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Volume I

RCRA Facility Investigation
Three-Mile Ditch and Evaporation Ponds
Phase II Report
Navajo Refinery
Artesia, New Mexico

(Revised)

prepared for

Navajo Refining Company
501 East Main Street
P.O. Drawer 159
Artesia, New Mexico 88210

by

K. W. Brown Environmental Services
501 Graham Road
College Station, Texas 77845

NOVEMBER 1993

KWBES

RCRA FACILITY INVESTIGATION
THREE-MILE DITCH AND EVAPORATION PONDS
PHASE II REPORT
NAVAJO REFINERY,
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November 1993

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CERTIFICATION STATEMENT

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(Signature)

Matthew P. Clifton
Senior Vice President
(Printed Name and Title)

November 29, 1993
(Date)

1.0 EXECUTIVE SUMMARY

The objective of Phase II of the RCRA Facility Investigation (RFI) conducted at two solid waste management units (SWMUs) at the Navajo Refinery (EPA ID No. NMD 048918817) located in Artesia, New Mexico, was to expand upon the Phase I findings (submitted to the U.S. Environmental Protection Agency in May 1991) and thereby better define the source characteristics and the nature and extent of any contamination from the SWMUs. The two SWMUs are Three-Mile Ditch, an unlined wastewater conveyance channel that was operated for approximately 50 years, and a partially active evaporation pond system that covers approximately 115 acres.

The RFI Phase II investigation included sampling and chemical analyses of soils, soil gas, surface water and sediments, and groundwater within and around the two SWMUs. The investigation included 43 soil sampling points, 39 soil vapor points, and approximately 50 monitor wells (including 30 newly installed monitor wells and piezometers).

Key findings of the RFI Phase II investigation are as follows:

Three-Mile Ditch — Soils

- Results of the soils investigation at the ditch confirmed the findings of the RFI Phase I investigation concerning the presence of volatile organic constituents. The combined results of both the Phase I and Phase II investigations indicate that the presence of volatile constituents in ditch soils occur only sporadically and at concentrations significantly below applicable health-based numbers.
- With respect to semivolatile constituents, analytical problems caused higher than desired detection levels. However, available data from the Phase II investigation are not inconsistent with the results of the Phase I investigation, in which the presence of residual semivolatile organic compounds are indicated at various locations and depths along the length of the unit.
- The failure of the Toxicity Characteristic Leaching Procedure (TCLP) evaluation for organic constituents contained in soil samples from Three-Mile Ditch to yield any leachate concentrations that exceeded the toxicity characteristic (TC) limits demonstrated that organic constituents remain strongly sorbed to the soil matrix. Further, the processes of biodegradation will additionally minimize the availability of organic constituents to the water phase.
- The soils data for the ditch indicated the presence of elevated concentrations of certain metals (arsenic, chromium, and lead). However, maximum concentrations observed for these three metals were significantly less than the levels recorded for ditch samples obtained during the preceding Phase I investigation.Taken as a whole, the data from the RFI Phase I and II investigations indicate that the individual incidences of arsenic, chromium, and lead in excess of applicable health-based limits are generally neither widespread along the length of the ditch or throughout the entire contaminant zone profile at any given point within the unit.

- TCLP evaluation of the soil samples from Three-Mile Ditch failed to yield any exceedances for metals regulated under the TC rule, demonstrating the minimal leaching potential for metal contamination within the unit. Further, neither the preceding RFI Phase I investigation or the current Phase II investigation has revealed any data to indicate that unit soils in immediate proximity to, or potentially in contact with, the water table possess metal concentrations which could potentially serve as a source of an ongoing release of metal constituents to the water table.

Three-Mile Ditch — Groundwater

- In the vicinity of Three-Mile Ditch, no organic contaminants were observed in the groundwater monitor wells, with the sole exception of monitor well MW-45, in the vicinity of the refinery process area, which yielded one detection each of carbon disulfide and xylene. The detected levels for these two constituents were significantly below allowable health-based levels.
- Evidence of groundwater contamination by metals in the vicinity of Three-Mile Ditch was limited to the elevated levels of chromium and nickel in monitor wells MW-8 and MW-9. However, the available evidence indicates that the detection of these two constituents resulted from the corrosion of the stainless-steel casing used in the two wells. Groundwater samples obtained from PVC-cased monitor well MW-21, installed intermediately between MW-8 and MW-9, did not yield analytical evidence of elevated chromium and nickel contamination.
- The near-surface water zone in the vicinity of Three-Mile Ditch is too discontinuous to provide a potentially usable water source, and the quality of the groundwater is poor owing to excessive concentrations of total dissolved solids (TDS). The quality of the shallow water near the evaporation ponds is also very poor because of excessively high salt concentrations.
- A comprehensive comparison of groundwater water-quality parameters revealed that there are no similarities between shallow groundwater in the vicinity of Three-Mile Ditch and nearby deep domestic wells, which indicates that the shallow and deep zones are not hydrologically connected in the vicinity of the ditch.
- A similar comparison between the shallow groundwater quality and current and past wastewater quality does not identify similarities indicative of obvious mixing of the wastewater and shallow groundwater.

Evaporation Ponds — Pond 1 Soils

- Analytical results of the soils investigation for at Evaporation Pond 1 revealed that residual organic constituents are associated with elevated levels of oil and grease concentrated in the upper portion of the profile (within 3 ft or less of the soil surface). TCLP tests performed on soil samples from Pond 1 failed to yield any TC exceedances for organic constituents.
- Although the data suggest that localized occurrences of elevated levels of metal constituents of concern (i.e., arsenic, chromium, and lead) may be present within the soils of Evaporation Pond 1, the occurrence of these three constituents at levels that exceed health-based criteria apparently are not widespread within the unit.
- The soil contamination profile of Evaporation Pond 1 reveals a distinct trend in which the concentration of organic constituents diminishes abruptly with increasing depth. A similar trend was even more developed for metal constituents. Metal concentrations observed at all sample intervals below the 1-ft sample depth yielded values ranging from background concentrations to only slightly elevated above background. Metal

concentration values for all samples obtained below a depth of 1 ft were significantly below health-based criteria.

- Significant concentrations of organic and inorganic constituents were detected only at soil depth intervals well above the shallow groundwater zone underlying the unit. Further, TCLP evaluation of the Pond 1 soil samples did not yield leachate concentrations in exceedance of allowable concentrations for any TC-regulated organic or inorganic constituents. Overall, these findings demonstrate the minimal potential for groundwater contamination resulting from the migration of constituents present within this unit.
- Continued mechanical mixing and aeration of surface soils in Evaporation Pond 1 will enhance the degradation of residual organic constituents and the fixation of metal constituents. This has been demonstrated in those areas previously subject to such mixing.

Evaporation Ponds — Groundwater

- Benzene was the only volatile constituent detected in groundwater in the vicinity of the ponds that exceeded health-based drinking water standards. Benzene was reported in groundwater samples obtained from several monitoring wells located immediately south and southeast of Evaporation Pond 1 and in one monitor well immediately east of Evaporation Pond 2. The maximum detected values were approximately four times the federal drinking water standard for benzene.
- Of the metals tested, arsenic was the only metal repeatedly detected and verified in the groundwater in the area of the evaporation ponds. Slightly elevated levels of arsenic (approximately three times the level of the current drinking water standard) were detected in the groundwater immediately adjacent to the ponds.
- Relatively high concentrations of target volatile constituents in the groundwater southeast of the ponds were reported in a 1987 study using piezometers and summarized in the RFI Phase I Report. These previous findings are strongly contradicted by the Phase II investigation, which did not detect the presence of target volatile organic constituents in the groundwater in the vicinity of one 1987 sample location. Because the sampling and analytical methods used in the 1987 study are not identified in the RFI Phase I Report, these suspect results cannot be substantiated.
- Groundwater elevation data indicate that groundwater movement in the vicinity of the ponds is to the southeast. An aquifer test conducted in the valley fill alluvium southeast of the ponds indicates that the values of hydraulic conductivity and seepage velocity of the valley fill the aquifer at this location are in the range of the values reported for these properties in the RFI Phase I Report.
- A well point subsurface gas survey measuring headspace vapors from the degassing of water was employed to delineate the extent of hydrocarbon-impacted shallow groundwater downgradient of the ponds. The measurement of subsurface gas is the best method for detecting the overall presence of hydrocarbon contamination of soil and shallow groundwater. However, the type or level of individual constituents can not be determined using the method employed for this study.
- The results of the subsurface gas survey defined a hydrocarbon-impacted groundwater plume that extends approximately 3,000 ft south-southeast of the Pond 1/Pond 2 juncture. The well point survey data were used to define appropriate downgradient locations for the installation of additional monitor wells in the vicinity of the ponds.
- Comparison of groundwater elevations in shallow monitor wells with elevations in monitor wells screened at lower depths in the valley fill alluvium demonstrate the existence of an upward vertical gradient in the vicinity of the evaporation ponds. This

observation confirms the findings of a previous U.S. Geological Survey study of this area of the Pecos River. The presence of an upward vertical gradient greatly reduces the potential for any shallow groundwater contaminants to migrate to deeper zones of higher quality groundwater.

- The existence of an upward vertical gradient in the vicinity of the ponds is also verified by the presence of a natural discharge zone for the shallow aquifer located southeast of the ponds. Such zones are typically characterized by elevated TDS values which were observed for shallow groundwater in this area.
- Further evidence confirming the existence of an upward vertical groundwater gradient is provided by the integration of groundwater modeling results with the comparative analysis of groundwater chemistry data for various monitor wells in the vicinity of the ponds. The results and observations obtained from these two information sources are reciprocally validating, providing strong evidence that the downward vertical groundwater gradient underlying the ponds is in effect only to a limited depth. Thereafter, upwelling of deep alluvial groundwater redirects the downward-moving contaminated groundwater upwards to the shallow groundwater zone.
- The shallow groundwater in the vicinity of the ponds, as well as the water of the Pecos River, is naturally high in TDS. The salty nature of this groundwater renders it unusable for domestic, agricultural, or industrial purposes. As a result, there are no potential environmental receptors for any hydrocarbon-impacted groundwater that may exist downgradient of the ponds.

The results of groundwater sampling and analysis in the vicinity of the evaporation ponds indicate that the deeper groundwater in the river alluvium of the valley fill aquifer has not been excessively impacted by refinery activity. The southeastly flow direction of water in the alluvium moves contamination entering the groundwater from the ponds to the southeast, away from the better quality groundwater to the west. The prevailing upward vertical flow should also minimize the downward migration of any possible contamination to the deeper portion of the valley fill aquifer. Because of the lack of potential environmental receptors downgradient from the ponds and the restriction of any contamination to the uppermost portion of the river alluvium, the evaporation ponds do not currently pose a significant environmental risk to the area and are not likely to become such in the future.

Based on the results of Phase II (and Phase I) of the RFI, it can be concluded that the two-phase investigation has adequately characterized the nature and extent of contamination and releases from the SWMUs. The relatively low levels of organic and inorganic constituents beneath and in proximity to the SWMUs pose little threat to human health and the environment, as defined by federal and state criteria. Therefore, it is recommended that no further investigations are necessary beyond the routine monitoring of water levels and selected constituents to verify the nature and extent of releases from these units.

2.0 INTRODUCTION

The following sections provide a brief introduction to the background and the scope and goals of the investigation reported herein and the organization of the report.

2.1 BACKGROUND TO THE RCRA FACILITY INVESTIGATION

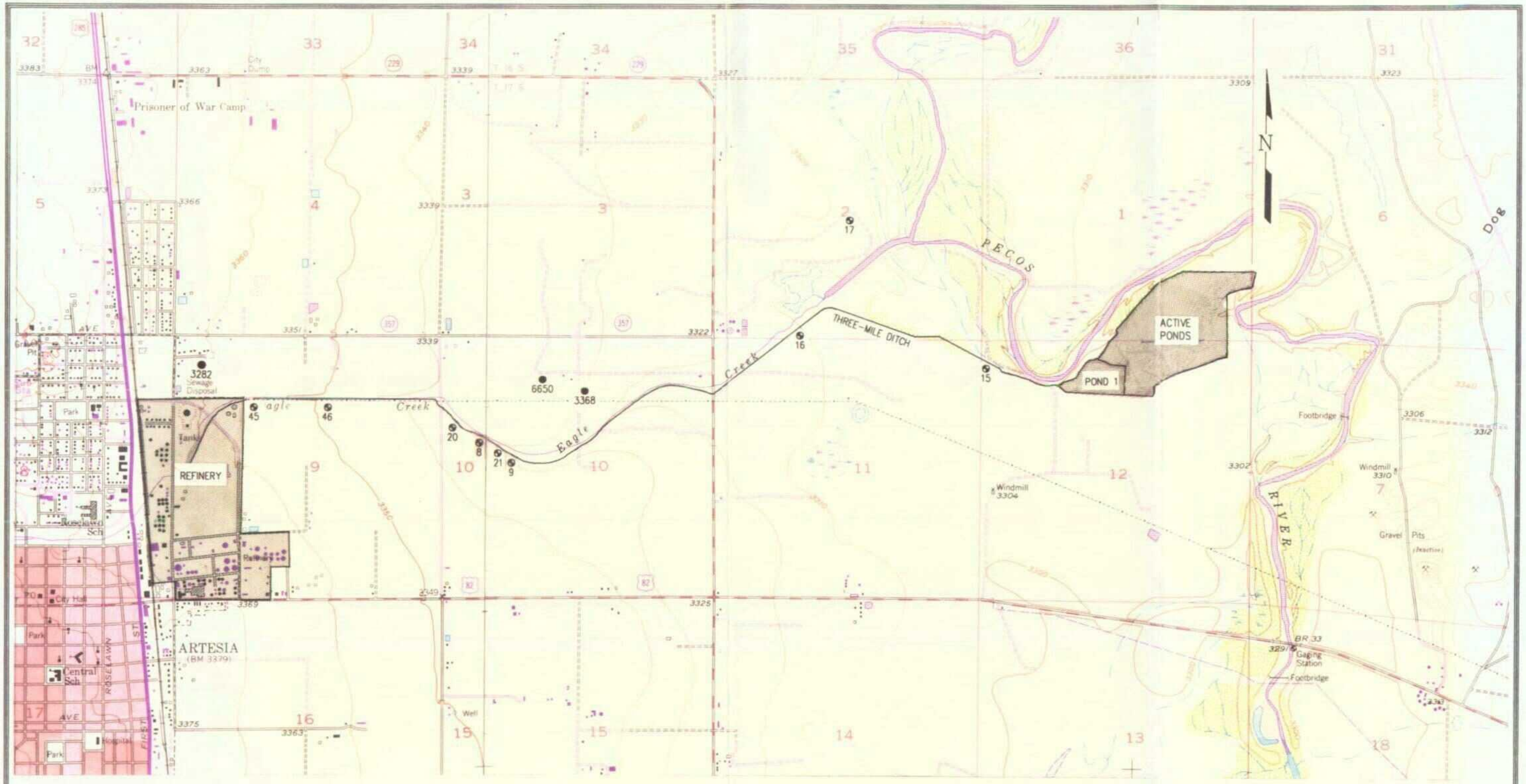
The Navajo Refinery (EPA ID No. NMD 048918817), located in Artesia, Eddy County, New Mexico, is regulated under the Resource Conservation Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments of 1984 (HSWA). As the first step in implementing the RCRA Corrective Action Plan at the facility, the U.S. Environmental Protection Agency (EPA) conducted a Preliminary Review (PR) of 15 solid waste management units (SWMUs) at the process and other areas of the refinery. Based on the PR and additional information, the EPA determined that the second step of Corrective Action, a RCRA Facility Investigation (RFI), was necessary for some of the SWMUs.

The purpose of the RFI was to determine whether releases of hazardous waste or constituents had occurred from the SWMUs identified in the facility's permit and to determine the nature and extent of any release found to have occurred. The RFI was conducted in two phases based on workplans submitted to and approved by the EPA for Three-Mile Ditch, which also addressed Eagle Creek, and the evaporation ponds (Figure 1). Three-Mile Ditch is a 3-mile-long ditch (approximately 20,000 linear ft) that was used from the 1930s to 1987 to convey wastewater from the refinery to Evaporation Pond 1. Although the bermed ditch approximately parallels the natural drainage path of Eagle Creek, it is not in the creek and its base is approximately 5 to 10 ft above the creek bed. Evaporation Pond 1, which is out of service, reportedly contains approximately 60,000 tons of waste material. Evaporation Ponds 2, 3, 5 and 6 — which are essentially a single pond because the dikes separating the two ponds have been breached — receive approximately 650,000 gallons of wastewater per day from the refinery wastewater treatment plant via a 20,000-linear-ft enclosed pipeline. The buried high-density polyethylene pipe replaced the previously described open, earthen ditch in 1987.

Several reports that have been generated since the beginning of the RFI program at the refinery serve as background documents to this Phase II effort, as follows:

- RFI Phase I Report, sections 5.0 through 7.0 (final submittal) — December 1990
- RFI Phase I Report (second submittal) — October 1990

Figure 1. Location map, Navajo Refinery, RFI, Phase II.



LEGEND

- ● DOMESTIC WELLS SAMPLED
- ⊗ MONITOR WELL LOCATIONS THREE-MILE DITCH

2000 0 2000 6000 FEET

NOTE: MAP COMPILED FROM USGS ARTESIA AND SPRING LAKE 7.5 MINUTE QUADRANGLE (1973). MONITOR WELLS ADJACENT TO EVAPORATION POND NOT SHOWN

KWBES

prepared for:

Navajo

Location Map, Navajo Refinery,
RFI, Phase II.

PROJECT:	622092005-237		
LOCATION:	ARTESIA, NEW MEXICO		
APPR:		DATE:	04/26/93
DRAWN BY:	RMO	SCALE:	AS SHOWN
DATE:	04/26/93	FIGURE:	1

- RFI Phase II Work Plan (second submittal) — December 1990
- RFI Phase II Work Plan (final submittal) — May 1991
- RFI Phase II Workplan (revised) — June 1992
- RFI Phase II Report (1st submittal) — April 1993
- RFI Phase II Report (2nd submittal) — November 1993 (this report)

Although summaries of the historical information used in this report are presented herein, the reader is also referred to these earlier reports for additional information.

2.2 SCOPE AND GOALS OF THE RFI

The scope of the RFI is based on the EPA-approved RFI Phase I and Phase II Workplans, the requirements of which are outlined in Section C (Corrective Action for Continuing Releases) and in Section F (Scope of Work for a RCRA Facility Investigation at Navajo Refinery) of the permit issued to the facility on 25 March 1988. The annual soil monitoring plan for the Truck Bypass Landfarm, which is presented in Appendix A of the 1992 RFI Phase II Workplan, was performed and reported in a separate submission from this report.

