NM1-62

Permit Application

Volume 4
Part 1 of 11

STATE OF NEW MEXICO
DIRECTOR OF OIL CONSERVATION DIVISION

IN THE MATTER OF THE APPLICATION OF SUNDANCE WEST, INC. FOR A SURFACE WASTE MANAGEMENT FACILITY PERMIT

APPLICATION FOR PERMIT
SUNDANCE WEST

AUGUST 2016

VOLUME IV: SITING AND HYDROGEOLOGY

Prepared For:

Sundance West, Inc.
1001 6th Street
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Submitted To:

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Oil Conservation Division
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APPLICATION FOR PERMIT

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY

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APPLICATION FOR PERMIT

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY

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APPLICATION FOR PERMIT
SUNDANCE WEST

VOLUME IV: SITING AND HYDROGEOLOGY
SECTION 1: SITING CRITERIA

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APPLICATION FOR PERMIT
SUNDANCE WEST

VOLUME IV: SITING AND HYDROGEOLOGY
SECTION 1: SITING CRITERIA

1.0 INTRODUCTION

Sundance West is a proposed new commercial Surface Waste Management Facility for oil field waste processing and disposal services. The proposed Sundance West Facility is subject to regulation under the New Mexico Oil and Gas Rules, specifically 19.15.36 NMAC, administered by the Oil Conservation Division (OCD). The Facility is designed in compliance with 19.15.36 NMAC, and will be constructed and operated in compliance with a Surface Waste Management Facility Permit issued by the OCD. The Facility is owned by, and will be constructed and operated by, Sundance West, Inc. (Sundance West).

1.1 Purpose

This section provides compliance demonstrations for the Siting Criteria for Surface Waste Management Facilities specified in the NM Oil and Gas Rules, 19.15.36.13.A-C NMAC. These requirements include depth to groundwater; and proximity of watercourse, floodplains, wetlands, mines, residences/institutions, and unstable areas. The proposed Sundance West Site meets the Siting Requirements applicable to a Surface Waste Management Facility (i.e., 19.15.36.13.A-C NMAC).

1.2 Site Location

The Sundance West Site is located approximately 3 miles east of Eunice, 18 miles south of Hobbs, and approximately 1.5 miles west of the Texas/New Mexico state line in unincorporated Lea County, New Mexico (NM). The Sundance West Site is comprised of a 320-acre ± tract of land located in the South ½ of Section 30, Township 21 South, Range 38 East, Lea County, NM. Site access will be provided via NM 18 and Wallach Lane. A Site Location Map is provided as **Figure IV.1.1**. The Site Plan, provided as Figure IV.1.2, provides a plan view of the Facility showing the Facility layout, perimeter fencing, and gates.

2.0 SITING CRITERIA FOR SURFACE WASTE MANGEMENT FACILITIES

In order to confirm the suitability of the proposed Sundance West Site for a Surface Waste Management Facility, an evaluation with respect to the Siting Requirements detailed in 19.15.36.13.A-C NMAC was performed and is presented herein. Based upon available information, the proposed Sundance West Site satisfies the size restriction and each of the 8 siting criteria. Following is a detailed description of the Sundance West Site's compliance with the siting criteria. Each siting criterion is defined, applied and discussed individually. The following sections provide the regulatory citation for each criterion, followed by a narrative response. In most cases, a Figure or study is referenced to demonstrate compliance with applicable standard(s).

2.1 Depth to Groundwater

No landfill shall be located where ground water is less than 100 feet below the lowest elevation of the design depth at which the operator will place oil field waste. (19.15.36.13.A.(1) NMAC).

For the purpose of this Permit Application, Groundwater will be defined as subsurface interstitial water within the saturated zone in which all voids are filled with water under pressure equal or greater to than atmospheric which is capable of entering a well in sufficient amounts to be utilized as a water supply. Vadose Zone (or Perched) water will define the unsaturated zone above the groundwater that is not a source of radially available water for human consumption equivalent to **80 gallons per day** of groundwater production.

No other surface waste management facility shall be located where ground water is less than 50 feet below the lowest elevation at which the operator will place oil field waste. (19.15.36.13.A.(5) NMAC).

Regional groundwater data (Dutton and Simkins 1986) show that groundwater is encountered between 3,000 and 3,250 feet (ft) below ground surface (bgs). A preliminary subsurface investigation was conducted at the Sundance West Site in April 2009. This work consisted of the installation of five soil borings (MP-1 through MP-5), and the installation of two shallow wells (MP-2P and MP-4P). The two wells were installed to monitor the thin, isolated vadose zone of limited water perched on top of and/or within the Chinle Formation (see *Completion Report-Drilling, Sampling, and Monitoring Well Installation*, GEI June

2009). **The first regulated water-bearing zone (groundwater) is greater than 100 ft below the deepest oil field waste management units (Volume IV.2)**. The upper perched water-bearing zone (vadose zone) will be protected from additional impacts by the Facility's liner systems, surface water controls, operating procedures, etc.

2.2 Watercourse, Lakebed, Sinkhole, or Playa Lake

No surface waste management facility shall be located: within 200 feet of a watercourse, lakebed, sinkhole or playa lake (19.15.36.13.B.(1) NMAC).

Sundance West waste disposal facilities are not located within 200 ft of a watercourse, lakebed, sinkhole or playa lake. **Figure IV.1.3A**, USGS Quadrangle Map, shows surface features on and adjacent to the Sundance West Site, and **Figure IV.1.3B** provides detailed topographic information for the footprint of the facility. These figures, accompanied by focused site reconnaissance, document that there are no regulated surface water features on or adjacent to the Site. The "Karst Terrain Map" (**Figure IV.1.9**) also shows that the potential for subsidence features that might create sinkhole or playa conditions are absent from the region.

2.3 Wellhead Protection Area; 100-Year Floodplain

No surface waste management facility shall be located: within an existing wellhead protection area or 100-year floodplain (19.15.36.13.B.(2) NMAC).

"Wellhead protection area" means the area within 200 horizontal feet of a private, domestic fresh water well or spring used by less than five households for domestic or stock watering purposes or within 1000 horizontal feet of any other fresh water well or spring. Wellhead protection areas does not include areas around water wells drilled after an existing oil or gas waste storage, treatment or disposal site was established. (19.15.2.7.W(8) NMAC)

Sundance West is **not located within an existing wellhead protection area or 100-year floodplain**. The Wellhead Protection Area Map (**Figure IV.1.4**) provides the locations, with 200-ft setbacks, for water supply wells in the area based on data provided by the Office of the State Engineer (OSE). There are no wells located on Site, or within 200 ft of the Sundance West Site. The closest wells are located greater than ½-mile to the southeast of the Site as shown on **Figure IV.1.4**. The closest municipal water supply well belongs to the City of Eunice and is located over 2.5 miles west of the Sundance West Site.

A Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) has not been produced for this unincorporated area of Lea County. The closest mapped area consists of the area encompassing the Eunice corporate limits (FIRM 35025C1670D). This map was reviewed for 100-year floodplain delineations, and none were found. A review of produced maps, in addition to site inspections, does not indicate watercourses or surface features characteristic of a regulated floodplain within or adjacent to the Site; or any "waters of the United States" regulated by Army Corps of Engineers, Section 404. The FEMA FIRM Map Index is provided as **Figure IV.1.5**.

2.4 Wetlands

No surface waste management facility shall be located: within, or within 500 feet of, a wetland (19.15.36.13.B.(3) NMAC).

"Wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions in New Mexico. This definition does not include constructed wetlands used for wastewater treatment purposes. (19.15.2.7.W(9) NMAC).

The Sundance West surface waste management facility site is not located within 500 ft of a wetland. The applicable wetlands map, excerpted from the National Wetlands Inventory, is provided as **Figure IV.1.6**. The closest wetland is identified as "PUSCx": palustrine, unconsolidated shore, seasonally flooded, and excavated. Palustrine are non-tidal wetlands, including inland swamps and marshes. This wetland is located approximately 2,000 ft east of the Site.

2.5 Subsurface Mines

No surface waste management facility shall be located: within the area overlying a subsurface mine (19.15.36.13.B.(4) NMAC).

The Sundance West surface waste management facility site is not located within an area overlying a subsurface mine. The applicable section of the New Mexico Energy, Minerals, and Natural Resources Department's *Mines, Mills and Quarries* Map is provided as **Figure IV.1.7**. The closest mine is a surface gravel extraction operation owned by Wallach Concrete, Inc., and located approximately ½ mile east of the Sundance West Site.

2.6 Land Use Setbacks

No surface waste management facility shall be located: within 500 feet from the nearest permanent residence, school, hospital, institution or church in existence at the time of initial application (19.15.36.13.B.(5) NMAC).

The Sundance West Site **is in excess of 500 ft from the nearest permanent residence, school, hospital, institution, or church.** The examination of land use setbacks for the Sundance West facility includes a site reconnaissance, and aerial photo review (**Figure IV.1.8**). The results of this analysis conclude that:

- The nearest residential area is located within Eunice and is approximately 2.7 miles west of the Site.
- The nearest church is located within Eunice, approximately 2.9 miles west of the Site.
- There is no trend for development of residential, institutional, or educational facilities in the vicinity of the proposed Facility.

2.7 Unstable Areas

The oil field waste disposal facility siting requirements set forth in 19.15.36.13.B(6) NMAC specify that:

> ***No surface waste management facility shall be located within an unstable area, unless the operator demonstrates that engineering measures have been incorporated into the surface waste management facility design to ensure that the surface waste management facility's integrity will not be compromised.***

An "Unstable Area" is defined in 19.15.2.7.U(6) NMAC as follows:

> ***"Unstable area" means a location that is susceptible to natural or human-induced events or forces capable of impairing the integrity of some or all of a division-approved facility's structural components. Examples of unstable areas are areas of poor foundation conditions, areas susceptible to mass earth movements and karst terrain areas where karst topography is developed as a result of dissolution of limestone, dolomite, or other soluble rock. Characteristic physiographic features of karst terrain include sinkholes, sinking streams, caves, large springs or blind alleys.***

Figure IV.1.9 shows that the nearest areas with potential Karst subsidence are greater than 3 miles south of the Sundance West Site. The location was also evaluated for geologic faults (**Figure IV.1.10**) and potential seismic impacts (**Figure IV.1.11**).

There are no known active faults known within 200 ft of the Site; therefore, earthquake risk is low. The Geologic Faults Map, provided as **Figure IV.1.10** indicates that the closest quaternary fault zone is located approximately 110 miles southwest of the Site in Texas. The USGS Seismic Impact Zones Map (**Figure IV.1.11**) indicates a potential maximum horizontal acceleration of 0.11 g in 250 years. The Site topography is characterized by relatively gently sloping surfaces underlain by shale, sandstone, and alluvium. No limestone or other carbonate rock is exposed near the Site, and no sinkholes or slumps have been reported within the region (Ward, 1990).

Select textural and hydrologic properties of the stratigraphic units encountered in boreholes and in the regional geology are described in the *Completion Report-Drilling, Sampling, and Monitoring Well Installation* (GEI, June 2009). These properties and the inferred geotechnical characteristics of the units, together with the low seismic risk, document that foundation conditions are suitable for the surface ponds at this Site. In summary, the topography of the Site, and the nature of the sediments beneath the Sundance West Facility, indicate that the Site is stable and suitable for the installation of the proposed waste processing and containment facilities allowed pursuant to 19.15.36 NMAC.

2.8 Maximum Size

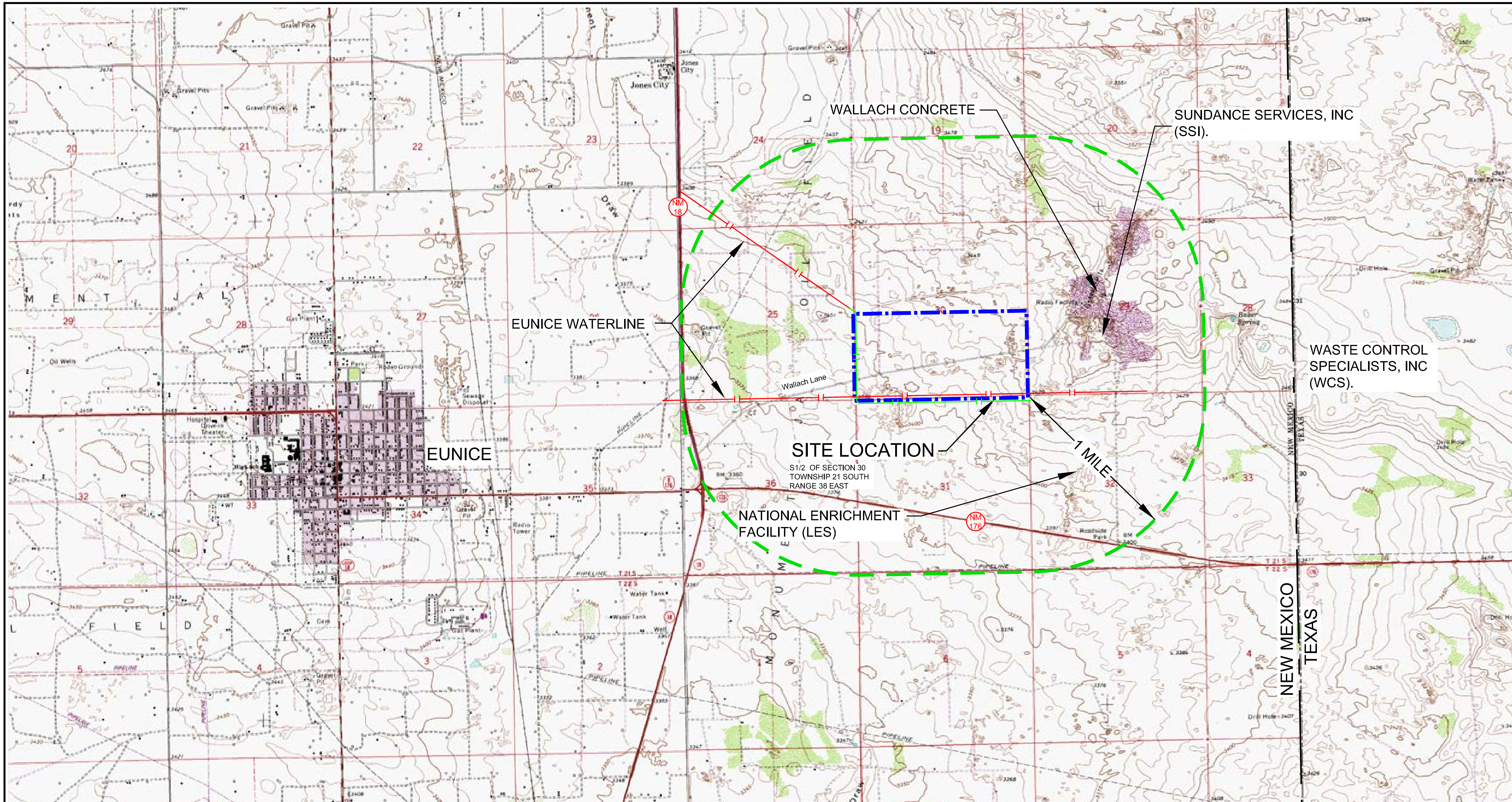
"No surface waste management facility shall exceed 500 acres" per 19.15.36.13.C NMAC.

The Sundance West Surface Waste Management Facility will not exceed 500 acres. The proposed facility will occupy 320 acres ± including an 80-acre ± Processing Area and an 180-acre ± Landfill, located in the south ½ of Section 30, Township 21 South, Range 38 East NMPM. The remainder of the Site will be dedicated to ancillary operations, waste receiving and processing, soil stockpiling, stormwater management, buffer zone, etc. The Site Location Map, included as **Figure IV.1.1**, identifies the limits of the Site. The Site footprint is identified on the Site Plan, provided as **Figure IV.1.2**.

APPLICATION FOR PERMIT
SUNDANCE WEST

VOLUME IV: SITING AND HYDROGEOLOGY
SECTION 1: SITING CRITERIA

FIGURES



Based on Eunice NE, TX.- NM (1969) Photorevised (1979);
Eunice, NM (1969) Photorevised (1978);
Quadrangles, USGS 7.5' SERIES (1:24,000 Scale)

NOTE:
NO STREAMS, SPRINGS OR WATER COURSES WITHIN
1/2 MILE OF SITE

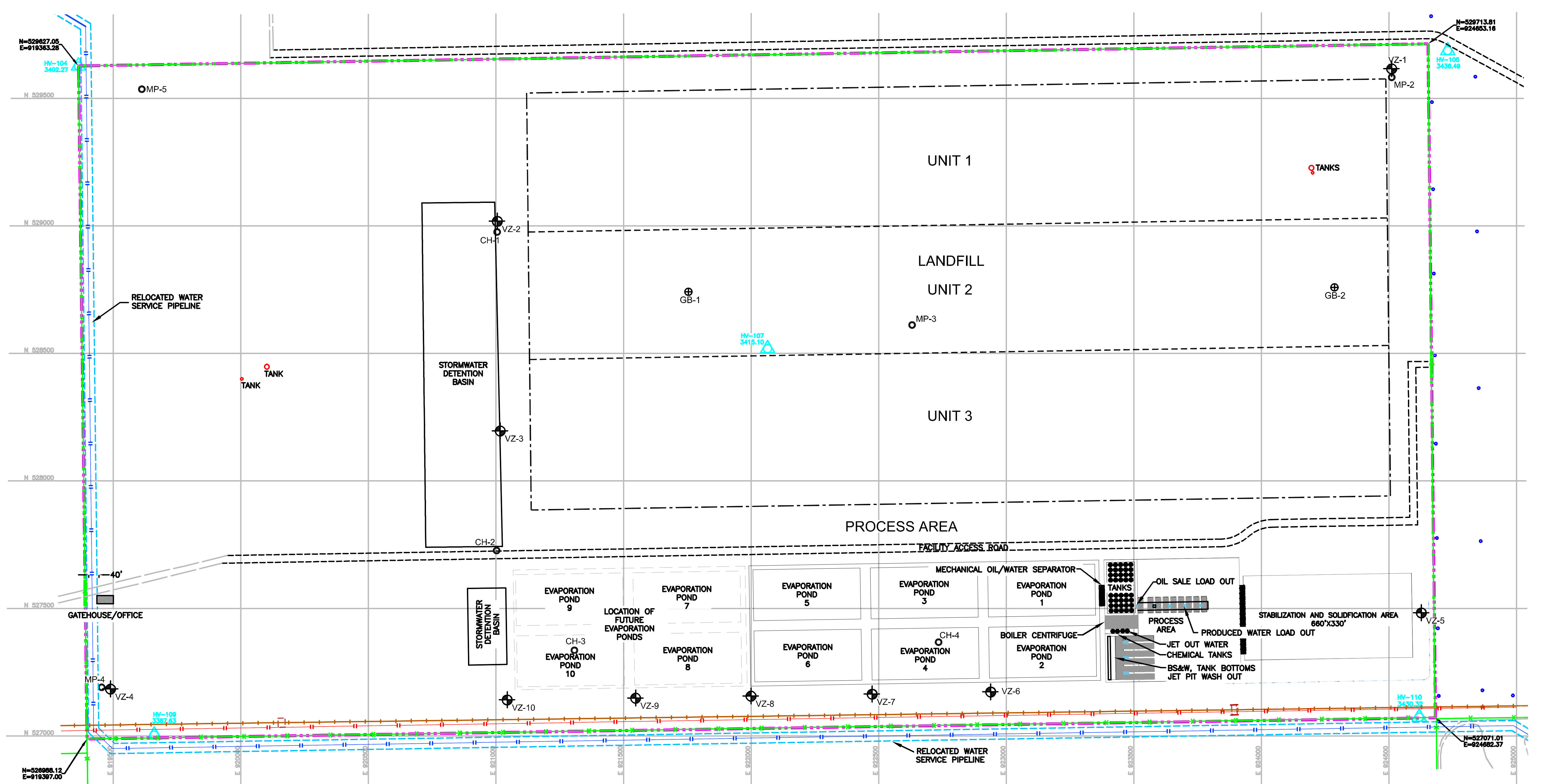
Drawing:P:\acad 2003\530.06.01\REVISED FIGURES(RAI 1)\SITE LOC REVISED 11 x17.dwg
Date/Time:Aug. 09, 2016-12:23:45 ; LAYOUT: B (LS)

SITE LOCATION MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 07/22/2016	CAD: DWG NAME.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: CWF	FIGURE IV.1.1
APPROVED BY: IKG	gei@gordonenvironmental.com	



LEGEND

	FACILITY BOUNDARY		LOCKING GATE
	LIMIT OF WASTE BOUNDARY	GB-1	GEOTECHNICAL BOREHOLE
	UNIT BOUNDARY	MP-2	SOIL BORING
	FENCE (EXISTING)	CH-3	COREHOLE BORING
	PROPOSED 4-STRAND BARBED WIRE FENCING	VZ-1	VADOSE ZONE MONITORING WELL
	NEW UNPAVED ROAD		POWER POLE
	EXISTING PAVED ROAD		STORAGE TANK
	EXISTING UNPAVED ROAD		EXISTING BOX CULVERT
	RAILROAD TRACK	HV-109 3387.63	SURVEY CONTROL POINT
	RELOCATED WATER SERVICE PIPELINE		
	EXISTING EUNICE WATERLINE	N 527500 E 922000	SITE GRID
	PIPELINE EASEMENT		

NOTE

AERIAL SURVEY BY THOMAS R. MANN & ASSOCIATES AERIAL MAPPING SERVICES, 5115 COPPER NE, ALBUQUERQUE, NM 87108
DATE OF PHOTOGRAPHY: 10-01-08

Drawing:P:\acad 2003\530.06.01\REVISED FIGURES(RAI 1)\SITE DEV.dwg
Date/Time:Jul. 19, 2016-05:15:59

NORTH

0 200' 400'

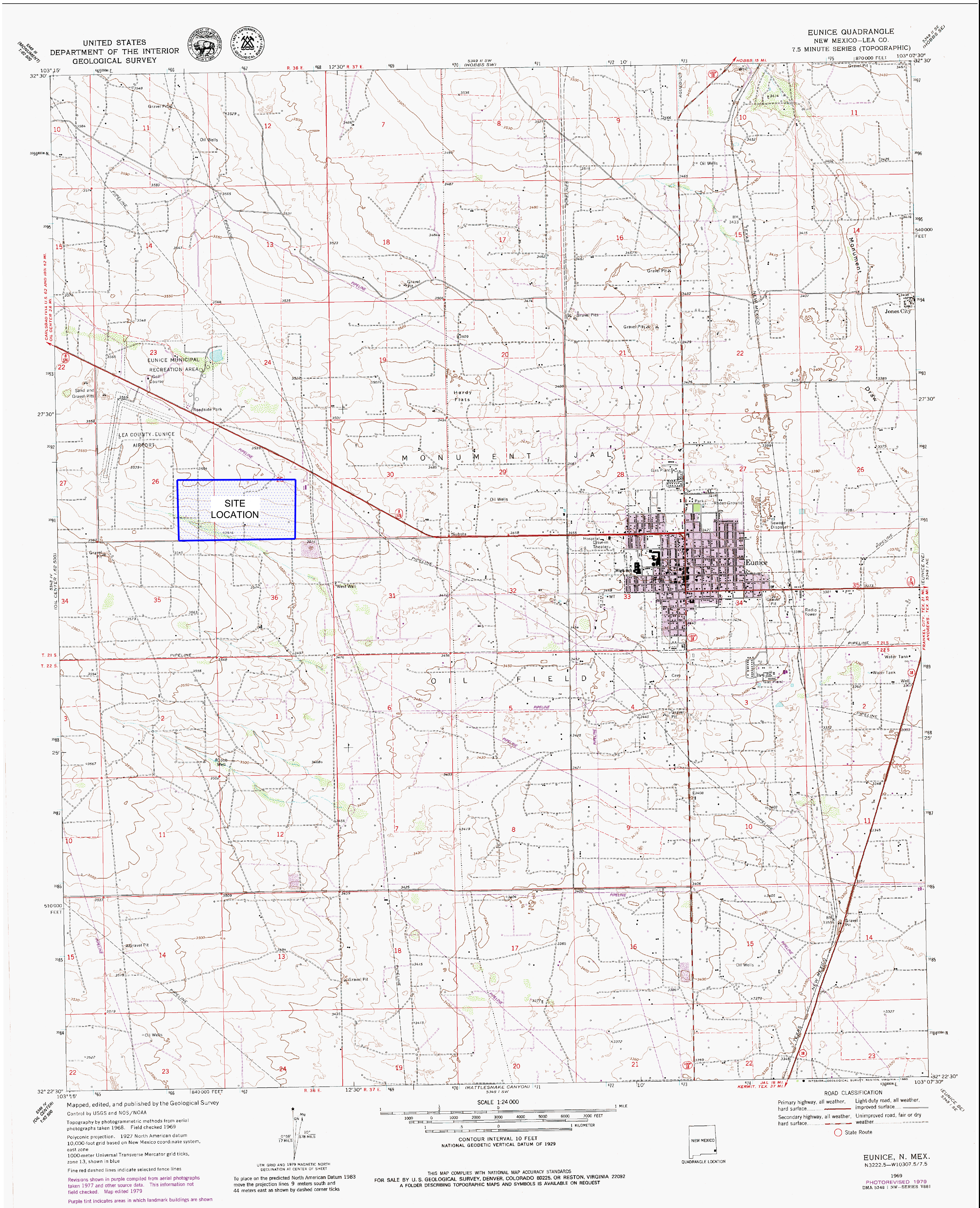
SITE PLAN

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 07/18/2016	CAD: SITE DEV.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.2
APPROVED BY: IKG	gei@gordonenvironmental.com	

PRINT SIZE: 24" x 36"



NORTH

0 2000' 4000'

USGS QUADRANGLE MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
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213 S. Camino del Pueblo
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DATE: 01/08/2015	CAD: QUAD SITE.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: CWF	FIGURE IV.1.3A
APPROVED BY: IKG	gei@gordonenvironmental.com	

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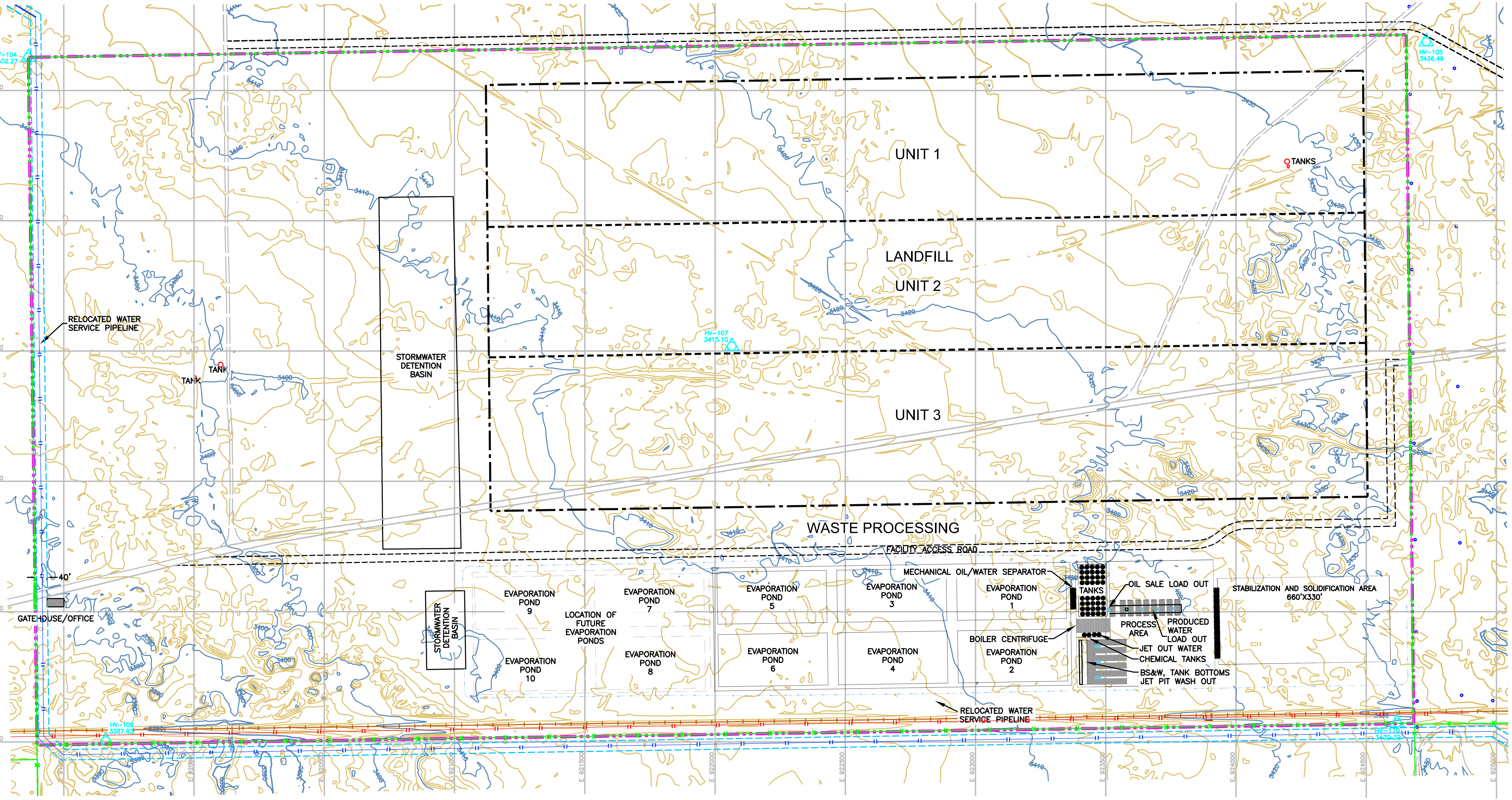

