.: 3,457.65
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 300'	

Sample Method(s): CONTINUOUS FROM 5' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.

Unified Soil Classification/Description (Color, Texture; Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled
		235	
238'–249' Silty CLAY (CL): reddish brown and maroon silty claystone with greenish gray mottling.		240, 245	
249'–251' SILT (ML): greenish gray siltstone.		250	
251'–257' Silty CLAY (CL): reddish brown and maroon silty claystone with slight purplish gray mottling.		255	
257'–260.5' Silty CLAY (CL): maroon and purple silty claystone with greenish gray mottling.		260	
260.5'–291' V. Silty CLAY (ML): reddish brown and maroon very silty claystone with heavy mottling of mustard yellow and purple.		265, 270, 275	

Well Design



FILE NAME: A-LOG30.DWG

Terra Dynamics Incorporated

SOIL BORING & WELL COMPLETION LO

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92; 1/23/93	Boring No.: E-21	Grid/Well No.: 9-G(3)

Log By: M. JOHNSON; A. WEEGAR	WELL COMPLETED ON: 1/26/93	Survey Data: Northing: 6260.8293 Easting: 10544.8903 Ground Surface Elev. (MSL): 3,454.55 Top of PVC Casing Elev.: 3,457.65
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS		
Drilling Method & Bit Sizes: AIR ROTARY	Total Depth: 300'	

Sample Method(s): CONTINUOUS FROM 9' TO 231' USING SPLIT SPOON AND CORE BARREL; GRAB SAMPLES EVERY 5' FROM 231' TO TD.

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
V. Silty CLAY (ML): same as above.		275		
		280		
		285		
		290		
291'-300' Silty CLAY (CL): dark reddish brown silty claystone.		295		
TOTAL DEPTH = 300'		300		
		305		
		310		
		315		

FILE NAME: A-LOG93.DWG

Terra Dynamics Incorporated

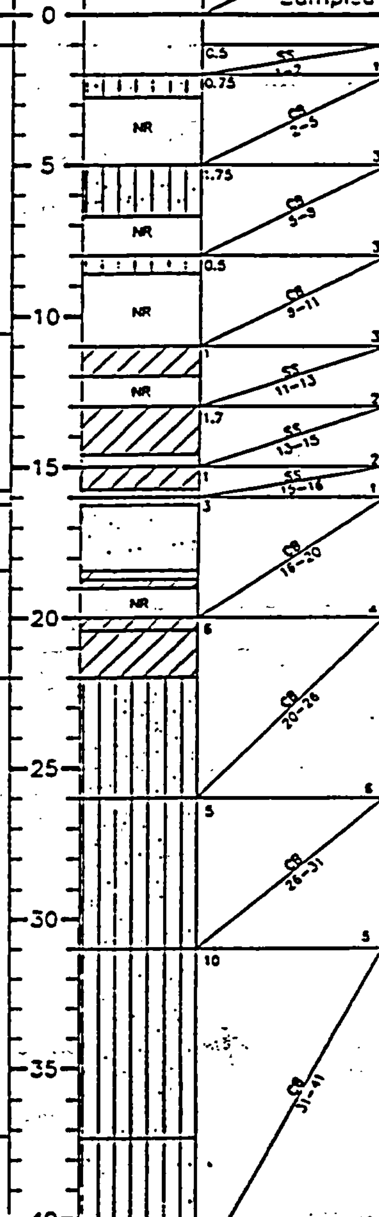
SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12-10-92	Boring No.: B-14	Grid No.: 9-H

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5807.9313 Easting: 10333.6242
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	Ground Surface Elev. (MSL): 3,439.66
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
0' – 1'	TOP SOIL: brown silty sand; organic plant material & roots; moist.
1' – 10.5'	CALICHE: pinkish tan sandy silt; mod. hard; crumbly; calcite crystals along laminations and in vugs; dry; basal contact from driller.
10.5' – 15.7'	Silty CLAY(CL): mottled dusky red, yellow, pink and gray; crumbly; non-plastic; carb. plant material; mica frags.; sl. soapy; dry.
15.7' – 16.2'	SILT (SL): greenish gray siltstone; soft; crumbly; chalky; very strong reaction w/ HCl; mica frags; dry.
16.2' – 18.3'	Silty SAND (SM): reddish brown sand w/ greenish gray, silty matrix; sand is granitic fg. subang. to ang.; contains dk. min. frags. and mica frags; mod. hard; crumbly; blocky fracture; strong reaction w/ HCl to matrix; dry.
18.3' – 22'	Silty CLAY (CL): alternating layers of greenish gray and mottled dusky red and yellow; crumbly; soft to mod. hard; blocky fracture; carb. plant material mica frags; dry.
22' – 37.2'	Silty SAND (SM): reddish brown sand w/ greenish gray, silty matrix; sand is granitic fg. subang. to ang.; mod. reaction w/ HCl to matrix; natural vertical fractures; thinnly bedded and cross bedded sandstone and sandy siltstone; mod. perm. to acid; dry.
37.2' – 43'	V. Sandy SILTSTONE (ML): greenish gray siltstone and olive tan sandstone; sand is vfg. subr.; hard; sl. crumbly; mod. reaction to HCl; mica frags.; dk. min frags; horiz. to crossbedded; dry.

Depth (feet) | Graphic Log | Recovered Ft. / Ft. Sampled | Stratigraphic Interval



Stratigraphic Interval: OGALLALA / TRIASSIC

FILE NAME: A-LOG9H.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12-10-92	Boring No.: B-14	Grid No.: 9-H
Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5807.9313 Easting: 10333.6242 Ground Surface Elev. (MSL): 3,439.66		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL			
Driller: LANE SCARBOROUGH	Total Depth: 100'			
Remarks:				

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
		40		10	
43' - 60.1'	Silty SAND (SM): olive, red and pink sand w/ greenish gray matrix; sand is vfg - cg angular to subrounded and poorly sorted; mica & dk. min. frags. througout; mod. hard; sl. crumbly; mod. perm. to HCl; no reaction w/ HCl; horiz. and crossbedded; slightly higher angle x-bedding and larger grain sand than above; apparent weathered iron oxide zone throughout; dry; basal contact from driller.	45–50		10 / 10 (CB 41-51)	
		50–60		9.1 / 10 (CB 51-61)	
60.1' - 61.70'	CLAY (CL): tannish yellow; soapy; plastic; mod. hard; moist.	60	NR		
61.70' - 65.75'	CLAY (CL): dk. maroon; sl. plastic; soapy; sticky; mod. hard; moist; core jammed in barrel.		NR	0.85 / 4 (CB 61-65)	
?	?	65	NR		
65.75' - 75'	Clayey Sandy SILT (ML): dusky red sandy, clayey siltstone; dk. min. frags. and mica throughout; hard; blocky fracture; no reaction w/ HCl; non - permeable to HCl; dry.			3.25 / 4 (CB 65-69)	
		70		5.1 / 6 (CB 69-75)	
75' - 100'	V. Clayey SILT (ML): dusky red siltstone; hard; conchoidal fracture; mica and dk. min. frags.; thinnly laminated; dry; occasional streaks of light greenish gray clay.	75–80		8.2 / 10 (CB 75-85)	

FILE NAME: A-LOG9H.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12-10-92	Boring No.: B-14	Grid No.: 9-H

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 5807.9313 Easting: 10333.6242 Ground Surface Elev. (MSL): 3,439.66
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
V Clayey SILT (ML): same as above.	80		8.2 / 10 (CB 75-85)	
		NR		
	85		3.2 / 6 (CB 85-91)	
		NR		
	90			
			8.7 / 9 (CB 91-100)	
	95			
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG9H.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/23/93	Boring No.: B-50	Grid No.: 10-B
Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8738.0161 Easting: 11148.0894 Ground Surface Elev. (MSL): 3,480.41		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL			
Driller:	Total Depth: 100'			
Remarks:				

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0.0'–1.0'	TOP SOIL: dk. brown, sand, silt, organic material, loose, dry.	0		
1.0'–10'	CALICHE: lt. tan, calcitic cemented silt and sand, vfg–fg quartz sand, soft, dry. – reddish tan 8'–10'.	5	DRILL OUT; LOG CUTTINGS	
10'–20'	SAND (SW): tan to reddish tan vfg–fg quartz sand; scattered calcitic cemented sand clasts; soft; dry.	10–15		
20'–30'	CALICHE: lt. tan–gray calcitic and micritic cemented sand and silt, vfg–fg quart sand; micritic cement has concretion rings; sandstone lithoclasts with silica concretions in micritic matrix; hard; dry.	20–25		
30'–32.5'	SAND and GRAVEL (SW): lt. tan,–gray vfg–fg quartz sand and pebbles; pebbles rounded to angular.	30		OCALLALA
32.5'–71.5'	CLAY (CL): red with whitish mottling; friable; soft; dry. – silt nodules approx. 1.5" at 36' and 38'.	35–40	2 / SS 33–35 / 2; 2 / SS 35–37 / 2; 2 / SS 37–39 / 2; 2 / SS 39–41 / 2	TRIASSIC

FILE NAME: A-LOG10B.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/23/93	Boring No.: B-50	Grid No.: 10-9

Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8738.0161 Easting: 11148.0894 Ground Surface Elev. (MSL): 3,480.41
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

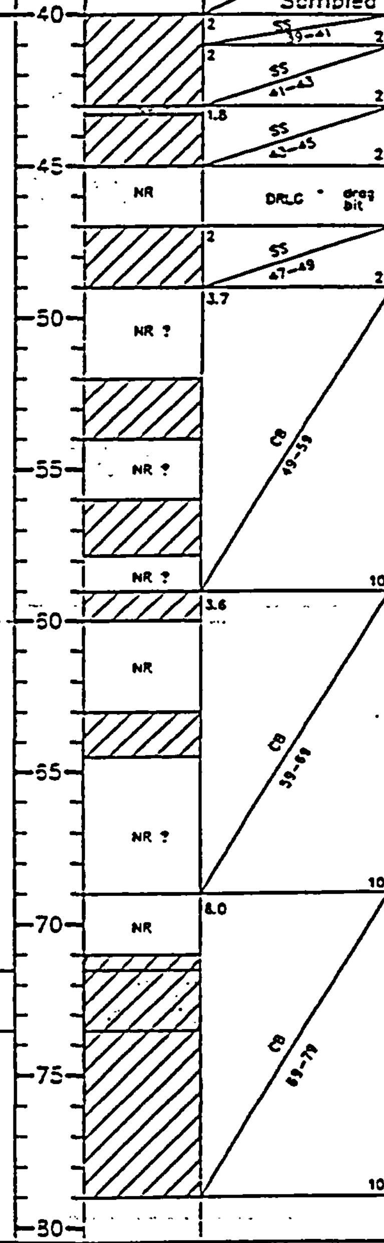
Unified Soil Classification/Description (Color, Texture, Structure, Grain Size) | Depth (feet) | Graphic Log | Recovered Ft. / Ft. Sampled | Stratigraphic Interval

- cohesive; plastic; damp; yellow and purple slight mottling.
- purplish red with yellow at 43'-45'.
- yellow mottling back at 47'.
- healed fracture oriented 30° from vertical.

71.5'-73.5' — Silty CLAY (CL): greenish white nodules (3"-4" nodules); dry; brittle; vertical fractures 72'-73'.

73.5'-100' — CLAY (CL): filled (1/4") frac.; calcite Spar, oriented 60° from verical at 78.0'.

- red orange with yellow and purple mottling and greenish white nodule.



FILE NAME: A-LOG108.DWG

Terra Dynamics Incorporated			**SOIL BORING LOG**		
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152		Date Drilled: 0:/24/93	Boring No.: B-50	Grid No.: 10-B
Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY		Survey Data: Northing: 8738.0151 Easting: 11148.0894 Ground Surface Elev. (MSL): 3,480.41		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL				
Driller:	Total Depth: 100'				
Remarks:					

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	80		4.9	
		NR ?		
- 1/2" wafer of spary calcite cemented clay and silt.				
	85	NR ?	CB 79-89.5	
- approx. 86' red, yellow and purple mottled, no whitish nodules.				
		NR ?	10.5	
	90		10.6	
- 95'-97' whitish green clay nodules scattered 0.5"-0.75".	95		CB 89.5-100.1	
TOTAL DEPTH = 100'	100		10.6	
	105			
	110			
	115			
	120			

FILE NAME: A-LOG108.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/12/93	Boring No.: B-36	Grid No.: 10-C

Log By: A. WEEGAR/R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8284.7750 Easting: 10936.8294 Ground Surface Elev. (MSL): 3,475.51
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 100'	
Remarks:		

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
0'–0.3'	TOP SOIL: dk. brown, loose sand and silt; organic material; moist.	0			
0.3'–17'	CALICHE: whitish to lt. tan, calcite cemented silt and sand; vfg quartz sand; soft.	5, 10, 15		DRILLED OUT WITH ROCK BIT TO 31' – LOG CUTTINGS	
17'–29'	CALICHE: gray to lt.tan, calcitic–micritic cemented silt and sand; vfg quartz and feldspar sand; micritic fragments show concretions; sandstone lithoclasts with silica rims in calcitic matrix; concoidal silica fragments; hard.	20, 25			OGALLALA
29'–55'	CLAY (CL): red; scattered calcitic sand particles; soft and moist. – small nodules of green clay – absense of calcite grains; less moist.	30, 35, 40	NR NR	1 SS 31–33 2 2 SS 33–35 2 2 SS 35–37 2 2 SS 37–39 2 1.8 SS 39–41 2	TRIASSIC

FILE NAME: A-LOG10C.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/13/93	Boring No.: B-36	Grid No.: 10-C

Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8284.7750; Easting: 10936.8294; Ground Surface Elev. (MSL): 3,475.51
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
– Purplish color at 41'.	40	NR	1.8 / 2 SS 40–41	
–30–40% green clay, 41'–42' (Nodular).			1.9 / 2 SS 41–43	
– Mostly red clay <10% green.	45		2 / 2 SS 43–45	
		NR	1.8 / 2 SS 45–47	
– Yellow clay mottling.		NR	1.8 / 2 SS 47–49	
– Less purple color.	50	NR ?, NR ?	2.5 / 5 CB 49–54	
	55	NR ?, NR ?, NR ?	6.9 / 10 CB 54–64	
59'–85' CLAY (CL): red-orange with yellow-green mottling and some green nodules.	60			
– Vertical fracture; from 60'–60.8'; black secondary mineralization.				
– Quasi brittle.	65	NR ?, NR ?, NR ?	6 / 10 CB 64–74	
– Vertical fracture with black mineralization.	70			
– 45° fracture; healed with yellow clay.				
– Yellow/green clay nodules with purple clay concretions. – Brittle	75	NR ?, NR	8 / 10 CB 74–84	
– Green clay nodule approx. 0.15 ft.	80			

FILE NAME: A-LOG10C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/13/93	Boring No.: B-36	Grid No.: 10-C

Log By: R.McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8284.7750 Easting: 10936.8294 Ground Surface Elev. (MSL): 3,475.51
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 100'	
Remarks:		

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
		80–85		8 / 10 (CB 74–84)	
85'–96'	CLAY (CL): pinkish yellow due to increased content of yellow to whitish green clay. – green clay nodules approx. 0.15 ft. – 45° healed fracture 91'. – 30° healed fracture 89' – hard and brittle and dry. – purple 95'–96'	85–95	NR (at 85)	9.9 / 10 (CB 84–94)	
96'–100'	CLAY (CL): orange yellow. – 45° frac. healed 99.5' and 98.5'.	95–100	NR ? (at 95)	4.9 / 6 (CB 94–100)	
TOTAL DEPTH = 100'		100–120			

FILE NAME: A-LOG10C.DWG 1=360

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/18/93	Boring No.: B-44	Grid No.: 10-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7831.6956 Easting: 10725.4492 Ground Surface Elev. (MSL): 3,469.62
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'-0.2'	TOP SOIL: brown; silty sand; organic material; moist.	0			
0.2'-5'	CALICHE: yellowish white; trace dark and pink vfg sand fragments; soft; mod. hard pinkish tan layers; dry.				
5'-18'	CALICHE: yellowish white; hard; trace vfg to cg dark and pink sand frags.; dry.	5		DRILL OUT TO 26'; LOG CUTTINGS	
18'-23'	Gravelly SAND (SW): tan; fg to cg sand; angular to subrounded; dark, white, pink and opaque gravel throughout; angular; loose; dry.	20			OGALLALA
23'-42.8'	Silty CLAY (CL): maroon clay; dense; sl. plastic; moist.	25			TRIASSIC
		26-28	NR	1.4 / SS 26-28 / 2	
		28-30	NR	1.7 / SS 28-30 / 2	
		30-32	(GRAB)	0 / SS 30-32 / 2	
		32-34	(GRAB)	0 / SS 32-34 / 2	
		34-36	(GRAB)	0 / SS 34-36 / 2	
		36-38	(GRAB)	0 / SS 36-38 / 2	
		38-40	NR	1.6 / SS 38-40 / 2	

FILE NAME: A-LOG130.DWG

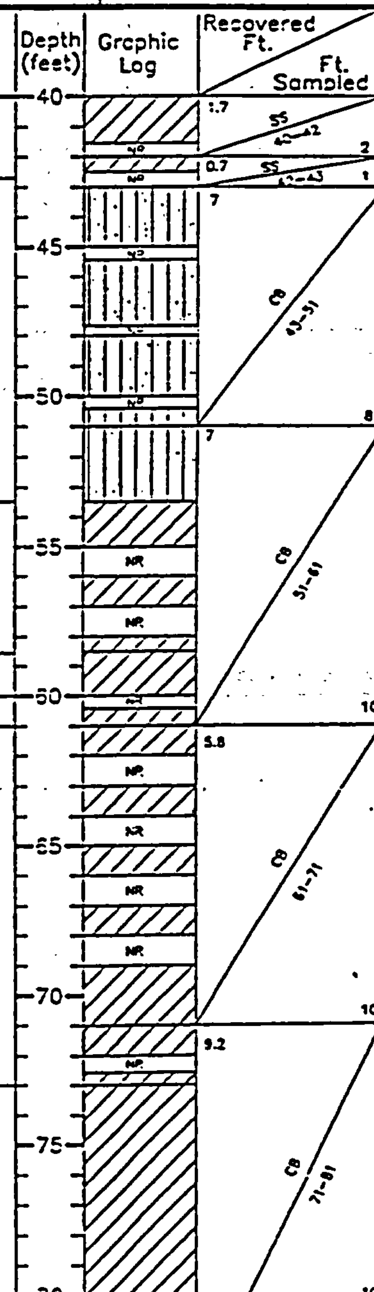
Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/18/93	Boring No.: B-44	Grid No.: 10-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7831.6956; Easting: 10725.4492; Ground Surface Elev. (MSL): 3,469.62
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
42.8'–53.4'	Silty SAND (SM): multicolored grayish green, yellow, tan and pink silty sandstone and thin intervals of sandy siltstone: "salt and pepper" appearance of vfg to fg quartz and feldspar sand with fg to cg mica and biotite flakes; gray and yellow clay clasts throughout; increased clay clasts in basal 3'; trace black mineralization along bedding; mod. hard; calcium carbonate cemented; blocky fracture and crumbly; dry.
53.4'–58.6'	Silty CLAY (CL): purple red with heavy mottling of yellow and gray; fg–cg mica frags; crumbly; dry.
58.6'–60'	Silty CLAY (CL): rusty red silty claystone; crumbly; dry
60'–61'	Silty CLAY (CL): purple red with heavy mottling of yellow and grey; vfg mica frags.; tubes and inclusions of silty/sandy material similar to that found at 42.8'–53.4'; crumbly; dry.
61'–73'	Silty CLAY (CL): alternating layers of purple/rusty red and heavily mottled yellow and pinkish red silty claystone; occasional clasts and tubes of greenish gray clay; blocky fracture to crumbly; mod. hard; dry.
73'–82'	Silty CLAY (CL): dusky red silty claystone; greenish gray clasts and tubes throughout; dense; blocky fracture; dry. – primary slickenside at 78.5' with calcium carbonate cementation along fracture plane (30°–45° angle).



Stratigraphic Interval

FILE NAME: A-LOG10D.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/18/93	Boring No.: B-44	Grid No.: 10-D

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7831.6956; Easting: 10725.4492; Ground Surface Elev. (MSL): 3,469.62
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	80			
82'–88' Silty CLAY (CL): rusty red and heavily mottled with yellow and grayish purple; greenish gray clasts and tubes throughout; blocky fracture; dry.	85		8.1 / 10 CB 81–91'	
88'–100' Silty CLAY (CL): purple claystone with yellow and greenish gray mottling; crumbly; greenish grey tubes throughout; dry.	90, 95	NR; NR; NR; NR; NR; NR	5.5 / 9 CB 91–100	
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG100.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92	Boring No.: B-19	Grid No.: 10-E
Log By: A. WEEGAR; R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7378.4802 Easting: 10514.3251 Ground Surface Elev. (MSL): 3,467.75		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL			
Driller: LANE SCARBOROUGH	Total Depth: 100'			
Remarks:				

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'-1'	TOP SOIL: brown silty sand; organic material; soft; loose; moist.		DRILL OUT TO 19' W/ROCK BIT	
1'-13'	CALICHE: pinkish white; calcium carb. cemented; hard; microcrystalline; dry.	NR (GRAB)		
13'-19'	Gravelly SAND (SW): pink sand with white, red, black and opaque gravel; sand is vfg-cg quartz; well rounded; gravel is subr. to well rounded quartzite; loose; dry.	NR (GRAB)		OGALLALA
19'-36'	Slightly Silty CLAY (CL): dusky red with whitish gray mottling; dense; sl. plastic, moist. - color change to maroon with whitish grey mottling below 21'.			TRIASSIC
36'-37.9'	Slightly Silty CLAY (CL): dusky red; crumbly; mod. hard; dry.			
37.9'-41'	Clayey SILT (ML): greenish white, gray and yellow siltstone; mica frags., mod. hard; chalky, crumbly, dry.			

Sample	Recovered Ft.	Ft. Sampled	Graphic Log
SS 19-21	2	2	
SS 21-23	2	2	
SS 23-25	2	2	
SS 25-27	2	2	
SS 27-29	2	2	
SS 29-31	2	2	
SS 31-33	1.5	2	NR
SS 33-35	1.5	2	NR
SS 35-37	1.6	2	NR
SS/37-37.5			
CB 37.5-41	3.5		

Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40

FILE NAME: A-LOG1CE.DWG

Terra Dynamics Incorporated	**SOIL BORING LO**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92	Boring No.: B-19	Grid No 10-E

Log By: A. WEEGAR: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7378.4802 Easting: 10514.3261 Ground Surface Elev. (MSL): 3,467.76
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON: CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
40'-51'	Silty SAND (SM): speckled appearance of red, pink, white and green sand frags. with white, yellow and green matrix; sand is vfg-fg; subr. to rounded; small to large biotite and mica flakes throughout; mod. perm. to HCl; no reaction with HCl; low angle cross-bedding; mod. hard; chalky; sl. crumbly; dry.	40–51		3.5 / 2.5; 10 / 10 (CB 41-51)	
51'-53.9'	Silty SAND (SM): top 0.3': speckled red, white and green sand frags., white, yellow and green matrix; sand fg. uncemented. additional as above, no rip-up clasts: drilling break at 53'.	51–53.9	NR	6.4 / 9 (CB 51-60)	
53.9'-60'	Slightly Silty CLAY (CL): maroon; crumbly; mod. hard; very slightly moist.	53.9–60			
60'-62.8'	No sample recovered.	60–62.8	NR	7.2 / 10 (CB 60-70)	
62.8'-70'	Slightly Silty CLAY (CL): dusky red; crumbly; mod. hard; dry; numerous gray-white silty clay clasts with black speckles, (soapy clasts) some silt clasts, (tan).	62.8–70			
70'-80'	Slightly Silty CLAY (CL): dusky red; crumbly; mod. hard; dry; gray-white, tan mottling.	70–80		9.9 / 10 (CB 70-80)	

FILE NAME: A-LOG1CE.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16/92	Boring No.: B-19	Grid No.: 10-E

Log By: A. WEEGAR; R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7378.4802 Easting: 10514.3261 Ground Surface Elev. (MSL): 3,467.76
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LANE SCARBOROUGH	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
80'–90' Slightly Silty CLAY (CL): dusky red; slightly maroon; mod. hard, grey-white, tan mottling; crumbly; dry.	80–90	NR (80–84.5)	5.6 / 10 (CB 80-90)	
90'–100' Slightly Silty CLAY (CL): maroon; mod. hard; less mottling; slightly sticky, dry.	90–100	NR (90–93)	7.0 / 10 (CB 90-100)	
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG1CE.DWG

Terra Dynamics Incorporated	**SOIL BORING LO**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/19/92	Boring No.: B-25	Grid N: 10-F

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6925.4458 Easting: 10302.9162 Ground Surface Elev. (MSL): 3,467.67
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LIZARO CASTILLO JOHN SCARBOROUGH	Total Depth: 100'	
Remarks:		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
0'-0.3'	TOP SOIL: brown silty sand; organic material; moist;
0.3'-5'	CALICHE: grayish white; calcium carb. cemented silt w/ vfg pink sand frags.; concentric growth rings; v. hard; dry.
5'-11'	CALICHE: grayish pink; quartz sand and gravel througrout; mod. hard (i.e., softer than above); dry.
11'-19.5'	Silty Gravelly SAND (SW): pink and opaque sand grains, white dark and red gravel with pinkish tan silt matrix; sand is vfg-fg; sand and gravel is subrounded to rounded quartz; loose; dry.
19.5'-31'	CLAY (CL): maroon w/mottling of pinkish gray; dense; sl. soapy; blocky fracture; crumbly in upper 2'; moist.
31'-38'	Silty CLAY (CL): dusky red w/ pinkish gray mottling; trace vfg mica frags; mod. dense; moist.
38'-83.2'	Slightly Sandy Silty CLAY (CL): (see next page for description).

Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
0-0.5	NR (GRAB)		
0.5-19.5	NR (GRAB); NR (GRAB); NR (GRAB)	DRILL OUT WITH ROCK BIT TO 19.5'- LOG CUTTINGS	OGALLALA
19.5-21.5	NR	1.9 / 2 — SS 19.5-21.5	TRIASSIC
21.5-23.5	NR	1.7 / 2 — SS 21.5-23.5	
23.5-25.5		2 / 2 — SS 23.5-25.5	
25.5-27.5	NR (GRAB)	0 / 2 — SS 25.5-27.5	
27.5-29.5	NR (GRAB)	0 / 2 — SS 27.5-29.5	
29.5-31	NR (GRAB)	DRILL OUT	
31-33	NR	1.7 / 2 — SS 31-33	
33-35	NR	1.7 / 2 — SS 33-35	
35-37	NR	1.75 / 2 — SS 35-37	
37-39		1.6 / 2 — SS 37-39	
39-49		9.3 — CB 39-49	

FILE NAME: A-LOG10F.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/19/92	Boring No.: B-25	Grid No.: 10-F
Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6925.4458 Easting: 10302.9162 Ground Surface Elev. (MSL): 3,467.67		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL			
Driller: UZARO CASTILLO JOHN SCARBOROUGH	Total Depth: 100'			
Remarks:				

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)		Depth (feet)
38'–63.2'	Slightly Sandy Silty CLAY (CL): multicolored mottling of light greenish grey, yellow, dusky red and purple sandy siltstone and claystone; silty claystone clasts and layers floating within a sandy siltstone matrix; sand is vfg quartz with small mica flakes throughout; carb. plant material; calcareous veins throughout; mod. dense; sl. crumbly, blocky fracture; claystone is sl. soapy, dry, becoming siltier toward base.	40–63.2
63.2'–99'	Silty CLAY (CL): interbedded purple and dusky red silty clay with clasts and layers of greenish gray clayey silt; vfg mica frags. within silty layers; carb. plant material common in clayey zones; mod. hard to 67'; very crumbly below 67'; dry.	63.2–80

Sample	Recovered Ft.	Ft. Sampled	Graphic Log
CB 39–49	9.3	10	
CB 49–59	0	10	NR (GRAB)
CB 59–63	0	4	
CB 63–67	3.8	4	NR
CB 67–72	3	5	NR, NR, NR
CB 72–77	1.5	5	NR, NR
CB 77–81	0.5	4	NR (GRAB)

Stratigraphic Intervals:

FILE NAME: A-LOG10F.DWG

R

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/19/92	Boring No.: B-25	Grid No.: 10-F

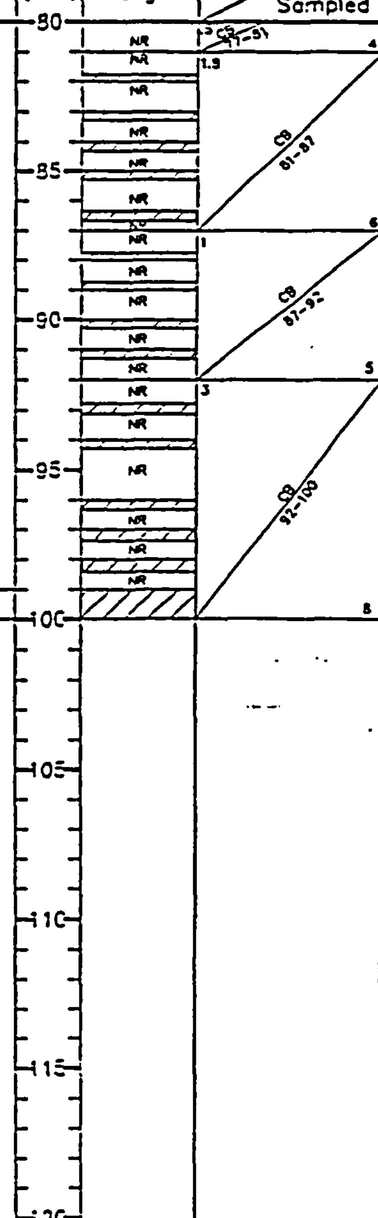
Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 6925.4458 Easting: 10302.9162 Ground Surface Elev. (MSL): 3,467.67
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller: LIZARO CASTILLO JOHN SCARBOROUGH	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size) | Depth (feet) | Graphic Log | Recovered Ft. / Ft. Sampled | Stratigraphic Intervals

Silty CLAY (CL): interbedded purple and dusky red silty clay with clasts and layers of greenish gray clayey silt; v/g mica frags. within silty layers; carb. plant material common in clayey zones; very crumbly; dry.

