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AIR COMBAT COMMAND

HOLLOMAN AFB
NEW MEXICO

FINAL

SOIL AND GROUNDWATER STUDY OF THE 20,000 # EOD FACILITY

OCTOBER 1993

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EXECUTIVE SUMMARY

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This soil and groundwater study was conducted at the 20,000 Pound Explosive Ordnance Disposal (EOD) Facility at Holloman Air Force Base (AFB), New Mexico. The EOD Facility is located at the north end of the High Speed Test Track in the northern expanse of Holloman AFB. The facility is presently active, and has been in operation for over five years. The facility is used to dispose of explosives and rocket propellants, by detonation of the materials in two open pits. The objective of the study was to determine if the use of the facility has contaminated the soils or groundwater in the area.

To investigate the subsurface lithology and groundwater, one upgradient and three downgradient borings were drilled and sampled. Monitoring wells were installed in these four borings. The lithology of the facility consisted of sand and silt-fine sand resting on silty clay. The sand and silt-fine sand deposits are about 35 feet thick. The thickest sequence of sand and silt-fine sand was observed in the southwestern downgradient well (HAFB/EOD-MW02). A two-foot thick layer of silty clay was found 12 feet below the surface. The thickest layer of the silty clay was found in the upgradient well (HAFB/EOD-MW01).

During the May 1993 field investigation, groundwater was found to be flowing to the southwest, parallel to Allen Draw. Groundwater was found at about 30 feet below ground level. The hydraulic gradient across the site was about one vertical foot for every 41.4 feet traversed horizontally. The hydraulic conductivity was between low and moderate with values ranging between 1.0×10^{-4} to 5.3×10^{-4} feet/minute. The more permeable sediments were found downgradient of the facility.

Groundwater samples were taken from the four borings. Chemical analysis of the groundwater showed the presence of several metals and cyanide. The metals in the groundwater most likely originated from metals found in the silty clay. Cyanide was found in trace concentrations in the downgradient wells. The cyanide may be associated with the burning of carbon-containing materials in the presence of nitrogen during the detonation of explosives.

Soil samples were taken from the well borings, and from the surface of the EOD pits. The chemical analysis of the subsurface soil and surface soil samples showed various metals to be present. Most of the metals found occur naturally in the area. Cadmium, however, may be a residual metal associated with the detonation of explosives. The organic analysis identified diethylphthalate in the surface samples taken from the detonation pits. Dimethylphthalate was found in one surface soil sample. Nitroglycerin was found in three surface samples. Several other organic analytes found during this study are suspected of being laboratory contaminants.

Several areas needing further investigation were identified as a result of this study. Groundwater samples should be collected within 50 feet of the center of the detonation pits. This sample could be collected from a new well or from a Hydropunch. During the study, minute scattered yellow resinous fragments were seen around the detonation pit. A chemical analysis of this material is recommended, in order to assess the potential environmental impact of this material on the site. Finally, a surface soil sampling program was requested by the New Mexico Environmental Department (NMED). This program should include random sampling, samples from Allen Draw, samples of outcropping silty clay, and quality assurance/quality control samples.

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This field investigation was conducted to assess the impact of the disposal of explosives on the soils and groundwater at the 20,000 Pound EOD Facility at Holloman AFB, New Mexico. The EOD Facility is presently active, and has been in operation for over five years. This report contains the findings of the field investigation.

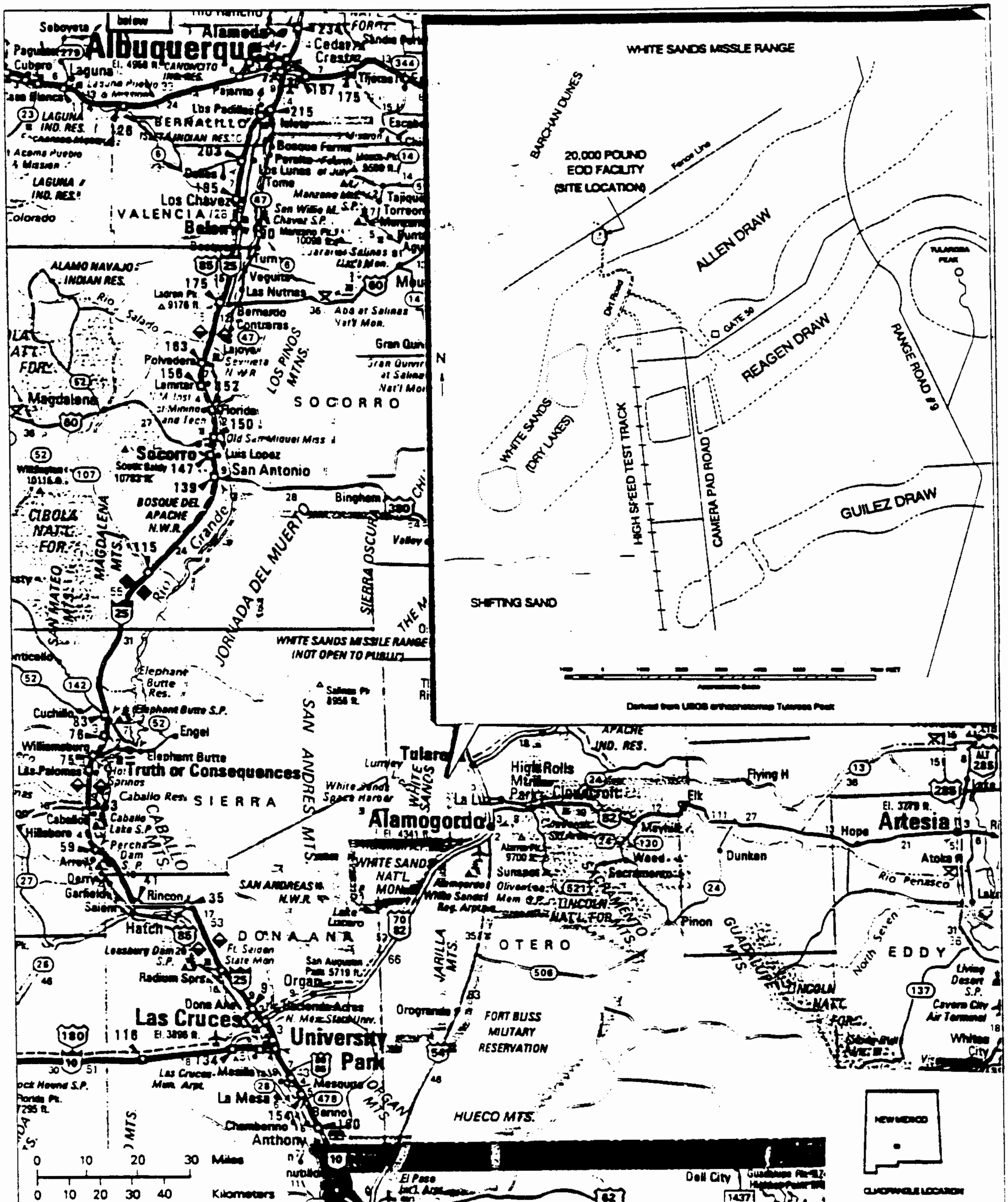
The investigation included four borings, groundwater sampling, and the installation of monitoring wells, in the four borings, at the facility. The study also included subsurface soil sampling from the borings, and surface soil samples from within the EOD pits. The sampling and analysis program identified the presence of explosives, inorganics, and phthalates in the surface soils, and trace amounts of several inorganics and cyanide in the groundwater. The inorganics probably occur naturally in the area. The explosives and phthalates found within the EOD pits are associated with disposal activities. The cyanide may be a result of disposal activities, but was identified at levels of 0.01 and 0.02 ppm, which are near the method detection limits (0.01 ppm) for cyanide. Additional sampling of the groundwater is warranted, as recommended in Chapter 5.

1.1 Location and Site Description

Holloman AFB is located on approximately 50,700 acres of land in Otero County, New Mexico. The base is located south of the White Sands Missile Range and northeast of White Sands National Monument, as shown in Figure 1.1-1. The nearest population center is the city of Alamogordo located approximately seven miles to the east. Regional metropolitan centers include El Paso, Texas, located 75 miles to the south and Albuquerque, New Mexico, located 210 miles north of the facility.