NOTE

AERIAL SURVEY BY THOMAS R. MANN & ASSOCIATES AERIAL MAPPING SERVICES, 5115 COPPER NE, ALBUQUERQUE, NM 87108
DATE OF PHOTOGRAPHY: 10-01-08

LEGEND

	FACILITY BOUNDARY		EXISTING EUNICE WATERLINE
	LIMIT OF WASTE BOUNDARY		RELOCATED WATER SERVICE PIPELINE
	UNIT BOUNDARY		PIPELINE EASEMENT
3390	10' CONTOUR		LOCKING GATE
	2' CONTOUR		POWER POLE
	FENCE (EXISTING)		STORAGE TANK
	PROPOSED 4-STRAND BARBED WIRE FENCING		EXISTING BOX CULVERT
	NEW UNPAVED ROAD	HV-109 3387.63	SURVEY CONTROL POINT
	EXISTING PAVED ROAD	N 527500 E 922000	SITE GRID
	EXISTING UNPAVED ROAD		
	RAILROAD TRACK		

NORTH

0 200' 400'

Drawing:P:\acad 2003\530.06.01\REVISED FIGURES(RAI 1)\SITE TOPO.dwg
Date/Time:Jul. 19, 2016-07:26:20

SITE TOPOGRAPHIC MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

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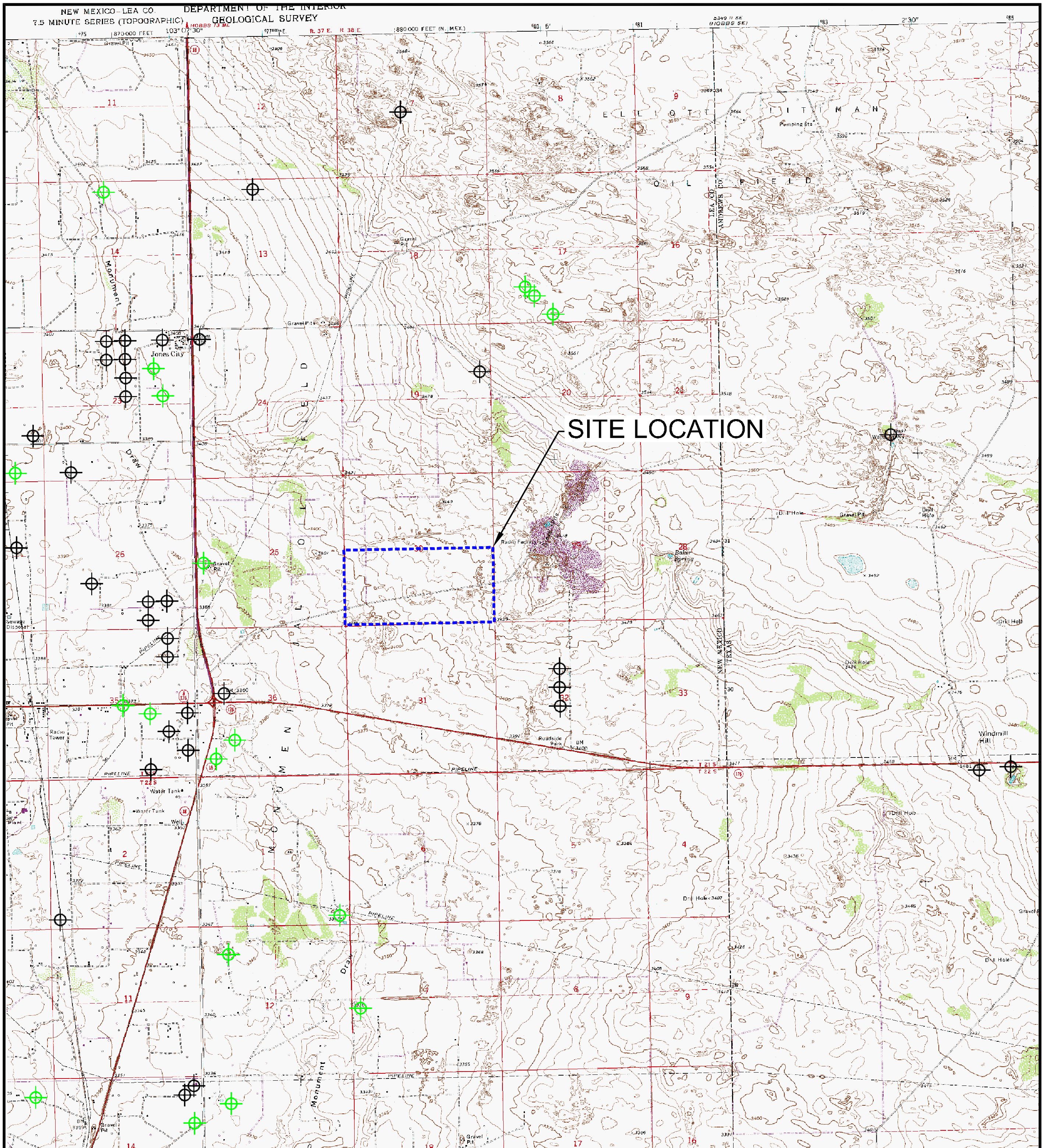
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 07/18/2016	CAD: SITE TOPO.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.3B
APPROVED BY: IKG	gei@gordonenvironmental.com	



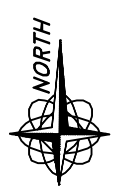
LEGEND

DOMESTIC WATER WELL SHOWING 200' RADIUS

OTHER USE WATER WELL (INDUSTRIAL, EXPLORATION, MONITORING, OR LIVESTOCK WATERING WELL SHOWING 200' RADIUS)

WATER WELL DATA FROM NMOSE 2008 GIS DATABASE AND TWDB GIS DATABASE.

MAP BASE: EUNICE NE, TEX.-N. MEX. 1969, PHOTOREVISED 1979, 1:24000, USGS 7.5 MIN. SERIES TOPOGRAPHIC QUADRANGLE



0' 2500' 5000'

Drawing:P:\acad 2003\530.06.01\PERMIT FIGURES\WH PROTECTION.dwg
Date/Time:Jan. 05, 2015-08:06:13

WELLHEAD PROTECTION AREA MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

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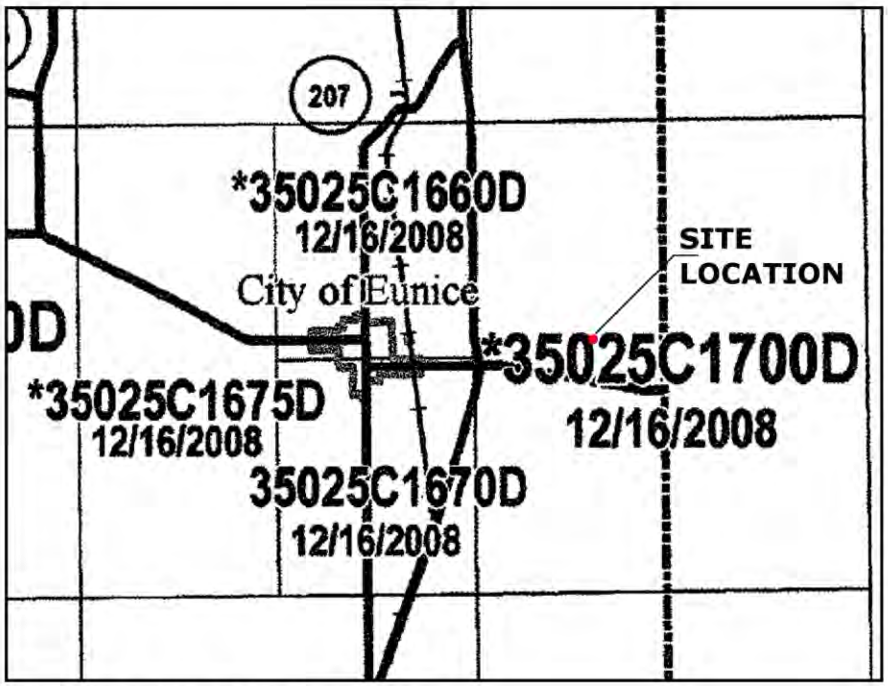
DATE: 01/05/2015	CAD: WH PROTECTION.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: AY	FIGURE IV.1.4
APPROVED BY: IKG	gei@gordonenvironmental.com	

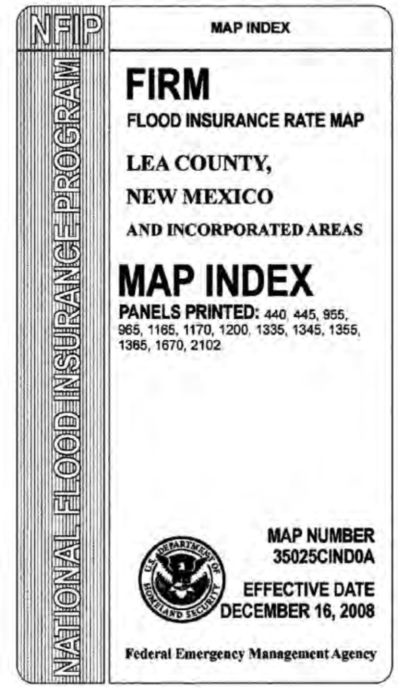
LISTING OF COMMUNITIES

COMMUNITY NAME	COMMUNITY NUMBER	LOCATED ON PANEL(S)	INITIAL NFIP MAP DATE	INITIAL FIRM DATE	MOST RECENT FIRM PANEL DATE
EUNICE, CITY OF	350028	1660[1], 1670	August 30, 1974	August 22, 1978	December 16, 2008
HOBBS, CITY OF	350029	1165, 1170, 1335, 1345, 1350[1], 1355, 1365	April 2, 1976	July 16, 1991	December 16, 2008
JAL, CITY OF	350030	1975[1], 2102, 2110[1]	July 9, 1976	August 19, 1985	December 16, 2008
LOVINGTON, CITY OF	350031	955, 965	June 21, 1974	November 1, 1989	December 16, 2008
LEA COUNTY, UNINCORPORATED AREAS	350130	25[1], 50[1], 75[1], 100[1], 125[1], 150[1], 175[1], 200[1], 225[1], 250[1], 275[1], 300[1], 325[1], 350[1], 375[1], 400[1], 425[1], 440, 445, 450[1], 475[1], 500[1], 525[1], 550[1], 575[1], 600[1], 625[1], 650[1], 675[1], 700[1], 725[1], 750[1], 775[1], 800[1], 825[1], 850[1], 875[1], 900[1], 925[1], 950[1], 955, 965, 975[1], 1000[1], 1025[1], 1050[1], 1075[1], 1100[1], 1125[1], 1150[1], 1165, 1170, 1175[1], 1200, 1225[1], 1250[1], 1275[1], 1300[1], 1325[1], 1335, 1345, 1350[1], 1355, 1365, 1400[1], 1425[1], 1450[1], 1475[1], 1500[1], 1525[1], 1550[1], 1575[1], 1600[1], 1625[1], 1650[1], 1660[1], 1670, 1675[1], 1700[1], 1725[1], 1750[1], 1775[1], 1800[1], 1825[1], 1850[1], 1875[1], 1900[1], 1925[1], 1950[1], 1975[1], 2000[1], 2025[1], 2050[1], 2075[1], 2100[1], 2102, 2105[1], 2110[1], 2125[1], 2150[1]	December 16, 2008	December 16, 2008	December 16, 2008
TATUM, TOWN OF	350032	440, 445, 625[1]	June 21, 1974	July 1, 1988	December 16, 2008

[1] PANEL NOT PRINTED - ALL ZONE D



* PANEL NOT PRINTED - AREA IN ZONE D



Inset map and table extracted from the 12/16/2008 FEMA Floodplain Map Index sheet for Lea County, New Mexico (Map No. 35025CIND0A)

FEMA FLOODPLAIN MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

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DATE: 1/14/10	CAD: Figure IV.1.5.doc	PROJECT #: 530.01.01
DRAWN BY: PG	REVIEWED BY: DRT	FIGURE IV.1.5
APPROVED BY: IKG	gei@gordonenvironmental.com	

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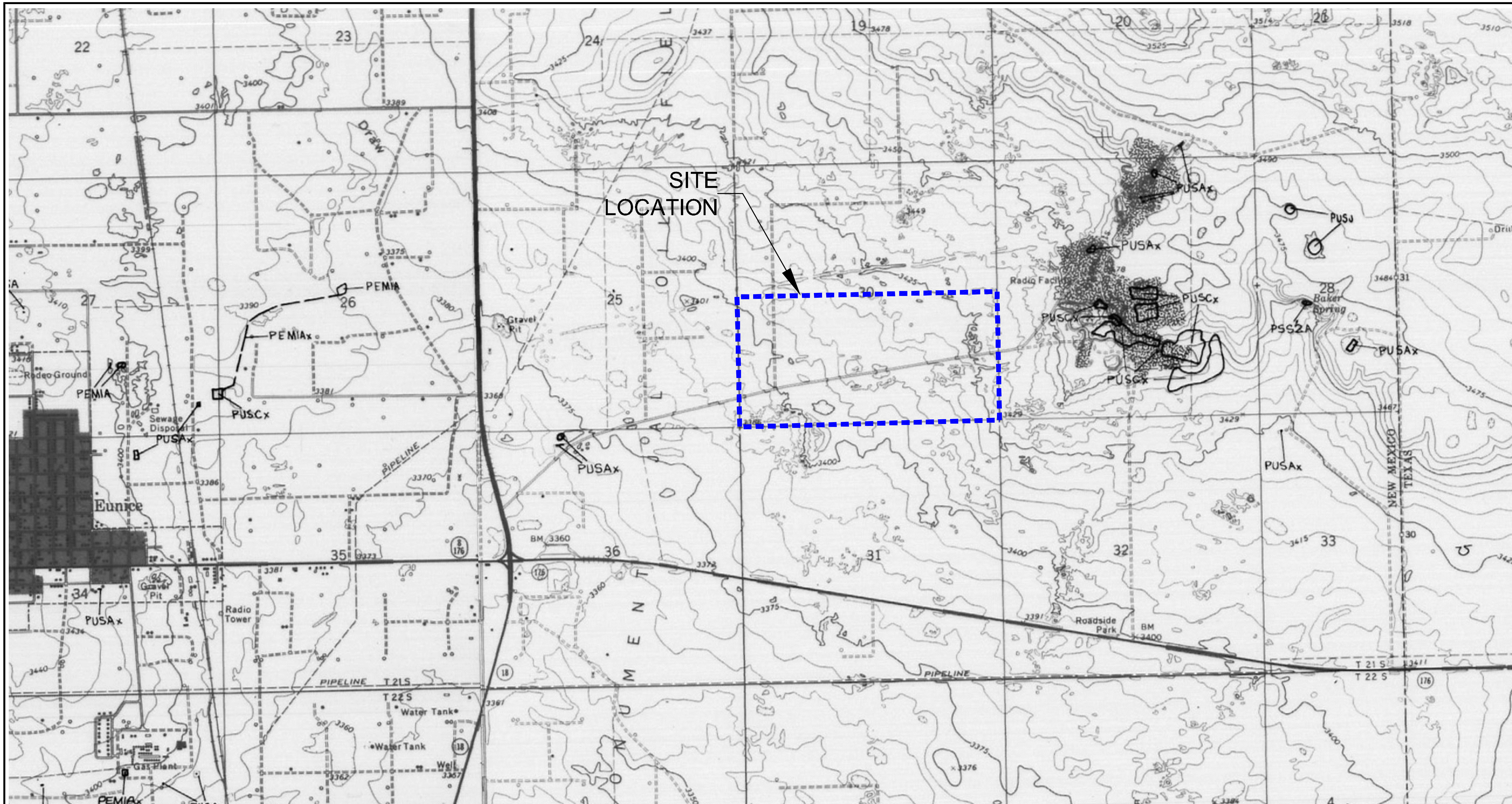

LEGEND

SITE BOUNDARY

MAP BASE:
EUNICE NE, TEX.-N. MEX. ,1:24000, 1980 NATIONAL WETLANDS INVENTORY MAP, U.S. DEPT. OF THE INTERIOR, FISH AND WILDLIFE SERVICES.

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PEM1A: P_EM1____A____________
[P] Palustrine, [EM] Emergent, [1] Persistent, [A] Temporarily Flooded

PUSAx: P_US_____A____x________
[P] Palustrine, [US] Unconsolidated Shore, [A] Temporarily Flooded, [x] Excavated

PUSCx: P_US_____C____x________
[P] Palustrine, [US] Unconsolidated Shore, [C] Seasonally Flooded, [x] Excavated

PUSJ: P_US_____J____________
[P] Palustrine, [US] Unconsolidated Shore, [J] Intermittently Flooded

PSS2A: P_SS2____A____________
[P] Palustrine, [SS] Scrub-Shrub, [2] Needle-Leaved Deciduous, [A] Temporarily Flooded

NORTH

0 1000' 2000'

NATIONAL WETLANDS INVENTORY MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
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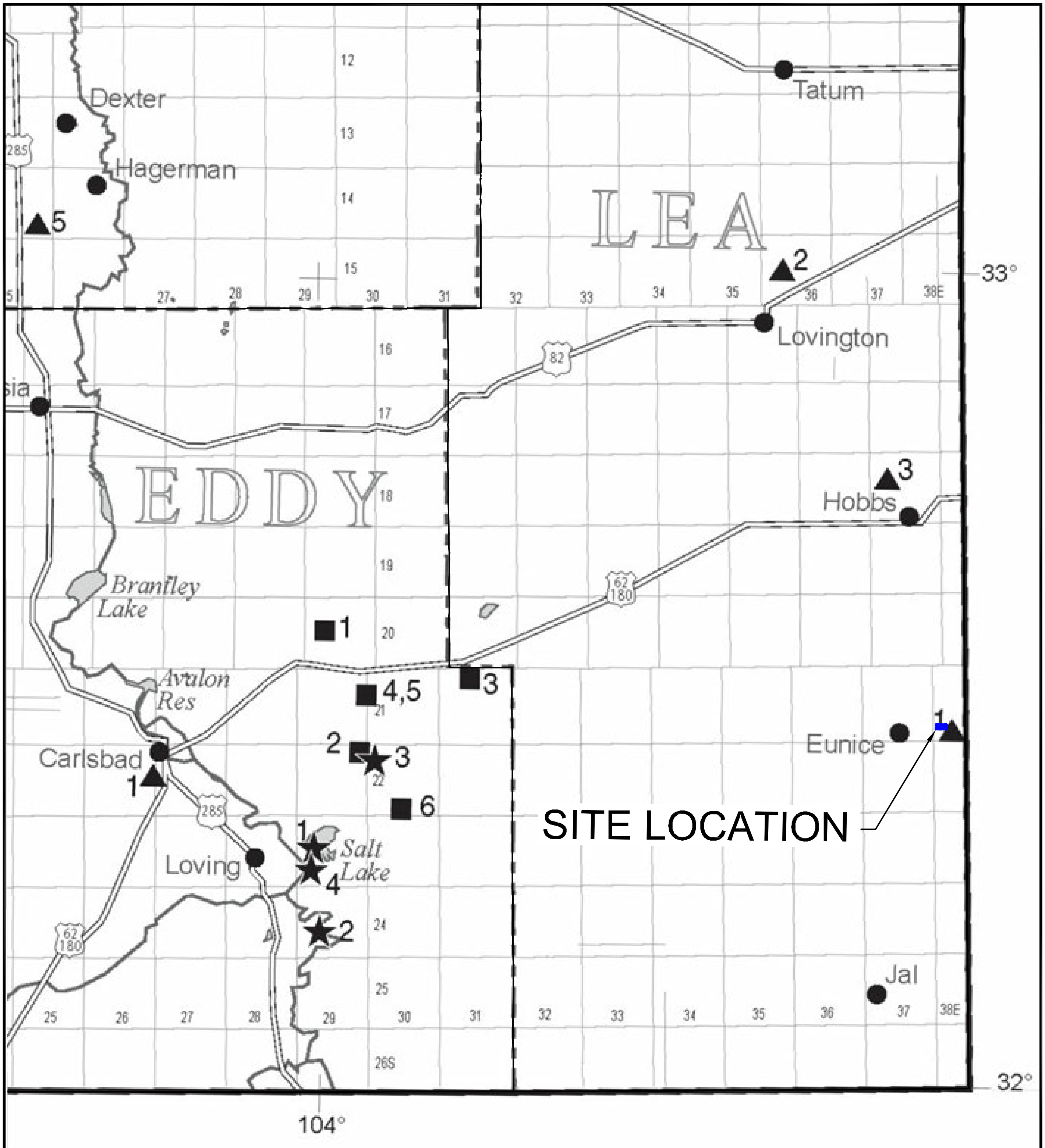
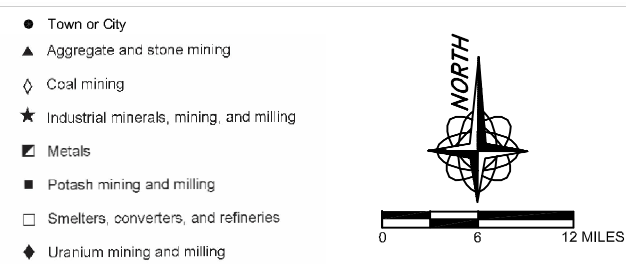
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/05/2015	CAD: WETLANDS.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.6
APPROVED BY: IKG	gei@gordonenvironmental.com	





Drawing:P:\acad 2003\530.06.01\PERMIT FIGURES\MINES.dwg
Date/Time:Jan. 05, 2015-08:02:57

MINES, MILLS AND QUARRIES MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/05/2015	CAD: MINES.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.7
APPROVED BY: IKG	gei@gordonenvironmental.com	

NAIP 2011 COLOR MOSAIC OF LEA COUNTY
SOURCE:
Earth Data Analysis Center
University of New Mexico, Albuquerque, NM
RGIS FTP SITE

NORTH

0' 2500' 5000'

Drawing:P:\acad 2003\530.06.01\PERMIT FIGURES\AERIAL 2011.dwg
Date/Time:Jan. 05, 2015-07:58:03

AERIAL PHOTOGRAPH–LAND USE MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
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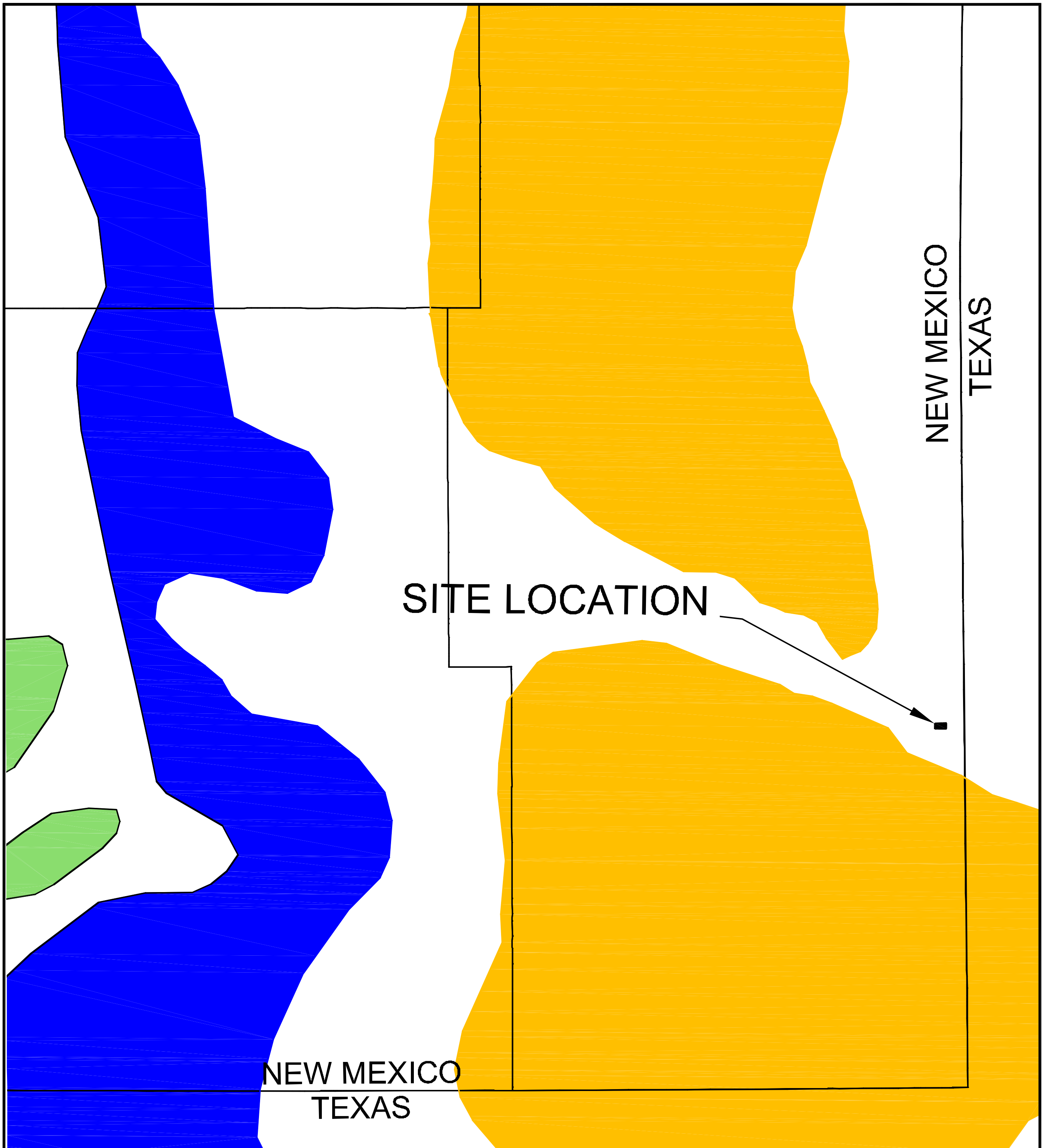
DATE: 01/05/2015	CAD: AERIAL 2011.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.8
APPROVED BY: IKG	gei@gordonenvironmental.com	



LEGEND

- Fissures and voids present to a depth of 250 ft (75 m) or more in areas of subsidence from piping in thick, unconsolidated material.
- Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in gently dipping to flat-lying beds of carbonate rock.
- Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in gently dipping to flat-lying beds of gypsum.

NORTH

0 6 12 MILES

Drawing:P:\acad 2003\530.06.01\PERMIT FIGURES\KARST.dwg
Date/Time:Jan. 05, 2015-07:55:37

KARST DATA FROM:digital version of U.S. Geological Survey Open FileReport 2004-1352, Engineering Aspects of Karst. NATIONAL ATLAS GIS DATA.

KARST TERRAINS MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

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Bernalillo, New Mexico, USA
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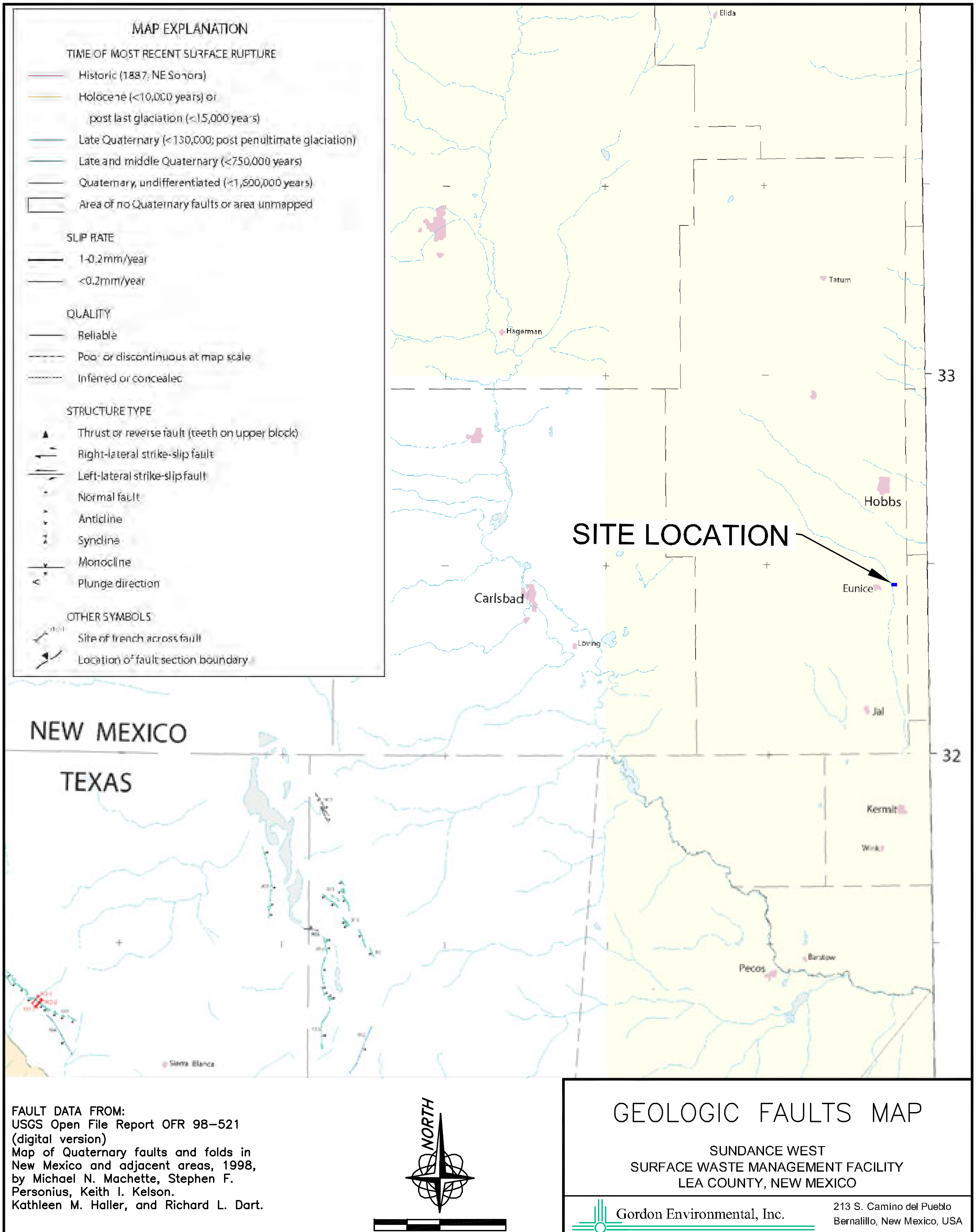
Fax: 505-867-6991

DATE: 01/05/2015	CAD: KARST.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.9
APPROVED BY: IKG	gei@gordonenvironmental.com	



FAULT DATA FROM:
USGS Open File Report OFR 98-521 (digital version)
Map of Quaternary faults and folds in New Mexico and adjacent areas, 1998, by Michael N. Machette, Stephen F. Personius, Keith I. Kelson. Kathleen M. Haller, and Richard L. Dart.