99 – 100 Very Silty CLAY (CL): dusky red with light greenish gray inclusions; dense; slightly soapy;

TOTAL DEPTH AT 100'



FILE NAME: A-LOG10F.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location:	ANDREWS CO. LANDFILL SITE
Project No.:	92-152
Date Drilled:	01/11/93
Boring No.:	B-35
Grid No.:	11-C
Log By:	A. WEEGAR/R. M^cGOWEN
Drilling Method & Bit Sizes:	0-31.7 MUD ROTARY (HOLT) 31.7- AIR ROTARY (SCARBOROUGH)
Drilling Company:	SCARBOROUGH DRILLING, INC. LAMESA, TEXAS
Sample Method(s):	CORE BARREL; SPLIT SPOON
Driller:	
Total Depth:	100'
Survey Data:	Northing: 8496.1842 Easting: 10483.4609 Ground Surface Elev. (MSL): 3,474.91
Remarks:	

Depth	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
0'-0.1'	TOP SOIL: brown silty sand; organic material; loose; moist.
0.1'-5.5'	SILT (ML): yellow to light tan caliche cemented silt; mod. soft; dry.
5.5'-12.5'	Gravelly Silty SAND (SM): yellow to light tan calcium cemented silt (same as above); overlying light tan/pink caliche cemented silty sand; overlying caliche cemented pink sand with dark and red gravel; mod. soft with increasing hardness towards base.
12.5'-19.3'	CALICHE: pinkish brown calcium carb./dolomitic cemented sand, silt, gravel with concentric growth clasts; appears as growth clasts floating in matrix of silty sandy gravel; sand is vfg-fg quartz and feldspar; gravel is dark and red; v. hard; non-fractured.
19.3'-23.8'	CALICHE: whitish tan calc. carb./dolomitic cemented silty sand with clasts of pink gravelly sand; whitish tan silty sand is vfg qtz. and feldspar with trace dark gravel; pink clasts are granitic vfg sand and gravel; partially healed vertical fracture; v. hard.
23.8'-28.7'	CALICHE: pinkish tan sand with gravel; sand is vfg-fg qtz. and feldspar; sub rounded; gravel is angular red, black and opaque; trace vugs (<2 mm) and diagonal fractures; reduced cementation in basal 0.5'; v. hard; basal contact from drill-break.
28.7'-30.7'	Sandy GRAVEL (GW): pink sand with opaque, white, dark and red gravel and cobbles; sand is vfg; gravel and cobbles angular to well rounded; v. loose; basal contact from drill break; red clay below 30.7'.
30.7'-42'	CLAY (CL): dusky red; hard; dense; with white calc. carb. inclusions; moist; yellow and purple mottling below 38'.

Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
0-5.5	NR (GRAB)	DRILL OUT WITH AUGER	
5.5-11.5	NR	0.5 / 6 — CB 5.5-11.5	
11.5-16.5	NR	3.8 / 5 — CB 11.5-16.5	
16.5-21.7		5.2 / 5.2 — CB 16.5-21.7	
21.7-26.7	NR	4.1 / 5 — CB 21.7-26.7	
26.7-31.7	NR	1.1 / 5 — CB 26.7-31.7	OGALLALA / TRIASSIC
31.7-32	NR	DRILL OUT	
32-34		1.55 / 2 — SS 32-34	
34-36		2 / 2 — SS 34-36	
36-38		2 / 2 — SS 36-38	
38-40		2 / 2 — SS 38-40	

FILE NAME: A-LOG11C.DWG

Terra Dynamics Incorporated

SOIL BORING LC

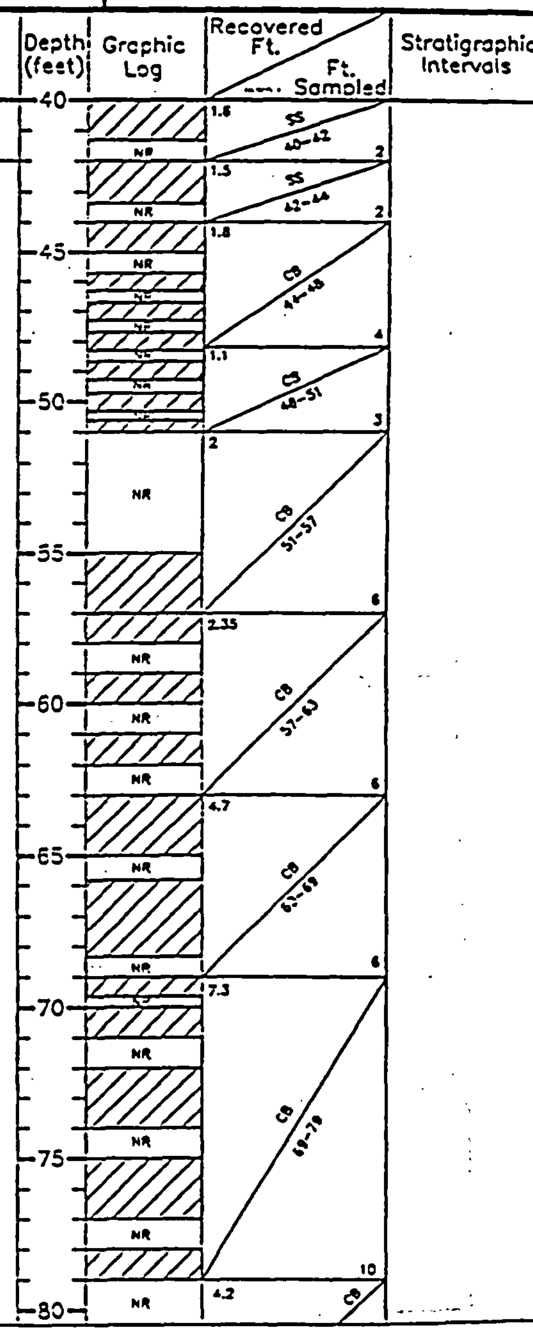
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/11/93	Boring No.: B-35	Grid N 11-C

Log By: A. WEEGAR/R. McGOWEN	Drililng Method & Bit Sizes: 0-31.7 MUD ROTARY (HOLT) 31.7- AIR ROTARY (SCARBOROUGH)	Survey Data: Northing: 8496.1842 Easting: 10483.4609 Ground Surface Elev. (MSL): 3,474.91
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description
(Color, Texture, Structure, Grain Size)

42'-100' <u>CLAY (CL)</u>: heavily mottled purple, gray and yellow; claystone; mod. hard; brittle; primarily blocky fracture with some zones of fissile claystone; greenish gray inclusions throughout; trace ferros oxide nodules; dry.

- calc. carb. cemented layers and nodules common below 69'.



FILE NAME: A-LOG11C.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/11/93	Boring No.: B-35	Grid No.: 11-C

Log By: A. WEEGAR/R. McGOWEN	Drilling Method & Bit Sizes: 0-31.7 MUD ROTARY (HOLT) 31.7- AIR ROTARY (SCARBOROUGH)	Survey Data: Northing: 8496.1842 Easting: 10483.4609 Ground Surface Elev. (MSL): 3,474.91
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): CORE BARREL; SPLIT SPOON	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Intervals
CLAY (CL): same as above.	80		4.2 / 6 (CB 79-85)	
– vertical fracture at 82'–83'; indications of ferros oxide mineralization along fracture plane.		NR		
– green clay nodule approx. 0.2 ft.	85	NR	2.8 / 5 (CB 85-90)	
– purplish color; rubbly; upper 1.0 ft.	90	NR	7.2 / 10 (CB 90-100)	
	95	NR		
– green clay nodule approx. 0.1 ft.				
– scattered green clay nodules: 0.05'–0.1'.				
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOC11C.DWG

Terra Dynamics Incorporated
AUSTIN, TEXAS (512) 795-8183

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16-12/18/92	Boring No.: B-20	Grid/Well No.: 11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130' TO TD

Driller:

Drilling Company: SCARBOROUGH DRILLING, INC. AMESA, TEXAS

Total Depth: 275'

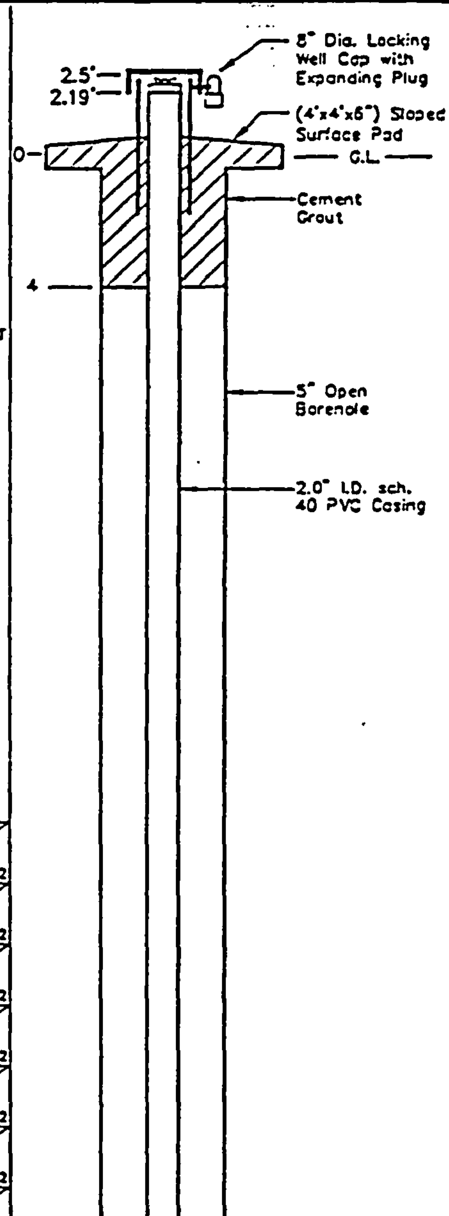
Drilling Method & Bit Sizes: AIR ROTARY

Sample Method(s): 2"SS + 3"CB; GRAB SAMPLES EVERY 5' FROM
CONTINUOUS: 201' TO TD

Survey Data:
Northing: 8042.8943
Easting: 10272.5320
Ground Surface Elev. (MSL): 3,470.04
Top of PVC Casing Elev.: 3,472.23

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled
		-5	
0'-1' TOP SOIL: brown silty sand; loose; organic material; moist		0	
1'-7' CALICHE: pinkish white; calc. carb. cemented silt with vfg sand; sand grains are pink and opaque; mod. hard; crumbly; chalky; dry.		5	DRILL-CUT W/ROCK BIT NR (GRAB)
7'-18' CALICHE: brownish gray & pinkish brown; microcrystalline with calcite crystals; vfg to cg sand throughout; sand is brown, red and opaque qtz; subrounded-well rounded; v. hard; dry.		10, 15	
18'-20' CALICHE: pinkish white; calc. carb. cemented sand and gravel; sand is vfg-cg, subr. to rd. qtz.; gravel is red, black, white and opaque, subr. to rd. quartzite; mod. hard; dry.		20	
20'-22' Gravelly SAND (SW): pinkish tan; vfg-cg qtz. sand; subr. to rd.; gravel is white, black, red and opaque quartzite; subr. to rd.; loose; dry.			
BASE OF OGALLALA - TRIASSIC TOP			
22'-46' CLAY (CL): maroon with greenish gray and purple mottling; mod. hard; dense; sl. plastic; blocky fracture; moist.			2 / SS 22-24 / 2
- no mottling below 24'		25	2 / SS 24-26 / 2
			2 / SS 26-28 / 2
			1.5 / SS 28-30 / 2
		30	2 / SS 30-32 / 2
			2 / SS 32-34 / 2
		35	2 / SS 34-36

Well Design



File Name: A-LOG113.DWG

Terra Dynamics Incorporated

AUSTIN, TEXAS (512) 795-8183

SOIL BORING & WELL COMPLETION LOG

Location:	Project No.:	Date Drilled:	Boring No.:	Grid/Well No.:
ANDREWS CO. LANDFILL SITE	92-152	12/16-12/18/92	B-20	11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130' TO TD

Driller:

Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS

Total Depth: 275'

Drilling Method & Bit Sizes: AIR ROTARY

Sample Method(s): 2"SS + 3"CB; GRAB SAMPLES EVERY 5' FROM
CONTINUOUS: 201' TO TD

Survey Data:
Northing: 8042.8943
Easting: 10272.5320

Ground Surface Elev. (MSL): 3,470.04

Top of PVC Casing Elev.: 3,472.23

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)
– color change to dusky red with gray infilled tubes and inclusions below 36'.	NR (thin intervals)	35–46
46'–51.6' Sandy SILT (ML): speckled mottling dusky red and greenish gray; trace vfg sand grains, mica and biotite flakes throughout; mod. hard; blocky fracture; increased sand content.		46–51.6
51.6'–70.3' Silty CLAY (CL): dusky red with yellow, gray and purple mottling; carbonaceous plant material; mod. hard; sl. soapy; blocky fracture; dry.	NR (approx. 56.5–61.5, 63.5–67.5)	51.6–70.3
70.3'–72.5' Clayey SILT (ML): heavily mottled dusky red and purple silty clay and light pinkish gray clayey silt; convoluted bedding structure; mica frags. within silty zones; mod. hard; block fracture; dry.	NR	70.3–72.5
72.5'–80' Slightly Silty CLAY (CL): dusky red with slight mottling of yellow and gray, claystone; mod. hard; dense; blocky fracture; dry, basal contact from cutting.		72.5–80

Recovered Ft. / Ft. Sampled

Sample	Type	Recovered Ft.	Ft. Sampled
(35–36)		–	2
36–38	SS	2	2
38–40	SS	2	2
40–42	SS	1.5	2
42–44	SS	2	2
44–48	CB	3.4	4
48–52	CB	4	4
52–62	CB	5	10
62–67	CB	1.3	5
67–72	CB	4.2	5
72–81	CB	7.3	

Well Design

2.0" I.D. sch. 40 PVC Casing

5" Open Borehole

File Name: A-LOG11D.DWG

Terra Dynamics Incorporated

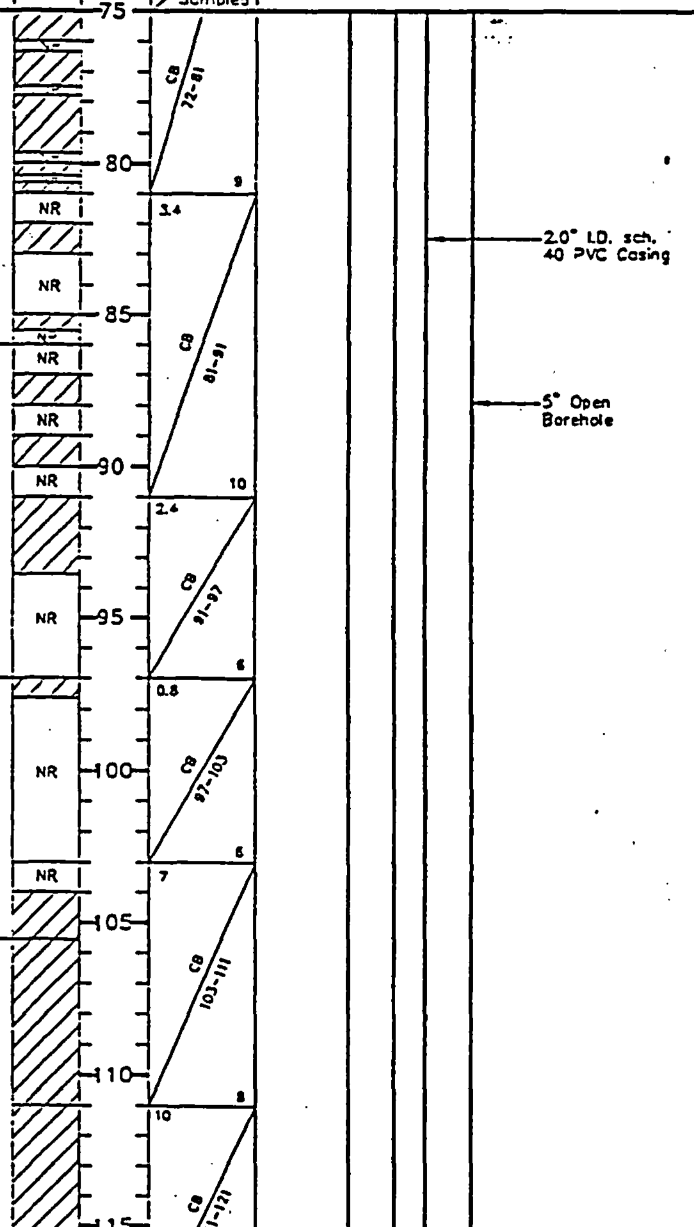
AUSTIN, TEXAS (512) 795-8183

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16-12/18/92	Boring No.: B-20	Grid/Well No.: 11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130'. TO TD	Driller:	Survey Data: Northing: 8042.8943 Easting: 10272.5320 Ground Surface Elev. (MSL): 3,470.04 Top of PVC Casing Elev.: 3,472.23
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Total Depth: 275'	
Drilling Method & Bit Sizes: AIR ROTARY		
Sample Method(s): 2"SS + 3"CB: GRAB SAMPLES EVERY 5' FROM CONTINUOUS: 201' TO TD		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design



86'-97' Silty CLAY (CL): purple with light gray mottling; crumbly; dry.

97'-105.6' CLAY (CL): purple with slight gray mottling: hard; v. dense; sl. plastic; moist.

105.6'-151' Silty CLAY (CL): dusky red silty claystone mottled with grey & pink in a dendritic pattern; contains inclusions of greenish grey silt; hard; mod. dense; blocky fracture; dry.

File Name: A-LOG2G.DWG

Terra Dynamics Incorporated

AUSTIN, TEXAS (512) 795-8183

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16-12/18/92	Boring No.: B-20	Grid/Well No.: 11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130' TO TD	Driller:	Survey Data: Northing: 8042.8943 Easting: 10272.5320
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Total Depth: 275'	Ground Surface Elev. (MSL): 3,470.04
Drilling Method & Bit Sizes: AIR ROTARY		Top of PVC Casing Elev.: 3,472.23
Sample Method(s): 2"SS + 3"CB; GRAB SAMPLES EVERY 5' FROM CONTINUOUS: 201' TO TD		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
Silty CLAY (CL) cont.: same description as previous page.		115–120	CB 111-121; 10	2.0" I.D. sch. 40 PVC Casing; 5" Open Borehole
		120–130	8 / CB 121-131; 10	
	NR	130		
- 0.1' green-gray clayey silt (ML); dry.		130–140	5.8 / CB 131-141; 10	
	NR	140		
- 0.25' greenish- grey silty clay (CL); dry.		140–150	7.6 / CB 141-151; 10	
	NR	150		
151'-162.3' CLAY (CL): reddish purple with gray-green mottling and inclusions throughout; mod. hard; mod. dense; sl. plastic; dry.	NR	150–155	3.5 / CB 151-161	

File Name: A-LOG2C.DWG

Terra Dynamics Incorporated

AUSTIN, TEXAS (512) 795-8183

SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16-12/18/92	Boring No.: B-20	Grid/Well No.: 11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130' TO TD	Driller:	Survey Data: Northing: 8042.8943 Easting: 10272.5320 Ground Surface Elev. (MSL): 3,470.04 Top of PVC Casing Elev.: 3,472.23
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Total Depth: 275'	
Drilling Method & Bit Sizes: AIR ROTARY		
Sample Method(s): CONTINUOUS: 2"SS + 3"CB; GRAB SAMPLES EVERY 5' FROM 201' TO TD		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
	NR	155–160	CB 151-161; 10	
	NR	160		
162.3'–172' CLAY (CL): grayish-purple claystone with gray-green mottling and larger inclusions throughout; mod. hard; dense; sl. plastic; finely veined with calcite(?) filled fractures; dry.	NR	165–170	7.3; CB 161-171; 10	2.0" I.D. sch. 40 PVC Casing; 5" Open Borehole
172'–243' CLAY (CL): reddish purple with gray-green mottling and scattered inclusions; mod. hard; mod. dense; sl. plastic; scattered calcite(?) filled veins; dry.	NR	170–180	3; CB 171-181; 10	
(CL) same as above but with few veins.	NR	180–190	3; CB 181-191; 10	
(CL) same as above but no veins. drill rate-2 min./ft.	NR	190–195	4.7; CB 191-201	

File Name: A-LOG20.DWG

Terra Dynamics Incorporated AUSTIN, TEXAS (512) 795-8163	SOIL BORING & WELL COMPLETION LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16-12/18/92	Boring No.: B-20	Grid/Well No.: 11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130' TO TD	Driller:	Survey Data: Northing: 8042.8943 Easting: 10272.5320 Ground Surface Elev. (MSL): 3,470.04 Top of PVC Casing Elev.: 3,472.23
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Total Depth: 275'	
Drilling Method & Bit Sizes: AIR ROTARY		
Sample Method(s): 2"SS + 3"CB; GRAB SAMPLES EVERY 5' FROM 201' TO TD CONTINUOUS:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
CLAY (CL) same as above.		195	191-201	5" Open Borehole; 2.0" I.D. sch. 40 PVC Casing
	NR	200	10	200 — Bentonite Pellet Seal
at 201' switch over to drag bit(fantail bit) to drill down until cuttings show sand; bagged cuttings every 5'; reamed out to 5".				
		205	GRAB SAMPLES AT 5' INTERVALS	205 — Filter Sand
		210		
		215		
		220		
		225		
		230		232 — 2.0" Sch. 40 PVC Well Screen .010 SLOTS
		235		

File Name: A-LOG20.DWG

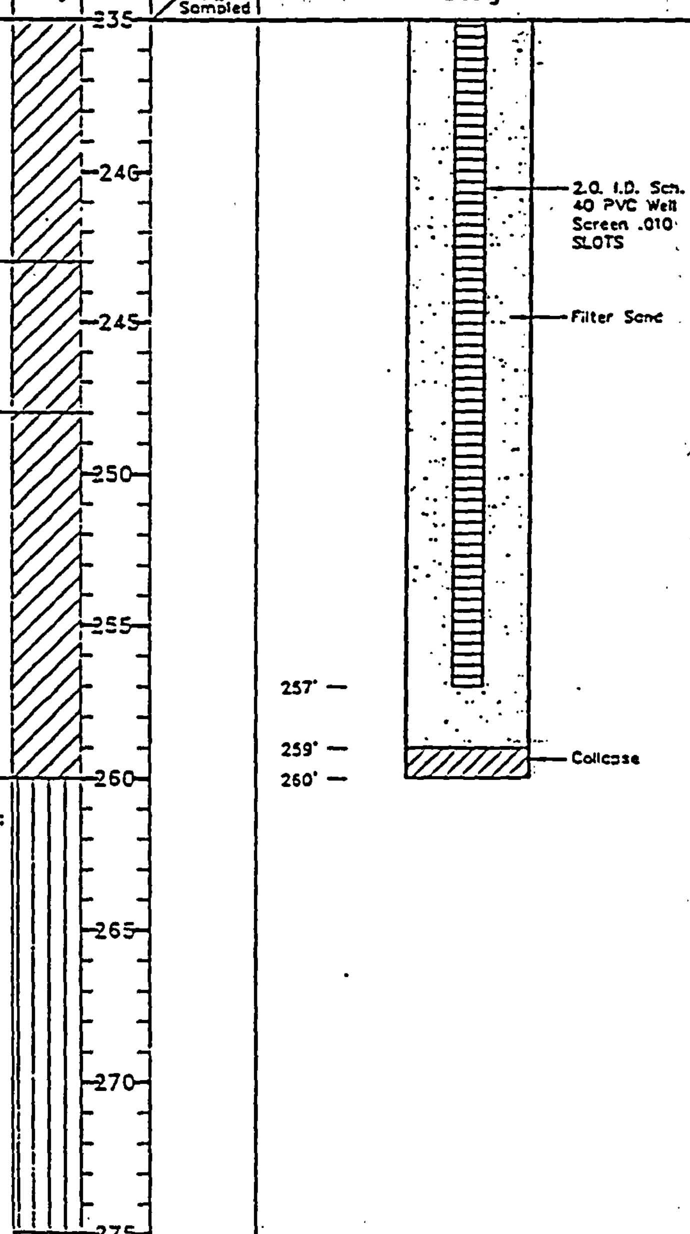
Terra Dynamics Incorporated AUSTIN, TEXAS (512) 795-8183	**SOIL BORING & WELL COMPLETION LOG**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 12/16-12/18/92	Boring No.: B-20	Grid/Well No.: 11-D

Log By: A. WEEGAR; P. GRANT 0-130' 130'- TO TD	Driller:
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Total Depth: 275'
Drilling Method & Bit Sizes: AIR ROTARY	
Sample Method(s): 2"SS + 3"CB; GRAB SAMPLES EVERY 5' FROM CONTINUOUS: 201' TO TD	

Survey Data:
Northing: 8042.8943
Easting: 10272.5320
Ground Surface Elev. (MSL): 3,470.04
Top of PVC Casing Elev.: 3,472.23

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Lithic Log	Depth (feet)	Recovered Ft. / Ft. Sampled	Well Design
at 239' cuttings color lightened, but still (CL) as above.				
243'-248' Silty CLAY (CL): light tan color plus previous dark clay.				
248'-260' CLAY (CL): reddish purple with gray-green mottling and scattered inclusions; mod. hard; mod. dense; sl. plastic; dry.				
260'-275' Clayey SILTSTONE (ML): dusky red and tan siltstone with claystone interbeds; greenish gray mottling throughout; increased greenish gray siltstone below 270 feet; brittle; trace of vfg. mica frags.; dry.				
Total Depth = 275 feet				



File Name: A-LOG20.DWG

Terra Dynamics Incorporated	SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/20/93	Boring No.: B-45	Grid No.: 11-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7590.39; Easting: 10860.29; Ground Surface Elev. (MSL): 3,468.3
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0'-0.4'	TOP SOIL: brown; silty sand; organic material; moist.	0		DRILL OUT; LOG CUTTINGS	
0.4'-12'	CALICHE: pinkish white; calc. carb. cemented quartz silt and sand; mod. hard; trace dark, red and opaque quartz gravel frags.; dry.	5, 10			
12'-19'	Sandy SILT (ML): pink; quartz silt and sand; slight calc. carb. cementation; loose; dry.	15			
19'-24'	Silty CLAY (CL) reddish brown silty clay with white powdery calc. carbonate in layers along vertical fractures disseminated throughout; dense; sl. plastic; moist.	20	NR		OGALLALA / TRIASSIC
24'-39.4'	Silty CLAY (CL): reddish brown silty clay with grayish tan and bluish gray mottling and casts; dense; sl. plastic; moist. - trace mottling below 31'.	25, 30, 35, 40			

Sample	Interval (ft)	Recovered Ft.	Ft. Sampled
SS	19-21	0.7	2
SS	21-23	2	2
SS	23-25	2	2
SS	25-27	2	2
SS	27-29	2	2
SS	29-31	2	2
SS	31-33	2	2
SS	33-35	2	2
SS	35-37	2	2
SS	37-39	1.7	2
SS	39-40	0.80	[illegible]

FILE NAME: A-LOG112.DWG

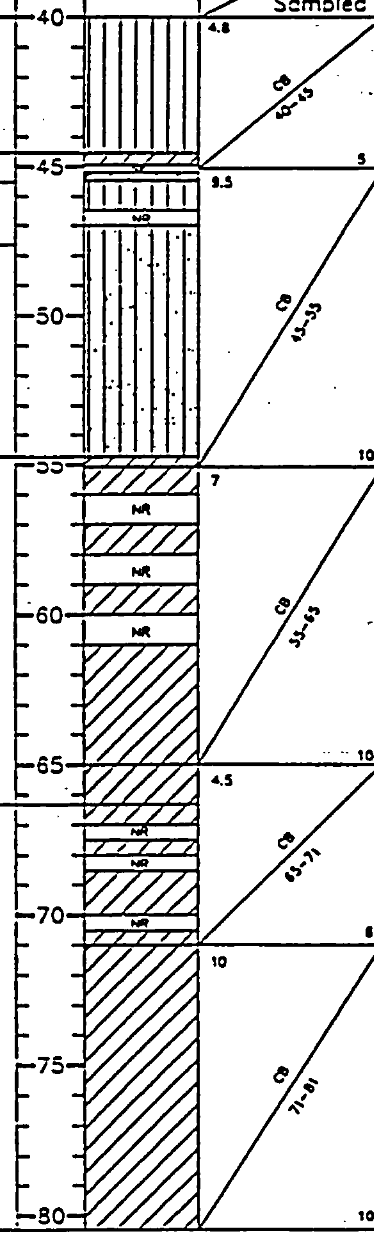
Terra Dynamics Incorporated	**SOIL BORING LO**

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/20/93	Boring No.: B-45	Grid No. 11-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7590.39 Easting: 10860.29 Ground Surface Elev. (MSL): 3,458.3
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Depth interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)
39.4'–44.6'	Sandy Cl SILT (ML): mottled tan, brown and rusty red clayey siltstone with sand; vfg white quartz sand grains throughout; trace vfg mica frags.; black mineralization througnout; mod. hard; blocky fracture; crumbly 42'–43.5'; dry.
44.6'–45.5'	Sandy Silty CLAY (CL): mustard to greenish gray claystone; silt and vfg quartz sand throuhout;.
45.5'–47.6'	Sandy Clayey SILT (ML): yellow, tan and gray clayey siltstone with white and opaque vfg quartz sand grains and vfg mica frags.; mod. hard; horizontally laminated; blocky fracture and crumbly; dry.
47.6'–54.9'	Silty Sand (SM): yellow and grayish tan siltstone matrix with vfg white, opaque and pink quartz and feldspar sand grains; vfg to cg mica and biotite flakes througnout; cross-bedded; blocky fracture; dry.
54.9'–66.2'	Silty CLAY (CL): dark red silty claystone with bluish gray mottling; greenish gray elliptical zones and apparent worm burrows below 62'; burrows have sandy material incorporated into center portion of burrow; trace black mineralization througout; blocky to concoidal fracture; dense; mod. hard; dry.
56.2'–100'	Slightly Silty CLAY (CL): dark red claystone with purple and grey mottling througnout; yellow and mustard coloration below 69' with greenish gray clasts and worm holes below 70'; trace black mineralization througout; mod. hard; sl. soapy; blocky fracture; dry. – diagonal fractures from 71'–79'; fractures are at 45° and bidirectional (> and <); healed with calc. carb. cementation and clay; occasional drilling-induced slickensides.

Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval



FILE NAME: A-LOG11E.DWG

Terra Dynamics Incorporated

SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/20/93	Boring No.: B-45	Grid No.: 11-E

Log By: A. WEEGAR	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 7590.39 Easting: 10860.29 Ground Surface Elev. (MSL): 3,468.3
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
Slightly Silty CLAY (CL): same as above.	80			
		NR	8.1	
		NR		
	85		CB 81-90	
	90		9	
– increased purple color and crumbly below 91'.			4.7	
		NR		
		NR		
	95	NR	CB 90-100	
		NR		
		NR		
TOTAL DEPTH = 100'	100		10	
	105			
	110			
	115			
	120			

FILE NAME: A-LOG11E.DWG

Terra Dynamics Incorporated				SOIL BORING LO[illegible]		
Location: ANDREWS CO. LANDFILL SITE		Project No.: 92-152		Date Drilled: 1/24/93	Boring No.: B-51	Grid No 12-[illegible]
Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY			Survey Data: Northing: 9160.6675 Easting: 10241.7105 Ground Surface Elev. (MSL): 3,475.71		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL					
Driller:	Total Depth: 100'					
Remarks:						

Depth Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0.0'–1.3'	TOP SOIL: dk. brown, sand, silt; organic material; loose; dry.	0			
1.3'–19'	SAND (SW): lt. tan to red tan, vfg–fg sand, with scattered clasts of calcitic cemented sand and silt; soft; loose; dry.			DRILL OUT; LOG CUTTINGS	
19'–29'	CALICHE: lt. tan–gray calcitic micritic cemented sand and silt, vfg–fg qtz sand; sandstone lithoclasts with silica concretions in micritic matrix; concretion rings in micrite; hard; brittle; dry.	20			
29'–32.5'	SAND and GRAVEL (SW): tan–lt. brown, sand, fg quartz to quartz pebbles and cobbles; rounded to angular; soft; dry.	30			OGALLALA
32.5'–37'	CLAY (CL): red with white mineralization (flaky, nonreactive to HCl), and some silt; soft; moist.	35		2 / 2 SS 33–35; 2 / 2 SS 35–37	TRIASSIC
37'–100'	CLAY (CL): red with yellow mottling; soft; dry. – red, yellow, and purple mottling at 39'.	40		1.8 / 2 SS 37–39; 2 / 2 SS 39–41	

FILE NAME: A-LOG12B.DWG

Terra Dynamics Incorporated			**SOIL BORING LOG**		
Location: ANDREWS CO. LANDFILL SITE		Project No.: 92-152	Date Drilled: 1/24/93	Boring No.: B-51	Grid No.: 12-B
Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY		Survey Data: Northing: 9160.6675 Easting: 10241.7105 Ground Surface Elev. (MSL): 3,475.71		
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL				
Driller:	Total Depth: 100'				
Remarks:					

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
CLAY(CL): same as above.	40		2 / 2 SS 39–41	
			2 / 2 SS 41–43	
		NR	0 / 2 SS 43–45	
	45	NR	0 / 6 CB 45–51	
	50			
		NR	0 / 6 CB 51–57	
	55			
		NR ?	1.7 / 6 CB 57–63	
– red, yellow and purple mottled: from 59' to 59.5' was hard calcitic cemented clay–broken and watered(hard and brittle).				
	60	NR ?		
– from 61' to 61.2' was red, yellow, and purple mottled; brittle; dry.				
		NR ?		
			4.4 / 8 CB 63–71	
	65	NR ?		
	70	NR ?		
		NR	1.0 / 10 CB 71–81	
	75			
	80			

FILE NAME: A-LOG129.DWG

Terra Dynamics Incorporated

SOIL BORING LO~

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 1/24/93	Boring No.: B-51	Grid N… 12-

Log By: R. M^cGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 9160.6675 Easting: 10241.7105 Ground Surface Elev. (MSL): 3,475.71
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
CLAY (CL): same as above.	80			
- rubble - 81'-87'		NR	1.5 / 6 CB 81-87	
	85	NR		
			1 / 4 CB 87-91	
	90	NR ?		
			5.7 / 9 CB 91-100	
- red, yellow and purple mottled with whitish green clay nodules.	95	NR ?		
		NR ?		
TOTAL DEPTH = 100'	100			
	105			
	110			
	115			
	120			

FILE NAME: A-LOG12B.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/24/93	Boring No.: B-52	Grid No.: 12-C

Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8707.59 Easting: 10003.09 Ground Surface Elev. (MSL): 3,473.3
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Interval	Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
0.0'-0.5'	TOP SOIL: dk. brown, sand, silt; organic material; loose; dry.	0		DRILL OUT; LOG CUTTINGS	
0.5'-4.0'	CALICHE: lt. tan; calcitic cemented sand and silt; vfg quartz sand; soft; dry.				
4.0'-9.0'	SAND and SILT (SM): lt. tan to lt. brown, vfg-fg quartz with scattered clasts of calcite cemented sand and silt; soft; dry.	5			
9.0'-21.5'	CALICHE: lt. tan-gray, calcitic and micritic cemented sand and silt; vfg-fg quartz sand; concretion rings in micrite frags.; sandstone lithoclasts with silica concretion; hard; dry.	10, 15, 20			
21.5'-26'	Silty SAND (SW): lt. tan, vfg quartz sand; sorted; rounded; soft; dry.	25			
26'-30'	SAND and GRAVEL (SW): reddish brown, fg-mg quartz sand, rounded and sorted, pebbles and cobbles; quartz rounded to angular; poorly sorted, soft; dry.	30			OCALLALA / TRIASSIC
30'-77'	CLAY (CL): red, purple, and yellow mottled; plastic; damp.			0 / 2 SS 31-33	
				1.9 / 2 SS 33-35	
		35	NR ?	0.2 / 2 SS 35-37	
	- dry; plastic; less purple 37'-39'.		NR ?	1.5 / 2 SS 37-39	
		40		1.8 / 2 SS 39-41	

FILE NAME: A-LOG12C.DWG

Terra Dynamics Incorporated	**SOIL BORING LOG**		
Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/24/93	Boring No.: B-52; Grid No.: 12-C

Log By: R. M^c^GOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8707.59; Easting: 10003.09; Ground Surface Elev. (MSL): 3,473.3
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
	40		1.5 SS 39–41 / 2	
– red, purple and yellow mottling white silt nodule 0.75" at approx. 41.5'; plastic; dry.		NR	1.8 SS 41–43 / 2	
		NR	0 SS 43–45 / 2	
– scattered nodules of yellow to white clay.	45		1.4 SS 45–47 / 2	
			2 SS 47–49 / 2	
– red, purple and yellow mottling; no nodules.	50		2 SS 49–51 / 2	
			2 SS 51–53 / 2	
	55	NR	0 CB 53–59 / 6	
– red-orange with yellow and purple mottling; dry; brittle.	60	NR ?	1.5 CB 59–65 / 6	
		NR ?		
	65		6 CB 65–71 / 6	
	70			
		NR ?	1.5 CB 71–81 / 10	
– 0.75 ft. red-orange clay with yellow and purple mottling.				
	75	NR ?		
77'–81' SANDSTONE (SU): red-orange and white, vfg quartz sand with calcite cement and mica flakes; hard; brittle; dry.				
	80	NR ?		

FILE NAME: A-LOG12C.DWG

Terra Dynamics Incorporated — SOIL BORING LOG

Location: ANDREWS CO. LANDFILL SITE	Project No.: 92-152	Date Drilled: 01/24/93	Boring No.: B-52	Grid No.: 12-C

Log By: R. McGOWEN	Drilling Method & Bit Sizes: AIR ROTARY	Survey Data: Northing: 8707.59; Easting: 10003.09; Ground Surface Elev. (MSL): 3,473.3
Drilling Company: SCARBOROUGH DRILLING, INC. LAMESA, TEXAS	Sample Method(s): SPLIT SPOON; CORE BARREL	
Driller:	Total Depth: 100'	
Remarks:		

Unified Soil Classification/Description (Color, Texture, Structure, Grain Size)	Depth (feet)	Graphic Log	Recovered Ft. / Ft. Sampled	Stratigraphic Interval
- plugged core bit	80	NR ?	1.4 / 10 CB ?-81	
81'-100' CLAY (CL): red, yellow and purple mottled, dry, brittle.	85, 90	NR ? / hatched / NR ?	2 / 10 CB 81-91	
- purple cuttings.	95	NR	0 / 6 CB 91-97	
TOTAL DEPTH = 100' - purple clay with nodule approx. 2" of greenish white clay.	100	NR ? / hatched / NR ?	1.3 / 3 CB 97-100	
	105, 110, 115, 120		END OF CORE	

FILE NAME: A-LOG12C.DWG

Evaluation of Potential Groundwater Impacts by the WCS Facility in Andrews County, Texas

by

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Prepared for

The Andrews Industrial Foundation
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December, 1996

Executive Summary

The Andrews Industrial Foundation retained Dr. Ken Rainwater to evaluate the suitability of the Waste Control Specialists, Inc. waste treatment, storage, and disposal facility currently under construction in western Andrews County with respect to its potential impact on local and regional groundwater resources. The site was already permitted for acceptance of hazardous wastes, and a new permit for low-level radioactive wastes is sought. Special concern was placed on the possible presence of the Ogallala aquifer at the site location. The identification of the presence or absence of the Ogallala aquifer at the site was based on the definition of an aquifer as containing sufficient saturated permeable material to yield water to wells. The study approach included review of permit documents, site visits, public meeting attendance, inspection of core samples, evaluation of water quality sampling, and review of published descriptions of local and regional hydrogeologic information.

A report was delivered to the Foundation in December, 1996, with these conclusions:

[1] The presence of a thick Triassic clay layer near the ground surface at the site makes it an excellent location for a properly designed and constructed landfill.

[2] A thin stratum at the site was originally identified as the Ogallala formation, but it does not contain sufficient water for classification of the formation as an aquifer.

[3] Previous publications and recent field study of the local hydrogeologic conditions in Andrews County show that the Ogallala aquifer is not present, and the shallow permeable formation is actually the Antlers Sandstone.

[4] Publications about the regional hydrologic conditions in the Southern High Plains implied the presence of water in the Ogallala formation throughout Andrews County, but the assumed saturated thicknesses in the western portion are not well supported by field data.

[5] The siltstone layers in the Dockum group appear to be the uppermost water-bearing zone and may be acceptable for monitoring, but their low permeability and possibly limited extent do not meet the traditional definition of an aquifer.

[6] If properly constructed and operated, the landfill should have no impact on usable groundwater in Andrews County.

It is recommended that the Foundation continue to pursue the use of this site as a waste treatment, storage, and disposal facility. Proper design, construction, and operation should allow the site to serve its purpose without damage to groundwater resources.

Evaluation of Potential Groundwater Impacts by the WCS Facility in Andrews County, Texas

Objective and Approach

The primary objective of this report is to evaluate the suitability of the western Andrews County site for the Waste Control Specialists (WCS) facility with specific concern to the site's impact on groundwater resources. This report was commissioned by the Andrews Industrial Foundation, Inc. (AIF), as an independent, impartial review of the suitability of the site for development as a hazardous waste treatment and disposal facility. Drs. Lloyd Urban and Ken Rainwater originally collaborated in this study beginning in 1993, and each produced reports based on data available at that time. The site received its permit in 1994, and construction began in 1996. During 1996, Drs. Tom Lehman, Harold Gurrola, and Priyantha Jayawickrama were brought in to address related geological and geotechnical issues as the site owners pursued a permit for low-level radioactive waste disposal at this site. Dr. Rainwater composed this report as an update of the 1993 document, while the other scientists and engineers provided their own documents as appropriate to the AIF. The WCS site is located at the western boundary of Andrews County, north of state highway 176 and east of the Texas-New Mexico border. Due to the lack of dependable fresh surface water, groundwater resources are precious in this county. The major water-bearing aquifer in the Southern High Plains of Texas is the Ogallala formation, which supplies water for agricultural and domestic purposes for much of the region. Site selection for landfill installations for safe, long-term disposal of hazardous materials in this region must minimize or completely prevent future deterioration of this water resource. The state agency with regulatory jurisdiction for this project is the Texas Natural Resource Conservation Commission (TNRCC), and this agency actively enforces waste management regulations with intent of groundwater protection.

A special concern of this report is determination of the local characteristics of the Ogallala formation and other shallow permeable strata, as expressed in the geologic setting and the storage and transmission of water. Many citizens are concerned with the protection of the Ogallala aquifer in the High Plains of Texas as the primary water source for irrigation, rural families, and many municipalities. Some use the presence of the Ogallala aquifer as a reason to oppose any industrial and/or waste disposal projects that involve hazardous chemicals that may somehow enter the aquifer. There is debate as to whether the Ogallala aquifer is actually physically present at the WCS site. The definition of an aquifer is given by Freeze and Cherry (1979) as "a saturated permeable geologic unit that can transmit significant amounts of water under ordinary hydraulic gradients," and also states that "an aquifer is permeable enough to yield economic quantities of water to wells" (p. 47). Todd (1980) defined an aquifer as "a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs" (p. 25). The operative words in these two definitions are "saturated" and "permeable," implying water must be present in adequate amounts to move through the geologic stratum. This investigation of the subsurface hydrogeologic conditions at the proposed WCS site specifically considers whether the formation, whether or not it is the Ogallala, at this location fits both these criteria for definition as an aquifer.

The approach taken in this study can be described as a series of tasks. These tasks are summarized in the following list:

[1] Review of the 1993 permit documents and recent site-specific hydrogeologic data;

[2] Visits to the WCS site;

[3] Attendance at TNRCC public meeting in Andrews to hear local concerns;

[4] Inspection of core samples collected during subsurface investigation;

[5] Recommendation and evaluation of water quality sampling and analyses; and

[6] Review of regional and local hydrogeologic information.

In this report, the efforts and results associated with each task are briefly presented in separate sections. It should be noted that this updated report benefits greatly from the recent work by Dr. Tom Lehman on the description of the local geologic setting (Lehman, 1996). The last section of the report summarizes the major conclusions and recommendations appropriate to the information reviewed.

Review of Permit Documents and Recent Monitoring Data

Copies of Volumes II, IV, and V of the "RCRA Permit Application For A Hazardous Waste Storage, Treatment, and Disposal Facility" (AME, 1993) were provided by the design firm, AM Environmental, Inc. (AME), of Austin, Texas. The material of concern to the groundwater evaluation in these volumes included the landfill engineering design documents (Vol. II), geotechnical investigation results and groundwater monitoring plan (Vol. IV), and local geologic and hydrogeologic descriptions (Vol. V). These documents were submitted to the TNRCC for regulatory review. This report does not constitute another form of regulatory approval, but does provide additional expert evaluation of the environmental suitability of the site for the proposed facility. The regulatory agency is also interested in protection of groundwater resources, and the permit application contains much useful site-specific information for evaluation of the possible impacts, if any, of the site on the local and regional groundwater. The principal points associated with the local groundwater are summarized in this section. AME also provided summaries of the results of groundwater monitoring events since 1993 (Messenger, personal communication). The regional geologic evaluation by Lehman (1996) was also used in evaluation of this information.

The main strength of this specific location for a hazardous waste landfill is the presence of a thick natural clay (or claystone) layer at less than 30 ft below the ground surface. This red clay material is referred to as the upper portion of the Triassic Dockum Group, sometimes referred to separately as the Chinle formation. The upper surface of this formation has a local topographic high directly beneath the proposed site as shown in Figure 1 (AME, 1993). Lehman (1996) demonstrated that this local high is actually part of regional "Red Bed Ridge" that extends from eastern New Mexico through western Andrews County southward to Winkler and Ector Counties. At the WCS site, the clay layer is over 200 ft thick, with three to four separate interbedded siltstone/sandstone layers. The hydraulic conductivities of the clay and siltstone were measured in the laboratory at 1.76×10^{-8} cm/sec (5.0×10^{-5} ft/d or 3.7×10^{-4} gpd/ft^2) and 3.20×10^{-6} cm/sec (9.1×10^{-3} ft/d or 6.8×10^{-2} gpd/ft^2), respectively. The natural permeability of the clay is in the range of design hydraulic conductivity for engineered landfill liner materials. The selection of the landfill

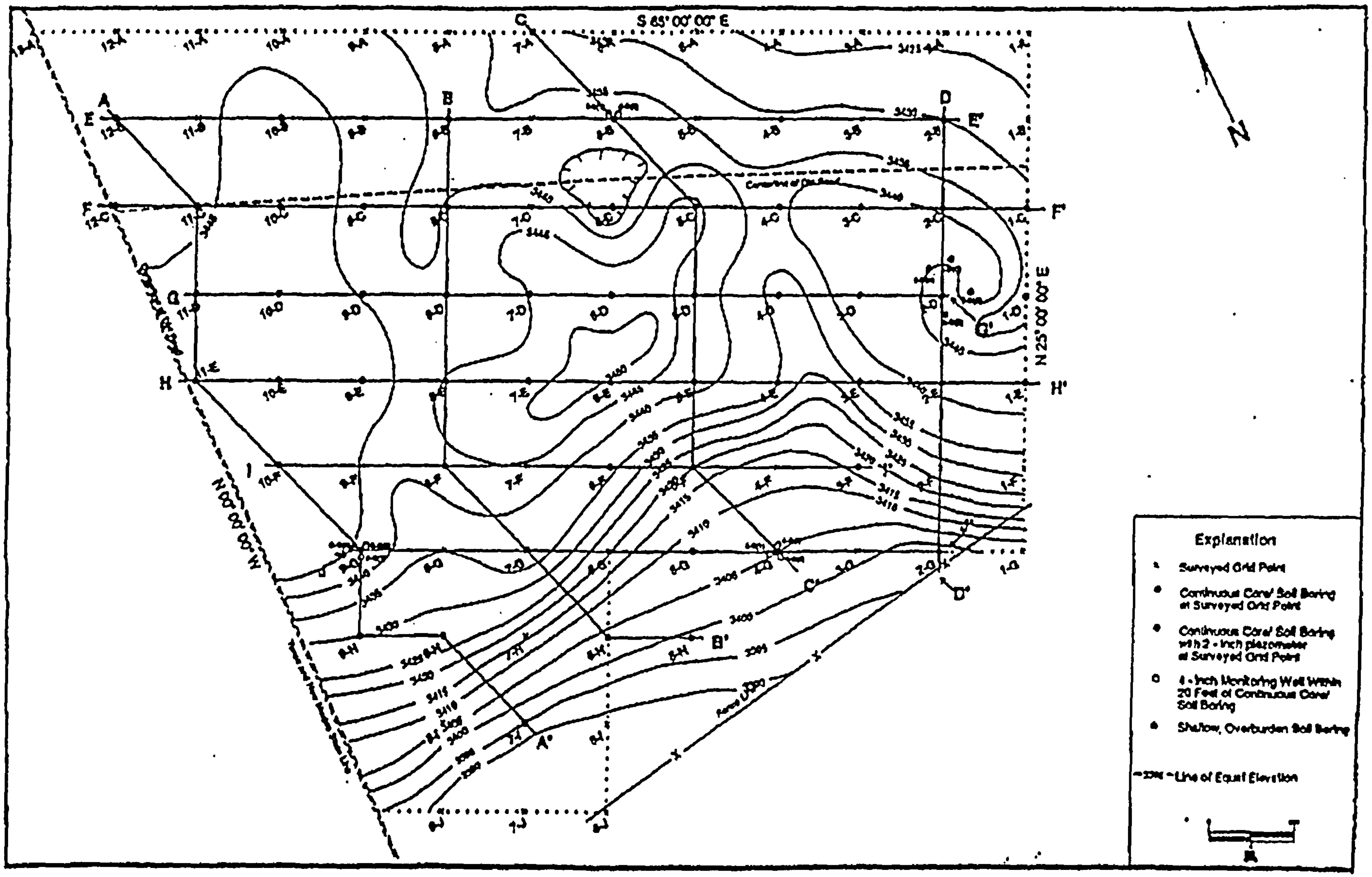

Figure 1. Topographic contour map of the upper surface of the Dockum group beneath the WCS site [Source: AME (1993)]

dimensions takes advantage of the shallow depth to this low permeability material by locating the bottom of the landfill excavation within the Triassic clay, completely penetrating the more permeable materials above the top of the Dockum group. The constructed landfill double liner system will rest atop the Triassic clay. The conventional double liner system includes two geomembranes, two compacted clay layers, and one leachate collection layer and one leachate detection layer. Unless the Triassic clay has significant fractures, it should provide a good foundation for the landfill construction.

The geotechnical investigation of the proposed site included collection of cores from a large number of borings and installation of several monitoring wells in suspected water-bearing zones. As previously stated, the Ogallala aquifer is the principal regional freshwater aquifer. In the geologic descriptions in the permit application, the geologic material above the Triassic clay was referred to as the typical Ogallala formation, with a caliche caprock overlying a layer of permeable alluvial sands and gravels, but the thickness of the permeable sands and gravels was usually less than 15 ft. Based on close examination of the gravels in the exposure of the formation at the WCS site and other outcrops in Andrews County, Lehman (1996) identified this material beneath the caprock as the Antlers Sandstone, not the Ogallala formation. The Antlers Sandstone has sufficient sand and gravel content with limited cementation to have significant permeability, but the thin formation apparently is not continuously saturated over significant areal extent in this vicinity.

Due to the low average rainfall amounts, the local high in the elevation of the top of the Dockum group, and the undulating shape of the top of the Dockum group, the permeable sediments atop the Triassic clay do not store significant amounts of water in this western part of Andrews County. Saturated sediments were only encountered beneath a local depression referred to as a "buffalo wallow," and it was concluded that a similar depression existed in the top of the Dockum beneath the surface depression, trapping the water in a small volume. Domestic and windmill wells that exist in the area do not produce much water during dry periods. Although the Ogallala formation was initially identified at the site, that identification was in error. No matter what the shallow permeable formation is named, it apparently does not hold and transmit sufficient amounts of water for development of wells. Control of stormwater drainage at the site may affect the storage of water in the formation beneath the "buffalo wallow," other natural depressions, or constructed impoundments if the collected runoff is kept on site and allowed to infiltrate.

Within the Dockum group, three or four separate siltstone layers were encountered in the grid of borings. These materials were found to have laboratory-measured hydraulic conductivities two orders of magnitude higher than the claystone. Screened monitoring wells were established in these zones at several locations within the grid. The water levels in these wells were measured several times between November, 1992 and April, 1995. A complete listing, Table A-1, is provided in the Appendix summarizing the well identities (based on original boring grid locations), top-of-casing elevations, screened intervals, depths to water, and water surface elevations for monitoring events by AME (Messenger, personal communication). Table 1 was derived by grouping monitoring wells with approximately similar screened interval locations. These groups roughly align with the identification of three possibly continuous siltstone layers. Groups A and B are most likely the first siltstone, while groups C and D roughly correspond to the second and third siltstone layers, respectively. The lateral and vertical extents of these layers are not completely known.

Inspection of Tables A-1 and 1 allows several important conclusions. First, when bailed to dryness, the water levels in the wells typically took several weeks to return to static levels. This delay indicated either low local permeability, little water volume in storage, or both controlled the return of water to the screened interval. Second, the equilibrated water surface elevations at most of the monitoring wells with similar depths of screen were not close enough to imply hydraulic continuity. For example, only well pairs 4-C and 5-C in group B, 4-G2 and 9-G2 in group C, and 4-G3 and 9-G3 in group D had water surface elevations within a few feet of each other. Third, the height of the water columns above the tops of the screens at wells 7-G, 2-G, 11-D, 6-B1, and 6-B2 were 44.3, 67.4, 107.13, 41.7, and 98.75 ft, respectively. These values indicate that the water in the siltstones at those locations was under pressurized confined conditions, yet the permeability or discontinuity still restricted the flow.

Table 1. Well Screened Intervals and Water Level Elevations Observed on April 19, 1995

Group with Similar Intervals	Well	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Water Surface Elevation (ft)
A	9-G1	3330.17	3325.17	dry
B	5-E	3312.28	3302.28	dry
	5-C	3307.94	3287.94	3288.12
	4-C	3307.55	3285.55	3288.79
	4-G1	3294.56	3264.56	3260.65
	6-B1	3295.66	3285.66	3337.36
C	7-G	3262.72	3232.72	3307.15
	11-D	3241.07	3216.07	3348.20
	4-G2	3249.69	3219.68	3245.16
	9-G2	3248.99	3238.99	3242.36
	6-B2	3220.26	3210.26	3319.01
D	2-G	3214.93	3189.93	3282.33
	4-G3	3202.11	3197.11	3194.10
	9-G3	3197.02	3187.02	3193.06

The total dissolved solids (TDS) contents of the water samples taken from these wells were significantly higher (>1,800 mg/L) than typical regional values for the Ogallala aquifer (~500 mg/L). In addition, the TDS values varied significantly between the wells in these layers, possibly indicating little if any flow between the well locations. The upper siltstone layer was identified as the "uppermost aquifer" for monitoring purposes. Due to the difficulties in static water level equilibration and development, dedicated sampling pumps were recommended for future monitoring well installations. Further discussion of the hydrogeologic and geochemical data will be given in a later section of this report.

Site Visits

On July 28, 1993, Drs. Lloyd Urban and Ken Rainwater visited the proposed site. Allen Messenger and Andy Witteveld of AME conducted the tour. The site is currently part of the Flying W Diamond Ranch, a short distance east of Eunice, New Mexico. The property is used as a working ranch, with limited development for oil and gas wells. The grid of soil borings was still evident at the surface, as were the existing monitor wells. Mr. Witteveld described the bailer-development procedure he was using to encourage increased flow in the screened intervals of the wells. He also provided preliminary water quality data from sampling events since the preparation of the permit documents. Mr. Bill Vance, ranch manager, took the group over to the Monument Draw area on the other side of the state line for viewing of the 20- to 30-ft high cutbank of the draw. He also identified the Baker Spring location within the draw. No recent flow was evident at the spring.

During 1996, several visits to the site were made by Drs. Rainwater, Urban, Lehman, Gurrola, and Jayawickrama. On July 17, 1996, Drs. Rainwater, Urban, and Lehman visited the WCS site for their first view of the initial cell excavation, hosted by AME. Over the next three months, various combinations of the five scientists and engineers made additional visits to the site to gather geological and geophysical information about the vicinity.

Public Meeting in Andrews

At the request of the AIF, Drs. Urban and Rainwater attended a public meeting held by the TNRCC at the High School Auditorium in Andrews, Texas, on the evening of September 30, 1993. The purpose of the public meeting was to give local residents opportunity to ask questions of the TNRCC about the landfill and the permitting process. It was apparent that civic group support for the project was quite high, and that the AIF and AME had spent considerable effort describing the facility design to the residents. The TNRCC staff raised no questions at that time.

Inspection of Core Samples

On October 4, 1993, Dr. Rainwater visited the office of Jack H. Holt, Ph.D., and Associates, Inc. (JHA) with Mr. Witteveld to visually examine core samples from selected borings. Cores 6-B and 9-G, which are shown in Figure 1, represent locations in which almost all of the different lithological were penetrated. Of particular concern in this examination was the condition of the red claystone. In the samples from both cores, the red claystone core was typically continuous (few fracture planes not attributable to the sampling process), solid, and tight. As indicated by the results of the laboratory hydraulic conductivity tests, the claystone was probably naturally compacted by the weight of overburden during deposition. The zones identified as siltstone and sandstone were typically grayish or white cohesive materials with fine grains of silt or sand visible on the outside of the cores. The presence of the sand and silt apparently accounts for the higher hydraulic conductivities of these materials relative to that of the claystone. However, the siltstone and sandstone did not appear to have enough porosity to allow significant flow under typical natural gradients.

Recommendation and Evaluation of Water Quality Samples

AME provided the results of the analyses of water samples collected on July 23, 1993, from wells 2-G, 7-G, 11-D, and 6-B1. The surface locations of these wells are shown in Figure 1. The samples were analyzed for several water quality parameters, including some major ions, pH, and TDS. The major ion analyses are of primary concern to this report since ionic composition of groundwater sometimes provides clues about hydraulic connections in the local subsurface. For example, water quality in an aquifer generally deteriorates with distance from the point of recharge, as more materials are dissolved. Also, the nature and amount of dissolved species can indicate the rock types through which the water moved. Table 2 summarizes the results of the analyses. The concentrations of the ionic species were given by the laboratory in mg/L, and then converted to milliequivalents/L (meq/L) to check for electroneutrality. The condition of electroneutrality in a water solution requires that the sum of the meq/L of cations must equal the sum of the meq/L of anions. The "ion %" column lists the portion that each ionic constituent comprises in the major cations or anions as appropriate. The analyses for this sample set included all of the typical major ions in natural waters except for bicarbonate (HCO_3).