The EOD Facility is located in the northwest corner of Holloman AFB, approximately 20 miles north of the main access gate. The site is located at the northern end of the High Speed Test Track near the southeast corner of the White Sands Missile Range. The site is near the center of the NW 1/4 of Section 12, Township 15 South, Range 8 East, (New Mexico Prime Meridian), Otero County, New Mexico.

The EOD Facility is in the northern Chihuahuan Desert, in the region known as the Tularosa Basin. The basin is bounded to the east by the Sacramento Mountains and to the west by the San Andres Mountains. The topography at the EOD Facility slopes very slightly to the south and southeast towards Allen Draw. Scattered sand dunes occur to the west and a low north-south trending ridge lies south and west of the site. Tularosa Peak is a prominent landmark rising 300 feet above the surrounding terrain two miles east of the EOD Facility. Photographs of the site are presented in Appendix A.



HOLLOMAN AIR FORCE BASE NEW MEXICO	Figure 1.1-1 Site Location Map

The EOD site consists of two adjacent circular pits actively used in the disposal of explosives. These pits are occasionally backfilled with soils that have been ejected from the detonation pits, and therefore the dimensions of the pits are not constant. In May 1993, the approximate dimensions were 36 feet in diameter and nine feet in depth, and 52 feet in diameter and two feet in depth. A graded circular area of approximately 125 feet encircling the disposal pits serves as a firebreak. Prior to field operations in May, the graded area had an earthen berm that ranged from one to two feet in height. An access road enters from the south and skirts the eastern edge of the EOD Facility. An old barb wire fence cuts across the northern section of the facility extending from the northeast to the southwest. A topographic map of the facility is shown in Figure 1.2-1.

The area surrounding the site is covered by sagebrush and chaparral bush. The basal area of these plants show signs of being singed and burned. A safety zone of approximately 1,680 feet in radius from the pits is enforced during the disposal of explosives.

The nearest building, structure or construction is the High Speed Test Track located approximately half a mile to the south. An unimproved dirt road leads from the northern end of the test track to the EOD Facility.

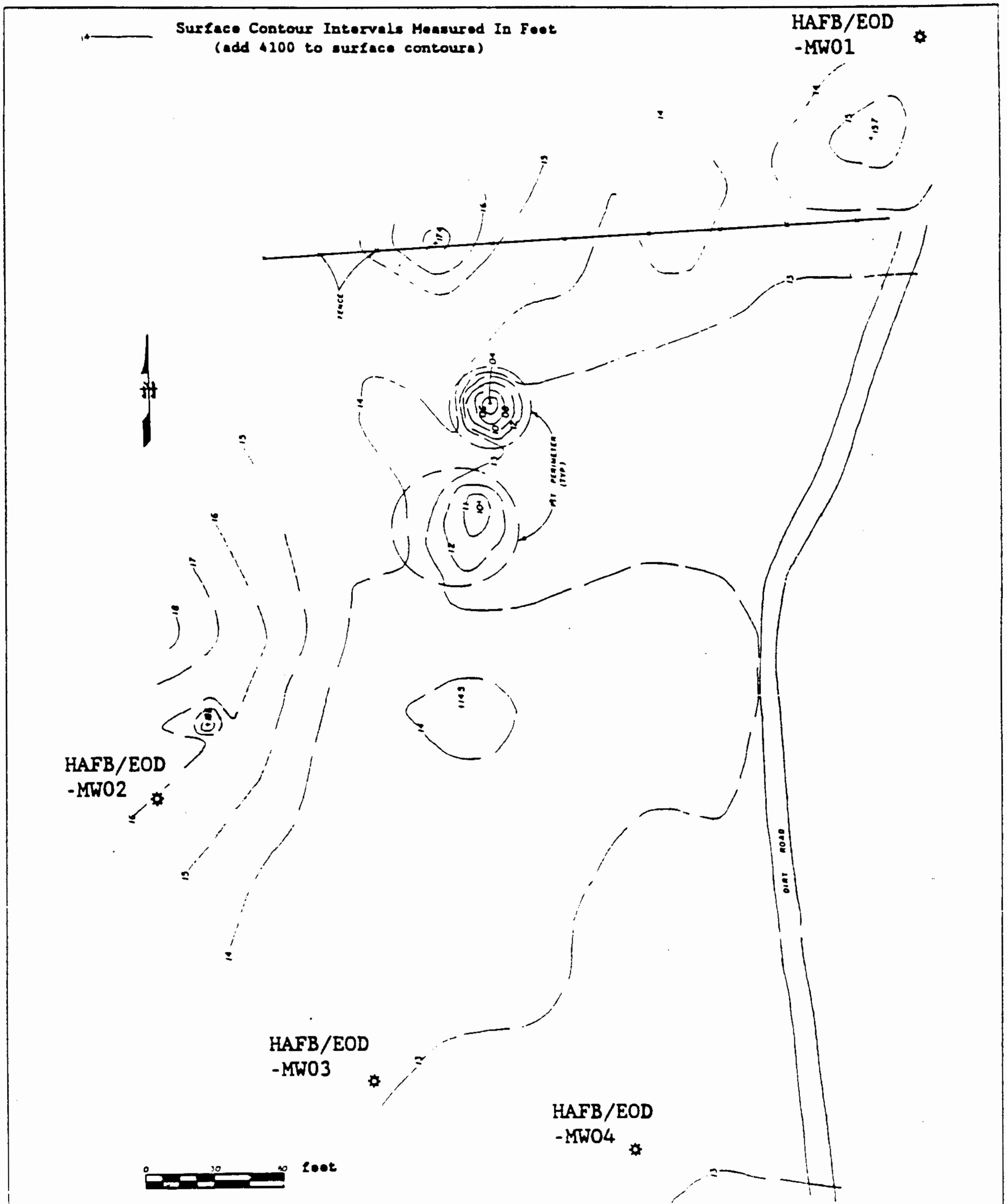
1.2 History of EOD Facility and Previous Studies

Holloman AFB began as a temporary facility developed to provide gunnery and bomber training to aircrews during World War II. The mission of the base was changed in the postwar years to the development of pilotless aircraft, guided missiles, and associated equipment. In the late 1950s, the base was transferred to the Air Force Systems Command (AFSC) and designated as the Air Force Missile Development Center. On January 1, 1971, the mission at Holloman AFB expanded to provide lead-in fighter training for the 479th Tactical Training Wing and its components.

Currently, Holloman AFB hosts the Air Combat Command (ACC) 49th Fighter Wing, which includes pilot training, mobility support, and combat support operations. The primary AFSC component located at Holloman AFB is the 6585th Test Group, which is responsible for evaluation of propulsion and navigational systems for aircraft, space vehicles, and missiles.

As a result of ACC readiness requirements and the 46th Test Group activities, a variety of ordnance, munitions, incendiaries, and propellants became nonfunctional due to exceeded shelf-life, unanticipated deterioration, and failure to be serviceable. The EOD Facility was therefore developed and used for treatment of these materials. This facility has also been used in the disposal (incineration) of confiscated marijuana. There have been no other known uses (i.e., dumping or other disposal of materials) at the EOD Facility (USAF, 1992a; USAF, 1992b).

The 20,000 Pound EOD Facility derives its name from the relevant operating procedures for this treatment activity. The total mass of materials that can be simultaneously treated in the pits is limited to 20,000 pounds. This total includes the mass of casings, other containment devices, and detonating charges. Although the EOD Facility usage varies, one treatment event typically occurs every two to three months. Treatment of the explosive material is accomplished by placing C-4 charges around the material marked for disposal and subsequent detonation. After detonation is completed, the area is thoroughly inspected to ensure that the explosive material has been destroyed and to collect ejected residuals. Once inspection is completed, the pit is closed by backfilling with the original soil. The waste explosives treated at the EOD Facility are considered hazardous due to reactivity. Rocket motors that exceed 300 pounds are treated at the EOD Facility, and are regulated under 40 CFR, Subpart X, codified at 40 CFR 264.600 et seq.



HOLLOMAN AIR FORCE BASE
NEW MEXICO

Figure 1.2-1 20,000 Pound EOD Facility Site Map

Access to the site is tightly controlled, because of the hazards and security requirements associated with an EOD area and the High Speed Test Track. Clearance to enter the area must be obtained from the test track personnel. These personnel are stationed at Building 1173, located at the southern end of the test track, next to the road that leads to the EOD Facility. Both the remoteness of the site and the restricted access, reduce the likelihood that the site has been used for purposes other than EOD operations.