GEOLOGIC FAULTS MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

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Bernalillo, New Mexico, USA
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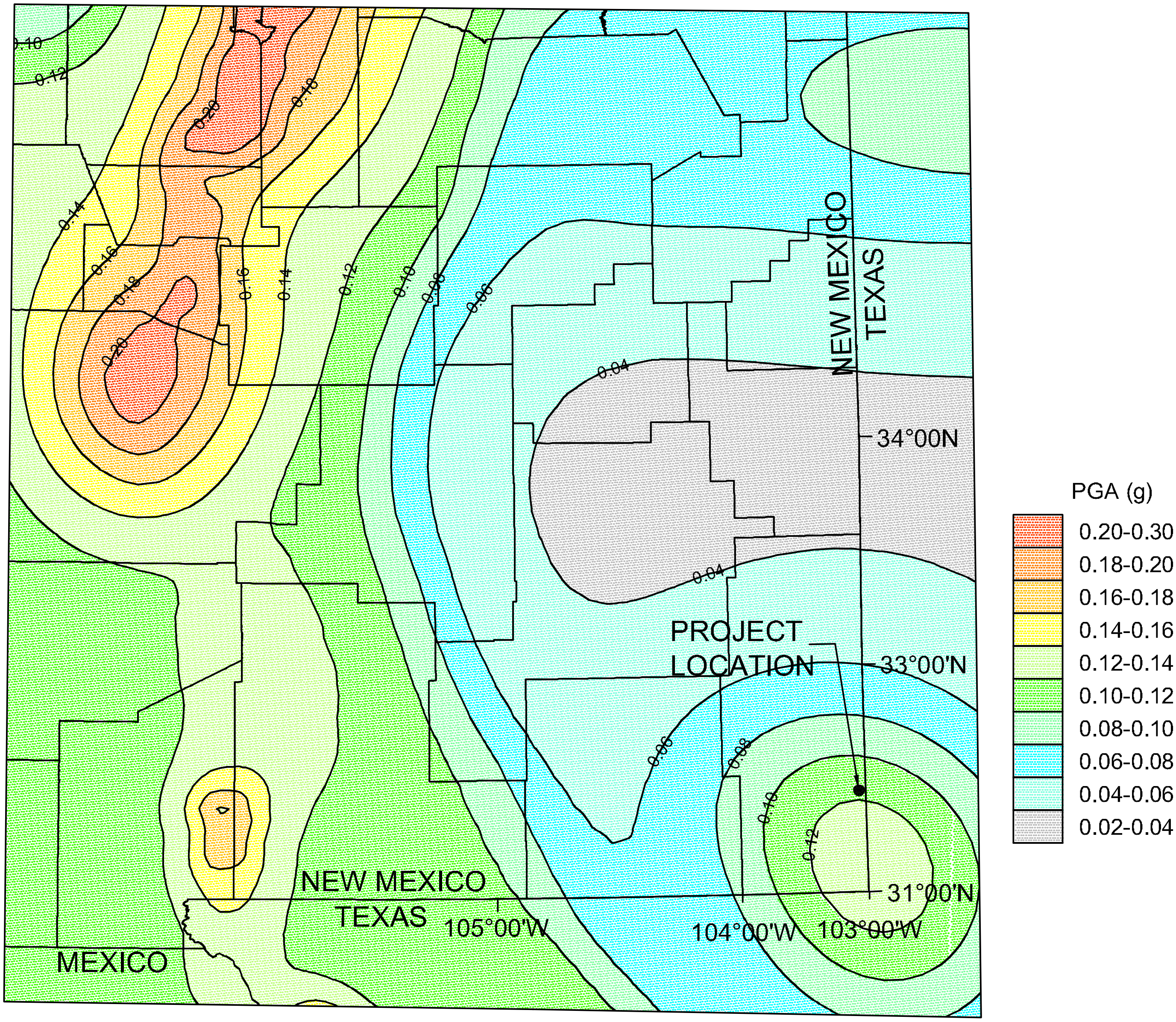
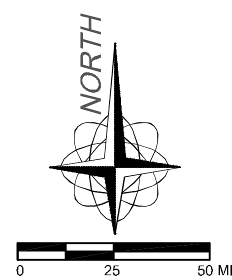
Fax: 505-867-6991

DATE: 01/05/2015	CAD: FAULTS.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: DRT	FIGURE IV.1.10
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.06.01\PERMIT FIGURES\FAULTS.dwg
Date/Time:Jan. 05, 2015-07:53:51



Peak Horizontal Ground Acceleration (g) with 10% Probability of Exceedance in 250 Years



SEISMIC DATA FROM: USGS NATIONAL HAZARD MAPPING PROJECT GIS DATA and Petersen, Mark D., Frankel, Arthur D., Harmsen, Stephen C., Mueller, Charles S., Haller, Kathleen M., Wheeler, Russell L., Wesson, Robert L., Zeng, Yuehua, Boyd, Oliver S., Perkins, David M., Luco, Nicolas, Field, Edward H., Wills, Chris J., and Rukstales, Kenneth S., 2008, Documentation for the 2008 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008-1128, 61

SEISMIC IMPACT ZONE MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

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Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
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Fax: 505-867-6991

DATE: 01/07/2015	CAD: SEISMIC 2008 DATA.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: MRH	FIGURE IV.1.11
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.06.01\PERMIT FIGURES\SEISMIC 2008 DATA.dwg
Date/Time:Jan. 08, 2015-12:49:00

APPLICATION FOR PERMIT
SUNDANCE WEST

VOLUME IV: SITING AND HYDROGEOLOGY
SECTION 2: HYDROGEOLOGY

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LIST OF ATTACHMENTS

APPLICATION FOR PERMIT
SUNDANCE WEST

VOLUME IV: SITING AND HYDROGEOLOGY
SECTION 2: HYDROGEOLOGY

1.0 INTRODUCTION

1.1 Facility Information

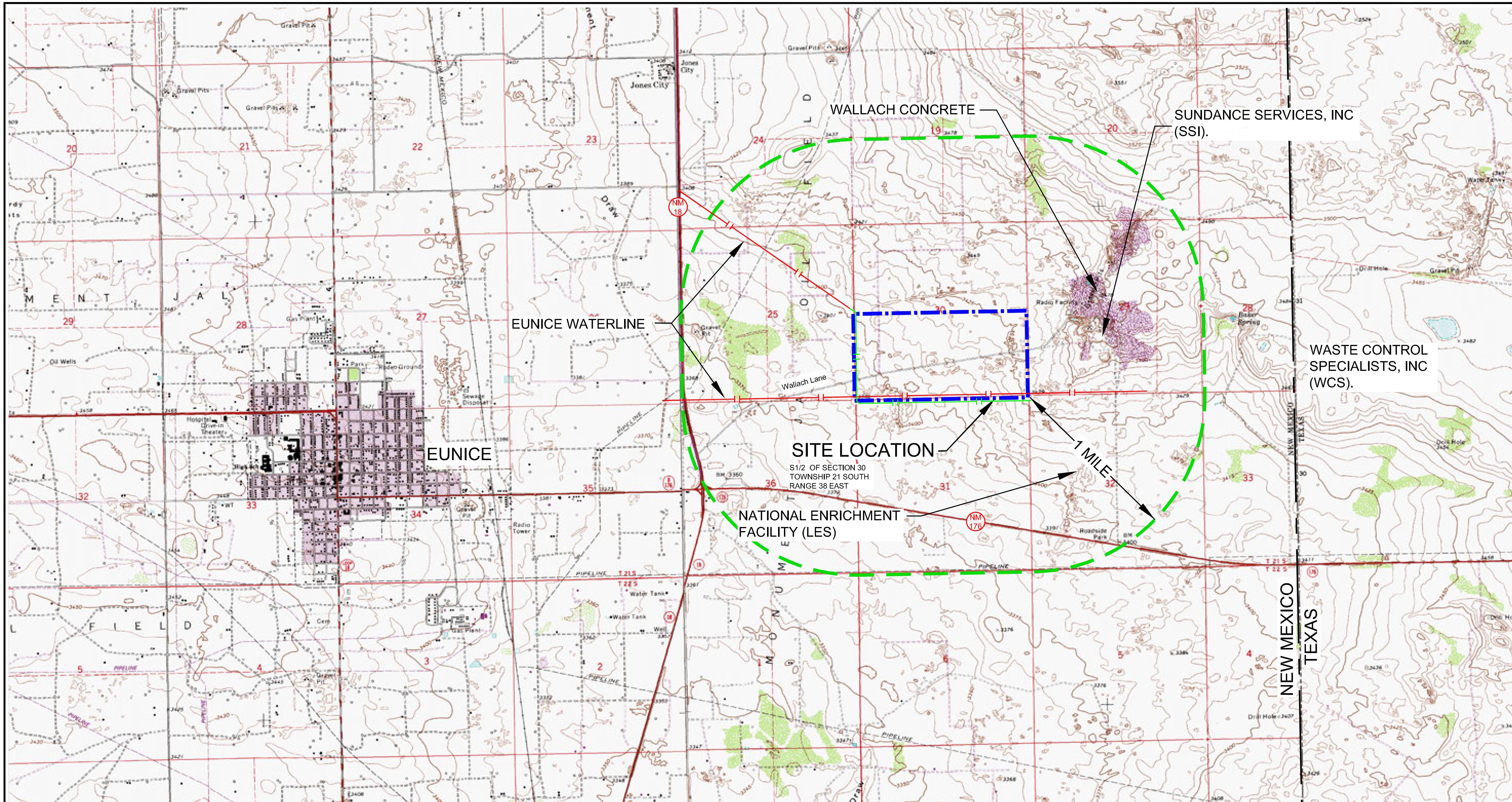
The proposed new commercial Surface Waste Management Facility (Sundance West Facility or Facility) is located approximately 3 miles east of Eunice and 18 miles south of Hobbs, in unincorporated Lea County, New Mexico (NM). The Sundance West Site will comprise approximately 320 acres, encompassing the South ½ of Section 30, Township 21 South, Range 38 East of the New Mexico Prime Meridian (**Figure IV.2.1**). The Sundance West Facility will be accessible via NM 18 and Wallach Lane. The Facility will be owned and operated by Sundance West, Inc. and will provide oil field waste processing and disposal services. Oil field waste will be delivered to Sundance West from southeast New Mexico and west Texas oil and gas production areas.

1.2 Purpose and Scope

This section of the Application, (**Volume IV.2**, Hydrogeology) provides geological and hydrological data for the proposed Sundance West Site as required per 19.15.36.8.C.15 NMAC. Hydrogeology also addresses the siting requirements related to depth to groundwater (19.15.36.13.A NMAC) beneath the proposed Facility.

1.3 Location and Site Conditions

A United States Geological Survey (USGS) Map which identifies the Sundance West Site location is provided as **Figure IV.2.1**. In addition, a Vicinity Map (**Figure IV.2.2**) shows the location of the proposed Sundance West Facility with respect to other local facilities [e.g., Waste Control Specialists (WCS), Lea County Landfill (LCLF), and Louisiana Energy Services (LES) National Enrichment Facility (NEF)] which have been the subject of extensive siting investigations. The proposed Sundance West Facility is located on



Based on Eunice NE, TX.- NM (1969) Photorevised (1979);
Eunice, NM (1969) Photorevised (1978);
Quadrangles, USGS 7.5' SERIES (1:24,000 Scale)

NOTE:
NO STREAMS, SPRINGS OR WATER COURSES WITHIN
1/2 MILE OF SITE

NORTH

0 1500' 3000'

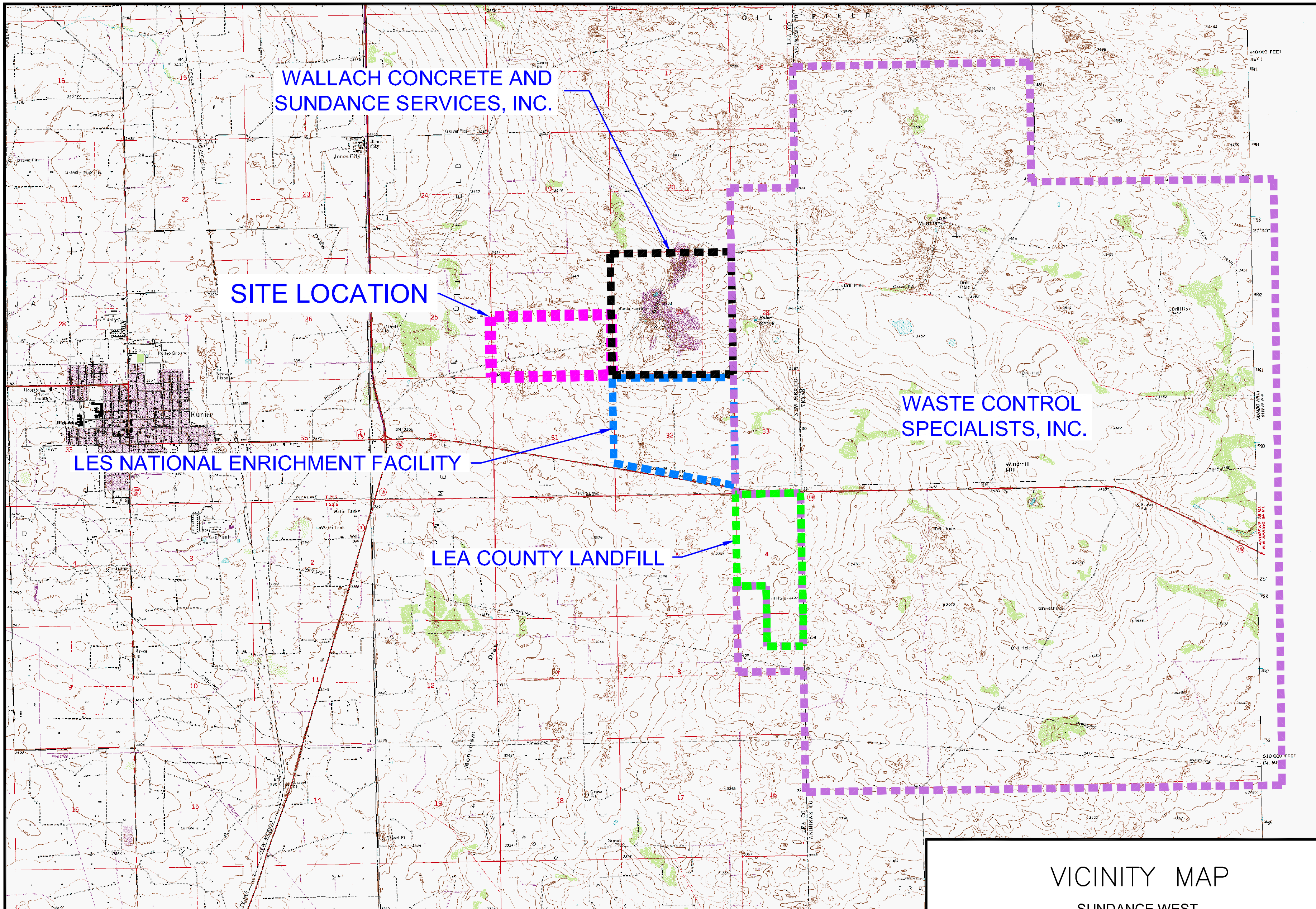
Drawing:P:\acad 2003\530.06.01\REVISED FIGURES(RAI 1)\SITE LOC REVISED 11 x17.dwg
Date/Time:Aug. 10, 2016-08:32:56 ; LAYOUT: B (LS)

SITE LOCATION MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 07/22/2016	CAD: DWG NAME.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: CWF	FIGURE IV.2.1
APPROVED BY: IKG	gei@gordonenvironmental.com	



MAP BASE:
EUNICE N. MEX. 1969, PHOTOREVISED 1979 AND
EUNICE NE, TEX.-N. MEX. 1969, PHOTOREVISED 1979,
1:24000, USGS 7.5 MIN. SERIES TOPOGRAPHIC QUADRANGLES

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\VICINITY MAP GIS.dwg
Date/Time:Jan. 19, 2010-14:06:13

VICINITY MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
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Fax: 505-867-6991

DATE: 01/11/2010	CAD: VICINITY MAP GIS.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: DRT	FIGURE IV.2.2
APPROVED BY: IKG	gei@gordonenvironmental.com	

undeveloped land immediately west of current Sundance Services, Inc. operations, and is otherwise surrounded by vacant land. Oil and gas exploration and extraction activities are not currently conducted on-site, but are concentrated to the west of the Site (**Figure IV.2.3**).

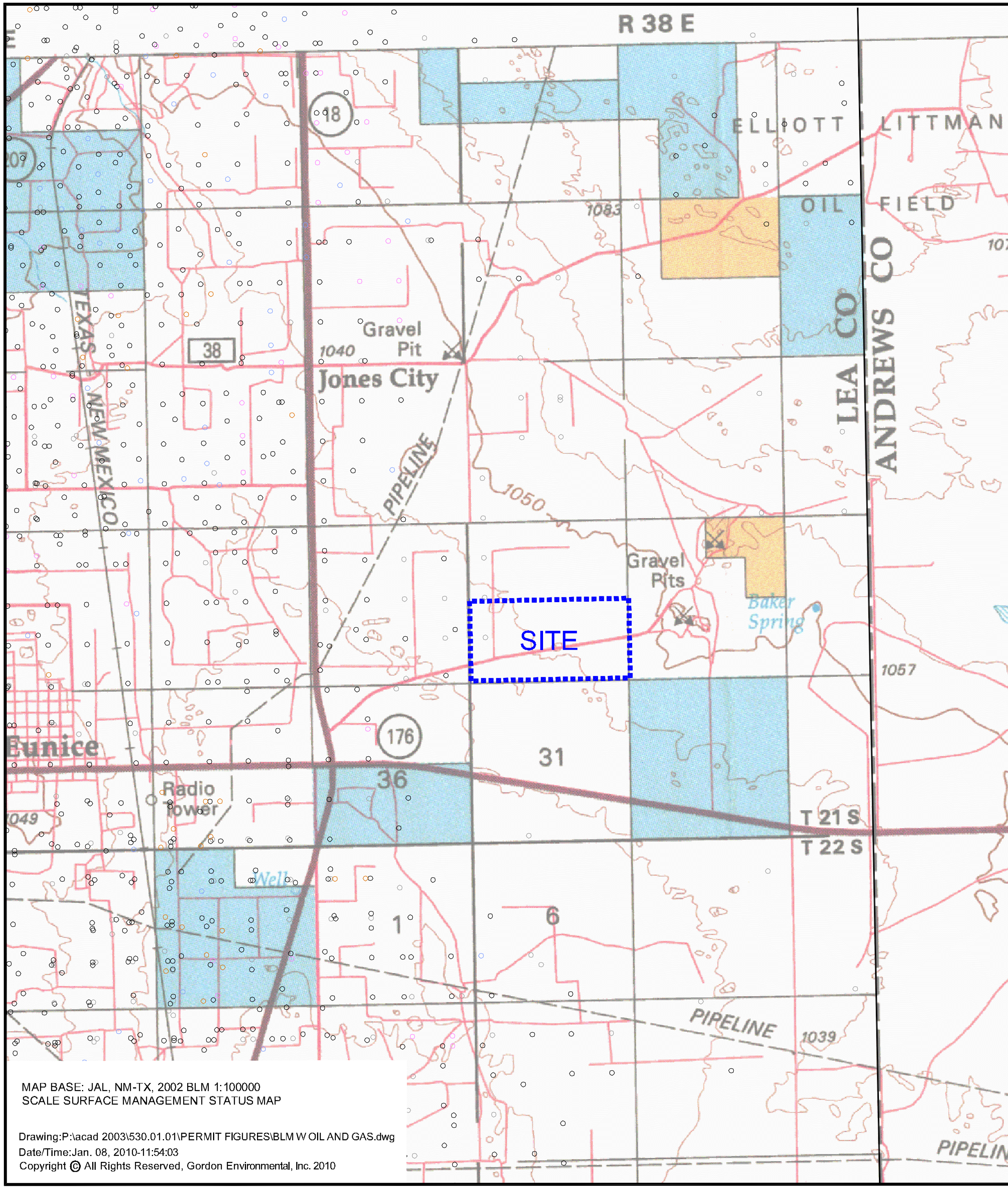
Existing Site conditions have been documented via aerial photogrammetry; and a Site topograph is provided as **Figure IV.2.4**. Also included on **Figure IV.2.4** are the locations of borings, coreholes, wells, and the Landfill footprint of 126 acres ± on the 320 acre ± Site. There is an existing right-of-way for a 14-inch diameter water supply line shown on **Figure IV.2.4** that provides water from Eunice to the LES project that will be relocated in the future.

1.4 Streams, Springs, Watercourses and Water Wells

In conformance with 19.15.36.8.C.15(a) NMAC, **Figure IV.2.5** is a map which identifies the locations of streams, springs, water courses, and water wells within a one-mile radius of the proposed Site.

The Pecos River is the only perennial stream in the area and it lies about 56 miles southwest of the Site. According to Nicholson and Clebsch (1961) there is no integrated drainage in southern Lea County, hence there is no through-going drainage to the Pecos River, which is west and south of the area. All watercourses in southern Lea County are ephemeral, the longest one being Monument Draw, which is about 35 miles long following a north-south direction west of the Site towards the Pecos River in Texas. Monument Draw is the only watercourse within one mile of the Site.

There are no domestic wells registered within the Site according to the New Mexico Office of the State Engineer's May, 2009 water well database. A total of four non-domestic wells and one domestic well are within the one-mile radius as shown in **Figure IV.2.5**. There are no springs within one mile of the Site.



MAP BASE: JAL, NM-TX, 2002 BLM 1:100000
SCALE SURFACE MANAGEMENT STATUS MAP

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\BLM W OIL AND GAS.dwg
Date/Time:Jan. 08, 2010-11:54:03

LEGEND

- PUBLIC LANDS (ADMIN BY BLM)
- STATE LANDS
- PRIVATE LANDS
- OIL/GAS WELL (ACTIVE)
- OIL/GAS WELL (NEW OR NOT COMPLETED)
- OIL/GAS WELL (NEVER DRILLED)
- OIL/GAS WELL (PLUGGED)
- OIL/GAS WELL (ZONE PLUGGED)
- OIL/GAS WELL (DRY HOLE)
- OIL/GAS WELL (STATUS UNKNOWN)
- OIL/GAS WELL (TEMPORARILY ABANDONED)
- SUNDANCE WEST FACILITY BOUNDARY

OIL WELL DATA FROM:
GO-TECH PETROLEUM WEB (OCTANE.NMT.EDU\GOTECH)
PERMIAN BASIN DATABASE UPDATED 05-09-2008
NOTE: ONLY OIL/GAS WELLS WITHIN NEW MEXICO ARE SHOWN

NORTH

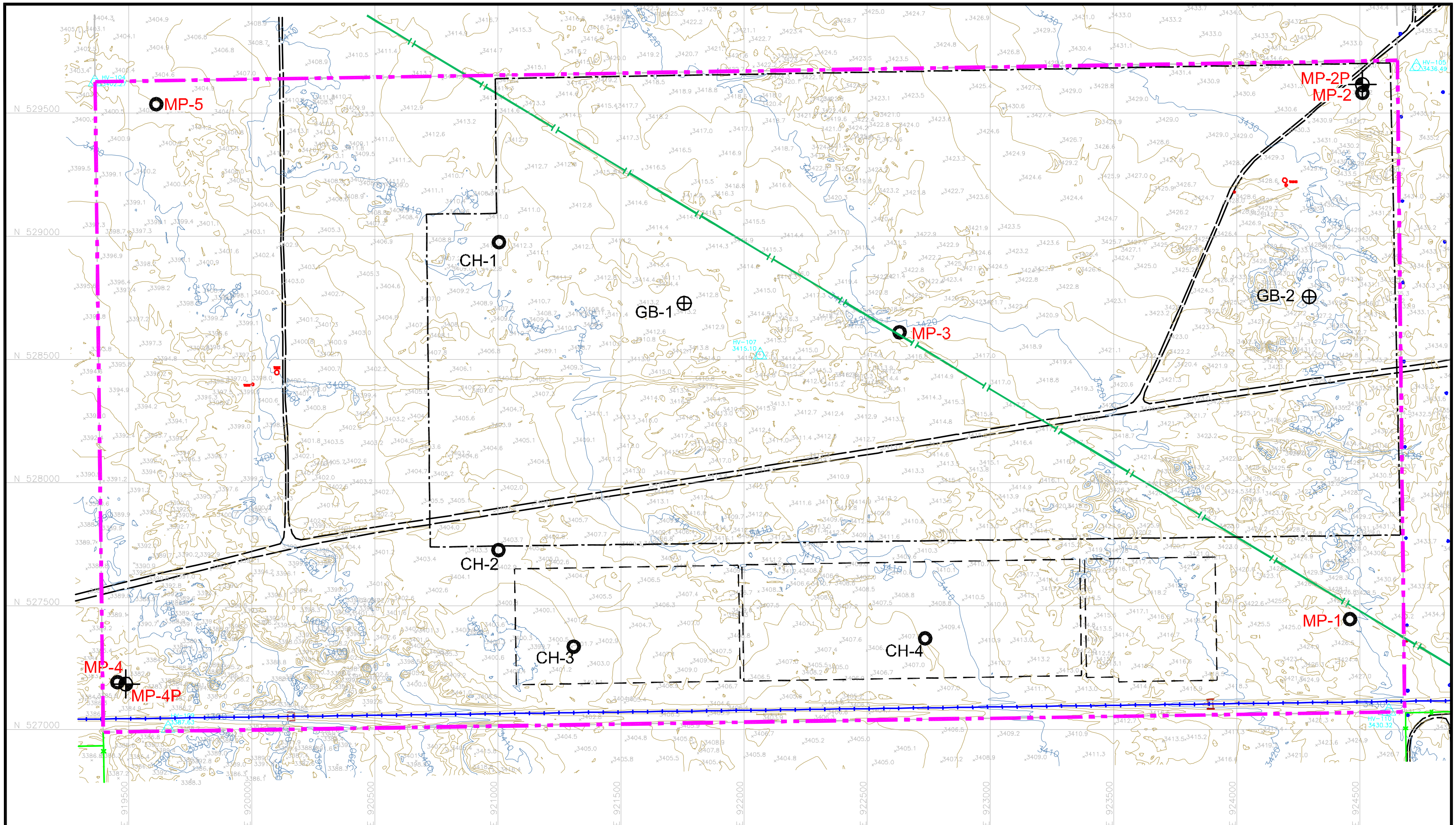
0' 2500' 5000'

BLM LAND STATUS MAP WITH OIL/GAS WELLS

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/08/2010	CAD: BML W OIL AND GAS.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: IKG	FIGURE IV.2.3
APPROVED BY: IKG	gei@gordonenvironmental.com	



LEGEND

	LANDFILL BOUNDARY
	PROCESS AREA BOUNDARY
	FENCE
	SECTION, 1/4 SECTION LINE
	UNPAVED ROAD
	POWER POLE
	MISC./UNIDENTIFIED OBJECT
	RAILROAD TRACK
	BOX CULVERT
	STORAGE TANK
	CONCRETE SLAB
	EXISTING WATER SUPPLY PIPELINE
× 5835.1	SPOT ELEVATION
	INTERMEDIATE CONTOUR
3460	INDEX CONTOUR
	INTERMEDIATE DEPRESSION
3440	INDEX DEPRESSION
	FACILITY BOUNDARY
	CONTROL POINT
N 529000	GRID LINE/LABEL
GB-1	GEOTECHNICAL BOREHOLE LOCATION (PLUGGED)
CH-1	COREHOLE LOCATION (PLUGGED)
MP-1	BOREHOLE LOCATION (PLUGGED)
MP-2P	MONITORING WELL LOCATION

NORTH

0' 300' 600'

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\MP BOREHOLES W GEOTECH BORINGS.dwg

Date/Time:Jan. 19, 2010-14:10:24

AERIAL SURVEY BY THOMAS R. MANN & ASSOCIATES
AERIAL MAPPING SERVICES
5115 COPPER NE, ALBUQUERQUE, NM 87108
DATE OF PHOTOGRAPHY 10-01-08

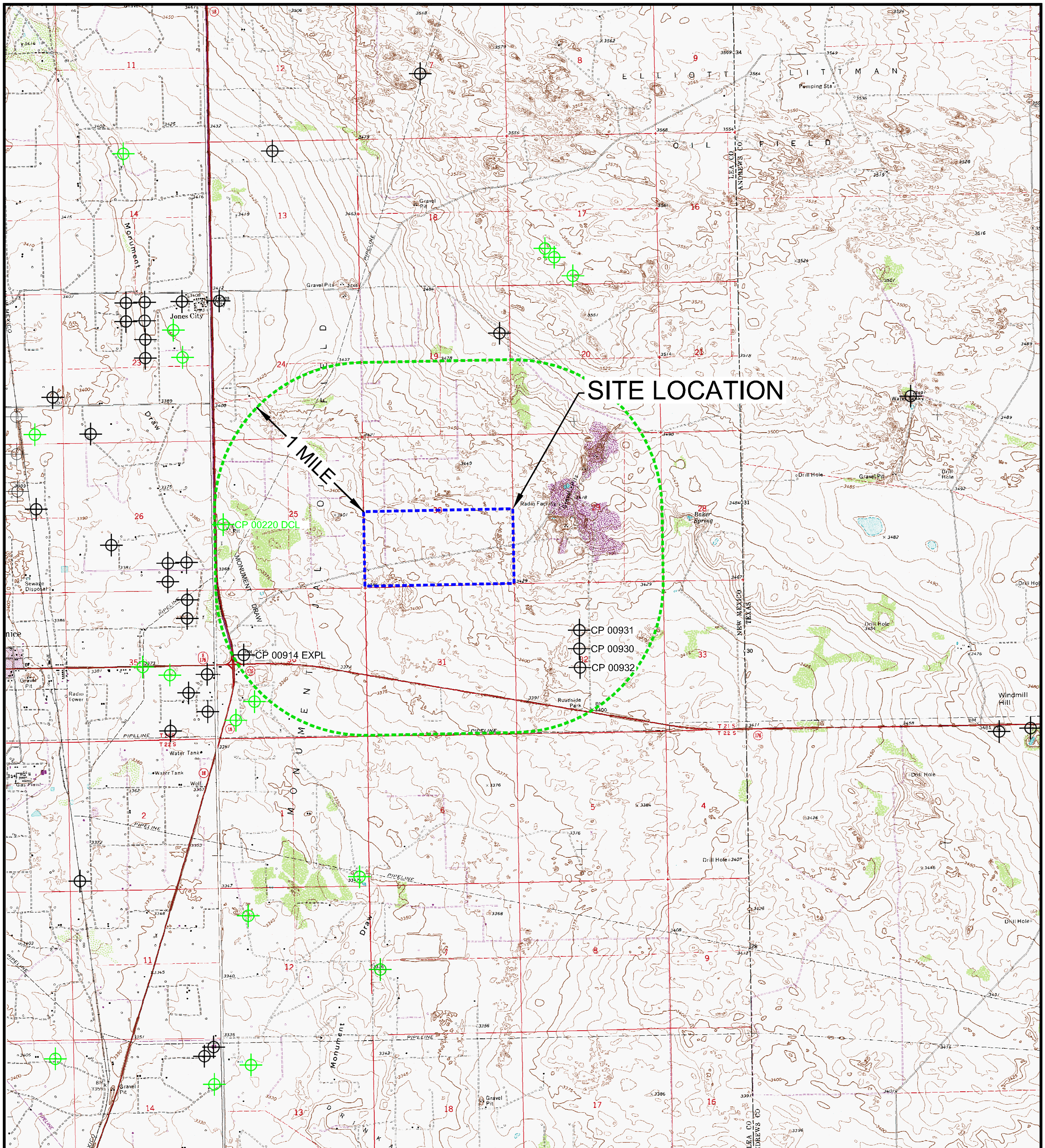
SITE TOPOGRAPHY AND LOCATIONS OF COREHOLES, BOREHOLES AND WELLS

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers

213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/19/2010	CAD: MP BOREHOLES W GEOTECH BORINGS.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: IKG	FIGURE IV.2.4
APPROVED BY: IKG	gei@gordonenvironmental.com	



LEGEND

WELL NUMBER — DOMESTIC WATER WELL SHOWING 200' RADIUS

WELL NUMBER — OTHER USE WATER WELL (INDUSTRIAL, EXPLORATION, MONITORING, OR LIVESTOCK WATERING WELL SHOWING 200' RADIUS)

WATER WELL DATA FROM NMOSE 2008 GIS DATABASE AND TWDB GIS DATABASE.