Table 2 shows that there was little similarity in the waters from the four wells. The measured TDS varied from 1800 to 5500 mg/L. In each sample, sodium (Na) was the dominant cation and sulfate (SO_4) was the dominant anion, but the relative concentrations varied by a factor of almost 3. It is possible to check a major ion analysis by comparing the measured and calculated TDS values. The measured TDS is normally done with a conductivity meter based on the ionic strength of the solution. The calculated TDS is found by summing the total mg/L of the cations

Table 2. Water Quality Analyses for Samples Collected 7/23/93

Well	2-G			7-G			11-D			6B-1			26-40-602(Ogallala)		
Constituent	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %
Cations															
Ca	28	1.40	4.1	64	3.20	4.2	60	3.00	6.1	7	0.35	1.3	78	3.90	53.3
Mg	20	1.65	4.8	58	4.77	6.3	51	4.20	8.5	11	0.91	3.3	21	1.73	23.6
Na	710	30.87	90.5	1560	67.83	88.8	960	41.74	84.7	590	25.65	94.0	36	1.57	21.4
K	8	0.19	0.6	22	0.56	0.7	13	0.32	0.6	15	0.37	1.4	5	0.13	1.7
Total	766	34.1	100.0	1704	76.36	100.0	1084	49.26	100.0	623	27.28	100.0	140	7.32	100.0
Anions															
Cl	200	5.63	17.1	1157	32.59	38.6	290	8.17	24.4	200	5.63	23.1	39	1.10	15.3
SO4	1300	27.08	82.3	2460	51.25	60.7	1200	25.00	74.7	900	18.75	76.9	39	0.81	11.3
HCO3	nr			nr			nr			nr			304	4.98	69.4
NO3	12	0.19	0.6	33	0.53	0.6	19	0.31	0.9	0	0.00	0.0	18	0.29	4.0
Total	1512	32.91	100.0	3650	84.37	100.0	1509	33.48	100.0	1100	24.38	100.0	400	7.19	100.0
Neutral															
SiO2	11			13			11			13			43		
TDS(meas)	2600			5500			4000			1800			431		
TDS(sum)	2289			5367			2604			1736			583		
TDS Error(%)	6.4			1.2			21.1			1.8			15.0		
Ion Error(%)		1.8			5.0			19.1			5.6			0.9	

Well 24-40-602 (Ogallala) - Flying W Diamond Ranch well, sampled by TWDB on 10/10/1990, included for comparison
TDS Error(%) = 100 |TDS(sum) - TDS(meas)| / [TDS(sum) + TDS(meas)]
Ion Error(%) = 100 |Total Cations(meq/L)-Total Anions(meq/L)| / [Total Cations(meq/L)+Total Anions(meq/L)]
nr = not run

(Ca, Mg, Na, and K), the anions (Cl, SO_4, NO_3), and neutral compounds (SiO_2). The TDS (meas) and TDS (sum) should agree within 5 percent, as shown for wells 7-G and 6B-1. Electroneutrality is checked by comparing the total meq/L of the cations with the total meq/L of the anions in what is called the ion balance error. The ion balance error should also be less than 5 percent for an acceptable analysis, as it is for wells 2-G and 7-G. When these two checks are not consistent for all the analyses, especially when the TDS (sum) is less than the TDS (meas) for all the samples, it is quite possible that one or more other significant ions should be analyzed in the samples. Other errors could have taken place in one or more of the analyses which were performed on the samples. Dr. Rainwater suggested to Mr. Witteveld that bicarbonate should be added to the list of analyses for the next round of samples. A fifth water sample is included in Table 2 for comparison of typical local shallow groundwater quality to that in the Dockum group. Well 26-40-602 is located on the Flying W Diamond Ranch near state highway 176, and this well is occasionally monitored and sampled by the Texas Water Development Board (TWDB). The well is referred to as an "Ogallala" well by the TWDB.

A second set of samples was collected by AME on September 21, 1993, from wells 2-G, 7-G, 11-D, 6B-1, and 6B-2. Table 3 summarizes the results of the ion analyses. Comparison of Tables 2 and 3 show limited agreement between the two sets of analyses of wells 2-G, 7-G, 11-D, and 6B-1. This disagreement is not surprising, considering the difficulty of purging and sampling the wells in these siltstone layers. It is possible that there were sampling, handling, or analytical errors between the two sample sets, but it is also possible that the chemical composition of the water in the vicinity of each well has not been homogenized by mechanical mixing due to flow. This question would hopefully be resolved as additional samples were collected from these wells in subsequent monitoring events. The TDS values for well 2-G were similar, while the TDS values were higher in September for wells 7-G, 11-D, and 6B-1. Well 6B-2 showed very poor agreement between TDS (meas) and TDS (sum), and only well 7-G had acceptable agreement between TDS (meas) and TDS (sum).

With the addition of HCO_3 to the ion analyses, it was hoped that the ion balance errors

Table 3. Water Quality Analyses for Samples Collected 9/21/93

Well	2-G			7-G			11-D			6B-1			6B-2			26-40-602(Ogallala)		
Constituent	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %
Cations																		
Ca	53	2.65	12.2	170	8.50	10.4	156	7.80	16.0	28	1.40	8.4	33	1.65	11.5	78	3.90	53.3
Mg	25	2.06	9.5	55	4.53	5.5	33	2.72	5.6	11	0.91	5.5	12	0.99	6.9	21	1.73	23.6
Na	387	16.83	77.4	1560	67.83	82.6	870	37.83	77.8	324	14.09	84.9	264	11.48	80.2	36	1.57	21.4
K	8	0.20	0.9	49	1.25	1.5	11	0.28	0.6	8	0.20	1.2	8	0.20	1.4	5	0.13	1.7
Total	473	21.74	100.0	1834	82.11	100.0	1070	48.62	100.0	371	16.60	100.0	317	14.32	100.0	140	7.32	100.0
Anions																		
Cl	200	5.63	15.6	1700	47.89	45.7	590	16.62	32.1	210	5.92	16.6	200	5.63	21.8	39	1.10	15.3
SO4	1300	27.08	75.0	2600	54.17	51.7	1600	33.33	64.4	1200	25.00	70.1	740	15.42	59.6	39	0.81	11.3
HCO3	190	3.11	8.6	150	2.46	2.3	100	1.64	3.2	290	4.75	13.3	290	4.75	18.4	304	4.98	69.4
NO3	18	0.29	0.8	12	0.19	0.2	10	0.16	0.3	0	0.00	0.0	4	0.06	0.2	18	0.29	4.0
Total	1708	36.12	100.0	4462	104.71	100.0	2300	51.75	100.0	1700	35.67	100.0	1234	25.87	100.0	400	7.19	100.0
Neutral																		
SiO2	10			22			10			11			12			43		
TDS(meas)	2700			6900			4600			1900			2600			431		
TDS(sum)	2191			6318			3380			2082			1563			583		
TDS Error(%)	10.4			4.4			15.3			4.6			24.9			15.0		
Ion Error(%)		24.9			12.1			3.1			36.5			28.7			0.9	

Well 24-40-602 (Ogallala) - Flying W Diamond Ranch well, sampled by TWDB on 10/10/1990, included for comparison
TDS Error(%) = 100 |TDS(sum)-TDS(meas)| / [TDS(sum)+TDS(meas)]
Ion Error(%) = 100 |Total Cations(meq/L)-Total Anions(meq/L)| / [Total Cations(meq/L)+Total Anions(meq/L)]

would be reduced. In this sample set, however, only the analyses from well 11-D met the 5 percent limit. It is difficult to identify a specific explanation for the larger ion balance errors. Analytical laboratories sometimes have difficulty with these balances in saline waters due to the differing concentration ranges measurable in the different ion procedures. The cations are normally quantified in elemental analyses by atomic spectrophotometry, which requires dilution of the sample, while anions may be analyzed by ion chromatography, titrations, colorimetry, or ion specific electrode methods which may or may not require dilution. The different methods are sometimes interfered with by high concentrations of other compounds. In any case, the accuracy of these analyses is in question. However, it is possible to make some useful comparisons. The ion percentages were used to visually compare ion grouping among these water samples using a trilinear, or Piper, diagram (Freeze and Cherry, 1979) in Figure 2. From this figure, the waters at all of the Dockum group wells are classified as Na-SO_4+Cl dominated solutions. Note that the sample from well 26-40-602 plots far away from the Dockum samples, as a Ca+Mg-HCO_3 water. The 26-40-602 water is essentially a much "younger" water, more recently recharged from the atmosphere. Although the Dockum water samples show somewhat similar ionic distributions, the large differences in their TDS values cannot be directly correlated to a reasonable flow phenomenon in the siltstone.

Three more monitoring events occurred in October, 1993, January, 1994, and March, 1994. The results of these sampling events are summarized in Tables 4, 5, and 6, respectively. The results from these three events compare somewhat more closely overall than the first two sampling events. The ion and TDS balance errors often exceeded the 5 percent target, but the TDS values are much more comparable across events. In addition, the concentrations of the ionic constituents in each well are much more similar across events. When plotted on trilinear diagrams, the results are practically identical to those in Figure 2 within the scale of that configuration, so additional figures are not provided. The improved consistency is encouraging, and does not change the conclusions drawn in the previous paragraph.

In summary, the ionic analyses of the sampled wells were useful in describing the potential

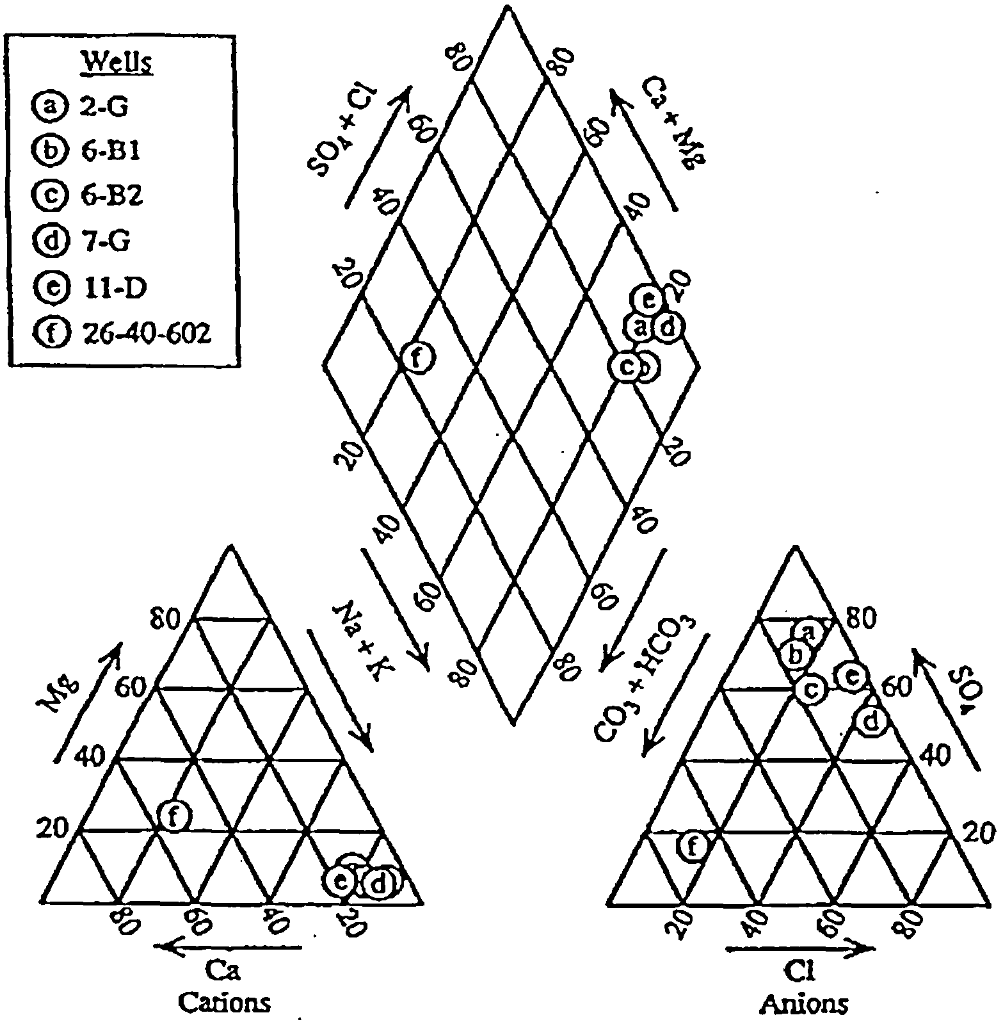

Figure 2. Trilinear Representation of Major Ion Analyses

Table 4. Water Quality Analyses for Samples Collected 10/20/93

Well	2-G			7-G			11-D			6B-1			6B-2			26-40-602(Ogallala)		
Constituent	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %
Cations																		
Ca	72	3.60	10.4	126	6.30	6.3	158	7.90	12.6	42	2.10	8.5	33	1.65	4.4	78	3.90	53.3
Mg	36	2.96	8.6	106	8.72	8.7	68	5.60	9.0	17	1.40	5.7	15	1.23	3.3	21	1.73	23.6
Na	640	27.83	80.4	1940	84.35	84.0	1120	48.70	77.9	480	20.87	84.9	800	34.78	91.9	36	1.57	21.4
K	8	0.20	0.6	41	1.05	1.0	11	0.28	0.5	8	0.20	0.8	7	0.18	0.5	5	0.13	1.7
Total	756	34.59	100.0	2213	100.42	100.0	1357	62.47	100.0	547	24.57	100.0	855	37.85	100.0	140	7.32	100.0
Anions																		
Cl	180	5.07	11.2	1300	36.62	34.4	550	15.49	21.1	190	5.35	18.9	200	5.63	15.3	39	1.10	15.3
SO4	1700	35.42	78.1	3200	66.67	62.5	2700	56.25	76.5	880	18.33	64.7	1260	26.25	71.3	39	0.81	11.3
HCO3	190	3.11	6.9	150	2.46	2.3	100	1.64	2.2	280	4.59	16.2	300	4.92	13.4	304	4.98	69.4
NO3	110	1.77	3.9	52	0.84	0.8	10	0.16	0.2	3	0.05	0.2	1	0.02	0.0	18	0.29	4.0
Total	2180	45.38	100.0	4702	106.58	100.0	3360	73.54	100.0	1353	28.32	100.0	1761	36.82	100.0	400	7.19	100.0
Neutral																		
SiO2	10			12			11			13			12			43		
TDS(meas)	2500			6700			4400			1800			2500			431		
TDS(sum)	2946			6927			4728			1913			2628			583		
TDS Error(%)	8.2			1.7			3.6			3.0			2.5			15.0		
Ion Error(%)		13.5			3.0			8.1			7.1			1.4			0.9	

Well 24-40-602 (Ogallala) - Flying W Diamond Ranch well, sampled by TWDB on 10/10/1990, included for comparison

TDS Error(%) = 100 |TDS(sum)-TDS(meas)| / [TDS(sum)+TDS(meas)]

Ion Error(%) = 100 |Total Cations(meq/L)-Total Anions(meq/L)| / [Total Cations(meq/L)+Total Anions(meq/L)]

Table 5. Water Quality Analyses for Samples Collected 1/26-27/94

Well	2-G			7-G			11-D			6B-1			6B-2			26-40-602(Ogallala)		
Constituent	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %
Cations																		
Ca	94	4.70	7.7	186	9.30	8.3	194	9.70	13.7	46	2.30	4.9	34	1.70	2.9	78	3.90	53.3
Mg	42	3.46	5.7	104	8.56	7.6	19	1.56	2.2	9	0.74	1.6	9	0.74	1.2	21	1.73	23.6
Na	1200	52.17	85.9	2150	93.48	83.1	1350	58.70	83.2	1000	43.48	92.7	1300	56.52	95.3	36	1.57	21.4
K	17	0.43	0.7	44	1.13	1.0	24	0.61	0.9	15	0.38	0.8	13	0.33	0.6	5	0.13	1.7
Total	1353	60.77	100.0	2484	112.46	100.0	1587	70.57	100.0	1070	46.90	100.0	1356	59.29	100.0	140	7.32	100.0
Anions																		
Cl	200	5.63	11.5	1500	42.25	37.0	730	20.56	27.2	230	6.48	21.9	230	6.48	13.2	39	1.10	15.3
SO4	1900	39.58	80.8	3300	68.75	60.2	2500	52.08	68.8	890	18.54	62.6	1800	37.50	76.6	39	0.81	11.3
HCO3	190	3.11	6.4	150	2.46	2.2	130	2.13	2.8	280	4.59	15.5	300	4.92	10.0	304	4.98	69.4
NO3	41	0.66	1.3	42	0.68	0.6	56	0.90	1.2	0	0.00	0.0	5	0.08	0.2	18	0.29	4.0
Total	2331	48.99	100.0	4992	114.14	100.0	3416	75.68	100.0	1400	29.61	100.0	2335	48.98	100.0	400	7.19	100.0
Neutral																		
SiO2	11			12			12			14			12			43		
TDS(meas)	2700			7100			4500			1900			2700			431		
TDS(sum)	3695			7488			5015			2484			3703			583		
TDS Error(%)	15.6			2.7			5.4			13.3			15.7			15.0		
Ion Error(%)		10.7			0.7			3.5			22.6			9.5			0.9	

Well 24-40-602 (Ogallala) - Flying W Diamond Ranch well, sampled by TWDB on 10/10/1990, included for comparison
TDS Error(%) = 100 |TDS(sum)-TDS(meas)| / [TDS(sum)+TDS(meas)]
Ion Error(%) = 100 |Total Cations(meq/L)-Total Anions(meq/L)| / [Total Cations(meq/L)+Total Anions(meq/L)]

Table 6. Water Quality Analyses for Samples Collected 3/17-18/94

Well	2-G			7-G			11-D			6B-1			6B-2			26-40-602(Ogallala)		
Constituent	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %	mg/L	meq/L	ion %
Cations																		
Ca	84	4.20	8.9	200	10.00	7.6	180	9.00	9.3	31	1.55	3.7	30	1.50	3.0	78	3.90	53.3
Mg	26	2.14	4.5	98	8.07	6.1	56	4.61	4.8	19	1.56	3.7	12	0.99	1.9	21	1.73	23.6
Na	930	40.43	85.6	2600	113.04	85.5	1900	82.61	85.3	890	38.70	91.6	1100	47.83	94.2	36	1.57	21.4
K	19	0.49	1.0	45	1.15	0.9	23	0.59	0.6	17	0.43	1.0	17	0.43	0.9	5	0.13	1.7
Total	1059	47.26	100.0	2943	132.26	100.0	2159	96.81	100.0	957	42.24	100.0	1159	50.75	100.0	140	7.32	100.0
Anions																		
Cl	220	6.20	15.0	1640	46.20	40.7	610	17.18	25.5	230	6.48	23.7	230	6.48	17.8	39	1.10	15.3
SO4	1500	31.25	75.6	3100	64.58	56.9	2300	47.92	71.0	780	16.25	59.6	1200	25.00	68.7	39	0.81	11.3
HCO3	191	3.13	7.6	148	2.43	2.1	125	2.05	3.0	278	4.56	16.7	298	4.89	13.4	304	4.98	69.4
NO3	48	0.77	1.9	13	0.21	0.2	22	0.35	0.5	0	0.00	0.0	0	0.00	0.0	18	0.29	4.0
Total	1959	41.35	100.0	4901	113.42	100.0	3057	67.50	100.0	1288	27.29	100.0	1728	36.36	100.0	400	7.19	100.0
Neutral																		
SiO2	11			12			11			14			12			43		
TDS(meas)	2660			7300			4650			1790			2700			431		
TDS(sum)	3029			7856			5227			2259			2899			583		
TDS Error(%)	6.5			3.7			5.8			11.6			3.6			15.0		
Ion Error(%)		6.7			7.7			17.8			21.5			16.5			0.9	

Well 24-40-602 (Ogallala) - Flying W Diamond Ranch well, sampled by TWDB on 10/10/1990, included for comparison

TDS Error(%) = 100 |TDS(sum)-TDS(meas)| / [TDS(sum)+TDS(meas)]

Ion Error(%) = 100 |Total Cations(meq/L)-Total Anions(meq/L)| / [Total Cations(meq/L)+Total Anions(meq/L)]

for flow and mixing in the sampled siltstone. Although the TDS and ion error values are higher than those typically accepted in fresh water analyses, they are not uncommon in more saline waters with high ion concentrations that can cause interferences for some of the analytical techniques. These results are sufficient to verify the large difference in quality between the shallow fresh groundwater and the Dockum waters. In addition, the large differences in composition of the Dockum water samples indicate little mixing due to flow in the siltstone.

Review of Geologic and Hydrogeologic Information on Andrews County

As stated previously in this report, protection of existing groundwater resources is of utmost concern in siting and design of hazardous waste facilities. The major high quality groundwater source in the Southern High Plains of Texas is the Ogallala aquifer. In this section, the direct impacts of the WCS facility on the Ogallala aquifer in both the local and regional scale are considered. The site investigation results from the permit application (AME, 1993) and the historical findings published in the professional literature are combined in this evaluation. As stated previously, the shallow permeable formation in the site vicinity is evaluated under the two aquifer criteria of [1] presence of geologic media that easily transmit water flow and [2] presence of sufficient volume of water for flow to production wells. This section includes discussion of geologic and hydrogeologic information from the AME (1993) permit documents, existing literature descriptions, and the most recent field work by Lehman (1996). Please note that all of the references prior to Lehman (1996) refer to the shallow permeable formation in western Andrews County as the Ogallala formation. Lehman's (1996) clarification is presented at the end of this section.

As reported in the hydrogeologic section in the permit application (AME, 1993), the borings drilled in the subsurface investigation encountered permeable sands and gravels identified as the lower portion of the Ogallala formation. Saturated conditions in these sediments were only rarely encountered, and then only beneath a surface depression. The saturated zone beneath the "buffalo wallow" was not sufficient to allow water to collect in the borehole. The conclusion of the site characterization was that the Ogallala formation is present beneath the site, but the formation does not contain an extensive, continuous volume of water suitable for development. The experience of Mr. Vance with the shallow Ogallala well at the Flying W Diamond Ranch corroborated this view, since the well was known to produce water only sporadically after sizable rainfall events. The mounded shape, as shown in Figure 1, of the top of the Dockum group, apparently encourages water that infiltrates into the shallow permeable formation from the surface to flow away from beneath the WCS site. It is also possible that rainfall may be so low in this location that soil and vegetation combinations in the area may prevent infiltration of significant amounts of water.

Documents describing the Ogallala aquifer conditions in the Andrews County vicinity were obtained from the TWDB and the holdings of the Texas Tech libraries. Six documents directly addressed the groundwater resources in the county, but, as will be shown in the following discussion, little accurate historical information exists that describe the conditions in the western portion of the county.

In 1940, the Texas Board of Water Engineers published a report on the groundwater development in Andrews County (TBWE, 1940). This report was a compilation of drillers' logs, well and test hole reports, and chemical analyses from wells in existence prior to 1940. The reports referred to a few hundred wells in the county, with most of the pumping wells in the eastern two-thirds of the county near the city of Andrews. No wells were shown in the vicinity of the WCS site.

Cronin (1961) presented a report on the occurrence and use of groundwater in the Southern High Plains as part of a joint effort between the U.S. Geological Survey (USGS), TBWE, and the High Plains Underground Water Conservation District. The report included a thorough discussion of the regional lithology as understood at that time and a number of contour maps that showed the elevation of the water table in the Ogallala aquifer, the elevation of the base of the Ogallala, and the saturated thickness of the aquifer across the region. Figure 3, which shows the elevation of the base of the Ogallala, provides no resolution of that quantity in the western one-fifth of Andrews County, implying that acceptably accurate records were not available to the author. Figure 4,

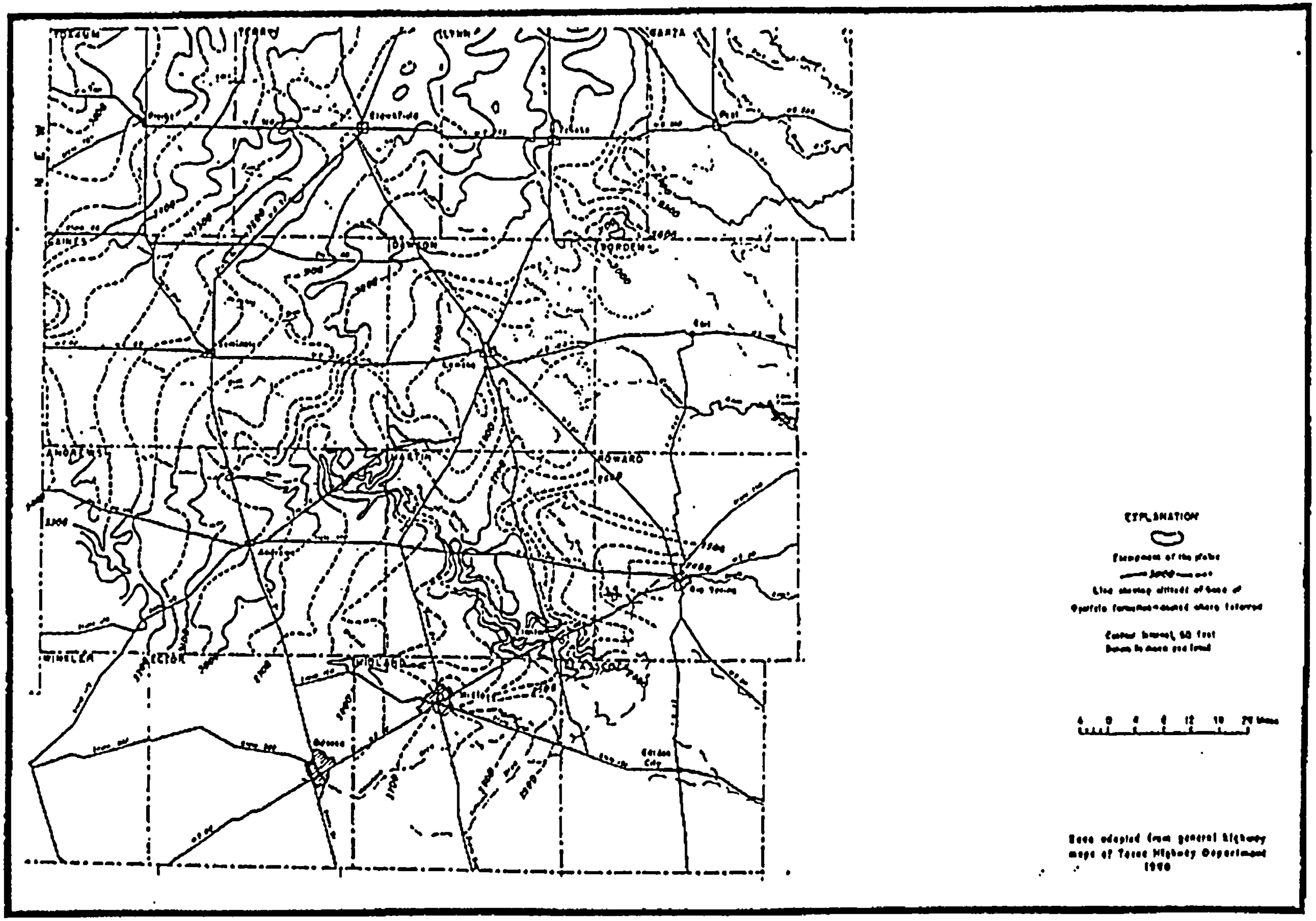

Figure 3. Contour Map of Base of Ogallala Formation. [Source: Cronin (1961)]

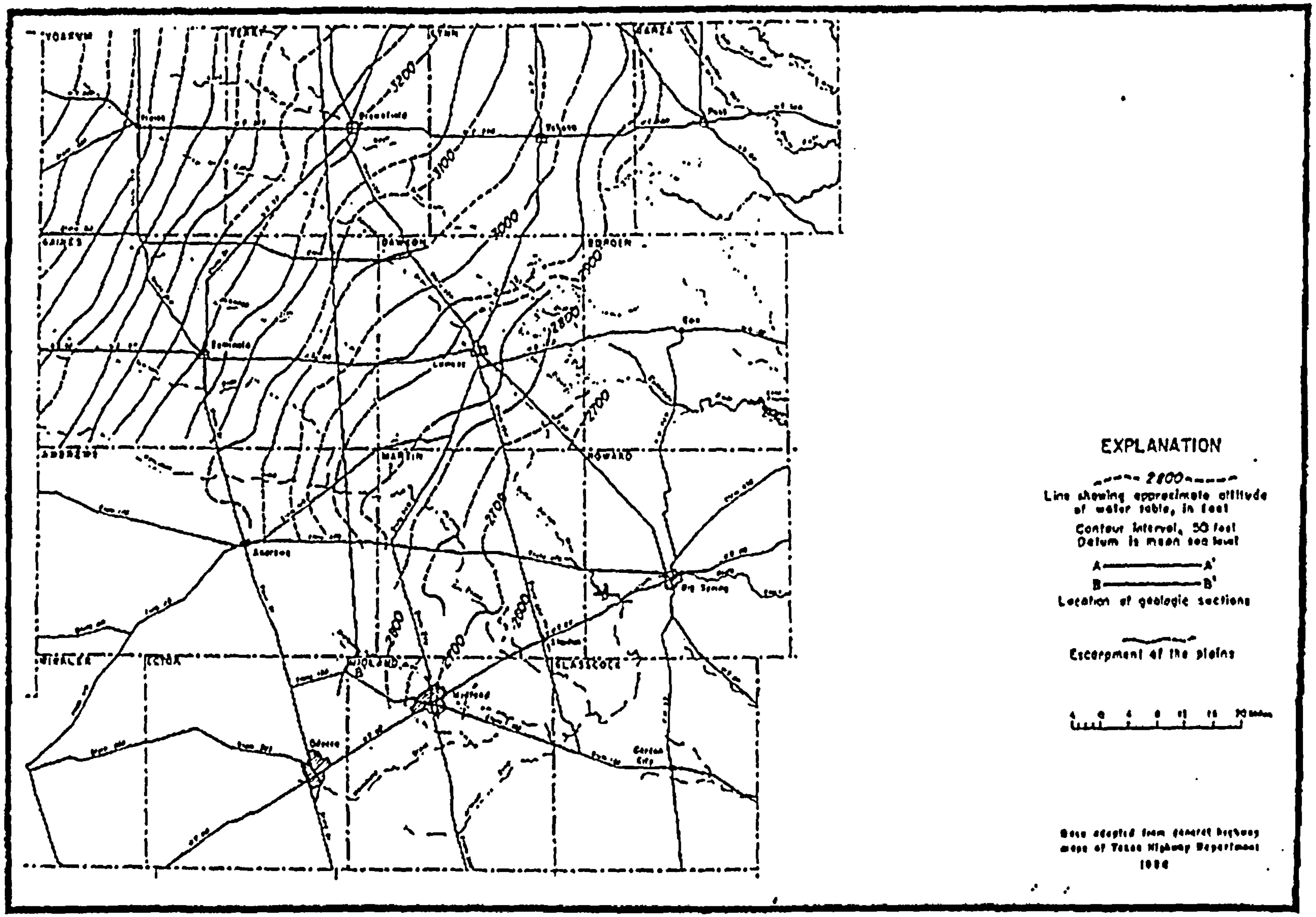

Figure 4. Contour Map of Water Level Elevation in Ogallala Formation. [Source: Cronin (1961)]

which shows the elevation of the water table in 1958, only indicates measured values in the northeast corner of Andrews County. Figure 5, the contour map of saturated thickness in the Ogallala, is directly related to the limited information in Figures 3 and 4. Figure 5 displays the estimated saturated thickness at the intersection of state highway 176 and the state line, near the WCS site, to be 0 (zero) ft. The method used to derive this estimate was not explained in the report. Apparently, the only appreciable Ogallala water storage in Andrews County was believed to be in the eastern portion of the county.