1.3 Scope of Work and Objectives

This study was divided into four phases:

1. Subsurface Sampling and Well Installation Phase;
2. Surface Soil Sampling Phase;
3. In Situ Aquifer Testing Phase; and
4. Groundwater Sampling Phase.

The <u>**Subsurface Sampling and Well Installation Phase**</u> included two steps, the subsurface investigation and the installation of the groundwater monitoring wells. The objective of the subsurface soil sampling program was to investigate the subsurface geology and to determine if contamination has migrated from the explosive detonation pits. Four boreholes were drilled and sampled using RCRA and CERCLA guidelines. Three of the borings were located downgradient of the site and one boring was upgradient, as specified in the Technical Enforcement Guidance Document of RCRA (US EPA, 1986). Three subsurface soil samples per boring were submitted to a laboratory for analysis to determine if any contamination existed. The boreholes had monitoring wells installed in them after the drilling and initial sampling was completed. The purpose of the wells was to collect information on the groundwater geochemistry, the hydraulic gradient (flow direction) across the site, and permeability of the aquifer. An explanation as to the purpose of each individual well is outlined in Table 1.3-1. The well locations are shown on Figure 2.1-1.

Subsurface soil samples were analyzed for the following parameters:

Volatile Organic (SW846-8240);
Semivolatile Organics (SW846-8270);
Total Metals (SW846-6010/7000);
Total Petroleum Hydrocarbons (SW846-8013 modified); and
Explosives (SW846-8330).

TABLE 1.3-1 PURPOSE OF MONITORING WELL LOCATIONS	
WELL NUMBER	PURPOSE OF MONITORING WELL LOCATION
HAFB/EOD-MW01	This well location was selected to the northeast of the EOD Facility to provide an upgradient background well.
HAFB/EOD-MW02	Regional groundwater flows towards the southwest. This well was placed in the path of groundwater flow from the detonation pits to monitor groundwater movement traveling beneath the pits.
HAFB/EOD-MW03	The close proximity of Allen Draw to the site, the expected low- to-moderate permeability, and the low hydraulic gradient suggest that any contamination would have been dispersed, and therefore be present at this location.
HAFB/EOD-MW04	The close proximity of Allen Draw to the site, and a potential variation of the general seasonal flow direction, could force groundwater to flow in this direction.

The Surface Soil Sampling Phase was to assess if any residual explosives or chemicals associated with the explosives were present in the detonation area. This information was needed to determine potential impacts to the surrounding surface, substrata and groundwater.

Surface soil samples were analyzed for the following parameters:

Volatile Organic (SW846-8240);
Semivolatile Organics (SW846-8270);
Total Metals (SW846-6010/7000);
Total Petroleum Hydrocarbons (SW846-8013 modified); and
Explosives (SW846-8330).

The Aquifer Slug Testing was to analyze the hydraulic conductivity of the aquifer. The information ascertains the rate at which groundwater flows through the aquifer, and assists in evaluating the transport of possible contamination. Water level measurements were collected to determine the direction of flow and the hydraulic gradient.

The Groundwater Sampling Phase was to collect representative samples of formation water for analysis to assess if the groundwater geochemistry had been affected by contamination released during the detonation of explosives.

One round of groundwater samples were obtained from all newly installed monitoring wells at the EOD Facility. Sampling occurred three days after well development was completed. Groundwater samples underwent analyses for:

Volatile Organics (SW846-8240)[1]
Base Neutral Acid (Semivolatiles) Extractables (SW846-8270)[1]
Pesticides/PCBs (SW846-8270)[1]
Herbicides (SW846-8270)[1]
Total and Dissolved Metals (SW846-6010/7000)[1]
Cyanide (EPA-335.3)[1]
Explosives (USATHAMA UW-35)
Phosphates (EPA-365.2)
Nitrates/Nitrites (EPA-353.3)
Sulfides (EPA-376.1)
Total Dissolved Solids (TDS)/Anions/Alkalinity (EPA-160.1, 325.2, 340.2, 375.3, 305.1)

[1] Appendix IX parameters excluding Dioxins and Furans.

CHAPTER 3

ANALYSIS AND EVALUATION OF GEOLOGY AND HYDROGEOLOGY

3.0 ANALYSIS AND EVALUATION OF THE GEOLOGY/HYDROGEOLOGY

This section examines the regional and site geology and hydrogeology in the area of the EOD Facility. Section 3.1 summarizes the known regional information. Section 3.2 examines and interprets the findings of the subsurface soil investigation. Section 3.3 examines and analyzes the aquifer characteristics beneath this facility.

3.1 Regional Geologic and Hydrological Setting

Holloman AFB is located in the Tularosa Basin. The basin was formed when the surrounding mountains were uplifted, creating an elongated, north-south, faulted valley known as a graben. The EOD Facility is located down slope of the Sacramento Mountains, which form the eastern boundary of the Tularosa Basin. The San Andres Mountains form the western boundary of the basin.

Precambrian to Permian rocks form the surrounding mountains are predominantly composed of granite, limestone, dolomite, and gypsum with interbedded clays, sands, and gravels. Eroded sediments from these mountains were deposited by streams, filling the Tularosa Basin. The sediments that fill the basin vary in thickness from near zero feet at the boundaries to about 4,000 feet near the center of the basin (Orr and Myers, 1986; USAF, 1993a).

The site is located within a long narrow corridor separating alluvial fan deposits to the east, and eolian (wind blown) and evaporite deposits to the west. The site is approximately 1.5 miles from each of these two depositional environments. This narrow corridor contains playa lakebed (lacustrine) deposits that are likely interconnected to the lacustrine deposits ten miles to the north and to the central basin alluvial (Bolsin) deposits 30 miles to the south. These deposits range in age from the Middle Tertiary (35 million years before present) to the Holocene (present). Playa sediments are estimated to be about 3,500 feet thick beneath the EOD Facility, overlying a thinner sandy layer of basin fill sediments (Orr and Myers, 1986).

Surface water drainage into the Tularosa Basin across the EOD Facility is towards Lake Lucero, 30 miles to the southwest (Figure 1.1-1). Most surface drainages are intermittent and surface flow is only associated with heavy rainfall or snow melt events. The site is located on relatively flat terrain far above the 100-year floodplain boundaries (USAF, 1988). Annual precipitation near Holloman AFB generally ranges from eight to ten inches per year. Higher elevations of the Sacramento Mountains receive about 25 inches per year (Burns and Hart, 1988). The potential evapotranspiration exceeds the precipitation by an approximately 59 inches. Surface water resources within the Tularosa basin are limited by the high evapotranspiration rate and low annual rainfall (USAF, 1988).

Groundwater recharge to the Tularosa Basin takes place primarily along the mountain ranges and alluvial fans as infiltration from surface runoff. Sediments range in size from boulders and gravels near the mountain slopes to very fine sand, silt, and clay in the center of the Tularosa Basin. The groundwater recharge is reduced by evaporation, public, industrial, domestic usage, and irrigation along the Sacramento Mountains, approximately seven miles to the east. It is estimated that only twenty percent of surface runoff actual reaches the Tularosa Basin groundwater (Burns and Hart, 1988).

The regional groundwater flow beneath the EOD site was shown to flow southwesterly towards the center of the basin. However, the local groundwater flow direction may be affected by surface features, such as Allen Draw (Figure 1.1-1) when the groundwater is higher.

Water quality in the Tularosa Basin varies inversely with the distance from the recharge area. Regions of groundwater recharge near the mountain escarpments have the best water quality. Wells installed in the alluvial fans that surround the valley floor are used for domestic and agricultural purposes (Burns and Hart, 1988). Water percolating through sediments high in gypsum, limestone, and dolomite becomes highly mineralized. Groundwater in the Tularosa Basin contains concentrations of dissolved solids ranging from 3,000 milligrams per liter (mg/L) to 25,000 mg/L, and is unusable for domestic or agricultural water supplies (Weir, 1965). Groundwater in the center portions of the basin can contain in excess of 100,000 mg/L TDS (USAF, 1993b).

