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First Interstate Bank Tower
1445 Ross Avenue
Dallas, Texas 75202-2733

Enclosed please find one copy each of the above subject report. The point of contact for this transmittal is Sharon Moore, (505) 479-3931.

Howard E. Moffitt
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Deputy Base Civil Engineer

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Attn: Ellen Graber
US Environmental Protection Agency, Region VI, 6H-CS
First Interstate Bank Tower
1445 Ross Avenue
Dallas, Texas 75202-2733

Dr. Bruce Swanton Certified Mail - Return Receipt Request P 754 967 687
Hazardous Waste Bureau
New Mexico Health and Environment Department
1190 St. Francis Dr.
Santa Fe, New Mexico 87503

Mr Mark Peycke, Assistant Regional Counsel, (Certified Mail - Return Receipt
US Environmental Protection Agency, Region VI, 6C-H Request P 754 967 686)
First Interstate Bank Tower
1445 Ross Avenue
Dallas, Texas 75202-2733

U.S. Department of the Interior
Bureau of Land Management
Attn: Joan Resnick
1800 Marquess
Las Cruces, NM 88005

Fish and Wildlife Service
3530 Pan American Highway NE
Albuquerque, NM 87107

AFRCE
Attn: Mr Lopez and Mr Jahns
PO Box 116
525 Griffin St
Dallas, TX 75202

cc w/o ATCH

833 AD/JA
Holloman AFB, NM 88330

HQ TAC/JA & HQ TAC/DEV
Langley AFB, VA 23665

US Army Corps of Engineers
Omaha District
Attn: Larry Janis
215 N. 17th Street
Omaha, NE 68102-4978

Radian Corporation
8501 Mo-Pac Blvd
Austin, TX 78720-1088

Mr. Raymond P Churan
Regional Environmental Officer
United States Department of the Interior
PO Box 649
Albuquerque, NM 87103

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Final

GROUNDWATER ASSESSMENT MONITORING PLAN FOR THE SEWAGE TREATMENT LAGOONS HOLLOMAN AIR FORCE BASE, NM

Prepared for:

833 CSG/DEV
Holloman Air Force Base, NM

and

HQ, Tactical Air Command
Langley Air Force Base, VA

Prepared by:

Radian Corporation
8501 MoPac Blvd.
Austin, Texas

Under Contract No. DACW45-89-D-0515 with:

Department of the Army
Corps of Engineers, Omaha District
Omaha, Nebraska

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17 September 1991

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17 September 1991

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EXECUTIVE SUMMARY

Radian Corporation (Radian), under contract with the Omaha District, U.S. Army Corps of Engineers (USACE), on behalf of the U.S. Air Force Tactical Air Command's Environmental Office, developed this RCRA Groundwater Assessment Monitoring Plan for the Holloman Air Force Base (AFB) sewage treatment lagoons. This plan will be implemented in accordance with the requirements of 40 CFR Section 265.93. The plan was prepared as directed by the Federal Facilities Compliance Agreement (Docket Number RCRA VI-502-H and VI-661-H) following measurements of elevated levels of the indicator parameter total organic carbon (TOC) in monitor wells located downgradient of the sewage treatment lagoons. The TOC concentrations were determined to be elevated relative to background concentrations by a statistical study completed by the U.S. Environmental Protection Agency, Region VI, as documented in a letter to Holloman AFB dated 3 May 1991.

In accordance with the regulations, this groundwater quality assessment program is designed to determine:

- Whether hazardous waste or hazardous waste constituents from the facility (i.e., the sewage treatment lagoons) have entered the groundwater;
- The rate and extent of migration of hazardous waste constituents in the groundwater; and
- The concentrations of hazardous waste or hazardous waste constituents in the groundwater.

To accomplish this program, the plan discusses requirements for assessment monitoring outlined in the RCRA Technical Enforcement Guidance Document (EPA, 1986) (1). The following paragraph briefly discusses the technical approach for this groundwater assessment monitoring plan.

In order to determine conclusively whether or not the elevated downgradient TOC concentrations are the result of a release of hazardous waste or waste constituents from the sewage treatment lagoons, one set of samples (including appropriate QA/QC samples) will be collected from each of the monitor wells in the detection monitoring network, and will be analyzed for Appendix IX organic constituents and TOC. Detection of any of the Appendix IX organic constituents at levels above the method detection limit in any downgradient sample will trigger immediate resampling and analysis for only those parameters detected. If detection of any of the Appendix IX organic constituents is verified by resampling, it will be concluded that a release of hazardous waste and/or hazardous waste constituents has occurred from the sewage treatment lagoons. Assuming that a release has occurred, this plan outlines the assessment monitoring program. A general, phased approach was developed to determine: 1) the nature, magnitude, and areal and vertical extent of any contaminant plume(s); and 2) the potential migration pathways and rates of contaminant migration. Three broad phases of activity are planned:

Phase 1 - Definition of the nature and extent of contamination in the uppermost aquifer.

Phase 2 - Identification of contamination in the second aquifer (if any), definition of the maximum vertical extent of groundwater contamination, and determination of vertical concentration gradients.

Phase 3 - Identification of preferential pathways for contaminant migration (if any) and migration rates.

A combination of direct and indirect measurement techniques are proposed to accomplish the objectives of each phase. The main direct techniques are monitor well installation, groundwater sampling and analysis, and aquifer testing. The main indirect techniques are geostatistical analysis and groundwater modeling.

This plan was developed in part using the results and conclusions of previous reports and plans completed for the sewage treatment lagoons. The following is a list of those reports and plans, and a brief summary of their contents:

- Final Hydrogeologic Investigation Report and Groundwater Monitoring Plan (HIR/GWMP) for the Sewage Lagoons, Holloman Air Force Base, New Mexico, Volume 1 (Radian, 1989) -- summary of an intensive hydrogeologic investigation conducted at the sewage treatment lagoons in 1987, and a preliminary plan for the detection monitoring program that was implemented in 1989;

- Final A-E Quality Control Plan and Sampling Plan (A-E QCP/SP) for Groundwater Study and Monitoring Program, Holloman Air Force Base, New Mexico (Radian, 1989) -- detection monitoring sampling and analysis plan for the sewage treatment lagoons;

- A-E Groundwater Monitoring Report/Quality Control Summary report for the First Groundwater Sampling Round, Holloman Air Force Base (Radian, 1989) -- summary of the first round of groundwater samples collected for the detection monitoring program;

- Second Monthly Groundwater Sampling Report, September 25 - 28, 1989, Holloman Air Force Base, New Mexico, (IT Corporation, 1990) -- summary of the second monthly sampling and analysis for the detection monitoring system;

- Third Monthly Groundwater Sampling Report, November 5 - 8, 1989, Holloman Air Force Base, New Mexico (IT Corporation, 1990) -- summary of the third monthly sampling and analysis for the detection monitoring program;

- Fourth Monthly Groundwater Sampling Report, December 10 - 14, 1989, Holloman Air Force Base, New Mexico (IT Corporation, 1990), -- summary of the fourth monthly sampling and analysis for the detection monitoring program;

- First Semi-Annual Groundwater Sampling Report, January 15 - 17, 1990, Holloman Air Force Base, New Mexico (IT Corporation, 1990) -- summary of the first semi-annual sampling and analysis for the detection monitoring program;

- Background Contamination Indicator Parameter Summary Statistics for Upgradient Comparisons with Data from the First Semi-Annual Groundwater Sampling Episode, Sewage Treatment Lagoons Monitoring Wells, Holloman Air Force Base, New Mexico (IT Corporation, 1990) -- a statistical summary of the data collected during the 4 monthly and first semi-annual sampling events at the sewage treatment lagoons, where upgradient groundwater conditions were statistically compared to downgradient groundwater conditions;

- Quality Control Summary Report (A-E QCSR), Hazardous Waste Sewage Sludge Removal, Holloman Air Force Base, NM (Radian, 1989) -- summary of sampling and analysis of sludge mounds in Ponds A and B;

- Quality Control Summary Report (A-E QCSR) for Additional Sampling, Hazardous Waste Sewage Sludge Removal, Holloman Air Force Base, NM (Radian, 1988) -- summary of sampling and analysis of sludge and soil in Ponds A and B;

- Sampling and Quality Control Summary Report (A-E SQCSR) for Field Investigation to Support Sewage Lagoon Closure, Holloman Air Force Base, NM (Radian, 1991) -- summary of sampling and analysis of 1) soil in Ponds A and B following removal of PCB-contaminated sludge, and 2) soil and sludge in the influent portion of Pond C; and

- Quality Control Summary Report (A-E QCSR) for Sewage Lagoon Surface Water Sampling, Holloman Air Force Base, NM (Radian, 1991) -- summary of sampling and analysis of water in the wastewater treatment plant headworks, Ponds B through G, and Lake Holloman.

1.0 DESCRIPTION OF SITE CONDITIONS

A thorough understanding of site hydrogeologic conditions is necessary to conduct an adequate assessment monitoring program. An understanding of the hydrogeologic conditions at the sewage treatment lagoons allows identification of likely contaminant pathways necessary for tracking and characterizing plume movement. Included in this section are discussions of the hydrogeologic conditions and potential contaminant pathways, as well as the overall site conditions.

1.1 Location

As illustrated in Figure 1-1, Holloman AFB is situated in south-central New Mexico in the northwest-central portion of Otero County. The Base is located about 75 miles northeast of El Paso, Texas, and about seven miles west of Alamogordo, New Mexico.

1.2 Background

The data reported in this section were primarily compiled from the Final Hydrogeologic Investigation Report and Groundwater Monitoring Plan (HIR/GWMP) (Radian, July 1989) (2). The purpose of that investigation was to gather hydrogeologic data for the area adjacent to the sewage treatment lagoons at Holloman AFB. The investigation was conducted from 29 July to 18 December 1987, and consisted of the following: interpretation of subsurface geology; determination of contaminant pathways; aquifer characterization and analysis; and development of conclusions and recommendations for additional activities. To accomplish these activities, soil borings were drilled, piezometers were installed, and aquifer tests were completed. The conclusions of this investigation are referred to throughout this section.

As part of the 1987 Hydrogeologic Investigation (HI), a total of 16 shallow and 6 deep piezometers were installed (reference Figure 1-5 for soil boring/piezometer

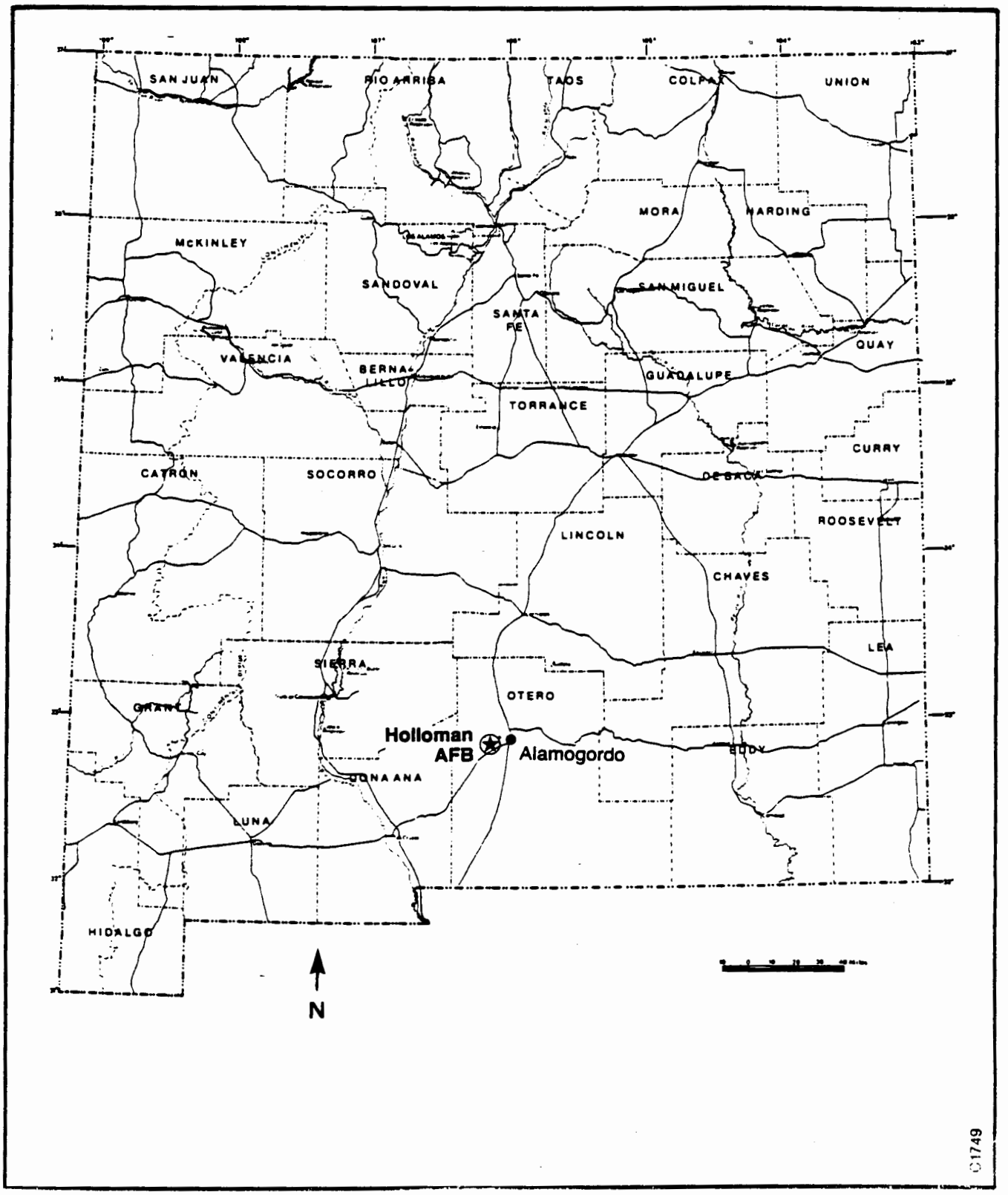


Figure 1-1. Location Map of Holloman AFB, New Mexico

locations). The shallow piezometers, labeled with the prefix S, were completed in the first water-bearing sand and ranged in depth from 9 to 19 feet below land surface (bls). The deep piezometers, labeled with the prefix D, were installed to depths ranging from 58 to 77 feet bls. Deep piezometers were placed at locations across the site to compare water quality characteristics and variability between the two saturated units. In the pump-test area, a piezometer (S-14) was installed in a clay unit separating the shallow and deeper saturated sand units.

The 22 piezometers were considered adequate to describe both the horizontal and vertical flow paths and gradients. The piezometers were installed after the borehole data were reviewed in the field to ensure proper screen placement. Piezometers were installed at all but one borehole location (B-1), near Hurtz Spring. This borehole was completed for geologic control purposes and to assess the change, if any, in the occurrence of the water table west of a bedrock high that intersects Hurtz Spring. The information obtained from the piezometers included:

- Water levels;
- Groundwater flow gradients;
- Gross indicators of water quality (pH, temperature, specific conductance); and
- Evidence of the degree of vertical communication between shallow and deeper water-bearing units.

Seasonal water table fluctuations could not be determined due to the short period of observation; however, short-term water table fluctuations were monitored. Water levels were measured from a permanently marked point on the well casing to assure that correct and consistent water level data were obtained each time. This point was also used by the surveyor in determining the elevation of the well above mean sea level. Based on

surveyed elevations of piezometers and subsequent water table measurements, hydraulic gradients and flow paths were determined.

Prior to Radian's study, an investigation was conducted by the USGS in 1985 during which twelve monitor wells were installed around the sewage treatment lagoons. One of these wells was located upgradient of Pond E; ten wells were placed on the berm and southwest of Pond D; and one well was placed near Lake Holloman. Based on the USGS report (USGS, 1985) (3), the wells were suspect in construction and completion integrity. These wells were properly abandoned in March 1990 by drilling out the PVC casing, followed by pressure-grouting Type I cement grout into the annulus of the uncased borehole.

1.3 Climate

Holloman AFB is located in the southern part of the Tularosa Basin with mountain ranges to the east and west. The climate is arid with low annual rainfall and low relative humidity. The mountain ranges have a dramatic influence on the local weather; they provide orographic lifting to produce summer thunderstorms and modify approaching weather systems.

Meteorological data for Holloman AFB are presented in Table 1-1. The mean daily high averages 75°F while the mean daily low averages 47°F. The average frost-free dates range from April 5 to November 10. The annual precipitation averages 7.9 inches, with annual extremes ranging from 2.5 inches to 13.5 inches (CH2M Hill, 1983) (4). The greatest amount of precipitation usually occurs during July, August, and September.

The mean annual lake evaporation rate, commonly used to estimate the mean annual evapotranspiration, is estimated at 67 inches per year. The net precipitation (mean annual precipitation minus mean annual evapotranspiration) for the Holloman AFB area is approximately -59 inches per year.

Table 1-1

Meteorological Data for Holloman AFB[a]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average or Extreme
Temperature (°F)													
Monthly mean	41	46	52	61	69	81	79	73	62	49	49	42	61
Mean daily high	54	60	66	76	84	93	91	86	76	63	63	55	75
Mean daily low	28	31	37	45	54	68	66	60	48	35	35	26	47
Record high	78	80	90	94	103	108	106	102	92	82	82	75	109
Record low	-11	0	9	23	26	52	54	38	26	3	3	2	-11
Precipitation (in)													
Monthly mean	0.5	0.4	0.3	0.2	0.4	0.7	1.2	1.3	1.2	0.9	0.3	0.5	7.9
Record maximum	1.9	1.4	3.0	0.8	2.9	3.6	3.7	4.4	3.9	4.2	2.5	2.4	4.4
Record minimum	0	T[b]	0	0	0	T	T	0.2	T	0	0	0	0
Relative humidity (%)													
4 a.m. mean	66	61	52	40	42	42	60	66	68	61	61	63	57
1 p.m. mean	42	35	27	19	20	19	31	35	38	34	34	37	31
Surface wind													
Mean velocity	4	4	6	7	6	6	5	5	4	4	4	4	5
(Knots)	N	N	S	S	S	S	S	S	S	S	S	S	S
Prevailing direction													

[a]Source: Holloman Air Force Base Installation Restoration Program Records Search; CH2M Hill; August 1983.
Period of record: September 1942 to December 1981.

[b]T = trace.

1.4 Physical Geography

The location of Holloman AFB in relation to major geographic features in New Mexico is shown in Figure 1-2. The Tularosa Basin is an arcuate downfaulted closed intermontane basin that is part of a structural depression approximately 170 miles long, extending from the Chupadera Mesa in the north, southward to approximately the Texas-New Mexico state line.

The Tularosa Basin is bounded on the south by a low topographic divide near the state line; on the west by the uplifted Organ, San Andres, and Oscura Mountains; Chupadera Mesa on the north; and on the east by the uplifted Jicarilla, Sierra Blanca, and Sacramento Mountains. The interior plain has low relief with altitudes ranging from about 4000 feet in the southwest portion of the basin to about 4400 feet on the northeastern portion of the basin. The surrounding mountains rise abruptly to altitudes of 7,000 to 12,000 feet. The topography of Holloman AFB is a fairly flat plain. The highest surface elevations occur in the northeastern Base area and gently slope toward Lake Holloman to the southwest at a rate of about 30 feet per mile. Lake Holloman is at an altitude of about 4,000 feet above mean sea level.

1.5 Soils and Geology

1.5.1 Soils

The U.S.D.A. Soil Conservation Service has identified two soil associations at the Base: the Holloman-Gypsum Land-Yesum complex and the Mead silty clay loam (USDA/SCS, 1971) (5). Most of the surficial soils at the Base are Holloman-Gypsum Land-Yesum complex which consists of a well-drained sandy loam with gypsum content increasing with depth. The Mead silty clay loam occurs over a small area of the Base. The soil consists of a reddish-brown silty clay loam, silty clay, and clay.