MAP BASE: EUNICE NE, TEX.-N. MEX. 1969, PHOTOREVISED 1979, 1:24000, USGS 7.5 MIN. SERIES TOPOGRAPHIC QUADRANGLE

Drawing:P:\acad 2003\530.06.01\REVISED FIGURES(RAI 1)\WATER COURSE-WW.dwg
Date/Time:Jul. 19, 2016-07:33:34

NORTH

0' 2500' 5000'

WATERCOURSE AND WATER WELL MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 07/11/2016	CAD: WATER COURSE-WW.dwg	PROJECT #: 530.06.01
DRAWN BY: DMI	REVIEWED BY: CWF	FIGURE IV.2.5
APPROVED BY: IKG	gei@gordonenvironmental.com	

2.0 REGIONAL GEOLOGY AND HYDROLOGY

The regional geology and hydrogeology in the vicinity of the Site has been studied extensively in conjunction with permitting and licensing of nearby waste disposal facilities including the WCS Site, LCLF, and LES NEF, which are located immediately to the southeast of the proposed Sundance West Site. These facilities, subject to intense geologic and hydrogeologic investigations, are identified on the Vicinity map provided as **Figure IV.2.2**.

2.1 Climate

The proposed Site is located approximately 3 miles east of Eunice in southeastern New Mexico. The nearest weather station is located 19 miles north of Eunice at the Hobbs FAA Airport. A climate summary for the Hobbs FAA Airport station is provided in **Table IV.2.1**. The climate is hot during summer when daytime temperatures are typically in the upper 80's and 90's; and cool to cold during winter when temperatures tend to be in the 50's and 60's. The warmest month of the year is July with an average maximum temperature of 93.6 degrees Fahrenheit (°F), while the coldest month of the year is January with an average minimum temperature of 27.9 °F. Temperature variations between night and day are typically moderate during summer with a difference that can reach 27 °F, and relatively large during winter with an average difference of more than 30 °F. The annual average precipitation at Hobbs is 12.35 inches (in.). The majority of the precipitation falls between April and October. The wettest month of the year is September with an average rainfall of 2.09 in.

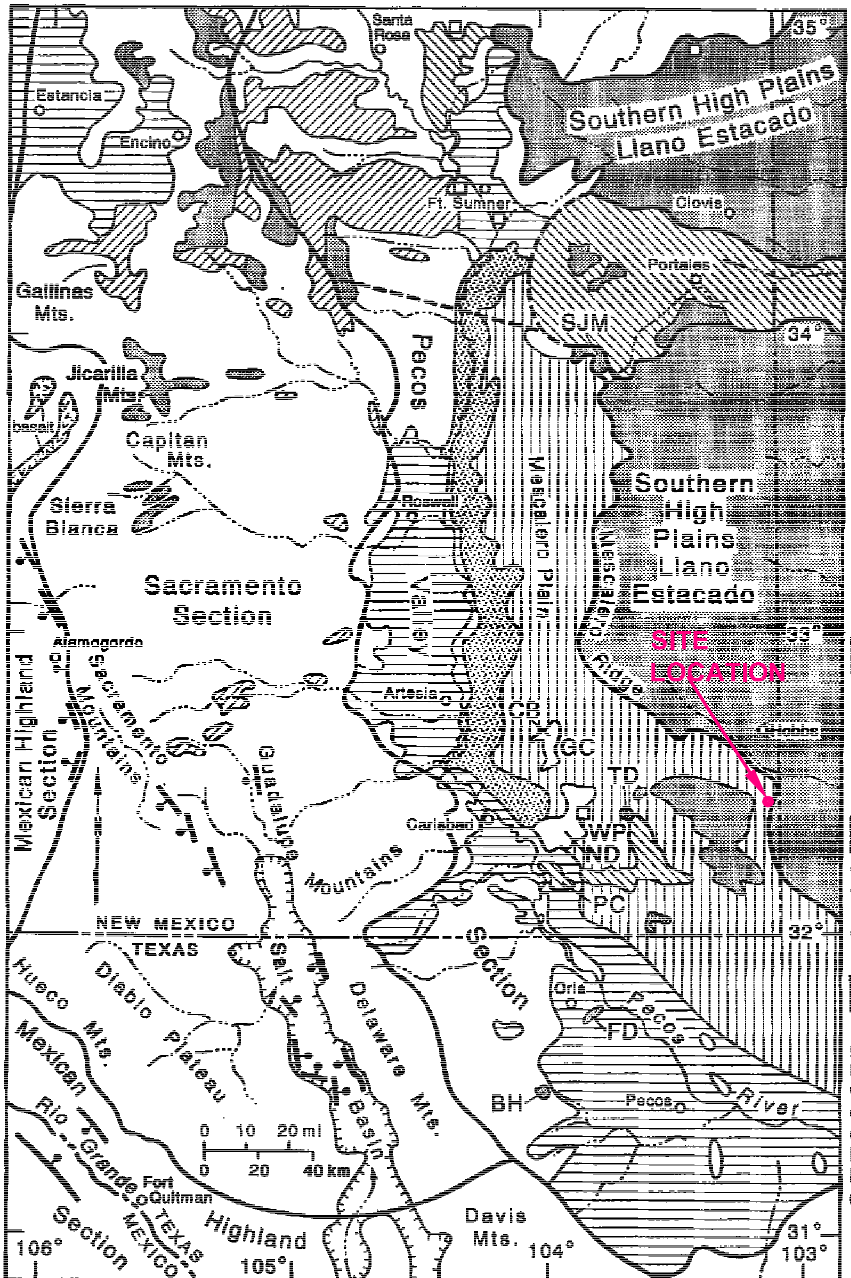
2.2 Physiographic Setting

The proposed Site lies near the boundary between the Southern High Plains Section (Llano Estacado) and the Pecos Valley Section of the Great Plains Physiographic Province (Hawley 1993b; **Figure IV.2.6**). The physiographic province is characterized by mildly deformed Triassic and Permian sedimentary rocks capped by the late Miocene-Pliocene Ogallala Formation (Hawley 1993b). The local Site region is underlain primarily by the Late Tertiary/Quaternary-aged pedogenic caprock caliche that developed on all pre-Quaternary

TABLE IV.2.1
Sundance West
Climate Summary for Hobbs FAA Airport, New Mexico

Averages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum Temp (ºF)	56.4	60.9	66.6	74.5	83.9	93.1	93.6	92.7	86.3	75.7	64.2	59.1	**75.6**
Minimum Temp (ºF)	27.9	30.3	35.5	44.3	53.8	63.9	66.5	65.2	57.8	48.0	33.9	28.8	**46.3**
Total Precip (in)	0.40	0.33	0.32	0.91	1.98	0.87	1.56	1.74	2.09	1.79	0.22	0.14	**12.35**
Total Snowfall (in)	1.5	2.7	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	**6.7**
Snow Depth (in)	0	0	0	0	0	0	0	0	0	0	0	0	**0**

Source: Western Regional Climate Center, www.wrcc@dri.edu
Station 294028: Hobbs FAA Airport, New Mexico
Period of Record: September 1, 1941 – July 31, 2006



Explanation

Undivided valley fill and Permian bedrock units in Fort Sumner to Carlsbad segment of the Pecos Valley; complex of valley-floor alluvium, terrace deposits and solution-subsidence depression fills (Pliocene–Quaternary), including "upper" Gatuña Formation, with extensive exposures of Dewey Lake–Quartermaster (Ochoan), residual Salado–Rustler (Ochoan), and Artesia Group (Guadalupian) rocks.

Undivided valley and basin fill of the Estancia and Roswell–Artesia basins, and Carlsbad–Pecos segment of the lower Pecos Valley (Delaware basin); complex of fluvial and eolian deposits, and undifferentiated fills of solution-subsidence depressions (Middle Miocene–Quaternary); includes Ogallala and Gatuña Formations, "quartzose and limestone conglomerates", and younger valley fill. Outcrops of Triassic and Permian rocks are locally extensive, and small exposures of Precambrian rocks are present on the Pedernal uplift.

Older surficial sediments of the Mescalero Plain and eastern border of the lower Pecos Valley; complex of eolian, fluvial and depression-fill deposits and pedogenic calcretes (Pliocene to Middle Pleistocene) inset below the High Plains (Llano Estacado) surface and the Ogallala caprock calcrete zone; primarily "upper" Gatuña Formation with Quaternary eolian cover, but includes exposures of "lower" Gatuña–Ogallala, and Triassic and upper Permian rocks in solution-subsidence depressions and tributary valleys.

Older piedmont and valley-fill alluvium, and karst-depression fills on upland erosion surfaces of the upper Pecos Valley and Sacramento sections; coarse gravelly to sandy deposits and pedogenic calcretes (late Miocene to early Pleistocene); includes undivided Ogallala and Gatuña Formations, exposures of Precambrian, upper Paleozoic, and Triassic rocks, and discontinuous cover of younger Quaternary alluvial and eolian deposits.

Older fills of the Portales, and upper and lower Pecos Valley segments; complex of fluvial and eolian deposits, calcretes, and solution-subsidence depression fills (middle Miocene to Quaternary); includes Ogallala and "lower" and "upper" Gatuña Formations, and overlying eolian cover sediments correlative with the Blackwater Draw Formation of the Llano Estacado.

Ogallala Formation (middle Miocene to early Pliocene); thick complex of eolian, fluvial, and minor lacustrine deposits (sand, silt, clay, with local gravelly facies), and caprock calcrete zones east of the Pecos Valley; and thin gravelly to sandy alluvial deposits, with calcrete zones, capping upland valley and piedmont erosion surfaces west of the Pecos. Includes 1) extensive cover of Plio–Pleistocene eolian sediments (Blackwater Draw Formation) on the Southern High Plains (Llano Estacado), and 2) Pliocene–Quaternary alluvium, eolian deposits and karst depression fills west of the High Plains.

□ Early to middle Pleistocene ash-fall deposits derived from Jemez and Yellowstone volcanic centers.

Quaternary fault zones.

Physiographic section boundaries.

Index map of southeastern New Mexico region showing location of major physiographic subdivisions and general distribution patterns of upper Cenozoic deposits that include the Ogallala and Gatuña Formations or their correlatives. Occurrences of Plio-Pleistocene volcanic ashes and zones of known Quaternary faults are also shown. BH = Burnt Hills (TX), CB = Clayton Basin (NM), FD = Fourmile Draw (TX), GC = Gatuña Canyon (NM), ND = Nash Draw (NM), PC = Pierce Canyon (NM), TD = The Divide, SJM = San Juan Mesa (NM) and WP = WIPP site.

FROM: HAWLEY, 1993b,FIGURE 1, P. 262

NORTH

0' 22 44 MILES

GEOMORPHIC–PHYSIOGRAPHIC MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/08/2010	CAD: GEOMORPHIC.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.6
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\GEOMORPHIC.dwg
Date/Time:Jan. 19, 2010-14:14:31

formations on the southern High Plains. Young windblown sands of the Blackwater Draw Formation (BDF) overlie the caprock caliche. Unconsolidated to semi-consolidated sands and gravels of the Ogallala, Antlers, and Gatuña Formations (locally referred to as OAG) lie between the caprock and underlying red beds of the Dockum Group (Chinle Group) (Cook-Joyce, Inc et. al., 2007, Page 2-10; Hawley, 1993b).

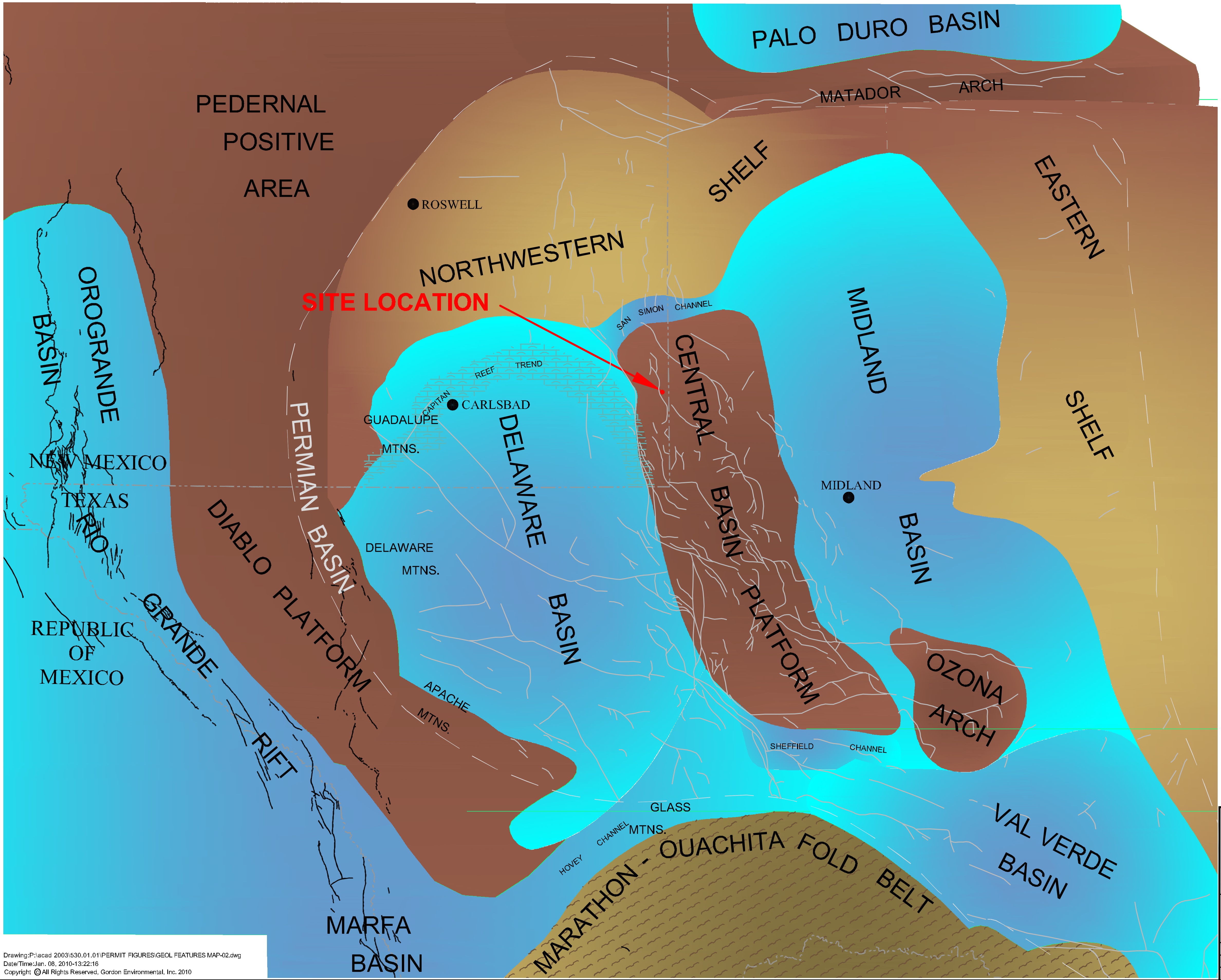
2.3 Structural Setting

The local Site region lies over the Central Basin Platform structural feature; a deep-seated horst-like structure that extends northwest to southeast from southeastern New Mexico to eastern Texas (**Figure IV.2.7** and **Figure IV.2.8**). From Cambrian to late Cenozoic, regional tectonic activity and related deformation produced the structure and stratigraphy characteristic of the Site region. **Table IV.2.2** summarizes the major tectonic activity through the structural geologic history of the Site region. **Figure IV.2.8** shows a diagrammatic, generalized cross section through the Delaware and Midland Basins south of the Site (Lucas et al, 1994).

2.4 Surface Geology and Stratigraphy

The generalized surface geology of the local Site region is shown in **Figure IV.2.9**. The associated generalized late Cenozoic stratigraphy in the vicinity of the Site is presented in **Figure IV.2.10**.

As shown on **Figures IV.2.6** and **IV.2.9**, the geologic units exposed at the surface consist of Quaternary alluvial and eolian deposits with isolated exposures of Tertiary, Triassic and Permian rocks. The Quaternary alluvial and eolian deposits generally form a thin veneer overlying Tertiary Ogallala Formation rocks or Late Triassic Chinle Group rocks in eastern Lea County. The Chinle Group rocks consist of, in descending order, the San Pedro Arroyo Formation and the Santa Rosa Formation (**Figure IV.2.11**; Lucas et al, 1994). The Chinle Group rocks disconformably overlie the Late Permian (Ochoan) Quartermaster Formation. The Quartermaster Formation is described as "a relatively thin sequence of red to reddish-orange fine-grained sandstone, siltstone and shale" (Lucas and Anderson, 1993). The



STATE OR INTERNATIONAL BOUNDARY
PERMIAN SHELF AREAS
PERMIAN BASINS
CAPITAN REEF
BASEMENT HIGH AREAS
FOLD–THRUST BELT
BASEMENT FAULT
QUATERNARY FAULT

MAP DATA FROM:
Bureau of Economic Geology, The University of Texas at Austin, (in preparation), Integrated Synthesis of the Permian Basin (GIS data), Stephen C. Ruppel, Ph.D., principal investigator.

NORTH

0 16 32 MILES

REGIONAL GEOLOGIC STRUCTURE MAP

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
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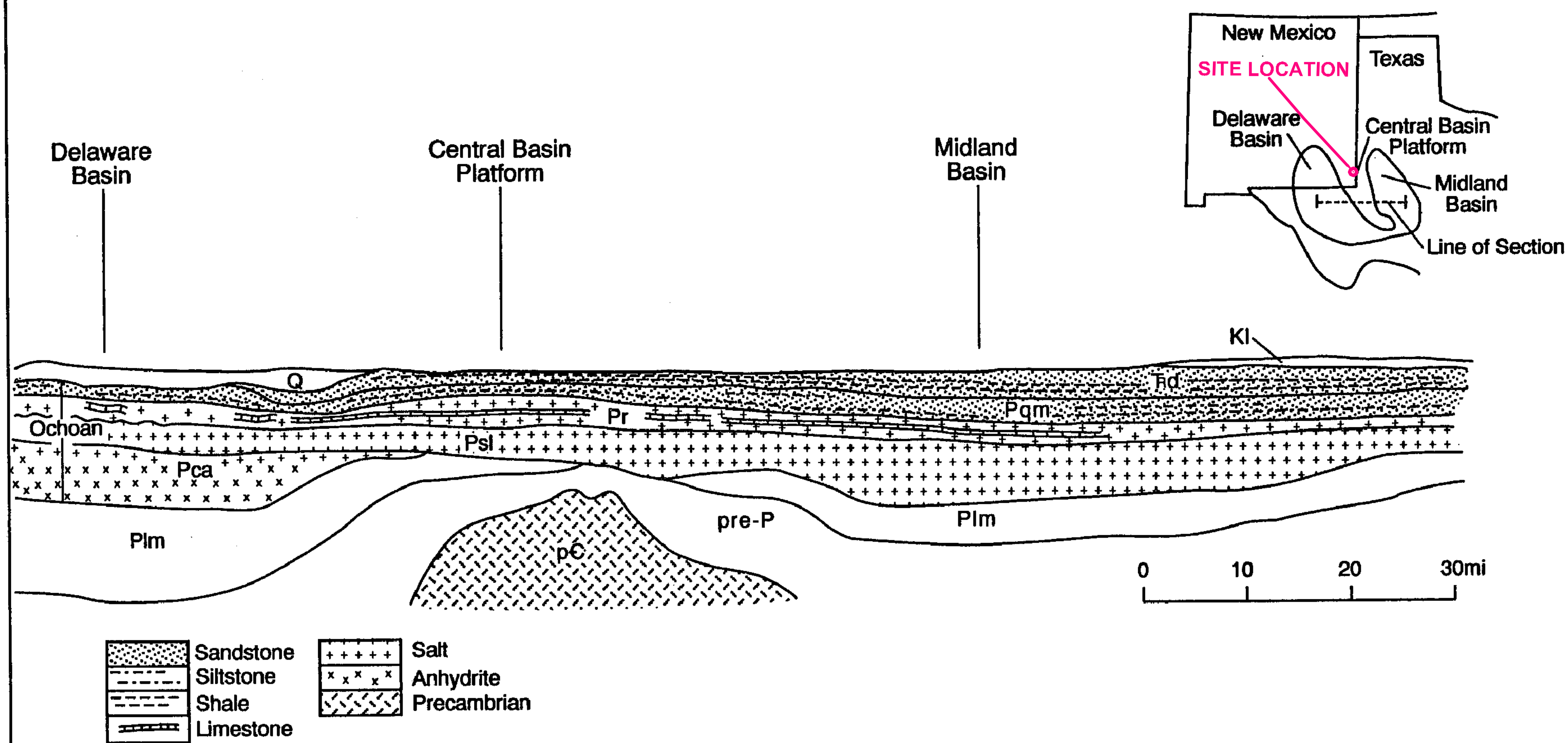
DATE: 01/08/2010	CAD: GEOL FEATURES.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.7
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\GEOL FEATURES MAP-02.dwg
Date/Time:Jan. 08, 2010-13:22:16



Generalized cross section through Delaware and Midland basins showing regional extent of Ochoan strata. Pe = Precambrian, pre-P = pre-Permian rocks, Plm = Lower and Middle Permian rocks, Pcz = Castile Formation, Psl = Salado Formation, Pr = Rustler Formation, Pqm = Quartermaster Formation, Trd = Dockum Group , Kl = Lower Cretaceous rocks, Q = Quaternary deposits. Modified from King (1942).

FROM: Lucas and Anderson, 1994, FIGURE 4, P. 31

GENERALIZED DIAGRAMMATIC CROSS SECTION

SUNDANCE WEST
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DATE: 01/08/2010	CAD: GEN XS PERM BASIN.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.8
APPROVED BY: IKG	gei@gordonenvironmental.com	

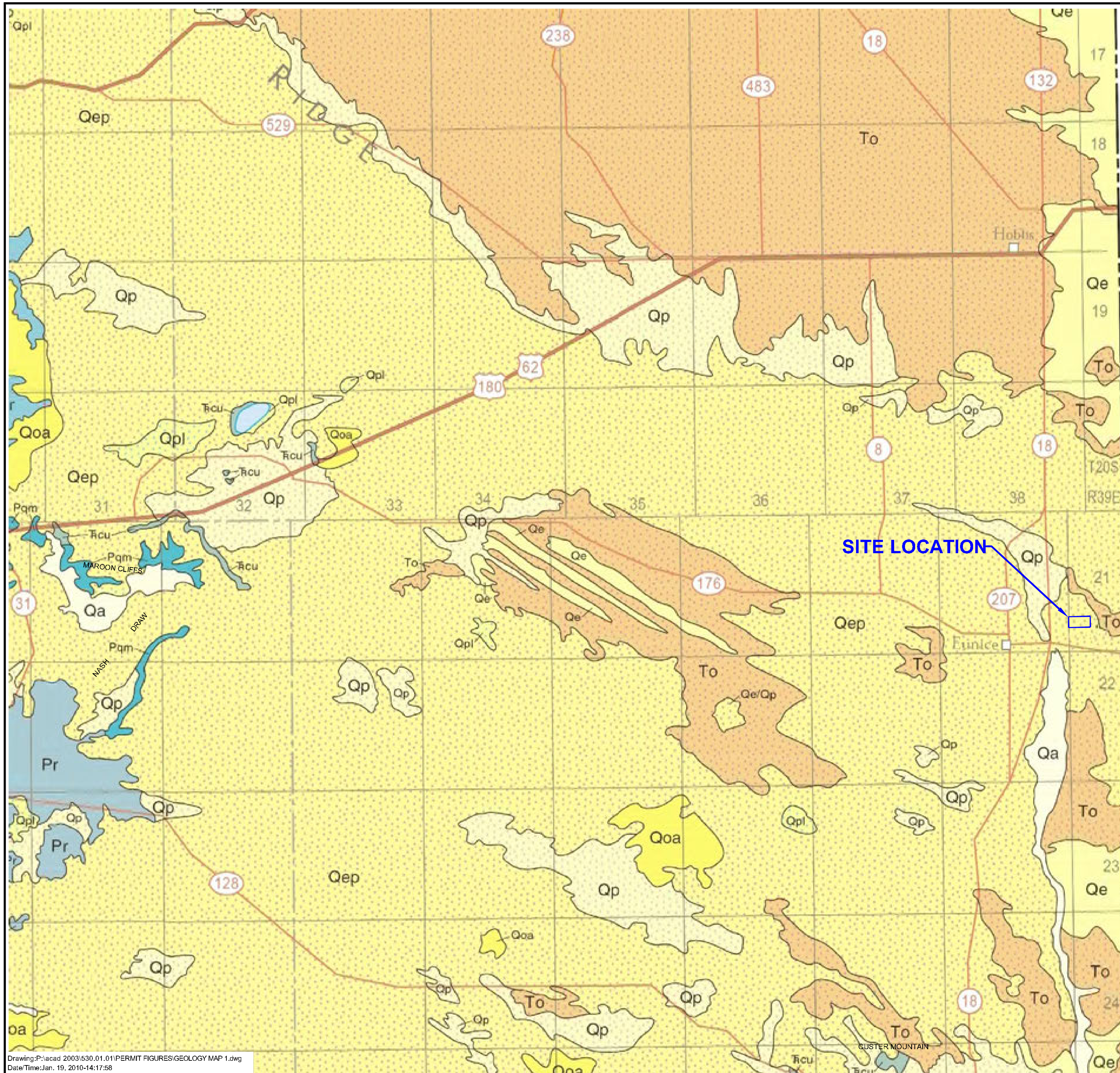
Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\GEN XS PERM BASIN.dwg
Date/Time:Jan. 19, 2010-14:16:21

TABLE IV.2.2
Summary of Tectonic History and Structural Geologic History of Southeast New Mexico and Southwest Texas
Sundance West

Time Period	Tectonism/Deformation
Cambrian to Late Mississippian	Mild structural deformation; broad regional arches and shallow depressions
Mississippian and Pennsylvanian	Uplift and formation of separate basins (Delaware, Midland, and Val Verde Basins)
Late Mississippian	Uplift and folding of the platform
Late Pennsylvanian and Early Permian	Compression and faulting; local deformation created mountain ranges oriented parallel with the main axis of the platform
Late Paleozoic/Permian	Long period of gradual subsidence and erosion bringing the Central Basin Platform to near-base level; filling of the Permian Basin with several thousand feet of evaporites, carbonates and shales
Permian to Late Cretaceous	Relatively quiescent; slight regional uplifting and downwarping
Early to Late Triassic	Slow uplift and slight erosion
Late Triassic	Gentle downwarping and formation of a large land-locked basin; deposition of terrigenous sediments of the Dockum Group in alluvial flood plains and as deltaic and lacustrine deposits
Jurassic	Regional erosion
Cretaceous	Sea submersion and deposition of basil clastic sediments (Trinity, Antlers and Paluxy sands) and overlying shallow marine carbonates
Cretaceous to Early Tertiary	Uplift and retreating sea; Laramide Orogeny and formation of the Cordilleran Range and Permian Basin bringing the region to essentially its present position
Early Tertiary to Present	No major tectonic events; episode of volcanism 38 to 28 Mya; Basin and Range extension, development of the Rio Grande Rift, and uplift of the Colorado Plateau and High Plains; uplift of the Guadalupe Mountains and eastward tilting of the Delaware Basin

REFERENCE:

Alnaji, 2002; Scholle, 2000; Cook-Joyce, Inc. et. al., 2007, Section 4.1.1.1



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Date/Time:Jan. 19, 2010-14:17:58

DESCRIPTION OF MAP UNITS

QUATERNARY

- **Qa** Alluvium (Holocene to upper Pleistocene)
- **Qpl** Lacustrine and playa deposits (Holocene)––Includes associated alluvial and eolian deposits of major lake basins
- **Qp** Piedmont alluvial deposits (Holocene to lower Pleistocene)––Includes deposits of higher gradient tributaries bordering major stream valleys, alluvial veneers of the piedmont slope, and alluvial fans. May locally include uppermost Pliocene deposits
- **Qe** Eolian deposits (Holocene to middle Pleistocene)
- **Qep** Eolian and piedmont deposits (Holocene to middle Pleistocene)––Interlayered eolian sands and piedmont–slope deposits along the eastern flank of the Pecos River valley, primarily between Roswell and Carlsbad. Typically capped by thin eolian deposits
- **Qoa** Older alluvial deposits of upland plains and piedmont areas, and calcic soils and eolian cover sediments of High Plains region (middle to lower Pleistocene)––Includes scattered lacustrine, playa, and alluvial deposits of the Tahoka, Double Tanks, Tule, Blackwater Draw, and Gatuña Formations, the latter of which may be Pliocene at base; outcrops, however, are basically of Quaternary deposits

TERTIARY

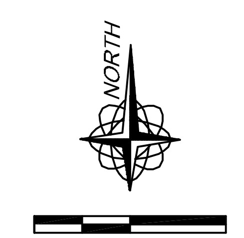
- **To** Ogallala Formation (lower Pliocene to middle Miocene)––Alluvial and Eolian deposits, and petrocalcic soils of the southern High Plains. Locally includes Qoa

TRIASSIC

- **Tῆcu** Upper Chinle Group/Dockum Group, Red shales with minor siltstone and sandstone. San Pedro Arroyo Formation.
- **Tῆs** Santa Rosa Formation

PALEOZOIC

- **Pqm** Quartermaster Formation (Upper Permian)––Red sandstone and siltstone (Equivalent to Dewey Lake Red Beds)
- **Pqr** Quartermaster and Rustler Formations (Upper Permian)
- **Pr** Rustler Formation (Upper Permian)––Siltstone, gypsum, sandstone, and dolomite
- **Psl** Salado Formation (Upper Permian) –– Evaporite sequence, dominantly halite



MAP DATA FROM:
New Mexico Bureau of Geology and Mineral Resources, 2003, Geologic Map of New Mexico, Scale 1:500,000.