3.1.1 Upgradient Mineral Deposits

All subsurface soil samples had measurable quantities of copper, lead, chromium, and zinc. According to the New Mexico Bureau of Mines (Bulletin 39), two mining districts, Sacramento (High Rolls) and Tularosa (Bent) were located to the east in the Sacramento Mountains. The Tularosa District (near the town of Tularosa) was upgradient of the site, and was active for 13 years. The Sacramento District encompassed an area between Cloudcoft and Alamogordo, and was active for decades. The ore deposits are found in Permian and Pennsylvanian aged rocks (280 million to 310 million years old). In the Tularosa area, the mineralization is directly associated with a volcanic intrusive (diorite porphyry). The ore has disseminated into sandy beds of adjacent limestones. This deposit is believed to be hydrothermal in origin. In the adjacent Sacramento District, the ore deposits appear as carbonates and nodules in the arkosic sandstones and interbedded shales.

The amounts of metals present in the rocks of these two mining districts is sparse. A random sampling from nine mines along with several other assays in the Sacramento District showed the following metals are present: cadmium, copper, lead, manganese, mercury, molybdenum, nickel, silver, tin, tungsten, uranium oxides, vanadium, and zinc (Jerome et al., Undated).

The mining districts are about 10 to 20 miles to the east and up slope from the basin. After millions of years of weathering and erosion, the probability that the metals found in the Tularosa Basin originated from these districts is high.

3.1.2 Background Soil Surveys

A nationwide soil study analyzing the naturally occurring metals content was conducted by the U.S. Geological Survey (USGS), resulting in two reports. The raw data was published in 1981 as USGS Open-File Report 81-197, and the analyzed results in the USGS Professional Paper 1270 in 1984. The data pertaining to the Tularosa Basin and to a specific sample collected five miles south of Tularosa on US Highway 54, are presented in Table 3.1-1. The analytical results of the subsurface soils and surface soils at the EOD Facility are less than the results reported in Table 3.1-1, except for lead. Lead was found, in one of the EOD surface soil samples, to be ten ppm higher than levels listed in the 1984 USGS report. Seven of the remaining 20 samples had elevated levels of one to seven ppm.

TABLE 3.1-1
METAL CONCENTRATIONS IN SOIL FROM USGS STUDIES

METALS	TULAROSA BASIN[1]	5 MILES SOUTH OF TULAROSA ON US 54[2]
Arsenic (ppm)	4.1	4.3
Beryllium (ppm)	2 to 15	Not Detected
Chromium (ppm)	1 to 20	50
Cobalt (ppm)	10	10
Copper (ppm)	15	15
Lead (ppm)	20	Not Detected
Mercury (ppm)	0.051	0.03
Nickel (ppm)	20	15
Strontium (ppm)	500 to 3000	700
Vanadium (ppm)	100	100
Calcium (%)	4.2 to 33	13
Phosphorus (%)	0.049	0.016
Potassium (%)	2.5 to 6.5	1.2
Sodium (%)	1.5 to 10	1.5
Zinc (%)	45	40

(1) Shacklette and Boerngen, 1984. (2) Boerngen and Shacklette, 1981.

3.2 Subsurface Investigation

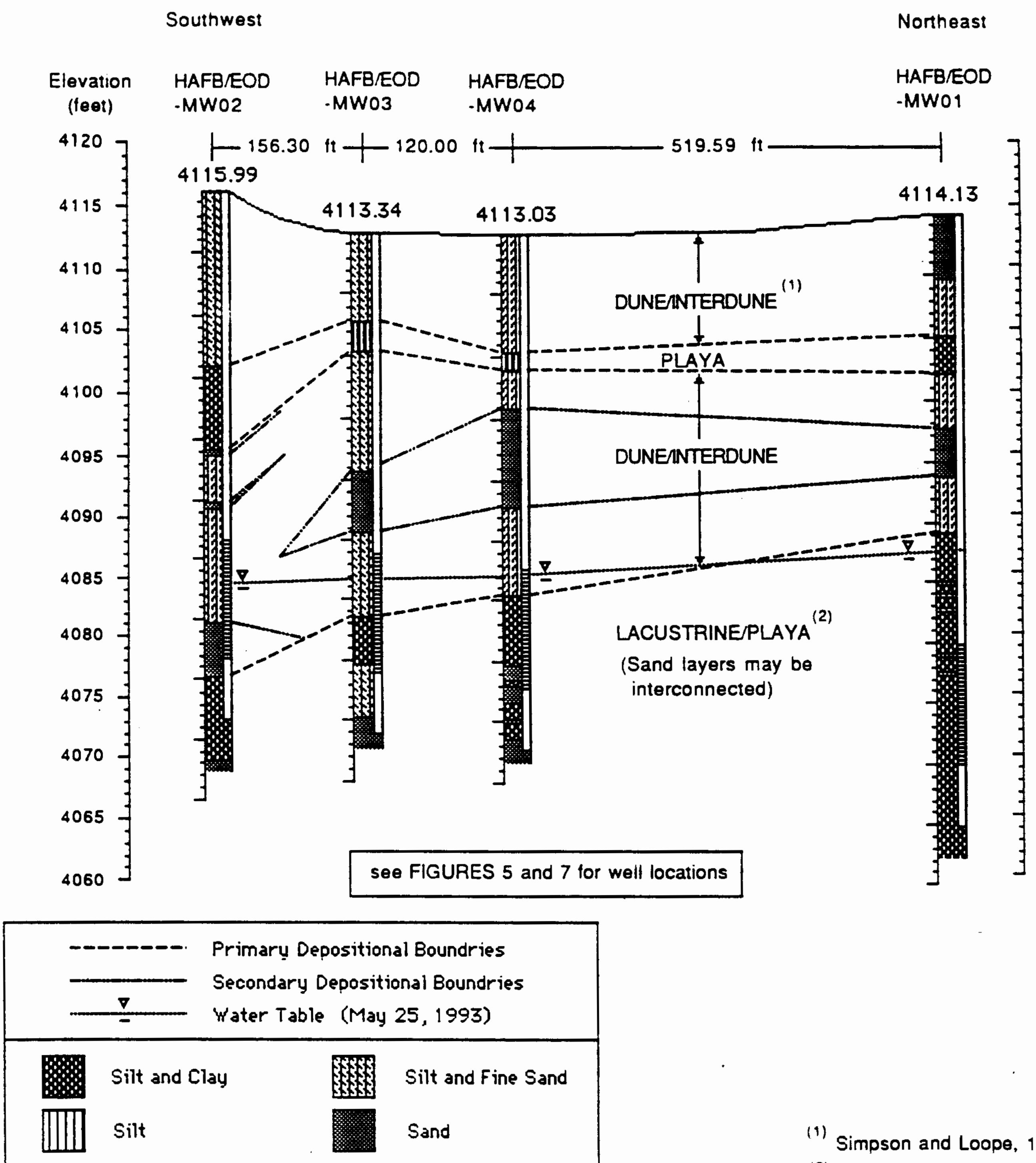
During this investigation four boreholes were drilled to a depth of 40 to 50 feet. The location of these boreholes are shown on Figure 3.3-3. The upper 30 feet consisted of sand and silt-sand layers with a silt to silty clay layer at about 12 feet. Below 30 feet, silty clay with inner layers of sand and silt-sand was encountered. Similar geologic conditions were outlined in the geologic report for the Coco Block House (IRP Site 41), approximately five miles south of this EOD Facility. The subsurface geology at the Coco Block House consists of clean, well sorted fine-grained sand at the surface with layers of silty sand overlying silty clay at depth. The generalized geologic log for the EOD site and interpretation of the geologic sequence is presented in Table 3.3-1.

Analysis of the geologic cross section presented in Figure 3.2-1 shows a slight change in depositional environments across the EOD Facility. The thickest sequence of silty clay (playa-lacustrine deposits) is shown in HAFB/EOD-MW01, while HAFB/EOD-MW02 shows the thickest sequence of sand and silt-fine sand mixtures (eolian deposits). The eolian deposits present are predominantly interdune deposits consisting of fine sand and silt (Simpson and Loope, 1985). Below 30 feet the geologic interpretation becomes complex. The geologic logs show lithologic changes across the site between silty clay, silty sand and sand at the downgradient wells (HAFB/EOD-MW02, 03 and 04). The upgradient well (HAFB/EOD-MW01) shows massive silty clay with stringers or lenses of sand. A petrographic investigation would be necessary to assess the interrelation between these sediments. Probable scenarios include:

1. The playa was partially eroded and wind blown sediment filled in the eroded space; or
2. During deposition this may have been the western edge of this playa and a gradational change between the two depositional environments is being observed.