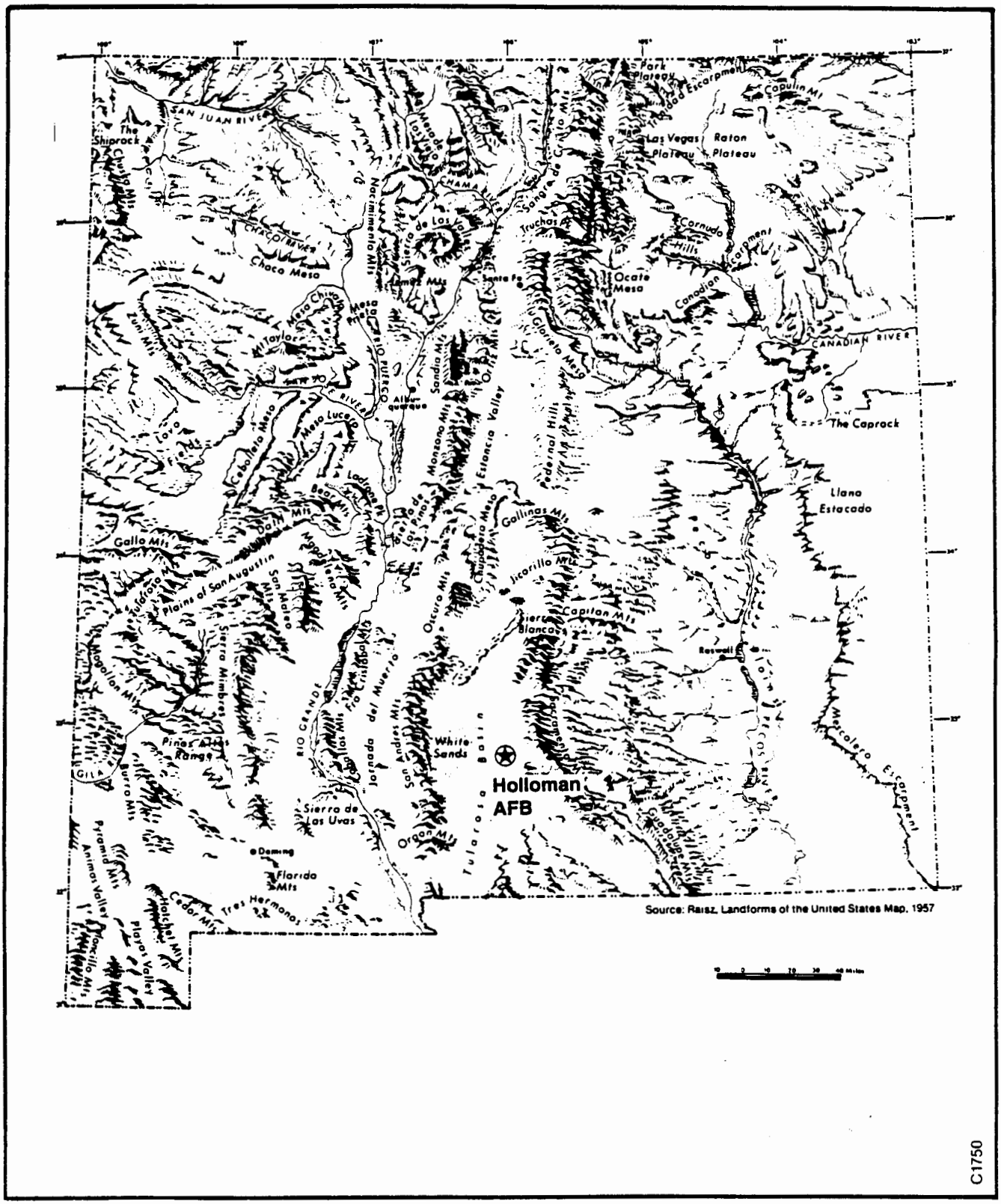


Figure 1-2. Relationship Between Holloman AFB and Major Geographic Features and Rivers in New Mexico

1.5.2 Regional Geology

Middle to late Cenozoic faulting formed the structural trough known as the Tularosa Basin. Geologically, the Tularosa Basin is a graben, bounded on the east and west by mountains which are actually tilted fault blocks (Sacramento Mountains and San Andres, respectively). The Tularosa Basin is the central area which collapsed between the fault scarps on either side of the valley. Alluvial filling of the Tularosa Basin began during the Pliocene era (10 million years ago).

Further basin adjustment occurred as buried fault blocks shifted within the Tularosa Basin. A geologic map of the present-day Tularosa basin is presented in Figure 1-3. Consolidated rocks (Permian Hueco and Yeso Limestone) are exposed in a north-south bedrock high beginning south of Holloman AFB in the Jicarilla Mountains trending north through Tres Hermanos and Twin Buttes. The bedrock high extends through a small bedrock outcrop near Hurtz Spring west of the Base, and through a bedrock knob north of the Base test track (Figure 1-3). A schematic east-west cross-section of the southern basin is shown in Figure 1-4. The line of bedrock outcrops represents a large, buried down-faulted block. The fault block is en-echelon to the main basin-forming fault scarp at the base of the Sacramento Mountains. The fault block is tilted to the east slightly and plunges to the north (Orr, 1987) (6). The fault scarp is buried by bolson fill deposits in the Holloman AFB area, but the fault is suspected to trend north-south in line with the bedrock outcrops. This tilted fault block divides the larger Tularosa Basin/White Sands area from the Alamogordo subbasin.

Bolson fill deposits are thin from Alamogordo toward Holloman AFB on the western edge of the sub-basin. Bolson sediments range in thickness from 4,000 feet near Alamogordo to less than 100 feet near Hurtz Spring (USGS, 1986) (7). Bolson fill deposits in the central portion of the Tularosa Basin are 8,000 feet thick or more.

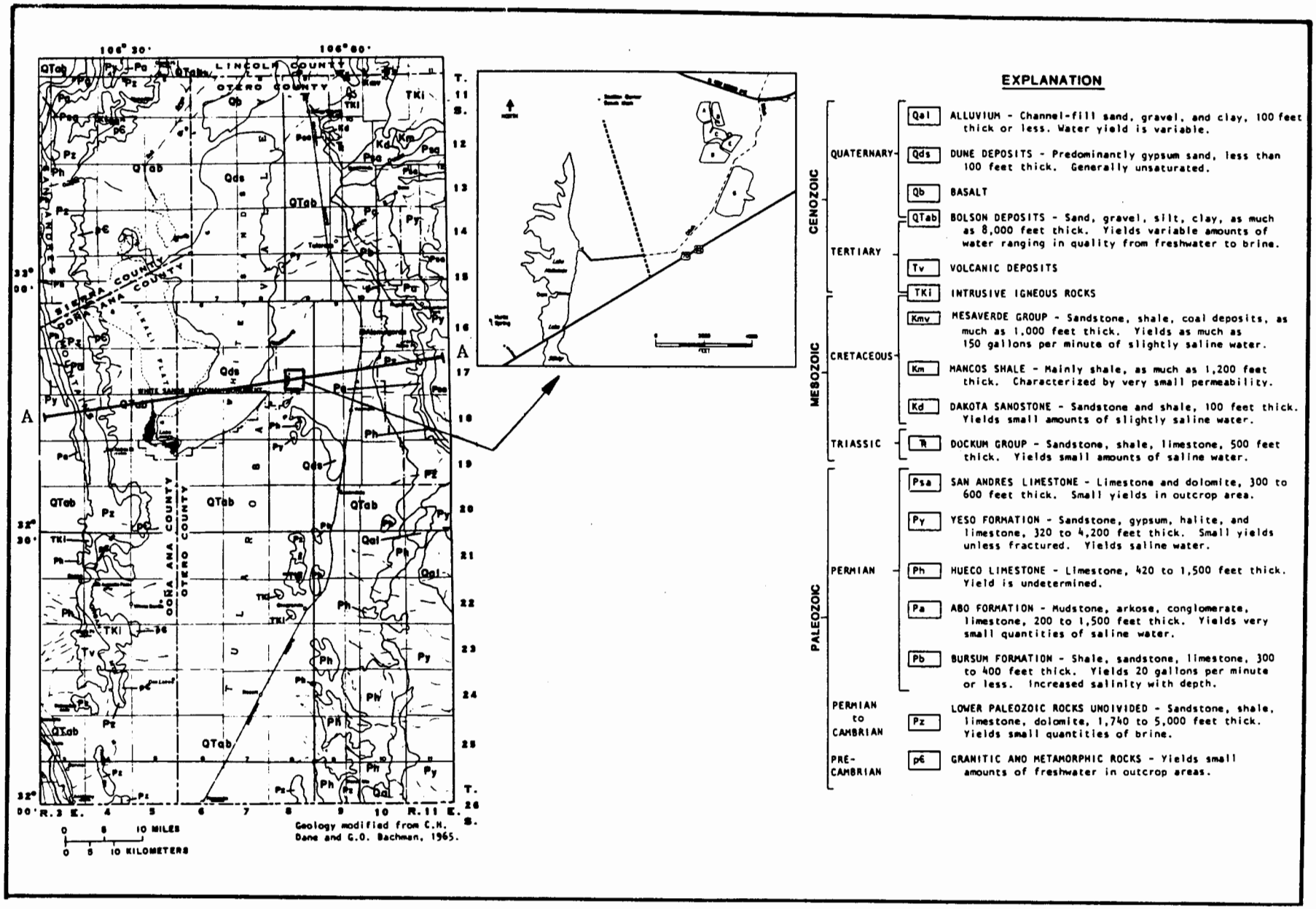


Figure 1-3. Geologic Map of the Tularosa Basin Relative to Locations of Lake Holloman and Sewage Treatment Lagoons, Holloman AFB, New Mexico

Source: Orr, 1986

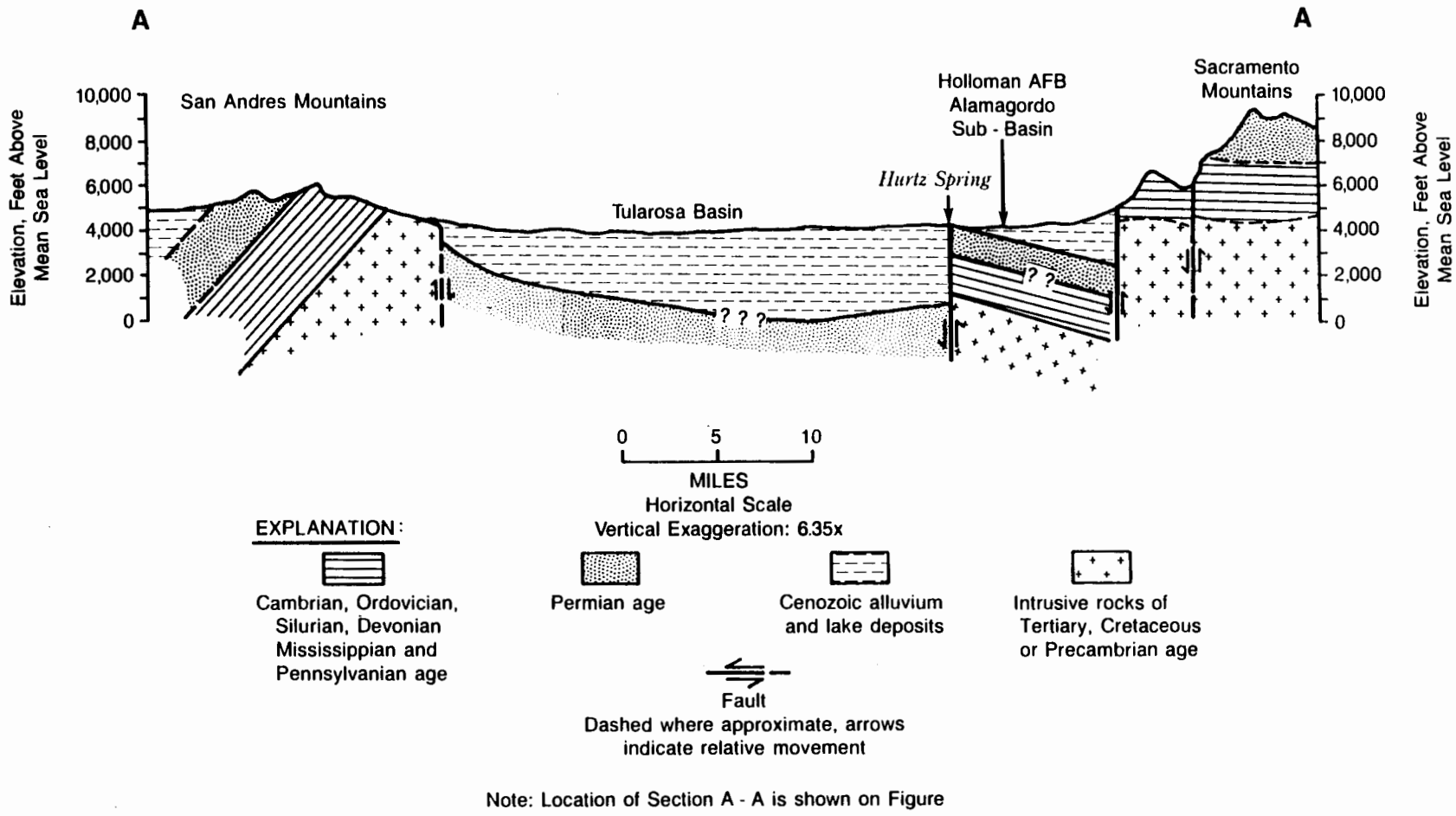


Figure 1-4. Geologic Cross-Section (looking north) of the Tularosa Basin, Holloman AFB, New Mexico

1.5.3 Interpretation of Site Geology

A summary of the site geology, taken from the HIR/GWMP and subsequent reports, is presented in the following paragraphs. Figure 1-5 is a location map showing soil borings and three geologic cross-sections.

As illustrated in Figures 1-6, 1-7, and 1-8, the subsurface geology of the site is shown in part by three cross-sections, A-A', B-B', and C-C', respectively. The cross-sections are aligned east to west across the entire study area. The lithologic units appear to be generally continuous across the site. The top 2 to 3 feet is either the Holloman-Gypsum Land-Yesum or Mead silty clay loam soil complexes. The soil complexes grade into the upper sand unit which consists of 6 to 40 feet of sand, silt, or silty sand. Clay lenses are common in the upper sand unit. A discontinuous middle clay unit underlies the upper sand. The middle clay is reddish brown with abundant gypsum crystals, and ranges from 10 to 40 feet thick where it was present. A lower sand unit consisting of interbedded sand, clay, and silt lies beneath the middle clay. This unit is lithologically heterogeneous and ranges from 10 to 20 feet thick.

At three of the six deep boring locations, the lower sand is underlain by a green, stiff plastic clay. The clay was encountered in borings D-2, D-3, and D-4 at 63 feet, 65 feet, and 53 feet, respectively. This green clay may be present at locations D-1, D-5, and D-6 at elevations below the total depth drilled; however, it is more likely that the green clay is absent at these locations based on the expected depth of occurrence from the cross-sections.

A buried north-south trending vertical fault appears to cross the western edge of the site. The fault runs between Hurtz Spring and White Sands National Monument. Both surficial and subsurface evidence of the fault were found. On the ground surface, fault gouge was observed in a limestone outcrop (partially excavated) east of B-1. Results of field

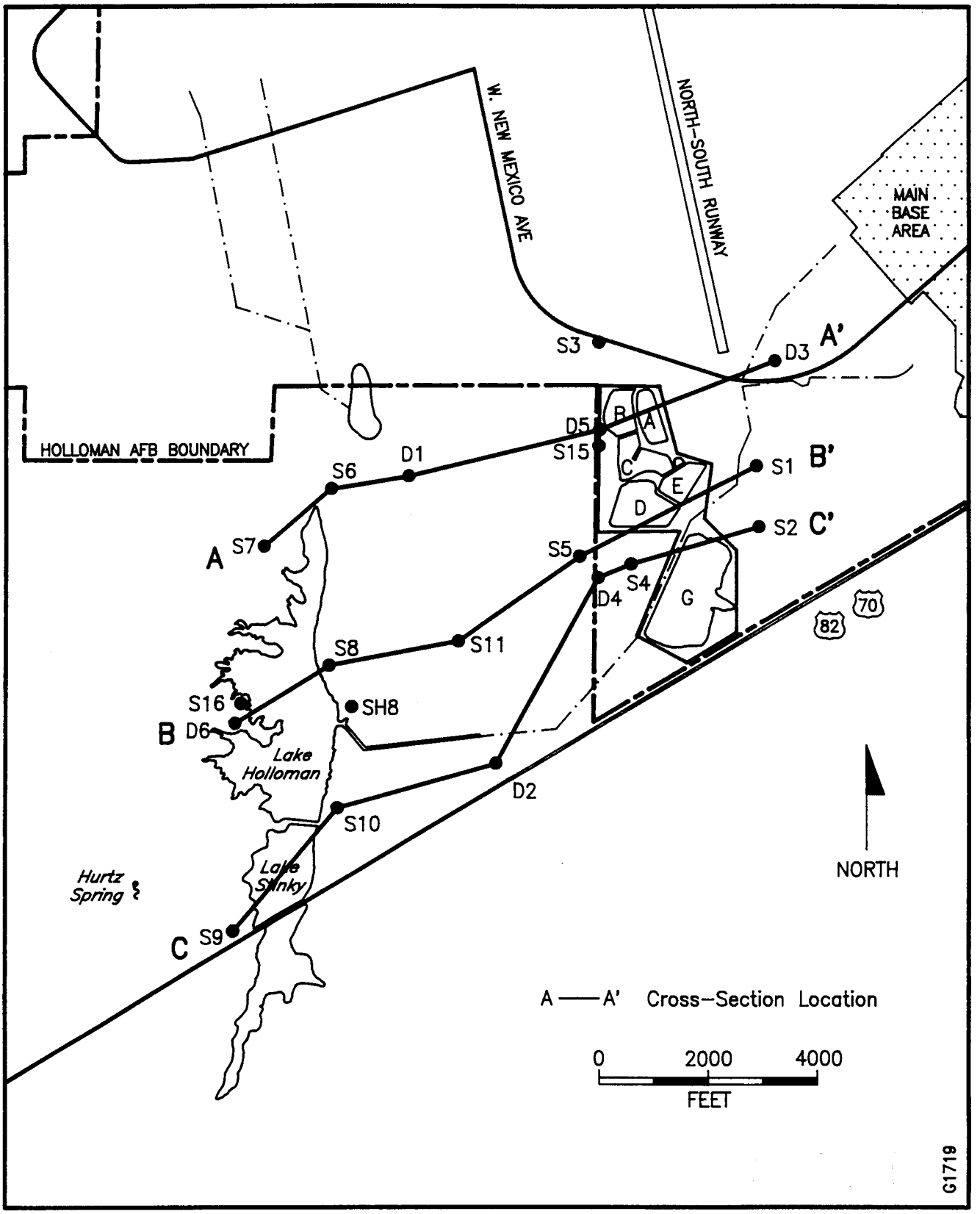


Figure 1-5. Location Map Showing Soil Boring Locations and Three Geologic Cross-Sections (A-A', B-B', C-C'), Holloman AFB, New Mexico

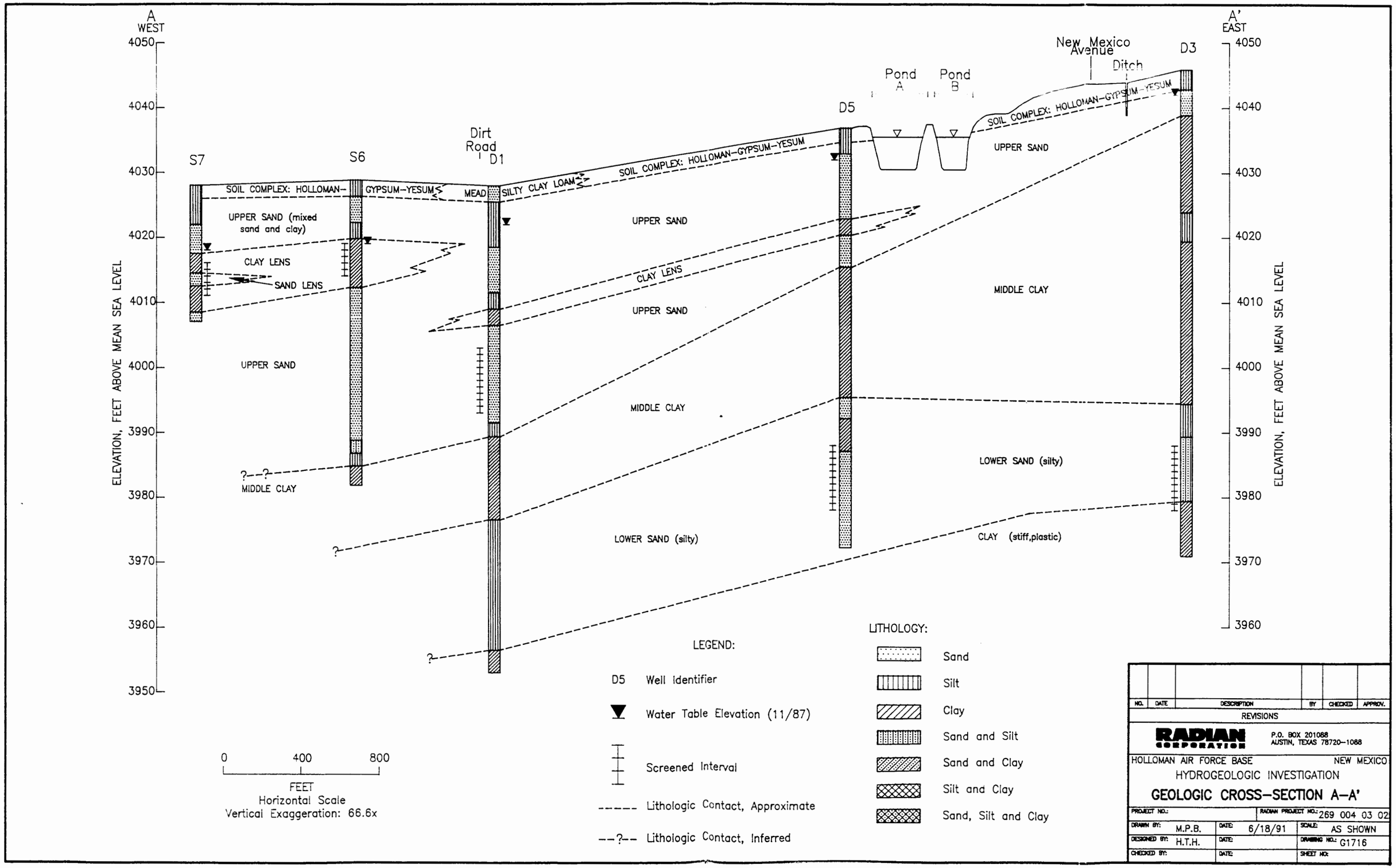
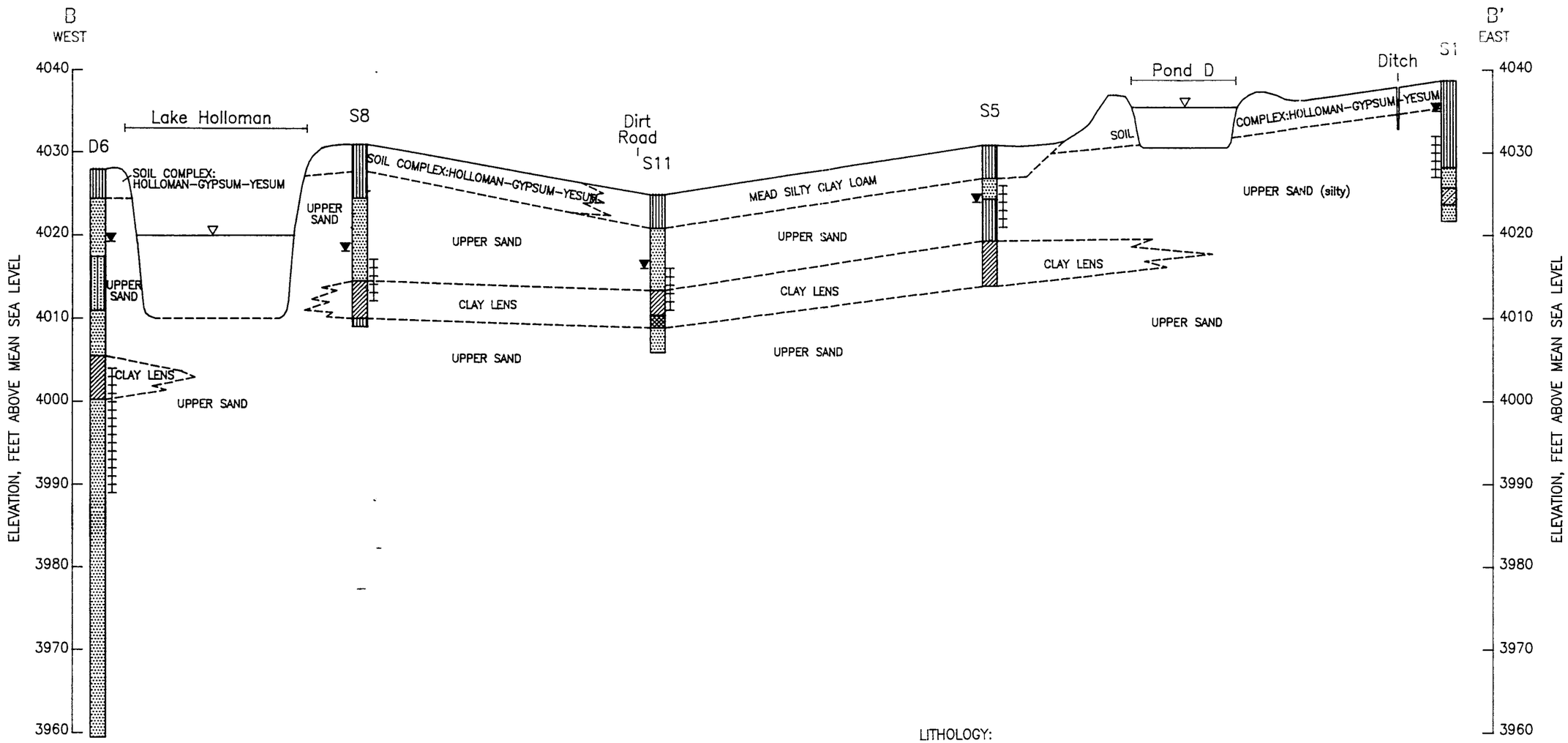