The TWDB is now the state agency that manages the database describing the state's surface and groundwater resources. Within this responsibility, the TWDB monitors groundwater levels and water quality at selected locations around the state. This data is then used in modeling efforts for projections of groundwater usage and storage for periods 20 to 50 years in the future. Three TWDB wells were identified within 2 miles of the WCS site (AME, 1993, Plate VI.A.1). A visit was made on October 4, 1993 to the TWDB office in Austin to obtain the records for these three wells. Well 26-40-201, owned by Mr. Ed Tinsley, is located approximately 1.2 miles northeast of the WCS site. Wells 26-40-601 and 26-40-602 (about 1200 ft east of 26-40-601), both associated with the Flying W Diamond Ranch, are located about 1.4 miles east-southeast of the WCS site. Table 7 summarizes the reported water depth measurements at these wells. Without a site-specific value of the elevation of the base of the Ogallala at wells 26-40-201 and -601, it is impossible to estimate the local saturated thickness. Also, it appears that no water depth measurement was made by the TWDB at well 26-40-602. Therefore, the wells monitored and reported by the TWDB provide no assistance in estimating local storage in the Ogallala aquifer. A total of four water samples have been collected from the three wells since 1974, with the most recent at well 26-40-602 (Table 2). The water quality at wells 26-40-601 and -602 have been quite similar, as would be expected due to their proximity. Well 26-40-201 has about twice the TDS of the other two wells, due to larger concentrations of calcium, sulfate, and chloride.

Ashworth and Flores (1991) of the TWDB published a set of two maps that delineated the areal extents of the major and minor aquifers in Texas, along with a report which described the

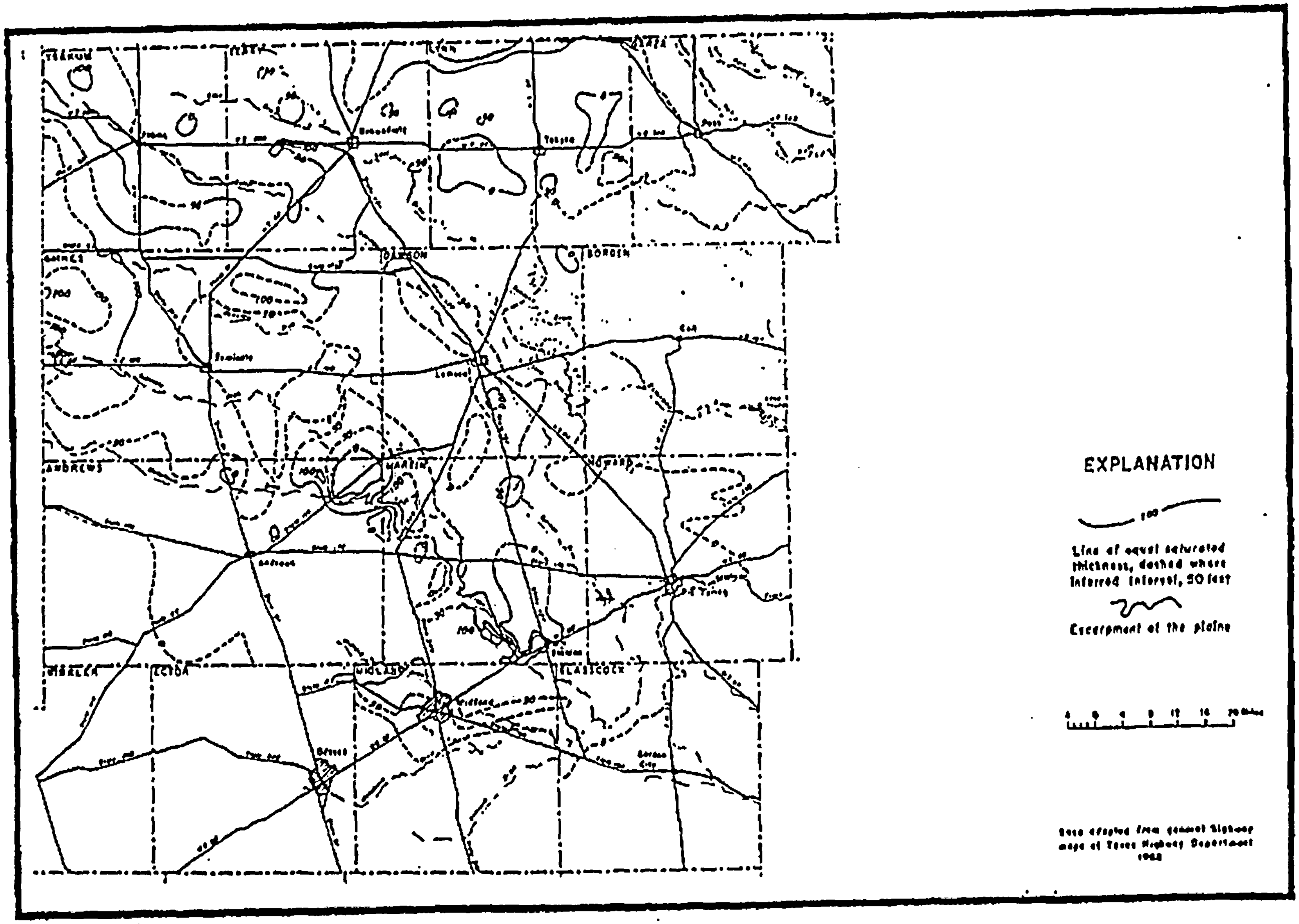

Figure 5. Contour Map of Saturated Thickness in Ogallala Formation. [Source: Cronin (1961)]

Table 7. Water Depth Measurements at TWDB Wells Near WCS Site
(na = information not available)

Well	Depth of Well (ft)	Date Measured	Depth to Water (ft)	Water Surface Elevation (ft)
26-40-201	na	11/25/79 1/13/93	82.47 87.14	3408.53 3403.86
26-40-601	na	12/10/69 1/13/93	78.55 80.03	3411.45 3409.97
26-40-602	80	na	na	na

criteria used to define the aquifer locations on the maps. Figure 6 is a color copy of their major aquifer map, which identifies the presence of the Ogallala aquifer in virtually all of Andrews County. The primary reference for this map was Cronin (1961). According to Ashworth (personal communication), this classification was based on the presence of the geologic formation, with only secondary consideration of the amount of water in storage at any given location. The fact that the western portion of Andrews County is identified as underlain by the Ogallala aquifer does not mean that the formation holds sufficient, if any, water for production. The publication of the maps was intended to show regional distribution of the formations that serve as aquifers across the state, not to define site-specific representation of available water.

Ashworth and others (1991) published an "Evaluation of the Ground-Water Resources in the Southern High Plains of Texas" under the direction of the state legislature as part of a state-wide effort to identify areas with potentially critical problems of groundwater quantity or quality in the next 20 years. This report was supported by the TWDB's on-going computer modeling of the aquifer's response to recharge and withdrawal, later published by Peckham and Ashworth (1993). Ashworth and others (1991) included data describing historical groundwater usage in Andrews County for municipal, agricultural, and industrial purposes as well as contour maps of water level changes and storage in the aquifer. Of particular interest to this study of the WCS site is Figure 7, a regional contour map of the water table elevation that shows that the approximate altitude of the water table in the Ogallala at the WCS location as of 1990 was 3400 ft. This value of 3400 ft cannot be accurate in the site-specific sense for the WCS site, since the elevation of the base of the

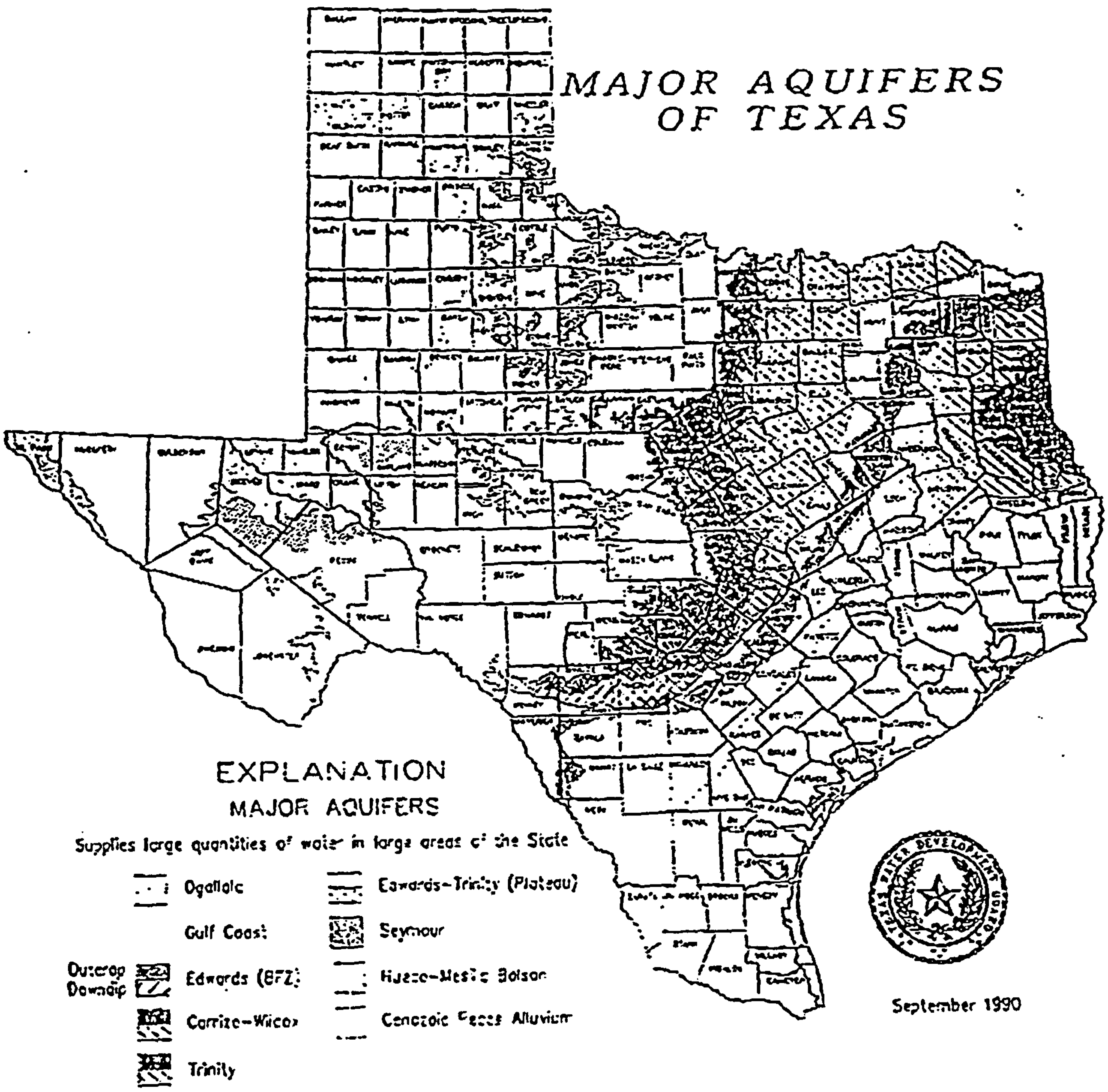

Figure 6. Major Aquifers in Texas. [Source: Ashworth and Flores (1991)]

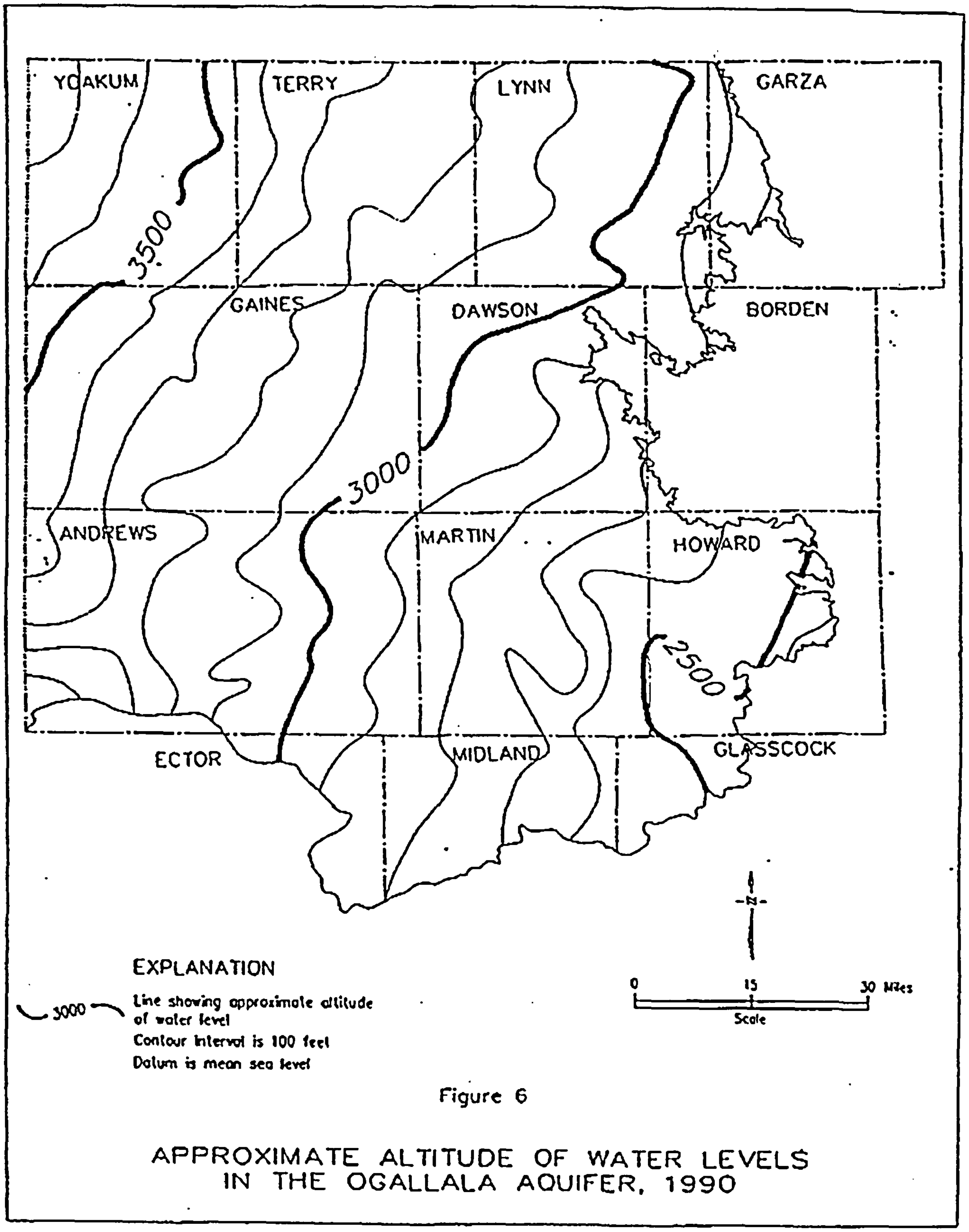

Figure 7. Contour Map of Water Levels in Ogallala Formation, 1990
Source: Peckham and Ashworth, 1993)

Ogallala at the WCS site ranges from 3400 to 3450 ft as shown in Figure 1. In addition, Figure 8, a contour map of regional saturated thickness, shows an approximate saturated thickness for 1990 at the WCS site location of 50 ft. This thickness is also not possible at the WCS location since the thickness of the shallow permeable formation is less than 40 ft, most of which is caliche. Again, it is not surprising that the regional information in the report by Ashworth and others (1991) does not accurately represent the conditions at the WCS site. The publication was intended to show regional distribution of the water in the Ogallala formation, not to define site-specific description of storage. The detailed subsurface investigation reported in the permit application (AME, 1993) provides the necessary spatial resolution for description of the site-specific conditions for the proposed WCS facility.

Two very recent publications of the TWDB also included Andrews County within their study areas. Peckham and Ashworth (1993) described their efforts to calibrate a computer model for the behavior of the Ogallala aquifer in terms of changes in storage from 1980 to 1990. The intent of the effort was to align the model's output with the observed changes in water levels during that decade by manipulation of the input to the model, especially local aquifer recharge. The initial 1980 conditions assumed a saturated thickness of approximately 50 ft near the WCS site. The report did not detail how the initial saturated thicknesses were assigned at specific points in the region. It is interesting that the simulation of the 50-yr period from 1990 to 2040 with the calibrated model showed no appreciable change in saturated thickness in the western half of Andrews County. This result implies little withdrawal activity relative to that predicted for counties with more irrigated acreage. Hopkins (1993) summarized regional water quality information for the Ogallala aquifer in Texas. Samples were collected and analyzed over a 6-yr period. The only point of interest in this report is that only 4 wells were sampled in the western third of Andrews County. The scarcity of wells in this poorly productive area limited the number of wells available for analyses.

Lehman (1996) evaluated the literature and field evidence in western Andrews County as a direct attempt to determine the presence or absence of the Ogallala formation at the WCS site. His

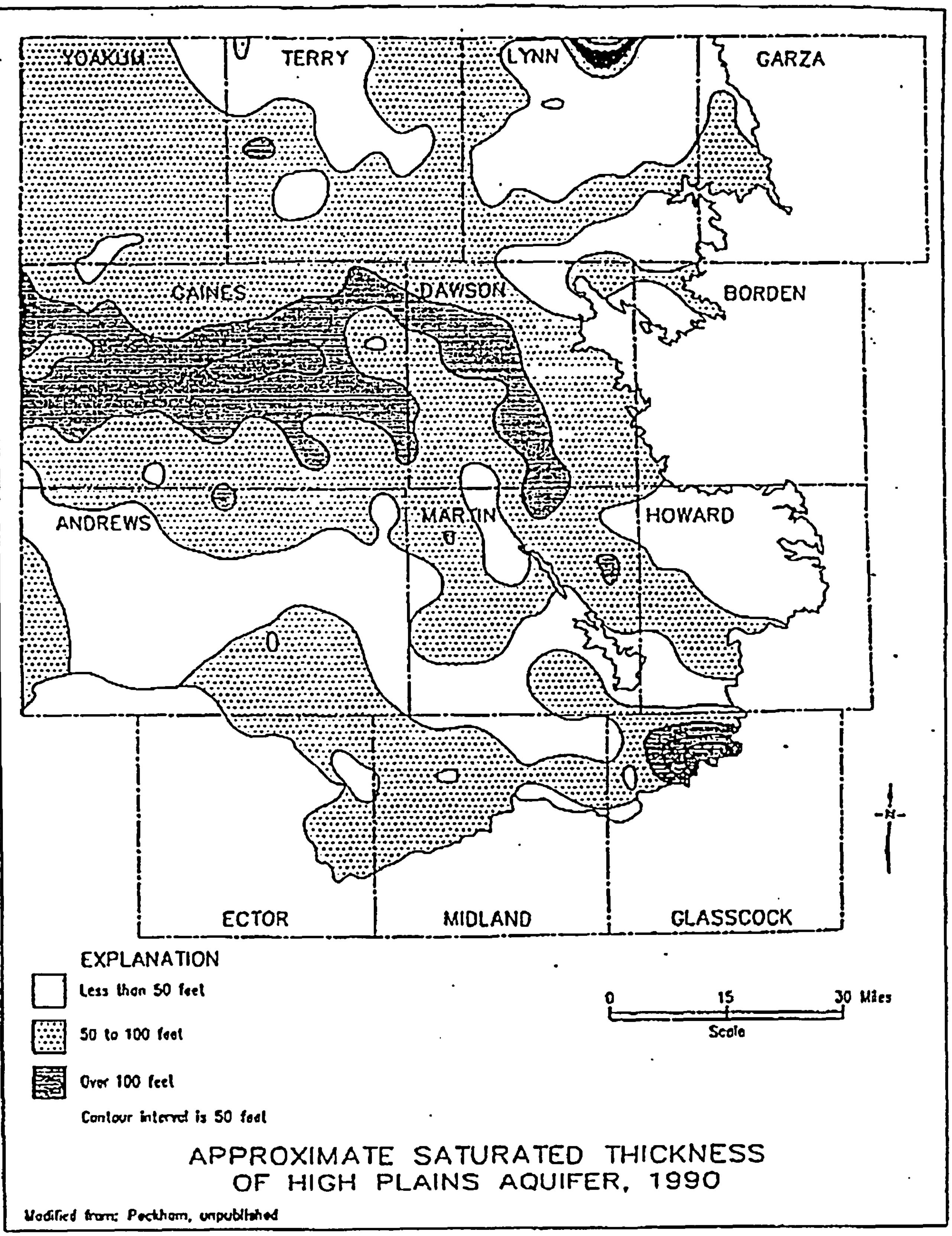

Figure 8. Contour Map of Saturated Thickness in Ogallala Formation, 1990
Source: Peckham and Ashworth, 1993)

study indicated that the "Red Bed Ridge" that makes the WCS site so desirable is a regional feature over 160 km in length and 5 to 10 km in width. His map of the ridge extent is not included with this report due to its large size. The ridge runs from the northwest to the southeast from the state line through Andrews County into Winkler and Ector Counties. It serves as a paleo-drainage divide that separates the Ogallala aquifer on the northeast from the Cenozoic basin fill aquifer to the southwest. Directly above the ridge, the shallow permeable sediments are the Cretaceous Edwards Limestone, Comanche Peak formation, or the Antlers Sandstone. These formations may be overlain by a caprock caliche, which in turn may have a thin veneer of younger sediments. The Ogallala likely pinches out near the line defined by Monument Draw in northern Andrews County, and it may be hydraulically connected to the Cretaceous sediments. However, the lack of developable groundwater resources in western Andrews County south of Monument Draw makes it unlikely that significant flow could move from the WCS site northward to the producing areas in Gaines County. At the WCS site, the shallow permeable formation was positively identified as the Antlers Sandstone by its characteristic gravels and absence of Cretaceous *Gryphaea* shells that occur in the Ogallala formation. The exposure of the Antlers Sandstone at the WCS excavation and other locations in Andrews County show that this formation is permeable, but it does not have significant water storage for development of dependable water wells other than low-flow windmills. In light of these findings, the water wells monitored by the TWDB in the vicinity may also not be in the Ogallala formation. Groundwater collects in the Antlers Sandstone only where the Triassic surface relief allows storage volume. The combination of low rainfall and high evapotranspiration likely limit recharge to this formation in the site vicinity.

In summary, the TWDB and TBWE generated several reports over the years that have included descriptions of the groundwater resources of Andrews County. In all cases, the vast majority of the water in storage was located in the eastern portion of the county. Close examination of the contour maps in these reports results in estimated saturated thickness of the Ogallala at the WCS site to be 0 (zero) ft. The shallow permeable formation at the site was originally identified as the Ogallala in the subsurface investigation. Lehman (1996) showed that the Ogallala formation is not present at the WCS site, nor is it present in a significant portion of Andrews County. No matter what the name of the local shallow permeable formation is, the local high in the upper surface of the Dockum group apparently encourages water that infiltrates, if there is enough for recharge, into this formation to flow away from the site. According to typical definitions of an aquifer, both sufficient permeability and saturated conditions are necessary for a stratum to be an economical water source. The shallow permeable formation at the WCS site does not meet both requirements.

Conclusions and Recommendations

After review of the permit documents and available information about the local hydrogeology, the operation of the WCS facility should have no significant impact on local groundwater resources. The installation of the landfill with its bottom excavated through the Antlers Sandstone formation into the red clays of the Dockum group should prevent transport of contaminants into that shallow permeable formation. The conventional double liner system coupled with the thick Triassic clay foundation provide multiple barriers to contaminant migration. Careful operation of the facility during construction and over its useful life as controlled by state and federal regulations should meet the objectives of safe disposal and protection of the environment.

The Ogallala aquifer does not exist at the site. The shallow permeable formation is more correctly identified as the Antlers Sandstone. This formation does not meet both criteria for classification as an aquifer at this location. The presence of the "Red Bed Ridge" in the Dockum group apparently encourages water that infiltrates into the sands and gravels in the base of the formation to move away to the northeast and southwest. The shallow permeable formation does not contain sufficient water at this location for development with pumping wells. Low rainfall and high evapotranspiration in this area limit the potential for groundwater recharge.

It is recommended that questions about the Ogallala aquifer as this site be considered be put aside as irrelevant based on the available information and landfill design. Emphasis should be placed on the positive features of the site, primarily the proximity of the Triassic clay as the foundation for the landfill bottom, in presentation to regulatory and public groups.

The siltstone layers in the Dockum group, identified as the "uppermost aquifer" for monitoring purposes, also do not fit the two criteria for an aquifer in the water resource development sense. The monitoring wells established in the siltstone are the only alternative for detection of leachate in the remote possibility that the landfill's multiple liner systems fail. The lack of a typical productive aquifer beneath the proposed site is an advantage, since that type of medium could easily transport contaminants if the double liner system failed.

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Appendix

Water Level Measurements Provided by AME (Messenger, personal communication)

Table A-1. Water Level Measurements
(Source, AM Environmental [Messenger, personal communication])

WELL NO./ GRID LOC.	7-G	4-C	2-G	11-D	4-G1	4-G2	4-G3	9-G1	9-G2	9-G3	6-B1	6-B2	5-E	5-C
DATE INSTALLED	12/2/92	12/1/92	12/22/92	12/22/92	1/23/93	2/11/93	1/27/93	1/29/93	1/24/93	1/25/93	1/30/93	1/30/93	1/28/93	1/28/93
T.O.C. ELEV. (FT)	3447.72	3476.55	3439.93	3473.07	3439.56	3439.68	3439.11	3460.17	3459.99	3460.02	3486.66	3482.26	3457.28	3480.94
SCREENED INTERVAL DEPTHS	185-215	169-191	225-250	232-257	145-175	190-220	237-242	130-135	211-221	263-273	191-201	262-272	145-155	173-193
TOP-BOTTOM SCREENED INTERVAL ELEVATIONS	3262.72-3232.72	3307.55-3285.55	3214.93-3189.93	3241.07-3216.07	3294.56-3264.56	3249.69-3219.68	3202.11-3197.11	3330.17-3325.17	3248.99-3238.99	3197.02-3187.02	3295.66-3285.66	3220.26-3210.26	3312.28-3302.28	3307.94-3287.94
DATE: 11/30/92 depth to water	200.15	185.23	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3247.57	3291.32												
DATE: 12/01/92 depth to water	200.15	187.67	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3247.57	3288.88												
DATE: 12/03/92 depth to water	214.50	187.80	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3233.22	3288.75												
DATE: 12/10/92 depth to water	173.10	186.30	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3274.62	3290.25												
DATE: 12/15/92 depth to water	169.40	187.43	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3278.32	3289.12												
DATE: 12/21/92 depth to water	-----	-----	-----	248.00	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation				3225.07										
DATE: 12/29/92 depth to water	157.10	187.60	219.80	183.90	-----	-----	-----	-----	-----	-----	-----	-----	217.00	-----
water surface elevation	3290.62	3288.95	3220.13	3289.17									3240.28	
DATE: 1/10/93 depth to water	151.45	187.85	181.10	164.40	-----	-----	-----	-----	-----	-----	-----	-----	183.90	-----
water surface elevation	3296.27	3288.70	3258.83	3308.67									3273.38	
DATE: 1/14/93 depth to water	149.78	187.79	181.05	161.82	-----	-----	-----	-----	-----	-----	-----	-----	176.15	-----
water surface elevation	3297.94	3288.76	3258.90	3311.25									3281.13	

WELL NO./ GRID LOC.	7-G	4-C	2-G	11-D	4-G1	4-G2	4-G3	9-G1	9-G2	9-G3	6-B1	6-B2	5-E	5-C
T.O.C. ELEV. (FT)	3447.72	3476.55	3439.93	3473.07	3439.56	3439.68	3439.11	3460.17	3459.99	3460.02	3486.66	3482.26	3457.28	3480.94
DATE: 1/17/93														
depth to water	148.88	187.51	181.05	158.58	-----	-----	-----	-----	-----	-----	-----	-----	172.00	-----
water surface elevation	3298.84	3289.04	3258.88	3314.49									3285.28	
DATE: 1/20/93														
depth to water	148.00	187.72	181.08	154.72	-----	-----	-----	-----	-----	-----	-----	-----	167.80	-----
water surface elevation	3299.72	3288.83	3258.85	3318.35									3289.48	
DATE: 1/23/93														
depth to water	147.10	187.60	188.01	151.61	-----	-----	-----	-----	-----	-----	-----	-----	164.55	-----
water surface elevation	3300.62	3288.95	3251.92	3321.46									3292.73	
DATE: 1/27/93														
depth to water	148.92	187.97	184.10	153.47	-----	-----	-----	-----	-----	-----	-----	-----	160.80	-----
water surface elevation	3298.80	3288.58	3255.83	3319.60									3296.48	
DATE: 1/30/93														
depth to water	152.05	188.23	186.45	156.15	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3295.67	3288.32	3253.48	3316.92										
DATE: 2/5/93														
depth to water	156.30	188.20	189.80	155.28	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
water surface elevation	3291.42	3288.35	3250.13	3317.79										
DATE: 2/9/93														
depth to water	159.60	187.20	191.10	156.23	179.15	DRY	DRY	DRY	224.40	271.70	162.70	DRY	DRY	DRY
water surface elevation	3288.12	3289.35	3248.83	3316.84	3260.41				3235.59	3188.32	3323.96			
DATE: 2/12/93														
depth to water	157.90	187.75	187.70	153.90	179.10	DRY	245.20	DRY	224.20	270.30	158.15	DRY	DRY	DRY
water surface elevation	3289.82	3288.80	3252.23	3319.17	3260.46		3193.91		3235.79	3189.72	3328.51			
DATE: 2/17/93														
depth to water	154.21	187.95	181.10	150.23	179.15	DRY	245.45	DRY	224.10	270.17	154.77	232.90	DRY	DRY
water surface elevation	3293.51	3288.60	3258.83	3322.84	3260.41		3193.66		3235.89	3189.85	3331.89	3249.36		
DATE: 2/24/93														
depth to water	152.18	187.46	179.52	146.02	DRY	DRY	245.35	DRY	223.70	269.91	152.69	218.20	DRY	DRY
water surface elevation	3295.54	3289.09	3260.41	3327.05			3193.76		3236.29	3190.11	3333.97	3264.06		
DATE: 3/3/93														
depth to water	149.85	187.65	176.98	142.96	DRY	DRY	245.37	DRY	223.43	269.75	151.75	207.00	DRY	DRY
water surface elevation	3297.87	3288.90	3262.95	3330.11			3193.74		3236.56	3190.27	3334.91	3275.26		
DATE: 3/10/93														
depth to water	148.50	187.80	174.70	139.90	179.20	DRY	245.36	DRY	223.13	269.73	151.25	188.80	DRY	DRY
water surface elevation	3299.22	3288.75	3265.23	3333.17	3260.36		3193.75		3236.86	3190.29	3335.41	3293.46		