The primary goals of the RFI at the Navajo Refinery are to characterize the facility's environmental setting and potential receptors, characterize the sources of contamination, and define the degree and extent of contamination. To achieve these goals, a series of tasks, as outlined in the workplans, was completed. The RFI Phase II tasks at the Three-Mile Ditch and the evaporation ponds included the collection and analysis of samples from various media, compilation and evaluation of existing and newly acquired data, and preparation of this RFI Phase II Report. The RFI Phase II Report is designed to fulfill meeting these goals and also serves as the basis for the determination of the need for a Corrective Measures Study (CMS) within the RCRA Corrective Action Plan.

2.3 ORGANIZATION OF THE RFI REPORT

This report for Phase II of the RFI is organized into 11 sections and supporting appendices. The remainder of this section outlines the organization of the RFI Phase II Report. Section 3.0 describes the environmental setting at the facility, including the identification of potential receptors. Section 4.0 provides a synopsis of the history of the Navajo Refinery and the current status of the SWMUs, including the waste characteristics. Section 5.0 is a review of the Phase I investigation at Three-Mile Ditch, and the methods and results for the Phase II investigation at Three-Mile Ditch are presented in Section 6.0. Section 7.0 is a review of the Phase I investigation at the evaporation ponds, and the methods and results for the Phase II investigation at the ponds are presented in Section 8.0. The RFI results are discussed in Section 9.0, and recommendations based on the results are subsequently presented in Section 10.0. The cited references are collected in Section 11.0. Acronyms and abbreviations used in this report are listed in Appendix A. Streamflow and water quality data at the Artesia gauge are shown in Appendix B. Available wastewater and evaporation pond analytical data is reproduced in Appendix C. Pertinent soils and water quality data from the RFI Phase I Report are presented in Appendix D. Appendix E includes the Three-Mile Ditch and Evaporation Pond trench description logs and figures. Appendix F includes the monitor well and piezometer boring logs, and Appendix G includes the aquifer test data and graphs. A discussion of the computer modeling methodology is presented in Appendix H. The laboratory analytical data from Phase II of the RFI are presented in Appendix I. Analytical data from the EPA contractor's report of the Phase II split sampling is reproduced in Appendix J. Analytical results for Pond 1 remediation efforts are shown in Appendix K.

3.0 ENVIRONMENTAL SETTING

The environmental setting for the refinery, which was described initially in the PR, was supplemented and verified during the RFI program, as described in the following sections.

3.1 CLIMATOLOGY

The Artesia, New Mexico, area has a semiarid continental climate, characterized by hot summers and mild winters (USDA-SCS, 1971). Measurable rainfall occurs approximately 42 days per year and annual snowfall averages 3 to 8 in. to yield an average annual precipitation of 10 to 14 in., with nearly 80% falling from May through October. Lake evaporation in the Eddy County area is 66-72 in./year, of which two-thirds also takes place from May through October. Thus, the net loss between precipitation and evaporation ranges from 52 to 62 in./year. Minimum temperatures are typically 44.0° to 49.0°F, but can fall below 0°F in winter; maximum temperatures can exceed 100°F on summer days. The frost-free season is April to October (NOAA, 1982).

3.2 TOPOGRAPHY AND SURFACE WATER

The Navajo Refinery facility on the east side of Artesia is located in the eastern plains of New Mexico in the broad Pecos River Valley. The average elevation of the city of Artesia is 3,380 ft above mean sea level (MSL). The plain on which Artesia lies slopes eastward at about 30 ft per mile. Surface drainage is dominated by small ephemeral creeks and arroyos that flow eastward to the Pecos River, located approximately 3 miles east of the facility. The wastewater disposal system, which formerly included Three-Mile Ditch and currently comprises the pipeline to the evaporation ponds, also drains by gravity eastward of the refinery process area.

Natural surface drainage at the facility is to the north and east. The major drainage in the immediate area of the site is Eagle Creek, an ephemeral watercourse that runs southwest to northeast through the process area of the refinery, and then runs eastward into the Pecos River. As it passes through the city of Artesia, Eagle Creek functions as a major stormwater conveyance for the community as well as the outlying agricultural areas, and the creek is periodically scoured by intense stormwater events. The storm runoff conveys non-point source contaminants common to urban and agricultural environments.

The elevation of Eagle Creek is 3,360 ft at its entrance to the refinery and decreases to approximately 3,305 ft at its junction with the Pecos River. The Three-Mile Ditch between the refinery and the evaporation ponds parallels Eagle Creek on its south side at an elevation approximately 5 to 10 ft higher than the creek bed.

A large portion of the facility is within the 100-year floodplain of either Eagle Creek or the Pecos River. However, Eagle Creek has been channelized from west of Artesia to the Pecos, and the area of modification is being extended. In the vicinity of the refinery, the channel of Eagle Creek has been cemented to protect developed areas during flood events. A check dam also was constructed west of Artesia along Eagle Creek. According to the PR prepared for this facility, once these measures are completed, they should effectively remove Artesia and the refinery from Eagle Creek's 100-year floodplain.

Portions of Three-Mile Ditch and the evaporation ponds lie within the Pecos River floodplain. However, the construction of flood control dams upstream of the evaporation ponds has reduced the risk of flooding at the facility, although tributary streams can contribute heavy flow from severe convective thunderstorms. For the 1991 water year (1 October 1990 to 30 September 1991), the mean flow measured by the U.S. Geological Survey (USGS) at the Artesia gauge on U.S. Highway 82 was 250 cubic ft per second (cfs), but the base flow of 2,000 cfs was exceeded on 18 July (4,060 cfs) and 16 August (2,040 cfs). The minimum daily flow was 3.5 cfs on 30 June (Borland et al., 1992). The New Mexico Water Quality Control Commission (WQCC) groundwater discharge permit issued for the evaporation ponds by the New Mexico Oil Conservation Division requires that they be able to withstand a 100-year flood event. Neither flood event in 1990 caused damage to the ponds, which have a required freeboard of 2 ft.

Water quality is also measured at the Artesia gauge, which is 1 mile downstream from the evaporation ponds (Borland et al., 1992). The chemistry of the surface water for the 1991 water year is given in Table 1. Once-daily measurements of specific conductance for the 1991 water year (Borland et al., 1992, p. 331) document the highly variable and relatively poor quality of the surface water in the river. For example, for December 1990 and January 1991, the specific conductance had mean values of 8,670 and 8,940 µs/cm and minimum values of 8,120 and 8,100 µs/cm, respectively. Streamflow, specific conductance, and water quality records for the Artesia gauge for the period 1980 through 1990 are shown in Appendix B. State of New Mexico Stream Standards for this reach specify that TDS shall be less than 14,000 mg/L, sulfate less than 3000 mg/L, and chloride less than 5000 mg/L (NMWQQC, 1991).

Table 1. Pecos River water quality data from the Artesia Station, water year October 1990 to September 1991 (Borland et al., 1992).

Chemical property	November 1990	March 1991	May 1991	September 1991
pH (s.u.)	8.6	8.3	7.9	8.2
Water temperature (°C)	1.5	8.0	19.0	24.0
Specific conductance (µs/cm)	3,410	10,500	3,750	7,100
Dissolved oxygen (mg/L)	13.2	11.3	12.0	8.8
Oxygen demand, chemical (high level) (mg/L)	61	140	62	54
Hardness (mg/L as $CaCO_3$)	2,100	2,200	1,300	2,100
Total dissolved solids (mg/L)	5,630	6,620	3,200	5,040
Nitrate total/dissolved (mg/L as N)	0.020/0.020	<0.010/<0.010	--/--	0.020/<0.010
Suspended sediment (mg/L)	63	2370	2560	252

3.3 SOILS

Soils mapped at the refinery by the U.S. Soil Conservation Service (SCS), and confirmed during previous field investigations, are primarily of the Pima and Karro series in the vicinity of the process area and the Arno and Harkey series at the evaporation ponds (USDA-SCS, 1971). Properties of these series are listed in Table 2 and profiles are presented in the boring logs included in Appendix F. The frost-free season for the soils is 195 to 210 days. Extended periods of cold weather are rare and frost action potential is slight. In general, soils in the area do not freeze at depths greater than a few inches for more than a few days at a time.

The Pima, Karro, Arno, and Harkey soils have similar properties. Pima soils are deep, well-drained, dark-colored, calcareous soils that occur on the floodplains of narrow drainageways (e.g., Eagle Creek). These soils have moderate shrink-swell potential and are subject to periodic flooding. Runoff from Pima soils is slow, permeability is moderately slow, and the water-holding capacity is high. The effective rooting depth is greater than 5 ft, and the water table is deeper than 5 ft.

The Karro soils are highly calcareous. Calcium carbonate typically accumulates at a depth of about 45 in. These soils are found on level to gently sloping terrains and are susceptible to wind erosion. Runoff is slow and water-holding capacity is high. Permeability is moderate, and the effective rooting depth and the water table are both deeper than 5 ft.

Table 2. Physical and chemical properties of the Pima, Karro, Arno, and Harkey series (USDA-SCS, 1971).

Property	Pima series	Karro series		Arno series	Harkey series
		Loam	Clay loam		
Permeability (in./hr)	0.2-0.8	0.8-2.5	0.8-2.5	2.5-5.0	0.8-2.5
Available water capacity (in./in. of soil)	0.18-0.20	0.16-0.18	0.18-0.20	0.15-0.20	0.17-0.19
Electrical conductivity (mmho/cm x 10^3 at 25°C)	0-4.0	4.0-10.0	8.0-15.0	4.0-12.0	2.0-12.0
Percent passing sieve:					
No. 4 (4.7 mm)	100	100	100	100	100
No. 10 (2.0 mm)	100	100	100	100	100
No. 200 (0.074 mm)	85-95	60-75	70-80	90-95	60-75
pH (s.u.)	7.4-7.8	7.9-8.4			
Organic carbon (%)		0.20-0.74			0.25-0.74
ASTM classification	A-6	A-4	A-6	A-6, A-7	A-4
Cation exchange capacity (Meq/100 g)		8.6-12.3			12.7-19.2
Moisture at saturation (%)		32-38			32-28

The Arno soils are calcareous and moderately saline. Runoff and permeability are slow and the water-holding capacity is high. Where isolated from surface water bodies, the water table is usually below a depth of 6 ft.

The Harkey soils are strongly calcareous soils that occur on low terraces on the flood plains of major streams. They are naturally free of salts, except in areas adjacent to Pecos River, where the water table is at a depth of less than 5 ft part of the year. Permeability is moderate, and the water-holding capacity is high.

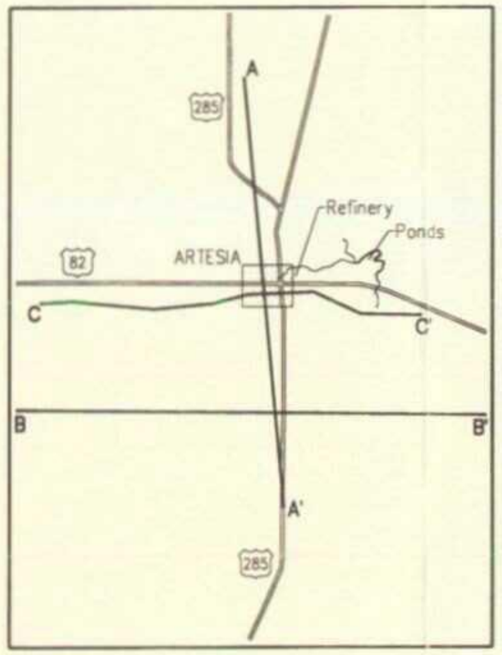
3.4 GEOLOGY

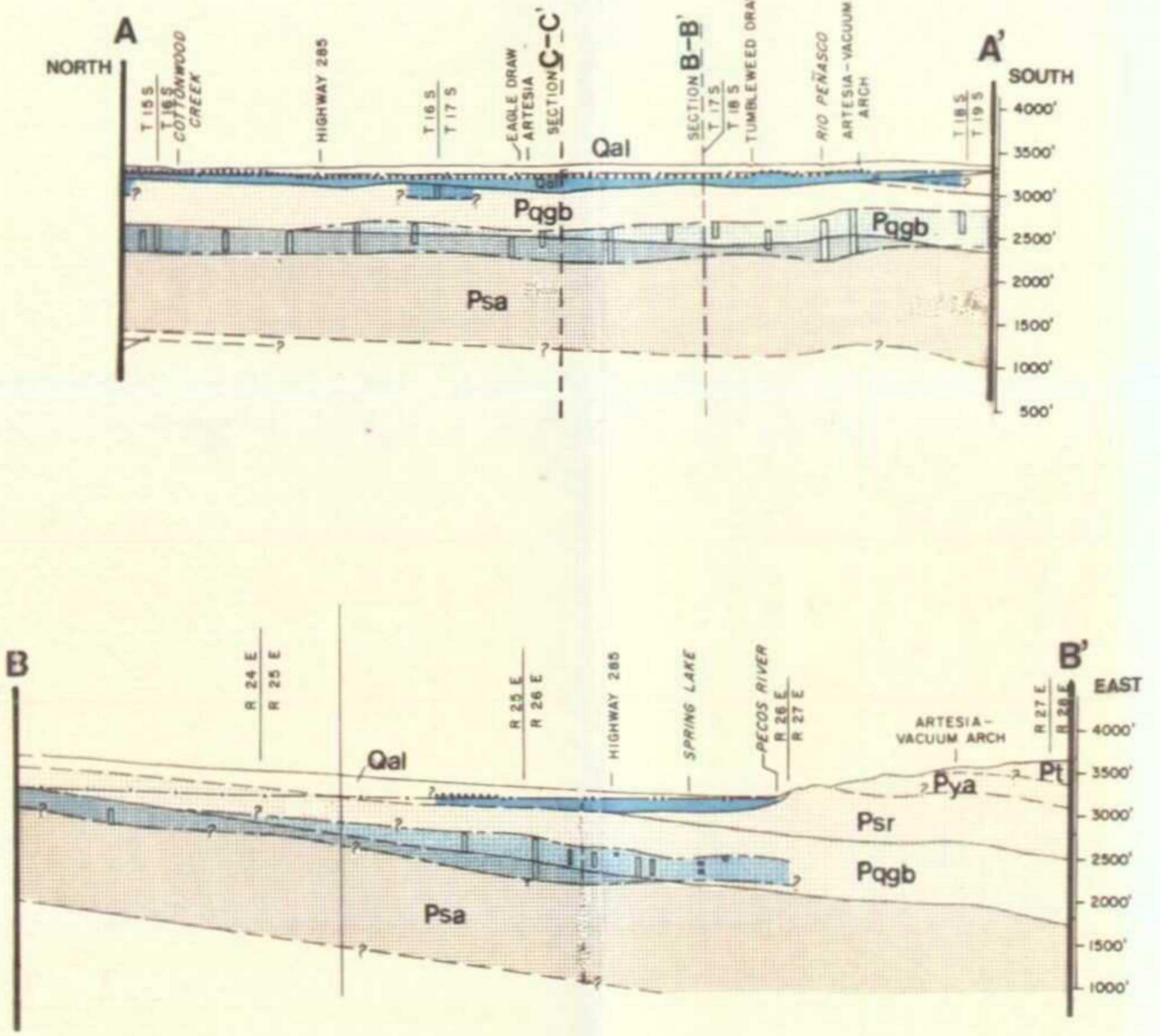
The geology of the Pecos River Valley in the vicinity of the refinery is marked by a sequence of Permian formations at depth overlain unconformably by Quaternary alluvium (Figures 2 and 3) (Lyford, 1973). This uppermost formation is commonly referred to as valley fill alluvium. In the Artesia area the total thickness of the material is approximately 300 ft (Welder, 1983) with all but the upper 50 ft water saturated. The alluvium is overlain by a thin veneer (<20 ft thick) of terrace deposits. The Orchard Park terrace deposit in the area of the refinery is composed of silt interbedded with poorly sorted lenses of pebbles in a silt and sand matrix. Caliche and clay zones are common. In some areas the caliche may be composed of calcium sulfate (gypsum) rocks instead of the more common calcium carbonate.

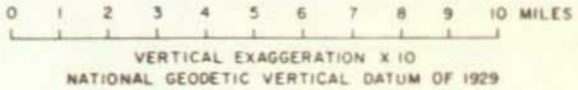
Figure 2. Regional cross-sections A-A', and B-B',

EXPLANATION

Qal	Alluvial deposits– Not mapped in detail might include rocks of Pliocene age and part of the Gatuna Formation of Pleistocene age. Contains the main part of the shallow aquifer of the Roswell basin.
Pt	Tansill Formation
Pya	Yates Formation
Psr	Seven Rivers Formation– (A large part of the shallow aquifer near Lake McMillan)
Pqgb	Queen and Grayburg Formations, undivided. Includes upper part of San Andres Limestone where it is solution altered.
Psa	San Andres Limestone– Contains the main part of the artesian aquifer north of T. 19N. Also includes the "Slaughter zone" (local usage)
—— —?—	Formation contact--Dashed where approximately located; queried where probable
···············	Water-level surface in the shallow aquifer of the Roswell basin, January 1975
—·—·—	Potentiometric surface--Shows level to which water will rise in wells tapping the artesian aquifer of the Roswell basin, January 1975.
—··—··—	Water-level surface and potentiometric surface--Where the two are separated by less than about 20 feet.
— — —?—	Aquifer boundary--Marks the generalized boundaries of the shallow and artesian aquifers of the Roswell basin where their boundaries do not coincide with a formation contact: queried where probable.
▯	Water-producing interval--Projected into the sections from wells generally less than 2 miles away.
🟦	Shallow aquifer of the Roswell basin. Shows general distribution only. Contains some nonproductive zones.
▒	Artesian aquifer of the Roswell basin. Shows general distribution only. Contains some nonproductive zones







VERTICAL EXAGGERATION X 10
NATIONAL GEODETIC VERTICAL DATUM OF 1929

NOTE: MODIFIED FROM WELDER (1983)

KWBES	Regional cross-sections A-A' and B-B'.