Figure 1-6. Cross-Section A-A', Holloman AFB Sewage Treatment Lagoons



LEGEND:

D5	Well Identifier
▼	Water Table Elevation (11/87)
┼	Screened Interval
-----	Lithologic Contact, Approximate
--?--	Lithologic Contact, Inferred

LITHOLOGY:

- Sand
- Silt
- Clay
- Sand and Silt
- Sand and Clay
- Silt and Clay
- Sand, Silt and Clay

0 400 800
FEET
Horizontal Scale
Vertical Exaggeration: 66.6x

NO.	DATE	DESCRIPTION	BY	CHECKED	APPROV.

REVISIONS

RADIAN CORPORATION
P.O. BOX 201088
AUSTIN, TEXAS 78720-1088

HOLLOMAN AIR FORCE BASE NEW MEXICO
HYDROGEOLOGIC INVESTIGATION
GEOLOGIC CROSS-SECTION B-B'

PROJECT NO.:		RADIAN PROJECT NO.: 269 004 03 02	
DRAWN BY: M.P.B.	DATE: 6/18/91	SCALE: AS SHOWN	
DESIGNED BY: H.T.H.	DATE:	DRAWING NO.: G1717	
CHECKED BY:	DATE:	SHEET NO:	

Figure 1-7. Cross-Section B-B', Holloman AFB Sewage Treatment Lagoons

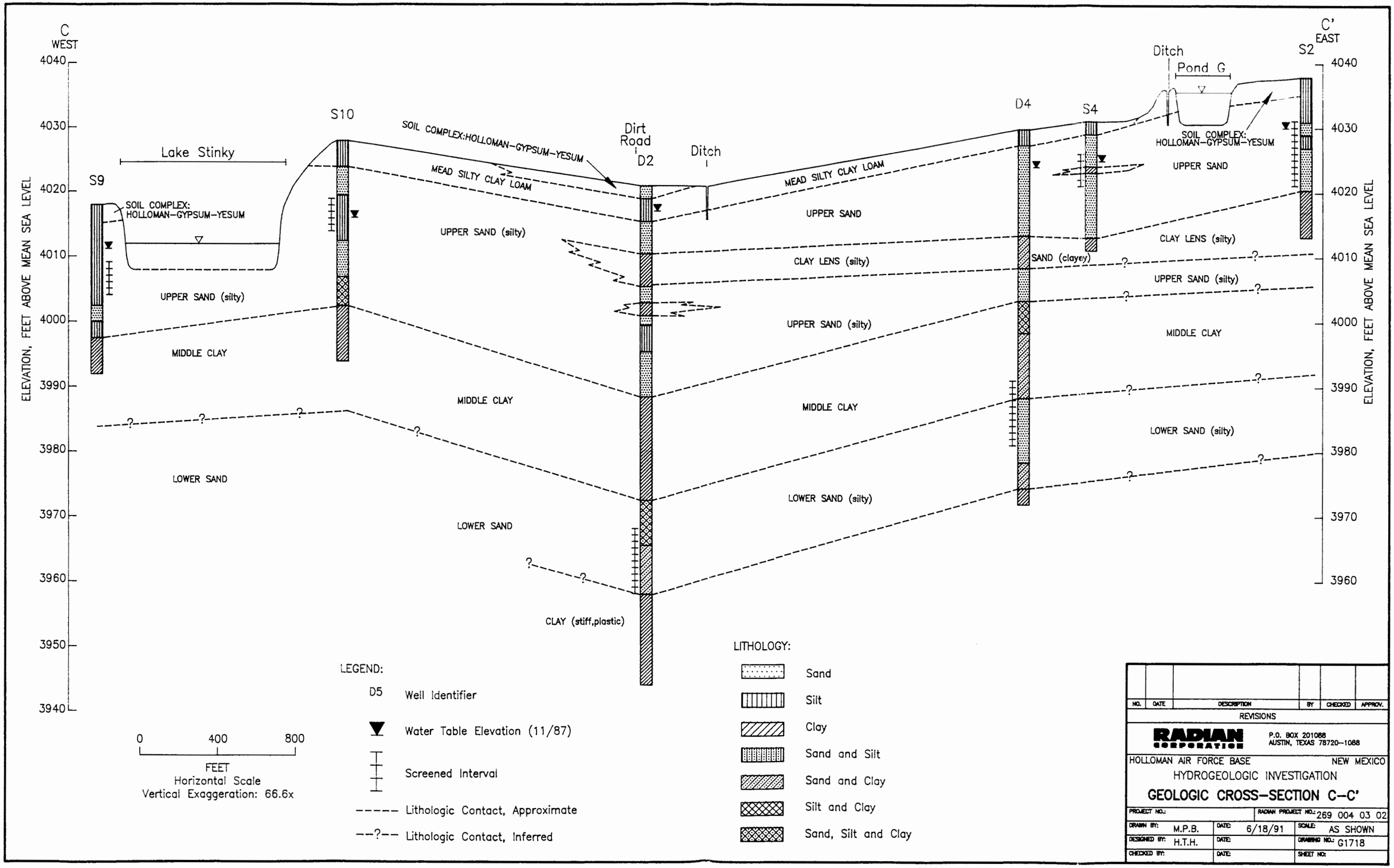


Figure 1-8. Cross-Section C-C', Holloman AFB Sewage Treatment Lagoons

measurements taken at the outcrop show vertical joints and small scale north-south trending faults. It is possible that the outcrop and Hurtz Spring area represent the edge of the fault scarp and that the spring emerges at the surface along the fault plane. At S-9, D-6, and S-16, unconsolidated sands, silts, and clays were encountered. At B-1, consolidated sandstone and rock gouge were encountered at a depth of 7 feet. The sandstone is completely dissimilar to the Hueco limestone outcrop located about 600 feet east. The sandstone is presumed to be recent in age, and is consolidated by calcite cement.

1.6 Hydrology

1.6.1 Surface Water

The Tularosa Basin is a closed basin; no surface water drainage leaves the basin. Surface water is either lost to evaporation and infiltration, or collects in the lowest point in the basin at or near Lake Lucero. This lake is located approximately 20 miles southwest of Holloman AFB.

The Base is crossed by several southwest-trending arroyos (intermittent streams). One of these drainages, Lost River, is fed by shallow (less than 10 feet bls) groundwater seeps or springs. Lost River flows from the northwest corner of the Base property to the southwest. The river appears and disappears along its course as springs discharge to it and evapotranspiration and infiltration recapture it. Surface drainage within the undeveloped parts of the Base is controlled by the major arroyos including Lost River and Dillard Draw and their tributaries. Surface flows are to the southwest toward the White Sands National Monument.

Drainage within the developed portion of the Base flows through ditches and culverts to the southwest, into the sewage treatment lagoons. The wastewater treatment system at Holloman AFB consists of seven aeration/evaporation lagoons located in the southwest corner of the Base. Just southwest of these lagoons, a natural playa lake known

as Lake Holloman receives runoff from the Base as well as effluent from the sewage treatment lagoons. A dam/dike has been constructed across the southern quarter of Lake Holloman. Seepage through the dam and overflow has created a small playa lake known as Lake Stinky.

Surface-water bodies in the study area consist of the sewage treatment lagoons and Lakes Holloman and Stinky. All are artificially recharged by wastewater effluent and shallow groundwater. No natural water bodies exist in the Base area.

1.6.2 Regional Hydrogeology

Groundwater occurs within the unconsolidated bolson deposits at shallow depth beneath Holloman AFB. The water table is very near the surface (less than 10 feet bls) over most of the Base. Figure 1-9 illustrates of the relationship between the Sacramento Mountains and the bolson fill relative to groundwater occurrence. At the base of the mountains, the hydraulic gradient is quite steep, but flattens out quickly. In the vicinity of Holloman AFB, the ground surface slopes to the southwest at a very low gradient, but at a slightly steeper grade than the hydraulic gradient of the water table. As a result, the depth to water decreases from 270 feet bls (or more) near the mountains to less than 10 feet bls at Holloman AFB.

Most of the groundwater recharge to the bolson aquifer occurs through the coarse, unconsolidated alluvial fan deposits along the western flank of the Sacramento Mountains. Water percolates downward into the bolson fill aquifer in this area and migrates downgradient (westward) through progressively finer-grained sediments into the basin. Groundwater discharge occurs either through evapotranspiration, springs, or seeps along steep-sided arroyos or into closed playa lakes such as Lake Lucero, the regional groundwater discharge area.

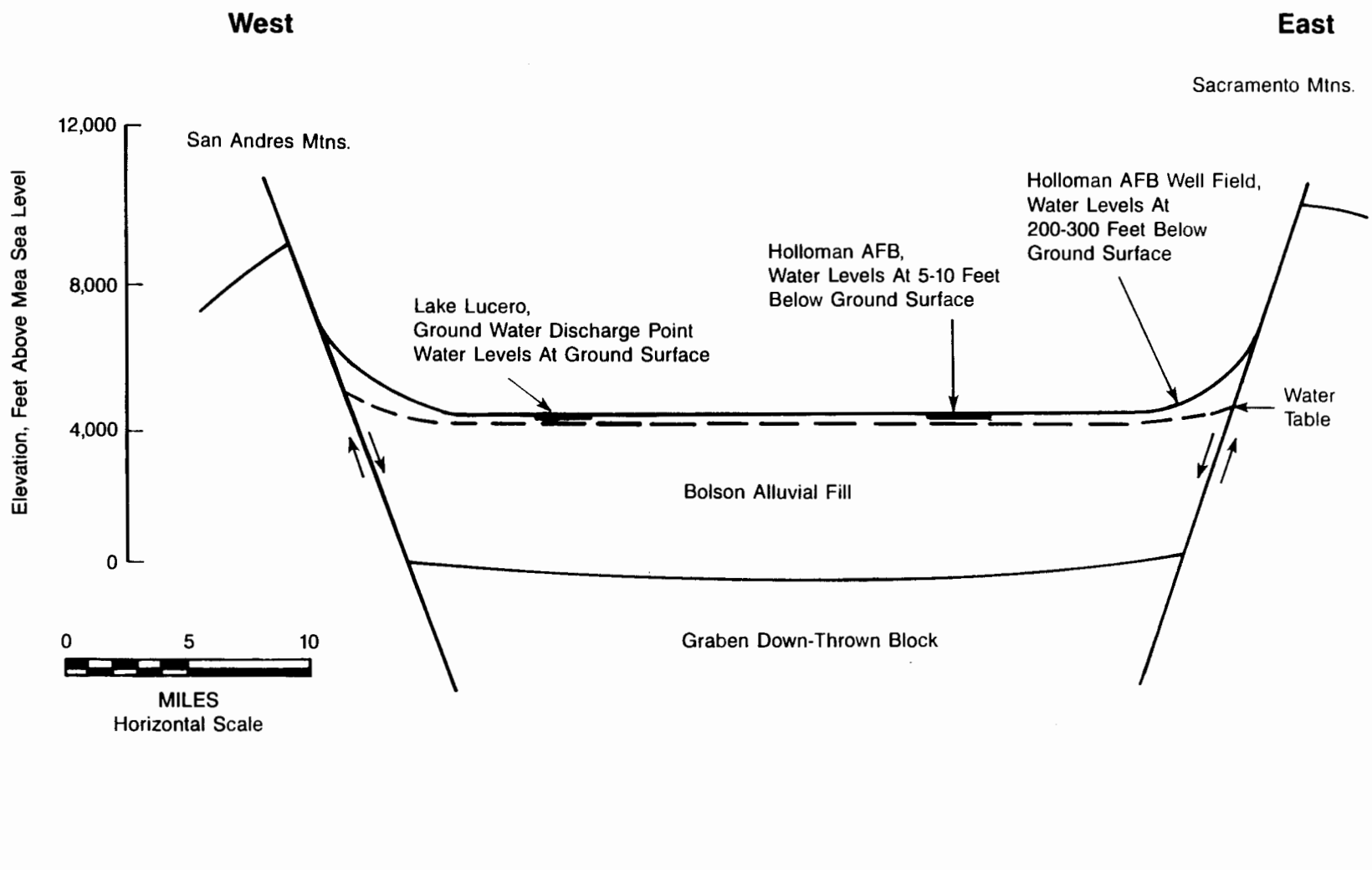


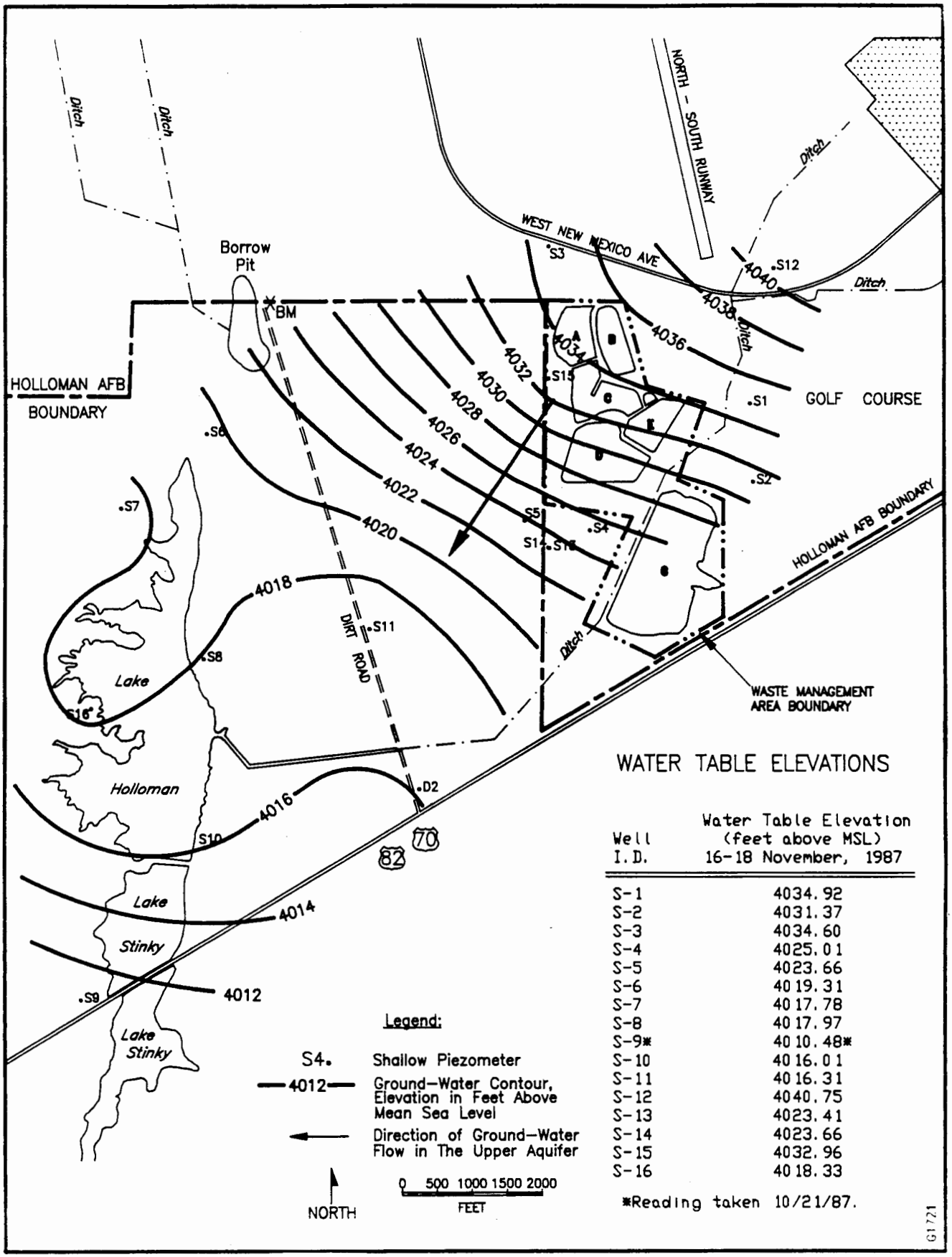
Figure 1-9. Schematic Cross-Section (looking north) of Groundwater Occurrences and Discharge Areas Beneath the Tularosa Basin, Holloman AFB, New Mexico

Groundwater of good quality occurs near recharge areas, but becomes progressively more mineralized downgradient toward the interior of the Tularosa Basin. This is attributable to the slow migration rate of groundwater from recharge to discharge areas, and the presence of readily soluble minerals in the bolson sediments. The primary dissolved ions in the groundwater are sulfate and chloride. Because groundwater below Holloman AFB contains high total dissolved solids (TDS) (in excess of 10,000 mg/L), the groundwater is designated as unfit for human consumption based upon New Mexico Water Quality Control Commission Regulations (NMWQR Parts 3-100 through 3-103) dated September, 1987.

1.6.3 Site Hydrogeology

Groundwater occurs under water table conditions at Holloman AFB. The depth to groundwater ranges from 2 to 13 feet bls, increasing in depth from the sewage treatment lagoons toward Lake Holloman. Figure 1-10 depicts the flow direction beneath the area of the investigation measured 17-18 November 1987. The hydraulic gradient is consistently 0.3 percent. The groundwater flow direction is fairly consistent, from northeast to southwest. A slight flexure occurs beneath the sewage treatment lagoons. This flexure is most likely a result of groundwater mounding beneath the lagoons (resulting from radial flow). During high groundwater conditions, the mounding causes the local groundwater flow to change direction. The effect of the mounding on the detection monitoring network is discussed in detail in Section 2. Downgradient of the sewage treatment lagoons, before groundwater reaches Lake Holloman, the hydraulic gradient returns to 0.3 percent, to the southwest.

A shift in the flow direction occurs east of Lake Holloman based on water levels measured in piezometers S-8, S-10, S-11, and D-2. Groundwater flow is redirected from Lake Holloman to the south-southeast toward D-2. Mounding may be caused by either the topographic high near Hurtz Spring (and bedrock outcrop area), or Lake Holloman and the backed-up portion of the runoff ditch.



Well I.D.	Water Table Elevation (feet above MSL) 16-18 November, 1987
S-1	4034.92
S-2	4031.37
S-3	4034.60
S-4	4025.01
S-5	4023.66
S-6	4019.31
S-7	4017.78
S-8	4017.97
S-9*	4010.48*
S-10	4016.01
S-11	4016.31
S-12	4040.75
S-13	4023.41
S-14	4023.66
S-15	4032.96
S-16	4018.33

*Reading taken 10/21/87.

Figure 1-10. Groundwater Flow Direction Measured 17-18 November 1987, Sewage Treatment Lagoons, Holloman AFB, New Mexico

West of Lake Holloman, the flow direction is redirected toward the southwest, based on water table data from S-9. The downgradient flow west of Lakes Holloman and Stinky conforms to the regional southwestern gradient toward Lake Lucero.

In summary, a groundwater divide occurs between the sewage treatment lagoons and Lake Holloman. The divide is the result of either a topographic high west of Lake Holloman which causes groundwater to flow toward the south, and/or mounding beneath Lake Holloman which redirects groundwater originally moving southwest from the sewage treatment lagoons toward Lake Holloman, to the south toward D-2. West of Lake Holloman, groundwater resumes a southwesterly flow direction.