WELL NO./ GRID LOC.	7-G	4-C	2-G	11-D	4-G1	4-G2	4-G3	9-G1	9-G2	9-G3	6-B1	6-B2	5-E	5-C
T.O.C. ELEV. (FT)	3447.72	3476.55	3439.93	3473.07	3439.56	3439.68	3439.11	3460.17	3459.99	3460.02	3485.66	3482.26	3457.28	3480.94
DATE: 3/18/93														
depth to water	147.20	187.55	172.10	137.00	179.60	DRY	245.37	DRY	222.76	269.60	150.78	189.23	DRY	DRY
water surface elevation	3300.52	3289.00	3267.83	3336.07	3259.96		3193.74		3237.23	3190.42	3335.88	3293.03		
DATE: 3/30/93														
depth to water	145.13	187.45	169.16	133.85	179.15	203.77	245.40	DRY	222.24	269.48	150.30	179.40	DRY	DRY
water surface elevation	3302.59	3289.10	3270.77	3339.22	3260.41	3235.91	3193.71		3237.75	3190.54	3336.36	3302.86		
DATE: 4/13/93														
depth to water	143.45	187.48	167.86	131.11	179.29	203.90	245.49	DRY	221.70	269.42	150.05	171.21	DRY	195.94
water surface elevation	3304.27	3289.07	3272.07	3341.96	3260.27	3235.78	3193.62		3238.29	3190.60	3336.61	3311.05		3285.00
DATE: 4/28/93														
depth to water	141.63	187.66	163.70	129.04	179.28	201.25	245.50	DRY	221.01	269.28	149.85	164.92	DRY	194.44
water surface elevation	3306.09	3288.89	3276.23	3344.03	3260.28	3237.43	3193.61		3238.98	3190.74	3336.81	3317.34		3286.50
DATE: 5/24/93														
depth to water	140.40	187.52	160.90	126.77	179.28	200.84	245.45	DRY	219.90	269.08	149.58	157.67	DRY	192.33
water surface elevation	3307.32	3289.03	3279.03	3346.30	3260.28	3238.84	3193.66		3240.09	3190.94	3337.08	3324.59		3288.61
DATE: 6/10/93														
depth to water	139.62	187.48	159.05	125.58	179.31	199.97	245.45	DRY	219.16	268.95	149.44	154.45	DRY	191.78
water surface elevation	3308.10	3289.07	3280.88	3347.49	3260.25	3239.71	3193.66		3240.83	3191.07	3337.22	3327.81		3289.16
DATE: 7/14/93														
depth to water	140.20	187.50	159.58	124.60	179.30	198.20	245.38	DRY	218.89	268.68	149.31	150.10	DRY	192.18
water surface elevation	3307.52	3289.05	3280.35	3348.47	3260.26	3241.48	3193.73		3241.10	3191.34	3337.35	3332.16		3288.76
DATE: 7/15/93														
depth to water			232.13								181.34			
water surface elevation			3207.80								3305.32			
DATE: 7/16/93														
depth to water	198.78			225.89										
water surface elevation	3248.94			3247.18										
DATE: 7/23/93														
depth to water	164.01		178.56	149.54							151.74			
water surface elevation	3283.71		3261.37	3323.53							3334.92			
DATE: 8/9/93														
depth to water	150.90	187.60	167.50	128.28	179.30	196.90	245.32	DRY	216.80	268.50	150.30	148.25	DRY	192.22
water surface elevation	3296.82	3288.95	3272.43	3344.79	3260.26	3242.78	3193.79		3243.19	3191.52	3336.36	3334.01		3288.72

WELL NO./ GRID LOC.	7-G	4-C	2-G	11-D	4-G1	4-G2	4-G3	9-G1	9-G2	9-G3	6-B1	6-B2	5-E	5-C
T.O.C. ELEV. (FT)	3447.72	3476.55	3439.93	3473.07	3439.56	3439.68	3439.11	3460.17	3459.99	3460.02	3486.66	3482.26	3457.28	3480.94
DATE: 9/21/93														
depth to water	147.29	187.90	164.28	130.15	179.27	197.40	245.31	DRY	215.30	168.18	149.90	166.32	DRY	192.29
water surface elevation	3300.43	3288.65	3275.65	3342.92	3260.29	3242.28	3193.80		3244.69	3291.84	3336.76	3315.94		3288.65
DATE: 10/18/93														
depth to water	144.78	187.85	162.40	129.10	179.30	193.20	245.30	DRY	214.20	267.90	151.14	154.65	DRY	192.81
water surface elevation	3302.94	3288.70	3277.53	3343.97	3260.26	3246.48	3193.81		3245.79	3192.12	3335.52	3327.61		3288.13
DATE: 10/18/93														
depth to water	144.78	187.85	162.40	129.10	179.30	193.20	245.30	DRY	214.20	267.90	151.14	154.65	DRY	192.81
water surface elevation	3302.94	3288.70	3277.53	3343.97	3260.26	3246.48	3193.81		3245.79	3192.12	3335.52	3327.61		3288.13
DATE: 3/16/94														
depth to water	141.25	187.65	158.05	125.06	179.30	194.99	244.95	DRY	217.78	267.05	149.50	163.20	DRY	192.80
water surface elevation	3306.47	3288.90	3281.88	3348.01	3260.26	3244.69	3194.16		3242.21	3192.97	3337.16	3319.06		3288.14
DATE: 1/17/95														
depth to water	140.76	187.80	158.30	124.90	179.30	194.45	245.01	DRY	217.68	266.98	149.43	163.21	DRY	192.79
water surface elevation	3306.96	3288.75	3281.63	3348.17	3260.26	3245.23	3194.10		3242.31	3193.04	3337.23	3319.05		3288.15
DATE: 4/19/95														
depth to water	140.57	187.76	157.60	124.87	179.31	194.32	245.01	DRY	217.63	266.96	149.30	163.25	DRY	192.82
water surface elevation	3307.15	3288.79	3282.33	3348.20	3260.25	3245.16	3194.10		3242.36	3193.06	3337.36	3319.01		3288.12
Current thickness of water	74.43	3.24	92.40	132.13	0.00	25.48	0.00	0.00	3.37	6.04	51.70	108.75	0.00	0.18

——— AM ENVIRONMENTAL RESPONSIBLE FOR WATER LEVEL MEASUREMENTS

☐ depth to water FROM OPEN BORE HOLE

Monitor wells 6-B1 and 2-G were developed to dryness on 7/14/93
Monitor wells 7-G and 11-D were developed to dryness on 7/15/93
Monitor wells 6-B1 and 6-B2 were developed to dryness on 8/9/93
Monitor wells 7-G and 11-D were developed to dryness on 8/10/93
Monitor well 2-G was developed to dryness on 8/11/93
Monitor wells 6B-1, 6B-2, 11-D, 4-C, and 5-C were developed to dryness on 10/18/93
Monitor wells 9G-2, 7-G, 4G-2, and 2-G were developed to dryness on 10/19/93
Approximate site elevation 3484.75 ft

Geology of the WCS – Flying "W" Ranch, Andrews County, Texas

by

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Geology of the WCS - Flying "W" Ranch, Andrews County, Texas

1. Introduction

The general geological setting of the WCS - Flying "W" Ranch area in western Andrews County, Texas, has been previously described in permit applications (e.g., AM Environmental, 1993) and unpublished reports (Lehman, 1996a; 1996b). These reports provide an adequate overview of the regional geological setting and a detailed description of the site-specific conditions at the WCS facility. For example, Figure 1 shows the local topography of the "red bed" surface as was determined by the thorough geotechnical investigation done during the design of the WCS facility (AME, 1993). An exploratory drilling program conducted from March through June 1999 has greatly expanded the database on subsurface geologic conditions and groundwater in this area. In this report, some pertinent general information from the earlier documents is repeated, but attention is focussed instead on new detailed information that has resulted from the recent drilling program.

Thirty-five air-rotary boreholes were completed as piezometers on the WCS - Flying "W" Ranch (Figure 2). Three of the boreholes (#22, 23, and 24) were offset and drilled to greater depth (#22B, 23B, 24B). One borehole (#4) partially collapsed and remains problematic. Detailed geologic logs for each of the 35 boreholes are included as an appendix to this report. This report provides the following:

[1] further delineation of the "Red Bed Ridge" beneath the ranch property,

[2] description of each of the geologic units penetrated in the boreholes,

[3] discussion of the relationship between the occurrence of groundwater and subsurface geologic conditions, and

[4] methods used to discriminate deposits of the Ogallala and Antlers Formations.

Several figures are included to document the subsurface geology and groundwater distribution, and are discussed where appropriate in the report. Figure 2 shows the locations of five lithologic cross-sections that are provided as Figures 3 through 7. Figures 8 through 10 map the elevation of the "red beds," the thickness of the Antlers sand, and the areal distribution of saturated thickness.

2. Nature and Origin of the Buried Triassic "Red Bed Ridge"

2.1 General Information

The WCS-Flying "W" Ranch straddles a prominent buried ridge developed on the upper surface of the Triassic Dockum Group "red beds." This feature is referred to informally as the "Red Bed Ridge." Previous reports (e.g., Lehman, 1996a) have described this feature, but the recent drilling program provides additional information on its nature and extent (Figure 8).

The crest of the buried "Red Bed Ridge" is a mile or so in width and extends for at least 100 miles from northern Lea County, New Mexico, through western Andrews County and into Winkler and Ector Counties, Texas. The modern surface topography roughly coincides with the trace of this buried ridge, but is in general more subdued. In Lea County, the buried ridge runs parallel to and less than a mile northeast or southwest of the Mescalero Escarpment (Nicholson and Clebsch, 1961; Ash, 1963; Cronin, 1969), and similarly in Winkler and Ector counties the buried ridge coincides roughly with the western escarpment of the High Plains. The ridge is at least in part a product of structural deformation, as underlying Triassic strata have subsided in response to dissolution of Permian salt beds to the south and west of the ridge, underlying the Monument Draw Trough, San Simon Swale, and Pecos River Valley (Maley and Huffington, 1953; Nicholson and Clebsch, 1961; Anderson, 1980; Baumgardner et al., 1982; Gustavson and Finley, 1985). The ridge also roughly parallels the western margin of the buried Central Basin Platform in underlying Permian strata. However, the ridge is also in part a product of post-Triassic erosion, which has removed part of the Triassic section both northeast and southwest of the ridge. Cretaceous strata are absent southwest of the ridge. To the north and east of the "Red Bed Ridge", the High Plains surface is relatively undisturbed, and underlying Cretaceous and Tertiary strata are gently inclined to the southeast. In contrast, to the south and west of the ridge, dissolution of underlying Permian salt beds has resulted in deformation of the Triassic and Tertiary strata, and the High Plains surface has been locally disrupted by subsidence.

Several authors have commented on the nature and importance of this buried ridge, but it has not received widespread attention. Hawley (1984, pp. 161-162) regarded this as the position of a major drainage divide in the sub-Ogallala topography, and that this divide separated two major fluvial systems throughout Late Cenozoic time. Deposits of the Ogallala Formation lie to the north and east of the buried ridge, while deposits of the ancestral Pecos River (variously mapped as "Cenozoic Basin Fill," Gatuña Formation, or Ogallala Formation) lie to the south and west of this ridge (Reeves, 1972; Kelley, 1980; Hawley, 1984, 1993). Hawley (1993) suggested that use of the name "Ogallala Formation" could be restricted to deposits northeast of this divide, while the name "Gatuña Formation" could be used for equivalent deposits to the southwest. Little or no sediment accumulated on the summit of the buried "Red Bed Ridge", where instead, the "Caprock" Caliche developed directly on the exposed surface of underlying Triassic or Cretaceous strata, or on a thin veneer of eolian sediment. Reeves (1972) indicated that basal Ogallala gravels are present, at least locally on the crest of the ridge, suggesting that it may not have been an effective drainage divide during the later phases of Ogallala deposition. It is apparent that the buried ridge marks the position of a persistent ancient drainage divide between the ancestral Pecos River (to the southwest) and the Brazos and Colorado Rivers (to the northeast). It also roughly coincides with the modern drainage divide.

2.2 WCS - Flying "W" Ranch

The recent drilling program defined the extent of the "Red Bed Ridge" on the ranch area in greater detail than known previously, and provided further evidence for the origin of this feature. Cretaceous strata overlie the summit of the ridge along its length. AM Environmental (1993) had previously reported over 50 boreholes and well logs within the WCS site (Figure 1), and these data points were considered in the construction of the "red bed"-related maps within Andrews County in this report. Weaver Boos & Gordon, Inc. (1997) also provided data at 11 boreholes west of the state line and west of the WCS site. The "Red Bed Ridge" enters the northwest corner of the ranch and extends to the WCS landfill area and southeastward to Windmill Hill (Figure 3). From there, the ridge branches southward to the vicinity of well #30 and eastward to the vicinity of well #26. The southern branch likely terminates south of the ranch boundary, while the eastern branch probably tracks the continuation of the ridge to the south and east. Along the length of the ridge, the "Caprock" Caliche is exposed at or near the land surface, and so generally corresponds to the mapped distribution of the Kimbrough soils or Blakeney and Conger soil association (Figure 2; Conner et al., 1974). Additional drilling is necessary to establish the continued course of the "Red Bed Ridge" to the east; however, it likely continues roughly south and east along the route of State Highway 176 where the Kimbrough and Blakeney-Conger soils are present.

The presence of the "Caprock" Caliche over the entire area, both north and south of the "Red Bed Ridge" suggests that the ridge is not the buried erosional edge of the Caprock Escarpment, one of several possible interpretations of this feature. The ridge was present prior to formation of the "Caprock" Caliche and subsequent erosional retreat of the escarpment of the High Plains. Nevertheless, the absence of Cretaceous strata southwest of the ridge indicates that at least part of the relief on this feature is a result of erosion.

On the WCS - Flying "W" Ranch, and along most of the length of the "Red Bed Ridge", the southwestern flank of the ridge is more steeply inclined than the northeastern flank. The decline in elevation of the basal sand interval of the Antlers Formation southwest of the ridge (e.g., Figure 4, well #15) suggests that some of the relief on the "Red Bed Ridge" is owing to post-Cretaceous/pre-Late Tertiary structural deformation. However, the irregular southern boundary of the ridge indicates that relief is likely not due to faulting, and may more likely reflect a gentle fold.

3. Subsurface Geology

In this following section, each of the geologic units documented in the WCS - Flying "W" Ranch drilling program is described. The formations are given in ascending order (from oldest to youngest). General information on the distribution and characteristics of each unit is provided, followed by information specific to conditions observed in the WCS - Flying "W" Ranch area.

3.1 Chinle Formation (= Cooper Canyon Formation, Dockum Group: Triassic)

3.1.2 General Information

The distribution and regional characteristics of the Triassic Dockum Group were recently reviewed by Lehman (1994a, 1994b). The Dockum Group consists of five formations; in ascending order these are the Santa Rosa, Tecovas, Trujillo, Cooper Canyon, and Redonda Formations. These strata attain their maximum total thickness in excess of 1800 ft in the subsurface of Yoakum County, and are over 1000 ft thick in western Andrews County. The uppermost unit in the Dockum Group was traditionally (but incorrectly) referred to as part of the Chinle Formation in the southern part of the High Plains region. More recently these strata have been identified as the Cooper Canyon Formation (Lehman, 1994; Lehman et al., 1992). These

1989) and Nativ and Gutierrez (1988). The entire local Cretaceous stratigraphic section consists of six formations; in ascending order these are the Antlers, Walnut, Comanche Peak, Edwards, Kiamichi, and Duck Creek Formations. In the Southern High Plains area, Cretaceous strata attain their greatest preserved thickness in the vicinity of Yoakum County where they exceed 220 ft in total thickness. Southward from Yoakum County, the Cretaceous section thins and is absent in some areas of Gaines and Andrews Counties, primarily due to erosion prior to deposition of the Ogallala Formation. In southern Andrews County, and areas further south, Cretaceous strata are thicker and widely exposed.

Only the basal Cretaceous unit, the Antlers Formation, is present in the WCS-Flying "W" Ranch area; although a small outcrop identified as Fort Terrett Formation (equivalent to the Comanche Peak Limestone) is mapped immediately west of the ranch in Section 29 T.21S. (Hobbs Sheet, 1976), and a thick bed of Cretaceous limestone is also exposed on the ranch in the floor of a gravel pit in the west-central part of Section 8 (Block A-39; see Figure 9). This material is also likely a part of the Fort Terrett (= Comanche Peak) limestone. The "basal sand" of the Cretaceous section in the High Plains region is identified as the Antlers Formation, but in older literature is also referred to as the Antlers Sandstone, Trinity Sandstone, or Paluxy Sandstone (see Fisher and Rodda, 1967). It is also referred to informally variously as the "Antlers Sand" or "Trinity Sand." This unit consists of weakly cemented fine to medium-grained quartz sandstone and chert-pebble conglomerate. The Antlers Formation varies regionally from 10 ft to 80 ft in thickness (Nativ and Gutierrez, 1988). The thick areas comprise several linear belts trending approximately southeastwardly across the High Plains, where the Antlers Formation fills erosional channels incised into the underlying "red beds" of the Dockum Group (Fallin, 1989).

3.2.2 WCS - Flying "W" Ranch

No outcrops of the Antlers Formation are found in the WCS - Flying "W" Ranch area, but these deposits are exposed in the walls of the excavation at the WCS facility, and are present within a few feet of the land surface in that vicinity. The Antlers Formation is present only in the northwest and central part of the ranch area where it forms a buried erosional remnant along the crest of the "Red Bed Ridge" (Figure 9). The top of the Antlers Formation is encountered in borings at depths between 5 and 80 ft below ground surface. The subcrop of the buried Antlers

Formation is expressed at the land surface, and corresponds roughly with the area bounded by a subtle increase in slope at a topographic elevation of about 3450 to 3485 ft.

In the WCS - Flying "W" Ranch area, the Antlers Formation attains a maximum thickness of about 70 ft and consists of three stratigraphic units; in ascending order these are [1] a lower coarse-grained gravelly sand, yellowish brown in color (10 YR 7/2 to 7/6), between 10 and 30 ft thick with distinctive multicolored chert gravel, [2] a very fine to fine-grained white (10 YR 8/2) quartzose sand, consisting of nearly pure quartzarenite, 10 to 30 ft thick, and [3] an upper interval of multicolored shale and mudstone, 5 to 45 ft thick. Where the upper shale interval is thickest, it exhibits a stratigraphic sequence with white siltstone (10 YR 8/2) at the base, grading upward to dark red or purple mudstone (10 R 4/4 or 5 YR 8/4 to 6/4), gray (5 Y 7/2) shale, and an upper layer of yellow (10 YR 7/6) calcareous shale or argillaceous limestone. The limestone layer at the top of this interval may actually be the base of the Fort Terrett (= Comanche Peak) limestone. It is exposed at the land surface in the floor of a gravel pit in Section 8 (Block A-39).

The upper shale interval (unit 3, above) is present only where the Antlers Formation exceeds 40 ft in thickness, in the northwestern corner of the WCS - Flying "W" Ranch area and in the central area surrounding Windmill Hill (see Figures 5, 7, and 9). Elsewhere in the area, the Antlers Formation has been thinned or entirely removed by post-Cretaceous erosion, and younger strata rest on the lower sandy strata of the Antlers or on the underlying Dockum Group "red beds". Only the lowermost part of the Antlers Formation (unit 1, above) is present within the WCS Facility boundaries and exposed in the walls of the excavation there.

Groundwater in the WCS - Flying "W" Ranch area is found almost exclusively in the lower sandy part of the Antlers Formation.

3.3 Ogallala Formation (Late Tertiary: Miocene)

3.3.1 General Information

The regional distribution and characteristics of the Ogallala Formation and the Ogallala aquifer are well known (Cronin, 1961; 1969), and have been documented in numerous reports (recently reviewed by Gustavson, 1990; Gustavson et al., 1991). Regionally, the Ogallala Formation thins southward across the High Plains, and so is relatively thin in Andrews County, which lies near the southwestern border of the High Plains. In the southern part of its distribution, the Ogallala Formation does not exceed 100 to 200 ft in thickness (Seni, 1980). On a local scale, the thickness of the Ogallala Formation also varies from relatively thick sections (typically exceeding 100 ft) dominated by gravel and coarse sand, to relatively thin sections (typically less than 100 ft) dominated by finer sand and silt. The thick sections represent fluvial paleo-valley fill deposits that trend southeastwardly across the High Plains. These paleo-valley deposits are marked by higher net thickness of sand and gravel, and a high percentage of sand and gravel (Seni, 1980). Such areas generally correspond to the greatest saturated thickness in the Ogallala aquifer. The broad areas where the Ogallala Formation is relatively thin or absent represent "interfluve" or upland regions between the paleo-valley axes, where fine-grained eolian sediments predominate. The Ogallala Formation is thin or absent over the top of remnant Cretaceous bedrock "highs" on interfluves (e.g., Reeves, 1972), and may never have been deposited in these areas. Where present in interfluve regions, the Ogallala has a low net sand and gravel thickness and low percentage of sand and gravel. The interfluve areas correspond to regions with lower saturated thickness in the Ogallala aquifer (e.g. Peckham and Ashworth, 1993; Nativ and Smith, 1987).

In northern Andrews County, northeast of the "Red Bed Ridge," the Ogallala Formation is relatively thick and consists of fluvial sand and gravel deposits filling the southernmost of the paleo-valleys, which roughly coincides with the present course of Monument Draw in northern Andrews and southern Gaines Counties. The Ogallala Formation is absent from central Andrews County and areas southward where Cretaceous strata are present at or near the land surface in most areas. The "Red Bed Ridge," including the WCS - Flying "W" Ranch area, is an interfluve region.

3.3.2 WCS - Flying "W" Ranch

The Ogallala Formation is not exposed in the WCS - Flying "W" Ranch area, but is present in the subsurface along the north and east sides of the ranch boundary at a depth of 45 to 105 ft below ground surface. In this area, the Ogallala Formation varies from 5 to 40 ft in thickness and rests on Dockum Group "red beds" or locally on the Antlers Formation (see Figures 4, 5, and 6). These deposits consist of yellowish brown (10 YR 8/4) fine to medium-grained sand with granule-pebble gravel. Where the Ogallala deposits are greater than 20 ft thick, an upper interval of very fine to fine-grained sand, slightly pink in color (5 YR 7/4) is present.

Groundwater was found in only three borings that penetrated the Ogallala Formation along the eastern border of the ranch area.

3.4 ?Gatuña Formation ("Cenozoic Basin Fill": Late Tertiary - ?Quaternary)

3.4.1 General Information

Southwest of the "Red Bed Ridge," deposits in part equivalent in age to the Ogallala Formation are present, but these have typically been identified informally as the "Cenozoic Basin Fill" (Maley and Huffington, 1953) or "Cenozoic Pecos Alluvium" (Ashworth and Flores, 1991). They are at least in part equivalent to the Gatuña Formation (Kelley, 1980). Some of these deposits have been mapped as Ogallala Formation (Nicholson and Clebsch, 1961; shown as "To" on the Geologic Atlas of Texas, Hobbs Sheet, 1976), but may more logically be included with the Gatuña Formation, as suggested by Hawley (1993). In the WCS - Flying "W" Ranch area, these deposits predate formation of the overlying "Caprock" Caliche, and therefore are equivalent in age to the Ogallala Formation. Nevertheless, they differ lithologically from sediments of the Ogallala. These deposits will be referred to here as the ?Gatuña Formation, using the question mark to indicate this uncertainty in formation assignment.

The alluvial fill of the Lower Pecos Valley (including the Gatuña Formation) is at least 13 million years old (as old as the basal sediments of the Ogallala Formation; Powers and Holt, 1993; Hawley, 1993), and so downcutting and widening of at least the lower part of the Pecos River Valley must have occurred before or during deposition of the Ogallala Formation. The youngest part of the Gatuña Formation is no older than 600,000 years.

The Pecos River Valley subsided in response to subsurface salt dissolution. A peripheral zone of subsurface (Permian) salt dissolution surrounds the High Plains, with its inner boundary generally coincident with the present escarpment of the High Plains (Gustavson and Simpkins, 1989). This peripheral belt of subsurface salt dissolution underlies the Pecos River Valley. A curvilinear belt of subsurface salt dissolution also coincides with the buried Permian Capitan Reef trend surrounding the Delaware Basin. Salt dissolution has occurred over the buried summit of the artesian reef aquifer (Anderson, 1980; Baumgardner et al., 1982; Reeves, *in* Gustavson et al., 1991). Extensive salt dissolution over the Capitan Reef trend resulted in subsidence of the Monument Draw Trough in Winkler and Ward counties, Texas and in the

Delaware Basin beneath the Pecos River Valley (Maley and Huffington, 1953). Subsidence over the reef trend resulted in a depression now filled with "Cenozoic Basin Fill," referred to locally as the Monument Draw Trough. This belt lies 15 to 20 mi west-southwest of the WCS - Flying "W" Ranch.

3.4.2 WCS - Flying "W" Ranch

The ?Gatuña Formation is exposed on the ranch only in a small area at Baker Spring (Figure 2; Section 28, T.21S.). Approximately 15 to 20 ft of coarse, red, cross-bedded gravelly sand, with scattered large boulders of sandstone and limestone, is exposed along the steep bluff on the north and east side of Baker Spring, overlain by the "Caprock" Caliche. The base of the ?Gatuña Formation is not exposed at this location, but must lie at shallow depth because the Dockum Group "red beds" crop out several hundred feet to the south. The ?Gatuña Formation is present extensively in the subsurface along the southern and southwestern boundary of the ranch area at depths from 45 to 115 ft below ground surface (see Figures 3, 4, 5, and 6). The ?Gatuña deposits are very thin in this area, from 5 to 15 ft, and consist of fine to medium-grained sand and sandstone with granule-pebble gravel. These sediments have a distinctive red coloration (10 R 6/4 to 5 YR 4/6-6/6). Deposits of the ?Gatuña Formation rest on Dockum Group "red beds" everywhere on the WCS - Flying "W" Ranch.

No groundwater was found in the boreholes in the ?Gatuña Formation, although groundwater appears to be discharging from these deposits at Baker Spring (see Figures 3 and 7).

3.5 "Caprock" Caliche (Late Tertiary - ?Quaternary)

3.5.1 General Information

Overlying all pre-Quaternary strata in the High Plains region is a thick bed of hard caliche. This dense layer of pedogenic limestone is often referred to informally as the "Caprock" Caliche in the Southern High Plains region where it overlies the Ogallala Formation. It is usually mapped as part of the Ogallala Formation. However, the term "Caprock" Caliche has not been accepted as a formally recognized stratigraphic unit, because in many areas it consists of several superimposed caliche beds that formed at different times, and includes caliche that formed earlier during deposition of the Ogallala Formation, as well as in more recent times, long after the end of Ogallala deposition (Gustavson et al., 1991). Caliche developed on the surface of older

Cretaceous rocks is mapped simply as "caliche" (shown as "Qcc" on the Geologic Atlas of Texas, Hobbs Sheet, 1976), and not as part of the Ogallala Formation although it is identical in composition and morphology to the "Caprock" Caliche and likely formed at the same time. The term "Caprock" Caliche is used here in quotation marks to reflect this informal status and uncertain correlation.

In areas such as western and southern Andrews County, where the Ogallala Formation is absent or very thin, the "Caprock" is highly brecciated, pisolitic, and silicified; and it formed directly on the eroded surface of older (Cretaceous) strata. Many of the exposures mapped as Ogallala Formation in Andrews County (shown as "To" on the Geologic Atlas of Texas, Hobbs Sheet, 1976) consist in reality only of "Caprock" Caliche developed on top of older Cretaceous strata. In many cases, no actual deposits of the Ogallala Formation are present. In southern Andrews County, and areas farther south, caliche developed on the surface of older Cretaceous rocks is mapped simply as "caliche" (shown as "Qcc" on the Geologic Atlas of Texas, Hobbs Sheet, 1976), and not as part of the Ogallala Formation.

The "Caprock" Caliche formed on the High Plains surface after deposition of the Ogallala Formation (Late Miocene) and at least in part prior to deposition of the Blanco Formation (Late Pliocene). It is likely that formation of the "Caprock" began when the High Plains surface was isolated by erosional incision of the Pecos, Canadian, Brazos, and Colorado rivers (Osterkamp and Wood, 1984).

3.5.2 WCS - Flying "W" Ranch

The "Caprock" Caliche is present over the entire ranch area, and the upper surface of the "Caprock" is exposed at the land surface in many places along crest of the "Red Bed Ridge" where erosion has removed the overlying cover of Quaternary windblown sediment (see Figure 2). Where the "Caprock" is present near the land surface, the thin Kimbrough soil, or Blakeney and Conger soil association, is developed (Conner et al., 1974). A complete section of the "Caprock" is exposed along the north and east sides of Baker Spring, and in several gravel pits (Figure 2; southeast Section 3 and west-central Section 8, Block A-39). The top of the "Caprock" typically lies at a depth of 25 to 50 ft, but is found at nearly 100 ft in the southwest corner of the ranch. The "Caprock" formed on the upper surface of the Antlers, Ogallala, and

?Gatuña Formations and engulfs materials of these formations, particularly in its lower part. It evidently formed on a land surface with substantial topographic relief (see Figures 3 through 7)

The "Caprock" Caliche consists of hard, laminated, and pisolitic caliche with included chert pebbles. It is typically 5 to 10 ft thick, but up to 20 ft thick in a few places. Where the "Caprock" is thick, it has been partially replaced with nodules and layers of opal. It has a dense brown (5 YR 6/4) laminated, pisolitic, and partly silicified upper layer that grades downward into softer lighter colored (5 YR 8/4) caliche. Where it is exposed at the land surface, the "Caprock" has degraded to form a broken rubble with fissure fillings and clasts of dark brown sand. Clasts of degraded caliche form a mantle of colluvium on slopes. In places, this degraded caliche rubble is mapped as "other Quaternary deposits" (Qao) on the Geologic Atlas of Texas Hobbs Sheet (1976).