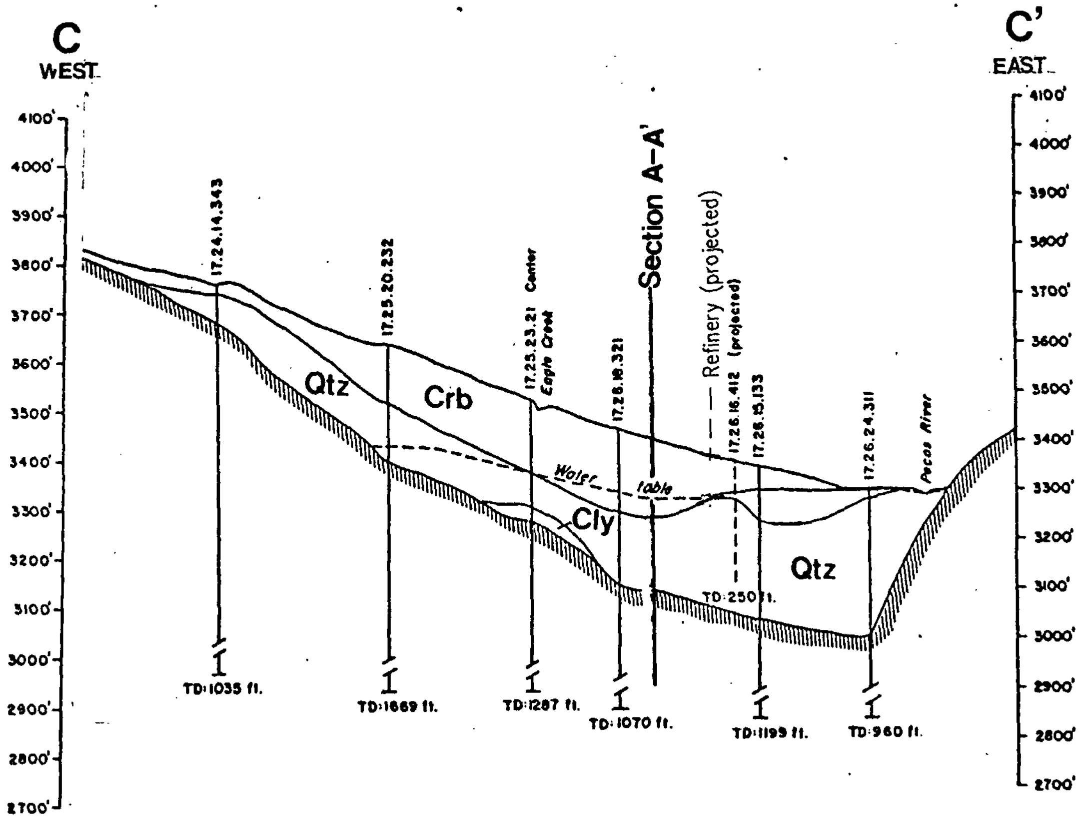
prepared for:
Navajo

PROJECT: 622092005-237	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/26/93
DRAWN BY: RMO	SCALE: AS SHOWN
DATE: 04/26/93	FIGURE: 2

Figure 3. Regional cross-section C-C',

EXPLANATION

Crb	Carbonate–gravel unit
Cly	Clay unit
Qtz	Quartzose unit
▨	Top of Permian rocks
—	Appropriate contact between lithologic units
— - - -	Water table determined from January 1969 water levels. Dashed where approximately located.



NOTE: Modified from Lyford (1973)

0 1 2 MILES

Vertical exaggeration x 53
Datum is mean sea level

KWBES

prepared for:

Navajo

Regional cross–section C–C'.

PROJECT:	622092001–237		
LOCATION:	ARTESIA, NEW MEXICO		
APPR:		DATE:	5/19/92
DRAWN BY:	SSA	SCALE:	AS SHOWN
DATE:	5/19/92	FIGURE:	3

The lower zones of the valley fill alluvium are composed of clay and of carbonate and quartzose sand and gravel. Near the surface, the clays and gypsum are more common, whereas the sand and gravel lenses are thinner and more isolated. The lower quartzose gravel zones are commonly used for groundwater production.

The uppermost Permian formation in the Artesia area is the Seven Rivers Formation, which outcrops east of the Pecos River. This eastward-dipping formation is eroded and buried by the valley fill alluvium at a depth of 300 ft in the area between the river and the refinery. In the vicinity of the refinery, the formation thins, and it disappears farther west. Where the formation is present at depth, it consists of a sequence of evaporites, carbonates, gypsum, and shale, with isolated sand and fractured anhydrite/gypsum lenses.

Below the Seven Rivers Formation, the Permian Queen and Grayburg Formations have been mapped as a single unit by geologists as collectively consisting of about 700 ft of interbedded gypsum, carbonates, sandstone, siltstone, claystone, and dolomite. The Permian San Andres Formation, which lies beneath the Queen and Grayburg Formations, is composed of limestone and dolomite containing irregular and erratic solution cavities, which range up to several feet in diameter. The San Andres Formation is greater than 700 ft in thickness.

The Permian formations dip 1° to 3° toward the southeast, without any reported major structural features (Lyford, 1973; Welder, 1983). The regional geology has been described in previous reports (IT Corp., 1989) and further review is not provided in the RFI Phase II Report unless germane to the investigation.

3.5 HYDROGEOLOGY

The principal aquifers in the Artesia area are within the San Andres Formation and the valley fill alluvium (Welder, 1983). Within the valley fill in the vicinity of the refinery process area is a near-surface water-bearing zone, apparently limited in vertical extent, that is shallow with respect to the surface and also exhibits artesian properties at some monitor wells. To avoid confusion and for consistency, the deeper carbonate aquifer is herein called the *deep artesian aquifer*, whereas the water-bearing zones of the shallower, alluvial valley fill aquifer, including those near the evaporation ponds, are referred to collectively as the *valley fill aquifer*. Adjacent to the refinery, the first water-bearing zone studied during the RFI is referred to as the *near-surface zone* or *first saturated zone.*

3.5.1 Deep Artesian Aquifer

The deep artesian aquifer is closely related to the Permian San Andres Limestone and generally consists of one or more water-producing zones of variable permeability located in the upper portion of the carbonate rocks. However, in the Artesia area, the producing interval rises stratigraphically and includes lower sections of the overlying Grayburg and Queen Formations. Beneath the refinery, the depth to the top of the producing interval is about 670 ft and the aquifer thickness is about 440 ft (Welder, 1983). The Seven Rivers Formation and the other members of the Artesia group are generally considered confining beds, although some pumpage occurs locally from fractures and secondary porosity in the lower Queen and Grayburg members.

The deep artesian aquifer has been heavily developed for industrial, municipal, and agricultural use. The quality of water from this aquifer ranges from 500 to more than 5,000 ppm total dissolved solids (TDS). Water is generally derived from depths ranging from 850 to 1,250 ft below ground surface. The aquifer is recharged in the Sacramento Mountains to the west of Artesia. Extensive use of this aquifer in recent decades has lowered the piezometric head in the aquifer to its current level of 50 to 80 ft below ground level, although extensive rainfall in 1991 brought the water levels in some wells close to the surface.

3.5.2 Valley Fill Aquifer

Quaternary alluvial deposits of sand, silt, clay, and gravel are the main components of the valley fill aquifer (also called the "shallow" aquifer by the NM State Engineer Office). These sediments are about 300 ft thick in the area between the refinery and the Pecos River. Lyford (1973) researched these deposits and described the three principal units in the valley fill as quartzose, clay, and carbonate gravel.

The quartzose unit is considered the primary production unit in the valley fill aquifer. Away from the Pecos River, the unit consists of fragments of sandstone, quartzite, quartz, chert, igneous, and carbonate rocks. The fragments range from medium grained (1/4 mm) to pebble size (16 mm) and commonly are cemented with calcium carbonate (Lyford, 1973). By contrast, in the vicinity of the river, the unit contains principally medium to coarse, uncemented quartz grains.

Silt and clay deposits in the valley fill aquifer are not continuous, but occur as isolated lenses, generally overlying the quartzose unit. Although the clay unit was not identified by Lyford (1973) as occurring in the Artesia area, most logs of wells located immediately to the north and east of the refinery show considerable thicknesses of clays or clay mixtures (e.g., "clay and gyp[sum]," "gumbo"). The thickness of these clay/gypsum mixtures ranges from 20 to 160 ft. The intervals of occurrence differ from well to well, and thin zones of sand or gravels are interspersed in the upper 100 ft. Drillers seeking deep artesian water drill through the valley fill zone and usually log large sections of the intervening zones as "clay and gyp." This lack of detail makes it difficult to correlate specific zones of coarse-grained sediments within the silt and clay deposits. However, drillers wanting to complete wells in the valley fill tend to be more careful in their descriptions and are more likely to record small-scale changes in lithology.

The carbonate-gravel unit described by Lyford (1973) blankets the other valley fill units and forms a fairly uniform slope from the Permian rock outcrop areas on the west side of the valley east to the Pecos River floodplain. The unit consists generally of coarse gravel along major drainageways and of calcareous silt and thin masses of caliche in interstream areas.

Welder (1983) believed that the carbonate-gravel unit includes the Lakewood, Orchard Park, and Blackdom terrace deposits described in detail by earlier authors and summarized by Kelley (1971) in his study of the Pecos Valley. The Lakewood deposits, the lowest of the three terrace units, essentially are the current alluvial sediments in the floodplain along the river. Lakewood deposits consist of sandy brown silt with lenses of gravel and some localized caliche in higher parts. Sediments of the Orchard Park deposit are 5 to 25 ft higher than those that make up the Lakewood terrace deposits, whereas west of Artesia, sediments of the Blackdom terrace are 40 to 60 ft higher than the Orchard Park deposits.

After examination of drillers' reports, Welder (1983) reported that the valley fill wells tap from one to five water-producing zones. Thicknesses of up to 170 ft have been reported for water-production zones, but most are less than 20 ft. Producing zones are principally sand and gravel separated by less permeable lenses of silt and clay. Wells in the valley fill are completed at depths from 125 ft to deeper than 300 ft, but most in the Artesia area are between 200 and 300 ft deep. Water levels in the valley fill range from 40 to 60 ft below ground level, and the formation yields water containing 500 to 1,500 ppm TDS. The average transmissibility of the alluvium has been estimated at 100,000 to 150,000 and the average coefficient of storage at about 10% (Hendrickson and Jones, 1952).

Recharge of the shallow valley fill aquifer is generally attributed to irrigation return flow from pumpage in both the valley fill and the deep artesian aquifers and from infiltration from the Pecos River. In areas of the valley where the San Andres and the valley fill aquifers are hydraulically connected in the subsurface, water tends to flow up from the deep to the shallow aquifer. The general direction of groundwater flow in the valley fill aquifer follows the regional stratigraphic dip eastward toward the Pecos River, then southward subparallel to the river. Above Artesia the river has been a gaining stream for most of the period of record (Welder, 1983). The potentiometric surface of the shallow aquifer slopes gently east and southeast, following regional stratigraphic dips. However, south of Artesia in the vicinity and immediately east of Highway 285, heavy pumping between 1938 and 1975 reversed the hydraulic gradient. In this area, the potentiometric surface forms a shallow trough owing to extensive water use for irrigation.

Adjacent to the Pecos River, the valley fill alluvium contains groundwater at a depth of 6 to 12 ft. Historically, this shallow water has not been utilized owing to its poor quality, with TDS levels commonly in excess of 15,000 mg/L. The alluvium is predominantly silty sand, which possibly contains lenses of higher permeability material. Groundwater flow is subparallel to the Pecos River Valley, and is generally toward the river, although during periods of high river flow, the hydraulic gradient may be away from the river into the alluvium. However, this reversal has not been adequately documented.

3.5.3 Near-Surface Saturated Zone

The agricultural land at Artesia is part of the Orchard Park deposit, which forms a thin veneer overlying older alluvium. The Orchard Park deposit is described as consisting of silt and sand, with some thin clay lenses and pebbly beds and chalky caliche common in upper areas of the deposit. Both the caliche and thin pebble beds were found during the drilling of monitor wells and borings during this and earlier site investigations. However, thick, extensive clay zones were also found in these deposits.

According to lithologic logs from monitor wells installed near the refinery process area during separate investigations, a near-surface saturated zone overlies the main valley fill alluvium in that vicinity and contains water of poor quality in fractured caliche and sand and gravel lenses at depths of 15 to 30 ft. This water is under artesian pressure with static water levels 3 to 5 ft above the saturated zones. Most wells and piezometers drilled near and adjacent to the ditch for the current study were under some artesian pressure as shown in the drilling log records. The exception was piezometer NP-3 drilled on the north side of Eagle Creek. Locally, this uppermost water zone may be connected to and recharged by Eagle Creek west of the refinery. The most likely discharge zones are the marshes and shallow alluvium along the west side of the Pecos River. Closer to the river, this shallow zone may have been utilized to provide low-quality water for stock use, but it is not known to have any current use. The water in this zone is highly variable in quality, volume, areal extent, and saturated thickness.

3.6 IDENTIFICATION OF POTENTIAL RECEPTORS

3.6.1 Previous Reviews

The community of Artesia is located directly adjacent to the facility. The EPA's Preliminary Review (PR) conducted at the facility concluded that it does not appear likely that releases from SWMUs at the refinery would affect groundwater quality in the deeper aquifers (San Andres and valley fill formations). Artesian pressure and depth from ground surface are apparently adequate to prevent downward migration of waste constituents. Additionally, public water supply wells are located to the west and upgradient of the refinery process areas.

The PR indicated that the deep aquifers (San Andres and valley fill formations) have been extensively developed for irrigation purposes but the shallow groundwater in the Pecos River Valley alluvium near the evaporation ponds is not currently utilized, except possibly for isolated stock use, owing to poor water quality. The PR concluded that because the river alluvium's westernmost extent is approximately 2.5 miles east of the city of Artesia, a release of waste constituents to groundwater from the SWMUs constructed in the alluvium would not pose a significant health threat to the population of Artesia.

The PR indicated that the Three-Mile Ditch and evaporation ponds could be susceptible to inundation in the event of major flooding. The PR report speculated that in the event of inundation, hazardous waste constituents contained in these SWMUs could be released to surface water. The PR concluded that it is unlikely that any public water supplies would be affected by releases into the Pecos River. Deep aquifers are used for water supplies in the Artesia area and the wells are located at least 3 miles west of the river.

3.6.2 Environmental Receptors — Three-Mile Ditch

Three-Mile Ditch formerly functioned as an unlined wastewater conveyance which conveyed various refinery wastewater streams to the facility surface impoundment system located adjacent to the Pecos River east of the town of Artesia. The Phase I RFI investigation discussed evidence of historical episodes in which wastewaters and waste materials overtopped the ditch in at least one location. Thus, the potential may have existed for wastewaters and waste materials to have entered Eagle Creek, an ephemeral creek which is adjacent to Three-Mile Ditch along some portions of the unit. Potential environmental receptors via the surface water pathway would include:

- aquatic invertebrates;
- minnows;
- aquatic plants and algae located in scattered shallow pools within the creek bed; and
- amphibians, reptiles, birds, and mammals that might utilize the intermittent pools as a source for water and/or food.

The unit is now covered by several feet of clean fill material. As a result, direct exposure of soil-borne contaminants does not currently constitute a potential exposure pathway for environmental receptors. The land bordering Three-Mile Ditch is used for agricultural purposes (e.g., pecan groves, cattle grazing). These privately held properties are fenced, thereby preventing direct public access to the SWMUs.

No utilization of shallow groundwater in the vicinity of the unit currently exists. Further, the poor quality of the shallow groundwater and low aquifer yield greatly diminish the potential that such utilization will occur at a future date.

3.6.3 Environmental Receptors — Evaporation Ponds

Pond 1 is surrounded by a berm maintained at a height of several feet above the surface of the impoundment. All stormwater runoff is contained within the unit, so that the potential for exposure of contaminants to environmental receptors via stormwater runoff is low.

Soils contained within the Pond 1 unit are currently undergoing active remediation to degrade residual hydrocarbon constituents. As a result, unit soils do not support a vegetative cover at this time. Therefore, the unit does not represent a potential habitat for invertebrate and animal receptors. Exposure to such receptors is essentially limited to infrequent events in which mammals such as coyote or deer briefly traverse the unit when moving from one area to another. It is not probable that the concentrations of waste constituents known to be present within the unit result in significant exposure to environmental receptors via such infrequent and short-term transits across the surface of the unit.

The active effluent pond complex occasionally serves as a temporary resting area for small numbers of various species of migratory waterfowl, which typically congregate in the large open areas at the northern and eastern ends of the ponds. Some birds have been observed to nest in the above-water branches of submerged vegetation present near the center of the ponds. Because the pond complex does not function as a general feeding habitat for waterfowl or other wildlife, waterfowl do not experience long-term exposure to surface waters of the pond complex.

The land bordering the evaporation ponds on both sides of the river is used for livestock grazing. These privately held properties are fenced, thereby preventing direct public access to the SWMUs. However, cattle occasionally have been observed in the vicinity of the evaporation ponds apparently having crossed the unfenced areas directly adjacent to the river during periods of low flow.

3.7 ENDANGERED SPECIES

The U.S. Fish and Wildlife Service (FWS) has previously identified four federally listed endangered species as possibility occurring near the Pecos River within the general area of the Navajo refinery: Gambusia nobilis (Pecos gambusia); Haliaeetus leucocephalus (bald eagle);

Falco perigrinus anatum (American peregrine falcon); and Mustela nigripes (black-footed ferret) (U.S. Dept. of the Interior, 1981).

The Pecos gambusia is a freshwater fish restricted in range to the Pecos River drainage basin of Texas and New Mexico. According to the FWS, Pecos gambusia is no longer extant in the mainstream of the Pecos River, but is limited a few tributary streams.

The bald eagle is not known to nest in New Mexico, although several hundred bald eagles are typically known to overwinter in the state.

The peregrine falcon is relatively rare in New Mexico, and no critical habitat determinations have been made for this species in the state. However, since it prefers to nest in cliffs generally 200 to 300 feet in height, it is unlikely that this species will be found within the vicinity of Three-Mile Ditch or the facility evaporation ponds.

The black-footed ferret is generally found in association with prairie dog towns. There are no recent records of the occurrence of this species in southeastern New Mexico (U.S. Dept. of the Interior, 1981).

4.0 SOURCE CHARACTERIZATION

4.1 FACILITY BACKGROUND

The Navajo Refinery is located at 501 East Main Street in Artesia, Eddy County, New Mexico, as shown in Figure 1.

The ownership of the facility has changed several times since the petroleum refinery began operations in the 1930s. In 1969, Navajo purchased both the North and South Divisions at the facility and began to integrate operations into a single refinery capable of processing New Mexico sour (i.e., asphalt-based) crude in the South Division and New Mexico intermediate (i.e., paraffin-based) crude in the smaller North Division. The facility has the capacity to refine about 60,000 barrels of crude oil per day, of which each division produces half.

The major refining processes at the facility are

- crude oil fractionation
- fluidized catalytic cracking
- alkylation
- reforming
- desulfurization

Auxiliary activities associated with these processes separate impurities from the feedstocks and products or are required for the operation and maintenance of the refinery. The units associated with these auxiliary activities include boilers, cooling towers, storage tanks, water purification facilities, desalting units, and drying and sweetening units.

The production activities at the Navajo Refinery generate a variety of solid wastes and wastewater streams. Prior to the 8 November 1990 effective date of the land disposal restrictions for third-third hazardous wastes, these RCRA wastes (oil/water separator sludges, heat exchanger bundle cleaning sludges, slop oil emulsion solids, and, when produced, leaded tank bottoms) were disposed at the facility's RCRA-permitted North Colony Landfarm. Subsequent to that date, Navajo recycles much of its hazardous waste and consolidates the remainder for shipment to disposal facilities outside New Mexico. The wastewater management system presently employed by Navajo consists of a wastewater treatment plant that discharges via a closed conduit to a system of evaporation ponds. The Truck Bypass

Landfarm receives nonhazardous solid wastes, including hydrocarbon-contaminated soils, unleaded tank bottoms, and various other nonhazardous hydrocarbon and soil materials.