It is highly probable that these sand zones are interconnected.

The cross section shows that the top of the water table at HAFB/EOD-MW01 is located within the upper portion of the silty clay. The wells to the south and southwest shows that the top of the water table is within the eolian (wind blown) sediments, above the silty clay. This indicates that the downgradient wells are in coarser grained material, with greater permeability and porosity.



(1) Simpson and Loope, 1985

(2) Orr and Myers, 1986

HOLLOMAN AIR FORCE BASE NEW MEXICO	**Figure 3.2-1**	**Geologic Cross Section** **20,000 Pound EOD Facility**

3.3 Aquifer and Groundwater Assessment

Groundwater parameters (hydraulic conductivity, flow direction, hydraulic gradient and transmissivity) were assessed. Depth to groundwater measurements were collected throughout the project to assess the parameters that are outlined in this section. The depth to groundwater measurements are presented in Table 3.3-1 and in Figure 3.3-2. The groundwater flow direction and hydraulic gradient were determined by following the USGS method outlined below and illustrated in Figure 3.3-1 (Heath, 1989):

1. HAFB/EOD-MWO4 was identified as the well with the intermediate water elevation (4,085.22 feet).

2. A line was drawn between HAFB/EOD-MW01, the well having the highest water elevation (4,087.01 feet) and HAFB/EOD-MW02, the well with the lowest water elevation (4,084.78 feet). To locate the elevated contour line along this line that corresponds to the water level in the intermediate well, the following equation was used:

$$\frac{\text{Highest MSL - Intermediate MSL}}{x} = \frac{\text{Highest MSL - Lowest MSL}}{\text{Distance Between Highest and Lowest Wells}}$$

$$\frac{4{,}087.01 - 4{,}085.22}{x} = \frac{4{,}087.01 - 4{,}084.78}{484.39}$$

$$x = 388.82 \text{ feet from HAFB/EOD-MW01}$$

where

MSL = Mean Sea Level (elevation in feet); and

x = the distance from the shallowest well to the deepest well where the contour of the intermediate well will be encountered.

3. The value (distance) obtained in step 2 was measured from HAFB/EOD-MW01 towards HAFB/EOD-MW02.

4. A line representing the intermediate elevation contour line (4,085.22 feet) was drawn between the intermediate well and the point identified in step 3 as being between the well having the highest water elevation and that of the lowest water elevation.

5. A line representing the direction of groundwater flow was drawn perpendicular from the contour line discussed in step 4 to the well with the lowest water level elevation. On May 25, 1993 the direction of groundwater flow at the EOD Facility was towards the southwest.

6. The hydraulic gradient was then calculated by dividing the difference between the head of the well and that of the contour by the distance between the well and the contour.

$$i = \Delta h/L$$
$$= (4087.01 - 4084.87)/(484.39 - 388.82)$$
$$= 2.23 \text{ feet}/92.37 \text{ feet}$$

where:

i	=	groundwater hydraulic gradient (dimensionless);
Δh	=	change in groundwater elevation across the site; and
L	=	distance across the site.

This analysis shows that the direction of groundwater flow during this field investigation was to the southwest. The resulting groundwater contour map is presented in Figure 3.3-3. Allen Draw had no effect on the groundwater flow direction. If the groundwater was closer to the surface, Allen Draw would have an effect on the direction of groundwater flow. The hydraulic gradient shows that the groundwater drops one vertical foot for 41.4 feet traversed horizontally.

Four aquifer slug tests were conducted at the EOD Facility. The data collected were from rising head tests. Several analytical methods were used in the analysis of these data, including Cooper et al. (1967), Hvorslev (1951), and Bouwer and Rice (1976). The Cooper et al. method applies to aquifers under confined conditions. The method was used because flowing sands were encountered at HAFB/EOD-MW02, suggesting that the aquifer might have been semiconfined. The Hvorslev (Time Lag) method is applicable, if the well screen is entirely submerged. HAFB/EOD-MW01 was entirely submerged, however, the removal of the slug at the start of the test lowered the water level two feet below the top of the screen making this method inappropriate. The most appropriate method to analyze the data was the Bouwer and Rice Method.

The following assumptions and conditions are needed to satisfy the Bouwer and Rice Method:

1. The aquifer is unconfined and has an apparently infinite areal extent;
2. The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the slug test;
3. Prior to the test, the water table is nearly horizontal over the area that will be influenced by the slug test;
4. The head in the well is lowered or raised instantaneously at $t_0 = 0$; the draw down in the water table around the well is negligible;
5. The inertia of the water column in the well and linear and nonlinear well losses are negligible;

6. The well either partially or fully penetrates the saturated thickness of the aquifer;
7. The well diameter is finite; and
8. The flow of the well is in a steady state (Kruseman and deRidder, 1990).