GENERALIZED GEOLOGIC MAP

SUNDANCE WEST
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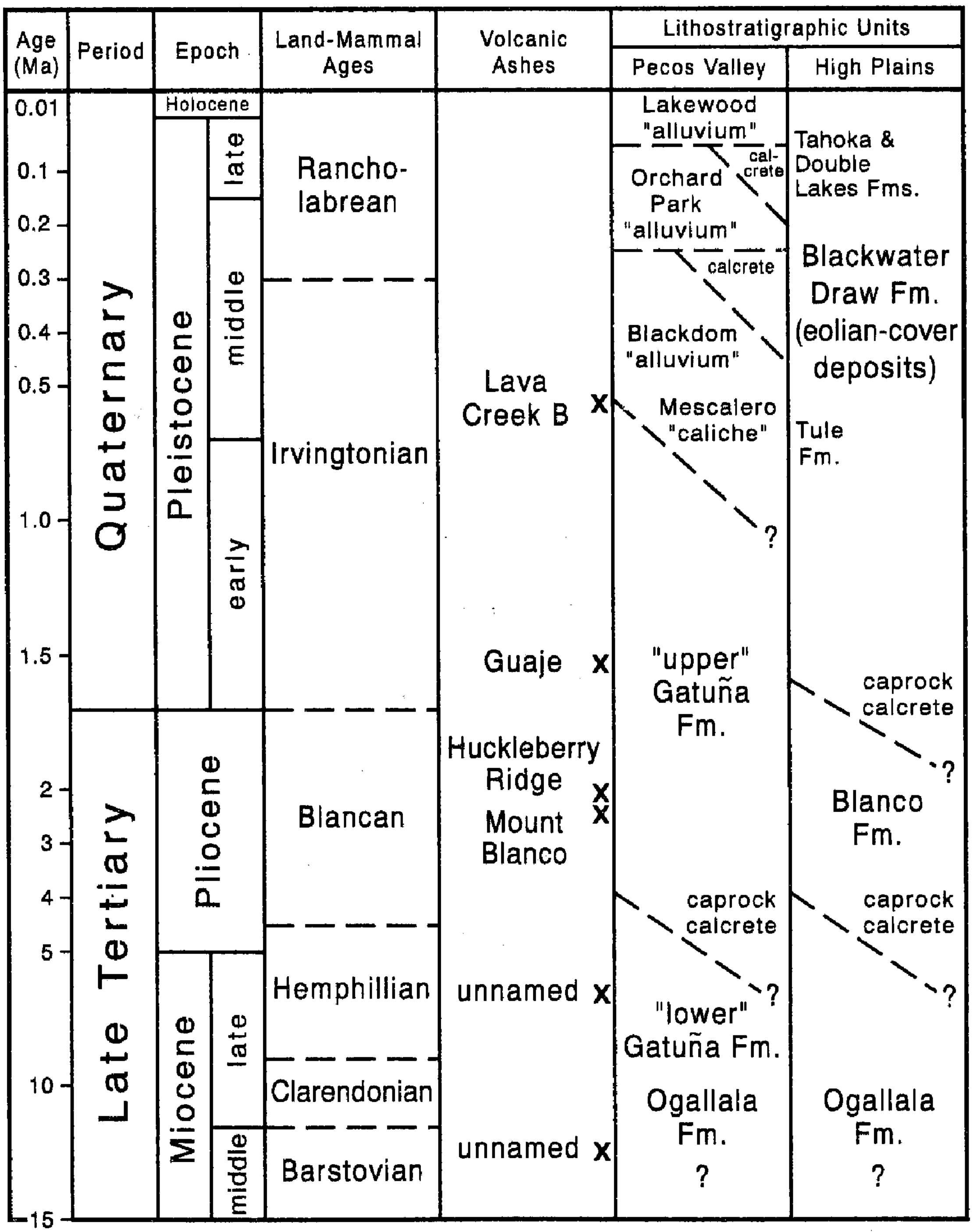
DATE: 01/08/2010	CAD: GEOLOGY MAP 1.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.9
APPROVED BY: IKG	gei@gordonenvironmental.com	



FROM: HAWLEY, 1993a,FIGURE 1.2, P. 2

LATE CENOZOIC STRATIGRAPHIC CHART

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DATE: 01/08/2010	CAD: LATE CENOZ STRAT.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.10
APPROVED BY: IKG	gei@gordonenvironmental.com	

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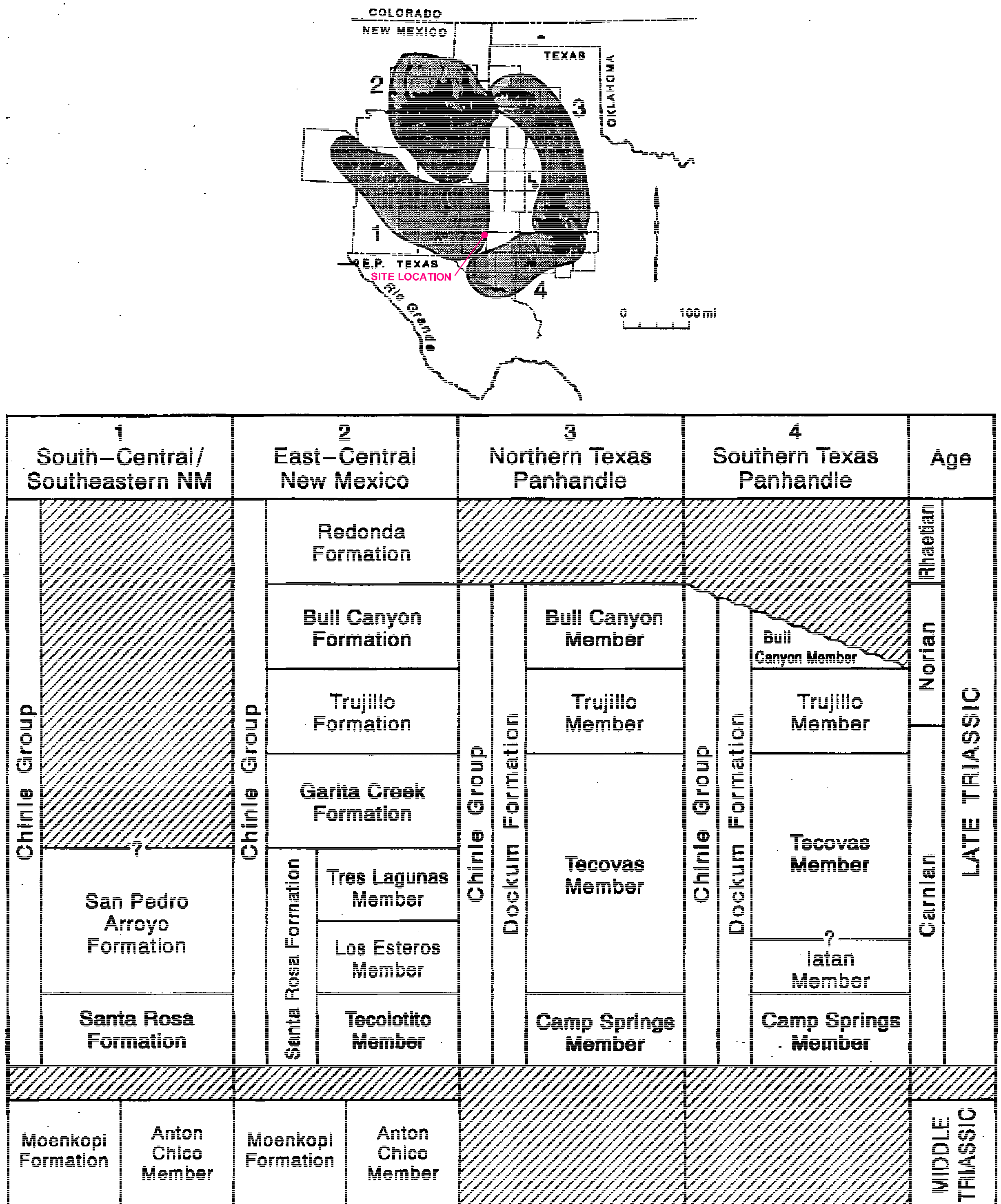
Date/Time:Jan. 19, 2010-14:20:15



Correlation of Triassic stratigraphic units in eastern New Mexico and west Texas.

FROM: Lucas and others, 1994, FIGURE 11, P. 122

TRIASSIC STRATIGRAPHIC CHART

SUNDANCE WEST
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Bernalillo, New Mexico, USA
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DATE: 01/08/2010	CAD: TRIASSIC STRAT.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.11
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\TRIASSIC STRAT.dwg
Date/Time:Jan. 19, 2010-14:23:33

Quartermaster Formation disconformably overlie a thick sequence of mostly marine evaporites, shales, and limestones, related to the evolution of the Permian Basins, Capitan Reef and associated shelf areas (**Figure IV.2.8**).

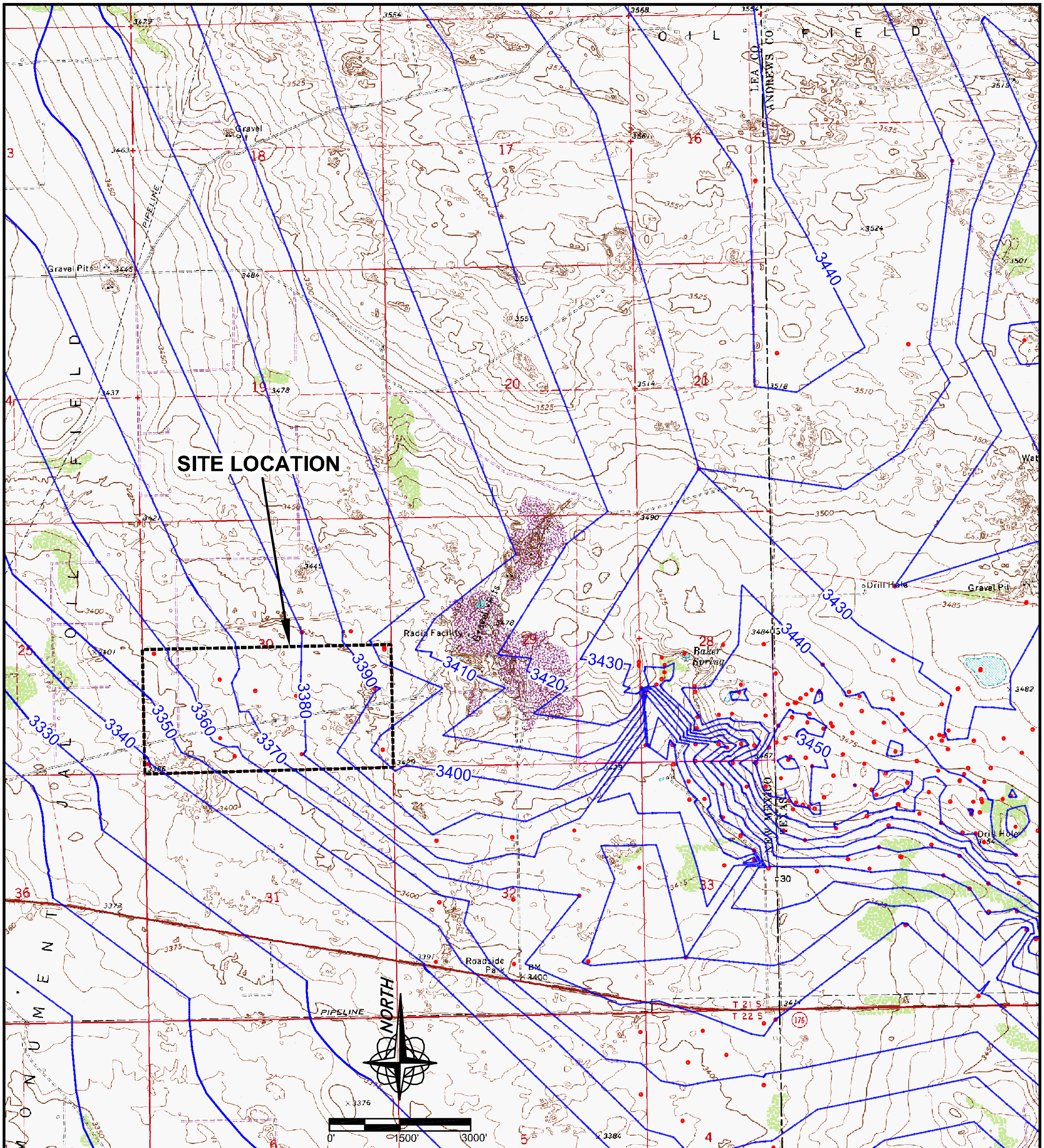
The post Triassic rocks, including the Tertiary Ogallala Formation rocks have mostly been removed by erosion over large areas south and west of Mescalero Ridge and the Caprock escarpment east of the Site, except where deep seated solution-collapse features are present (Leedshill-Herkenhoff et al, 1999, pp. 6-7 and 6-8).

There is considerable disagreement concerning correlations and naming of Triassic strata between New Mexico and west Texas (Lehman, 1994; Lucas and Anderson, 1993b; Lucas et al, 1994; Ziegler et al, 2008). The stratigraphic scheme of Lucas et al (1994) for south-central/southeastern New Mexico is used in this report. **Figure IV.2.11** shows their stratigraphic correlations for eastern New Mexico and west Texas. **Figure IV.2.12** shows structural contours at the top of the Chinle Group (from Nicholson and Clebsch, 1961; Cook-Joyce, Inc. et. al., 2007, Exhibits 5-1A through 5-1H).

2.4.1 Description of Triassic units

San Pedro Arroyo Formation. The San Pedro Arroyo Formation of the Chinle Group is considered to be roughly correlative to the Upper Dockum Group of Dutton and Simpkins (1986). Sandstone units within the San Pedro Arroyo Formation (Upper Dockum Group) are not considered to be laterally continuous in southeast New Mexico and west Texas (McGowen and others, 1977, p. 12 *in* Duton and Simpkins, 1986, p. 3; Cook-Joyce, Inc. et. al., 2007, p. 5-16).

The mudstone dominated San Pedro Arroyo Formation (Upper Dockum Group) of the Chinle Group underlies the Quaternary-Tertiary surfical deposits and overlies the Santa Rosa Formation of the Chinle Group of Lucas and Anderson (1993b). Lucas and Anderson describe outcrops of the unit as follows: “The most extensive outcrops are around Custer Mountain in Lea County where up to 22m of strata are *exposed*. These strata are mostly pale



KEY

DATA SOURCES:
Gordon Environmental, Inc, 2009, (borehole point data).
Nicholson, A. , Jr., and Clebsch, 1961, Plate 1,(contour data).
Cook-Joyce, Inc. et. al., 2007, Exhibit 5-1-A, through, Exhibit 5-1-I, (borehole point data).

FACILITY BOUNDARY

3440 STRUCTURE CONTOUR ON TOP OF CHINLE REDBEDS

DATA POINT

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\CHINLE TOP CONTOURS REGIONAL.dwg
Date/Time:Jan. 20, 2010-14:47:56

STRUCTURE CONTOURS ON TOP OF THE CHINLE GROUP REDBEDS

SUNDANCE WEST
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DATE: 01/08/2010	CAD: CHINLE TOP CONTOURS SPLINE.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.12
APPROVED BY: IKG	gei@gordonenvironmental.com	

reddish brown (10 R 5/4) and yellowish gray (5 Y 7/2), slope-forming smectitic mudstone and siltstone. Some minor ledges of yellowish gray (5 Y 7/2) micaceous quartzarenite sandstone also are present".

The thickness of the San Pedro Arroyo Formation (Upper Dockum Group) is considered to be at least 165 feet (ft) thick in western Lea County (Leedshill-Herkenhoff et al, 1999, p.6-7) to 400 ft thick at the Sundance West Site (Dutton and Simpkins, 1986, Figure 2b, p. 5).

Santa Rosa Formation. The Santa Rosa Formation of the Chinle Group is considered to be roughly correlative to the Lower Dockum Group of Dutton and Simpkins (1986).

An outcrop of the Santa Rosa Formation of southeastern New Mexico is described by Lucas and Anderson, (1993b) as: "mostly trough-crossbedded extraformational conglomerate and sandstone with minor beds of mudstone or siltstone. Typical colors are grayish red (10 R 4/2) and pale reddish brown (10 R 5/4) for the sandstones, siltstones and mudstones, whereas conglomerate beds are mostly yellowish gray (5 Y 8/1) to light greenish gray (5G Y 8/1). Sandstones are micaceous subarkoses or litharenites. Conglomerate clasts typically are rip-ups of underlying Permian red beds (Artesia Group or Quartermaster Formation) at the base of the Santa Rosa Formation. Some quartzite clasts (usually in the very coarse to pebbly size range) also are present in basal Santa Rosa conglomerates. Conglomerates higher in the unit contain reworked Triassic siltstone and sandstone clasts."

Several laterally discontinuous sandstone units have been documented at various stratigraphic horizons/positions in the Santa Rosa Formation (Cook-Joyce, Inc. et al, 2007, p. 2, 2-2 and 2-3; Dutton and Simpkins, 1986, p. 3 and Figure 4a, p. 8). The thickness of the Santa Rosa Formation (Lower Dockum Group) is reported to be up to 800 ft thick near the Site (Dutton and Simpkins, 1986, Figure 2a, p. 4).

Santa Rosa Sandstone. The definition of the Santa Rosa Sandstone is another source of considerable disagreement (Leedshill-Herkenhoff et al, 1999 p. 6-7; Lehman, 1994; Lucas and Anderson, 1993b; Lucas et al, 1994; Ziegler et al 2008). The Santa Rosa Sandstone is considered to be the basal sandstone-conglomerate unit of the Santa Rosa Formation (Lower

Dockum Group) in this report. Using this definition, it might be more appropriate to call it the Santa Rosa Sandstone Member of the Santa Rosa Formation or the basal sandstone unit of the Santa Rosa Formation. The Santa Rosa Sandstone is considered to be laterally continuous in subsurface for at least a few miles surrounding the Sundance West Site (Johns and Granata, 1987, p 56). Santa Rosa Sandstone is reported to range from 85 to 300 ft thick from western Lea County (Leedshill-Herkenhoff et al, 1999 p. 6-7) to west Texas (USNRC 2005, Table 3-8, p. 3-30; Cook-Joyce, Inc. et al, 2007, Figure 5-18).

2.5 Hydrogeology

Several rock units of Tertiary through Quaternary age strata are sources of fresh water in southeastern Lea County, New Mexico. These units are unsaturated, discontinuous or too thin on the Sundance West Site to be significant sources of groundwater (Section 3.3 of This Report; Leedshill-Herkenhoff et al, 1999, pp. 6-7, 6-8 and Figure 15; USNRC 2005, p. 3-36; Cook-Joyce, Inc. et al, 2007, pp. 3-5, 6-7 and 6-8).

Due to the high salt content of the pre-Triassic rocks, water from these deeper units are not considered sources of fresh water. "No useable ground water is obtained from rocks older than the Triassic, but highly saline water is produced along with oil from Paleozoic rocks." (Nicholson and Clebsch, 1961, p. 1).

The Santa Rosa aquifer is a major source of groundwater for domestic and livestock wells in the southwest part of Lea County and was the primary source of groundwater for the City of Jal prior to 1954. The community of Oil Center currently pumps some of its water from the Dockum Group (Chinle Group) (Leedshill-Herkenhoff et al, 1999, p. 6-12). The WCS facility obtains industrial water from the sandstone sections of the lower Dockum Group Santa Rosa Formation at a depth of about 1,140 to 1,400 ft below ground surface (bgs) (Cook-Joyce, Inc. et al, 2007, pp. 2, 3, 2-2 and 2-3).

For the reasons stated above, only Triassic age rock units will be considered as potential "fresh water" aquifers under the Sundance West Site. Due to the absence of Ogallala Formation rocks under the Site and the high salinity of waters in the Permian Rocks, Triassic

Chinle Group rocks are considered to contain be the shallowest water bearing units under the Site.

East of the Sundance West Site on the WCS Site (**Figure IV.2.2**), geologic investigations have revealed a 1,400 ft thick sequence of Chinle Group red beds. Within this sequence, water bearing sandstone units were encountered at 225 ft, 600-700 ft, and 1,140-1,400 ft bgs (Cook-Joyce et al 2007, pp. 3-3 and 3-4). The sandstone unit encountered at 225 ft is reported to have low permeability and does not yield groundwater readily (Cook-Joyce et al 2007, p. 2-3 and 5-11; USNRC 2005, p. 3-36). The water-bearing sandstone encountered at 600-700 ft is not considered to be laterally continuous to the west. The sandstone unit encountered at 1,140-1,400 ft below ground surface is reported to be the Santa Rosa Sandstone (Cook-Joyce et al 2007, p. 2-2).

Triassic sandstone and conglomerates of the Santa Rosa Formation are considered to be the only potential source of fresh water under the Sundance West Site. The Santa Rosa Sandstone is considered to be the only laterally continuous water-bearing unit of regional extent occurring under the Site (Johns and Granata, 1987, p 56; USNRC 2005, p. 3-36). As such, the Santa Rosa Sandstone is considered to be the shallowest fresh water aquifer in the local region of the Sundance West Site (19.15.36.8.C.15(c) NMAC).

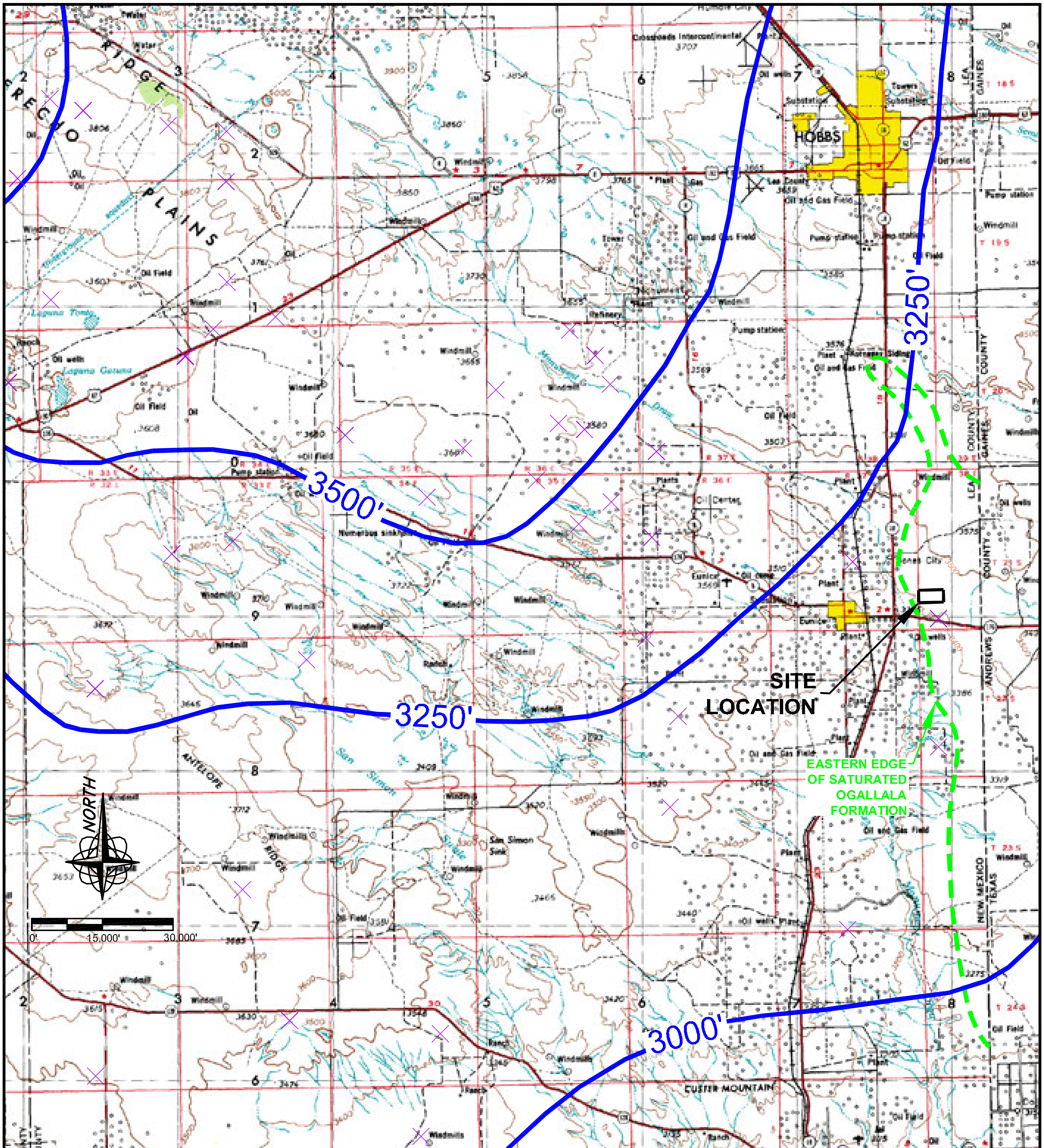
The Santa Rosa Sandstone is reported to be hydrologically isolated from the shallower sandstone units (USNRC 2005, p. 3-37). This is due to the thick impermeable claystone and mudstone units separating the various sandstone units. For these same reasons the Santa Rosa Sandstone is under confined conditions beneath the Site. The Santa Rosa Sandstone is probably under water table conditions at the westernmost parts of Lea County where the unit subcrops under alluvial and eolean deposits 35-40 miles east of the Sundance West Site (Leedshill-Herkenhoff et al, 1999, p. 6-13).

Recharge of lower Chinle/Dockum Group groundwater in the vicinity of the Sundance West Site apparently ceased or dramatically declined during the Pleistocene (Dutton and Simpkins, 1986). "Lower Dockum Group water was recharged by precipitation during the Pleistocene at elevations of 6,000 to greater than 7,000 ft (1,830 to greater than 2,130 m) in Dockum

Group sandstones that were later eroded from the Pecos Plains and Pecos River Valley" (Dutton and Simpkins, 1986, p. 24; Dutton, 1995 in Cook-Joyce et al 2007, p. 3-4).