The "Caprock" Caliche can be distinguished from younger caliche deposits in overlying Quaternary strata (e.g., Blackwater Draw Formation) which are lighter in color, softer, lower in density (owing to higher porosity), include abundant sand, and are not laminated or pisolitic.

The "Caprock" typically lies within the unsaturated zone. Groundwater was found within the "Caprock" Caliche at one location (well #2).

3.6 Blackwater Draw Formation (Quaternary: Pleistocene)

3.6.1 General Information

The regional distribution and characteristics of the Blackwater Draw Formation were reviewed by Reeves (1976) and Holliday (1989). These deposits were formerly referred to as the "windblown cover sand" and are so designated on the Geologic Atlas of Texas (shown as "Qcs" on the Hobbs Sheet, 1976).

The Blackwater Draw Formation is eolian in origin, and forms an extensive mantle over the surface of the High Plains, diminishing in grain size from predominantly sand on the southwestern side of the High Plains to clay on the northeast. Alluvial sediments of the Pecos River Valley served as the source area for windblown sediment transported to the northeast onto the High Plains surface (Holliday, 1989). Modern effective sand-transporting winds blow from the west-southwest (Machenberg, 1984, 1986); grain-size trends and orientation of Pleistocene vegetated dune ridges indicate that this has been the case for most of Quaternary time. Over the past 2 million years, most of the High Plains surface experienced periods of wind erosion and deposition, alternating with periods of stabilization of the surface by vegetation, resulting in soil formation and accumulation of the Blackwater Draw Formation (Holliday, 1989). Radiometric age determinations on ash beds, and interbedded playa deposits demonstrate that deposition of the Blackwater Draw Formation began prior to 1.4 million years ago and continued until at least 100,000 to 50,000 years ago (Gustavson et al., 1991). Interbedding of the Blackwater Draw Formation with radiocarbon-dated playa basin deposits suggests that deposition continued at least locally up to 3000 years ago (Gustavson et al., 1991; Holliday, et al., 1996).

3.6.2 WCS - Flying "W" Ranch

The Blackwater Draw Formation is present at or near the land surface over much of the ranch area, but is absent along the crest of the "Red Bed Ridge", and is buried under younger windblown sand in the northern and southern parts of the ranch (Figure 2). Where these deposits are present at the land surface, the Triomas and Wickett soil association has developed (Conner et al., 1974). A typical section of the upper part of the Blackwater Draw Formation is exposed in the gravel pit along the common southern borders of Sections 16 and 17 (Figure 2; Block A-29). Sediments of the Blackwater Draw Formation are up to 60 ft thick on the north side of area, and as much as 100 ft thick on the south, substantially thicker than previously reported (typically less than 10 ft according to the Geologic Atlas of Texas, Hobbs Sheet, 1976). The upper 5 to 15 ft of these sediments consists of reddish brown (10 R 5/6 to 5 YR 5/6 or 6/6) clayey fine to very fine sand with nodules of soft sandy caliche. Locally, the upper 5 ft is very clayey and contains a dark brown (10 YR 5/2 to 5 YR 6/6) organic surface horizon. Sand grains have iron oxide and clay coatings which give the sediment its distinctive dark red coloration. These grain coatings are a result of soil formation (Holliday, 1989). The lower part of the Blackwater Draw Formation was less affected by soil development (i.e., iron and clay illuviation), and is lighter in color (typically 5 YR 7/4 to 8/4) with many layers of soft sandy caliche. The lower 10 to 20 ft contains some coarse to very coarse sand as well as layers of granule-small pebble gravel, and may be partly alluvial rather than eolian in origin.

The Blackwater Draw Formation typically lies within the unsaturated zone. No groundwater was found in these deposits.

3.7 Playa Deposits (Quaternary: Holocene)

3.7.1 General Information

The origin and history of playa basins on the High Plains has been a subject of study and debate for nearly a century (reviewed by Reeves, in Gustavson, 1990 and Gustavson et al., 1991; Holliday et al., 1996). Playa basins range in size from 30 ft to 1.5 miles in diameter, though most are less than half a mile in diameter, and exhibit up to 30 ft of topographic relief. The basins originated 30,000 to 10,000 years ago, although some may be older, and have partially or completely filled with up to 3 to 30 ft of sediment since that time (Holliday et al., 1996). The basins formed within the eolian "cover sands" of the High Plains (Blackwater Draw Formation) primarily by wind erosion, and hence are larger and more numerous where the "cover sands" are thicker (Holliday et al., 1996). The basins typically hold water temporarily only after extended periods of rainfall, and focussed infiltration of water through the floors of the playas may cause dissolution of shallow soil caliche layers beneath the basin, resulting in subsidence and gradual enlargement of the basins over time (Osterkamp and Wood, 1987; Wood and Osterkamp, 1987). However, Holliday et al. (1996) argued that dissolution-induced subsidence is not generally responsible for the origin of playa basins. Formerly, buffalo (and more recently, cattle) may also have played a role in enlarging the original depressions by transporting mud or dust out of the basins on their hooves and hides. Playa basins are apparently a surficial phenomenon, and do not reflect deep-seated subsidence or salt dissolution.

3.7.2 WCS - Flying "W" Ranch

Playa deposits are found only in one area, south of the WCS facility boundary (Figure 2; vicinity of borehole #19). The deposits consist of 10 ft of dark brown clayey fine sand, underlain by 5 ft of color mottled yellow and brown ("gleyed") clayey fine sand. The deposits occupy a subcircular depression in the land surface, approximately 2000 ft in diameter. This playa basin is not active, since it is not known to accumulate surface runoff, and the deposits appear to be undergoing erosion. An arcuate dune deposit (shown as "Qsd" on the Geologic Atlas, Hobbs Sheet; 1976) bounds the northeastern margin of the depression (see Figures 2 and 4). There are no mapped occurrences of Lipan clay soils (as are typically developed in the bottoms of modern playas in this region) on the ranch area (Conner et al., 1974).

No groundwater was found in playa deposits on the WCS - Flying "W" Ranch.

3.8 Windblown Sand (Quaternary: Holocene)

3.8.1 General Information

Recent deposits of eolian dunes, now mostly stabilized by vegetation, are mapped as "windblown sand sheets, dunes, and dune ridges undivided" (Qsu) on the Geologic Atlas of Texas (Hobbs Sheet, 1976). These are probably equivalent in part to those referred to as the Monahans Formation to the southwest in the Pecos River valley (Green, 1961; Machenberg, 1984). These surficial eolian deposits are younger than the Blackwater Draw Formation that they overlie in many areas, and are typically 5 to 10 ft in thickness. In places these deposits are undergoing active transport as modern dunes, but in most areas they are at least partially stabilized by vegetation.

3.8.2 WCS - Flying "W" Ranch

Windblown sand deposits are present extensively in the north, northeast, and southwest part of the area. Their distribution generally corresponds with the Jalmar and Penwell soil association (Conner et al., 1974). Windblown sand deposits are up to 35 ft thick, and consist of light yellowish brown (5 YR 5/4 to 7.5 YR 6/4) clean, very well sorted sand. In most areas, they form a thin irregular veneer, 5 to 15 ft thick, over the land surface, with the thickest accumulations in northwest-southeast trending vegetated linear dune ridges. These deposits are distinguished from similar sands in the Blackwater Draw Formation by their pale coloration (locally very pale; e.g. 10 YR 8/4), absence of iron oxide grain coatings, and absence of caliche nodules.

Deposits of windblown sand typically lie within the unsaturated zone. No groundwater was found in these deposits on the WCS - Flying "W" Ranch.

4. Geological Control on Groundwater Hydrology

4.1 General Information

Three regional aquifers converge in central Andrews County. The "Ogallala aquifer" extends southward across the Southern High Plains into the northern part of Andrews County (e.g., Cronin, 1969). The "Edwards-Trinity (Plateau) aquifer" extends northward from the Edwards Plateau into southeastern Andrews County (e.g., Ashworth et al., 1991). The "Cenozoic Pecos Alluvium aquifer" extends northward from the Pecos River Valley into southwestern Andrews County (e.g., Ashworth and Flores, 1991). The boundaries between these aquifers are as yet poorly defined in Andrews County. Cretaceous strata on the High Plains, such as documented here on the WCS - Flying "W" Ranch area, are thought to be in hydraulic continuity with the Ogallala Formation; and they are included together as part of the "High Plains aquifer" in many studies (e.g., Knowles et al., 1984; Peckham and Ashworth, 1993) although the nature of cross-formational flow between these units is not well established. In such regional studies, the WCS - Flying "W" Ranch area has been generally included within the distribution of the Ogallala (High Plains) aquifer.

However, the WCS - Flying "W" Ranch area straddles the "Red Bed Ridge," which exerts control on local and regional groundwater flow. The "Red Bed Ridge" probably acts as a regional groundwater divide, separating the Ogallala (High Plains) aquifer to the northeast from the "Cenozoic Basin Fill" aquifer (or the "Cenozoic Pecos Alluvium" aquifer of Ashworth and Flores, 1991) to the southwest. Groundwater flow in the Cenozoic Basin Fill aquifer is to the south-southwest, while flow in the High Plains aquifer is to the east-southeast (Nicholson and Clebsch, 1961). The Triassic bedrock "high" beneath the overlying Cenozoic deposits interrupts the groundwater table in many areas along its length. In northern Lea County, the crest of the "Red Bed Ridge" lies above the water table in the Ogallala Formation to the northeast (Ash, 1963; see his sheet 1, cross-section A-A'). Similarly, in central Lea County, Nicholson and Clebsch (1961, their Plate 2) illustrated several areas where the water table in Cenozoic deposits is interrupted by bedrock highs on the Triassic "Red Bed Ridge". In western Andrews County, the crest of the "Red Bed Ridge" coincides with the belt of 0 to less than 20' saturated thickness in the High Plains aquifer (Knowles et al., 1984).

4.2 WCS - Flying "W" Ranch

Groundwater is not present continuously beneath the WCS - Flying "W" Ranch, but was encountered in 17 of 35 boreholes completed (see Figure 10). Over 60 previous boreholes and well logs, all of which located the "red bed" surface contact without finding water, were reported by AM Environmental (1993) on the WCS site and Weaver Boos & Gordon, Inc. (1997) to the west of the state line, and these data points were also considered in construction of Figure 10. Groundwater occurs in two discrete areas, one in the northwestern corner of the ranch, and the other in the central area surrounding Windmill Hill. In both cases the groundwater occurs almost exclusively (14 of 17 wells) within the basal sand unit of the Antlers Formation, and the limits of observed groundwater (Figure 10) clearly correspond with the subcrop of the Antlers Formation (Figure 9). The two groundwater-bearing areas are not connected, although the complete lateral extent of both areas is yet to be established. The saturated thickness is typically less than 10 ft in each area. The maximum saturated thickness observed is 25 ft in the northwestern area (Figure 10). Both areas are overlain by the upper shale interval of the Antlers Formation (unit 3, above) which could conceivably act as a confining layer (see Figures 3 and 5). However, in most wells the sand interval in the Antlers Formation is not entirely saturated. Water table elevations suggest that groundwater here likely reflects local recharge and not regional lateral flow within the "High Plains aquifer." The many closed surface depressions along the crest of the "Red Bed Ridge" could act as local recharge points (Figure 5). These depressions are not playa basins, but have formed where the "Caprock" Caliche is at or near the land surface (e.g., see areas mapped as Kimbrough soils; Conner et al., 1974) and are known to hold surface runoff after extended periods of rainfall. One artificially deepened depression southeast of Windmill Hill (southeast Section 4, Block A-39) retains a significant amount of surface runoff. High water table elevations beneath the central area suggest that recharge may occur in the area southeast of Windmill Hill (Figure 5, see Figure 10; sections 3 and 8, Block A-39).

These local "pockets" of groundwater do not appear to contribute groundwater southward to the "Cenozoic Pecos Alluvium" (=Gatuña) Aquifer. No groundwater was encountered along the southern border of the WCS - Flying "W" Ranch. The Gatuña Formation was fully penetrated in at least ten borings and no groundwater was found, although water appears to discharge from the Gatuña Formation at Baker Spring. Similarly, in light of the declining water table elevation and declining saturated thickness along the north and east boundaries of the ranch area, the local groundwater "pockets" may also not contribute groundwater northward or eastward to the Ogallala Aquifer.

The absence of groundwater at lower elevations to the south, steep decline in the water table elevation, and low saturated thickness to the north and east together suggest that some barrier to lateral flow of groundwater may exist. The nature of such a barrier is unknown. Alternatively, it is possible that local groundwater flows laterally to the southeast beneath Windmill Hill and discharges at the land surface where the elevation falls below the level of the local water table at incised drainages immediately east of Sections 2 and 9 (Block A-39; see Figure 10, Figures 6 and 7). The incised drainage in the southeast corner of Section 2 flows intermittently eastward to an unnamed saline lake basin about 1 mile east of the WCS - Flying "W" Ranch. Saline lake basins are known to be sites of groundwater discharge on the High Plains (e.g., Wood et al., 1992). However, the incised surface drainage here is not known to be an area of spring discharge, but is dammed at points along its length, where it retains surface runoff. Further exploratory drilling to the north and east of the WCS - Flying "W" Ranch is necessary to firmly establish the limits of groundwater in these areas.

Similarly, it is not clear why the two areas where local groundwater occurs are not connected. The basal sand interval of the Antlers Formation is present continuously between the two areas (Figure 9), and elevations on the land surface, water table, and "red bed" surface suggest that lateral southeastward flow of groundwater could occur between the two areas (Figure 7). No barrier to lateral flow is apparent. Groundwater flowing southeastward from the northwestern area may be intercepted in the subsurface by a southwesterly-directed drainage (Section 16, Block A-29) to discharge at the land surface at Baker Spring (Figure 3). The lack of groundwater in boreholes both north and south of Baker Spring drilled by Weaver Boos & Gordon, Inc. (1997) in Lea County indicate it is also possible that groundwater may flow to Baker Spring from the west or northwest. This uncertainty might be resolved by installation of an additional borehole between well location #16 and the WCS facility (i.e., in the northwest corner of section 25, Block A-29) or west of Baker Spring in Lea County.

5. Discrimination of Ogallala and Antlers Deposits

5.1 General Information

Because of uncertainties regarding the nature of cross-formational flow of groundwater between Cretaceous strata and the Ogallala Formation, it is useful to discriminate these deposits in the subsurface where possible. In recent reports, Cretaceous strata are often not separated from the Ogallala Formation, and these are collectively included in the "High Plains aquifer" (e.g., Knowles et al., 1984; Ashworth et al., 1991; Peckham and Ashworth, 1993). Nevertheless, it may be important to distinguish these strata for regulatory considerations (e.g., Dutton, 1999).

Determining exactly where the Ogallala Formation pinches out in Andrews County is problematic. Existing compilations of water well driller's logs in the area are not very useful in discriminating whether or not the Ogallala Formation is actually present, because in well cuttings the hard caliche layers (such as the "Caprock" Caliche) are difficult for water well drillers to distinguish from Cretaceous limestone beds (such as in the Comanche Peak and Edwards Limestone), and the sand and gravel in the Ogallala Formation is difficult to distinguish from that in the Antlers Formation. The top of the underlying Dockum Group "red beds" is often readily identified in cuttings by water well drillers, and so this interface is often reliably picked on logs.

In well cuttings it is often difficult to distinguish the Antlers Formation from the Ogallala Formation, because both units consist predominantly of poorly cemented sand and gravel. Sands in the Antlers Formation are fine to medium-grained, white to yellow, and highly quartzose, with brightly colored chert pebble gravel, dominantly comprised of pink, red, and black chert, and white quartzite. Sand in the Ogallala Formation is fine to medium-grained and sublithic, with pebble gravel containing clasts of igneous and metamorphic rocks (quartzite, granite, rhyolite, and gneiss), sedimentary rocks (limestone and sandstone), and abraded Cretaceous *Gryphaea* shells (e.g., reviewed by Reeves, 1984).

5.2 WCS - Flying "W" Ranch

The excellent exposure in the walls of the excavation at the WCS facility leaves little doubt that this unit is the Antlers Formation, and not the Ogallala Formation. It is identical in composition to the same unit exposed to the east at Shafter and Whalen Lakes. Similarly, in the surrounding subsurface where the upper shale interval (unit 3, described above) is present at the top of the Antlers Formation, these deposits are readily identified because similar strata are not known to occur in the Ogallala Formation. Nevertheless, in many areas it remains difficult to discriminate the Antlers and Ogallala solely on the basis of well cuttings.

In an effort to systematically discriminate deposits of the Ogallala and Antlers Formations, samples of each unit were obtained from locations where their identification was certain. Two samples of gravel from the base of the Antlers Formation were obtained from definitively mapped exposures (SHA-5 from the western side of Shafter Lake in central Andrews County; FLU-1 from a roadcut on FM 1269 north of Fluvanna in Scurry County). Two samples of gravel were obtained from water wells drilled to the base of the Ogallala Formation (AND-1 and AND-2 from two wells in the Monument Draw paleo-valley adjacent to US Hwy 385 in northcentral Andrews County). These were compared with a sample of gravel (WCS-1) collected from the landfill excavation at the WCS facility. Approximately 1 kg samples were washed, disaggregated, and sieved to separate all pebbles larger than 8 mm (U.S. Standard #4 mesh sieve) for identification. All pebbles were identified as to lithology and counted (n = 247 to 2691) to determine their relative abundance in each sample. The results of this analysis are given in Figure 11.

Samples of the Antlers gravel are distinctive in consisting entirely of clasts of multicolored chert, hydrothermal "vein" quartz, and a few highly indurated dark brown sandstone (possibly quartzite) clasts (pebble types 1 - 8 in Figure 11). Samples of Ogallala gravel also contain these clast types, though in lower relative abundance, because the Ogallala gravel is derived in part from erosion and reworking of the Antlers deposits. Importantly however, samples of Ogallala gravel also contain high percentages of limestone clasts, reworked Cretaceous mollusc shells (e.g., *Gryphaea*), friable yellow, pink, and black sandstone clasts, and porphyritic igneous rock clasts (pebble types 9 - 12 on Figure 11). These are entirely absent in samples of gravel from the Antlers Formation.

Careful inspection of washed cuttings from borings will reveal at least a few of these distinctive clast types if present, and so it is not necessary to sieve, count, and identify all pebbles to obtain an accurate stratigraphic determination. Ogallala sand also typically has a high percentage of lithic grains compared to Antlers sand, which is virtually pure quartzarenite. These criteria were used to distinguish the two deposits over the WCS - Flying "W" Ranch area.

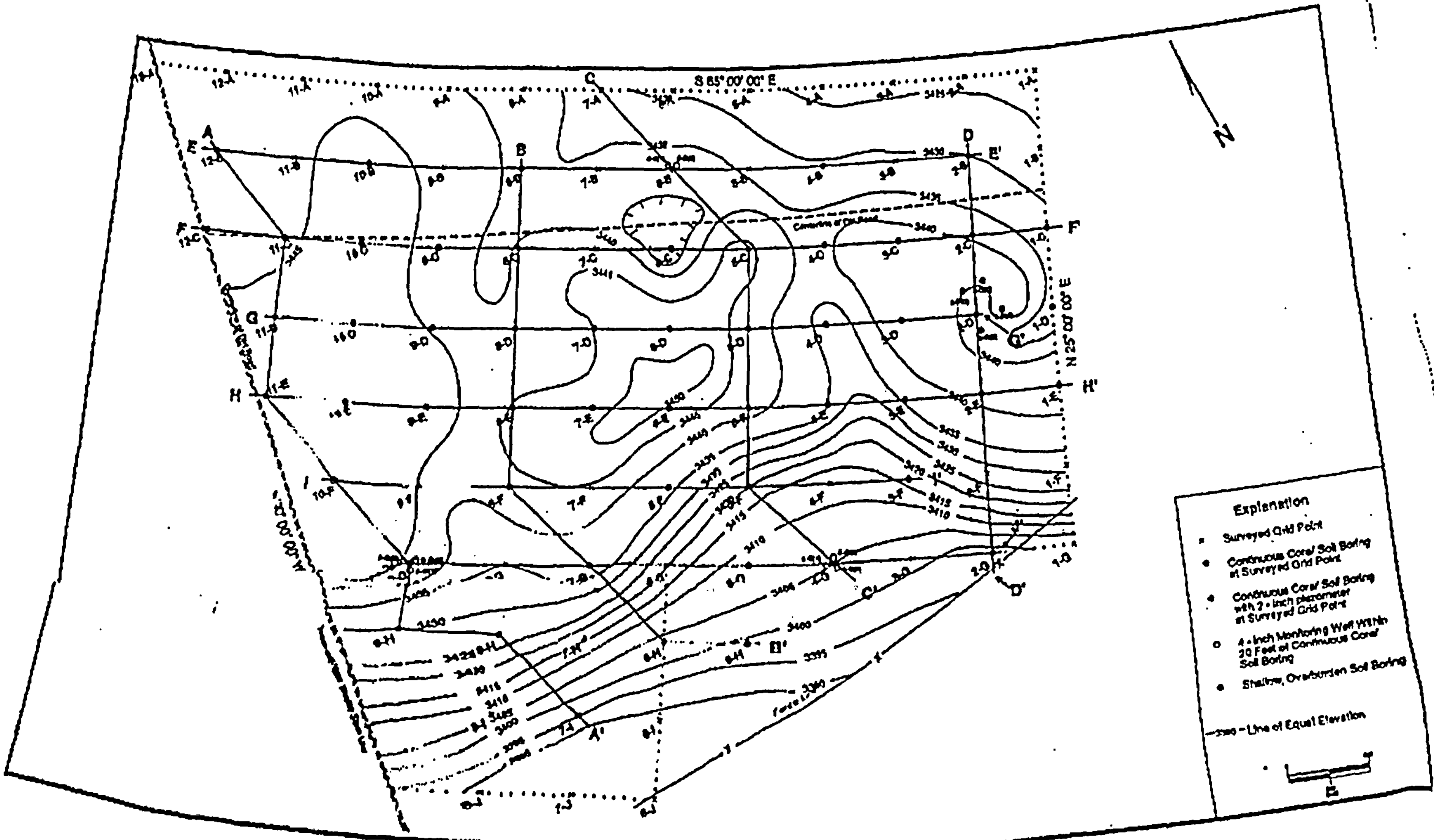

Figure 1. Contour Map of the Dockum ("red beds") Group Surface Beneath the WCS Site [Source: AME (1993)]

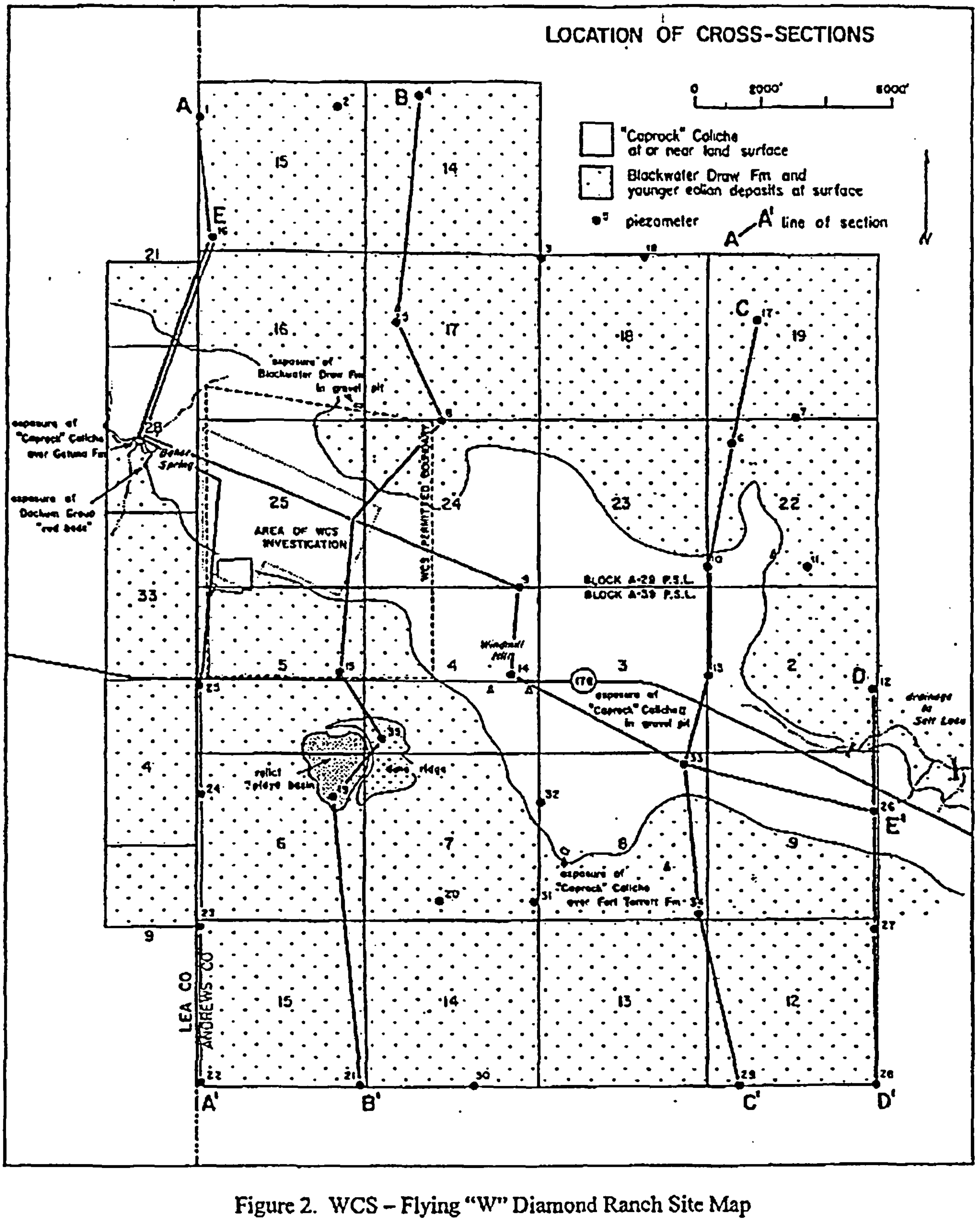

Figure 2. WCS – Flying "W" Diamond Ranch Site Map

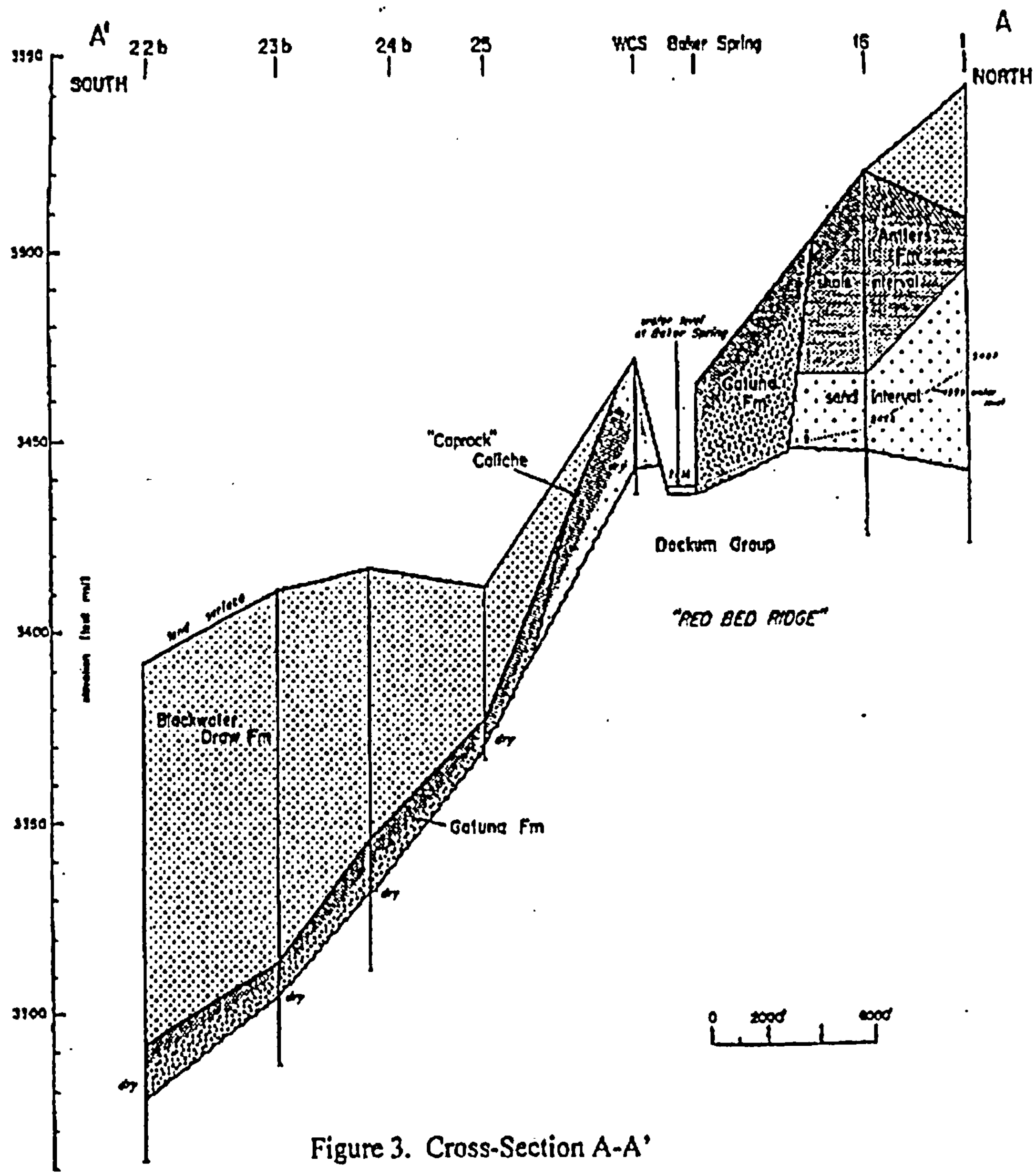

Figure 3. Cross-Section A-A'