1.6.4 Aquifer Test Results

Two types of aquifer tests were conducted during the 1987 HI at the Base: slug tests and pump tests. The purpose of aquifer testing was to determine aquifer characteristics such as transmissivity (T), storage coefficient (S) and hydraulic conductivity (K).

From these data, groundwater flow velocity was calculated and the extent of vertical hydraulic communication between the shallow and deeper water-bearing zones was estimated. The information derived from these studies for the saturated zones beneath the sewage treatment lagoons was generally consistent. Aquifer characteristics from monitor wells near the lagoons are summarized below:

- The first affected "aquifer" is composed of saturated sands, silts, and clays which are hydraulically interconnected.
- There are discontinuous clays separating coarser-grained, shallow water-bearing sand and silt units from deeper units of equal or greater grain size.

- The term "aquifer" may be used to describe hundreds of feet of bolson fill sediments beneath Holloman AFB. The basal contact of the bolson is estimated to be the top of Permian bedrock (depth unknown).

- The bolson fill "aquifer" exists under water table conditions in the first saturated shallow zone. However, with increased depth, successive clay and silt units create semi-confining conditions as shown in the response of observation wells S-13 and S-14 during the pump test. Artesian conditions do not exist at the depths investigated.

- Aquifer yield is based solely upon the porosity and permeability of the units screened; there are no secondary porosity factors to consider.

- Slug test methods generally revealed high T and S values, possibly due to the interference of the sand pack, and unsaturated portions of the screened interval above the static water level. Overall, the pump-test data are considered more reliable than slug test results when comparing T and S values between Radian and USGS wells. The results of the pump tests are presented on Table 1-2.

- A comparison of T and S calculations from the slug tests and two pump tests are similar. A comparison of the two test methods indicates that the first saturated sand has higher T and S values than deeper saturated units. The upper sand is a well drained, sandy loam of the Holloman-Gypsum Land-Yesum complex. With increasing depth, the sediments generally become progressively finer grained.

Table 1-3 presents a summary of slug test and pump test information compiled by the USGS (1985), Wilson and Associates (1986) (8) and Radian Corporation. Radian slug test results were determined using the method described by Ferris and Knowles (1962) (9). Pump test results were determined by using methods described by Cooper and Jacob (1946) (10) and Walton (1986) (11). USGS data were analyzed using Hantush-Jacob, Hvorslev, and Papadopoulos methods. USGS well data are described in the Wilson report (1986).

Table 1-2

Transmissivity, Storage Coefficient, and Hydraulic Conductivity Data From Pump Tests

Well I.D.	Transmissivity (gpd/ft)	Storage Coefficient	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)
P-1	126	NR	12.6	5.9×10^{-4}
D-3	377	0.00005	37.7	1.8×10^{-3}
S-12	ND	ND	ND	ND
P-2	106	NR	10.6	5.0×10^{-4}
S-13	ND	ND	ND	ND
S-14	ND	ND	ND	ND
D-4	330	0.0002	33	1.6×10^{-3}

NR = Not reported. Jacob straight line method and Theis curve matching technique unacceptable due to pump-well interference.

ND = Not determined. Drawdown response was insufficient or too sporadic to plot T and S values.

Source: HIR/GWMP (Radian, 1989)

Table 1-3

Horizontal Groundwater Velocity Results, Holloman AFB, New Mexico

Well I.D.	Test Method	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)	Porosity[a] (%)	Velocity[b] (ft/day)	Velocity[b] (ft/year)
UPPER SATURATED ZONE						
S-2	Recovery	7.1	3.4×10^{-4}	40	0.007	2.6
S-4	Slug	85.6	4.0×10^{-3}	30	0.13	47.5
S-5	Slug	61.8	2.9×10^{-3}	40	0.07	25.6
S-8	Slug	56.2	2.6×10^{-3}	40	0.06	20.5
S-11	Slug	80.2	3.8×10^{-3}	30	0.12	43.8
S-15	Slug	69.9	3.3×10^{-3}	30	0.11	40.2
S-16	Slug	45.8	2.2×10^{-3}	40	0.05	18.3
SH2B[c]	Hvorslev	16.1	7.60×10^{-4}	30	0.02	8.0
SH3B[c]	Hvorslev	8.3	3.94×10^{-4}	30	0.01	4.0
SH4B[c]	Hvorslev	35.4	1.67×10^{-3}	30	0.05	17.0
SH6A[c]	Papadopoulos	57.0	2.69×10^{-3}	30	0.08	28.0
	Hvorslev	18.3	8.66×10^{-4}	30	0.02	9.0
SH6B[c]	Hvorslev	11.0	5.18×10^{-4}	30	0.01	5.0
DEEPER SATURATED ZONE						
D-2	Slug	2.8	1.3×10^{-4}	40	0.003	1.1
D-5	Slug	3.1	1.5×10^{-4}	30	0.004	1.5
D-3	Pump test	37.7	1.8×10^{-3}	40	0.03	11.0
D-4	Pump test	33.0	1.6×10^{-3}	30	0.04	16.0
P-1	Pump test	12.6	1.2×10^{-4}	40	0.01	4.6
P-2	Pump test	10.6	5.0×10^{-4}	30	0.014	5.0
SH2A[c]	Hantush-Jacob	4.7	2.20×10^{-4}	30	0.005	2.0
	Papadopoulos	8.9	4.22×10^{-4}	30	0.01	4.0
	Hvorslev	10.8	5.10×10^{-4}	30	0.01	5.0
SH3A[c]	Hantush-Jacob	17.7	8.37×10^{-4}	30	0.02	9.0
	Papadopoulos	52.1	2.46×10^{-3}	30	0.07	25.0
	Hvorslev	8.9	4.20×10^{-4}	30	0.01	4.0

(Continued)

Table 1-3

(Continued)

Well I.D.	Test Method	Hydraulic Conductivity (gpd/ft^2)	Hydraulic Conductivity (cm/sec)	Porosity[a] (%)	Velocity[b] (ft/day)	Velocity[b] (ft/year)
SH4A[c]	Papadopoulos	6.9	3.28×10^{-4}	30	0.008	3.0
	Hvorslev	4.1	1.94×10^{-4}	30	0.005	2.0

[a] Based on the following values for porosity:
Sand = 30%, Silt = 40%, Clay = 50%

[b] Velocity (v) $= \frac{K(dh/dl)}{7.5a}$

dh/dl = Hydraulic gradient determined from piezometer elevation survey (0.003).

[c] USGS data from wells installed in 1985.

Source: HIR/GWMP (Radian, 1989)

1.7 Pathways of Contamination

Potential pathways for contaminant migration are discussed in the following paragraphs. This discussion is a summary of the pathways discussion found in the HIR/GWMP (Radian, July 1989). To facilitate the discussion of the potential constituent pathways, the area of investigation was divided into four "zones". They include:

- The sewage treatment lagoons and upgradient area;
- The area immediately downgradient of the sewage treatment lagoons;
- The area half-way between the sewage treatment lagoons and Lakes Holloman and Stinky; and
- Lakes Holloman and Stinky and the area downgradient of the lakes.

Sewage Treatment Lagoons and Upgradient Area

Potential pathways for contamination in the area upgradient of the sewage treatment lagoons include a runoff ditch, golf course, and flight line approach zone. The runoff ditch passes within 500 feet of piezometer S-1. The ditch drains the area north and east of the sewage treatment lagoons. Runoff, lawn-irrigation, and curb runoff enter the ditch from the Base housing area. The bottom of the runoff ditch is actually at a lower elevation than the present water table near the ditch. Evidence of salt accumulations left from fluctuating groundwater levels and seeps are visible along the ditch bank. The runoff ditch is unlined and is possibly recharged by shallow groundwater. However, when the ditches are filled with runoff water, it is likely that recharge occurs, and the ditch could act as a pathway for contamination.

Pond G was tentatively determined to be the primary source of leakage in the upgradient location based on a comparison of field measurements of specific conductance of water in the lagoon and in piezometer S-2. The groundwater from S-2 had low specific

conductivity values compared to the surrounding groundwater which could be caused by leakage of fresher water from Pond G. Fairly permeable sands line the sides and base of the lagoon. Pond G was a natural playa lake before it was converted into a sewage treatment lagoon. The playa sands and silts are naturally well sorted (based on field inspection) and the uppermost saturated unit is silty. This could provide a pathway for slow leakage of water from the lagoon. The horizontal velocity of groundwater through the shallow saturated silt was estimated to range from 2.5 ft/year (S-2 slug test) to 16 ft/year (D-3 drawdown data).

Area Immediately Downgradient of the Sewage Treatment Lagoons

In the area immediately downgradient of the sewage treatment lagoons, groundwater contamination would most likely occur through downward percolation of contaminated surface water from the lagoons, and subsequent migration of contaminants with groundwater flow, toward the southwest.

One piezometer, D-5, emitted strong sewage odors from the groundwater. The piezometer was screened in a sand between 49 and 59 feet bls. It is possible that anaerobic conditions naturally exist in this low area and that water percolating through decomposing plant material produced the offensive odor. Alternatively, the clay units above the screen could be leaky, thus allowing wastewater from the lagoons to percolate downward into the deeper screened units.

Pond A overflowed on several occasions in the past, releasing surface water to the adjacent area. The dike around Pond A was subsequently built up to preclude the recurrence of overflows. Surface water in Pond D was released in the past through side-wall seepage and by percolation through the unlined base of the lagoon. The USGS (1985) investigated the Pond D area where leakage occurred, as did Wilson and Associates (1986). Continuing leakage from Pond D is a potential pathway for groundwater contamination.

Potential pathways for contaminant migration also existed previously through the now abandoned USGS monitor wells, as previously discussed.

Groundwater velocity measurements were determined through slug tests of four piezometers: S-4, S-5, S-15, and D-5. A downgradient pump test supplemented the findings of some slug tests. Horizontal groundwater flow velocities immediately downgradient from the sewage treatment lagoons ranged from 25.6 ft/year to 47.5 ft/year in the shallow alluvium. In the deeper alluvium, the horizontal velocities determined from the pump test were slower, varying between 4.4 ft/year (P-2) and 13.7 ft/year (D-4).

Area Half-Way Between the Sewage Treatment Lagoons and Lakes Holloman and Stinky

The large area beginning half-way between the sewage treatment lagoons and the lakes and extending westward to the eastern shore of Lake Holloman has other pathways for contamination. All of the land in this area is public land maintained by the Bureau of Land Management. Concerns in this area focus on groundwater impacts from Lake Holloman (primarily) and the runoff ditch connecting Lake Holloman with the sewage treatment lagoons. As discussed previously, wastewater effluent is routed to Lake Holloman from the lagoons.

The effluent ditch passes approximately 500 feet north of piezometer D-2. The ditch is excavated to a depth at, or below, the existing water table. Because the ditch is excavated below the water table, it acts as a discharge point for groundwater. However, when filled with runoff water or effluent, the ditch could act as a recharge zone and provide a pathway for contamination. The main source of contamination is probably attributable to Lakes Holloman and Stinky.

Groundwater velocity measurements were obtained from slug tests conducted in piezometers S-8 and D-2. The groundwater flow is altered due to mounding from Lake

Holloman. The resultant horizontal groundwater velocity was determined to be 18.3 ft/year in S-8 and 1.1 ft/year in D-2. Groundwater flow is higher in the shallow saturated zone.

Lakes Holloman and Stinky and the Area Downgradient of the Lakes

The area west of Lakes Holloman and Stinky was investigated to correlate stratigraphic units beneath the lakes, and to potentially monitor groundwater quality changes as groundwater flows downgradient and off of Holloman AFB property. The major potential pathway for groundwater contamination is seepage of effluent through the bottom of Lakes Holloman and Stinky.

The horizontal groundwater velocity is estimated at about 18 ft/year (S-16 slug test). The outcrop area near Hurtz Spring may act as a barrier to flow which would result in impoundment of groundwater in Lake Holloman. However, alluvial deposits on either side of the outcrop are several hundred feet thick and the shallow saturated alluvium and general southwest hydraulic gradient would permit flow of groundwater around the outcrop into the central Tularosa Basin.

2.0 DESCRIPTION OF DETECTION MONITORING SYSTEM

This section discusses the detection monitoring program used for the Holloman AFB sewage treatment lagoons per 40 CFR Part 265, Subpart F. The detection monitoring program was completed as set forth in the Federal Facilities Compliance Agreement (FFCA) between Holloman AFB, EPA Region VI, and NMED, and conforms to the RCRA Technical Enforcement Guidance Document (EPA, 1986).

2.1 Detection Monitoring Network

As outlined in 40 CFR Section 265.91(a)(2), the entire sewage treatment lagoon area is considered the "waste management area"; therefore, monitor wells were located with respect to the entire facility and not installed for each lagoon. The number and placement of the wells were intended to be consistent with the requirements set forth by 40 CFR Section 265.91(a) such that:

- The number of upgradient wells, locations, and depths are representative of background water quality in the uppermost aquifer near the facility;
- Background wells are not affected by the facility; and
- Hydraulically downgradient wells are capable of immediately detecting statistically significant amounts of any hazardous waste constituents that migrate from the waste management area to the uppermost aquifer.

The detection monitoring network consists of a total of ten wells: eight monitoring wells (MW-1 through MW-8) were installed in 1989 and two piezometers (S-2 and S-4) were installed during the 1987 Hydrogeologic Investigation (HI). Table 2-1 lists the specifications for the detection monitoring network wells. Figure 2-1 illustrates the

Table 2-1

Specifications for Detection Monitoring Network Wells

Well I.D.	Up-Gradient	Down-Gradient	New Mexico State Plane Coordinates East;North	Top of Casing Elevation (Ft. MSL)	Concrete Pad Elevation (Ft. MSL)	Total Depth (Ft. bls)	Screened Interval (Ft. bls)	Construction Specifications
MW 1	X		548658.60; 666311.53	4053.42	4050.96	14.97	4.90-14.51	4" 316 St. Steel
MW 2		X	544566.85; 663814,83	4039.78	4037.45	15.00	4.99-14.54	4" 316 St. Steel
MW 3		X	544469.13; 662878.19	4037.38	4035.19	15.01	5.00-14.55	4" 316 St. Steel
MW 4		X	545215.83; 660699.42	4030.30	4028.08	15.00	4.99-14.54	4" 316 St. Steel
MW 5		X	544358.30; 664830.97	4039.30	4036.96	15.00	4.97-14.54	4" 316 St. Steel
MW 6		X	544970.02; 661445.18	4031.21	4028.85	14.99	4.52-14.53	4" 316 St. Steel
MW 7		X	544379.85; 665147.61	4039.88	4037.78	15.19	4.72-14.73	4" 316 St. Steel
MW 8		X	544474.40; 664520.54	4040.50	4038.20	15.00	4.99-14.54	4" 316 St. Steel
S-2	X		547271.07; 662911.05	4040.56	4037.99	17	7-17	2" Sch. 40 PVC
S-4		X	544926.56; 662213.66	4034.46	4031.49	11	6-11	2" Sch. 40 PVC

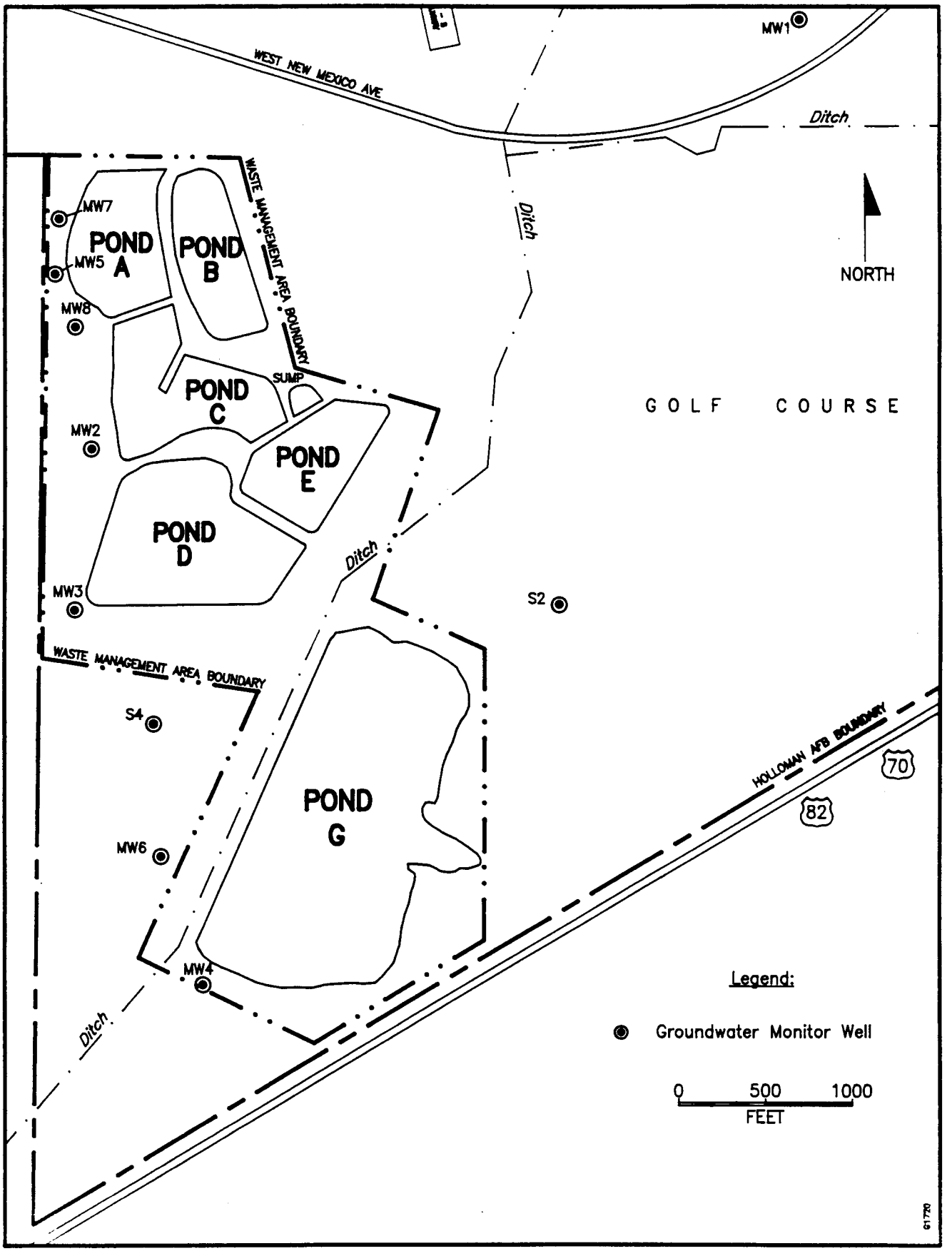


Figure 2-1. Detection Monitoring System for the Sewage Treatment Lagoons, Holloman AFB, New Mexico

location of the 10 detection monitoring wells with respect to the boundary of the waste management area. Two wells, MW-1 and S-2, were located in the assumed upgradient area, and the other eight wells were located downgradient of the lagoons. The detection monitoring wells are all screened at shallow depths (5 to 17 feet bls) because the uppermost water-bearing zone is most susceptible to any contaminants migrating from the lagoons. The wells, therefore, are adequately placed to detect any changes in water quality that would occur if hazardous constituents were released from the sewage treatment lagoons.

Piezometer S-2 was believed to be located upgradient of the sewage treatment lagoons. Figure 2-2, a potentiometric surface map of the groundwater on 10 December 1989, illustrates the typical groundwater surface configuration beneath the lagoons. However, during higher water-level conditions, groundwater mounding beneath the sewage treatment lagoons causes the groundwater flow to change direction. Figure 2-3, a potentiometric surface map of the groundwater on 15 January 1990, illustrates the effect of higher water-table conditions. Piezometer S-2, normally upgradient of the lagoons, is hydraulically downgradient of the sewage treatment lagoons during high water conditions. Therefore, contrary to the initial plan, groundwater samples collected from piezometer S-2 could not be, and were not, considered representative of background conditions.

With the exception of S-4, all piezometers installed during the 1987 HI are located over a large area surrounding the lagoons and, therefore, were not appropriate for inclusion in the RCRA groundwater monitoring well network. These piezometers (supplemental wells) were, however, used to determine groundwater levels, the potentiometric surface of the uppermost aquifer, and for calculation of the direction and magnitude of groundwater flow.