The depth to the Santa Rosa Sandstone under the Site is probably somewhat shallower than the 1,140-1,400 ft depth below ground surface reported at the WCS Site, (Cook-Joyce et al 2007, p. 2-2), due to the relatively low relief of the Permian-Triassic boundary and a general east or southeast dip (Ash, 1963 *in* Leedshill-Herkenhoff et al, 1999, p. 6-7) and thickening of the Chinle Group rocks to the east (Johns and Granata,1987, p. 56)**.** Oil and Gas Well logs near the Sundance West Site (New Mexico Department of Energy Minerals and Natural Resources, Oil Conservation Division online well files, emnrd.state.nm.us/ocd/ocd online.htm) indicate a sequence of "red beds" 1,490 ft to 1,525 ft thick, overlying Permian anhydrites in subsurface. The lower 495 ft of these red beds are probably Permian Quartermaster Formation strata (Nicholson and Clebsch, 1961, Table 4, p. 34). Assuming a thickness of 260 ft for the Santa Rosa Sandstone (Cook-Joyce et al 2007, p. 2-2), the top the fresh water bearing unit would range from 675 ft to 1,075 ft bgs. **Figure IV.2.14** shows calculated depth to the Santa Rosa Sandstone contours, based on the criteria above.

Potentiometric groundwater surface data for the Santa Rosa Sandstone is not available, mainly due to wide spacing of data representing only Santa Rosa Sandstone completed wells, poor drill logs and inconsistencies in the definition of the Santa Rosa Sandstone. As such, potentiometric surface contours of the Lower Dockum Group probably only represent the minimum possible depth of water bearing units of the Santa Rosa Formation (Lower Dockum Group), not necessarily the Santa Rosa Sandstone. In conformance with 19.15.36.8.C.15(f) NMAC, **Figure IV.2.13** shows the potentiometric groundwater surface for the Triassic Lower Dockum Group compiled from: Dutton and Simpkins, 1986, Figure 5; Leedshill-Herkenhoff et al, 1999, Figure 15. **Figure IV.2.14** also shows The Lower Dockum groundwater potentiometric surface to be 150 ft or greater depth bgs across the Sundance West Site. However, the Santa Rosa Sandstone is a confined aquifer, and the potentiometric surface illustrated in **Figure IV.2.14** represents confined hydraulic head in the aquifer; the actual depth to the aquifer is estimated to range from 675 ft to 1,075 ft below the



LEGEND

▭	FACILITY BOUNDARY
—— 3000' ——	LOWER DOCKUM GROUP GROUNDWATER POTENTIOMETRIC CONTOUR (FROM DUTTON AND SIMPKINS 1986, FIGURE 5)
×	DATA POINT (FROM DUTTON AND SIMPKINS 1986, FIGURE 5)
— — —	EASTERN LIMIT OF SATURATION IN THE OGALLALA FORMATION (FROM:LEEDSHILL–HERKENHOFF ET AL, 1999, FIGURE 15)

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\POTENTIO L DOCKUM.dwg
Date/Time:Jan. 19, 2010-14:32:43

GROUNDWATER POTENTIOMETRIC SURFACE (LOWER DOCKUM GROUP)

SUNDANCE WEST
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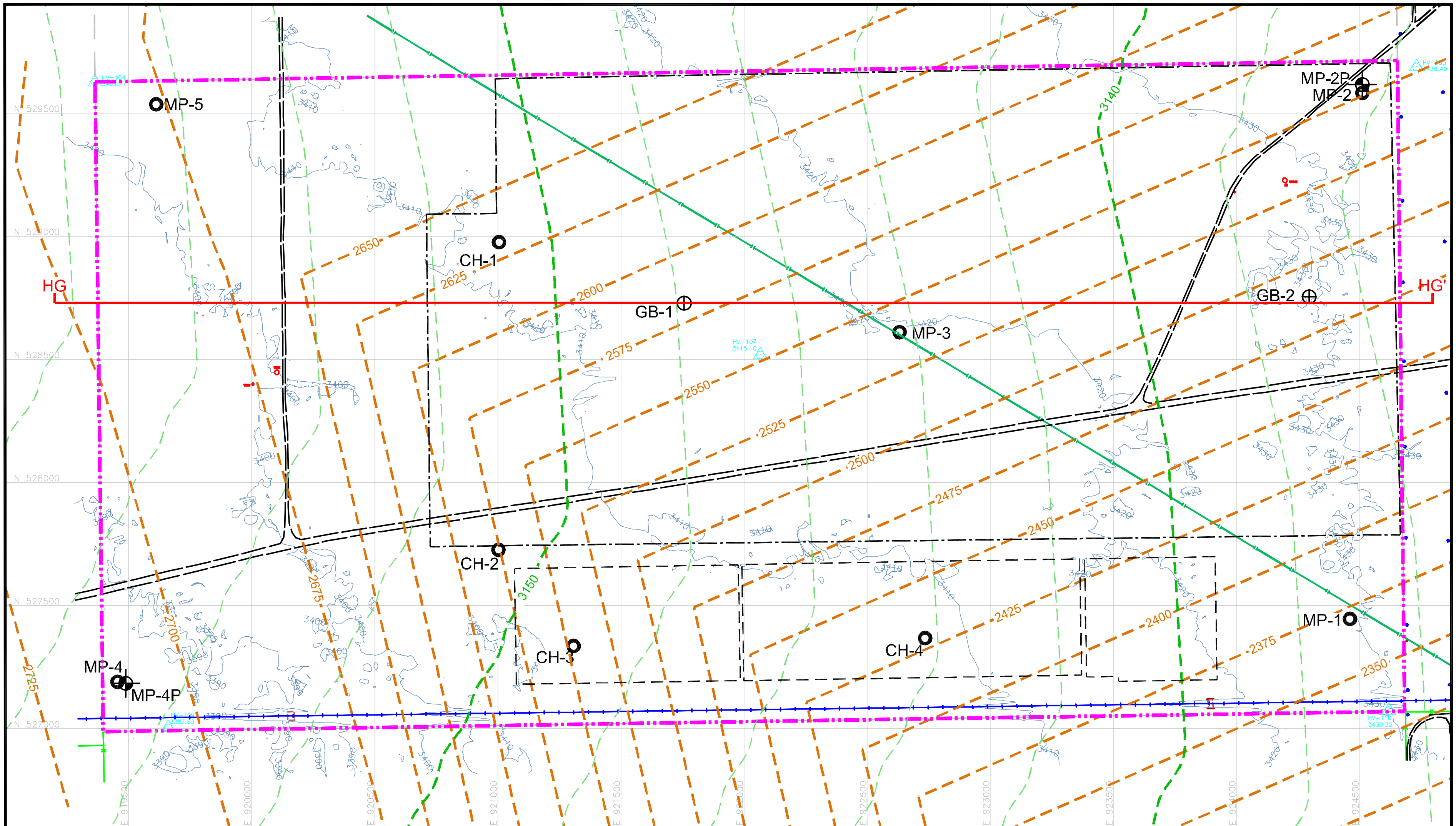
Fax: 505-867-6991

DATE: 01/11/2010	CAD: POTENTIO L DOCKUM.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: LMC	FIGURE IV.2.13
APPROVED BY: IKG	gei@gordonenvironmental.com	



LEGEND

LANDFILL BOUNDARY
PROCESS AREA BOUNDARY
FENCE
SECTION, 1/4 SECTION LINE
UNPAVED ROAD
POWER POLE
MISC./UNIDENTIFIED OBJECT
RAILROAD TRACK
BOX CULVERT
STORAGE TANK
CONCRETE SLAB
EXISTING WATER SUPPLY PIPELINE
CONTROL POINT
N 529000 GRID LINE/LABEL

HG HG' HYDROGEOLOGIC CROSS SECTION LOCATION
3460 10' EXISTING GRADE CONTOUR
3440 10' EXISTING DEPRESSION
FACILITY BOUNDARY
GB-1 GEOTECHNICAL BOREHOLE LOCATION
CH-1 COREHOLE LOCATION
MP-1 BOREHOLE LOCATION
MP-2P MONITORING WELL LOCATION
2675 TOP OF SANTA ROSA SANDSTONE 25' CONTOUR (CALCULATED)
3150 LOWER DOCKUM GROUNDWATER POTENTIOMETRIC SURFACE 10' CONTOUR (INTERPOLATED FROM FIGURE IV.2.13)
LOWER DOCKUM GROUNDWATER POTENTIOMETRIC SURFACE 2' CONTOUR (INTERPOLATED FROM FIGURE IV.2.13)

NORTH

0' 300' 600'

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\SANTA ROSA TOP W POT.dwg
Date/Time:Jan. 21, 2010-13:50:13

CALCULATED TOP OF SANTA ROSA SANDSTONE AND LOWER DOCKUM GROUP POTENTIOMETRIC SURFACE

SUNDANCE WEST
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DATE: 01/21/2010	CAD: MP BOREHOLES CHINLE TOP.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: IKG	FIGURE IV.2.14
APPROVED BY: IKG	gei@gordonenvironmental.com	

Sundance West Site. **Figure IV.2.15** is a diagrammatic hydrogeologic cross section showing the lower Dockum Group potentiometric surface and the calculated depth to Santa Rosa Sandstone. Extensive claystones and mudstones within the Chinle Group, having hydraulic conductivity values of 10^{-8} to 10^{-10} centimeter per second (cm/sec) (Cook-Joyce, Inc. et. al., 2007, Sections 5.3.4 and 6.2) serve to both separate the Santa Rosa Sandstone from the overlying OAG and to hydraulically confine the Santa Rosa Sandstone.

2.5.1 Water Quality

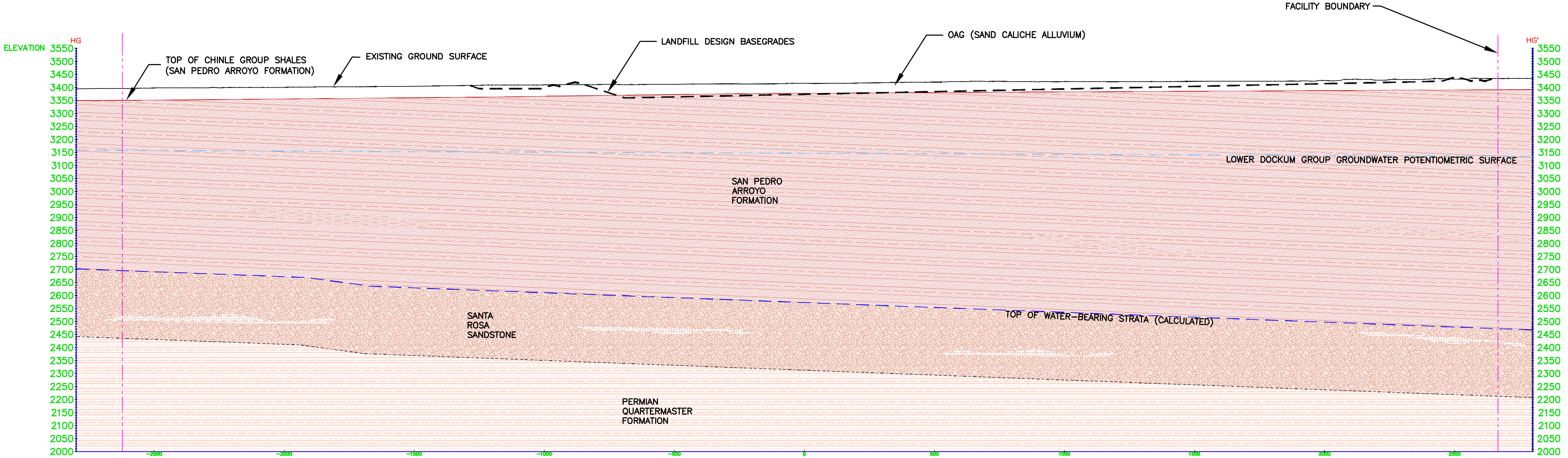
Water quality data for the Santa Rosa Sandstone is poorly documented in southern Lea County (Leedshill-Herkenhoff et al, 1999 p. 6-21). Nicholson and Clebsch (1961) report total dissolved solids (TDS) values ranged from 635 to 1,950 milligrams per liter (mg/L) for four wells sampled in 1942 and 1953 bottomed in the Santa Rosa Aquifer. Sulfate concentrations ranging from 71 to 934 mg/L were reported from these wells, with higher concentrations in the deeper wells.

Figure IV.2.16 shows regional TDS contours for the Lower Dockum Group (from Dutton and Simpkins 1986, Figure 10b). The data shown in **Figure IV.2.16** indicate a TDS range of 2,000 to 3,000 mg/L near the Sundance West Site. **Figure IV.2.17** shows hydrochemical facies of the Lower Dockum Group, indicating a Na-SO_4 type inferred from Piper diagrams (Dutton and Simpkins 1986, Figure 9, p. 18, and Figure 10a, p. 19). Although water samples from the Santa Rosa Sandstone (Lower Dockum Group) have not been tested from directly beneath the Sundance West Site, these data provide a general idea of the water quality of the shallowest fresh water aquifer in the Site area (19.15.36.8.C.15(b) NMAC).

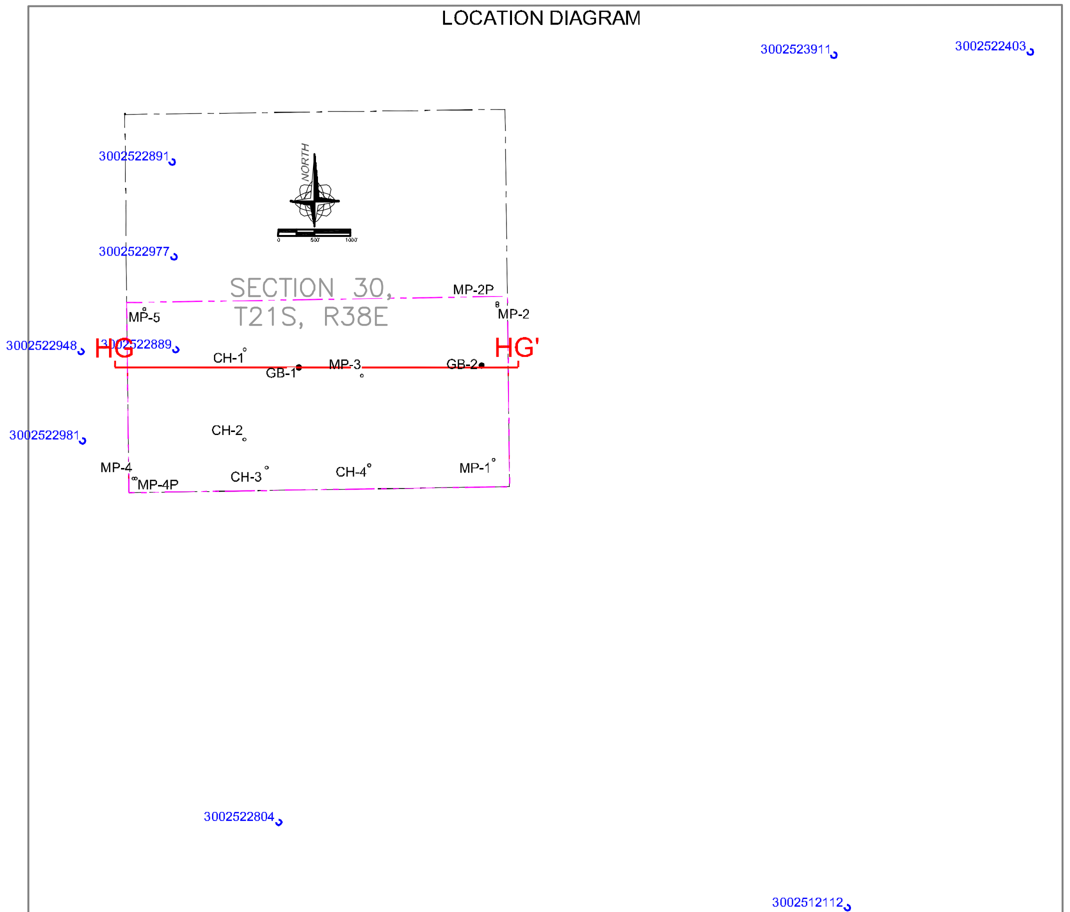
3.0 SITE GEOLOGY AND HYDROGEOLOGY

3.1 2009 Site Investigations

Two episodes of site-specific investigations were conducted to characterize the geology and hydrogeology of the proposed Sundance West Site in conformance with 19.15.36.8.C NMAC. The information obtained during the site-specific studies presented in this section are consistent with the regional conditions presented in Section 2.0.



LOCATION DIAGRAM



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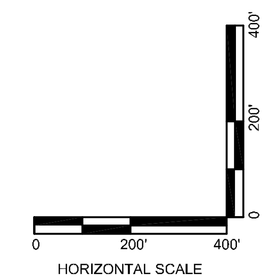


GROUND SURFACE
LANDFILL DESIGN BASEGRADES
SUNDANCE WEST FACILITY BOUNDARY
GROUNDWATER POTENTIOMETRIC SURFACE (LOWER DOCKUM GROUP)
TOP OF GROUNDWATER BEARING UNIT (CALCULATED)
TOP OF PERMIAN QUARTERMASTER FORMATION (CALCULATED)
MP-2P MONITORING WELL LOCATION
MP-3 BOREHOLE LOCATION (PLUGGED)
GB-2 GEOTECHNICAL BOREHOLE LOCATION (PLUGGED)
CH-1 COREHOLE LOCATION (PLUGGED)
3002523911 OIL/GAS WELL DATA POINT WITH API NUMBER

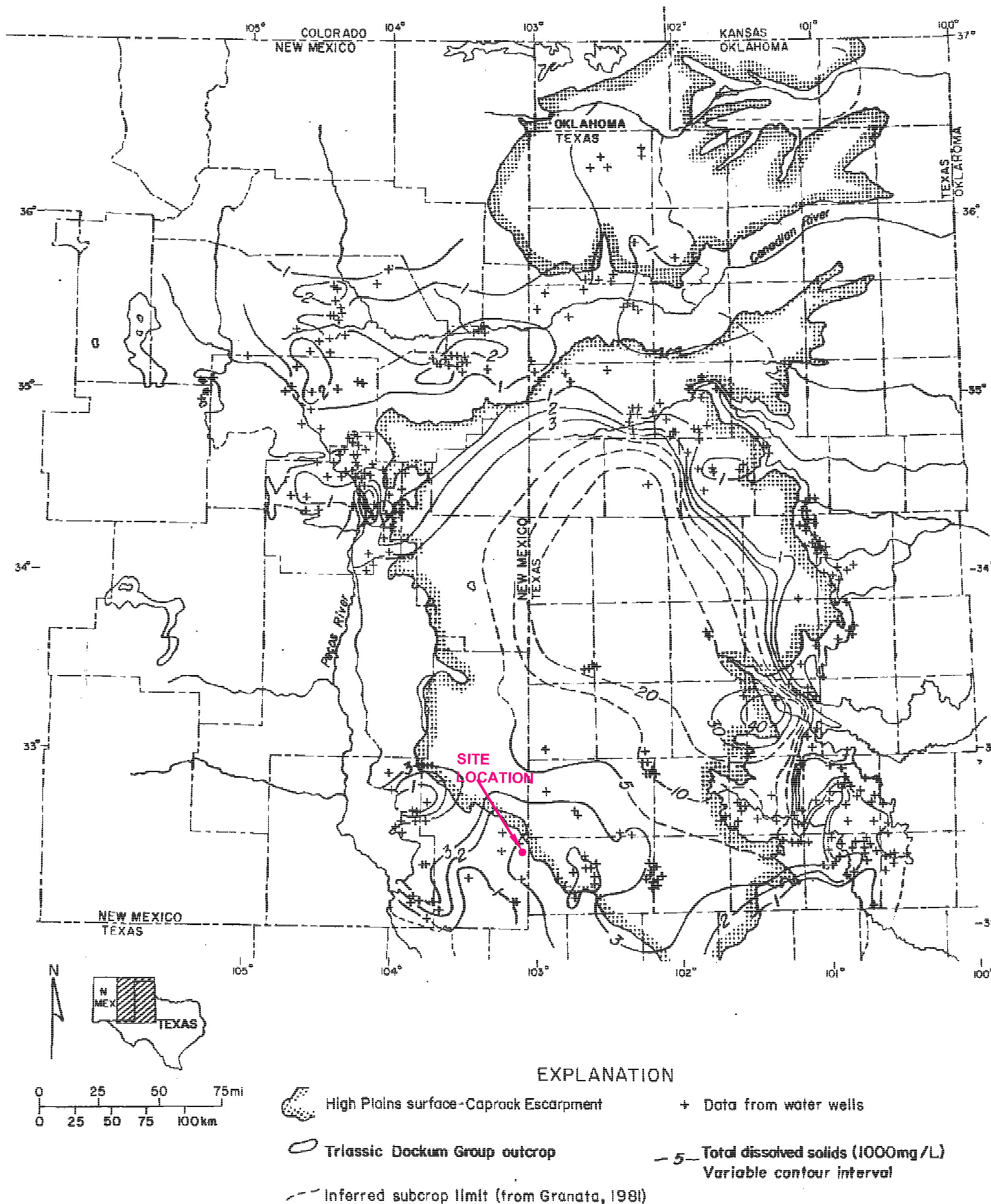
HYDROGEOLOGIC CROSS SECTION

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991
gei@gordonenvironmental.com

DATE: 01/21/2010	CAD: CROSS SECTION HG.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: DRT	FIGURE IV.2.15
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\CROSS SECTION HG.dwg
Date/Time:Jan. 21, 2010-13:57:57



FROM: DUTTON AND SIMKINS, 1986,FIGURE 10b, P. 20

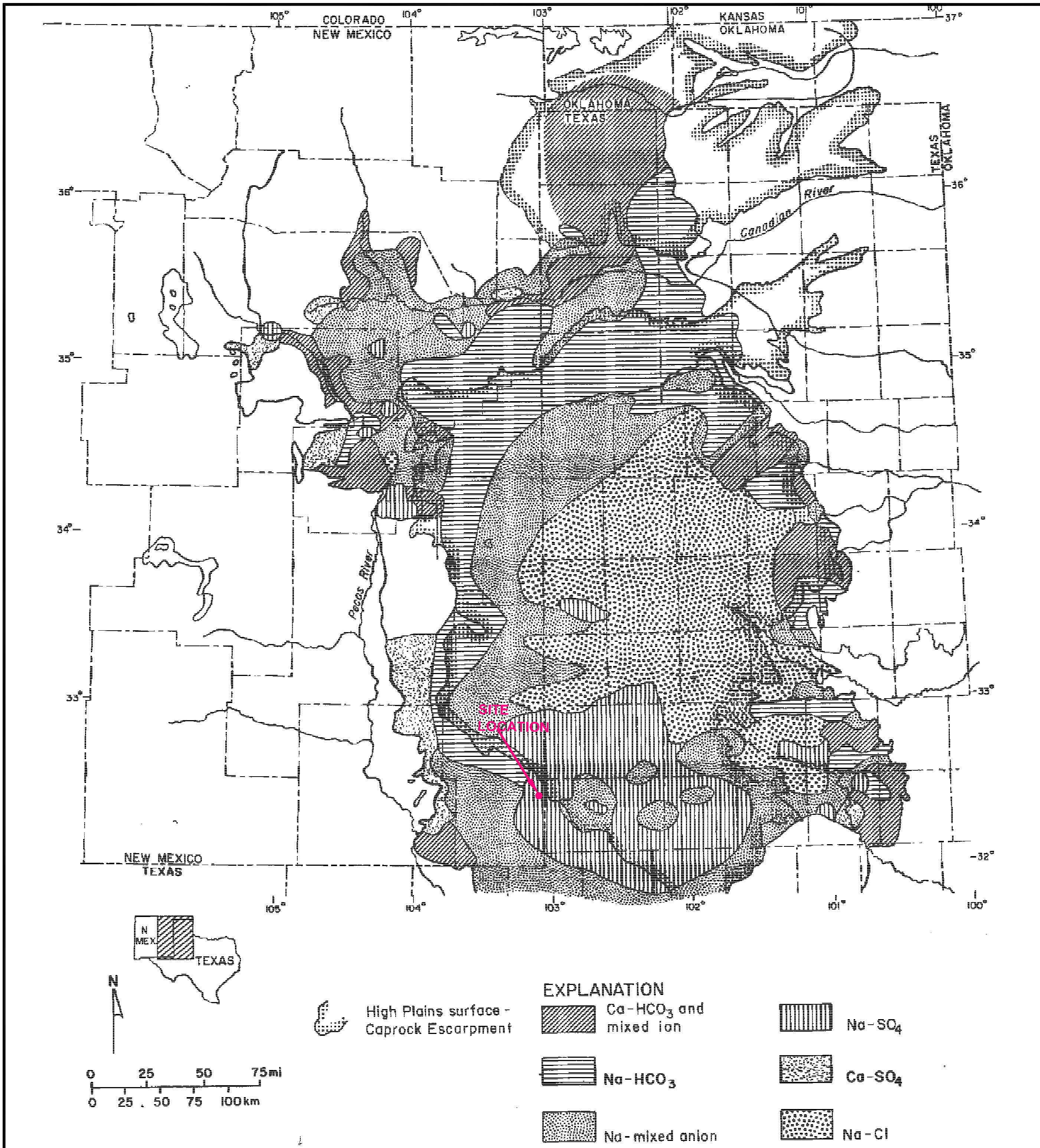
TDS MAP SANTA ROSA SANDSTONE (LOWER DOCKUM GROUP)

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers
213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/21/2010	CAD: TDS LDOCKUM.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.16
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\TDS LDOCKUM.dwg
Date/Time:Jan. 21, 2010-14:00:48



FROM: DUTTON AND SIMKINS, 1986,FIGURE 10b, P. 19

HYDROCHEMICAL FACIES MAP OF THE SANTA ROSA FORMATION (LOWER DOCKUM GROUP)

SUNDANCE WEST
SURFACE WASTE MANAGEMENT FACILITY
LEA COUNTY, NEW MEXICO

Gordon Environmental, Inc.
Consulting Engineers

213 S. Camino del Pueblo
Bernalillo, New Mexico, USA
Phone: 505-867-6990
Fax: 505-867-6991

DATE: 01/21/2010	CAD: HYDROCHEM LDOCKUM.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: GEI	FIGURE IV.2.17
APPROVED BY: IKG	gei@gordonenvironmental.com	

Drawing:P:\acad 2003\530.01.01\PERMIT FIGURES\HYDROCHEM LDOCKUM.dwg
Date/Time:Jan. 21, 2010-14:03:09

Figure IV.2.4 shows the locations of site-specific borings, coreholes, and wells in support of this Application. **Attachment IV.2.A** includes the *Completion Report for Drilling, Sampling, and Monitoring Well Installation* for the first episode of characterization in April 2009. **Attachment IV.2.B** includes the *Completion Report for Supplemental Drilling and Sampling* for the second (supplemental) episode of characterization in October 2009. The following sections summarize the site-specific characterization activity and data.

3.1.1 April 2009 Site Investigation

Gordon Environmental, Inc. (GEI), on behalf of SSI, oversaw the drilling of seven borings; and installation of two groundwater monitoring wells between April 16 and April 23, 2009 at the proposed Sundance West Site. Rodgers Environmental Services, Inc. (Rodgers), of Albuquerque, NM was contracted by GEI to complete the following services for this project:

- Drill five borings using a combination of hollow stem auger (HSA) and air rotary drilling methods (borings MP-1 through MP-5).
- Drill two additional borings using hollow-stem auger (HSA) drilling methods, and install groundwater monitoring wells at those locations (MP-2P and MP-4P).

The five soil borings (MP-1 through MP-5) were drilled at the locations shown on **Figure IV.2.4**. Two additional soil borings were drilled adjacent to MP-2 and MP-4 (MP-2P and MP-4P, respectively) in order to install shallow groundwater monitoring wells near these locations (**Figure IV.2.4**). Borings MP-1 through MP-5 were drilled at locations within the Site area to characterize the shallow geology and hydrogeology to depths up to 150 ft below existing Site grade. Wells MP-2P and MP-4P were completed subsequent to drilling and sampling borings MP-1 through MP-5 to monitor thin, isolated zone(s) of free water perched on top of, and/or within, the upper Chinle Group (Chinle) as described herein. **Table IV.2.3** provides surveyed coordinates for the April 2009 borings and wells.

Borings MP-1 through MP-5 were drilled using a single, portable CME 75 drill rig capable of using both hollow-stem auger (HSA) and air rotary methods. HSA was used in the upper 25 to 50 ft of the borings until claystone/siltstone of the Chinle was encountered. The Chinle was drilled to a total depth of 150 ft in each boring using air rotary.

TABLE IV.2.3
Summary of Surveyed Coordinates for Borings and Monitoring Wells (April 2009)
Sundance West

Boring	MP-1	MP-2	MP-3	MP-4	MP-5	MP-2P	MP-4P
Northing [1]	527446.10	529582.26	528611.24	527183.88	529535.82	529615.38	527183.88
Easting [1]	924459.82	924510.78	922630.93	919459.02	919611.93	924510.99	919489.02
Elevation[1]							
Ground Surface[2]	3,428.30	3,432.2	3,417.99	3,384	3,402.93	3,433.58	3,384.62
Concrete Pad[2]	NA	NA	NA	NA	NA	3433.58	3384.62
Top of Steel Casing	NA	NA	NA	NA	NA	3436.51	3387.56
Top of PVC Casing[3]	NA	NA	NA	NA	NA	3435.90	3387.09

Notes:
Survey by Pettigrew & Associates, Hobbs, New Mexico
N/A – Not applicable; borings MP-1 through MP-5 were plugged and abandoned
[1]NAVD88
[2]Ground surface elevation approximately equal to elevation of concrete pad
[3]Measuring point for groundwater static water levels

Samples of drill cuttings were collected at five-foot intervals for visual and physical classification of the subsurface materials (**Attachment IV.2.A**). During HSA drilling, split spoon samples were also collected at selected intervals for visual classification and laboratory analysis for geotechnical properties. Attachment C of **Attachment IV.2.A** includes the boring logs for borings MP-1 through MP-5.