4.2 DESCRIPTION OF SWMUs

The RFI Phase I Report identified Three-Mile Ditch and the evaporation ponds adjacent to the Pecos River as SWMUs with actual or potential contamination and needing additional soils and groundwater investigation.

4.2.1 Three-Mile Ditch

4.2.1.1 Unit Characteristics

From the 1930s to 1987, a 3-mile-long unlined earthen ditch (approximately 20,000 linear ft) was used to convey process wastewater from the refinery to Evaporation Pond 1. Three-Mile Ditch was constructed in the calcareous soils of the Pima and Karro series (USDA-SCS, 1971), which are moderately permeable and have a high water-holding capacity. The 3- to 4-ft-wide and 1- to 2-ft-deep ditch was bermed along its course to prevent overflow or the influx of surface water. The slope of the ditch is approximately 0.004 ft/ft. Although the ditch approximately parallels the natural drainage of Eagle Creek, it is not in the creek. Furthermore, the base of the conveyance ditch is approximately 5 to 10 ft above the creek bed. As the ditch approaches the Pecos River, its course shifts away from Eagle Creek, turning south toward the evaporation ponds.

Three-Mile Ditch originated at the discharge from the oil/water separator on the northeast side of the refinery, with a single tributary ditch from the southern half of the refinery. The system worked via gravity flow. The ditch was periodically cleared of surface debris and also dredged with a backhoe. The waste material removed from the bottom of the ditch was placed along the berms. None of the ditch waste was removed from the site. The berms were dozed into the ditch for approximately 4,500 ft at the eastern end in 1988 by the owners of the adjoining properties. An estimated 3,400 tons of waste material reportedly remains in the ditch.

4.2.1.2 Waste Characteristics

As discussed in Section 3.1.1.1 of the 1992 RFI Phase II Workplan, the available soils data adequately characterize the waste materials and characteristics residing in the Three-Mile Ditch, with both metals and semivolatile organic waste constituents found primarily in association with a relatively concentrated and refractory hydrocarbon fraction, which is readily identifiable by simple visual means.

4.2.2 Evaporation Ponds

4.2.2.1 Unit Characteristics

The evaporation ponds east of the Navajo facility receive approximately 650,000 gallons of wastewater per day from the refinery wastewater treatment plant, via a 20,000-linear-ft enclosed conduit. The conduit, constructed of high-density polyethylene with thermally welded joints, replaced the previously described open earthen ditch in 1987. The conduit discharges to Evaporation Pond 2, whereas the ditch discharged to Evaporation Pond 1. The volume being received by the ponds is presently being reduced by the addition of a reverse osmosis unit to treat raw water by removing salts thereby reducing the amount used in the cooling systems.

The pond series is numbered from upstream to downstream as Ponds 1, 2, 3, 5 and 6. Pond 1, which is out of service, reportedly contains approximately 60,000 tons of waste material, with a surface area of about 15.7 acres. Ponds 2 through 6 are essentially a single pond, because the dikes separating the ponds have been breached and are submerged in some locations. The total acreage of the active pond area is approximately 91 acres.

The ponds are constructed in the alluvium collected on the Pecos River floodplain, and are within 100 ft of the river in some places. These soils have a moderate permeability and high water-holding capacity. Depending on location relative to the river, the base of the ponds is approximately 2 to 10 ft above the surface of the Pecos River. The earthen dikes surrounding the ponds are 5 to 10 ft high and approximately 25 to 50 ft wide at the base. The dikes serve to keep the wastewater in and surface runoff out. At Evaporation Pond 1, the dike construction techniques resulted in a 20- to 30-ft-wide "trench" along the inner base of the dike. Thus, the center of the pond has a higher surface elevation than the zone around the rim of the pond.

Assuming an average depth of 5 ft for the solids in Pond 1, Pond 1 contains approximately 3.43 million ft^3, or 127,000 yd^3, of solids. Based on the ground surface elevations of the surrounding monitor wells, the maximum depth of water in the active ponds ranges between 3.4 and 7.0 ft, with an approximate average depth of 5.5 ft. The total maximum volume is estimated at about 177 million gallons, or 544 acre-ft. Because some of the volume is occupied by the submerged dikes of the original ponds, this maximum volume estimate may be slightly greater than the available capacity.

Solids at Pond 1 are currently undergoing initial remediation activities. A trackhoe is currently engaged in mechanical mixing of heavy surficial sludge deposits with adjacent soils in order to develop a firm base upon which to implement further remedial activities.

Navajo has been and is currently remediating hydrocarbon-contaminated soils in Pond 1. Appendix K presents initial monitoring data for total petroleum hydrocarbon (TPH) concentrations in Pond 1 surface soils, and the sample locations associated with the data are presented in Figure K-1 located in that Appendix.

4.2.2.2 Waste Characteristics

For purposes of general comparison with groundwater samples obtained from monitor wells in the vicinity of the evaporation ponds, a water grab sample was collected from the active area of the evaporation ponds 20 November 1992. For purposes of state permit compliance requirements, a wastewater grab sample of the evaporation pond influent also was collected at the pipeline intake on 11 February 1993. Analytical data for volatile and semivolatile constituents and metals of concern are summarized in Table 3. However, it is well recognized that data obtained from a grab sample may not be representative of overall wastewater quality, because the quantities and types of wastewater constituents may fluctuate frequently. Further, the Navajo wastewater treatment system has been upgraded since the sampling event, resulting in a general improvement of wastewater quality. Historical and current analytical information for the wasterwater effluent stream and evaporation pond (excluding data in the Phase I and II reports) is reported and tabulated in Appendix C.

Table 3. Summary of analytical data for refinery wastewater effluent and Evaporation Pond wastewater.

Constituent Sample date	Wastewater effluent concentration (mg/L) [a] 11 March 93	Evaporation pond concentration (mg/L) [b] 20 November 92
Acetone	NA	0.092
Benzene	0.267	0.043
Carbon disulfide	NA	0.032
Ethylbenzene	0.253	0.016
Toluene	0.788	0.061
m, p-xylene	0.444	NA
o-xylene	0.232	NA
Total xylenes	NA	0.045
Methylene chloride	0.008.	<0.005
2,4-dimethylphenol	0.240	0.180
2-methylphenol	0.750	NA
4-methylphenol	1.60	NA
Phenol	1.90	<0.05
1-methylnaphthalene	0.031	NA
2-methylnaphthalene	0.029	<0.05
Naphthalene	0.029	<0.05
Arsenic	0.042	0.167
Chromium	0.04	<0.02
Lead	<0.01	<0.02

a = EPA SW-846 Methods: BTEX — 8020; halogenated volatiles — 8010; semivolatiles — 8270; arsenic — 7061; chromium — 6010; lead — 7421.

b= EPA SW-846 Methods: volatiles — 8240; semivolatiles — 8270; arsenic — 7061; chromium — 7191; lead — 7421.

NA= Not analyzed.

5.0 REVIEW OF RFI PHASE I INVESTIGATION: THREE-MILE DITCH

The following sections include a review of the data presented in the RFI Phase I Report for soils, surface sediments in Eagle Creek, and groundwater in the vicinity of Three-Mile Ditch. Summary data tables from the Phase I Report are included in Appendix D.

5.1 SOILS

The analytical data obtained from soil samples collected from selected trench and boring locations along Three-Mile Ditch during the RFI Phase I soils investigation indicate distinct and consistent trends. Relevant data from the 48 samples collected from the 15 trenches (NMD-TR-S1, NMD-TR-000, and NMD-TR-004 through -013) and three soil borings (NMD-TR-001 through -003) completed at approximately 1,500-ft intervals along the ditch are included in Appendix D to this report.

Analytical results for volatile organic compounds indicated that the overall incidence and concentration levels for volatile constituents in samples obtained from the ditch were negligible (RFI Phase I Report, table 5.6).

In reference to semivolatile constituents, 10 of the 48 samples exhibited detectable concentrations for 11 to 14 semivolatile constituents. Cumulative (total semivolatiles) concentrations exceeded 50 ppm for the 10 samples (RFI Phase I Report, table 5.7). The same samples also exhibited oil and grease concentrations greater than 2%, and eight of the 10 samples exhibited oil and grease concentrations of 5% or greater. The overall average oil and grease concentration for the 10 samples was 8.6%. Thus, elevated semivolatile concentrations were consistently found to be linked to the presence of elevated oil and grease concentrations.

Of the 12 metals for which the RFI Phase I ditch samples were analyzed, metal constituents exhibiting significant concentration elevations over background values were, in order of frequency, chromium, lead, and to a lesser extent, arsenic and zinc (RFI Phase I Report, tables 5.8 and 5.9). As was the case for semivolatile constituents, elevated concentration levels for those metal constituents are generally linked to high oil and grease concentrations. For instance, of the 12 trench samples exhibiting total chromium concentrations in excess of 400 ppm, all 12 samples also exhibited oil and grease concentrations greater than 4% (10.3% average), whereas three of the four samples exhibiting total chromium concentrations between 100 to 400 ppm also exhibited oil and grease concentrations greater than 1% (3.4% average) (RFI Phase I

Report, tables 5.8 and 5.9). Similar correlations with oil and grease concentrations were observed for total lead, arsenic, and zinc.

Analysis of the RFI Phase I ditch samples also revealed a relationship between metal constituent concentrations and sample depth. During the Phase I sample collection, trench samples were collected from the original ditch surface, midpoint of the contaminated ditch materials, interface of the ditch materials with uncontaminated soils, and 3 ft below the visible zone of contamination (sample depth location designations "NMD-TR-XXX-01" through "NMD-TR-XXX-04," respectively). Data for those samples show that the incidence of samples possessing significantly elevated levels for chromium is highest at the original ditch surface, and that successive samples obtained at greater depth exhibit declining levels for that constituent.

Sample data for lead are somewhat less consistent, but as true for chromium, the data demonstrate that the number of samples exhibiting concentrations greater than 100 mg/kg declines significantly between the top and base of the zone of ditch contamination. No metal concentrations were found to be elevated above background concentrations in visually clean soils below the zone of contamination (sample depth location "-04" series samples).

The data set resulting from the RFI Phase I soils investigation of Three-Mile Ditch indicates that:

- elevated constituent concentrations are primarily, if not exclusively, limited to zones that are visually apparent on the basis of hydrocarbon contamination
- chromium and lead are the primary constituents of concern
- chromium and lead concentrations are most elevated at the top of the sludge profile and generally decline with increasing depth through the zone of contamination

In conclusion, the available soils data provide an adequate characterization of waste materials and constituents resident within the Three-Mile Ditch unit. These data strongly suggest that both metals and semivolatile waste constituents are found primarily in association with a relatively concentrated and refractory hydrocarbon fraction that is readily identifiable by simple visual means.

However, the Phase I investigation of soils in the Three-Mile Ditch unit was insufficiently focused to address specific regulatory concerns regarding the disposition of excavated materials.

5.2 EAGLE CREEK SEDIMENTS

Eagle Creek functions as a major stormwater runoff conveyance from upgradient runoff areas originating in the city of Artesia (including city streets, parking lots, industrial areas, etc.), as well as for outlying agricultural production areas. It is routinely subject to intense scouring action resulting from periodic storm events.

No significant or widespread contamination was evidenced from the RFI Phase I analytical results for the sediment samples collected at several locations along Eagle Creek, the ephemeral stream adjacent to Three-Mile Ditch (RFI Phase I Report, tables 5.16 and 5.17). The analytical results reveal that no evidence of contamination by either volatile, semivolatile, or metal constituents was found in sediment samples obtained from Eagle Creek in areas where it is proximal to Three-Mile Ditch. Thus, there is no evidence to suggest that the environmental quality of the creek has been impacted by its proximity to the ditch.

5.3 GROUNDWATER

Review of available information from the Phase I report (including data from earlier investigations) indicates that groundwater may be contaminated in the immediate vicinity of the ditch where the ditch intersects shallow or perched groundwater. The Phase I investigation determined that ditch contamination intersected groundwater at trenches NMD-TR-004, -005, and -009 east of the refinery. Groundwater in the area of trench NMD-TR-005 was investigated during Phase I using monitor wells MW-8 and MW-9, which had been previously installed near the center of the course of the ditch, but monitoring was not similarly performed at the other two trenches. However, the Phase I study was not designed to document groundwater and its possible contamination at all locations along the ditch. In fact, for a number of trenches, deep soil contamination was not found and/or contact with the groundwater was not made.

Analytical results from the Phase I sampling of groundwater from monitor wells MW-8 and MW-9 and monitor wells MW-30, MW-45, MW-46, and MW-47 at the western end of the ditch, near the refinery process area, included no detections of volatile and semivolatile organic compounds other than the common laboratory contaminant bis(2-ethylhexyl)phthalate (RFI Phase I Report, table 5.20).

Analysis for metals constituents in the groundwater samples from the monitor wells included elevated chromium and nickel levels in MW-8 and MW-9 and elevated lead values in MW-30, MW-45, and MW-46 (RFI Phase I Report, table 5.21).

Inorganic compound analytical data for the groundwater samples confirmed the generally poor quality of the groundwater within the valley fill alluvium, with TDS values in MW-8 and MW-9 at 5,640 and 5,440 mg/L, respectively (RFI Phase I Report, table 5.22).

6.0 RFI PHASE II INVESTIGATION — THREE-MILE DITCH

6.1 SOILS

The RFI Phase II soil investigation for Three-Mile Ditch was designed to provide confirmation of the findings obtained by the RFI Phase I investigation of the unit, provide additional data to be used in the development of an estimate for the total volume of sediment materials in the unit, and evaluate the status of the affected media in terms of toxicity characteristic (TC) testing. Sediment samples were also collected from Eagle Creek to also provide confirmation of the findings from the Phase I investigation. The following sections detail sample collection locations and methodology, laboratory analytical data, and the derivation of an estimate for the total volume of contaminated soils residing within the unit.

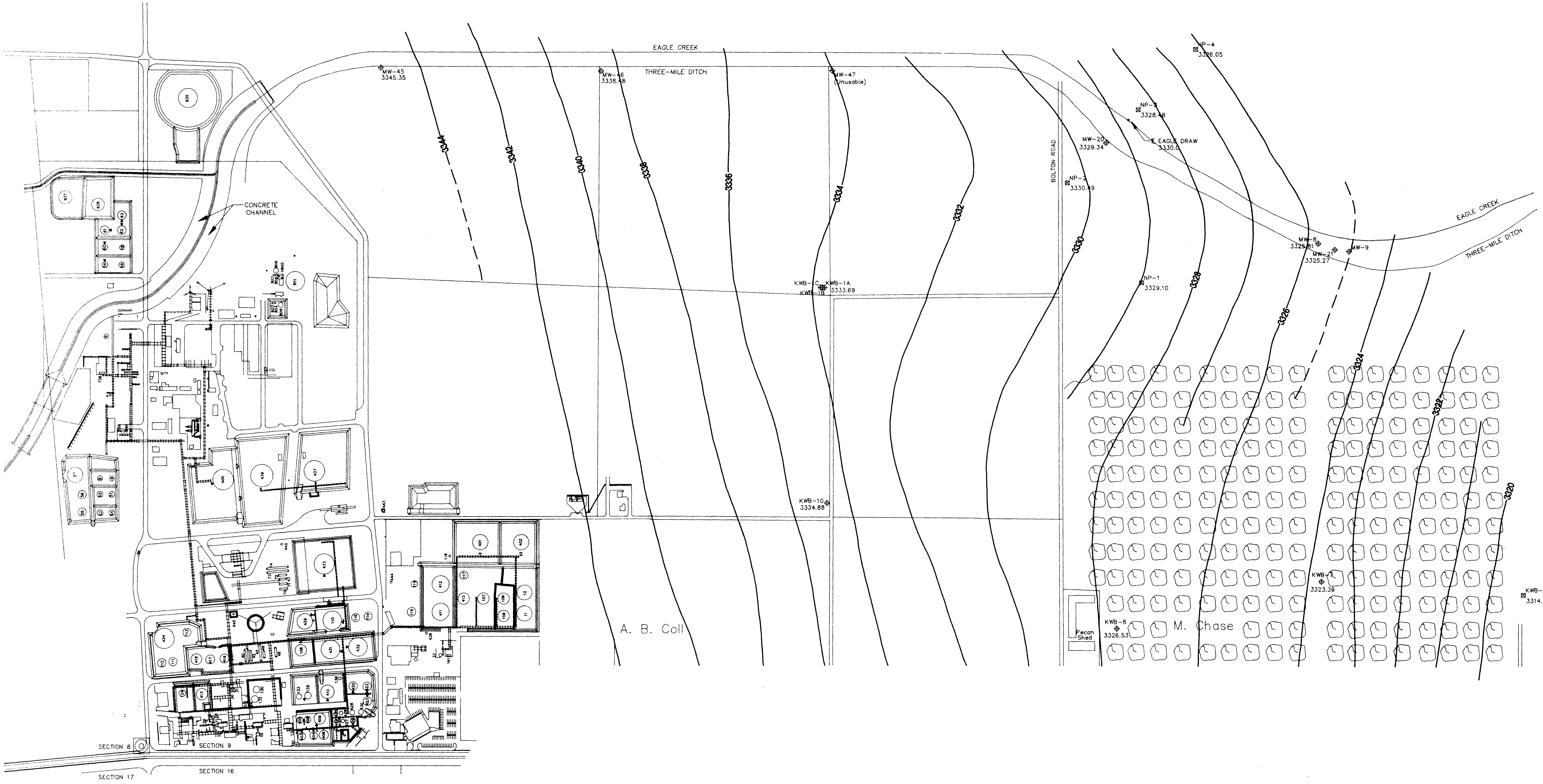
6.1.1 Soil and Sediment Investigation Procedures

The following sections describe the procedures followed during the Three-Mile Ditch soils investigation and the Eagle Creek sediments investigation. All sample collection, handling, and documentation and decontamination and other related field activities conformed to applicable state and EPA requirements.

6.1.1.1 Trench Location and Excavation

As specified in the Navajo 1992 RFI Phase II Workplan, four investigative trench locations were designated at locations along the unit that are situated midway between the trench locations installed during Phase I of the investigation. The Phase II trench locations and their designations are as follows: TMD-TR-001, situated between Phase I trench locations NMD-TR-012 and -013; TMD-TR-002, between NMD-TR-011 and -012; TMD-TR-003, between NMD-TR-008 and -009; and TMD-TR-004, between NMD-TR-004 and -005. A background trench location (BG-TR-001) was selected in an area approximately 115 ft north of monitor well MW-1 The location of the Phase II sample trench locations for Three-Mile Ditch are presented on Figure 4, Sheets A through E. The Phase II sample trench locations were selected on the basis of Phase I study results that indicated contaminated soils or sludge materials extended near or into groundwater in those areas of the unit.

Figure 4-A. Eagle Creek and Three-Mile Ditch RFI Phase II Sample Location Map.



EXPLANATION

KWB-7 ⊕	Monitor well with water elevation
NP-2 ⊠	Piezometer with water elevation
◎	Section corner
	Pecan trees

NOTE: Contour interval 2 feet unless otherwise shown, dashed where approximate

Map compiled from USGS Artesia 7.5 Minute Quadrangle, Navajo Refinery and NM State Highway Department Aerial Mapping, well locations and elevations surveyed 2/93, Jaquess & Associates.