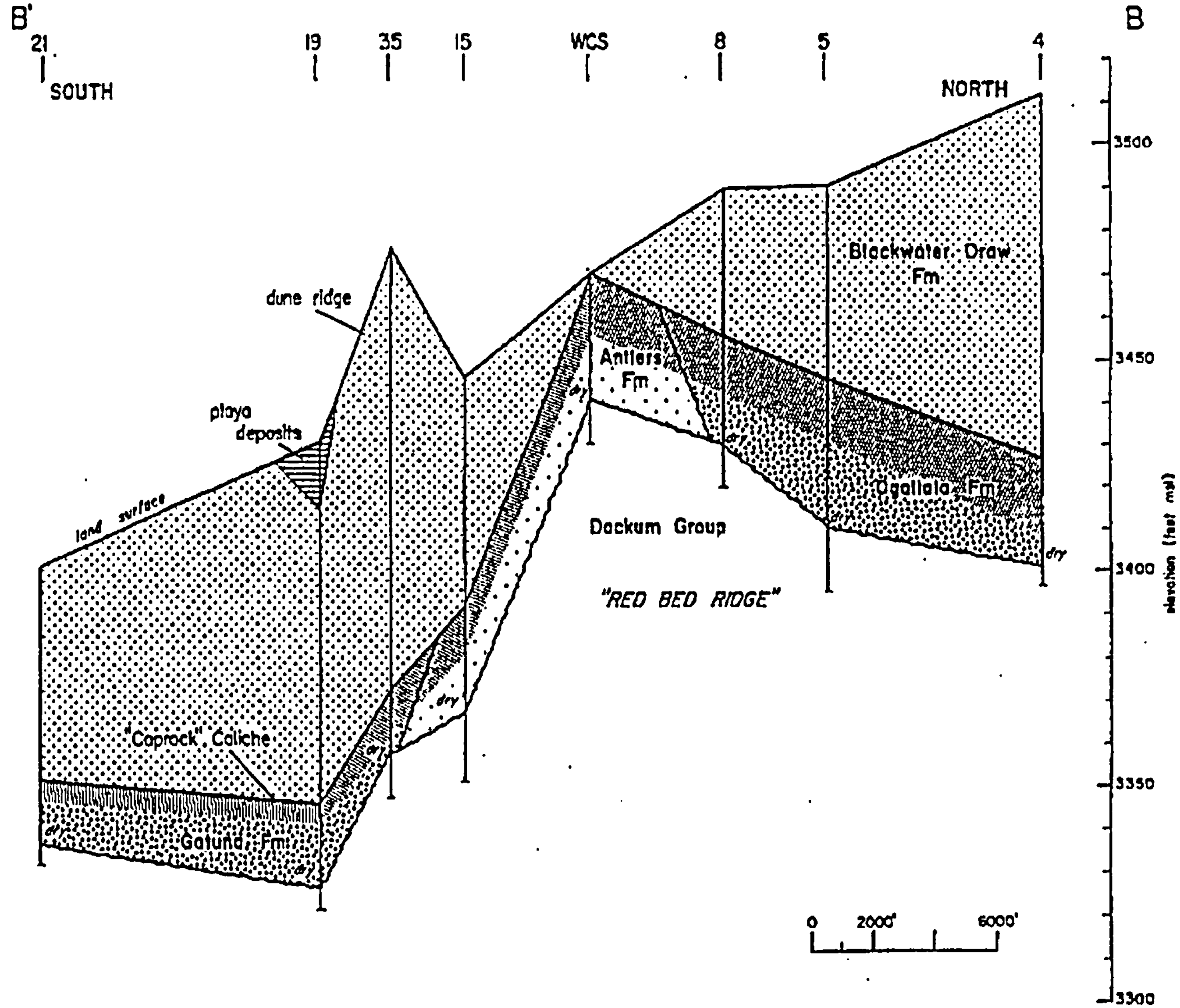

Figure 4. Cross-Section B-B'

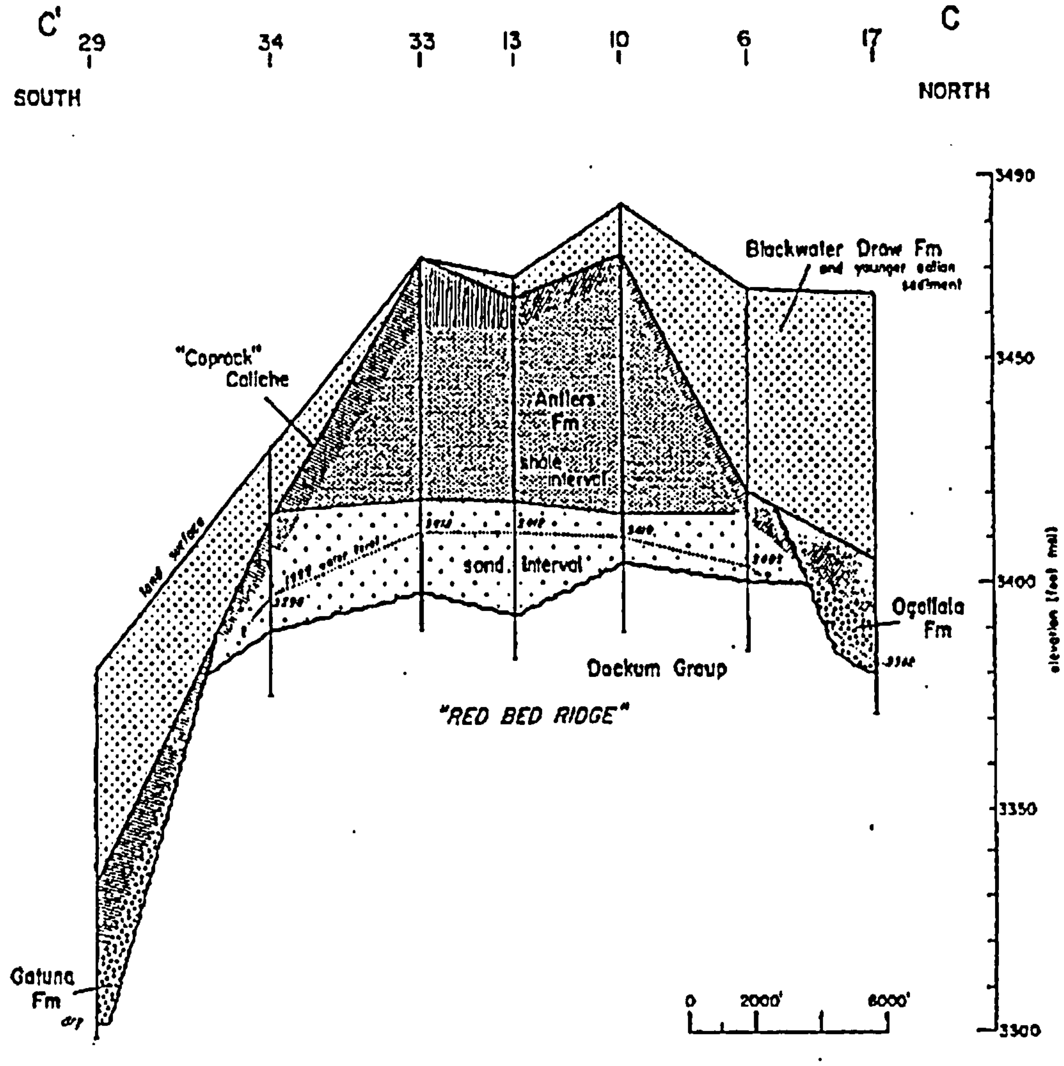

Figure 5. Cross-Section C-C'

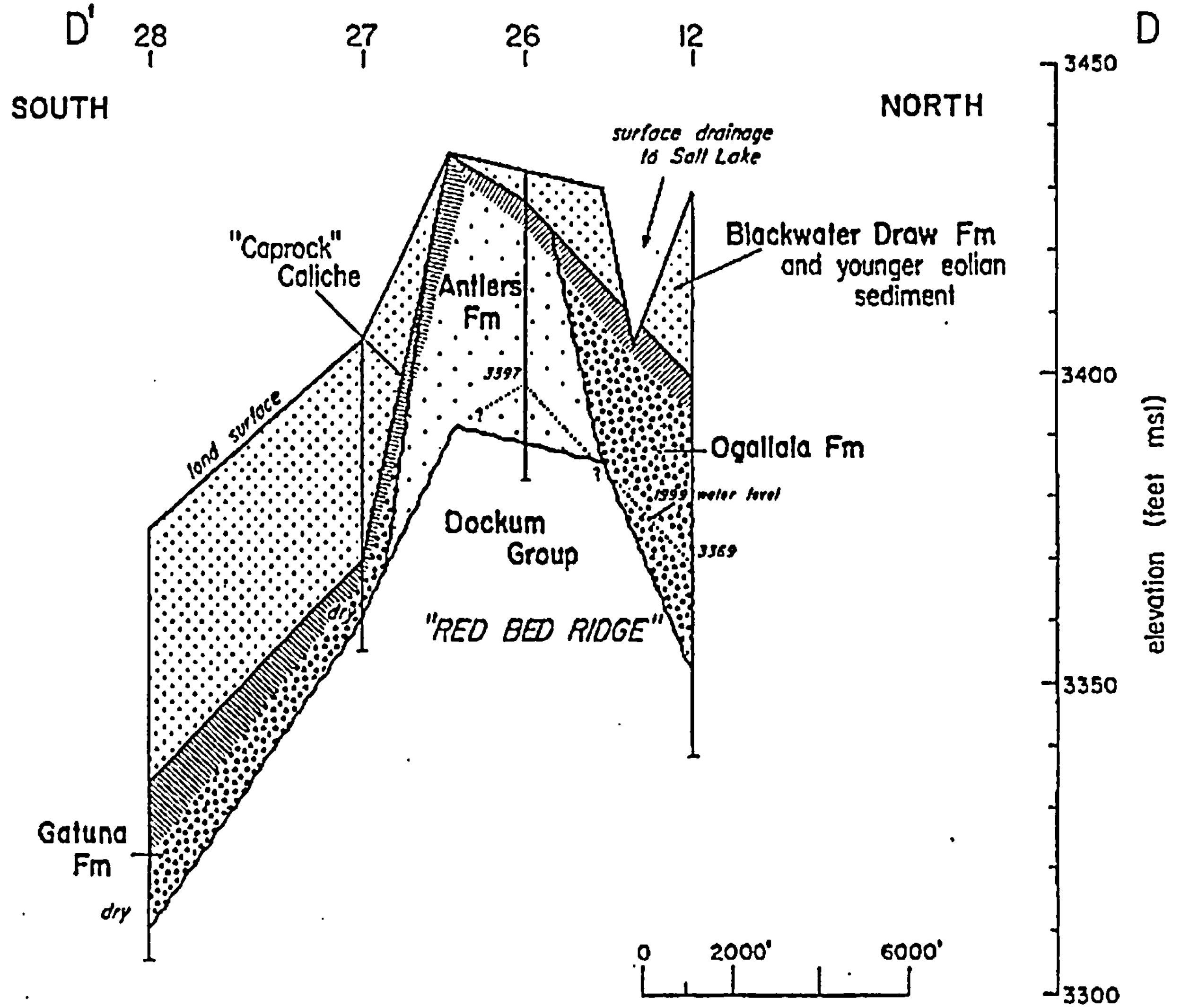

Figure 6. Cross-Section D-D'

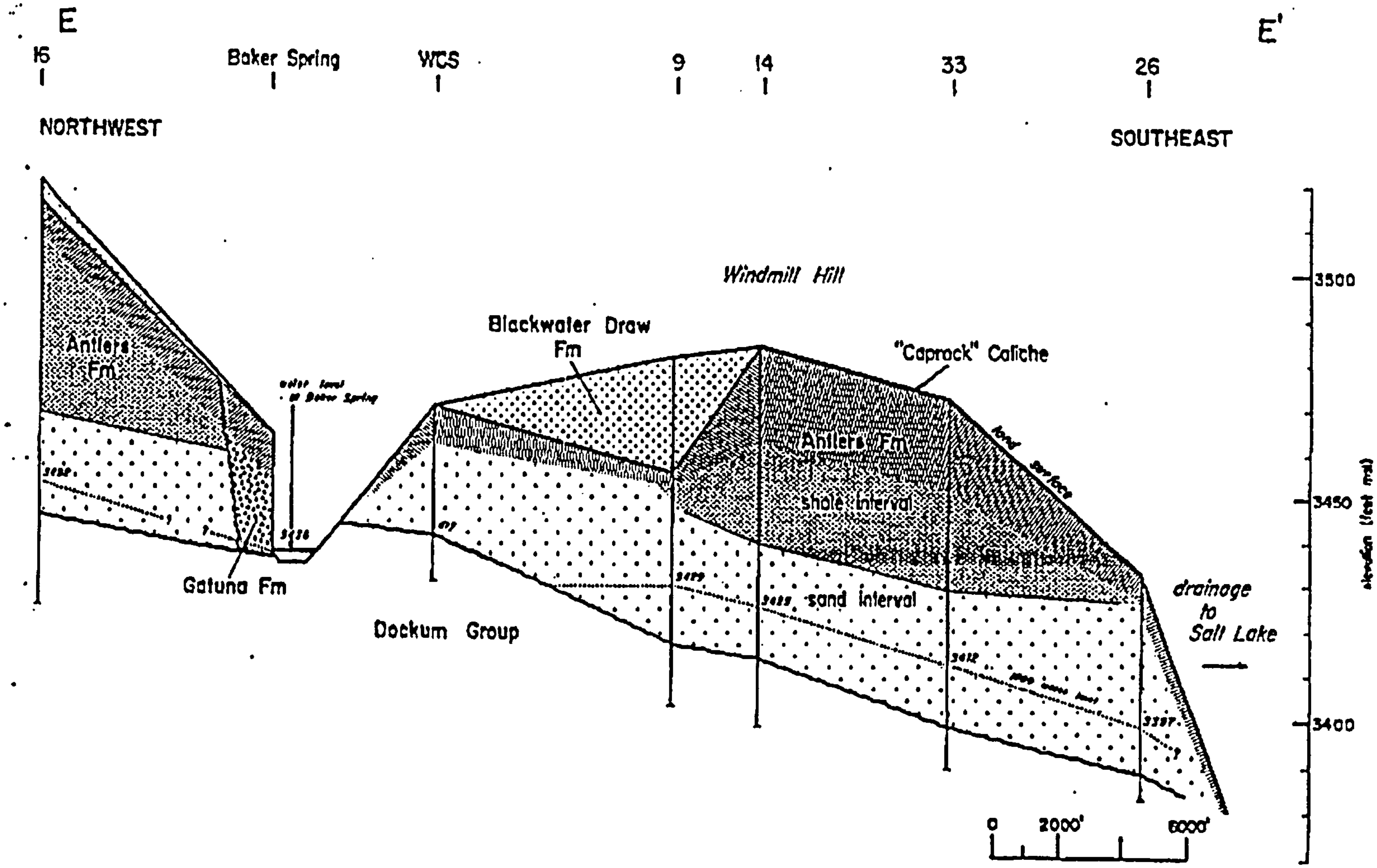

Figure 7. Cross-Section E-E'

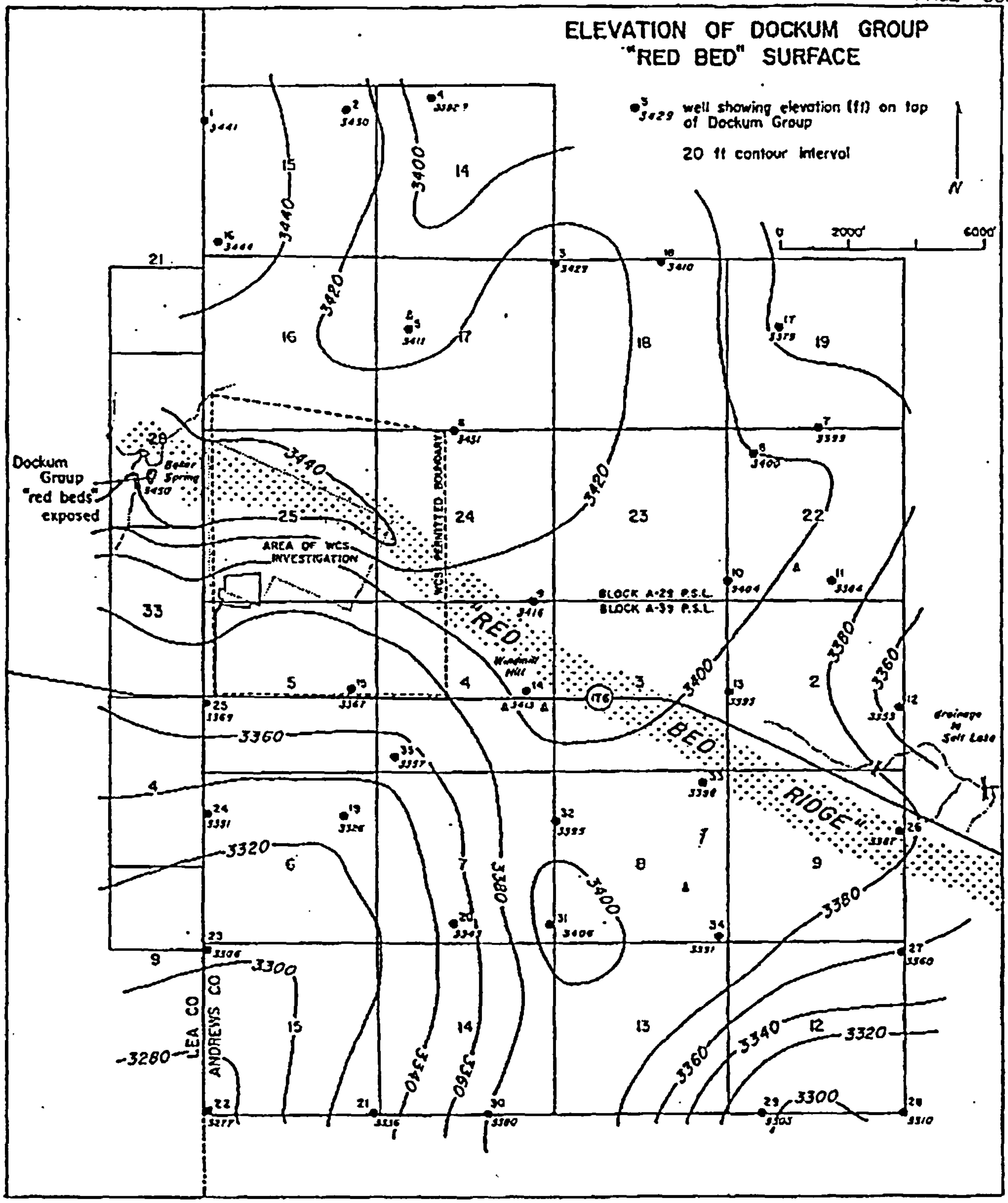

Figure 8. Elevation of Dockum Group "Red Bed" Surface

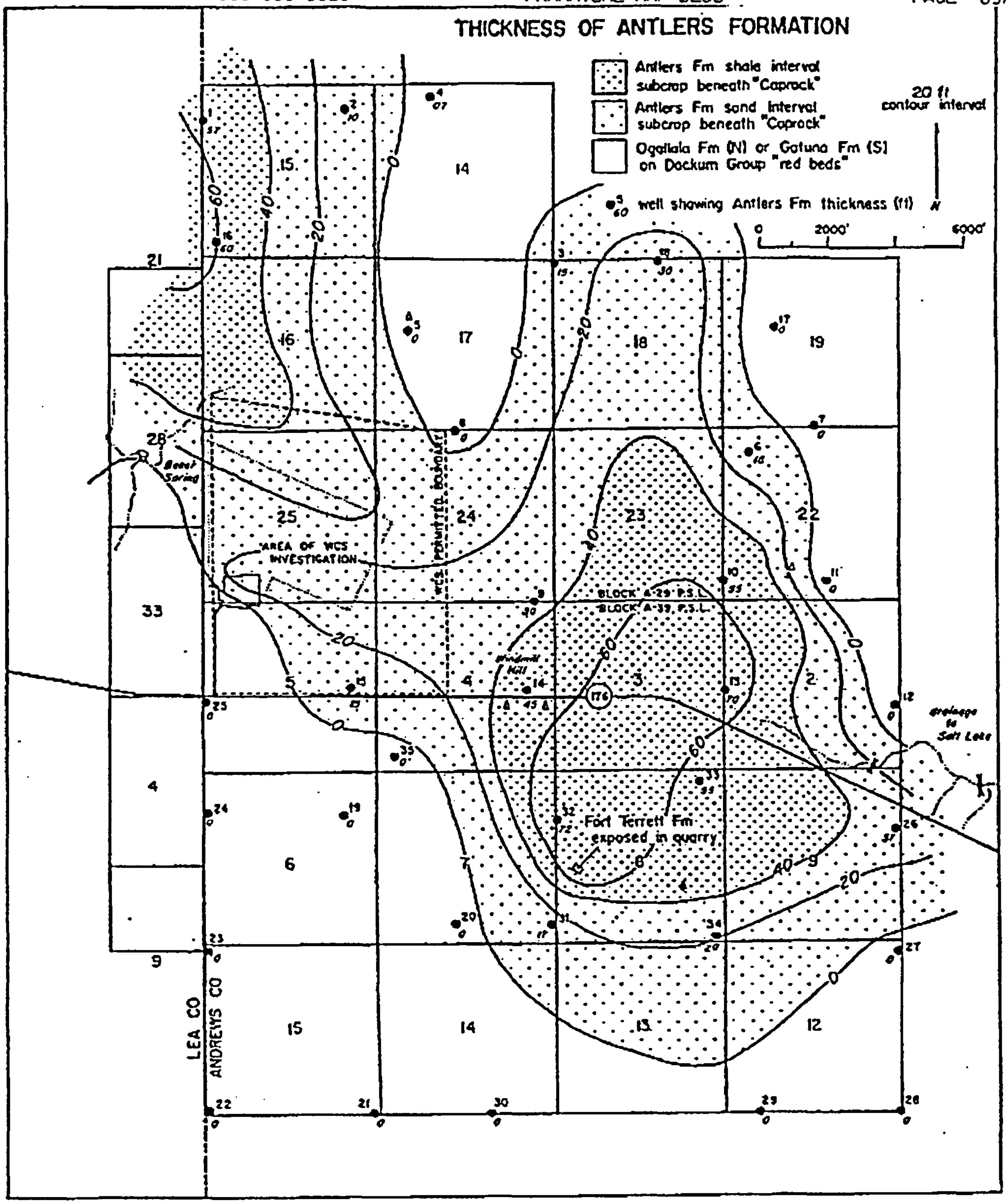

Figure 9. Thickness of Antlers Formation

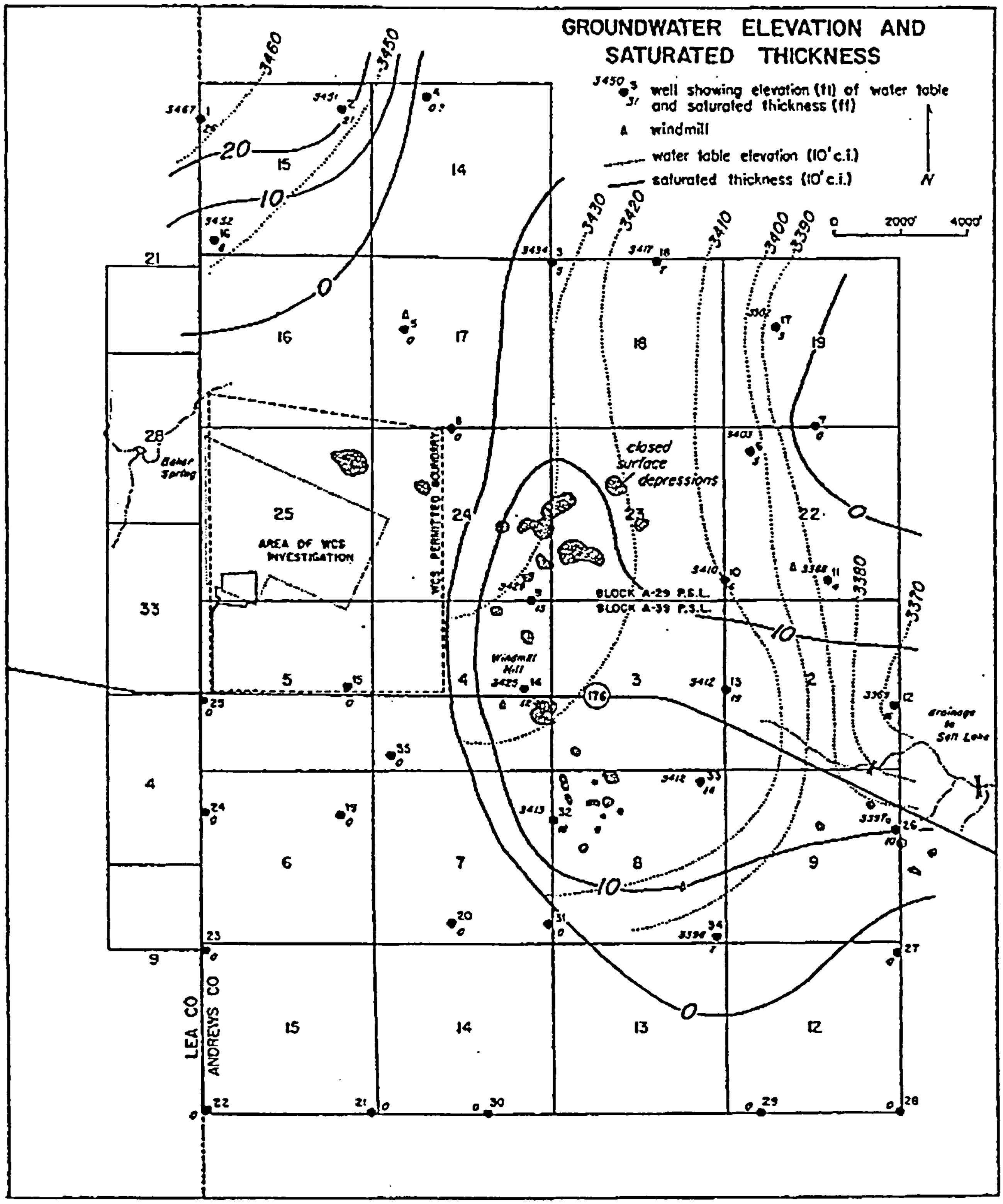

Figure 10. Groundwater Elevation and Saturated Thickness

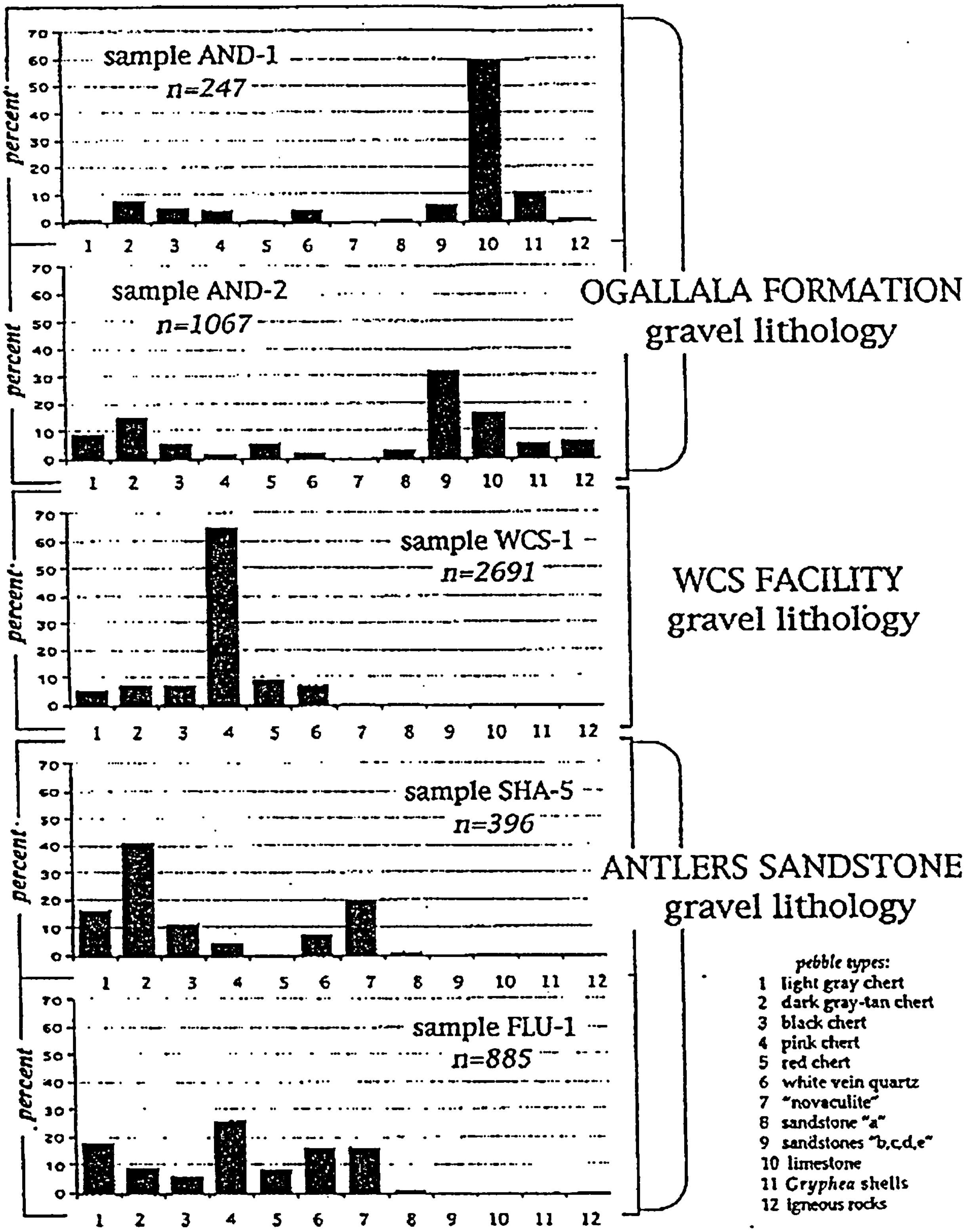

Figure 11. Comparison of Gravel Characteristics in Ogallala and Antlers Formations

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