As illustrated in the boring logs in **Attachment IV.2.A**, the shallow stratigraphy consists of very fine to medium-textured sand from the surface to the top of the Chinle. This layer is referred to as the Ogalalla/Antlers/Gatuña (OAG) formation in other local studies (Section 2.2). The sand may contain variable silt. Variable thickness of caliche and/or caliche-cemented sand is typical at depths of approximately 10 ft bgs. The Chinle redbeds below the unconsolidated sand are typically claystone to siltstone, with very isolated thin zones of very fine-to fine textured sand/sandstone. All materials encountered in borings MP-1 through MP-5 were dry to slightly moist with the exception of moist to wet sand at a depth of 21 to 26 ft bgs in boring MP-2 (see boring log in **Attachment IV.2.A**); and moist fine sand intervals at 47 to 48 ft, and 56 to 58 ft bgs in boring MP-4 (see boring log in **Attachment IV.2.A**). The drilling and installation of wells MP-2P and MP-4P were done in response to the isolated wet zones encountered in borings MP-2 and MP-4, respectively. Borings MP-1 through MP-5 were plugged and abandoned using cement-bentonite grout slurry (see well records in Attachment B of **Attachment IV.2.A**).

Following drilling of the MP borings shallow monitoring wells MP-2P and MP-4P were constructed at the locations shown on **Figure IV.2.4** to monitor any isolated zone(s) of saturation on top of and/or within the upper Chinle at those locations. The wells were constructed in response to moist/wet zones encountered in borings MP-2 and MP-4, respectively, as described above and illustrated on the boring logs (see **Attachment IV.2.A**).

Each well was constructed with an adequate length of screen and annular sand pack to capture any free water within the zones where moist/wet materials were encountered. Attachment C of **Attachment IV.2.A** includes the boring logs for borings MP-2P and MP-4P. Figures 3 and 4 of **Attachment IV.2.A** also includes the as-built construction schematics for monitoring wells MP-2P and MP-4P, respectively. **Table IV.2.4** summarizes the as-built construction specifications for MP-2P and MP-4P. **Table IV.2.4** also summarizes depth to groundwater measurements after the wells were installed.

3.1.2 October 2009 Site Investigation

GEI developed a *Supplemental Drilling Plan* (September 2009) that describes a proposed boring and testing program to further evaluate the subsurface conditions at the proposed Sundance West Site in compliance with the requirements of 19.15.36.8.C(15) NMAC and 19.15.36.13.A NMAC. **Attachment IV.2.C** includes a copy of the *Supplemental Drilling Plan*. The work proposed in the Supplemental Drilling Plan adds to the information obtained from the initial investigation conducted at the Site in April 2009; the scope of additional investigation was formulated in conjunction with OCD. The purpose of the Supplemental investigation was to complete the development of the site-specific geological, geotechnical, and hydrogeological database for the proposed Sundance West Site.

GEI, on behalf of Sundance, oversaw the drilling of four continuous coreholes and two geotechnical borings between October 3 and 10, 2009. Rodgers was again contracted by GEI to complete the following services for the supplemental drilling:

TABLE IV.2.4
As-built Construction Specifications for Monitoring Wells (April 2009)
Sundance West

Monitoring Well	**MP-2P**		**MP-4P**	
Specifications	***Elevation (fmsl)***	***Depth (fbgs)***	***Elevation (fmsl)***	***Depth (fbgs)***
Ground Surface [1]	3,433.58	-	3,384.62	-
Groundwater	3,405.49 3,405.48 3,404.92	30.41[a] 30.42[b] 30.98[c]	3,331.99 3,332.24	55.10[d] 54.85[c]
Top of PVC Casing	3,435.90	+2.32	3,387.09	+2.47
Total Well Depth	3,405.58	28	3,324.62	60
Well Screen Top	3,410.58	23	3,334.62	50
Well Screen Bottom	3,405.58	28	3,324.62	60
Filter Pack Top	3,412.58	21	3,336.62	48
Filter Pack Bottom	3,405.58	28	3,324.62	60
Annular Bentonite Seal Top	3,414.58	19	3,338.62	46
Annular Bentonite Seal Bottom	3,412.58	21	3,336.62	48
Annular Grout Seal Top	3,433.58	0	3,384.62	0
Annular Grout Seal Bottom	3,414.58	19	3,338.62	46
Borehole Diameter	7.25 inches (minimum)			
Length of Well Screen	MP-2P = 5 feet; MP-4P = 10 feet			
Well Screen	4-inch ID Schedule 40 PVC pipe, with 0.010 inch machined slots			
Well Casing	4-inch ID Schedule 40 PVC pipe, flush-threaded			
Filter Pack Material	10/20 Colorado silica sand			
Annular Bentonite Seal	Hydrated, coated bentonite pellets			
Annular Grout Seal	Cement-bentonite grout containing 2% to 5% bentonite			

NOTES:
[1]equals approximate elevation of concrete pad
[a]depth to groundwater measured below top of PVC casing on April 21, 2009
[b]depth to groundwater measured below top of PVC casing on April 22, 2009
[c]depth to groundwater measured below top of PVC casing on June 24, 2009
[d]depth to groundwater measured below top of PVC casing on May 1, 2009
fmsl = feet above mean sea level
fbgs = feet below ground surface ("+" indicates feet above ground surface)

- Drill four coreholes using a CME 75 HSA and continuously sample using a 5-foot long split barrel sampler.
- Drill two additional geotechnical borings using the same CME 75 HSA and sample at selected intervals using a 2-ft long split barrel (split spoon) sampler, or a 2-ft long split barrel ring sampler (California sampler).

The locations of the coreholes (CH-1 through 4) and geotechnical borings (GB-1 and 2) are shown on **Figure IV.2.4**. **Table IV.2.5** provides survey coordinates for the coreholes and geotechnical borings.

TABLE IV.2.5
Summary of Surveyed Coordinates for Coreholes and Geotechnical Borings
Sundance West

Boring	CH-1	CH-2	CH-3	CH-4	GB-1	GB-2
Northing [1]	528975.83	527727.07	527335.92	527368.07	528727.98	528754.35
Easting [1]	921004.45	921002.39	921307.46	922734.70	921756.64	924294.95
Surface Elevation[2]	3,410.89	3,403.40	3,401.30	3,408.44	3,412.93	3,427.14

Notes:
Survey by Pettigrew & Associates, Hobbs, New Mexico on October 30, 2009
All borings were plugged and abandoned to surface
[1]Modified ground coordinates; NM State Plane – East Zone NAD83
[2]Elevations are NAVD88

3.1.2.1 Continuous Coreholes CH-1 through CH-4

Coreholes CH-1 through CH-4 were drilled using a single, portable CME 75 drill rig using the HSA method. Drilling of the coreholes began on October 3, 2009; and concluded on October 10, 2009. Samples of auger drill cuttings were examined continuously to aid in visual and physical classification of the subsurface materials. During HSA drilling, the materials were cored continuously using a 5-ft long, 3.5-in. OD (2.5-in. ID) split barrel sampler. At each 5-ft interval to total depth, the sampler was tripped to the surface for detailed examination of the core and collection of samples at selected intervals for visual classification and laboratory analysis for geotechnical properties. The coreholes were drilled to depths ranging from 79 ft (CH-3 and 4) to 154 ft (CH-1) below existing grade. Attachment D of **Attachment IV.2.B** includes the boring logs for coreholes CH-1 through CH-4. Photographs of the coring operations are included in Attachment A of **Attachment IV.2.B.**

All materials encountered in coreholes CH-1 through CH-4 were dry to slightly moist. No free water or saturated materials were encountered in the coreholes. The stratigraphy encountered in coreholes CH-1 through CH-4 is consistent with that encountered during the initial Site investigation, and with regional investigations.

3.1.2.2 Geotechnical Borings GB-1 and GB-2

Following drilling of the CH coreholes, two geotechnical borings were drilled at the locations shown on **Figure IV.2.4** to characterize geotechnical conditions within the proposed landfill footprint. Each boring was drilled using the same CME 75 HSA drill rig used to drill the coreholes. Both of the geotechnical borings were drilled on October 10, 2009. Attachment D of **Attachment IV.2.B** includes the borehole logs for borings GB-1 and GB-2. Attachment A of **Attachment IV.2.B** includes photographs of the drill rig at borings GB-1 and GB-2.

Boring GB-2 was drilled first, and drive samples were attempted at five-ft intervals to a total depth of 46 ft below existing grade. Below a depth of 10 ft, the materials were hard/dense and standard blow counts using either a standard split spoon sampler or California sampler were greater than 50 per 6 in. Good samples of the material below 10 ft were not always possible because of their hard/dense nature. Good, undisturbed ring samples were retrieved at depths of 15 and 45 ft for analysis of geotechnical properties. Selected additional auger cuttings samples were collected for material classification and proctor density ("compaction ratios") as required in 19.15.36.8.C(15)(g) NMAC.

Boring GB-1 was also completed to a total depth of 46 ft below grade. Because of the difficulty driving the split spoon in boring GB-2, only two samples were collected from GB-1 for laboratory analysis at depths of 20 ft and 45 ft, respectively, using the California sampler. Selected additional auger cuttings samples were collected for material classification and proctor density ("compaction ratios") as required in 19.15.36.8.C(15)(g) NMAC.

All of the materials encountered in borings GB-1 and GB-2 were dry to slightly moist. No free water or saturated materials were encountered in the borings. The stratigraphy encountered in GB-1 through GB-2 is consistent with that encountered in coreholes CH-1 through CH-4; with the materials encountered during the initial Site investigation (Section 3.1.1); and with regional investigations (Section 2.0).

3.2 Geotechnical Evaluation

Attachment F of **Attachment IV.2.B** includes the laboratory report from AMEC Earth Environmental, Inc. (AMEC), for the samples submitted for testing as part of the October 2009 investigation. **Table IV.2.6** summarizes the standard engineering index properties (USCS soil classification; grain size distribution; natural dry density; Atterberg limits; and gravimetric moisture content) for the selected samples. **Table IV.2.6** also summarizes lab test results for standard proctor and permeability. The following sections address the specific geological/hydrological requirements of 19.15.36.8.C.15(g) NMAC: *"porosity, permeability, conductivity, compaction ratios, and swelling characteristics for the sediments on which the contaminated soils will be placed"*.

3.2.1 Porosity

Porosity was calculated for three samples submitted to AMEC for testing. Calculated porosities are summarized in **Table IV.2.7**. Two of the samples (GB-1 @ 20 ft; AMEC lab no. 9-1213-02 and GB-2 @ 15 ft; AMEC lab no. 9-1213-07) are representative of foundation material (clayey sand and silty sand, respectively) above the Chinle. Sample GB-1 @ 45 ft (AMEC lab no. 9-1213-04) is representative of Chinle (low-plasticity clay) foundation material.

TABLE IV.2.7
Summary of Calculated Porosities
Sundance West

Sample No.	Sample Depth (ft)	USCS Class[1]	Lab No.	Test Sample[2]	Porosity %
GB-1	20	SC	9-1213-02	Perm	50.6
	20	SC	9-1213-02	Collapse	50.5
GB-1	45	CL	9-1213-04	Perm	29.4
	45	CL	9-1213-04	Collapse	39.3
GB-2	15	SM	9-1213-07	Perm	41.6
	15	SM	9-1213-07	Collapse	29.9

AMEC Note (See Attachment F of **Attachment IV.2.B**): Based on a specific gravity of 2.6 g/cm^3. Note that Perm and Collapse porosities for lab number 9-1213-04 were taken from different ring samples
[1]Unified Soil Classification System: SM = silty sand; SC = clayey sand; CL = low-plasticity clay
[2]Porosity calculated from test sample from permeability or collapse test as shown

TABLE IV.2.6
Sumamry of Laboratory Geotechnical Testing Results
Sundance West

Sample Number[1]	Sample Depth (fbgs)	USCS Class[2]	Grain Size Distribution			Atterberg Limits[3]	Natural Dry Density (PCF)	Natural Moisture[4] (%)	Standard Proctor		Permeability (cm/sec)
			Pass #8 (%)	Pass #50 (%)	Pass #200 (%)	LL - PI			Max. Dry Density (PCF)	Optimum Moisture (%)	
GB-1	15-20	SC-SM	99	90	33.0	24-5		10.0	109.1	15.2	
	20	SC	80	70	29.0	42-18	80.2	12.0			9.4×10^{-5} R
	40-45	CL	96	79	56.0	30-14		9.0	114.4	14.6	
	45	CL	99	97	80.0	46-28	114.6	12.0			2.3×10^{-6} R
GB-2	5	SM	99	92	24.0	20-2		5.0			
	10-20	SM	94	80	27.0	NV-NP		3.0	111.6	13.5	
	15	SM	99	88	23.0	29-5	80.3	8.0			2.9×10^{-4} R
CH-1	154	CL	100	96	65.0	38-16		13.0			
CH-2	149	CL	100	91	73.0	30-11		8.0			
CH-3	79	ML	100	95	75.0	44-13		20.0			
CH-4	64	SM	97	67	30.0	24-3		5.0			

NOTES:

Blank field indicates test not conducted

[1]See **Figure IV.2.4** for locations of borings and Attachment D of **Attachment IV.2.B** for boring logs. Attachment F of **Attachment IV.2.B** includes complete laboratory analyses by AMEC

[2]Unified Soil Classification System: SM = silty sand; SC = clayey sand; ML = low-plasticity silt; CL = low-plasticity clay

[3]LL = liquid limit; PI = plasticity index; NV = non viscous; NP = non plastic

[4]Gravimetric basis

I = in-situ sample

3.2.2 Permeability/Conductivity

Permeability and hydraulic conductivity are terms used interchangeably in soils engineering to describe the capacity of a saturated soil to conduct water under a given hydraulic gradient. Permeability was determined in the laboratory on three brass ring (undisturbed) samples that were collected using a brass-ring sampler (see Section 3.1.2 and **Attachment IV.2.B**). **Table IV.2.8** summarizes the calculated permeability values. Two of the samples (GB-1 @ 20 ft; AMEC lab no. 9-1213-02 and GB-2 @ 15 ft; AMEC lab no. 9-1213-07) are representative of foundation material (clayey sand and silty sand, respectively) above the Chinle. Sample GB-1 @ 45 ft (AMEC lab no. 9-1213-04) is representative of Chinle (low-plasticity clay) foundation material.

TABLE IV.2.8
Summary of Calculated Permeabilities
Sundance West

Sample No.	Sample Depth (ft)	USCS Class[1]	Lab No.	ASTM[2]	Permeability (cm/s)
GB-1	20	SC	9-1213-02	D5856-95	9.4×10^{-5}
GB-1	45	CL	9-1213-04	D5084-03	2.3×10^{-6}
GB-2	15	SM	9-1213-07	D5856-95	2.9×10^{-4}

[1]Unified Soil Classification System: SM = silty sand; SC = clayey sand; CL = low-plasticity clay
[2]American Society for Testing and Materials: D5856-95 = Measurement of hydraulic conductivity by constant head method; D5084-03 = Measurement of hydraulic conductivity using a flexible wall permeameter

The calculated permeability values are generally representative of the materials sampled. While the low-plasticity clay sample (GB-1 @ 45 ft) has a relatively low calculated permeability of 2.3×10^{-6} centimeters per second (cm/s), clay/mudstone samples of the Chinle (see photographs in Attachment A of **Attachment IV.2.B**) that were not tested in the laboratory clearly have low permeability values estimated to be less than 10^{-7} cm/s and are likely high-plasticity clays (CH).

3.2.3 Compaction Ratios (Standard Proctor)

Compaction ratios (standard Proctor densities) were determined in the laboratory for three samples representative of foundation materials on which contaminated materials will be placed. **Table IV.2.9** summarizes the calculated densities and related optimum moisture contents. Two of the samples (GB-1 @ 15-20 ft; AMEC lab no. 9-1213-01 and GB-2 @ 10-20 ft; AMEC lab no. 9-1213-06) are representative of foundation material (clayey sand/silty sand and silty sand, respectively) above the Chinle. Sample GB-1 @ 40-45 ft (AMEC lab no. 9-1213-03) is representative of Chinle (low-plasticity clay) foundation material.

TABLE IV.2.9
Summary of Standard Proctor Densities and Optimum Moistures
Sundance West

Sample No.	Sample Depth (ft)[1]	USCS Class[2]	Lab No.	ASTM[3]	Maximum Dry Density (PCF)	Optimum Moisture (%)
GB-1	15-20	SC-SM	9-1213-01	D698-07	109.1	15.2
GB-1	40-45	CL	9-1213-03	D698-07	114.4	14.6
GB-2	10-20	SM	9-1213-06	D698-07	111.6	13.5

[1]Blended, composite 5-gallon sample collected within the specified depth interval
[2]Unified Soil Classification System: SM = silty sand; SC-SM = clayey sand/silty sand; CL = low-plasticity clay
[3]American Society for Testing and Materials: D698-07 = Moisture-density relationship using the standard Proctor method

3.2.4 Swelling Characteristics

Swell can be measured on a cohesive (clay) soil, while granular (sand) soils are tested for settlement (collapse). Two brass ring (undisturbed) granular (sand) samples representative of foundation materials on which contaminated materials will be placed (GB-1 @ 20 ft; AMEC lab no. 9-1213-02 and GB-2 @ 15 ft; AMEC lab no. 9-1213-07) were tested for collapse. One brass ring (undisturbed) clay sample representative of Chinle foundation material (GB-1 @ 45 ft; AMEC lab no. 9-1213-04) was tested for swell. **Table IV.2.10** summarizes the swell/collapse testing of the three samples.

TABLE IV.2.10
Summary of Swell/Collapse Characteristics
Sundance West

Sample No.	Sample Depth (ft)	USCS Class[1]	Lab No.	ASTM[2]	Collapse (c) Swell (s) (%)[3]	Surcharge (tsf)[4]
GB-1	20	SC	9-1213-02	D5333	5 (c)	6.25
GB-1	40	CL	9-1213-04	D4546-08	0 (s)	1
GB-2	15	SM	9-1213-07	D5333	5 (c)	6.25

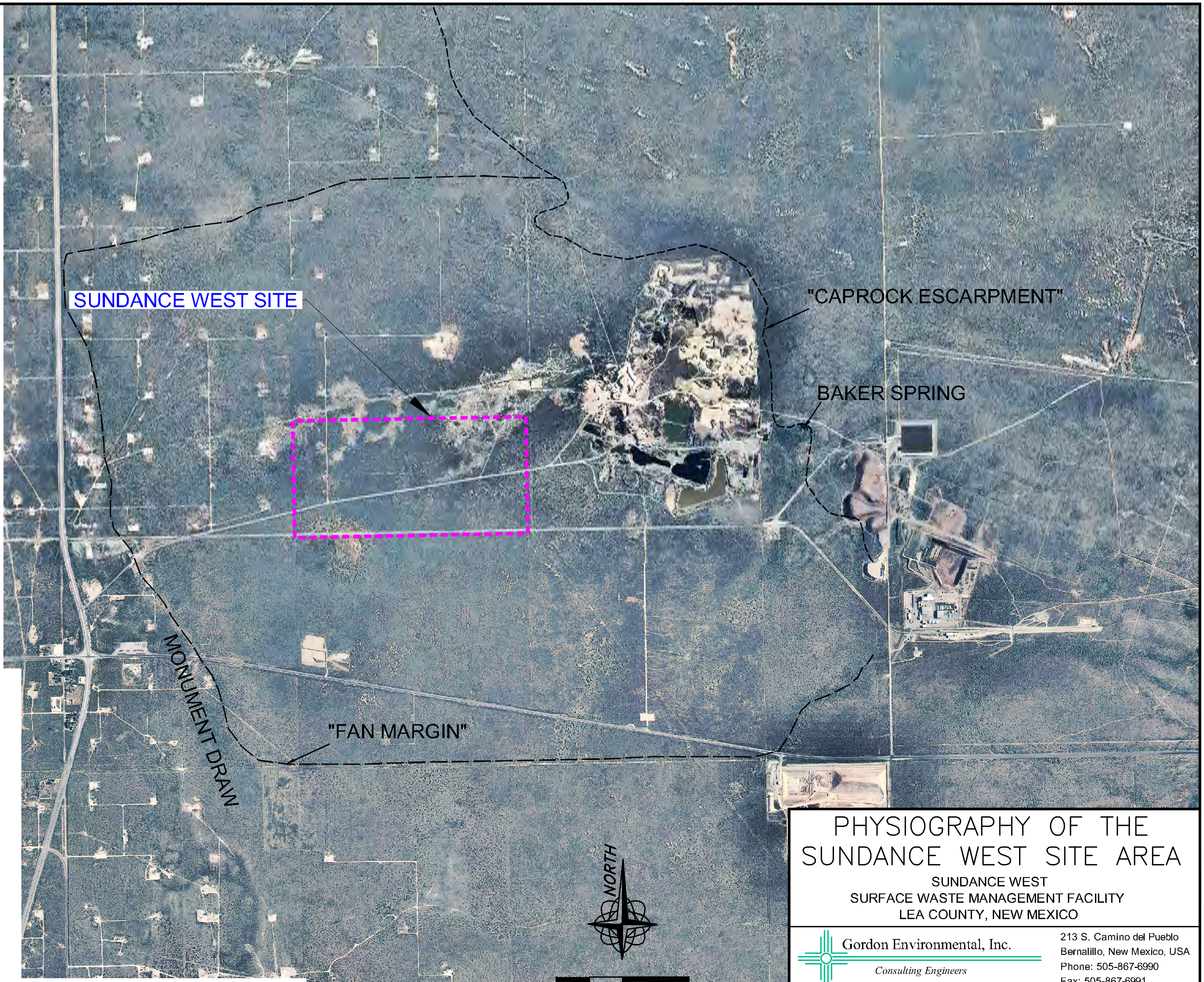
[1]Unified Soil Classification System: SM = silty sand; SC = clayey sand; CL = low-plasticity clay
[2]American Society for Testing and Materials: D5333 = Measurement of collapse potential of soils; D4546-08 = One-dimensional swell or settlement potential of cohesive soils
[3]Percent of initial sample height at maximum surcharge loading
[4]Maximum surcharge loading

3.3 Site Geology

The Site geology as determined from the site-specific investigations discussed herein is consistent with the regional geology as determined from extensive investigations surrounding the Site (Section 2.0).

In conformance with 19.15.36.8.C.15(d) NMAC and as illustrated in the boring logs in **Attachments IV.2.A** and **IV.2.B**; the shallow Site stratigraphy consists of very fine to medium-textured sand from the surface to the top of the Chinle. This layer is referred to as the Ogalalla/Antlers/Gatuña (OAG) formation in other local studies (Section 2.2). The sand may contain variable silt. Variable thickness of caliche and/or caliche-cemented sand is typical at depths of approximately 10 ft below the surface. The Chinle redbeds below the unconsolidated sand, to a depth of at least 150 ft below Site grade; are typically claystone to siltstone, with very isolated thin zones of very fine-to fine textured sand/sandstone.

Figure IV.2.18 is an aerial image showing the main physiographic features of the Site and local region. The local region and proposed Sundance West Site lie on an alluvial fan deposit. The fan deposit is the result of the drainage off the western edge of the Llano Estacado during a long span of geologic time beginning at least in the Pliocene Epoch of the Tertiary, 2 to 3 million years ago (Hawley, 2005). Drainage of the western Llano upland surface (over the Caprock Escarpment) from several large playas was strong during the several humid climatic phases of the late Tertiary and Pleistocene. The catchment area of this drainage reaches from the Llano edge eastward to the Rattlesnake Ridge divide (Geologic Atlas of Texas, 1976). The fan is a complex of several stages of deposition, corresponding to climatic phases. The base of the fan represents the most extensive phase of deposition, probably related to a long and intense humid period late in the Pliocene. Drainage during subsequent decreasingly humid pluvial periods of the Pleistocene-generated smaller fan deposits on the surface of the Pliocene fan. These account for local steepening of the gentle upper surface of the composite fan. The drainage that built the fan shaped the terrain along the entire margin between the Llano and the Pecos River valley in the Site region, which has changed little since the last Pleistocene pluvial period.



PHYSIOGRAPHY OF THE SUNDANCE WEST SITE AREA

SUNDANCE WEST
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DATE: 01/21/2010	CAD: BAKER SPRINGS-CAPROCK 01.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: IKG	FIGURE IV.2.18
APPROVED BY: IKG	gei@gordonenvironmental.com	

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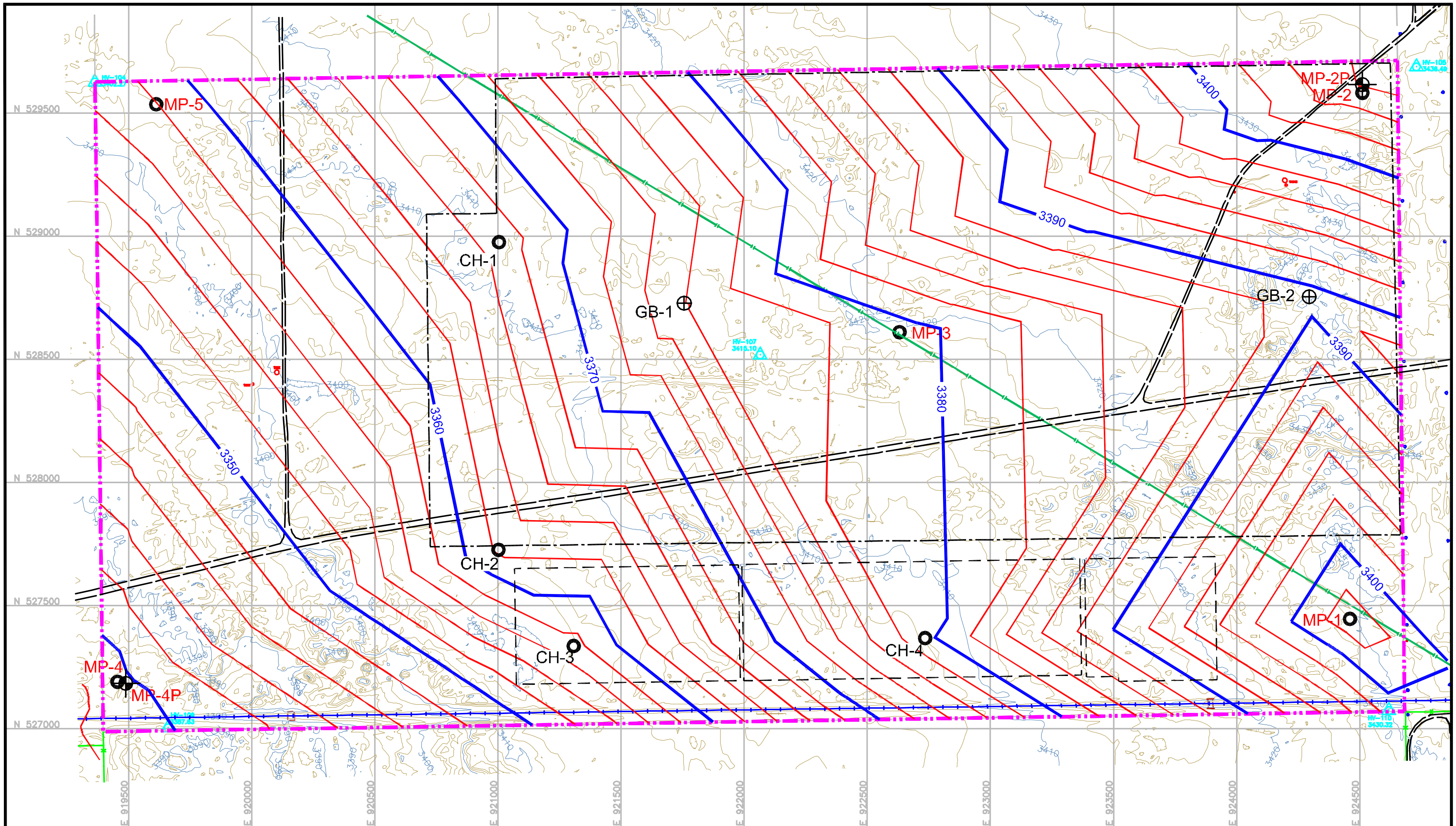
The alluvial fan is a thickened irregular conical body of alluvium of the type common in arid regions of the American Southwest. It consisted of sufficient volumes of sediment to push Monument Draw to the west and to narrow its valley. Its upper surface is covered by the reddish brown BDF of late Pleistocene age. The BDF is mostly dune and windblown sand with differentially developed horizons of a soft caliche and soil. The BDF is widely used for road surfacing throughout the region and there are many light colored areas on the upper surface of the fan where caliche has been harvested for that purpose.

The main body of the fan is made up of alluvial material that is difficult to assign to any of the regional stratigraphic units because of its origin by transport off the Llano by largely ephemeral drainage during a complex series of climatic regimes (Nicholson and Clebsch, 1961). Gravel, in a complex distributary channel system, and sand and silt with various degrees of caliche and soil development; are predominant. In general, the energy of transport diminished as runoff moved down the gentle westerly fan slope, away from the scarp and the average grain-size of the alluvium decreases. The distribution of alluvium is very complex in such bodies and is difficult to predict.