LOCATION: T17S, R26E, NMPM,
Eddy County, New Mexico

300 0 300 900 FEET

KWBES

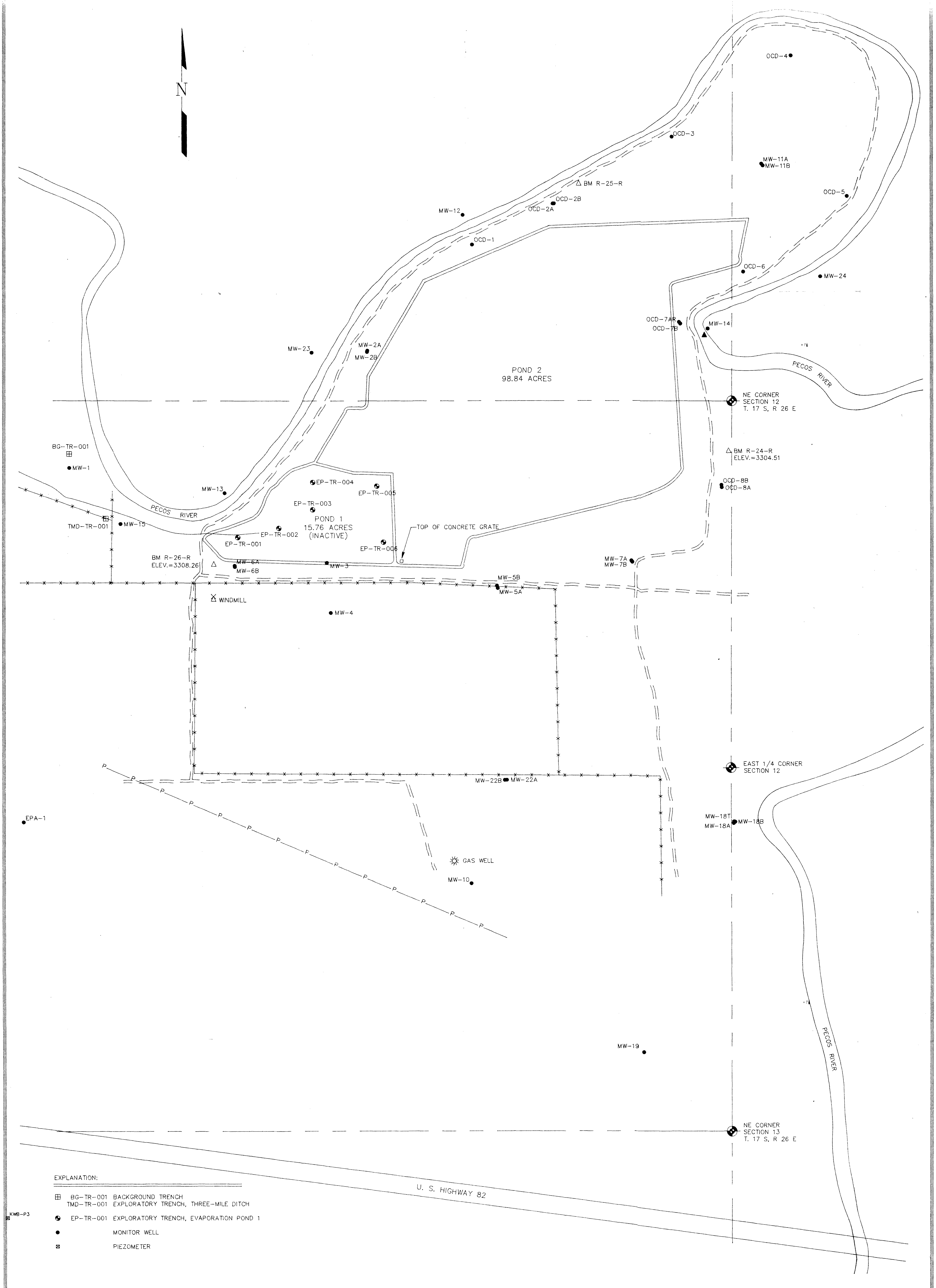
prepared for:

Navajo

Groundwater potentiometric map, March 1993, Three-Mile Ditch, refinery to Bolton Road Area, RFI Phase II.

PROJECT: 622092005-110 (GWPOTEN)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/08/93
DRAWN BY: RMO	SCALE: AS SHOWN
DATE: 04/21/92	FIGURE: 5

Figure 4-B. Eagle Creek and Three-Mile Ditch Truck Bypass Landfarm, RFI Phase II Sample Location Map.



NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

KWBES

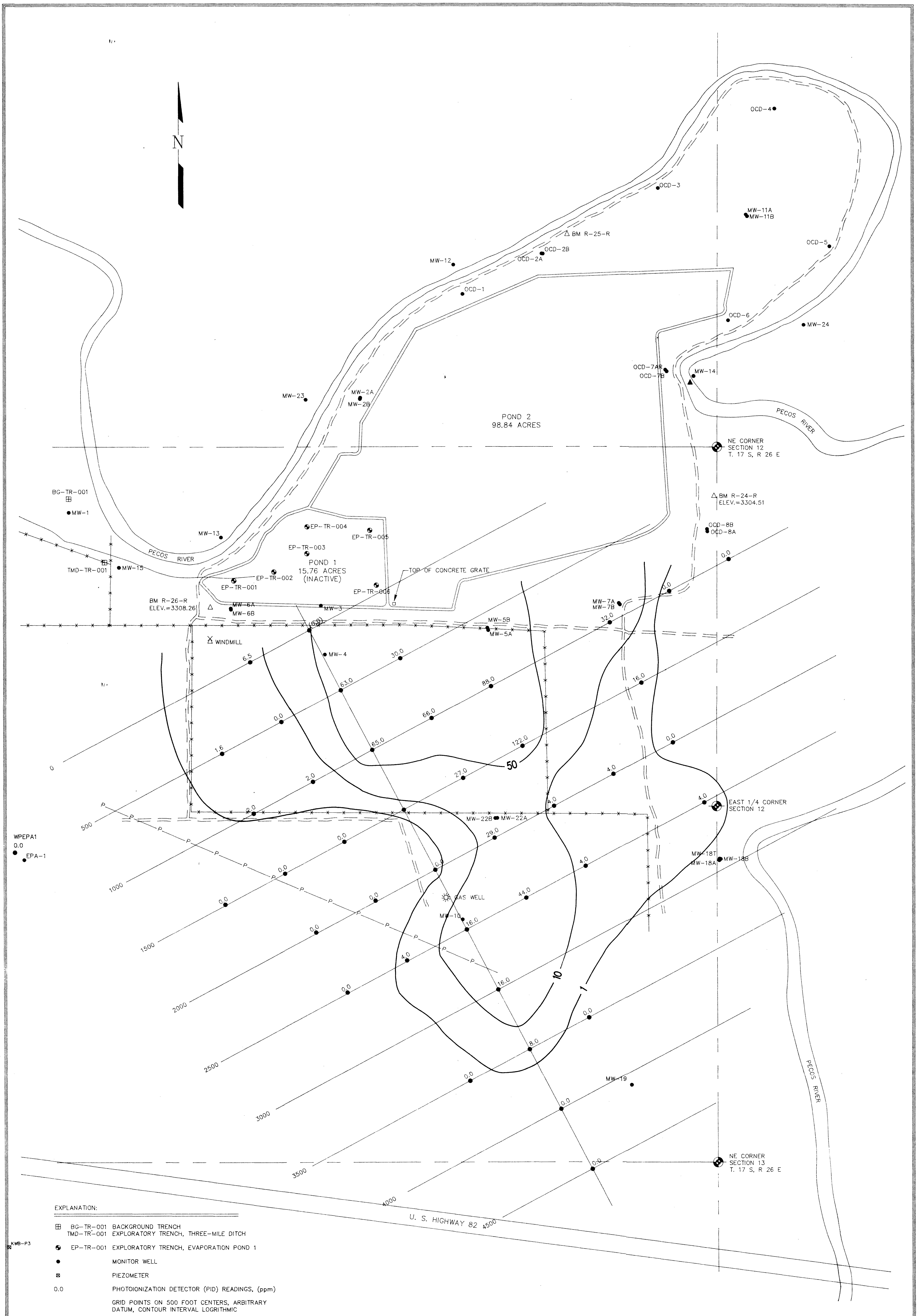
prepared for:

Navajo

Location map for trenches, monitor wells, and piezometers, Evaporation Pond Area, RFI Phase II.

PROJECT: 622092005-110 (NAV-BIG)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/14/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 02/25/93	FIGURE: 6

Figure 4-C. Eagle Creek and Three-Mile Ditch RFI Phase II Sample Location Map.



EXPLANATION:

⊞ BG-TR-001 BACKGROUND TRENCH
TMD-TR-001 EXPLORATORY TRENCH, THREE-MILE DITCH

◕ EP-TR-001 EXPLORATORY TRENCH, EVAPORATION POND 1

● MONITOR WELL

⊠ PIEZOMETER

0.0 PHOTOIONIZATION DETECTOR (PID) READINGS, (ppm)

GRID POINTS ON 500 FOOT CENTERS, ARBITRARY
DATUM, CONTOUR INTERVAL LOGRITHMIC

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

KWBES

prepared for:
Navajo

Well point survey, PID contour map, November 1992, Evaporation Pond Area, RFI Phase II.

PROJECT: 622092005-110 (NAV-BIG)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/14/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 02/25/93	FIGURE: 7

Figure 4-D. Eagle Creek and Three-Mile Ditch RFI Phase II Sample Location Map.

EXPLANATION:

⊞	BG-TR-001 TMD-TR-001	BACKGROUND TRENCH EXPLORATORY TRENCH, THREE-MILE DITCH
◕	EP-TR-001	EXPLORATORY TRENCH, EVAPORATION POND 1
●		MONITOR WELL
⊠		PIEZOMETER
0.0		FLAME IONIZATION DETECTOR (FID) READINGS, (ppm)
		GRID POINTS ON 500 FOOT CENTERS, ARBITRARY DATUM, CONTOUR INTERVAL LOGRITHMIC

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

KWBES

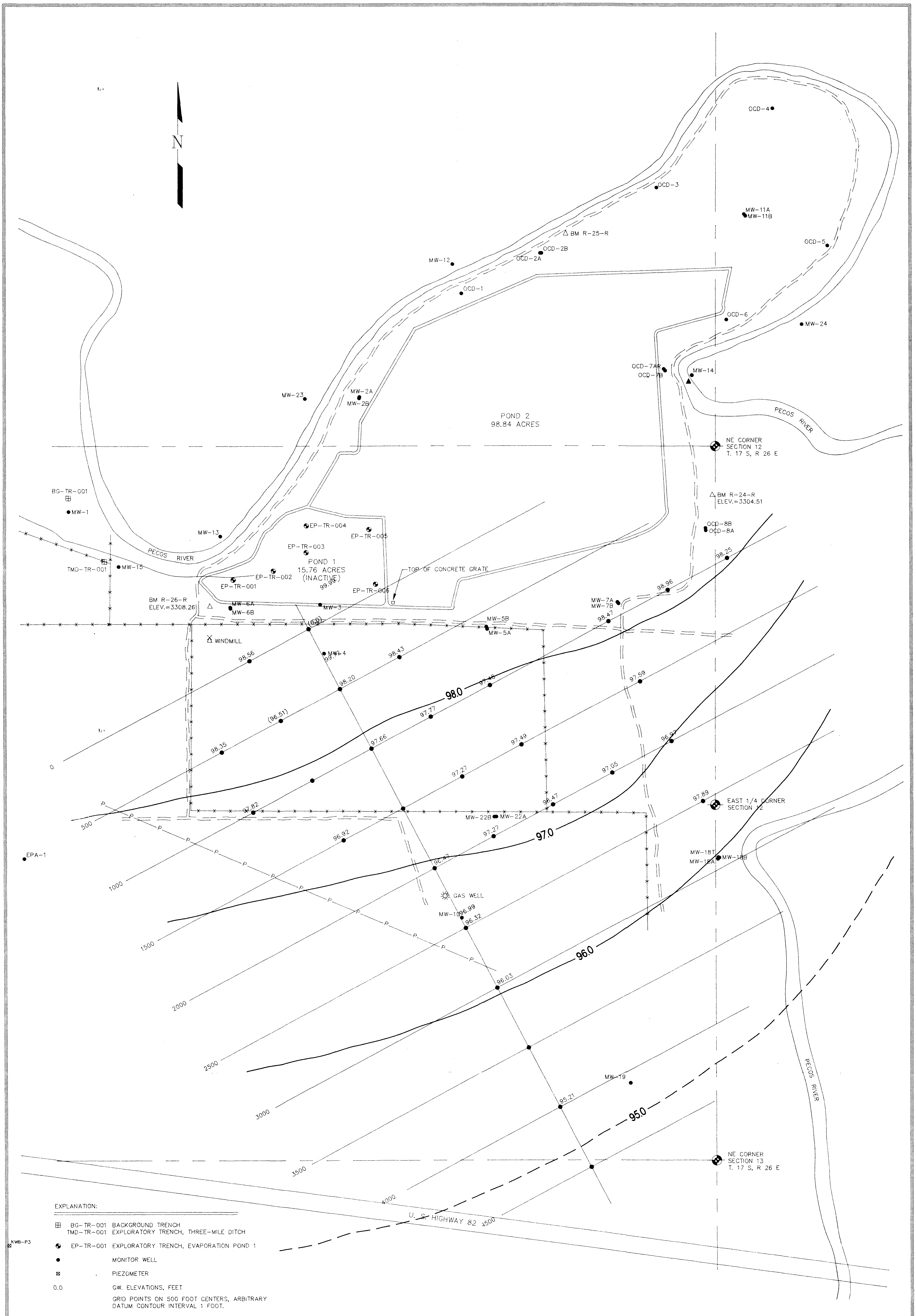
prepared for:

Navajo

Well point survey, FID contour map, November 1992, Evaporation Ponds Area, RFI Phase II.

PROJECT: 622092005-110 (NAV-BIG)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/14/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 02/25/93	FIGURE: 8

Figure 4-E. Eagle Creek and Three-Mile Ditch RFI Phase II Sample Location Map.



EXPLANATION:

⊞	BG-TR-001	BACKGROUND TRENCH
	TMD-TR-001	EXPLORATORY TRENCH, THREE-MILE DITCH
◒	EP-TR-001	EXPLORATORY TRENCH, EVAPORATION POND 1
●		MONITOR WELL
⊠		PIEZOMETER
0.0		GW. ELEVATIONS, FEET
		GRID POINTS ON 500 FOOT CENTERS, ARBITRARY DATUM CONTOUR INTERVAL 1 FOOT.

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

KWBES

Well point survey, groundwater elevations,
November 1992, Evaporation Pond Area,
RFI Phase II.

prepared for:
Navajo

PROJECT: 622092005-110 (NAV-BIG)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/14/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 02/25/93	FIGURE: 9

At each sample trench location, a trackhoe was used to excavate the trench until the upper limit of the water table was encountered. The vertical extent of visual contamination and the total depth from the ground surface to groundwater were measured and recorded in the field logbook. Contaminated soil materials and overlying clean fill materials were segregated in separate stockpiles during excavation. Upon completion of sample collection activities, the excavated trench materials were backfilled into each trench in the approximate order in which the materials were excavated, with the clean fill materials replaced last.

6.1.1.2 *Soil Sampling and Analysis From Trench Excavations*

Sample materials were collected at three points within each trench within the unit: the upper limit, approximate midpoint, and lower limit of the visually determined zone of contamination. For the background trench, samples were collected at depths of 5 and 8 ft. Soil materials from each target zone were collected in the trackhoe bucket, which was then brought to the surface where sample collection activities were completed. A stainless-steel spatula was used to trim the external face of the cutting, and a stainless-steel spoon was used to transfer the soil samples directly from the trackhoe bucket to the appropriate sample containers. At no time did sample team personnel enter the trenches.

Soil samples were collected for analysis for general chemistry parameters (pH, electrical conductivity), percent oil and grease, total metals (arsenic, chromium, lead, nickel, and zinc), Contract Laboratory Program (CLP) Target Compound List volatiles and semivolatiles, and TC constituents. Samples were collected in the order of volatiles, TC constituents, semivolatiles, oil and grease and metals, and general parameters, with sample collection accomplished in a manner to minimize volatilization of the soil samples.

6.1.1.3 *Eagle Creek Sediment Sample Collection and Analysis*

Sediment samples were obtained at the midpoint of the creek bed. At the time of the RFI Phase II sample collection for Eagle Creek, flowing waters were absent from the creek bed. The upgradient sample was collected at mid-creek in an area consisting of damp organic-rich sediments with no standing water. The downgradient sample was collected at mid-creek in a shallow pool (less than 6 in. standing water) that also exhibited organic-rich sediment materials as well as numerous minnows. The samples were excavated using a stainless-steel scoop and then transferred directly to appropriate sample containers. Sample analysis was similar to that listed for the samples collected at Three-Mile Ditch (Section 6.1.1.2, "Soil Sampling and Analysis from Trench Excavations").

The samples were excavated using a stainless-steel scoop and then transferred directly to appropriate sample containers. Sample analysis was similar to that listed for the samples collected at Three-Mile Ditch (Section 6.1.1.2, "Soil Sampling and Analysis from Trench Excavations").

6.1.1.4 *Procedures for Calculating Soil Volume*

EPA Region VI and Navajo have previously discussed the possibility of excavating contaminated materials from Three-Mile Ditch and subsequently conveying the excavated materials to Evaporation Pond 1 for treatment. Therefore, an estimate of the total volume of contaminated soils contained in Three-Mile Ditch was also developed.

Based on visual observations made during the RFI Phase I and Phase II trench excavation activities at Three-Mile Ditch, it was determined that the cross-sectional profile of contaminated soils within the unit was best approximated as a parabola. The area of a parabola is calculated according to the formula

$$A = 2/3\,sh$$

where:

A = area
s = maximum width of the parabola
h = perpendicular height

The three-dimensional volume of materials contained within an extended parabola may then be readily calculated by multiplying the two-dimensional area of the parabola by the appropriate length.

Fifteen sample trenches were excavated from Three-Mile Ditch during the course of RFI Phase I and Phase II activities. At each trench location, the width and depth (h) of visually contaminated materials were recorded and cross-sectional areas were calculated as described. Exceptions to this calculation protocol were made for trench locations NMD-TR-006 and NMD-TR-007. At those locations, because visual contamination was observed as a relatively narrow band, the cross-sectional area was judged to be best approximated as the direct product of the observed width and height of the contaminant band. At sample locations NMD-TR-001 through NMD-TR-003, soil borings were substituted for trench excavations. Because insufficient information was available at those locations, the section of the ditch between trench locations NMD-TR-000 and NMD-TR-004 was considered as a single interval in the calculations.