FIGURE 3.3-1 Hydraulic Gradient Analysis of the HAFB EOD Facility

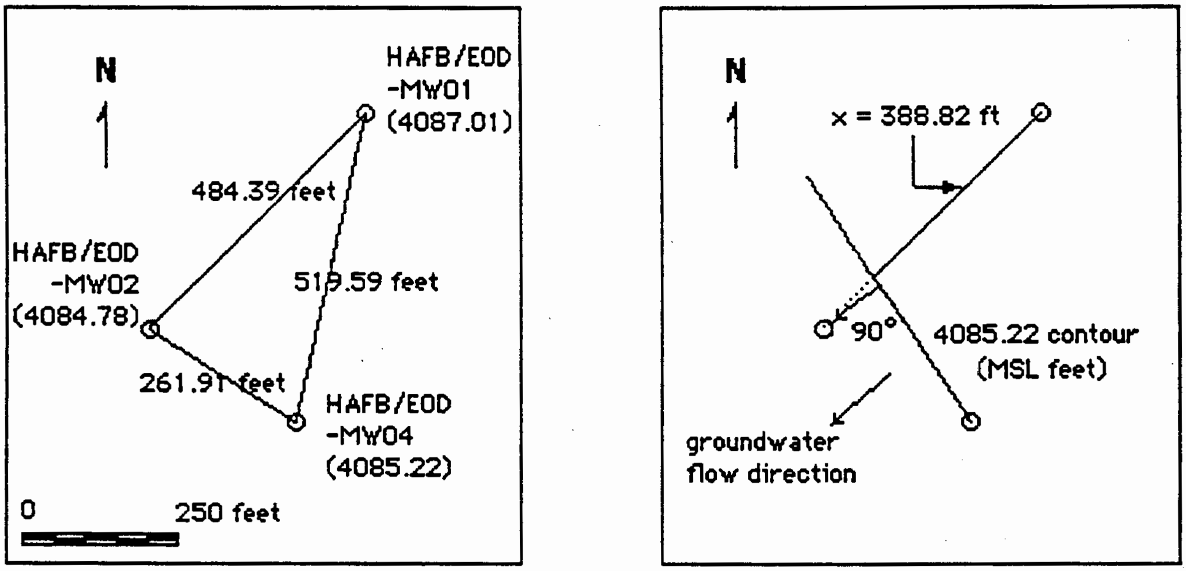


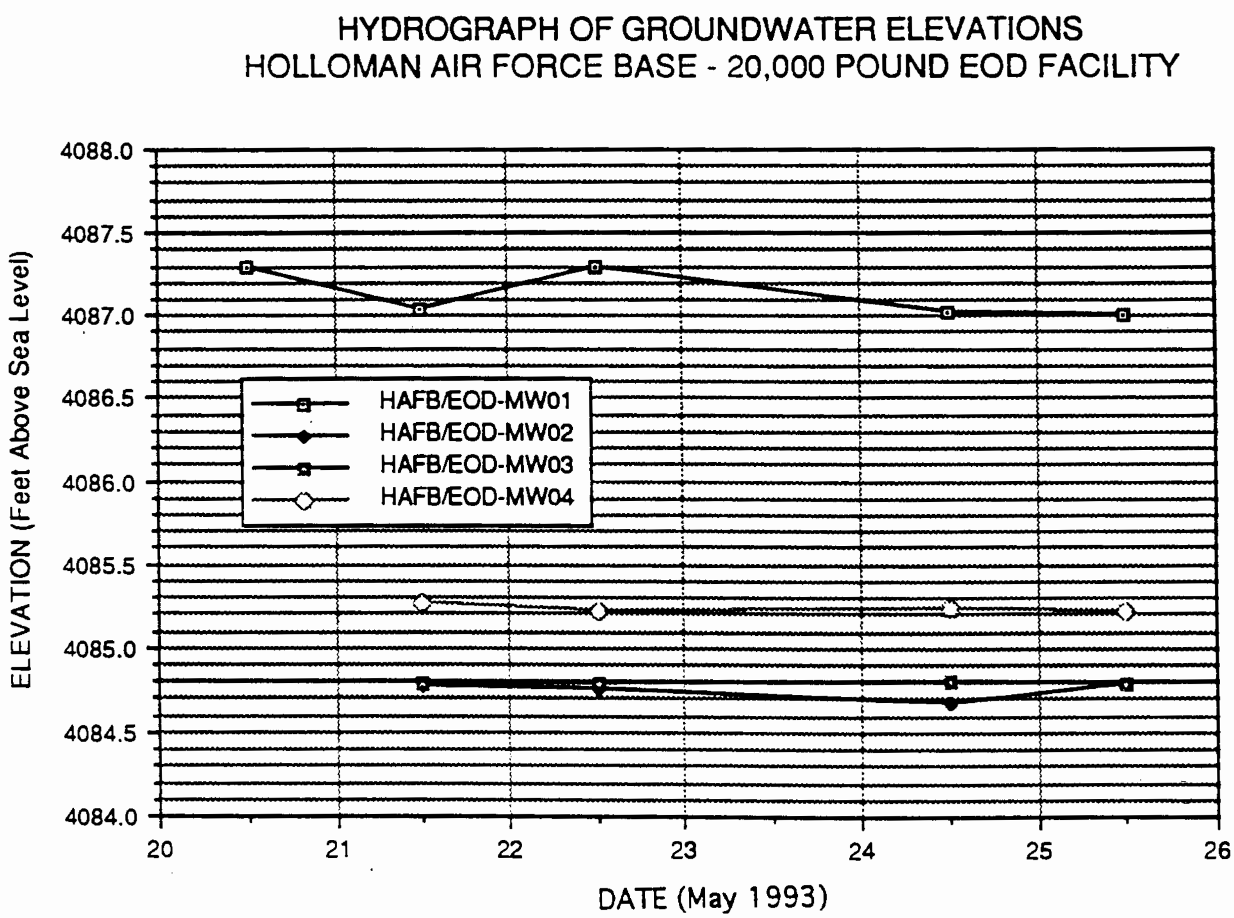
TABLE 3.3-1
GENERALIZED GEOLOGIC (SOIL BORING) LOG

DEPTH	GENERALIZED DESCRIPTION
0 to 10 feet	A light tan, yellowish-tan and light brown fine grained well-sorted sand with layer of silt-sand, porous, loose to slightly firm and dry to trace moisture present. This upper zone represents eolian type deposits. The sands are most likely dunes, and the silt-sand represent an interdune sequence (Simpson and Loope, 1985).
10 to 12 feet (Extends to 16 feet at HAFB/EOD-MW02)	Reddish-brown (HAFB/EOD-MW02 also had alternating layers of gray-green and light gray to white), silt to silty-clay, slightly firm, low to moderately plastic, and dry to trace moisture. Most likely represents a small playa at the site.[1,2]
12 to 30 feet (Extends to 40 feet at HAFB/EOD-MW02)	Light tan, yellowish-tan and light brown with reddish-brown and brown layers. Predominantly a fine grained well-sorted sand with occasional layers of medium to coarse grained sands, slightly firm to firm, with trace moisture present.
30 to 50 feet (HAFB/EOD-MW02 starts at 40 feet)	A gradational change of depositional environments can be observed in the logs. Reddish-brown silty clay representing playa/lacustrine deposits[1] with dune and interdunal deposits merge in and out of the clay, or back and forth across the playa. The occasional thin layers of sand in the larger clay units may represent wind blown particulate across the playa or an occasional sheet flood that are common in this type of environment. The clay deposits are thickest at HAFB/EOD-MW01. These deposits are reddish-brown silty clay with light gray or green-gray mottling[3] in the upper two feet, moderate to high plasticity, slightly firm to firm, ranging in moisture from trace to wet. At 50 feet, one to two mm of gypsum crystals were found. Sands found below 30 feet are fine to medium grained, with medium grain predominant. At HAFB/EOD-MW02, flowing sands were encountered at 42 feet.

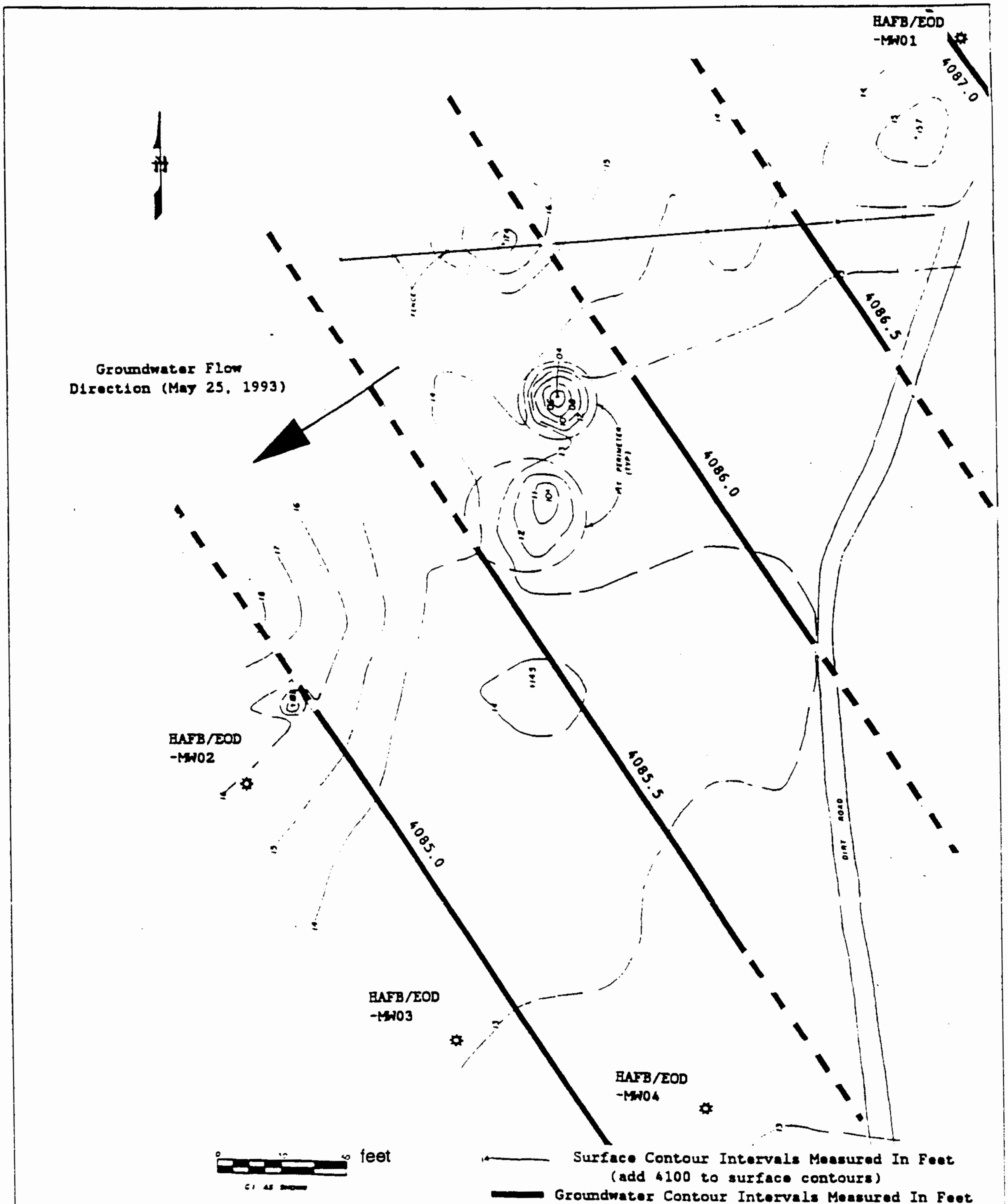
(1) The reddish-brown color associated with the playas are common and suggest an oxidizing environment of the iron present in the sediments. The coloration may also imply well drained soils.