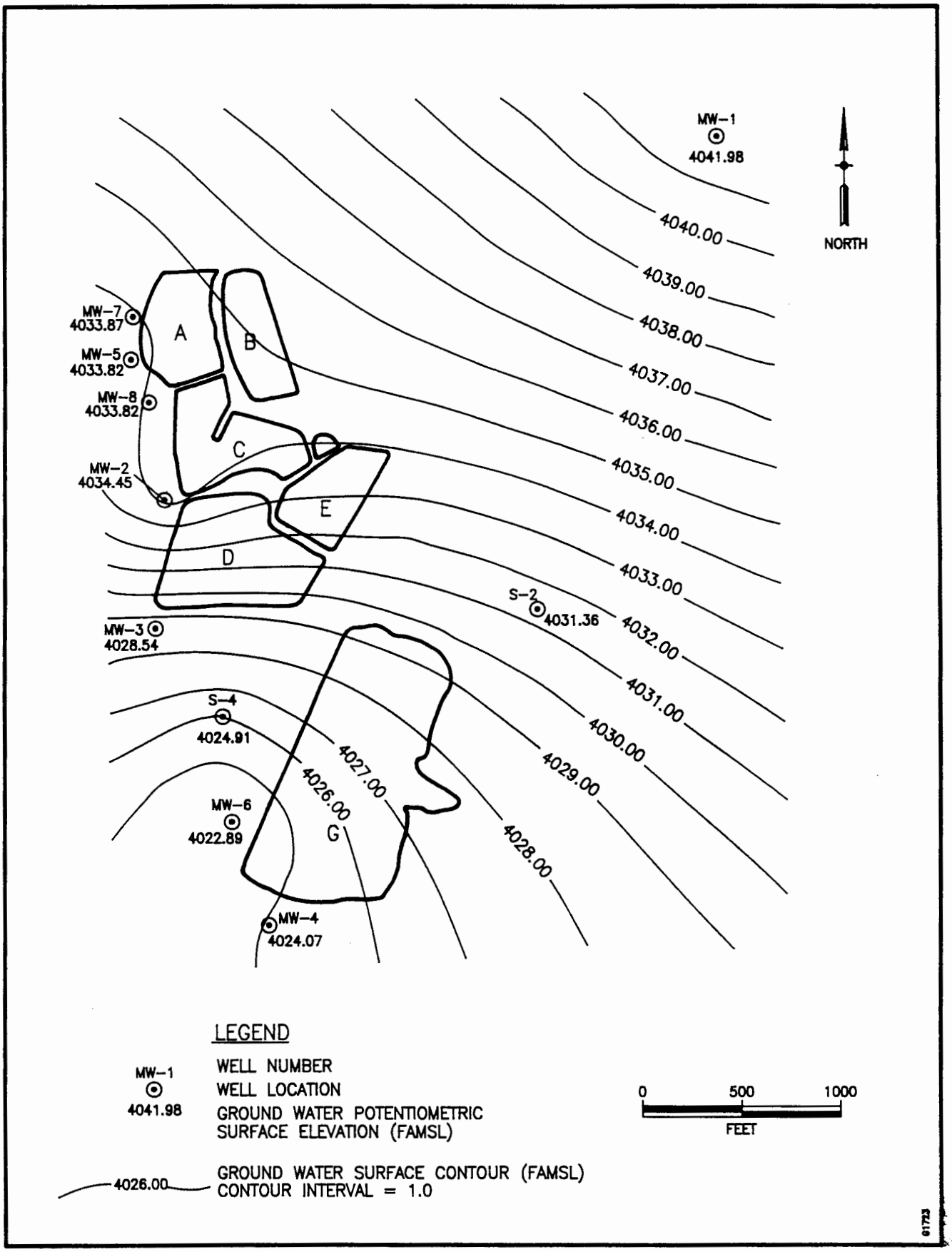


Figure 2-2. Potentiometric Surface Beneath the Sewage Treatment Lagoons (10 December 1989), Holloman AFB, New Mexico (IT Corporation, 1990)

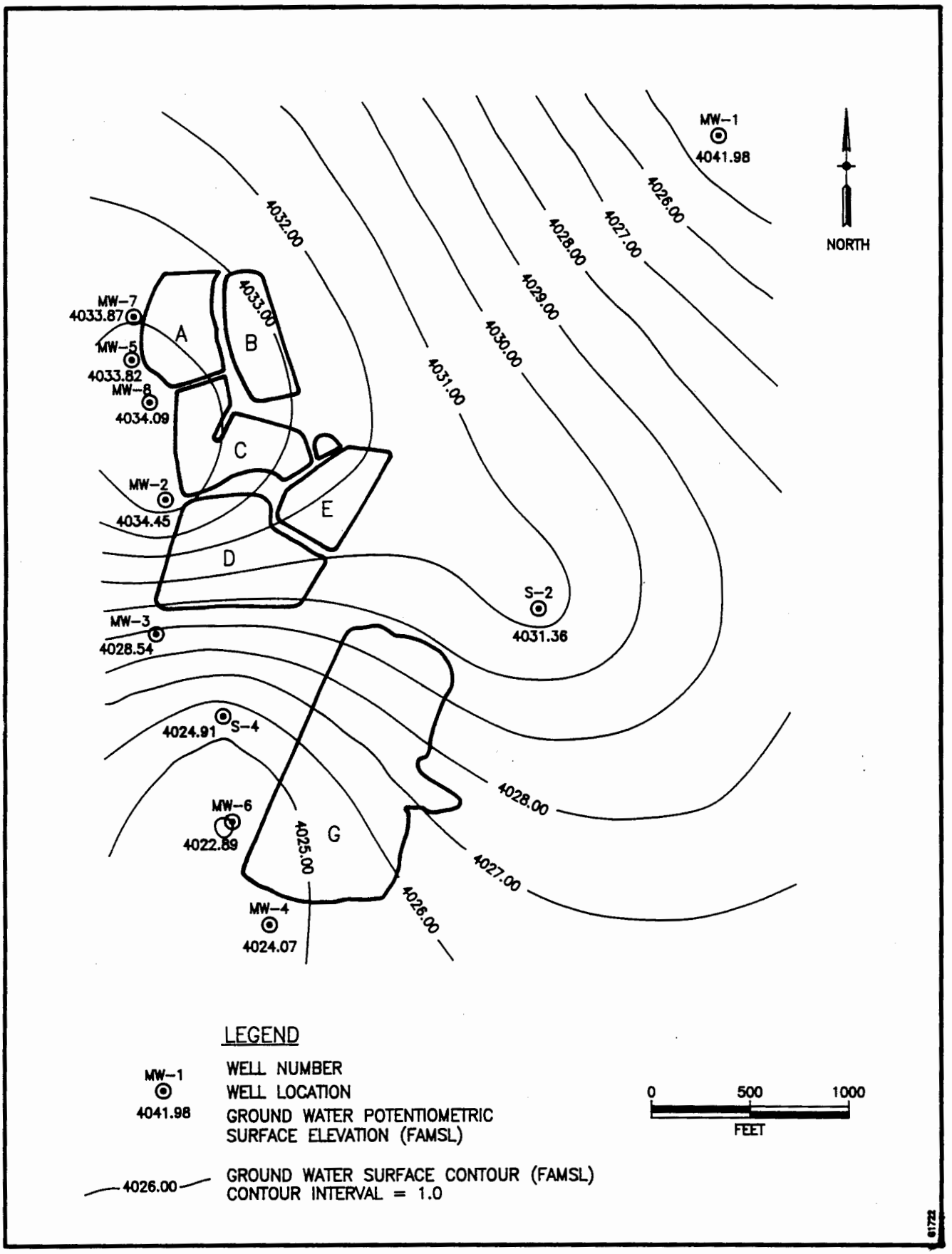


Figure 2-3. Potentiometric Surface Beneath the Sewage Treatment Lagoons (15 January 1990), Holloman AFB, New Mexico (IT Corporation, 1990)

2.2 Analytical Requirements

The analytical parameters for groundwater detection monitoring are based on the requirements in 40 CFR Section 265.92, "Sampling and Analysis." A list of the parameters is provided in Table 2-2 and found in Appendix III of 40 CFR Part 265. Table 2-2 includes parameters with Interim Primary Drinking Water Standards, groundwater contamination indicator parameters, and groundwater quality parameters. All detection monitoring wells were sampled for the parameters listed in Table 2-2. As outlined in the FFCA (item 9), all wells were sampled on a monthly basis for four months. Following the four monthly sampling events, semi-annual sampling began in January 1990.

Piezometer S-2 and monitoring well MW-1 were intended to represent background water quality conditions. As stated in 40 CFR Section 265.92(c)(1), the owner or operator (Holloman AFB) must establish initial background concentrations or values of all parameters listed in Table 2-2. To achieve this, four replicate measurements were collected from the two proposed upgradient wells sampled during the four-month period. Replicate samples were analyzed for the indicator parameters (pH, TOC, POX, and specific conductance). However, as previously discussed, the analytical data from piezometer S-2 could not be considered representative of background conditions in the final data review.

Table 2-2

Indicator Parameters and Appendix III Constituents for Groundwater Monitoring, Sewage Treatment Lagoons, Holloman AFB, New Mexico

Parameter	
Contamination Indicator Parameters	**Groundwater Quality Parameters**
pH	Chloride
Specific Conductance	Iron
TOX	Manganese
POX	Phenols
	Sodium
	Sulfate
EPA Interim Primary Drinking Water Standards	
Arsenic	Barium
Cadmium	Chromium
Lead	Mercury
Selenium	Silver
Fluroide	Nitrate/Nitrite
Endrin	Lindane
Methoxyclor	Toxaphene
2,4 D	2,4,5 TP Silvex
Coliform Bacteria	Radioactivity[a]

[a] Radioactivity includes radium, gross alpha, and gross beta.

3.0 DESCRIPTION OF APPROACH TO MAKE THE FIRST DETERMINATION FALSE POSITIVES RATIONALE

The RCRA requirement to develop a Groundwater Assessment Monitoring Plan was triggered when a statistically significant increase in total organic carbon (TOC) concentrations in groundwater samples from detection monitoring wells located downgradient of the sewage treatment lagoons was observed, relative to upgradient TOC concentrations. However, TOC is an indicator parameter that is not waste-specific, but reflects organic carbon from all sources. As such, it alone cannot be used to verify a release of hazardous organic waste or organic waste constituents because of its generic nature. The detected changes in TOC concentrations could also be related to variations in the presence or nature of naturally occurring organic compounds in the vicinity of the downgradient wells (i.e., false positives). As documented in Sections 1 and 2, the existing detection monitoring system is appropriately designed for the site-specific hydrogeologic conditions and is constructed to detect any leachate migrating from the lagoons. Therefore, a short-term sampling and analysis program is proposed to evaluate the possibility that the TOC data could represent a false positive determination.

In order to determine conclusively whether or not the elevated downgradient TOC concentrations are the result of a release of organic hazardous waste or organic hazardous waste constituents from the sewage treatment lagoons, one set of samples (including appropriate QA/QC samples) will be collected from each of the monitor wells in the detection monitoring network, and will be analyzed for Appendix IX (reference 40 CFR Part 264) organic constituents and TOC. The EPA Primary Drinking Water Standards for inorganic constituents were not detected at levels statistically above background in downgradient wells during the detection monitoring program. Therefore, Appendix IX inorganic constituents will not be analyzed for in the assessment monitoring program. The sampling and analysis protocol will be the same as those described in Section 7 of this plan.

The presence of any Appendix IX organic constituents at levels above the method detection limit (MDL) in any downgradient monitor well will trigger immediate resampling and analysis for only those parameters detected. The MDL is defined in SW-846 as the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. Appendix A of this plan lists the MDLs for the Appendix IX organic parameters. If detection of any Appendix IX organic constituent at a level above the MDL is verified by resampling, it will be concluded that a release of hazardous waste and/or hazardous waste constituents has occurred from the sewage treatment lagoons. Verification of a release by resampling will dictate quarterly sampling and analysis of the detection monitoring wells for constituents of concern.

If none of the Appendix IX organic constituents are detected at levels above the MDL, or if constituents detected above the MDL are not confirmed by resampling, it will be concluded that no release has occurred and a request will be made to return to the detection monitoring program as allowed in 40 CFR Section 265.93(d)(6). All results of the short-term sampling and analysis program will be provided in a report to the NMED and EPA Region VI. If the data support a return to detection monitoring, the basis for this determination will be completely documented. A discussion of the possible reason(s) the false positive determination may have occurred, as well as approaches to prevent or reduce the likelihood of future false positives, will be included.

The remaining sections of this plan describe the proposed approach to RCRA Groundwater Assessment Monitoring, should such a program be required at this time, or at some time in the future. A general, phased approach to determine the nature, magnitude, and areal and vertical extent of any contaminant plume(s), as well as to define potential migration pathways and rates of contaminant migration, is presented. Detailed identification of assessment monitoring well locations, numbers, and screened intervals will be developed in subsequent phases of assessment monitoring, as appropriate, based on findings from the initial phase of the assessment monitoring program.

4.0 DESCRIPTION OF APPROACH FOR CONDUCTING ASSESSMENT MONITORING

The main feature of the planned approach to groundwater assessment monitoring is the phasing of multiple investigative program elements, such that the scope of each successive phase is refined with information gained in the previous phase(s). The phased approach promotes the most cost-effective use of resources, as well as ensuring that the data obtained from the assessment monitoring program are adequate to support a Corrective Measures Study (CMS).

Three broad phases of activity are planned, the specific activities of which are described in Section 5:

Phase 1 - Definition of the nature and areal extent of contamination in the uppermost aquifer.

Phase 2 - Identification of contamination in the second aquifer (if any), definition of the maximum vertical extent of groundwater contamination, and determination of vertical concentration gradients.

Phase 3 - Identification of preferential pathways for contaminant migration (if any) and migration rates.

A variety of investigatory techniques will be considered for use during the groundwater assessment program. They can be broadly categorized as direct and indirect methods of investigation. The assessment program will be designed primarily around direct methods (i.e., installation of monitor wells, groundwater sampling and analysis, aquifer testing, etc.). Indirect methods of investigation may be used, as appropriate, to characterize groundwater contamination on a preliminary basis, but resulting information will be confirmed by direct means. The methods planned for use in the assessment are outlined in Section 5, and will be re-evaluated for suitability prior to implementation of each phase

of the investigation. Potential direct and indirect methods considered for this assessment are discussed separately below.

4.1 Direct Methods

Groundwater monitoring wells will be installed as necessary to provide sampling data to establish the concentration of hazardous constituents released from the hazardous waste management area, and the rate and extent of their migration. A detailed discussion of monitor well construction requirements is provided in Section 6. The wells will be installed in sufficient numbers to track the plume both horizontally and vertically through the bolson aquifer. It is expected that well installation will occur in multiple phases to completely characterize the plume(s). A detailed discussion of the sampling and analytical procedures is provided in Section 7 of this plan.

Another direct method to be considered for plume definition is sampling seeps and springs. Seeps and springs occur at the Base where the potentiometric surface intersects the land surface and groundwater discharges to surface water.

A soil gas survey will also be considered for approximating the location and extent of the plume(s) if volatile organic compounds are among the detected waste constituents. This technique is also limited to areas with favorable subsurface conditions for sample extraction (i.e., saturated, low permeability sediments strongly interfere with soil gas surveys). Based on the characteristics of the uppermost water-bearing zone in the area of the sewage treatment lagoons, this is not expected to be a limiting factor. A cone penetrometer or Hydropunch™ may also be used as a screening tool to help locate monitor wells. These methods facilitate the collection of groundwater samples from multiple locations without the lengthy process of well installation, development, and sampling. The groundwater samples are field or laboratory analyzed and the results provide a preliminary

indication of plume location and extent of migration. These results facilitate the design of a monitoring system that is well planned and more cost effective.

Aquifer physical properties can be evaluated in-situ using pumping tests, slug injection/withdrawal tests, or a combination of both. These methods will be used to supplement existing information on aquifer properties obtained in previous studies at the site. The results will be used to estimate contaminant migration rates and to evaluate pathways.

4.2 Indirect Methods

A variety of indirect methods will also be considered to identify and characterize contamination in the uppermost aquifer on a preliminary basis. Indirect methods are valuable for delineating the general areal extent of a contaminant plume. This is useful for two reasons:

- Knowing the general outline of the plume before additional monitor wells are installed reduces the need for "speculative" wells; and
- As the plume migrates and its margins change, indirect techniques can be used to track the plume's movement and select new monitor well locations.

Examples of indirect methods include mathematical modeling and geostatistical analysis. These methods are briefly discussed in the following paragraphs.

Mathematical Modeling

Mathematical and/or computer modeling provides information useful for assessment monitoring and in the design of corrective actions. The information may be used

to refine conceptualizations of the groundwater regime, to define likely contaminant pathways, and to design hydrologic corrective actions (i.e., pumping and treating, etc.).

Models use assumptions concerning the physical processes involved and spatial and temporal variations in field data. Therefore, modeling results provide, at best, a qualitative assessment of the extent, nature, and migration of a contaminant plume. Modeling results would not be unduly relied upon in guiding the placement of assessment monitoring wells or in designing corrective actions. Modeling results would be verified with site-specific direct measurements.

Geostatistical Analysis

A geostatistical technique called "Kriging" is useful for determining contaminant concentrations at points where no samples have been collected. Data that have already been collected during the detection monitoring program could be used with this statistical method. Geostatistics would be helpful in determining appropriate well locations and spacings to define the area of contamination with a desired degree of certainty.

5.0 DESCRIPTION OF SAMPLING NUMBERS, LOCATIONS AND DEPTHS

RCRA regulations require that the Groundwater Assessment Monitoring Plan specify the number, locations and depths of wells to be installed as part of the assessment. At this stage of the investigation, however, it is not possible to develop an overly specific monitoring plan because neither the occurrence nor the nature of a release has been determined. Assuming that hazardous waste constituents are detected, this plan outlines the general components of a three-phase approach to groundwater assessment monitoring. The actions taken in each phase of the assessment depend on the results obtained from the previous phase(s). Therefore, it is expected that this plan will be modified or refined as additional information is gathered. Prior to initiation of each major phase of field activity, a detailed sampling and analysis plan will be provided for agency review. The plans for each assessment program phase will include the rationale for proposed deviations from activities described in this section. This plan is written to permit technical flexibility, yet provide necessary guidance for each phase of the assessment program.

As outlined in Section 4, the three broad phases planned for assessment monitoring include:

Phase 1 - Definition of the nature and areal extent of contamination in the uppermost aquifer.

Phase 2 - Identification of contamination in the second aquifer (if any), definition of the maximum vertical extent of groundwater contamination, and determination of vertical concentration gradients.

Phase 3 - Identification of preferential pathways for contaminant migration (if any) and migration rates.

This section identifies and describes the investigatory techniques that will be considered during each phase of the investigation. Because this plan is based primarily on

available detection monitoring (and supporting hydrogeologic) data, it was necessary to make some assumptions regarding the applicability of the proposed methods of investigation. Obviously, the proposed methods can only be used if they are compatible with site-specific conditions as revealed by more detailed results of the assessment monitoring program.

5.1 Phase 1

Phase 1 of the assessment commences if Appendix IX organic constituents are detected, and then confirmed, in the initial short-term sampling program (first determination) outlined in Section 3. The main objectives of the Phase 1 investigation are to define the nature and areal extent of contamination in the uppermost aquifer. As described in Section 1, the uppermost aquifer consists of saturated sands, silts and clays that are hydraulically connected. Discontinuous clays separate the uppermost aquifer from a lower water-bearing sand (second aquifer) of equal or greater grain size. The following section presents the methods proposed to accomplish the Phase 1 objectives.

5.1.1 Data Review

Analytical data from the initial short-term sampling program will be reviewed to determine whether a revised list of analytical requirements is appropriate. The detected analytes will be grouped together by their general chemical properties. Benzene and toluene, for example, are aromatic volatile organic compounds, whereas trichloroethene and carbon tetrachloride are halogenated volatile organic compounds. If only aromatic volatile compounds are detected, it may be appropriate to replace the Appendix IX SW-8240 analysis with EPA Method SW-8020 to provide for determination of the key waste constituents more cost-effectively. The same procedure will be used to identify and evaluate alternative analytical methods for semivolatile organic compounds, pesticides/PCBs, herbicides and the other classes of Appendix IX organic parameters. Following this review, a revised set of analytical requirements will be developed and proposed to EPA and NMED

for the subsequent groundwater assessment program. The revised sampling and analysis requirements will be appropriately documented in a Phase 1 sampling and analysis plan.

A suite of analytes will be selected from the detected constituents to be used as "indicator compounds". The indicator compounds will be the constituents to be used for the mathematical and/or statistical calculations described in Section 5.1.2. The indicator compounds will be selected based on the frequency and concentrations at which they were detected in the 10 detection monitoring wells during the short-term sampling program.

The analytical results will also be reviewed to determine the physical and chemical characteristics of the detected contaminants and the state in which they occur in groundwater. For example, contaminants may occur as an immiscible phase, or as dissolved constituents in an aqueous phase. Density differences (relative to water) may result in stratification of contaminant occurrence and concentrations. Also the possibility of contaminant degradation/transformation products will be considered. These characteristics must be identified and understood to design the appropriate field and analytical investigations.

5.1.2 Phase 1 Indirect Methods

Indirect methods will be used to provide preliminary data to help determine the number, distribution and locations of wells for the Phase 1 investigation. Indirect methods can provide preliminary insight into site characteristics, which in turn facilitates design of a cost-effective monitoring system. However, the following limitations must be considered:

- Indirect methods are only useful if the appropriate site conditions or data set are available; and

- Results from indirect methods require confirmation through direct measurements.

The indirect methods that may be appropriate for the Phase 1 investigation are outlined below.

Mathematical Calculations

Mathematical calculations of solute transport, based on the observed potentiometric surface and other physical measurements, will be used to determine the fate and mobility of groundwater contaminants in the vicinity of the sewage treatment lagoons. These results will be used to estimate the required lateral extent of the monitoring network.

Solute transport calculations will include advective transport and may include other physical processes such as solute decay and sorption/desorption. Much of the necessary data for applying these predictive methods are available. These include multiple sets of synoptic water level data, calculated uppermost aquifer hydraulic properties, detection monitoring analytical data, and standard reference data to characterize contaminant behavior (fate and transport).

Geostatistical Analysis

Geostatistical analysis may be used to predict the appropriate well locations and spacing necessary to define the area of contamination with the desired degree of certainty. Specifically, Kriging is useful for predicting contaminant concentrations at points where no samples have been collected. Appropriate indicator compounds will be selected and used to perform the Kriging analysis.

5.1.3 Phase 1 Direct Methods

The primary method of direct investigation during Phase 1 involves the installation and sampling of groundwater monitoring wells in the uppermost aquifer to define the lateral extent of contamination. However, prior to well installation, a soil gas survey or cone penetrometer/Hydropunch™ study may be used to estimate the areal extent of the plume. A soil gas survey is only useful if volatile organic compounds are among the waste constituents, whereas, groundwater samples collected from a cone penetrometer or Hydropunch™ can be analyzed for any desired constituent. The results of both methods would facilitate the design of a cost-effective monitoring system.

Phase 1 monitor wells will be screened in the uppermost aquifer over the interval(s) where the detected contaminants are anticipated to occur. For example, the aquifer will be screened to intercept the water table or the base of the uppermost aquifer, respectively, if compounds that are "floaters" or "sinkers" are suspected, based on results of the short-term sampling program. The location and spacing of Phase 1 wells will be determined by the indirect methods discussed in the previous subsection. However, at least three wells will be installed for each downgradient well where hazardous waste constituents are detected, and at least 2 new upgradient wells will be installed. Phase 1 monitor well installation and groundwater sampling and analysis will be performed in stages until the lateral extent of contamination in the uppermost aquifer is defined.