Fourteen intervals of defined length were then defined on the basis of the sample trenches bracketing each end of a given interval. For each pair of adjacent trench locations defining a particular interval, the two trench cross-sectional areas were averaged to produce a single area value for the interval under consideration. The estimated volume of visually contaminated soil residing within each of the ditch intervals was then calculated on the basis of the interval length and the average cross-sectional area value.

6.1.1.5 Equipment Decontamination

In order to avoid cross-contamination, all hand-operated soil sampling equipment (e.g., spatulas, scoops, bowls, augers) was thoroughly decontaminated prior to reuse. Decontamination consisted of a Liquinox soap wash followed by successive rinses with drinking-quality water and distilled water. All decontamination solutions were collected for discharge into the refinery wastewater treatment system. Any disposable materials that may have been contaminated were collected and placed in appropriate containers for proper disposal.

6.1.2 Results

6.1.2.1 Three-Mile Ditch

Laboratory analytical results for the background and Three-Mile Ditch soil samples are included in Appendix I of this report. Analytical data for volatile organic compounds, oil and grease, semivolatile organic compounds, pH, electrical conductivity, and total metals are presented in this section. Cross-section depictions of the contaminant profiles and sample locations within each trench are presented in Appendix E-1, Figures A through D.

The trench samples from Three-Mile Ditch were analyzed for a total of 35 volatile organic compounds from the EPA's Target Compound List. Each analytical report included in Appendix I lists these compounds. Only six volatile compounds were detected in the trench samples (Table 4). The constituents detected, number of detection events, and concentration ranges (mg/kg) were: acetone — two detections: 0.035 and 0.463; benzene — one detection: 2.68; ethylbenzene — six detections: 0.054 to 16; methylene chloride — two detections: 0.04 and 0.245; toluene — four detections: 0.192 to 12; and total xylenes — six detections: 0.15 to 36.3. Acetone and methylene chloride are common laboratory contaminants. Twenty-one detection events were recorded, including 10 in the upper contaminant zone samples, five in the midzone samples, and six in the lower zone samples.

Values for percent oil and grease for the trench samples collected from Three-Mile Ditch ranged from less than 0.05% to 6.09% (Table 4). However, with the exception of the sample exhibiting the maximum value (TMD-TR-003), all other samples exhibited concentration values less than 1%.

A total of 65 semivolatile organic compounds on the EPA's Target Compound List were analyzed for in the trench soil samples. Four semivolatile constituents were detected in the

Table 4. RFI Phase II soil sampling, Three-Mile Ditch — oil and grease and volatile organic compounds.

Table 4. RFI Phase II soil sampling, Three-Mile Ditch — oil and grease and volatile organic compounds (mg/kg).

Sample	Sample depth (ft)	Oil and grease (%)	Acetone	Benzene	Ethyl-benzene	Methylene chloride	Toluene	Xylenes (total)
BG-TR-001-01	5	<0.05	NA	NA	NA	NA	NA	NA
BG-TR-001-02	8	0.17	NA	NA	NA	NA	NA	NA
TMD-TR-001-01	4.5	0.72	< 0.695	< 0.348	5.55	< 0.348	2.48	13.6
TMD-TR-001-02	9	0.05	< 0.631	< 0.316	2.32	< 0.316	0.798	4.84
TMD-TR-001-03	14	<0.05	< 0.014	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
TMD-TR-001-04	8	<6	< 0.013	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
TMD-TR-002-01	4.5	0.68	< 0.429	2.68	16	< 0.214	12	36.3
TMD-TR-002-02	7.5	0.68	< 1.25	< 0.625	< 0.625	< 0.625	< 0.625	< 0.625
TMD-TR-002-03	11	<0.05	< 0.620	< 0.310	1.34	< 0.310	< 0.310	3.35
TMD-TR-003-01	8.5	<0.05	< 0.013	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
TMD-TR-003-02	11	<0.05	<0.012	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
TMD-TR-003-03	5.5	6.09	< 0.279	< 0.140	2.12	< 0.140	0.192	6.46
TMD-TR-004-01	3.5	0.22	0.463	< 0.032	0.054	< 0.032	< 0.032	0.15
TMD-TR-004-02	6.5	0.05	0.035	< 0.007	< 0.007	0.04	< 0.007	< 0.007
TMD-TR-004-03	8.5	0.05	< 0.013	< 0.007	< 0.007	0.245	< 0.007	< 0.007

NA = not analyzed.

trench samples, including di-n-butyl phthalate, fluorene, 2-methylnaphthalene, and phenanthrene (Table 5). Of a total of 10 detection events, six were recorded for di-n-butyl phthalate. Phthalate compounds are common laboratory contaminants, and are generally recognized to be unreliable indicators of hydrocarbon contamination in environmental samples (Sullivan et al., 1993). Of the remaining detection events, three were obtained for one sample, TMD-TR-001-01, which exhibited detectable levels for fluorene, 2-methylnaphthalene, and phenanthrene, whereas the remaining detection was for phenanthrene at sample location TMD-TR-003-03.

For four of the trench samples analyzed for semivolatile organic constituents (TMD-TR-001-01, 002-01, 002-02, and 003-03), relatively high detection levels were achieved (17, 140, 45, and 240 mg/kg, respectively). According to the designated analytical laboratory (Inter-Mountain Laboratories, Inc.), the cause of the relatively high detection limits achieved for the samples in question resulted from extra dilution steps for sample extracts. Based on the visual appearance of the initial sample extracts, laboratory personnel used professional judgment to dilute the samples to the extent necessary to avoid matrix interference-associated problems such as poor resolution, column overloading, obstruction of injection ports, excessive wear to detector filaments, etc.

Analytical data for pH, electrical conductivity, and metals are presented in Table 6. Soil pH for both the background and unit soil samples averaged about 8.0, with electrical conductivity values for trench samples obtained from the unit significantly lower than those obtained for background samples (averages of 4.7 and 10.2, respectively). A review of the total metals data for unit trench samples indicated that concentrations for the metals of concern were elevated relative to the concentrations exhibited by the background soils. Maximum concentration levels for the metals of concern, in mg/kg, were arsenic — 18.1; chromium — 148; lead — 163; and zinc — 222. However, concentrations exhibited by the majority of the trench soil samples were well below the maximum concentration values measured for these metals.

All trench soil samples collected from Three-Mile Ditch underwent TC Leaching Procedure (TCLP) analysis. None of the trench samples yielded leachate concentrations in excess of the specified regulatory limits for the selected TC constituents.

The estimated cross-sectional area values for the sample trench parameters *s* and *h*, as described in Section 6.1.1.4, are presented in Table 7. The estimated area values at adjacent trench locations were then used to obtain an average cross-sectional value that was assigned to each interval between the adjacent trench locations. Table 8 presents the estimated volumes of visually contaminated soil for each of the defined ditch intervals and the total estimated volume for the entire ditch. The ditch intervals shown in Table 8 are presented in their order of occurrence, beginning at the refinery boundary and extending to Evaporation Pond 1.

Table 5. RFI Phase II soil sampling, Three-Mile Ditch — semivolatile organic compounds.

Table 5. RFI Phase II soil sampling, Three-Mile Ditch — semivolatile organic compounds (mg/kg).

Sample	Di-n-butyl phthalate	Fluorene	2-methyl-naphthalene	Phenanthrene
BG-TR-001-01	NA	NA	NA	NA
BG-TR-001-02	NA	NA	NA	NA
TMD-TR-001-01	< 42.4	22.5	20	77.5
TMD-TR-001-02	2.6	< 0.6	< 0.6	1.1
TMD-TR-001-03	1.7	< 0.7	< 0.7	< 0.7
TMD-TR-001-04	< 1.6	< 0.6	< 0.6	< 0.6
TMD-TR-002-01	< 340	< 140	< 140	234
TMD-TR-002-02	< 110	< 45	< 45	< 45
TMD-TR-002-03	1.8	< 0.4	< 0.4	< 0.4
TMD-TR-003-01	6.6 J	< 0.4	< 0.4	< 0.4
TMD-TR-003-02	2.2	< 0.5	< 0.5	< 0.5
TMD-TR-003-03	< 590	< 240	< 240	310
TMD-TR-004-01	< 22	< 8.7	< 8.7	< 8.7
TMD-TR-004-02	4.2	< 0.7	< 0.7	< 0.7
TMD-TR-004-03	1.9	< 0.6	< 0.6	< 0.6

NA = not analyzed.

Table 6. RFI Phase II soil sampling, Three-Mile Ditch — pH, electrical conductivity, and total metals concentrations (mg/kg).

Table 6. RFI Phase II soil sampling, Three-Mile Ditch — pH, electrical conductivity, and total metals concentrations (mg/kg).

Sample	Sample depth (ft)	pH	Electrical conductivity (mmhos/cm)	Arsenic	Chromium	Lead	Nickel	Zinc
BG-TR-001-01	5	8.2	8.1	1.3	10	6	1	23
BG-TR-001-02	8	7.8	12.4	2.1	13	7	12	34
TMD-TR-001-01	4.5	8.6	6.0	7.1	40	19	30	68
TMD-TR-001-02	9	7.7	5.6	10.6	16	7	12	38
TMD-TR-001-03	14	7.8	3.7	3.6	40	16	25	122
TMD-TR-001-04	8	7.7	6.7	1.8	14	2	5	12
TMD-TR-002-01	4.5	9.3	4.4	18.1	148	55	41	170
TMD-TR-002-02	7.5	7.4	7.4	9.2	32	23	32	83
TMD-TR-002-03	11	7.5	6.5	5.6	28	12	28	68
TMD-TR-003-01	8.5	7.6	1.7	4.8	15	5	17	15
TMD-TR-003-02	11	7.6	1.8	2.2	7	<1.0	11	13
TMD-TR-003-03	5.5	7.2	5.8	2.7	33	163	191	222
TMD-TR-004-01	3.5	8.8	3.9	2.2	34	13	26	80
TMD-TR-004-02	6.5	7.9	4.2	10.2	22	8	28	47
TMD-TR-004-03	8.5	7.7	3.1	16.1	14	7	18	33

Table 7. Values for parabola parameters obtained from the RFI Phase I and II sample trench cross sections at Three-Mile Ditch.

Trench location[a]	Approximate depth to groundwater (ft)[b]	Width (ft)	Depth (ft)	Cross-sectional area (ft^2)
NMD-TR-000	ND	6.6	14	61.6
NMD-TR-001	ND	NA	NA	NA
NMD-TR-002	ND	NA	NA	NA
NMD-TR-003	ND	NA	NA	NA
NMD-TR-004	6.0	30.6	4.4	89.8
NMD-TR-005	6.0	6.0	15.3	61.2
NMD-TR-006	ND	0.4	19.4	8.2
NMD-TR-007	ND	4.8	0.17	0.8
NMD-TR-008	ND	5.8	3.0	11.6
NMD-TR-009	6.5	14.5	7.5	72.5
NMD-TR-010	ND	12.9	3.8	32.3
NMD-TR-011	ND	5.6	6.0	22.4
NMD-TR-012	ND	12.1	6.0	48.4
NMD-TR-013	ND	25.8	5.3	90.3
TMD-TR-001	15	12.0	15.0	120
TMD-TR-002	18	18.0	5.5	66
TMD-TR-003	15	9.0	12.5	75
TMD-TR-004	6.5	5.0	3.5	11.7

NA= Not applicable to soil boring locations.
a= Trench prefix: NMD — RFI Phase I; TMD — RFI Phase II.
ND = Not determined
b= As measured from ground surface immediately above sample collection point.

A volume of 1,023,342 ft^3 of soils exhibiting visual contamination was estimated for Three-Mile Ditch over the distance of approximately 3.6 miles between trench locations NMD-TR-000 and NMD-TR-013. Assuming a total area of approximately 15.7 acres for Evaporation Pond 1, this volume of materials would add 1.5 ft to the elevation of the former surface impoundment. Considering the apparent variability in the amount of contaminants present in different areas of the trench, and the limited database from which the calculations were derived, this estimate must be considered to represent a gross approximation.

Table 8. Estimated volume of visually contaminated soils in Three-Mile Ditch.

Ditch interval	Interval length (ft)	Average cross-sectional area (ft^2)[a]	Calculated soil volume (ft^3)
NMD-TR-000 to NMD-TR-004	6,076	75.7	459,953.2
NMD-TR-004 to TMD-TR-004	535	50.8	27,178
TMD-TR-004 to NMD-TR-005	965	36.5	35,222.5
NMD-TR-005 to NMD-TR-006	1,466	34.7	50,870.2
NMD-TR-006 to NMD-TR-007	1,500	4.5	6,750
NMD-TR-007 to NMD-TR-008	1,380	6.2	8,556
NMD-TR-008 to TMD-TR-003	780	43.3	3,3774
TMD-TR-003 to NMD-TR-009	767	73.8	56,604.6
NMD-TR-009 to NMD-TR-010	1,500	52.4	78,600
NMD-TR-010 to NMD-TR-011	1,367	27.4	37,455.8
NMD-TR-011 to TMD-TR-002	753	44.2	33,282.6
TMD-TR-002 to NMD-TR-012	806	57.2	46,103.2
NMD-TR-012 to TMD-TR-001	720	84.2	6,0624
TMD-TR-001 to NMD-TR-013	840	105.2	88,368
Total	19,455	--	1,023,342

[a]= Calculated from Table 7.

6.1.2.2 *Eagle Creek Sediments*

Sample locations for sediment samples EC-SD-001-01 and EC-SD-002-01 (upgradient background location) are presented in Figure 4. Flowing water was absent from the creek bed at the time of the Phase II sediment sample collection. The upgradient sample was collected from the middle of the creek bed in an area consisting of damp, organic-rich sediments with no standing water. The downgradient sample was collected also from the middle of the creek, in a shallow pool (less than 6 in. of standing water) that exhibited organic-rich materials and contained numerous minnows.

Laboratory analytical results for the sediment samples collected from Eagle Creek are included in Appendix I of this report. The analytical results for chromium and lead in the sediment samples were as follows: EC-SD-001-01: 32 and 29 mg/kg, and EC-SD-002-01: 64 and 92 mg/kg, respectively. The samples also exhibited detectable levels of oil and grease (0.05% and 0.13%, respectively), but background levels for oil and grease in this range are not uncommon for organic-rich sediments.

6.2 GROUNDWATER

6.2.1 Groundwater Investigation Procedures

The objectives of the groundwater investigation program at the Three-Mile Ditch were to determine the lateral and vertical extent and concentration of contamination impacting on groundwater and to facilitate future decision making. This section describes the procedures followed during the groundwater portion of RFI Phase II investigation of this unit. Included are descriptions of drilling and well installation, hydrogeologic characterization, and sample collection.

The procedures presented herein were designed to produce:

- data of a consistently high quality and tailored to the needs and goals of the project
- samples representative of the media under investigation
- samples identified, preserved, and transported in a manner that ensured that they remained intact and produced legally valid data
- data compatible in both type and quality to those produced by previous investigations

All drilling, well installation, well development, groundwater sampling, and other related field activities conformed to state and EPA requirements.

6.2.1.1 Drilling Procedures

This section describes the specific procedures used for drilling monitor wells and piezometers at Three-Mile Ditch. To meet the previously stated objectives, the drilling program was performed by qualified personnel following recognized protocols, with all steps, measurements, and anomalies permanently recorded in the field logbook.

The objectives of the monitor well and piezometer installation program were to

- define the vertical and areal extent of groundwater contamination
- determine the hydrogeologic characteristics of the site
- develop a database for a Corrective Measures Study, if necessary
- supplement the existing monitor well network

6.2.1.1.1 Drilling Methods

The installation of four monitor wells and four piezometers along Three-Mile Ditch during Phase II field investigations during December 1992 and January 1993 was performed by Pool Environmental Drilling (NM license WD 1266), an environmental drilling firm headquartered in Roswell, New Mexico. Procedures specific to the completion of MW-15 and other monitor wells in the area of the evaporation ponds are described in Section 8.3.1.1. A CME 75 hollow-stem dry auger rig mounted on a truck was used to drill each well. Tools and augers were cleaned at the refinery steam rack prior to any drilling. Each well and piezometer boring was advanced using 4.25-in.-I.D. hollow-stem augers with a cutting head on the lead auger. For the optimum recovery of undisturbed cores, a CME 5-ft-recovery split barrel was placed within the augers and the barrel cutting shoe rode 6 in. in advance of the auger head. After each 5-ft interval was advanced, the barrel was retrieved and opened for the geologist to visually classify the subsurface soils. The boring was continued in this manner until the first water-saturated zone was found. Typically, coring would continue another 5 to 10 ft below that depth to ensure that the installation would be a producing well. The 4.25-in. augers were then removed from the boring. For piezometers, 2-in.-I.D. PVC casing was installed. For monitor wells, the hole was first overreamed to total depth with an 8.25-in.-I.D. auger before the placement of 4-in.-I.D. PVC casing.

All soils removed from a boring were placed on plastic sheeting for later collection and disposal by Navajo Refinery personnel.

6.2.1.1.2 Borehole Logs

Core samples and lithologic descriptions acquired during the drilling of both monitor wells and soil borings were recorded on a standard borehole log. The following information was entered in the log or attached to it:

- project name and number
- borehole location and number
- initials of geologist who logged the borehole
- drilling company and method of drilling
- special problems encountered and their resolution
- distinct boundaries between soil types and/or lithologies and depths of occurrence
- depth of first occurrence of groundwater
- description of each soil sample taken, according to the methodology in ASTM D2488-84 "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)," which includes the following:
    - soil type
    - grain size
    - plasticity of fines (nonplastic, low, medium, high)
    - odor, if organic or unusual
    - other observations such as presence of roots or rootholes; mica, gypsum, caliche, or other secondary precipitates; or surface coatings on coarse-grained particles
    - sample depths and sample numbers

6.2.1.1.3 Well Construction

The monitor wells were designed to

- allow sufficient groundwater flow for well sampling
- minimize the passage of formation materials (turbidity)
- provide sufficient structural integrity to prevent the collapse of the intake structure

After drilling, the well casing, screen, filter pack, bentonite seal, and grout were placed within the borehole, and the wellhead was completed with a cement seal and locking surface casing.

The monitor wells were completed with 4-in.-I.D. schedule 40 PVC casing with 0.01-in. machine-slotted screen using 8.25-in. augers. All piezometers were completed with 2-in.-I.D. schedule 40 PVC casing with 0.01-in. machine-slotted screen. The casing sections used are flush-threaded with screw joints. Well logs for the monitor wells and piezometers are shown in Appendix F.

The screened interval ranges from 10 to 15 ft and intercepts the water table (allowing for seasonal fluctuations) in the case of an unconfined aquifer or intercepts the upper confining boundary in the case of a confined aquifer. A 6-in. sediment sump was included below the screen on the casing of each monitor well and piezometer owing to the silty nature of the aquifer. The endings, casings, and screens were stored in factory-applied plastic wrapping until actual installation to prevent the introduction of any contamination.