(2) Poorly drained soils which are saturated most of the time are generally gray in color, because the iron has been reduced or removed. This is true for humid climates, however, not always true in arid environments.

(3) A mottled gray and reddish brown color suggests that the subsoils are subjected to alternating or seasonal periods of saturation.



HOLLOMAN AIR FORCE BASE NEW MEXICO	Figure 3.3-2	Hydrograph of Groundwater Elevations



HOLLOMAN AIR FORCE BASE
NEW MEXICO

Figure 3.3-3 Groundwater Contour Map

TABLE 3.3-2 ELEVATION AND DEPTH TO GROUNDWATER[1]				
DATE	HAFB/EOD -MW01	HAFB/EOD -MW02	HAFB/EOD -MW03	HAFB/EOD -MW04
May 25	27.12 (4,087.01)	31.15 (4,084.78)	28.49 (4,084.79)	27.57 (4,085.22)
May 24	27.11 (4,087.02)	31.26 (4,084.67)	28.47 (4,084.81)	27.56 (4,085.23)
May 22	26.83 (4,087.30)	31.17 (4,084.76)	28.49 (4,084.79)	27.57 (4,085.22)
May 21	27.07 (4,087.04)	31.16 (4,084.77)	28.49 (4,084.79)	27.52 (4,085.27)
May 20	26.85 (4,087.30)	NM	NM	28.5[2]
May 19	NM	NM	28.5[2]	—
May 18	NM	30[2]	—	—
May 17	38[2]	—	—	—

1 Measurements and (elevations) recorded in feet. Depth to water measurements collected from top of casing. Depth to water measurements collected prior to May 22 have been corrected. The height of the PVC casing was altered on May 21 during the final phase of surface well construction. This change in height has been taken into account to show the corrected measurement.

2 Date well was installed

NM = Not Measured

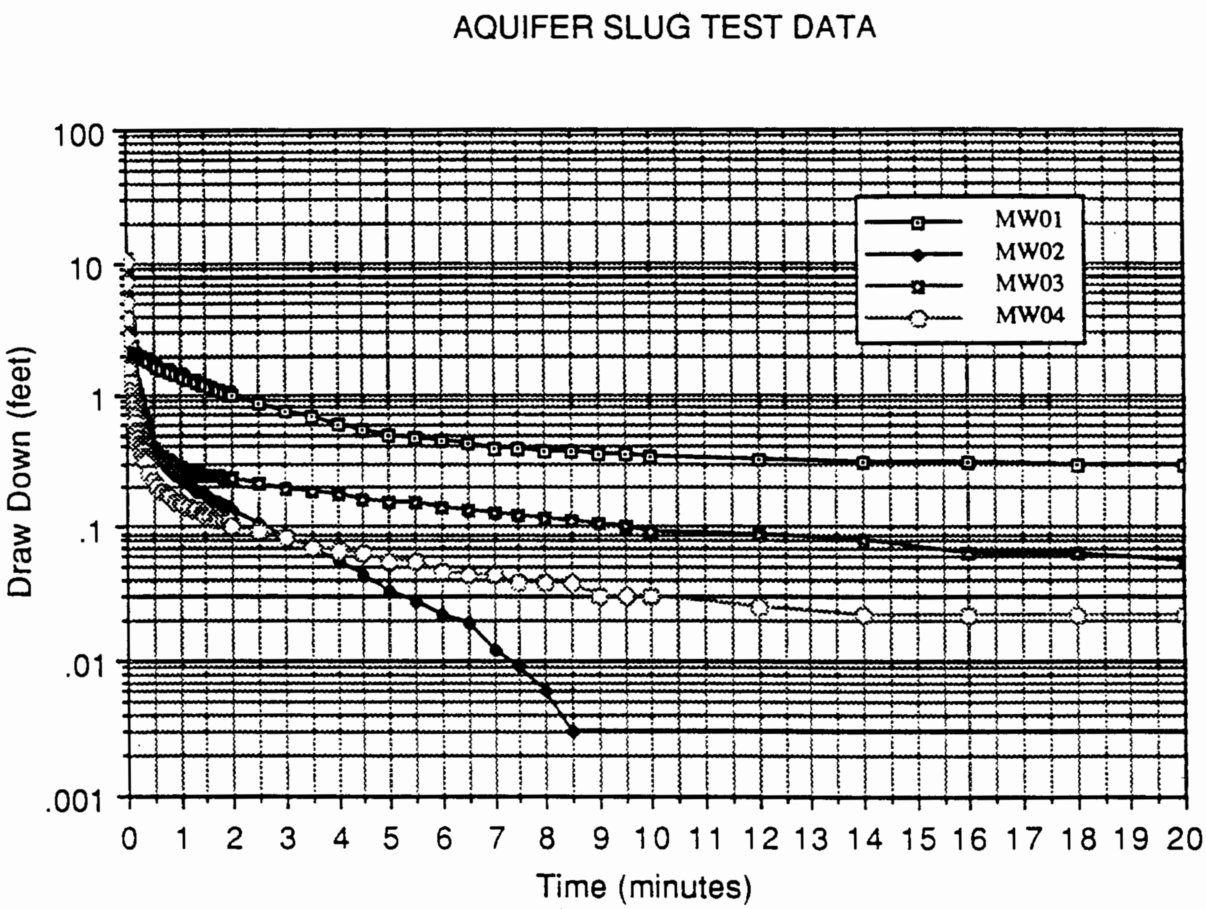
The data were first analyzed in the field using the Bouwer and Rice method, to assess the data collected. The data shows an initial rapid recovery occurring during the first 10 to 20 seconds, which was probably the result of the water flowing back into the well from the filter pack. This rapid recovery is followed by a more gradual change as the water level approaches the static water level for the well and reestablish an equilibrium state between the welland the aquifer. The data and field calculations are presented in Appendix D. A more definitive analysis of the data was conducted using the computer software AQTESOLV™ (Geraghty & Miller 1989). This software allows the user to visually connect a straight line from the displacement or draw down (semi-logarithm) axis to the time line axis, thus selecting Y_0, Y_t, and t. A discussion of the Bouwer and Rice method is presented in Appendix D. From the selected straight line, AQTESOLV™ computes the hydraulic conductivity. The semi-logarithmic plots for the individual tests are presented in Appendix D. The estimated hydraulic conductivity values from the AQTESOLV™ analysis and field calculations are presented in Table 3.3-3.

TABLE 3.3-3
HYDRAULIC CONDUCTIVITY ANALYSIS OF THE EOD FACILITY WELLS

	HAFB/EOD-MW01	HAFB/EOD-MW02	HAFB/EOD-MW03	HAFB/EOD-MW04
Field Calculations	3.07×10^{-4} ft/min 1.56×10^{-4} cm/sec	5.38×10^{-4} ft/min 2.73×10^{-4} cm/sec	1.22×10^{-4} ft/min 6.20×10^{-5} cm/sec	1.34×10^{-4} ft/min 6.81×10^{-5} cm/sec
Computer Analysis	2.42×10^{-4} ft/min 1.23×10^{-4} cm/sec	5.30×10^{-4} ft/min 2.69×10^{-4} cm/sec	1.03×10^{-4} ft/min 5.23×10^{-5} cm/sec	1.46×10^{-4} ft/min 7.42×10^{-5} cm/sec

A simplified analysis of this data is presented in Figure 3.3-4. This figure illustrates the effect that the type of sediment around the well screen has on the rate of recovery. The top line represents the recovery of HAFB/EOD-MW01 (referred to as MW01 on the figure), this well was screened in silty clay that has sand stringers or lenses present. In the bottom line, HAFB/EOD-MW02 (MW02), the well was screened in sand and silt/fine sand. The two wells in the center were screened in silt and fine sand. This variation in hydraulic conductivity values may be due to the differences in the hydrogeology between wells caused by different geological depositional environments of the sediments, ranging from eolian at HAFB/EOD-MW02 to lacustrine at HAFB/EOD-MW01, with HAFB/EOD-MW03 and MW04 having transitional environments.