The additional Phase 1 monitor wells will be installed, developed and sampled as outlined in Sections 6 and 7. At least one round of groundwater samples will be collected from the new Phase 1 wells and the 10 detection monitoring wells. Analytical requirements for the groundwater samples will be determined as discussed in Section 5.1.1.

Before and after the Phase 1 sampling effort, a synoptic water-level survey will be performed, including the 10 detection monitoring wells, the additional Phase 1 wells, and the piezometers installed during the 1987 Hydrogeologic Investigation.

5.1.4 Phase 1 Reporting Requirements

A Phase 1 Assessment Monitoring Report will be completed to document the results of the Phase 1 investigation. A detailed discussion of new hydrogeologic and analytical data will be provided, and analytical results will be presented as outlined in Section 8 of this plan.

5.2 Phase 2

The objectives of the Phase 2 investigation are: 1) to determine if groundwater contamination exists below the uppermost aquifer; 2) to define the maximum vertical extent of contamination in the uppermost aquifer or in the lower aquifer, if affected; and 3) to determine vertical contaminant concentration gradients. Because of the multiple objectives of the Phase 2 investigation, their accomplishment may require more than one field mobilization.

5.2.1 Phase 2 Data Review

Analytical results from the Phase 1 sampling program will be reviewed to determine if further revisions to the sampling strategy are necessary. As appropriate, the following adjustments may be made:

- Development of a new analytical program;
- Amend indicator compounds to reflect new data; and

- If necessary, based on the characteristics of any newly detected contaminants, modify the investigation design.

5.2.2 Phase 2 Indirect Methods

If adequate supporting data are available, geostatistical analysis, other appropriate statistical analysis and/or mathematical calculations will be used for preliminary determination of locations for Phase 2 monitor wells. An overview and explanation of the purpose of both methods is provided in Section 5.1.2 of this plan.

5.2.3 Phase 2 Direct Methods

As described in Section 1, a discontinuous clay unit separates the uppermost aquifer from the second aquifer. The second aquifer consists of 10 to 30 feet of sand and silt that begins 30 to 40 feet bls. In some of the deeper borings, a stiff clay was encountered below the second sand unit. The first monitor wells installed in the second aquifer will be screened at the top of the second aquifer, immediately below the discontinuous clay unit. If the discontinuous clay unit is not present, the formation will be screened immediately below the screened interval of the closest uppermost aquifer well in the monitoring network. The locations and numbers of wells will be determined based on the results of the Phase 1 investigation. The initial Phase 2 wells will be located within the identified area of the uppermost aquifer plume, so if contaminants have migrated into the second aquifer, they are likely to be present in detectable concentrations. Special precautions, (to include sealing off the uppermost aquifer by grouting a casing into the underlying clay prior to drilling into the second aquifer) will be observed to reduce the potential for accidental cross-contamination during well construction.

If contaminants are detected in the second aquifer, monitor wells will be screened at multiple intervals to profile the vertical distribution of hazardous waste

constituents. Sampling discrete intervals will define the maximum depth of constituent migration and vertical concentration gradients. The number of second aquifer wells will be determined by the thickness of the plume and the vertical variability observed in the geologic conditions. All potential migration pathways will be sampled. Well clusters will be installed to establish vertical concentration gradients of hazardous waste constituents in the plume. The first well in the cluster will be installed at the horizon where contamination was detected and the additional wells should be screened, where appropriate, above or below the initial sampling depth, until the margins of the plume are identified. Sampling intervals will be sufficiently discrete to permit vertical profiling; therefore, the screened intervals will be small (10 feet or less). Several well clusters will be placed on the fringes of the plume identified during Phase 1 to define its vertical margins, and several wells will be placed within the plume to identify contaminant constituents and concentration gradients.

If no contaminants are detected in the second aquifer, additional uppermost aquifer wells may be paired with existing wells and screened over discrete intervals. If the saturated thickness is sufficiently small to be bracketed by the screened intervals of existing assessment monitoring wells, a Kemmerer™ bottle or other point sampler may be used instead to collect discrete depth samples for determination of vertical concentration gradients.

If contaminants are detected in the second aquifer, the well installation procedures outlined in Section 6 will require modification for the Phase 2 wells (i.e., double casing). As more information is obtained about the contaminant characteristics and subsurface geology, the well construction specifications and installation procedures will be updated and documented.

Groundwater sampling will be performed to confirm the extent to which the assessment monitoring network defines the areal and vertical extent of contaminants and migration rates. Groundwater samples will be collected from the new Phase 2 wells, the

Phase 1 wells and the 10 detection monitoring wells. Analytical requirements will be determined as discussed in Section 5.2.1.

Before and after the Phase 2 sampling event, a synoptic water-level survey will be performed to include the 10 detection monitoring wells, the Phase 1 and 2 wells, and the piezometers installed during the 1987 Hydrogeologic Investigation.

5.2.4 Phase 2 Reporting Requirements

A Phase 2 Assessment Monitoring Report will be completed at the conclusion of the Phase 2 investigation. A detailed discussion of new hydrogeologic and analytical data will be provided, as well as presentation and interpretation of analytical results as outlined in Section 8 of this plan.

5.3 Phase 3

The purpose of the Phase 3 investigation is to determine migration rates and preferential pathways (if any) for contaminant migration. Mathematical calculations of solute transport, actual field monitoring and data analysis, and aquifer tests will be used, as appropriate, to determine the fate and transport of groundwater contaminants. However, prior to implementation of the Phase 3 activities, a risk assessment (using all available data) may be conducted to decide if the contaminants identified in Phases 1 and 2 represent a hazard to human health or the environment.

As discussed in the previous sections, mathematical calculations of solute transport, based on the observed potentiometric surface and other physical measurements, can be used to assess the fate and transport of groundwater contaminants. These methods are primarily applicable to the initial phases of the investigation to assist with well placement. However, additional calculations will be performed using data generated in the

Phase 1, 2, and 3 investigations. The results will be used to verify the adequacy of the existing monitoring network for defining all migration pathways.

Migration rates will be further defined by monitoring the concentrations of contaminants in groundwater over a period of time in monitor wells that are aligned in the direction of flow. Aligned wells that are installed at the edge of the plume and at the interior of the plume will provide an estimate of the rate of migration, both of the contaminant front and of the individual constituents within the plume.

Aquifer tests will be performed as necessary to supplement existing information on the physical properties of the uppermost aquifer, and additional data will be collected to determine the hydraulic properties of the lower aquifer. At a minimum, slug injection/withdrawal tests will be performed as outlined in Section 9. Also aquifer tests will be performed to determine the physical properties of the upper and lower aquifers and to determine the hydraulic relationship between the aquifers. The aquifer test results will be analyzed and reviewed as outlined in Section 9.

A Phase 3 Assessment Monitoring Report will be completed at the conclusion of the Phase 3 investigation. A detailed discussion of new hydrogeologic and analytical data will be provided, as well as a presentation and interpretation of analytical results as outlined in Section 8 of this plan. Recommendations for additional groundwater assessment activities will also be included.

6.0 MONITOR WELL INSTALLATION PLAN

This section contains well construction information pertaining to the installation of additional monitor wells for the assessment monitoring program at Holloman AFB. The monitor wells will be drilled in a manner similar to the existing wells installed for the detection monitoring system. Specifications for well construction are consistent with the requirements of RCRA (EPA, 1986).

6.1 Drilling Techniques

A hollow-stem auger drill rig will be used to install additional assessment monitoring wells for the Phase 1 investigation. This method has proven satisfactory for site conditions in the past, and especially because the rig operates without the use of potentially contaminating drilling fluids (water or foam). The drill rig was also easy to maneuver during past projects, even during wet weather.

Other drilling methods such as air or wet rotary can be used for deeper wells that may be necessary in Phases 2 and 3. If alternative drilling techniques are required, the rationale will be appropriately documented.

6.1.1 Borehole Drilling

Soil core samples will be collected continuously to the total depth of each boring. A supervising geologist will log the borehole during drilling operations. All borehole lithologic descriptions will be recorded on a lithologic log form similar to the one shown in Figure 6-1. The following information will be included on the boring log:

- Reference elevation for all depth measurements;
- Depth of each change of stratum;

	WELL ID: DATE: / /91
PROJECT: HOLLOMAN AFB	LOCATION: TOTAL DEPTH:
	ELEVATION: SURFACE:
	DRILLING PROCEDURE:
GEOLOGIST:	BOREHOLE DIAMETER:
DRILLER:	HNu BACKGROUND:

WELL LOG	GRAPHIC LOG	SAMPLE ZONE	SAMPLE BLOWS	SAMPLE DEPTH (FEET)	DESCRIPTION	REMARKS	HNu
R SC GR							

R RISER SC SURFACE CASING GR GROUT (CEMENT-BENT.), __ GAL. WATER, _-94 LB. SACKS CEMENT, __ LBS. BENTONITE, TREMIE B BENTONITE, _____ BUCKET, TREMIE SCR SCREEN, INCH FP FILTER PACK, SAND, __-100 LB. SACKS, TREMIE	SAMPLE TYPE SHELBY TUBE SPLIT SPOON G GRAB	SURFACE PROTECTION PROTECTIVE CASING WITH LOCKING COVER; 3'x3'x4" CONCRETE PAD; 3 PROTECTIVE STEEL POSTS.	D1644A
DEVELOPED:		WATER LEVEL:	

Figure 6-1. Typical Borehole Logging and Monitor Well Completion Form

- Thickness of each stratum;
- Identification of the material of which each stratum is composed according to the Unified Soil Classification System, or standard rock nomenclature, as necessary;
- Depth interval from which each formation sample was taken; and
- Depth at which groundwater is first encountered.

Boreholes will be drilled using a hollow-stem auger rig. For 2-inch diameter wells, augers will have at least an 8-inch outside diameter (O.D.) and a 3.75-inch inside diameter (I.D.). Soil cuttings produced during the drilling activities will be disposed of as required by the Base Environmental Coordinator. When the borehole reaches total depth, as determined by the supervising geologist, it will be completed as a monitor well as described in the following section.

6.1.2 Decontamination

The augers, drill rig, downhole samplers, and drill rods will be steam cleaned at a pre-designated location. Decontamination will be conducted prior to beginning the work and following completion of each well.

6.2 Monitor Well Construction

This section outlines monitor well construction specifications for the Phase 1 investigation. The specifications for monitor wells in subsequent phases, however, may require modifications. Phases 2 and 3, for example, may require pump test wells, nested wells, and/or deep wells, each of which require unique construction specifications. As appropriate, modifications for well construction specifications will be documented.

6.2.1 Screen and Casing

Since the sand units in the area of the sewage treatment lagoons are quite thin (ranging from 7 to 20 feet thick and averaging approximately 10 feet thick) 5- or 10-foot screens are proposed to intercept thin units of interest and detect contaminants concentrated within each unit. The shorter well screens will permit individual sand intervals of interest to be monitored separately. A general schematic illustrating typical monitor well construction is presented in Figure 6-2.

After the supervising geologist determines the total depth of the well, the screen and casing will be set directly into the borehole or through the hollow-stem augers, depending on the stability of the subsurface materials. The casing will extend from the top of the screen to approximately 2 to 3 feet above the ground surface.

The well screen and casing will consist of 2-inch diameter PVC or 316 stainless steel. Due to the documented high salinity of groundwater in this area, PVC is the preferred well construction material. However, in areas of lower salinity groundwater where PVC is not justified, wells will be constructed of stainless steel. The screen will be machine preslotted or wrapped, with a sealed end cap. The slot size will be 0.010-inch, which is compatible with the typical formation grain size range in the aquifer, and with the selected sand pack size. All joints between the screen and casing, and separate casing sections, will be tightly connected with flush-joint threaded couplings. No glues, lead shot, or lead wool will be used on any part of the screen or casing. Centralizers will be used at the discretion of the on-site geologist.

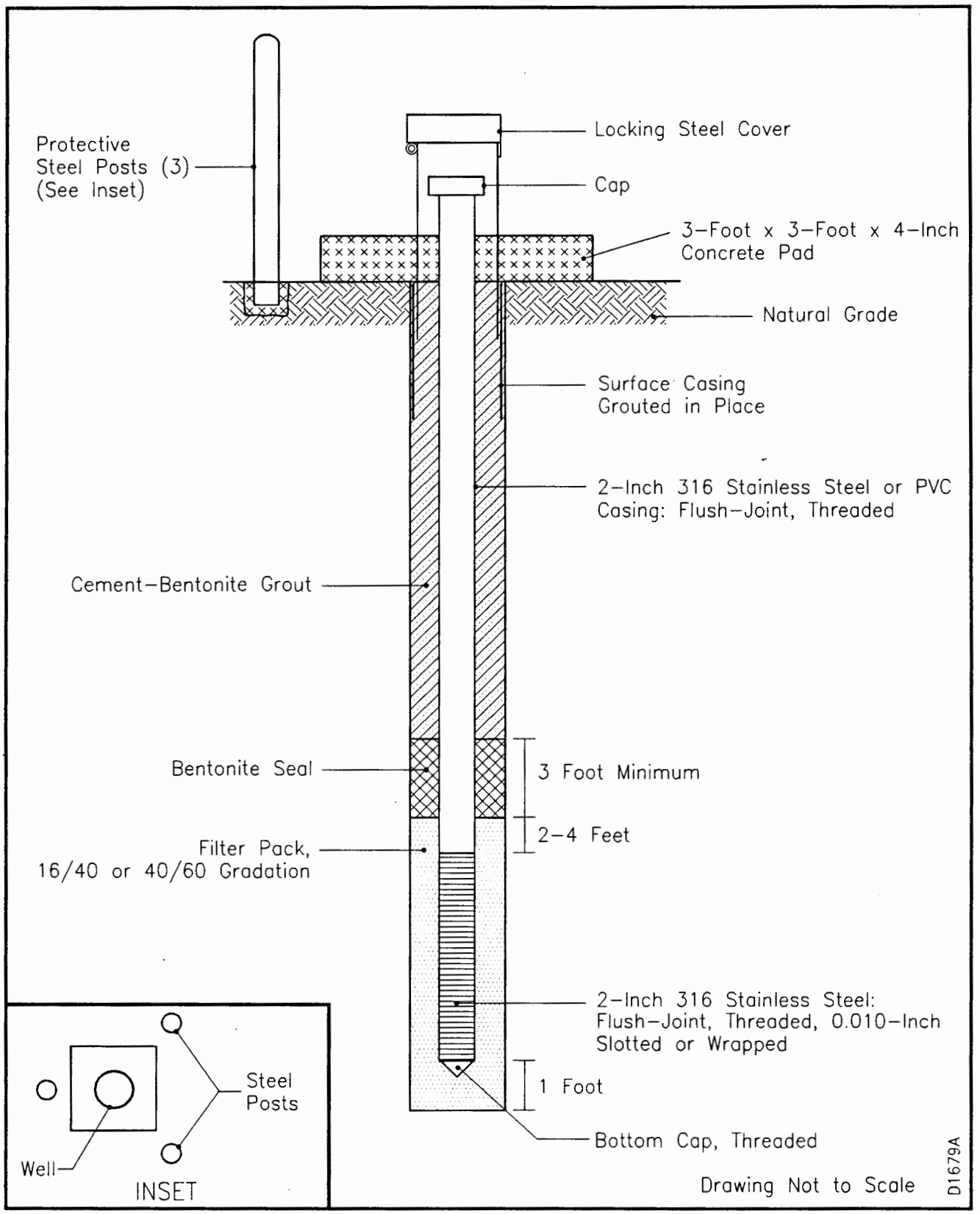


Figure 6-2. Typical Monitor Well Construction

6.2.2 Sand Pack

The sand/gravel filter pack will consist of clean, bagged silica (Colorado Silica) sand of fine enough mesh size (16/40 or 40/60 gradation) to prevent siltation of the well. Sand will be placed from the bottom of the boring to approximately 2 feet above the top of the screen.

Sand will either be poured directly down the annulus between the screen and borehole (or hollow-stem augers) or poured through a tremie pipe. The top of the casing string will be plugged during this operation to prevent sand from entering the well. After a calculated volume of sand (sufficient to bring the sand pack near the top of the screen) has been poured down the hole, the sand pack will be tamped and measured with a weighted tape. By sounding the level of the sand in the hole, the height of sand above the top of the screen can be accurately determined. Sounding the sand pack level with a measuring tape will detect any potential bridging that might occur.

6.2.3 Bentonite Seal and Grout

A bentonite seal (minimum 3 foot thickness) will be emplaced on top of the sand pack. The bentonite seal will consist of either a granular bentonite/water slurry or bentonite pellets which will be poured directly into the annular space between the well casing and borehole, unless the bentonite bridges inside the well. If this situation occurs, the bentonite will be emplaced in the hole through a tremie pipe. However, experience has shown that typically the sediments are tight, permitting the borehole to remain open and resulting in minimal well construction difficulties. The bentonite will be sounded with a weighted tape. If the bentonite seal consists of pellets, it will be hydrated before grouting.

A cement grout mix will be placed in the hole from the top of the bentonite seal to the ground surface. The cement grout will consist of a mixture of Type 1 Portland

cement (ASTM-C 150) and water. The mix will not exceed 7 1/2 gallons of clean water per bag of cement (94 lbs.). The grout mix will contain up to 3 percent bentonite powder by weight. The grout will be pumped under pressure through a tremie pipe to ensure positive placement of the grout. The pumping will continue until grout reaches land surface, at which time the tremie pipe will be removed.

6.2.4 Well Protection

If a well is temporarily left uncompleted, it will be protected with a heavy metal cover to avoid contamination of down-hole water and sediments. For permanent well completion, approximately 2 to 3 feet of stainless steel well casing will be left above ground. A screw-joint cap will be placed on the top of the casing stick-up. To protect the casing stick-up against vandalism or vehicles, a 5-foot protective steel casing will be slipped over the well stick-up and anchored 2 to 3 feet into the grout (before it sets) so that the protective steel casing will extend 2 to 3 feet above land surface. The steel casing will have a locking cap and lock. A 3-foot by 3-foot by 4-inch concrete pad will be poured into a form around the protective steel casing. The surface of the concrete pad will be sloped away from the well casing. Three 3-inch diameter steel posts will be placed radially around the well and set into concrete. The posts will extend approximately 3 feet above the concrete pad and will be painted. The ground surface around the well will be sloped away from the casing. The well number will be set using a die set on the outside of the protective casing and on the well cover.

6.2.5 Well Construction Logs

The supervising geologist will prepare a log documenting all well construction activities. Well construction and completion logs, similar to the example shown in Figure 6-1, will be used. The following information will be included in the well completion log:

- Total depth of completed well;
- Nominal diameter of boring;
- Depth of any grouting or sealing;
- Amount, type, and manufacturer of all materials used in well construction;
- Depth and type of well casing;
- Description (to include length, location, diameter, slot sizes, material, and manufacturer) of well screen;
- Method of well development;
- Static water level upon completion of the well and after development;
- Drilling date or dates; and
- Construction details of monitoring well as installed.

6.3 Well Development

Monitor wells will be developed by bailing and surging using pumps, bailers, surge blocks or a combination of these methods. Well development will proceed no sooner than 48 hours after well completion. Development will continue for a minimum of 4 hours, or until groundwater is free from sand and drill cuttings. Field measurements (pH, temperature, and specific conductance) will be made, as appropriate. Development water will be disposed of as directed by the Base Environmental Coordinator. A photographic slide will be taken of the development water and will be sufficiently back-lit to observe the clarity of the water after the well is developed. The well depth will be rechecked before and after development to ensure that all sand and fines have been removed from the well. Well development information will be maintained as part of the record-keeping process, and will be recorded onto a form similar to the one shown in Figure 6-3. Volumes of water purged

GROUND WATER DEVELOPMENT RECORD

Well ID _____
Time/Date Start Development _____
Installation ID _____
Project _____
Initial/Final Groundwater Depth _____/_____ (FT) Below Measuring Point
Initial/Final Depth to Bottom of Well _____/_____(FT) Below Measuring Point
Time/Date Finish Development _____
Logger Code _____
Type, Size/Capacitiy of Pump or Bailer _____
Total Volume to Purge for 3/5 (circle one) Well Volumes _____ Gallons
Actual Purged Volume _____ Gallons

Time	Cumulative Volume (gallons)	Clarity/Color	pH	Specific Conductivity (µmhos)	Temp °C	Comments

Figure 6-3. Groundwater Development Record

during development activities will be calculated. All other testing methods and results compiled during field activities will be recorded in a project notebook.

6.4 Surveying

At the completion of drilling operations, a State of New Mexico licensed and registered surveyor will determine the vertical and horizontal position of the newly installed wells. Elevations for the wells will be referenced to the 1929 National Geodetic Vertical Datum and will be referenced to the State Plane Coordinate System. Elevation and survey requirements are as follows:

- The top of ground elevation to the nearest 0.1 foot;
- The top of the well casing elevation to the nearest 0.01 foot;
- Survey points taken on the top of the well casing will be notched for future reference; and
- Horizontal coordinates to the nearest 1.0 foot.

Wells and survey control monuments will be located on a plan map of suitable scale to accurately plot these locations.

7.0 SAMPLING AND ANALYSIS PROCEDURES

This section outlines the sampling and analytical procedures that will be used for groundwater assessment monitoring at the sewage treatment lagoons. A detailed discussion of the sampling and field QA/QC procedures is not provided because the same procedures used for the detection monitoring program will also be used for the assessment monitoring program. A description of those sampling procedures is provided in the A-E Quality Control Plan and Sampling Plan (A-E QCP\SP) for Groundwater Study and Monitoring Program, Holloman Air Force Base, New Mexico (Radian, 1989) (12).