A sand pack consisting of CSSI 20/40 silica sand was placed using a tremie pipe to ensure that the annular space from the base of the boring to 2 ft above the top of the screen was completely filled. If flowing sands were encountered in the saturated zone the well casing and sand pack were installed within the auger-string to ensure the maintenance of the annular integrity.

The field geologist recorded the start and stop times of the sand packing, the depth intervals in which sand was packed, the amount of sand used, and any problems that arose. The geologist also recorded the type of materials used for packing, including trade name, source, supplier, and typical grain-size distribution.

A bentonite seal with a minimum thickness of 2 ft was placed in the annular space above the sand pack using a tremie pipe and allowed to set-up for at least 30 minutes prior to grouting. The bentonite used was either granular or a slurry sufficiently thick to prevent significant penetration of the underlying sand pack. The geologist recorded the start and stop times of the bentonite seal emplacement, the interval of the seal, the amount of bentonite that was used, and any problems that arose. The geologist also recorded the type of bentonite and the supplier.

All monitor wells and piezometers were grouted from the top of the bentonite seal to within 3 ft of the ground surface using a tremie pipe. The grout mixture placed above the bentonite was composed of a 10:1 ratio of Portland cement to bentonite powder (by weight) and contained only enough water for a pumpable mix. The grout was allowed to set-up for 24 hours before surface completion in order to avoid problems related to settlement.

Quality assurance/quality control (QA/QC) measurements of various well dimensions were completed for each well unless the depth of the well made measuring the total length of the screens and casings on the ground surface impractical. QC measurements consisted of the distances from the top of the well casing to the

- top of the bentonite seal
- top of the filter pad
- top of the screen
- bottom of the well

If direct measurements to the screens and casings could not be made, the number and length of screen and casing sections were counted individually and summed to determine the total length of the screens and casings.

The monitor wells and piezometers were completed at the surface with the well casing extending approximately 3 ft above grade where possible. The steel protective cover with locking cap placed over the casing riser extends 2 ft below grade. The well head is surrounded by a 4-ft by 4-ft by 4-in. cement pad that slopes away from the center.

The locks on the well caps have identical keys or are keyed for opening with one master key. The lock keys were delivered to Navajo Refinery personnel after the completion of fieldwork. Each well is clearly identified with a permanent identification tag on the inside of the protective cover.

The elevation and location of all monitor wells and piezometers were surveyed in March 1993 by John D. Jaquess & Associates, NM license 6290. The elevations of the natural ground surface, top of the PVC well casing, and top of the locking cap of the steel protective casing were determined to 0.01 ft based upon a previously established benchmark. The location of each well was determined to 0.01 ft relative to a previously established benchmark. The survey data are included in Appendix F.

6.2.1.1.4 Well Completion Documentation

Drilling details, lithologic descriptions from the soil boring log, well construction, sample collection, and other pertinent information are presented on a well completion form for each monitor well and piezometer installed at the Navajo Refinery:

- project name and number

- borehole or well identification number
- initials of the geologist(s) who logged the well
- driller's license number and company
- materials used for well casing, sand pack, grout, and surface completion
- final well construction specifications including total depth of the well, depth of the screened interval, depths to the top of the sand pack, bentonite seal, and grout
- elevation of the top of the well casing, top of the protective cover, and ground surface
- any special problems encountered during well installation and their resolution
- pertinent depth-to-water measurements to date
- complete lithologic description of geologic materials found (as presented in Section 6.2.1.1.2)
- visual observations of contamination including the presence of discolored geologic materials and odors

6.2.1.1.5 Well Development

Well development is the process by which the aquifer's hydraulic conductivity is restored by removing mobile particulates from within and adjacent to newly installed wells. Well development substantially minimizes the amount of fine materials that may accumulate in the well between sampling events, thus reducing the amount of purging needed to obtain a clear sample.

The wells were developed using a combination of bailing, surging, and pumping. The fine-grained materials accumulated in the well casing were bailed from the well until the bottom of the well casing could be reached. After bailing, a Grunfos Redi-Flo 2 2-in. electric submersible pump was used to develop the well. In the event the well appeared to be producing at an unusually low rate, the pump was removed and the well was surged using a surge block. Surging was accomplished by lifting and dropping the tool through the column of water in the well. The entire screened interval was surged in 5-ft sections using approximately 10-20 iterations per section. Any fine sediments that entered the well during surging were removed with a bailer prior to resuming pumping. If the discharge rate of the well remained low, the purging process was repeated.

Electrical conductivity, pH, and temperature were monitored throughout the development process. Completion of the development process was defined as the stabilization (i.e., less than 10% variability between readings) of these parameters and the removal of at least three well volumes. A single well volume is considered to be the volume of water in the well casing plus the volume of water in the sand pack.

All fluids produced during development were collected in drums provided by the refinery for disposal in the refinery wastewater treatment system.

6.2.1.1.6 Equipment Decontamination

All drilling equipment was thoroughly steam-cleaned prior to each monitor well and piezometer installation to prevent the possibility of cross-contamination. All steam-cleaning was performed at the refinery steam rack and all runoff entered the refinery wastewater treatment system. Any disposable materials that may have been contaminated were collected and placed in appropriate containers for proper disposal.

All well-development equipment was decontaminated prior to use at each monitor well and piezometer to prevent the possibility of cross-contamination. Decontamination consisted of washing the equipment in Liquinox detergent and rinsing first with drinking-quality water and then with distilled water. All decontamination solutions were discharged to the refinery wastewater treatment system. Any disposable materials that may have been contaminated were collected and placed in appropriate containers for proper disposal.

6.2.1.2 Groundwater Elevation Measurements

In this investigation, groundwater elevation was measured at each monitor well and piezometer prior to each sampling event using an electronic depth-to-water meter. The depth-to-water meter is accurate to 0.01 ft. The measurements were taken from a clearly marked reference point on the top of the well casing and recorded in the field logbook. The elevation of the reference point was established through surveying as described in Section 6.2.1.1.3, "Well Construction." The depth-to-water meter was decontaminated prior to use at each well.

A hydrocarbon/water interface probe accurate to 0.01 ft was available on site in the event that a measurable layer of free-phase hydrocarbon (>0.01 ft) was encountered on the surface of the groundwater. However, no free-phase hydrocarbons were found, and it was not necessary to measure depth to product and depth to groundwater following the prescribed protocol.

6.2.1.3 Groundwater Sample Collection

Groundwater sampling at both Three-Mile Ditch and the evaporation pond areas was performed in a two-step process. Existing wells were first sampled in November 1992 and, based on the analytical results, were used in decision making for the location of additional monitor wells. The second step involved sampling the newly installed monitor wells and resampling selected previously existing wells for verification in the event of anomalous results.

The following sections describe the well purging, sample collection, and equipment decontamination procedures for collecting groundwater samples from the monitor wells at the Navajo Refinery. Prior to purging or sampling, the groundwater elevation was measured and recorded at each monitor well using the protocol set forth in Section 6.2.1.2, "Groundwater Elevation Measurements."

6.2.1.3.1 Well Purging

Each well was purged prior to the collection of groundwater samples to ensure that the samples were representative of groundwater conditions. A minimum of three well volumes was removed using a submersible pump or a disposable bailer. A well volume is defined as the volume of water in the well casing plus the volume of water held in the pore space of the sand pack. The turbidity, electrical conductivity, pH, and temperature of the groundwater were monitored during purging until their values stabilized.

Turbidity was visually monitored, whereas the other parameters were monitored with electronic field meters. If the turbidity of a well was not sufficiently clear for sampling, a "slug" was then used to surge the well. Typically, the volume of water displaced by the submersible pump served as the slug. However, at some locations, a specially constructed sealed section of sand-filled PVC pipe served that function. When a well was pumped dry before three well volumes were removed, the well was allowed to recover to within 90% of the original water-level elevation and purged a second time. If the well was pumped dry a second time before three well volumes were removed, the well was considered purged. The water level was allowed to recover within 90% of the original elevation and the well was sampled. All readings were immediately recorded in the field logbook. An initial reading was taken 5 to 10 seconds after pumping had begun or after 1 gallon had been removed with a bailer. Subsequent readings were taken on an interval that allowed for at least five additional measurements to be taken during purging. Purging continued until the measured parameters had stabilized and at least three well volumes had been removed. If the field measurements had not stabilized after three well volumes had been removed, purging continued until they stabilized. The electrical conductivity, pH, and temperature meters were calibrated prior to purging to correct for any instrument drift.

All fluids produced while purging were collected in drums provided by the refinery for disposal in the refinery wastewater treatment system.

6.2.1.3.2 Sample Collection

Groundwater samples were taken first from the monitor wells expected to be least contaminated and proceeded in the order of expected increased contamination. Contamination levels were estimated from the available data and literature.

A groundwater sample was taken only after purging was complete and the depth-to-water level had recovered to within 90% of the pre-purged level. A disposable bailer and dedicated nylon twine were used to collect groundwater samples. Latex gloves were worn at all times during sample collection to ensure the safety of personnel and to prevent cross-contamination between wells. Plastic sheeting was placed around the wellhead to ensure that the bailer line did not touch the ground while the bailer was raised and lowered.

The sample was poured from the bailer directly into the appropriate sample container to which any necessary preservatives had been previously added. The sample bottles were filled in the order of volatiles, semivolatiles, metals, and general water chemistry. Special care was taken when filling the bottles for volatile organics analysis. These bottles were filled very slowly to prevent any loss of volatile organics. If appropriate, the sample was then immediately placed in an insulated container containing ice. Samples for dissolved metals were filtered in the field using a peristaltic pump and an in-line, high capacity, 0.45-micron filter. Each sample was collected directly from the bailer using 0.25-in. tygon tubing. All QA/QC samples — including trip blanks, field blanks, and duplicates — were added to the insulated container at the time of sampling. Precautions were taken to ensure that sample integrity was maintained during transport to the analytical laboratory.

Samples from water supply wells were handled somewhat differently. For drinking water/domestic wells, or irrigation wells not in operation, samples were collected after pumping for at least 10 minutes. Domestic wells were sampled from a faucet nearest the well and upstream of any water treatment equipment. Where possible, the pressure tank was also bypassed. Special care was also taken when filling the bottles for volatile organics analysis to prevent any loss of constituents.

6.2.1.3.3 Equipment Decontamination

All groundwater-sampling equipment was decontaminated prior to use at each monitor well and piezometer to prevent the possibility of cross-contamination. Interior pump decontamination was performed at the conclusion of each day. The discharge hose and flow meter were decontaminated with Liquinox detergent followed by a clean-water rinse after purging each well. Dedicated filters for dissolved metals were used on the peristaltic pump and the tubing was rinsed with distilled water.

The standard decontamination procedure consisted of scrubbing the equipment in Liquinox detergent and water, rinsing first with drinking-quality water, and then rinsing with distilled/deionized water. No nonaqueous phase liquids were encountered, and the use of special procedures (modified to include nonphosphate detergent and a final Hexane rinse) for high organic concentrations were not necessary. All decontamination solutions were discharged into drums for disposal to the refinery wastewater treatment system. Dedicated equipment at a well did not require decontamination after use. Any disposable materials that may have been contaminated were collected and placed in appropriate containers for proper disposal.

6.2.1.3.4 Quality Assurance/Quality Control Sample Collection

QA/QC samples included duplicates, field blanks, equipment blanks, and trip blanks. One duplicate sample was collected for every 10 groundwater sites sampled. An equipment and/or a field blank was collected for every 12 sites sampled. Sample and duplicate bottles for each analysis were filled simultaneously from the same bailer(s) to minimize inducing error into the result. Field blanks were collected by filling a set of sample bottles with reagent grade distilled water at the wellhead immediately following the collection of a groundwater sample from the well. An equipment blank was collected for equipment not dedicated to a well. For heavy metals, a blank was taken for dissolved metals by running reagent grade distilled water through the peristaltic pump with a clean filter installed. Most duplicates and field blanks were submitted to the laboratory as blind QA/QC samples.

A trip blank for volatiles, semivolatiles, and total metals accompanied each insulated cooler used for storing samples throughout the sampling effort. These blanks were prepared in the laboratory and placed in the insulated containers with the empty sample bottles prior to shipping them to the site. The blanks remained in the insulated containers until they were returned to the laboratory with the samples for analysis.

The sampler initialed each sample label along with the time of sampling for each well when filling out the labels. Duplicate samples were assigned a different collection time and all times were recorded in the field logbook. The 40-mL samples for volatile organics analysis were wrapped in bubble wrap and taped and then placed in pint-sized self-sealing plastic storage bags at the time of sampling. The samples were packed in the insulated containers to ensure that they remained cool and would not be subject to breakage. The lids on the sample containers for semivolatiles, metals, and general water chemistry were securely taped prior to shipping. The completed chain-of-custody form was sealed inside a plastic bag and placed inside each insulated container prior to shipment. Two signed and dated custody seals were placed over the container lid and covered with clear packing tape to prevent tampering. The insulated containers were then taped closed for additional security and shipped to the laboratory.

6.2.2 Results

As a result of Phase II of the RFI and earlier studies, a total of eight monitor wells were available to monitor groundwater quality adjacent to Three-Mile Ditch along its extent, from the northeast corner of the refinery to the entrance of the now-inactive Evaporation Pond 1.

Data from these wells provided a snapshot of the geology and water quality adjacent to the entire length of the ditch and the parallel portion of Eagle Creek. Groundwater elevation data from these wells and other monitor wells and piezometers east of the process area of the refinery provided detailed information on groundwater movement immediately downgradient from the refinery. In addition, the sampling of several domestic wells north of Eagle Creek provided information on the water quality of drinking-water zones.

6.2.2.1 Drilling Program Results

Review of the boring logs (Appendix F) from the four monitor wells installed adjacent to Three-Mile Ditch during the Phase II investigation illustrates the stratigraphic changes from east to west and upgradient from the Pecos River toward the Navajo Refinery. Monitor well MW-15 is situated on the Pecos River floodplain within 100 yards of Evaporation Pond 1. The MW-15 well log shows the well-graded sands and sandy fines exhibiting increasing particle size with depth. This and other well logs indicate a meandering river depositional environment, as described in Section 8.3.2.1 for the area at the evaporation ponds. MW-16 is approximately 4,500 ft upgradient of MW-15 and at a ground surface elevation approximately 4 ft higher. The subsurface soils were predominantly sandy clays and clays at this location. Monitor wells MW-21 and MW-20 are farther upgradient, approximately 5,300 and 6,600 ft, respectively, from MW-16, with respectively higher elevations of 21 and 25 ft. As at MW-16, the soils at MW-21 and MW-20 were predominantly clayey fines, but the abundant, well-rounded carbonate gravel at each location indicated channel deposition from the topographically higher regions to the north. Depth to the first saturated zone ranged from 10 to 14 ft below surface at these four wells.

Three of the four piezometers installed during Phase II to investigate groundwater conditions at Three-Mile Ditch are located along a line running roughly south to north across the position of MW-20. The soils described in these logs are sands, clayey fines, and clayey fines mixed with well-rounded carbonate gravels. Depths to the first saturated zone at piezometers NP-1, NP-2, and NP-3 are from 14 to 8 ft below ground surface. The fourth piezometer, NP-4, was located southeast of the first three piezometers to provide a triangulation point for groundwater measurements. It is approximately 600 ft north of NP-3 at a natural ground elevation approximately 3 ft above that of the other three piezometers. However, the depth of the first saturated zone at NP-4 is 25 ft. The reason for this difference in the depth of occurrence of the first saturated zone can not be readily determined owing to the lack of information about subsurface conditions north of Eagle Creek.

A possible task designated for the Phase II field investigations was replacement of monitor well MW-47, which had been damaged prior to the Phase I investigation. However, the well was not replaced because of safety concerns due to its dangerous proximity to high-pressure gas and product lines, and high-voltage electric power lines.

6.2.2.2 Groundwater Movement

Depth-to-water measurements were made on 16 March 1993 in five of the six monitor wells and the four piezometers adjacent to the westernmost part of Three-Mile Ditch and in the four monitor wells and one piezometer immediately south of the ditch. Water-level elevations were calculated by subtracting these readings from the surveyed elevations for the top of the well casings (Table 9). The water-level elevations were plotted on a 1:3600 (1 in. = 300 ft) base map prepared from aerial photographs of the Navajo Refinery and the USGS Artesia 7.5-minute quadrangle topographic map. Location coordinates were from the land survey conducted in February 1993. Water-level contour lines were drawn at 2-ft elevation intervals in the mapped area except for 1-ft intervals in the vicinity of the piezometer and monitor well locations along Three-Mile Ditch to the immediate east of Bolton Road (MW-8, -9, -20, and -21 and piezometers NP-1 through NP-4). The resulting contour map (Figure 5A) shows the generally eastward flow with a northeasterly component in the vicinity of Bolton Road. The hydraulic gradient as measured from the map varied from 0.005 ft/ft near MW-45 and MW-46, to 0.0067 ft/ft in the area of MW-20 and MW-21. In the area east of Bolton Road to the Pecos River, the contours are easterly, but swing southeasterly approaching the river (Figure 5B). Contour spacing changes nearer the river with the wider spacing indicating a flatter gradient. Besides mimicking the topographic surface gradient, the flatter contours likely indicate a lithologic change to more permeable sediments nearer the river.

Of note is the fact that the water level of the Eagle Creek channel bottom between NP-2 and NP-3 was about 1.2 ft below the elevation of the channel bottom. During the initial sampling of the existing monitor wells in November 1992, standing pools of water were observed in this reach of the channel even though the creek had not been flowing. At that time, water-level elevations in the existing wells MW-8 and MW-9 were 1.21 ft higher than the elevations measured in March 1993, which indicates that the water table intersects the channel bottom at some times during the year. Thus, in the area of these wells, the contour map shows that the near-surface water table aquifer discharges to the creek when water levels are high. Likewise, there will be recharge to the aquifer during periods of flow in Eagle Creek, but the volumes will be limited because water flow is generally associated with storm runoff events that are of only limited duration, usually on the order of several hours.

Table 9. Water elevations at monitor wells and piezometers along Three-Mile Ditch, March 16, 1993.

Table 9. Water elevations at monitor wells and piezometers along Three-Mile Ditch, March 16, 1993.

Well	Surveyed elevation (ft)	Depth to water (ft)	Water elevation (ft)
MW-8	3335.29	9.48	3325.81
MW-20	3340	10.66	3329.34
MW-21	3336.18	10.81	3325.37
MW-45	3356.32	10.97	3345.35
MW-46	3354.33	15.85	3338.48
KWB-1A	3350.87	17.18	3333.69
KWB-1C	3351.33	17.64	3333.69
KWB-7	3344.00	20.61	3323.39
KWB-8	3348.39	21.86	3326.53
KWB-10	3354.7	19.82	3334.88
KWB-2P	3337.28	22.56	3314.72
NP-1	3341.49	12.39	3329.1
NP-2	3341.89	11.4	3330.49
NP-3	3342.05	13.57	3328.48
NP-4	3344.84	18.79	3326.05

Figure 5A. Groundwater potentiometric map, February 1993, Three-Mile Ditch, refinery to Bolton Road Area, RFI Phase II.