The hydraulic conductivity values found at the EOD Facility are lower by a magnitude of 10 when compared to the Coco Block House study, conducted approximately five miles to the south. The Coco Block House reported values ranging from 1.36×10^{-3} to 2.09×10^{-3} feet/minute (6.91×10^{-4} to 1.06×10^{-3} centimeters/second), this is due to the fact that the block house is farther into the eolian deposits discussed in Section 3.1 and therefore has a higher percentage of sand and less silt. Similar values were also observed in the Atlas Test wells T-1, T-2 and T-4 installed in 1956 to the south of the EOD Facility along the High Speed Test Track. The hydraulic conductivity of the Atlas Test wells ranged between 1.04×10^{-3} and 2.99×10^{-3} feet/minute (5.29×10^{-4} and 1.52×10^{-3} centimeters/second). The Atlas Test wells were drilled to about 400 feet below ground surface and had about 200 to 300 feet of screen (perforated casing), compared to the shallow wells installed for this study (Orr and Myers, 1986).



HOLLOMAN AIR FORCE BASE NEW MEXICO	Figure 3.3-4 Aquifer Response to Rising Head Tests

The distance in which groundwater can flow over a given period of time is dependent upon a wide variety of variables. Using a basic advective transport equation derived from Darcy's Law (Freeze and Cherry, 1979):

$$\bar{V} = Ki/N_e$$

where:

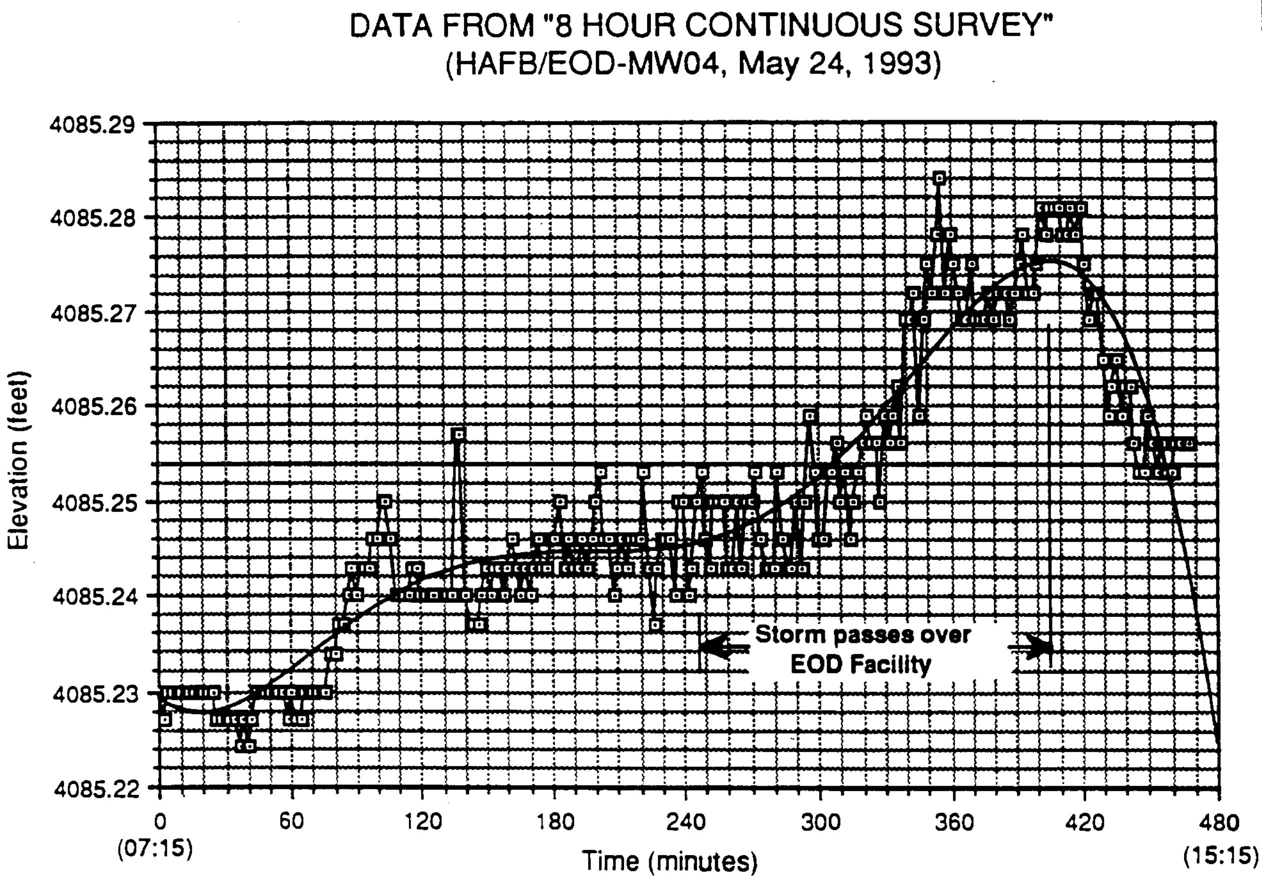
$\bar{V}$ = average flow velocity;
K = average hydraulic conductivity = 3.47×10^{-4} feet/minute
(The K increases towards the southwest from the EOD Facility. To compensate for this changing K, an average K was first calculated for the wells that were installed in finer grained material (HAFB/EOD-MW01, MW03 and MW04). Then an average K was calculated between the finer grained material and the coarser grained material (HAFB/EOD-MW02));
i = hydraulic gradient = 2.23 feet/92.37 feet = 2.4×10^{-2} feet/foot and
N_e = average effective porosity of the soils = 30% (EPA, 1991),

the flow velocity is equal to 2.79×10^{-5} feet/minute. Groundwater flowing at this velocity will travel approximately 14.7 feet per year. One site-specific factor that may have affected the flow velocity at the facility are the shock waves produced by past detonations at the facility. There is not sufficient information available to assess the possible impact of those detonations on groundwater flow velocity at the facility.

A simplified method to look at hydraulic conductivity is to consider it as the maximum capacity or rate that groundwater can flow through the sediment at a given location when the hydraulic gradient is one foot/foot. The average hydraulic conductivity of the finer grained material at the site is 1.64×10^{-4} feet/minute. This implies that if the velocity or hydraulic gradient were to increase towards one foot/foot, the distance groundwater could flow in one year would not exceed 86 feet. Therefore, it is possible that the downgradient well HAFB/EOD-MW02 could be intercepting water that passed beneath the detonation pits about three to five years ago.

In addition to the aquifer slug tests conducted at the EOD Facility, an Eight-Hour Continuous Test was conducted to assess background conditions. The data that was collected is in Appendix E. The transducer pressure probe was gently lowered into the well to minimize the effect on the static water level. The data logger was started moments later at 7:15 AM on May 24, 1993. The plotted data presented in Figure 3.3-5 shows a gradual rise of about 0.015 feet between 7:15 and 9:30, which may be associated with the storm that occurred later in the day or an early morning phenomena. At 8:55 and 9:35, unexplainable fluctuations of up to 0.017 feet in the data were observed. At 10:00, a launch occurred at the south end of the High Speed Test Track and braked towards the north end of the track. At 10:15, 10:35 and 10:55, a series of less intense peaks were observed, with no known cause. Between 11:30 and 12:45, a storm passed over the site, and is illustrated in the Figure 3.3-5. This figure shows that the water level in the well is easily influenced by barometric pressure.

During this study, it was noted that the groundwater level had risen to the surface in the White Sands National Monument area. White Sands National Monument is the general area where groundwater flows to in the Tularosa Basin. According to the New Mexico Fish and Wildlife Bureau, this rise in the groundwater was highest in 1992, and resulted in sections of the National Monument being closed to the public. Portions of the National Monument were also closed in 1993, but the rise in groundwater in 1993 was not as great as in 1992. However, no depth to groundwater or depth of surface water measurements have been recorded to determine the actual rise in water. This change in groundwater level in the basin may be a localized phenomena with regional effects. If this phenomena does have a regional effect, the hydraulic gradient, depth to groundwater, and groundwater flow velocity may be affected. However, insufficient information exists to make a final determination.



HOLLOMAN AIR FORCE BASE NEW MEXICO	Figure 3.3-5 8-Hour Continual Aquifer Test To Assess Background Conditions