The proposed analytical program, however, has been modified for the groundwater assessment monitoring program. Section 7.1 identifies the analytical requirements for the initial phase of the assessment monitoring program and describes why these parameters are suitable for determining the presence and concentration of contaminants potentially migrating from the sewage treatment lagoons. At this stage of the assessment, analysis of a wide range of parameters is appropriate to characterize constituents migrating from the sewage treatment lagoons. As key contaminants are identified, it may be appropriate to reduce the scope of the analytical program by focussing on waste-specific indicator compounds associated with the sewage treatment lagoons.

7.1 Justification of Analytical Program

The sewage treatment lagoon system was listed by the USEPA Region VI as a hazardous waste management unit because wastewater potentially containing hazardous constituents from various Base operations was discharged to the system on several occasions. After several investigations of the sludge and underlying soil in Ponds A, B, and C, and surface water in all lagoons, a comprehensive list has been developed of constituents known to be present in the sewage treatment lagoons. Table 7-1 lists the organic constituents

Table 7-1

Organic Constituents Detected in Soil or Sludge Samples Collected from Ponds A, B, and C

EPA Method 8240 - Volatile Organics

Acetone
1-Butanone
Carbon Disulfide
Methylene Chloride
Total Xylenes
1,1,2-Trichloroethane

EPA Method 8150 - Chlorinated Herbicides

2,4 D
2,4,5 T
Dichloroprop

EPA Method 8080 - Pesticides/PCBs

4,4'-DDD
4,4'-DDE
Endosulfan I
PCB-1254
PCB-1260

EPA Method 8270 - Semivolatile Organics

Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Bis(2-ethylhexyl)phthalate
Chrysene
p-Cresol
Dibenzofuran
Di-n-butyl phthalate
Di-n-ocytyl phthalate
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Isophoro
2-Methylnaphthalene
Phenanthrene
Phenol
Pyrene

detected in soil and sludge samples (13,14,15,16). Table 7-2 lists the organic constituents detected in surface water samples (13,17). The elevated levels of TOC measured during the detection monitoring program may be related, in whole or in part, to the organic hazardous waste constituents detected in the sewage treatment lagoons. The EPA Primary Drinking Water Standards for inorganic constituents were not detected at levels statistically above background in downgradient wells during the detection monitoring program. Therefore, Appendix IX inorganic constituents will not be analyzed for in the assessment monitoring program.

Appendix IX organic analytes were selected to determine if the elevated levels of TOC in the groundwater are related to any release of organic constituents from the sewage treatment lagoons for the following reasons:

- Elevated TOC levels measured in the downgradient wells may be related specifically to organic constituents in the groundwater;
- Appendix IX organic parameters include the constituents known to be present in the sludge, soil, and surface water of the sewage treatment lagoons; and
- Appendix IX organic parameters include constituents that may have been discharged to the sewage treatment lagoons.

In addition to the Appendix IX organic parameters, a sample will be collected and analyzed for TOC from each of the wells in the assessment monitoring network. The TOC results will be compared to the results of the Appendix IX organic parameters and to the previous TOC results that triggered the requirement for groundwater assessment monitoring.

Table 7-2

Organic Constituents Detected in Surface Water Samples Collected From the Sewage Treatment Lagoons

EPA Method 8270 - Semivolatile Organics	EPA Method 8080 - Pesticides/PCBs
Benzoic acid	Alpha-BHC
Bis(2-ethylhexyl)phthalate	Beta-BHC
Butyl benzyl phthalate	Chlordane
Diethyl phthalate	Endrin ketone
Di-n-butyl phthalate	Gamma-BHC/Lindane
Phenol	Methoxychlor
	4,4'-DDE

7.2 Analytical Methods and Procedures for Appendix IX Parameters and TOC

The specific methods to be used for groundwater analysis of Appendix IX parameters are identified in Section 7.2.1. Corresponding method detection limits are discussed in Section 7.2.2. Analytical methods are described in more detail in Section 7.2.3. Analytical quality control procedures, such as the analysis of spiked samples, are described in Section 7.2.4.

7.2.1 Identification of Analytical Methods

All parameters will be determined according to methods published in Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846 (U.S. EPA, Office of Solid Waste and Emergency Response, November 1986, third edition) (18). Methods for sample preparation and analysis are listed in Table 7-3.

7.2.2 Method Detection Limits

In SW-846, the method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. MDLs depend on the sample matrix, as well as on instrument capability. MDLs for the analytical parameters and methods identified in Section 7.2.1 are presented in Appendix A. The groundwater samples to be analyzed are expected to contain high concentrations of chloride. Total filterable residue (total dissolved solids) is expected to be approximately 20,000 mg/L.

Table 7-3

Methods for Groundwater Sample Preparation and Analysis for Determination of Appendix IX Organic Compounds and Total Organic Carbon

	Preparation		Analysis	
Parameter	Technique	Reference	Technique	Reference
Volatile Organic Compounds	Purge and Trap	SW-846:5030	GC/MS	SW-846:8240
Halogenated Voltaile Organics	Purge and Trap	SW-846:5030	GC/HSD	SW-846:8010
Semivolatile Organic Compounds (acid and base/neutral fractions)	Solvent Extraction	SW-846:3520	GC/MS	SW-846:8270
Organochlorine Pesticides and PCBs	Solvent Extraction	SW-846:3510 or 3520	GC/ECD	SW-846:8080
Organophosphorus Pesticides	Solvent Extraction	SW-846:3510 or 3520	GC/FPD	SW-846:8140
Chlorinated Herbicides	Solvent Extraction	SW-846:8150	GC/ECD	SW-846:8150
Polychlorinated Dioxins and Furans	Matrix-Specific Extraction	SW-846:8280	HRGC/LRMS	SW-846:8280
Total Cyanide	N/A	N/A	Colorimetric	SW-846:9012
Total Sulfide	N/A	N/A	Titrametric	SW-846:9030
Total Organic Carbon	Combustion or Oxidation	SW-846:9060	Infrared or FID	SW-846:9060

LEGEND:

SW-846	Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, November 1986, Third Edition.
GC/MS	Gas chromatography/mass spectrometry.
GC/HSD	Gas chromatography/halogen specific detector.
GC/ECD	Gas chromatography/electron capture detection.
HRGC/LRMS	High-resolution capillary column gas chromatography/low resolution mass spectrometry.
GC/FPD	Gas chromatography/flame photometric detection.
GC/FID	Gas chromatography/flame ionization detection.
N/A	Not applicable.

7.2.3 Description of Analytical Methods

The analytical methods identified in Section 7.2.1 are described in more detail in the following paragraphs. In this section, a description is given for the method referenced in Table 7-3. The methods include procedures for instrument operation and interference identification.

7.2.3.1 Volatile Organics - Method 8240

Samples for volatile organics are analyzed by scanning gas chromatography/ mass spectrometry (GC/MS) following SW-846 Method 8240, 3rd ed. Samples are introduced following the purge and trap technique described in Method 5030. Analyte identification and quantification is performed using response factors and retention times generated from a five point calibration curve, relative to the closest eluting of three internal standards. The three internal standards are:

- Bromochloromethane;
- 1,4-Difluorobenzene; and
- Chlorobenzene-d_5.

7.2.3.2 Halogenated Volatile Organics - Method 8010

Samples for halogenated volatile organics are analyzed by gas chromatography (GC) following SW-846, Method 8010, 3rd ed. Samples are introduced following the purge and trap technique described in Method 5030. Detection is by halogen specific detector (HSD). Any compounds tentatively identified in the primary analysis are confirmed on a second GC column.

7.2.3.3 Semivolatile Organics - Method 8270

Semivolatile extracts are analyzed by high resolution GC/MS following SW-846 Method 8270, 3rd ed. All samples are prepared following extraction procedures outlined in Method 3520. Identification and quantitation is performed using response factors and retention times generated from a five point calibration curve, relative to the closest eluting of six internal standards. The six internal standards are:

- Dichlorobenzene-d_4;
- Naphthalene-d_8;
- Acenaphthene-d_{10};
- Phenanthrene-d_{10};
- Chrysene-d_{12}; and
- Perylene-d_{12}.

7.2.3.4 Organochlorine Pesticides and PCBs - Method 8080

Samples for organochlorine pesticides and PCBs are analyzed by GC following SW-846, Method 8080, 3rd ed. Prior to the use of this method, samples are extracted following procedures outlined in Method 3510 or 3520. Both neat and diluted liquids are analyzed by direct injection. A 2- to 5-uL sample is injected into a gas chromatograph (GC), and compounds in the effluent are detected by an electron capture detector (ECD). Any compounds tentatively identified in the primary analysis are confirmed on a second GC column.

7.2.3.5 Organophosphorus Pesticides - Method 8140

Method 8140 is a gas chromatographic (GC) method used to determine the concentration of various organophosphorus pesticides. Prior to analysis, sample extraction is performed according to Method 3510 or 3520. Both neat and diluted organic liquids are analyzed by direct injection. A 2- to 5-uL aliquot of the extract is injected into a gas chromatograph, and compounds in the GC effluent are detected with a flame photometric detector (FPD). Any compounds tentatively identified in the primary analysis are confirmed on a second GC column.

7.2.3.6 Chlorinated Herbicides - Method 8150

Method 8150 is a GC method for determining certain chlorinated acid herbicides. Spiked samples are used to verify the applicability of the chosen extraction technique to each new sample type. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivatizing agent. After excess reagent is removed, the esters are determined by gas chromatography employing an ECD. The results are reported as the acid equivalents. Any compounds tentatively identified in the primary analysis are confirmed on a second GC column.

7.2.3.7 Polychlorinated Dioxins and Furans - Method 8280

Polychlorinated dioxins and furans (PCDDs/PCDFs) are analyzed according to the procedures outlined in Method 8280, SW-846, 3rd ed. Mass calibration of the instrument is performed daily with PFTBA and verified using DFTPP ion abundance criteria for mass 198 and greater. Adherence to Method 8280 criteria for isotopic ratio measurements for PCDDs and PCDFs is then verified.

7.2.3.8 Purge and Trap Method - Method 5030

Method 5030 is used to determine the concentration of volatile organic compounds in a variety of liquid and solid waste matrices. It is based on a purge and trap GC procedure. The method is applicable to nearly all types of samples. The success of this method depends on the level of interferences in the sample; results may vary due to the large variability and complexity of matrices of solid wastes samples.

For lower concentrations, an inert gas is bubbled through the groundwater sample at ambient temperature to transfer the volatile components to the vapor phase. The vapor is swept through a sorbent column where the volatile components are trapped. After purging is completed, the sorbent column is heated and backflushed with inert gas to desorb the components onto a GC column. Samples containing higher concentrations of volatile components will be diluted with methanol prior to purging.

7.2.3.9 Separatory Extraction - Method 3510

Method 3510 is designed to quantitatively extract nonvolatile and semivolatile organic compounds from liquid samples using standard separatory funnel techniques. The sample and extracting solvent must be immiscible in order to yield recovery of target compounds. Subsequent cleanup and detection methods are described in the organic analytical method that will be used to analyze the extract.

Samples are adjusted to a specified extraction pH and extracted with the appropriate solvent. Methylene chloride will be employed when a solvent is not specified. Samples are extracted three times, and the combined extracts are dried with anhydrous sodium sulfate and concentrated.

7.2.3.10 Continuous Extraction - Method 3520

Method 3520 is designed to quantitatively extract nonpurgeable organic compounds from liquid samples using a continuous extraction apparatus. The method minimizes emulsion formation, and thus improves recovery of target compounds. The sample and extracting solvent must be immiscible in order to yield recovery of target compounds. Subsequent cleanup methods and detection limits are described in the analytical methods. The method is designed for extraction solvents with greater density than the sample, although continuous extraction devices are available for extraction solvents that are less dense than the sample. The analyst must demonstrate the effectiveness of any such automatic extraction device before employing it in sample extraction.

Each sample is placed into a continuous extraction apparatus, adjusted to the specified extraction pH, and extracted with the appropriate solvent. Methylene chloride will be employed when a solvent is not specified. The extraction pH and solvent to be used are listed in the quantification method. Samples are extracted for 18 hours; the extract is collected, dried with anhydrous sodium sulfate, and concentrated. In some cases, the sample pH is adjusted after the first extraction, and continuous extraction is carried out for an additional 18 hours to recover another class of compounds.

7.2.3.11 Total Cyanide - Method 9012

Method 9012 uses colorimetry to detect cyanide in a sample matrix. The cyanide, as hydrocyanic acid (HCN), is released by refluxing the sample with strong acid, followed by distillation of the HCN into an absorber-scrubber containing sodium hydroxide. The cyanide ion in the absorbing solution is then determined by automated UV colorimetry.

7.2.3.12 Total Sulfide - Method 9030

Method 9030 is a titrametric method for determining sulfide in a sample. Excess iodine is added to a sample which has been treated with zinc acetate to produce zinc sulfide. The iodine oxidizes the sulfide to sulfur under acidic conditions. Excess iodine is back titrated with sodium thiosulfate or phenylarsine oxide to a starch end-point.

7.2.3.13 TOC Analysis - Method 9060

Method 9060 uses a carbonaceous analyzer to measure organic carbon. This instrument converts the organic carbon in a sample to carbon dioxide by either catalytic combustion or wet chemical oxidation. The carbon dioxide formed is then either measured directly by an infrared detector or converted to methane and measured by an FID. The amount of carbon dioxide or methane in a sample is directly proportional to the concentration of carbonaceous material in the sample. This method is most applicable to measurement of organic carbon above 1 mg/L.

7.2.4 Quality Control Procedures

A quality control (QC) program will be used to ensure that data quality objectives are met. Quality control efforts are twofold. First, they will provide the mechanism for ongoing control and evaluation of measurement data quality throughout the course of the project (i.e., system capability). Second, they will specify quality control data to be used to define natural-matrix data quality for various measurement parameters, in terms of precision and accuracy. Control of measurement data quality (i.e., control of error sources that affect data quality) is possible for sample collection and analysis. However, matrix interference, or non-homogeneity, is not amenable to control and thus imprecision or bias due to these natural sources of error must be estimated from QC samples. Sample collection error will be controlled through the use of standard sample collection methods

and field logbooks. Sample analysis error will be controlled through the use of standard analytical methods and SOPs, performed on a capable analytical system, with QC efforts as directed in the respective methods. Natural matrix error will be estimated by standard QC methods such as matrix spikes, field duplicates, and field and trip blanks.

Quality control procedures to control the analytical system will include the following:

- Analysis of method blanks;
- Calibration checks;
- Analysis of surrogate standards; and
- Analysis of standard reference materials.

The following procedures will be used to estimate precision and accuracy of the methods used for the groundwater matrix being analyzed:

- Duplicate analysis sample; and
- Analysis of samples spiked with a known amount of analyte.

8.0 PROCEDURES FOR EVALUATING ASSESSMENT MONITORING DATA

This section outlines the procedures for evaluating assessment monitoring data. These procedures are intended to determine the rate of migration, extent, and composition of hazardous constituents of the plume. Initially, a descriptive approach to data analysis will be used to broadly delineate the extent of contamination. Statistical comparisons of assessment monitoring data among wells and/or over time will be used as waste-specific analytical results are generated to provide a clear determination of the rate of migration, areal and vertical extent, and chemical complexity.

Listed below are specific evaluation and reporting procedures that are recommended in the RCRA TEGD (EPA, 1986) for recording and evaluating assessment monitoring data. These procedures are used to structure, analyze, simplify, and present the groundwater monitoring data in a readily useable format. Data evaluation and reporting procedures include:

- Listing data;
- Summary statistics tables;
- Data simplification; and
- Plotting data.

Detailed descriptions of the recommended reporting procedures are outlined in the RCRA TEGD (EPA, 1986). These descriptions will be used, as appropriate, to guide the selection of presentation formats used for data obtained in each phase of the assessment monitoring program.

Numerous database software packages are available that are capable of meeting the objectives for data handling outlined by EPA. The Paradox™ relational

database software is proposed to accomplish data listing, data simplication activities, and generation of summary statistics tables.

Graphic displays of data may be presented in either a two-dimensional or three-dimensional format, as appropriate, to convey the information desired. Auto-CAD™ and CPS™ are proposed for generating figures, maps, contour plots, etc.

On a preliminary basis, contaminant pathways and migration rates will be evaluated by identifying changes in the concentrations and distribution of detection monitoring analytes and other pertinent groundwater quality data. As hazardous waste-specific analytical results are obtained in the assessment monitoring program, groundwater flow and contaminant transport models will be used to more definitively evaluate contaminant migration rates and extent. Models will be selected for use based on the detected hazardous waste constituents, their predicted fate within the site-specific hydrogeologic setting, and whether they occur in the dissolved and/or immiscible phase.

9.0 RATE OF MIGRATION

As indicated in Section 8, preliminary estimates of contaminant migration rates can be made using historical analytical results, as well as previously calculated aquifer parameters. Calculated groundwater flow rates can be used as a first approximation of contaminant migration rates. However, depending on the physiochemical behavior of the detected contaminants, factors such as dispersion, retardation, and degradation/-transformation processes can result in significantly higher or lower actual transport rates. Both mathematical calculations of solute transport and actual field monitoring and data analysis will be used, as appropriate, to determine the main fate and transport mechanisms influencing the migration of groundwater contaminants from the sewage treatment lagoons. These results will help identify appropriate additional monitor well locations, as required.

Mathematical calculations of solute transport, based on the observed potentiometric surface and other physical measurements, will be used initially to determine the fate of groundwater contaminants in the vicinity of the sewage treatment lagoons. Solute transport calculations will include advective transport, and may include other physical processes such as decay and sorption/desorption. Much of the necessary data for applying these predictive methods are available. These include synoptic water level data to define flow directions and gradients, aquifer test results to define hydraulic properties, chemical analytical results to define contaminant source strengths, and standard reference data to define chemical and physical properties. These calculations can be used to predict the extent of the plume migration.

As the assessment monitoring program progresses, migration rates will be further defined by comparing the concentrations of groundwater contaminants over a period of time in monitoring wells that are aligned in the direction of flow. Using wells that are installed both on the edge of the plume and in the interior of the plume, subsequent evaluation of the monitoring data will provide an estimate of the rate of migration, both of

the contaminant front and of the individual indicator chemical analytes within the plume. Field measurements will be used to verify predicted differential transport rates resulting from dispersion due to diffusion and mechanical mixing; retardation due to adsorption and electrostatic interactions; and contaminant transformation due to physical, chemical, and/or biological processes.

No immiscible contaminant layers were evident during detection monitoring or in earlier site hydrogeologic characterization studies. However, if an immiscible layer(s) is identified during the assessment monitoring program, its site-specific migration behavior will be determined. Monitoring and analysis will be specifically designed for the physical and chemical properties of light phase, multiphase, or dense phase immiscible contaminants, as appropriate.

Aquifer tests will be performed as necessary to supplement existing information on site-specific physical properties of the uppermost aquifer. Insufficient data are available regarding the hydraulic properties of the second aquifer. At a minimum, slug injection/withdrawal tests will be performed on all wells completed in the second aquifer. Aquifer response data will be evaluated using the method of Bouwer and Rice (1989) or other accepted techniques. Recognizing that slug test results are of limited value (i.e., reflect conditions only in the area immediately surrounding the test well, including any potential interference due to the sand pack), at least one aquifer pumping test of the second aquifer will be performed if any contaminants are detected in the second aquifer. During the drawdown and recovery phases of the pump test, water level responses will be monitored in observation wells completed in both the uppermost and second aquifer. Resulting data will be analyzed to assess the degree of hydraulic connection between the two aquifers, and the hydraulic properties of the second aquifer, respectively.

10.0 SCHEDULE

A detailed schedule for implementation of the RCRA Groundwater Assessment Monitoring Program described in Section 5 is provided by phased activities/project milestones in Table 10-1. The estimated duration of the basic program is 20 months. However, as is acknowledged by EPA (RCRA TEGD, 1986), estimating the duration of program phases beyond the initial (Phase 1) effort cannot be done with a high degree of certainty because the scope of each subsequent phase is dependent on the results of the preceding phase(s). A reasonable level of effort was assumed to accomplish the objectives of each individual phase. However, it is possible that additional stages of activity within certain phases will be required to characterize the plume extent and migration rates/pathways adequately to support corrective action. Other assumptions used to estimate the program schedule are:

- Four week laboratory turn-around;
- Four week regulatory review cycles; and
- No contingency included for adverse weather conditions or other unavoidable delays.