The Dockum Group (Chinle Group or Chinle redbeds) within the Site area lies beneath the OAG. **Figure IV.2.12** is a contour map of the top of the Chinle developed from site-specific information collected during the two drilling programs in April and October, 2009. The attitude of the Chinle-OAG unconformity beneath the Site dips gently (less than 1 degree) to the west-southwest, generally consistent with the surface topography. The attitude of the top of the Chinle and overlying stratigraphy are consistent with the local regional conditions described in Section 2.4.1 and as illustrated in **Figure IV.2.19**.

In conformance with 19.15.36.8.C.15(e) NMAC; **Figure IV.2.20** shows the locations of six cross sections through the Sundance West Site (**Figures IV.2.21** through **IV.2.23**, respectively); and the footprint of the proposed landfill and associated lined ponds south of the landfill. **Figures IV.2.21** through **IV.2.23** present six geologic cross sections of the shallow Site geology developed from the site-specific information collected during the two



LEGEND

	LANDFILL BOUNDARY
	PROCESS AREA BOUNDARY
	FENCE
	SECTION, 1/4 SECTION LINE
	UNPAVED ROAD
	POWER POLE
	MISC./UNIDENTIFIED OBJECT
	RAILROAD TRACK
	BOX CULVERT
	STORAGE TANK
	CONCRETE SLAB
	EXISTING WATER SUPPLY PIPELINE
3350	TOP OF CHINLE REDBEDS 10' CONTOUR
	TOP OF CHINLE REDBEDS 2' CONTOUR
	INTERMEDIATE CONTOUR
3460	INDEX CONTOUR
	INTERMEDIATE DEPRESSION
3440	INDEX DEPRESSION
	FACILITY BOUNDARY
	CONTROL POINT
N 529000	GRID LINE/LABEL
GB-1	GEOTECHNICAL BOREHOLE LOCATION (PLUGGED)
CH-1	COREHOLE LOCATION (PLUGGED)
MP-1	BOREHOLE LOCATION (PLUGGED)
MP-2P	MONITORING WELL LOCATION

NORTH

0' 300' 600'

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TOP OF CHINLE REDBED CONTOURS

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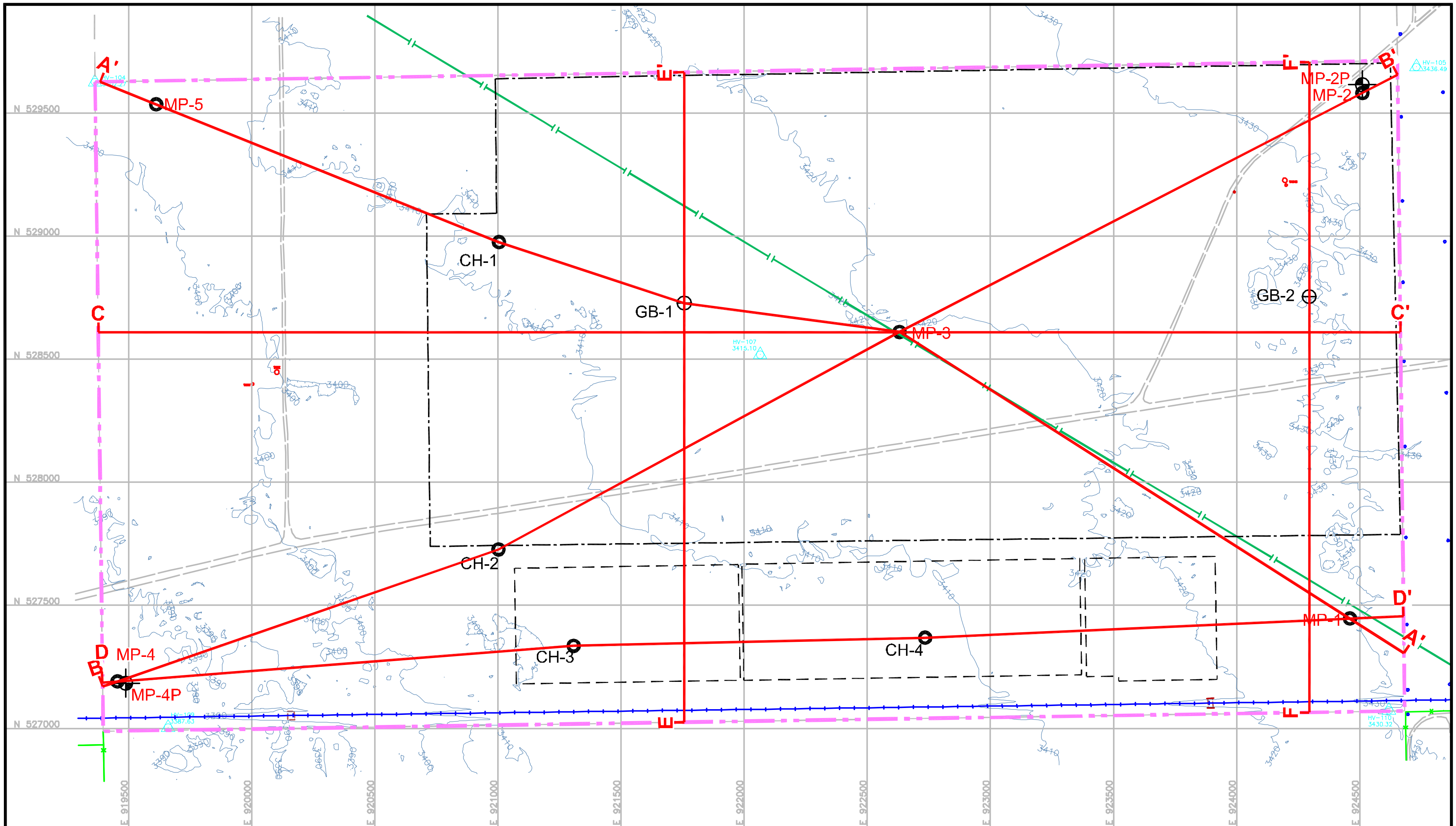
DATE: 01/21/2010	CAD: MP BOREHOLES CHINLE TOP.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: IKG	FIGURE IV.2.19
APPROVED BY: IKG	gei@gordonenvironmental.com	



LEGEND

	LANDFILL BOUNDARY
	LANDFILL PROCESS AREA BOUNDARY
	FENCE
	SECTION, 1/4 SECTION LINE
	UNPAVED ROAD
	POWER POLE
	MISC./UNIDENTIFIED OBJECT
	RAILROAD TRACK
	BOX CULVERT
	STORAGE TANK
	CONCRETE SLAB
	EXISTING WATER SUPPLY PIPELINE
A A'	CROSS SECTION LOCATION
3460	10' CONTOUR
3440	10' DEPRESSION CONTOUR
	FACILITY BOUNDARY
	CONTROL POINT
N 529000	GRID LINE/LABEL
GB-1	GEOTECHNICAL BOREHOLE LOCATION (PLUGGED)
CH-1	COREHOLE LOCATION (PLUGGED)
MP-1	BOREHOLE LOCATION (PLUGGED)
MP-2P	MONITORING WELL LOCATION

NORTH

0' 300' 600'

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AERIAL SURVEY BY THOMAS R. MANN & ASSOCIATES
AERIAL MAPPING SERVICES
5115 COPPER NE, ALBUQUERQUE, NM 87108
DATE OF PHOTOGRAPHY 10-01-08

SITE MAP AND LOCATIONS OF GEOLOGICAL CROSS SECTIONS A–A' THROUGH F–F'

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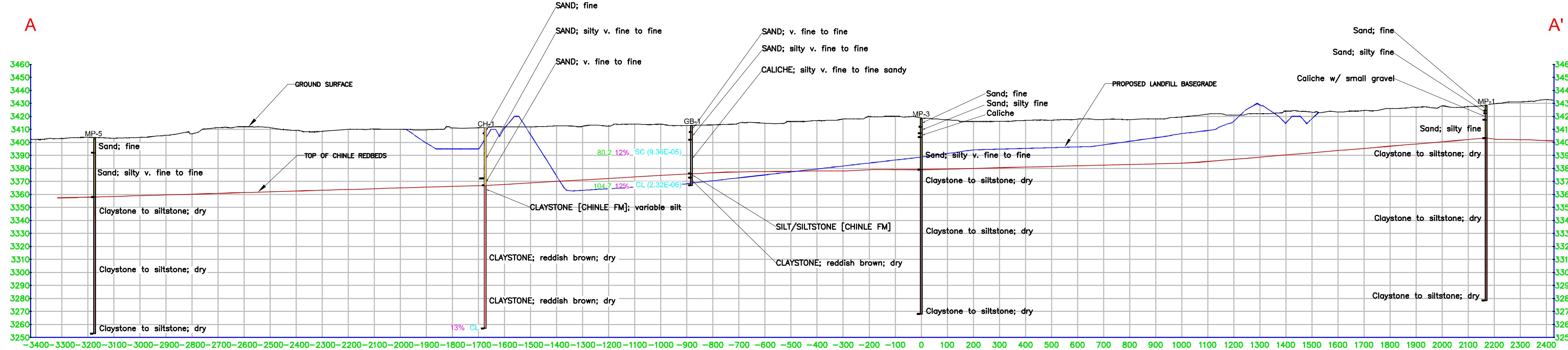
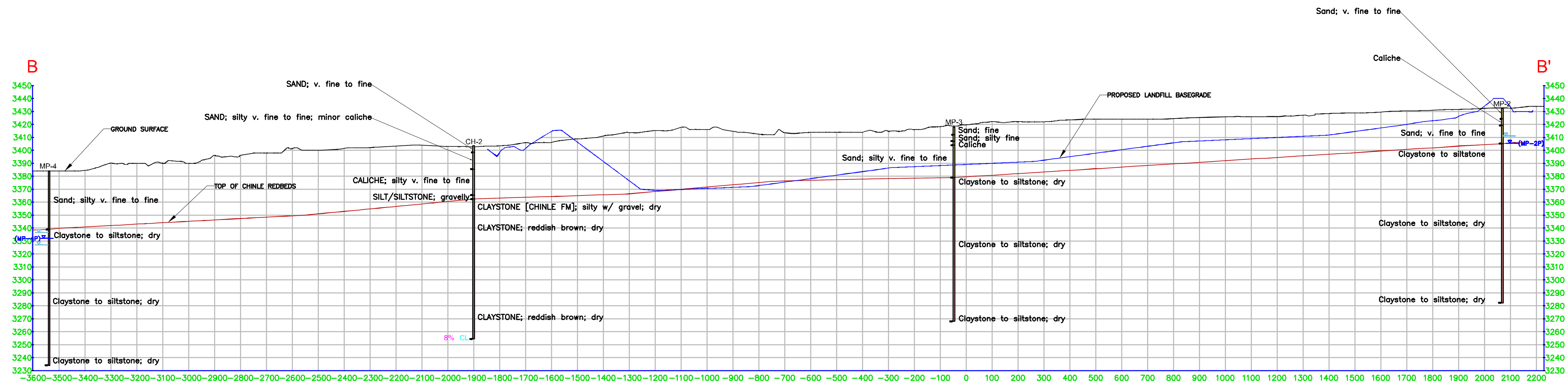
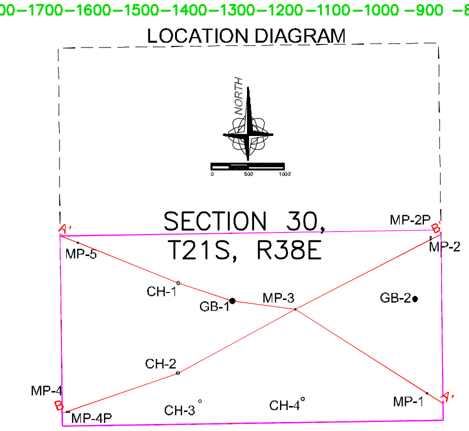
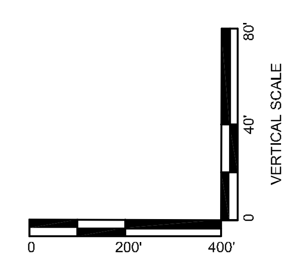
DATE: 01/19/2010	CAD: CROSS SECTION LOC.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: IKG	FIGURE IV.2.20
APPROVED BY: IKG	gei@gordonenvironmental.com	







KEY
WATER ENCOUNTERED DURING DRILLING
WATER LEVEL AFTER COMPLETION (NOTE: FROM MP-2P AND MP-4P WATER LEVELS)
SC (9.36E-05) LAB UNIFIED SOIL CLASSIFICATION (LAB PERMEABILITY CM/S)
12% LAB MOISTURE CONTENT (% DRY WEIGHT)
80.2 LAB DENSITY (lb/cu.ft.)



GEOLOGICAL CROSS SECTIONS A–A' AND B–B'

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DATE: 01/18/2010	CAD: CROSS-SECTIONS MP VE5.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: LMC	FIGURE IV.2.21
APPROVED BY: IKG	gei@gordonenvironmental.com	

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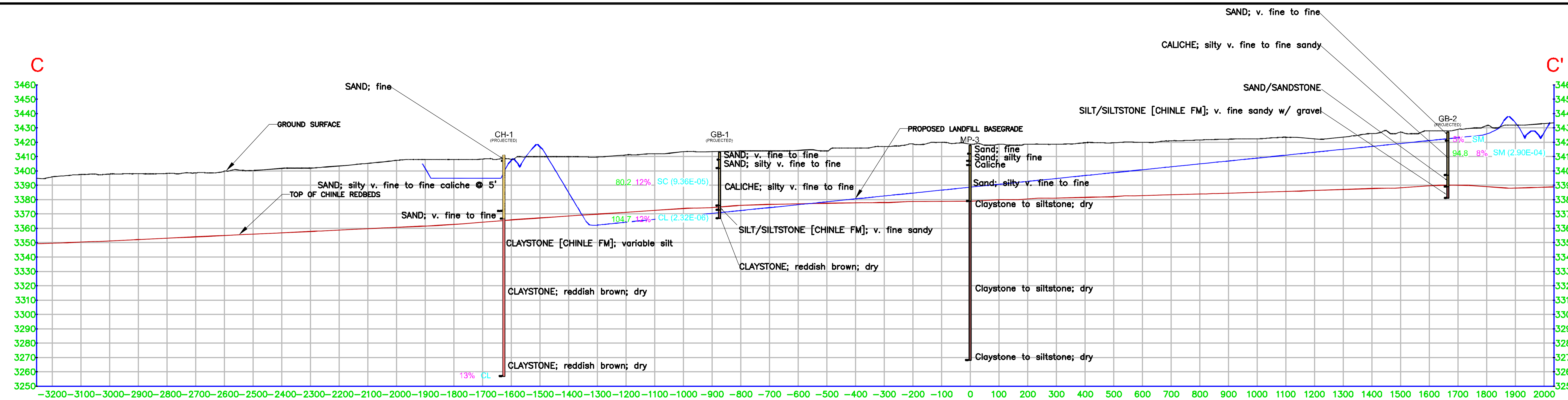
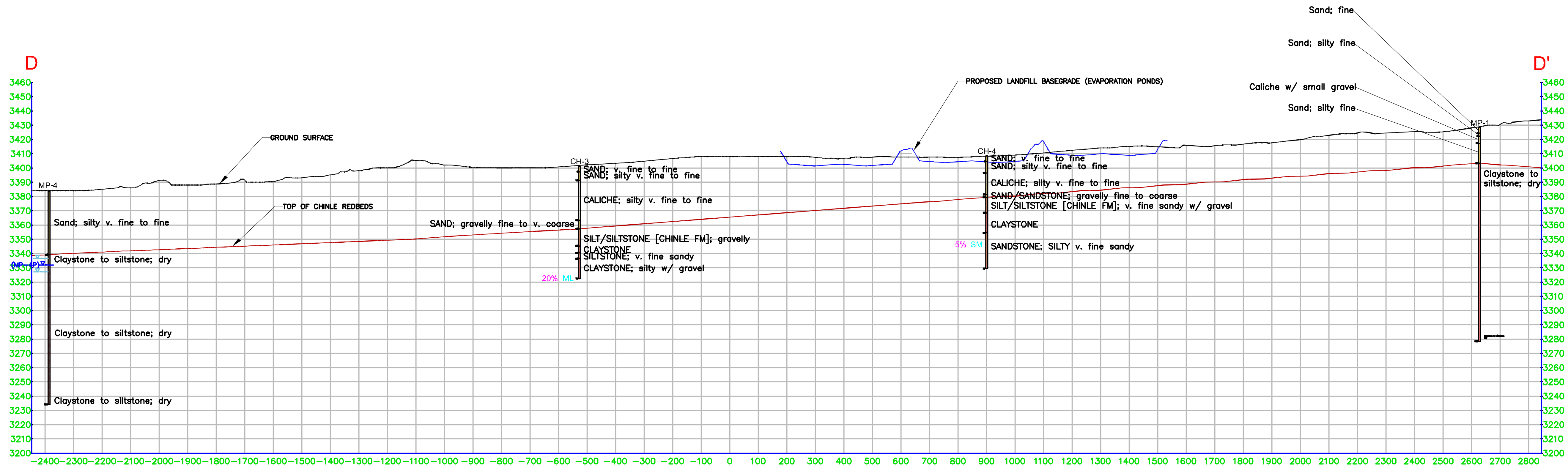
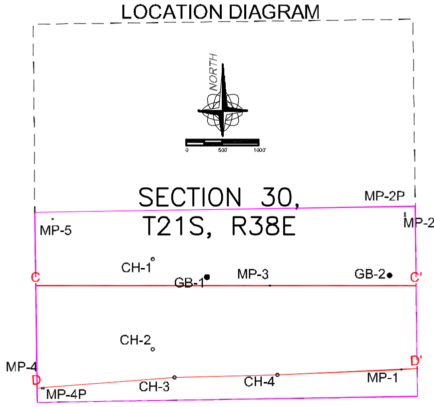


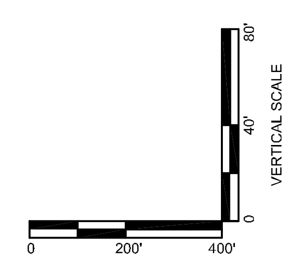


LOCATION DIAGRAM



KEY

SC (9.36E-05) LAB UNIFIED SOIL CLASSIFICATION (LAB PERMEABILITY CM/S)
12% LAB MOISTURE CONTENT (% DRY WEIGHT)
80.2 LAB DENSITY (lb/cu.ft.)



GEOLOGICAL CROSS SECTIONS C–C' AND D–D'

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DATE: 01/18/2010	CAD: CROSS-SECTIONS MP VE5.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: LMC	FIGURE IV.2.22
APPROVED BY: IKG	gei@gordonenvironmental.com	

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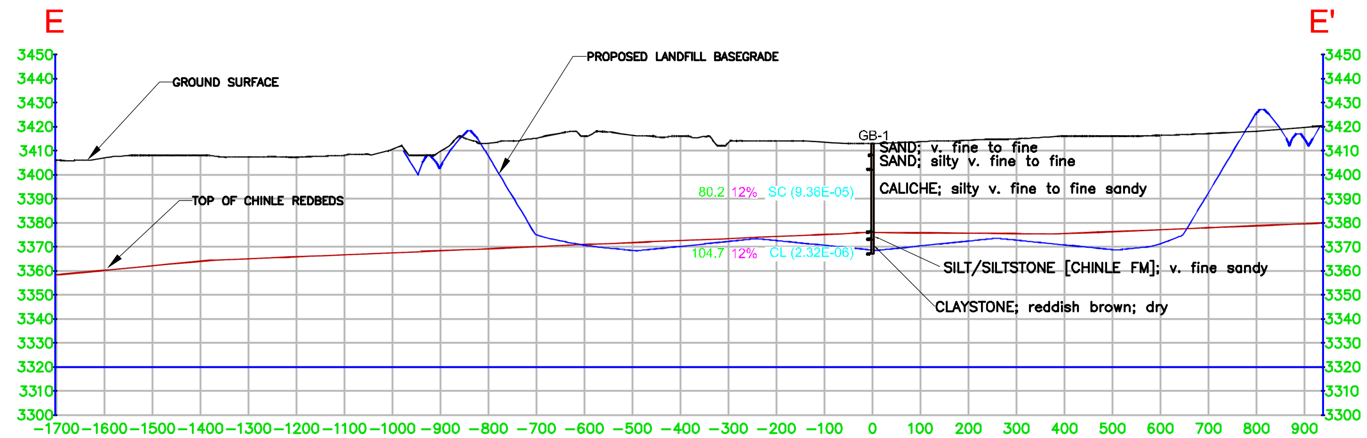
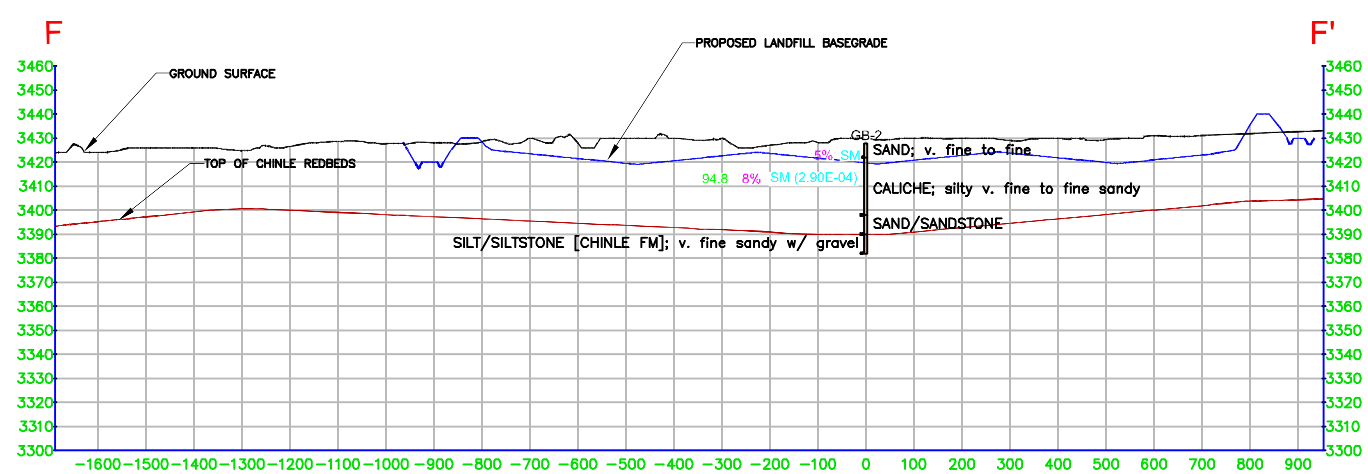
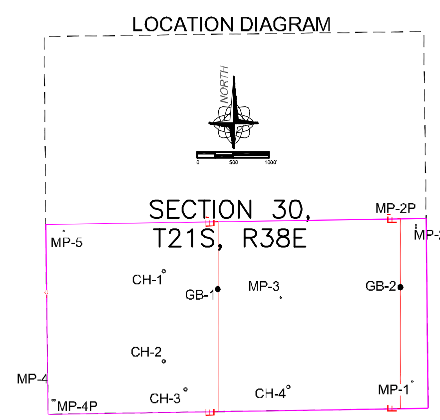




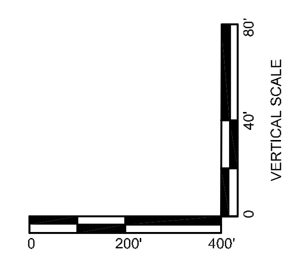


KEY

SC (9.38E-05) LAB UNIFIED SOIL CLASSIFICATION (LAB PERMEABILITY CM/S)

12% LAB MOISTURE CONTENT (% DRY WEIGHT)

80.2 LAB DENSITY (lb/cu.ft.)



GEOLOGICAL CROSS SECTIONS E–E' AND F–F'

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DATE: 01/18/2010	CAD: CROSS-SECTIONS MP VE5.dwg	PROJECT #: 530.01.01
DRAWN BY: MLH	REVIEWED BY: LMC	FIGURE IV.2.23
APPROVED BY: IKG	gei@gordonenvironmental.com	

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Date/Time:Jan. 19, 2010-09:18:23

drilling programs in April and October, 2009. The cross sections illustrate the Site stratigraphy as described in this section, and further illustrate consistency of the Site stratigraphy with regional conditions.

3.4 Site Hydrogeology

This section addresses the following 19.15.36 NMAC requirements:

Depth to groundwater: no landfill shall be located where groundwater is less than 100 feet below the lowest elevation of the design depth at which the operator will place oil field waste (19.15.36.13.A NMAC).

Depth to, formation name, type and thickness of the shallowest fresh water aquifer (19.15.36.8.C.15(c) NMAC).

Laboratory analyses, performed by an independent commercial laboratory, for major cations and anions; BTEX; RCRA metals; and TDS of groundwater samples of the shallowest fresh water aquifer beneath the proposed site (19.15.36.8.C.15(b) NMAC).

Section 3.3 and **Figure IV.2.18** describe the shallow alluvial fan geology within the Site area. The hydrogeology of alluvial fans is largely controlled by the distribution of grain-size of the alluvium and by the distribution of caliche and soil developed during the alternating humid and arid climatic phases characteristic of the history of the region. The fan within the local region of the proposed Sundance West Site lies on an eroded surface of the Chinle Group claystone (Chinle) at its eastern origin where it meets the Llano margin and may extend over the thickened OAG at its western terminus near Monument Draw (John Gibbons, pers. ref.).

The presence of any perched water within the OAG fan is no longer related to the drainage originating on the edge of the Llano Estacado. The upper surface of the fan (BDF) is permeable, and the rainfall on the fan surface infiltrates the very permeable alluvium generating only ephemeral local runoff. Any perched water originates as the result of retardation of downward percolation of rainwater that infiltrates the fan surface in patterns that reflect the fan micro-topography and the surface grain-size distribution of the alluvium. The three-dimensional fan permeability reflects the depositional and soil formation histories of the fan.

Buried surfaces of caliche formation and soil formation can locally control groundwater movement. Alluvial grain-size is related to the distribution of energy of transport at the time of deposition. Energy of transportation has shifted across the fan surface in complex patterns in response to the climatic cycles during fan building over a period of more than two million years. Local areas of near-surface perched water may be evident in the distribution of phreatophytic plants on the fan surface. Also, there may be local accumulations of perched water within the fan that are not reflected by plant distribution.

As described in Section 3.1; all materials encountered in borings MP-1 through MP-5 (see **Figure IV.2.4**) were dry to slightly moist with the exception of moist to wet sand at a depth of 21 to 26 ft bgs in boring MP-2 (see boring log in Attachment C of **Attachment IV.2.A**); and moist fine sand intervals at 47 to 48 ft, and 56 to 58 ft bgs in boring MP-4 (see boring log in Attachment C of **Attachment IV.2.A**). Wells MP-2P and MP-4P were completed subsequent to drilling and sampling borings MP-1 through MP-5 to monitor thin, isolated zone(s) of free water perched on top of, and/or within, the upper Chinle. Only well MP-2P is within the proposed landfill footprint area (see **Figures IV.2.4** and **IV.2.20**).

Subsequent to the initial field investigation in April 2009; wells MP-2P and MP-4P were bailed on June 24 and 25, 2009. On June 24, 2009 only 0.2 ft of water was measured in well MP-2P, and only 1.5 in. of water could be bailed (one time) from the well. The well did not recover, and only a very small amount of water was in the bottom cap of the well when measured on June 25. On June 24, a total of 15 liters (4 gallons) was bailed from well MP-4P. Approximately 15 hours after bailing (on June 25, 2009), the water level in MP-4P had recovered to within 94 percent of the pre-bailing static water level. The bailing and sampling conducted on June 24 and 25, 2009 indicates the following:

- The small amount of fluids in well MP-2P are not natural formation water; but rather a small amount of anthropogenic water either added during well construction to hydrate the bentonite pellets in the well annulus, and/or from activities associated with the Wallach gravel quarry operation to the east.
- The minor amount of water produced from well MP-4P is likely natural formation (non-anthropogenic) water.

Consistent with the requirements of 19.15.36.8.C(15)(b) NMAC, groundwater samples collected from well MP-4P on January 12, 2010 were analyzed by an independent commercial laboratory (i.e., Hall Environmental Analysis Laboratory, Albuquerque, NM) for the following constituents listed in 20.6.2.3103 NMAC for which a NM Water Quality Control Commission (WQCC) standard is established:

- Major cations and anions
- Benzene, toluene, ethylbenzene, xylenes (i.e., BTEX)
- RCRA 8 metals
- Total dissolved solids (TDS)

Additional samples were collected and analyzed for general chemistry parameters (i.e., total alkalinity, carbonate, bicarbonate, pH, and specific conductance). The analytical results show that only three constituents (barium, fluoride, and iron) were detected at concentrations above the WQCC groundwater protection standard (GWPS); and the remaining analytes for which a GWPS is established were not detected above the laboratory method practical quantitation limit (PQL). The laboratory analytical report for the January 2010 sampling event is provided as **Attachment IV.2.D**.

No groundwater was encountered in any of the borings or coreholes drilled during the October 2009 drilling program (see Section 3.1.2). Site-specific data collection demonstrates that the proposed Site meets the requirement for a minimum separation distance of 100 ft between the base of the proposed landfill area as shown in **Figure IV.2.14**, and the groundwater bearing unit (19.15.36.13.A NMAC); and for other non-landfill operations subject to the 50 ft vertical groundwater setback (lined ponds and process facilities) located south of the landfill footprint (19.15.36.13.A NMAC).

As described in Section 2.5, the permanent uppermost regional aquifer beneath the Site area lies at a depth of at least 675 to 1,075 ft in the Santa Rosa Formation of the Dockum Group. Above this depth, the Chinle Group consists predominantly of siltstones, claystones and mudstones having hydraulic conductivities in the range of 10^{-8} to 10^{-10} cm/sec.

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