Table 10-1

Proposed Schedule for Implementation of RCRA Groundwater Assessment Monitoring Program, Sewage Treatment Lagoons, Holloman AFB, New Mexico

Activity/Milestone	Weeks After Plan Approval
First determination (false positive) sampling (Appendix IX)	2
Receive analytical results	6
Validate analytical results	7
Verification sampling	9
Receive/validate resampling results	14
Prepare/submit groundwater quality report	16
Report review/approval by EPA/NMED	20
Phase 1:	
Review and modify scope (if necessary); submit Phase 1 sampling and analysis plan for agency review/approval	22
Mobilization	26
Implementation of field program (uppermost aquifer monitor well installation - assume 30 maximum; development/groundwater sampling - assume 40 maximum)	34
Receive/validate analytical results (indicator compounds)	39
Prepare/submit Phase 1 report	42
Report review/approval by EPA/NMED	46
Phase 2:	
Prepare/submit detailed Phase 2 sampling and anlaysis plan for agency review/approval	48

(Continued)

Table 10-1

(Continued)

Activity/Milestone	Weeks After Plan Approval
Mobilization	52
Implementation of field program (installation of cluster wells - assume 10 maximum; development/groundwater sampling - assume 50 maximum)	56
Receive/validate analytical results (indicator compounds)	61
Prepare/submit Phase 2 report	64
Report review/approval by EPA/NMED	68
Phase 3:	
Prepare/submit detailed Phase 3 sampling and analysis plan for agency review/approval	70
Mobilization	74
Implementation of field program (construction of pumping wells - assume 3 maximum; perform pump tests and slug tests - assume 10 maximum)	76
Analyze aquifer test data	77
Prepare/submit Phase 3 report and recommendations for additional activities (i.e., monitoring program to determine seasonal groundwater quality variations, other characterization activities to support corrective action)	80

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APPENDIX A

Method Detection Limits for Appendix IX Analytical Parameters

Analytical Methods, Requested Detection Limits, and Maximum Contaminant Levels

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
VOLATILE ORGANICS					
Acetone	GC/MS	SW-846:8240	100 µg/L	–	–
Acetonitrile	GC/MS	SW-846:8240	100 µg/L	–	–
Acrolein	GC/MS	SW-846:8240	75 µg/L	–	–
Acrylonitrile	GC/MS	SW-846:8240	50 µg/L	–	–
Benzene	GC/MS	SW-846:8240	5 µg/L	5	0.01
Bromodichloromethane	GC/MS	SW-846:8240	5 µg/L	–	–
Bromoform	GC/MS	SW-846:8240	5 µg/L	–	–
Bromomethane	GC/MS	SW-846:8240	10 µg/L	–	–
Carbon disulfide	GC/MS	SW-846:8240	5 µg/L	–	–
Carbon tetrachloride	GC/MS	SW-846:8240	5 µg/L	5	0.01
Chlorobenzene	GC/MS	SW-846:8240	5 µg/L	–	–
Chloroethane	GC/MS	SW-846:8240	10 µg/L	–	–
Chloroform	GC/MS	SW-846:8240	5 µg/L	–	0.1
Chloromethane	GC/MS	SW-846:8240	10 µg/L	–	–
3-Chloropropene	GC/MS	SW-846:8240	5 µg/L	–	–
1,2-Dibromo-3-chloropropane	GC/MS	SW-846:8240	20 µg/L	0.2	–
Dibromochloromethane	GC/MS	SW-846:8240	5 µg/L	–	–
1,2-Dibromoethane	GC/MS	SW-846:8240	5 µg/L	–	–
Dibromomethane	GC/MS	SW-846:8240	5 µg/L	–	–
trans-1,4-Dichloro-2-butene	GC/MS	SW-846:8240	10 µg/L	–	–
Dichlorodifluoromethane	GC/MS	SW-846:8240	20 µg/L	–	–
1,2-Dichloroethane	GC/MS	SW-846:8240	5 µg/L	5	0.01
trans-1,2-Dichloroethene	GC/MS	SW-846:8240	5 µg/L	100	–
1,1-Dichloroethane	GC/MS	SW-846:8240	5 µg/L	–	0.025
1,1-Dichloroethene	GC/MS	SW-846:8240	5 µg/L	7	0.005
1,2-Dichloropropane	GC/MS	SW-846:8240	5 µg/L	5	–
cis-1,3-Dichloropropene	GC/MS	SW-846:8240	5 µg/L	–	–
trans-1,3-Dichloropropene	GC/MS	SW-846:8240	5 µg/L	–	–

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
Ethyl benzene	GC/MS	SW-846:8240	5 µg/L	700	0.75
Ethyl methacrylate	GC/MS	SW-846:8240	5 µg/L	--	--
2-Hexanone	GC/MS	SW-846:8240	50 µg/L	--	--
Iodomethane	GC/MS	SW-846:8240	5 µg/L	--	--
Methylene chloride	GC/MS	SW-846:8240	5 µg/L	--	0.1
2-Butanone (MEK)	GC/MS	SW-846:8240	100 µg/L	--	--
Methyl methacrylate	GC/MS	SW-846:8240	5 µg/L	--	--
4-Methyl-2-pentanone	GC/MS	SW-846:8240	50 µg/L	--	--
Propanenitrile	GC/MS	SW-846:8240	100 µg/L	--	--
Styrene	GC/MS	SW-846:8240	5 µg/L	100	--
1,1,1,2-Tetrachloroethane	GC/MS	SW-846:8240	5 µg/L	--	--
1,1,2,2-Tetrachloroethane	GC/MS	SW-846:8240	5 µg/L	--	0.01
Tetrachloroethene	GC/MS	SW-846:8240	5 µg/L	5	0.02
1,1,1-Trichloroethane	GC/MS	SW-846:8240	5 µg/L	200	0.06
1,1,2-Trichloroethane	GC/MS	SW-846:8240	5 µg/L	5	0.01
Trichloroethene	GC/MS	SW-846:8240	5 µg/L	5	0.1
Trichlorofluoromethane	GC/MS	SW-846:8240	10 µg/L	--	--
Toluene	GC/MS	SW-846:8240	5 µg/L	1,000	0.75
1,2,3-Trichloropropane	GC/MS	SW-846:8240	5 µg/L	--	--
Vinyl Acetate	GC/MS	SW-846:8240	50 µg/L	--	--
Vinyl Chloride	GC/MS	Sw-846:8240	10 µg/L	2	0.001
Xylenes (total)	GC/MS	SW-846:8240	5 µg/L	10,000	0.62
HALOGENATED VOLATILE ORGANICS					
Bromodichloromethane	GC/HSD	SW-846:8010	0.10 µg/L	--	--
Bromoform	GC/HSD	SW-846:8010	0.50 µg/L	--	--
Bromomethane	GC/HSD	SW-846:8010	1.18 µg/L	--	--
Carbon Tetrachloride	GC/HSD	SW-846:8010	0.12 µg/L	5	0.01
Chlorobenzene	GC/HSD	SW-846:8010	0.25 µg/L	--	--
Chloroethane	GC/HSD	SW-846:8010	0.52 µg/L	--	--
2-Chloroethylvinylether	GC/HSD	SW-846:8010	0.50 µg/L	--	--

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
Chloroform	GC/HSD	SW-846:8010	0.10 µg/L	--	0.1
Chloromethane	GC/HSD	SW-846:8010	0.30 µg/L	--	--
Dibromochloromethane	GC/HSD	SW-846:8010	0.20 µg/L	--	--
1,2-Dichlorobenzene	GC/HSD	SW-846:8010	0.50 µg/L	600	--
1,3-Dichlorobenzene	GC/HSD	SW-846:8010	0.32 µg/L	600	--
1,4-Dichlorobenzene	GC/HSD	SW-846:8010	0.24 µg/L	75	--
1,1-Dichloroethane	GC/HSD	SW-846:8010	0.50 µg/L	--	0.025
1,2-Dichloroethane	GC/HSD	SW-846:8010	0.10 µg/L	5	0.01
1,1-Dichloroethene	GC/HSD	SW-846:8010	0.20 µg/L	7	0.005
trans-1,2-Dichloroethene	GC/HSD	SW-846:8010	0.20 µg/L	100	--
1,2-Dichloropropane	GC/HSD	SW-846:8010	0.10 µg/L	5	--
trans-1,3-Dichloropropene	GC/HSD	SW-846:8010	0.34 µg/L	--	--
cis-1,3-Dichloropropene	GC/HSD	SW-846:8010	0.30 µg/L	--	--
Methylene Chloride	GC/HSD	SW-846:8010	0.40 µg/L	--	0.1
1,1,2,2-Tetrachloroethane	GC/HSD	SW-846:8010	0.15 µg/L	--	0.01
Tetrachloroethene	GC/HSD	SW-846:8010	0.10 µg/L	5	0.02
1,1,2-Trichloroethane	GC/HSD	SW-846:8010	0.20 µg/L	5	0.01
1,1,1-Trichloroethane	GC/HSD	SW-846:8010	0.20 µg/L	200	0.06
Trichloroethene	GC/HSD	SW-846:8010	0.20 µg/L	5	0.1
Trichlorofluoromethane	GC/HSD	SW-846:8010	0.20 µg/L	--	--
Vinyl Chloride	GC/HSD	SW-846:8010	0.20 µg/L	2	0.001
SEMIVOLATILE ORGANICS					
Acetophenone	GC/MS	SW-846:8270	10 µg/L	--	--
2-Acetylaminofluorene	GC/MS	SW-846:8270	50 µg/L	--	--
4-Aminobiphenyl	GC/MS	SW-846:8270	10 µg/L	--	--
Aniline	GC/MS	SW-846:8270	10 µg/L	--	--
Anthracene	GC/MS	SW-846:8270	10 µg/L	--	0.03
Benzo(a)anthracene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03
Benzo(b)fluoranthene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03
Benzo(k)fluoranthene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
Benzo(a)pyrene	GC/MS	SW-846:8270	10 µg/L	0.2	0.0007
bis(2-Ethylhexyl)phthalate	GC/MS	SW-846:8270	10 µg/L	--	--
Butyl benzyl phthalate	GC/MS	SW-846:8270	10 µg/L	4	--
Chrysene	GC/MS	SW-846:8270	10 µg/L	0.2	--
Chlorobenzilate	GC/MS	SW-846:8270	10 µg/L	--	--
Dibenz(a,h)anthracene	GC/MS	SW-846:8270	10 µg/L	0.2	--
1,2-Dichlorobenzene	GC/MS	SW-846:8270	10 µg/L	600	--
1,3-Dichlorobenzene	GC/MS	SW-846:8270	10 µg/L	600	--
1,4-Dichlorobenzene	GC/MS	SW-846:8270	10 µg/L	75	--
Dimethylpthalate	GC/MS	SW-846:8270	10 µg/L	4	--
Diethylphthalate	GC/MS	SW-846:8270	10 µg/L	4	--
Di-n-butylphthalate	GC/MS	SW-846:8270	10 µg/L	--	--
Di-n-octylphthalate	GC/MS	SW-846:8270	10 µg/L	--	--
2,6-Dichlorophenol	GC/MS	SW-846:8270	10 µg/L	--	--
p-Dimethylaminoazobenzene	GC/MS	SW-846:8270	10 µg/L	--	--
7,12-Dimethylbenz(a)anthracene	GC/MS	SW-846:8270	25 µg/L	--	--
3,3'-Dimethylbenzidine	GC/MS	SW-846:8270	20 µg/L	--	--
Dimethylphenethylamine	GC/MS	SW-846:8270	10 µg/L	--	--
1,3-Dinitrobenzene	GC/MS	SW-846:8270	10 µg/L	--	--
Diphenylamine	GC/MS	SW-846:8270	10 µg/L	--	--
Ethyl methanesulfonate	GC/MS	SW-846:8270	10 µg/L	--	--
Fluoranthene	GC/MS	SW-846:8270	10 µg/L	--	--
Hexachlorophene	GC/MS	SW-846:8270	10 µg/L	--	--
Hexachloropropene	GC/MS	SW-846:8270	10 µg/L	--	--
Isosafrole	GC/MS	SW-846:8270	10 µg/L	--	--
Methapyriline	GC/MS	SW-846:8270	10 µg/L	--	--
Methyl methanesulfonate	GC/MS	SW-846:8270	10 µg/L	--	--
3-Methylcholanthrene	GC/MS	SW-846:8270	10 µg/L	--	--
2-Methyl naphthalene	GC/MS	SW-846:8270	10 µg/L	--	0.03
N-Nitroso-di-n-butylamine	GC/MS	SW-846:8270	10 µg/L	--	--

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
N-Nitrosodiethylamine	GC/MS	SW-846:8270	10 µg/L	--	--
N-Nitrosodimethylamine	GC/MS	SW-846:8270	10 µg/L	--	--
N-Nitrosomethylethylamine	GC/MS	SW-846:8270	10 µg/L	--	--
N-Nitrosomorpholine	GC/MS	SW-846:8270	10 µg/L	--	--
N-Nitrosopiperidine	GC/MS	SW-846:8270	10 µg/L	--	--
N-Nitrosopyrrolidine	GC/MS	SW-846:8270	10 µg/L	--	--
Naphthalene	GC/MS	SW-846:8270	10 µg/L	--	0.03
1-Naphthylamine	GC/MS	SW-846:8270	10 µg/L	--	--
2-Naphthylamine	GC/MS	SW-846:8270	10 µg/L	--	--
1,4-Napthoquinone	GC/MS	SW-846:8270	10 µg/L	--	--
5-Nitro-o-toluidine	GC/MS	SW-846:8270	10 µg/L	--	--
4-Nitroquinoline-N-oxide	GC/MS	SW-846:8270	100 µg/L	--	--
Pentachlorobenzene	GC/MS	SW-846:8270	10 µg/L	--	--
Pentachloroethane	GC/MS	SW-846:8270	10 µg/L	--	--
Pentachloronitrobenzene	GC/MS	SW-846:8270	10 µg/L	--	--
Phenacetin	GC/MS	SW-846:8270	10 µg/L	--	--
Phenanthrene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03
p-Phenylenediamine	GC/MS	SW-846:8270	10 µg/L	--	--
2-Picoline	GC/MS	SW-846:8270	10 µg/L	--	--
Pronamide	GC/MS	SW-846:8270	10 µg/L	--	--
Pyrene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03
2,4-Dimethylphenol	GC/MS	SW-846:8270	10 µg/L	--	--
2,4-Dinitrophenol	GC/MS	SW-846:8270	50 µg/L	--	--
4-Nitrophenol	GC/MS	SW-846:8270	50 µg/L	--	--
Phenol	GC/MS	SW-846:8270	10 µg/L	--	--
Pyridine	GC/MS	SW-846:8270	10 µg/L	--	--
Safrole	GC/MS	SW-846:8270	10 µg/L	--	--
1,2,4,5-Tetrachlorobenzene	GC/MS	SW-846:8270	10 µg/L	--	--
2,3,4,6-Tetrachlorophenol	GC/MS	SW-846:8270	20 µg/L	--	--
o-Toluidine	GC/MS	SW-846:8270	10 µg/L	--	--

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
Acenaphthene	GC/MS	SW-846:8270	10 µg/L	--	--
Acenaphthylene	GC/MS	SW-846:8270	10 µg/L	--	--
Benzo(g,h,i)perylene	GC/MS	SW-846:8270	10 µg/L	--	0.03
Benzyl Alcohol	GC/MS	SW-846:8270	20 µg/L	--	--
4-Bromophenyl phenyl ether	GC/MS	SW-846:8270	10 µg/L	--	--
4-Chloroaniline	GC/MS	SW-846:8270	20 µg/L	--	--
4-Chloro-3-methylphenol	GC/MS	SW-846:8270	20 µg/L	--	--
bis(2-Chloroisopropyl)ether	GC/MS	SW-846:8270	10 µg/L	--	--
bis(2-Chloroethyl)ether	GC/MS	SW-846:8270	10 µg/L	--	--
2-Chloronaphthalene	GC/MS	SW-846:8270	10 µg/L	--	--
2-Chlorophenol	GC/MS	SW-846:8270	10 µg/L	--	--
bis(2-Chloroethoxy)methane	GC/MS	SW-846:8270	10 µg/L	--	--
4-Chlorophenyl phenyl ether	GC/MS	SW-846:8270	10 µg/L	--	--
Dibenzofuran	GC/MS	SW-846:8270	10 µg/L	--	--
2,4-Dichlorophenol	GC/MS	SW-846:8270	10 µg/L	--	--
3,3'-Dichlorobenzidine	GC/MS	SW-846:8270	20 µg/L	--	--
2,4-Dinitrotoluene	GC/MS	SW-846:8270	10 µg/L	--	--
2,6-Dinitrotoluene	GC/MS	SW-846:8270	10 µg/L	--	--
4,6-Dinitro-2-methylphenol	GC/MS	SW-846:8270	50 µg/L	--	--
Fluorene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03
Hexachlorobenzene	GC/MS	SW-846:8270	10 µg/L	1	--
Hexachlorocyclopentadiene	GC/MS	SW-846:8270	10 µg/L	50	--
Hexachloroethane	GC/MS	SW-846:8270	10 µg/L	--	--
Hexachlorobutadiene	GC/MS	SW-846:8270	10 µg/L	--	--
Indeno(1,2,3-c,d)pyrene	GC/MS	SW-846:8270	10 µg/L	0.2	0.03
Isophorone	GC/MS	SW-846:8270	10 µg/L	--	--
2-Methylphenol	GC/MS	SW-846:8270	10 µg/L	--	--
3-Methylphenol	GC/MS	SW-846:8270	10 µg/L	--	--
4-Methylphenol	GC/MS	SW-846:8270	10 µg/L	--	--
2-Nitroaniline	GC/MS	SW-846:8270	50 µg/L	--	--

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
3-Nitroaniline	GC/MS	SW-846:8270	50 µg/L	--	--
4-Nitroaniline	GC/MS	SW-846:8270	50 µg/L	--	--
Nitrobenzene	GC/MS	SW-846:8270	10 µg/L	--	--
2-Nitrophenol	GC/MS	SW-846:8270	10 µg/L	--	--
n-Nitroso-di-n-propylamine	GC/MS	SW-846:8270	10 µg/L	--	--
n-Nitrosodiphenylamine	GC/MS	SW-846:8270	10 µg/L	--	--
Pentachlorophenol	GC/MS	SW-846:8270	50 µg/L	1	--
1,2,4-Trichlorobenzene	GC/MS	SW-846:8270	10 µg/L	9	--
2,4,5-Trichlorophenol	GC/MS	SW-846:8270	10 µg/L	--	--
2,4,6-Trichlorophenol	GC/MS	SW-846:8270	10 µg/L	--	--
ORGANOCHLORINE PESTICIDES AND PCBs					
Aldrin	GC/ECD	SW-846:8080	0.01 µg/L	--	--
alpha-BHC	GC/ECD	SW-846:8080	0.01 µg/L	--	--
beta-BHC	GC/ECD	SW-846:8080	0.01 µg/L	--	--
delta-BHC	GC/ECD	SW-846:8080	0.01 µg/L	--	--
gamma-BHC (Lindane)	GC/ECD	SW-846:8080	0.01 µg/L	0.2	--
Chlordane (technical)	GC/ECD	SW-846:8080	0.05 µg/L	2	--
4,4'-DDD	GC/ECD	SW-846:8080	0.01 µg/L	--	--
4,4'-DDE	GC/ECD	SW-846:8080	0.01 µg/L	--	--
4,4'-DDT	GC/ECD	SW-846:8080	0.02 µg/L	--	--
Dieldrin	GC/ECD	SW-846:8080	0.01 µg/L	--	--
Endosulfan I	GC/ECD	SW-846:8080	0.01 µg/L	--	--
Endosulfan II	GC/ECD	SW-846:8080	0.03 µg/L	--	--
Endosulfan sulfate	GC/ECD	SW-846:8080	0.05 µg/L	--	--
Endrin	GC/ECD	SW-846:8080	0.01 µg/L	2	--
Endrin aldehyde	GC/ECD	SW-846:8080	0.02 µg/L	--	--
Heptachlor	GC/ECD	SW-846:8080	0.01 µg/L	0.4	--
Heptachlor epoxide	GC/ECD	SW-846:8080	0.01 µg/L	0.2	--
Methoxychlor	GC/ECD	SW-846:8080	0.05 µg/L	40	--

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
Toxaphene	GC/ECD	SW-846:8080	0.50 µg/L	3	--
PCB-1016	GC/ECD	SW-846:8080	0.10 µg/L	0.5	0.001
PCB-1221	GC/ECD	SW-846:8080	0.20 µg/L	0.5	0.001
PCB-1232	GC/ECD	SW-846:8080	0.20 µg/L	0.5	0.001
PCB-1242	GC/ECD	SW-846:8080	0.10 µg/L	0.5	0.001
PCB-1248	GC/ECD	SW-846:8080	0.10 µg/L	0.5	0.001
PCB-1254	GC/ECD	SW-846:8080	0.20 µg/L	0.5	0.001
PCB-1260	GC/ECD	SW-846:8080	0.20 µg/L	0.5	0.001
ORGANOPHOSPHORUS PESTICIDES					
Disulfoton	GC/FPD	SW-846:8140	0.2 µg/L	--	--
Methyl parathion	GC/FPD	SW-846:8140	0.03 µg/L	--	--
Phorate	GC/FPD	SW-846:8140	0.15µg/L	--	--
CHLORINATED HERBICIDES					
2,4-D	GC/ECD	SW-846:8150	1.2 µg/L	70	--
2,4,5-T	GC/ECD	SW-846:8150	0.20 µg/L	--	--
2,4,5-TP (Silvex)	GC/ECD	SW-846:8150	0.15 µg/L	50	--
Dinoseb	GC/ECD	SW-846:8150	0.7 µg/L	7	--
POLYCHLORINATED DIOXINS AND FURANS					
2,3,7,8-TCDD	GC/MS	SW-846:8280	10 ng/L	--	--
TCDD	GC/MS	SW-846:8280	10 ng/L	--	--
TCDF	GC/MS	SW-846:8280	10 ng/L	--	--
PeCDD	GC/MS	SW-846:8280	10 ng/L	--	--
PeCDF	GC/MS	SW-846:8280	10 ng/L	--	--
HxCDD	GC/MS	SW-846:8280	10 ng/L	--	--
HxCDF	GC/MS	SW-846:8280	10 ng/L	--	--
WATER QUALITY PARAMETERS					
Total Cyanide	Colorimetric	SW-846:9012	0.01 mg/L	200	0.2
Total Sulfide	Titrametric	SW-846:9030	1.0 mg/L	--	--

(Continued)

Parameter	Analysis		Method Detection Limits[a]	Maximum Contaminant Level	
	Technique	Method	Groundwater	MCL[b] (µg/L)	HHS[c] (mg/L)
GENERAL					
Total Organic Carbon	Oxidation	SW-846:9060	1.0 mg/L	--	--

a Method Detection Limit is the minimum concentration of a substance that can be measured and reported. Method Detection Limits are highly matrix dependent and may not always be achievable.
b Federal Drinking Water Standards Maximum Contaminant Levels (MCL), Office of Drinking Water, USEPA.
c New Mexico Standards for Groundwater, Human Health Standards (HHS), New Mexico Water Quality Control Commission Regulations, November 24, 1988.