EXPLANATION:

⊞ BG-TR-001 BACKGROUND TRENCH
TMD-TR-001 EXPLORATORY TRENCH, THREE-MILE DITCH

◐ EP-TR-001 EXPLORATORY TRENCH, EVAPORATION POND 1

● MONITOR WELL

☒ PIEZOMETER

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

KWBES

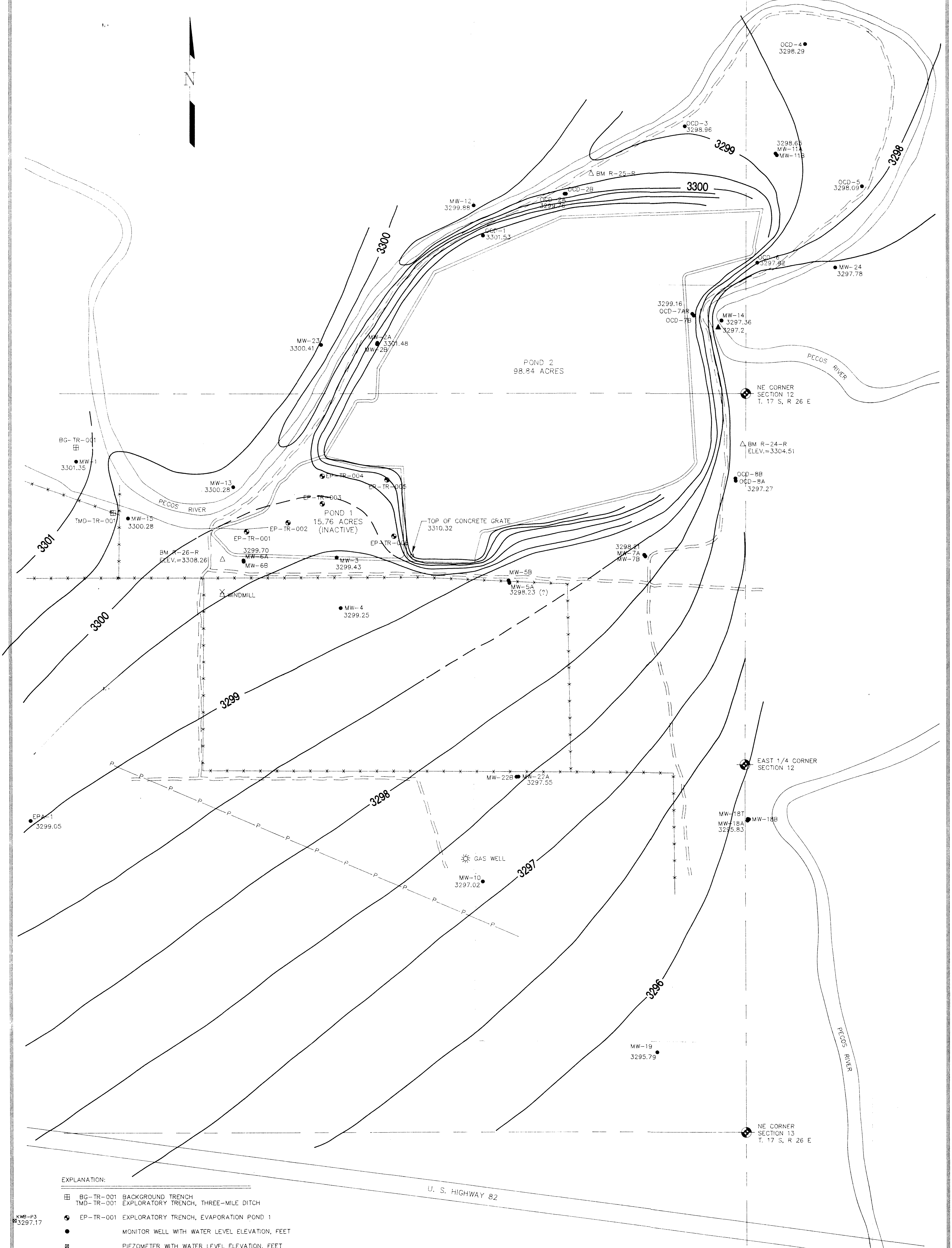
prepared for:

Navajo

Location of stratigraphic cross sections,
Evaporation Pond Area,
RFI Phase II.

PROJECT: 622092005-110 (NAV-BIG)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/14/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 02/25/93	FIGURE: 10

Figure 5B. Regional groundwater potentiometric map, February 1993, refinery to Pecos River, RFI Phase II.



EXPLANATION:

⊞	BG-TR-001 TMD-TR-001	BACKGROUND TRENCH EXPLORATORY TRENCH, THREE-MILE DITCH
◕	EP-TR-001	EXPLORATORY TRENCH, EVAPORATION POND 1
●		MONITOR WELL WITH WATER LEVEL ELEVATION, FEET
⊠		PIEZOMETER WITH WATER LEVEL ELEVATION, FEET
▲		RIVER WATER ELEVATION,FEET

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES, WATER LEVELS MEASURED 2/8-10/93.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

CONTOUR INTERVAL 0.5 FEET

300 0 300 900 FEET

KWBES

prepared for:

Navajo

Shallow groundwater potentiometric map, February 1993, Evaporation Pond Area, RFI Phase II.

PROJECT: 622092005-110 (NAV-BIG)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/14/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 02/25/93	FIGURE: 14

6.2.2.3 Groundwater Quality

Results of the RFI Phase II groundwater sampling of the ditch monitoring wells and proximal domestic wells are presented in this section, with the data included in Appendix I.

6.2.2.3.1 Monitor Wells and Piezometers

Results from prior sampling events and from the RFI Phase I study (as reviewed in Section 5.3) are in Appendix D. To facilitate comparison and interpretation, water quality results for metals and inorganic parameters from the Phase II investigation at Three-Mile Ditch are presented in order of location for the monitor wells, from the refinery to lower end of the ditch in the vicinity of the effluent ponds. Results from MW-15 and MW-1, which are located in the vicinity of the evaporation ponds, are included in the data presentations for both Three-Mile Ditch and the evaporation ponds. Also included with the results from the ditch monitor wells is an analysis of general water chemistry sampled from a standing water pool within the bed of Eagle Creek opposite MW-9. This sample was taken in November 1992, when the creek bed pools supported a variety of aquatic life including cattails and minnows.

Field parameters of pH, conductivity, and temperature were measured at each monitor well sampled. As described in the protocol in Section 6.2.1.3, sampling was performed after these field parameters had stabilized during pumping. The final readings taken for samples from the monitor wells along Three-Mile Ditch are shown in Table 10.

Sampling of the existing and new wells installed along Three-Mile Ditch for volatile organic compounds detected target compounds in only one well, MW-45, located at the northeastern end of the refinery process area. Carbon disulfide and total xylenes were detected at levels of 0.034 and 0.013 mg/L, respectively. For xylenes, the maximum contaminant level (MCL) set by the EPA under the Safe Drinking Water Act for drinking water is 10 mg/L with a proposed MCL of 0.020 mg/L as a recommended aesthetic standard. In New Mexico, the state WQCC health standard for total xylenes is 0.62 mg/L. No federal or state water quality standard exists for carbon disulfide. Well MW-45 is downgradient from an area known to have been impacted from past hydrocarbon releases, and the presence of these compounds is more likely the result of refinery activity than residual impact from operation of the ditch.

In addition, methylene chloride was detected in MW-45 at a level of 0.013 mg/L and also in monitor wells MW-8 and MW-9 and in the laboratory method blank for the date of sample analysis for all three wells. Methylene chloride is a common laboratory contaminant, and its detection in the method blank eliminates this compound from consideration as a groundwater contaminant. Results of the quality control procedures and complete data results for all analyses can be found in Appendix I.

Table 10. Groundwater and surface water indicator measurements at the time of field sampling, Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Table 10. Groundwater and surface water indicator measurements at the time of field sampling, Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Well sample identification	Laboratory number	Date sampled	Time sampled	pH	Conductivity (μmhos/cm at 25°C)	Temperature (°C)
TMD-GW-MW-45	C922354/15667	11/14/92	1135	7.03	4,500	20.1
TMD-GW-MW-46	C922359/15671	11/15/92	1055	6.83	5,100	18.7
TMD-GW-MW-20	C930223/W00269	1/26/93	1800	6.93	7,600	17.3
TMD-GW-MW-8	C922352/15665	11/14/92	1415	6.93	5,800	18.4
TMD-GW-MW-9	C922353/15666	11/14/92	1605	6.97	6,000	NA
NMD-EC-SW-1	C922349/15663	11/14/92	1555	7.00	6,100	NA
TMD-GW-MW-21	C930224/W00270	1/27/93	950	6.85	5,200	16.2
TMD-GW-MW-16	C930211/W00190	1/26/93	1550	6.86	4,100	17.7
NEP-GW-MW-01-01	C922278/15632	11/10/92	1725	7.1	15,000	19.6
TMD-GW-MW-15	C930105/W00055	1/20/93	1710	7.41	3,500	19.3

NA = Not available.

Metals analyses for total and dissolved arsenic, chromium, lead, and nickel are presented in Table 11 together with EPA and New Mexico water quality standards. The EPA MCL for lead is an action level requiring treatment at the tap if exceeded in drinking water. In New Mexico nickel is an irrigation standard, not a human health standard. Because New Mexico groundwater protection regulations require measurements be made on a dissolved (vs. total) sample, all samples were filtered in the field using a 0.45-micron dedicated filter, as described in Section 6.2.1.3, "Groundwater Sample Collection."

The results for Three-Mile Ditch groundwater sampling show no exceedances of federal or state standards for arsenic. Although the detection level for lead was slightly above the federal action level, lead was not detected in any of the wells along Three-Mile Ditch except for MW-45. In this well, total lead at 0.05 mg/l was slightly elevated above the detection level of 0.02 mg/L but no lead was detected in the dissolved sample. The total lead concentration observed in MW-45 is approximately 100 times less than the value of 1.83 mg/L reported from the RFI Phase I investigation. The value of total lead in MW-45 was equal to the New Mexico groundwater standard although the standard is applicable for filtered samples.

Chromium and nickel were both elevated in several of the wells along Three-Mile Ditch, with chromium levels in three wells ranging from 2 to 18 mg/L and nickel levels elevated in the same three wells. As discussed subsequently in Section 9.0, the three wells with highly elevated levels were constructed of stainless-steel casing, and the high values for the two metals are related to degradation of the well casing material in the saline environment rather than actual groundwater concentrations of chromium and nickel. PVC-cased wells installed during the RFI Phase II study had uniformly low values of both constituents.

Verification analyses for both arsenic and nickel are shown for some wells because examination of the preliminary analysis results and comparison with draft results from PRC, Inc., EPA's onsite contractor during water quality sampling, indicated possible testing problems may have occurred at either of the analytical laboratories processing the samples. Further discussion of this issue can be found in Section 9.0. The PRC data are reported in Appendix J.

The laboratory analytical data for the inorganic water quality constituents and indicator constituents for groundwater in the vicinity of Three-Mile Ditch are shown in Table 12. In addition to the major constituents, the minor constituent fluoride, measured and calculated values of TDS, cation-anion totals, and percent difference are shown in the table. The latter three values provide a rapid check of completeness and accuracy of the water analysis. For good-quality, low-TDS water, a percent difference of 1% to 2% is easily obtained. For wastewater and high-TDS water that can cause analytical instrument interference, a 5% difference may be acceptable. Although discussion and interpretation of these results are

Table 11. Results of metals analyses (mg/L), Three-Mile Ditch groundwater sampling, Navajo Refinery, RFI Phase II.

Table 11. Results of metals analyses (mg/L), Three-Mile Ditch groundwater sampling, Navajo Refinery, RFI Phase II.

Well sample identification	Lab number	Date sampled	TAS [a]	TAS [b]	TAS [c]	DAS [d]	TCR [e]	DCR [f]	TPB [g]	DPB [h]	TNI [i]	TNI [j]	DNI [k]	pH	EC [l]
TMD-GW-MW-45	C922354/15667	11/14/92	0.009	0.008	0.011	0.008	0.03	ND	0.05	ND	0.10	ND	0.09	7.1	5050
TMD-GW-MW-45	W09083/G02747	10/29/93	0.007				0.03		0.05		0.04				
TMD-GW-MW-46	C922359/15671	11/15/92	0.010	0.008	NV	ND	0.02	ND	ND	ND	0.12	NV	0.09	6.9	5890
TMD-GW-MW-46	W09084/G02748	11/01/93	0.006				ND		0.01		0.01				
TMD-GW-MW-20	C930223/W00269	1/26/93	0.008	0.007	NV	0.005	ND	ND	ND	ND	0.03	NV	ND	7.5	8510
TMD-GW-MW-08	C922352/15665	11/14/92	0.014	0.014	0.027	ND	2.26	ND	ND	ND	0.74	0.71	0.36	7.0	6510
TMD-GW-MW-21	C930224/W00270	1/26/93	0.005	ND	NV	ND	ND	ND	ND	ND	ND	NV	ND	7.2	6380
TMD-GW-MW-09	C922353/15666	11/14/92	0.021	0.025	0.015	ND	18.42	0.03	ND	ND	8.04	9.02	2.60	6.6	6720
TMD-GW-MW-16	C930211/W00190	1/26/93	ND	NV	NV	ND	ND	ND	ND	ND	0.03	NV	0.01	7.5	4870
NEP-GW-MW-01-01	C922278/15632	11/10/92	0.020	0.023	0.010	ND	3.65	ND	ND	ND	0.35	0.22	0.20	7.5	14900
NEP-GW-MW-01-01	C922278/15635 (DUP)	11/10/92	0.022	NV	NV	ND	3.62	ND	ND	ND	0.34	NV	0.18	7.5	14900
NEP-GW-MW-15	C930105/W00055	1/20/93	0.010	0.006	NV	0.006	0.03	ND	ND	ND	ND	NV	ND	7.5	3590

Key:	**Test description/method**	**Detection limits**
a	Total arsenic — Method 7061	0.005
b	Total arsenic — Method 7061 — verification	0.005
c	Total arsenic — Method 7060 — verification	0.005
d	Dissolved arsenic — Method 701	0.01
e	Total chromium — Method 7191	0.02
f	Dissolved chromium — Method 7191	0.02
g	Total lead — Method 7421	0.02 (0.01, 10/29/93 sample event)
h	Dissolved lead — Method 7421	0.02
i	Total nickel — Method 7520	0.01
j	Total nickel — Method 7520 — verification	0.05
k	Dissolved nickel — Method 7250	0.01
l	Electrical conductivity, µmhos/cm @ 25_C	

ND = Not detected.
NV = No verification test.

Standards	**EPA Drinking Water (mg/L)**	**NMWQCC Groundwater**
As	0.05	0.1
Cr	0.1	0.05
Pb	0.015 (Action level)	0.05
Ni	0.1	0.2 (irrigation)

Table 12. Results of inorganic water quality analyses, groundwater sampling of Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Table 12. Results of inorganic water quality analyses, groundwater sampling of Three-Mile Ditch, Navajo Refinery RFI, Phase II.

Well sample ID	Laboratory no.	Date sampled		pH (Laboratory)	Electrical conductivity at 25°C (Laboratory)	Total dissolved solids at 180°C	Total dissolved solids (calc)	Total alkalinity	Total hardness	Fluoride	Calcium	Calcium	Magne-sium	Magne-sium	Potas-sium	Potas-sium
			Detection level Units	0.1 (s.u.)	1 (µmhos/cm)	1 (mg/L)	1 mg/l	1 (mg/L)	1 (mg/L)	0.1 (mg/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)
NEP-GW-MW-01-01	C922278/15632	10-Nov-92		7.5	14900	11200	10500	406	3880	1.1	764	38.12	480	39.47	14.0	0.36
NEP-GW-MW-01-01	C922278/15635	10-Nov-92		7.5	14900	11300	NA	408	NA	1.1	769	NA	480	NA	16.0	NA
(Lab Dup)	C922278/15635	10-Nov-92		7.5	14900	11300	NA	408	NA	1.1	769	NA	480	NA	16.0	NA
TMD-GW-MW-08	C922352/15665	14-Nov-92		7.0	6510	6120	5490	312	3270	2.2	574	28.64	446	36.68	4.4	0.10
TMD-GW-MW-09	C922353/15666	14-Nov-92		6.6	6720	6270	5640	252	3280	2.3	608	30.34	428	35.20	4.8	0.13
TMD-GW-MW-15	C930105/W00055	20-Jan-93		7.5	3590	2790	2670	150	1190	1.1	308	15.37	102	8.39	11.0	0.28
TMD-GW-MW-16	C930211/W00190	26-Jan-93		7.5	4870	4250	2910	307	1600	2.2	257	12.82	232	19.08	15.0	0.38
TMD-GW-MW-20	C930223/W00269	26-Jan-93		7.5	8510	8460	7680	359	4560	3.5	470	23.45	824	67.76	8.0	0.20
TMD-GW-MW-21	C930224/W00270	26-Jan-93		7.2	6380	6140	5560	313	3420	2.1	603	30.09	466	38.32	9.0	0.23
TMD-GW-MW-45	C922354/15667	14-Nov-92		7.1	5050	3740	3740	330	2130	2.5	477	23.80	228	18.75	11.0	0.28
TMD-GW-MW-46	C922359/15671	15-Nov-92		6.9	5890	5210	4750	375	2640	2.9	495	24.70	341	28.04	5.6	0.13
NMD-EC-SW-1	C922349/15663	14-Nov-92		7.7	6840	6510	5930	306	3520	2.7	565	28.19	512	42.11	3.9	0.10

Table 12. Continued.

Well sample ID	Laboratory no.	Date sampled	Detection level Units	Sodium	Sodium	HCO_3	HCO_3	CO_3	CO_3	OH	OH	Chloride	Chloride	SO_4	SO_4	Cation sum	Anion sum	Percent difference
				1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	(meq)	(meq)	(%)
NEP-GW-MW-01-01	C922278/15632	10-Nov-92		2130	92.65	495	8.11	0	0.00	0	0.00	3750	105.78	3020	62.88	170.60	176.77	-1.78
NEP-GW-MW-01-01	C922278/15635	10-Nov-92		2130	NA	NA	NA	NA	NA	NA	NA	3740	NA	3010	NA	NA	NA	NA
(Lab Dup)	C922278/15635	10-Nov-92		2130	NA	NA	NA	NA	NA	NA	NA	3740	NA	3010	NA	NA	NA	NA
TMD-GW-MW-08	C922352/15665	14-Nov-92		453	19.70	380	6.23	0	0.00	0	0.00	550	15.51	3280	68.29	85.12	90.03	-2.80
TMD-GW-MW-09	C922353/15666	14-Nov-92		498	21.66	307	5.03	0	0.00	0	0.00	616	17.38	3330	69.33	87.33	91.74	-2.46
TMD-GW-MW-15	C930105/W00055	20-Jan-93		447	19.44	182	2.98	0	0.00	0	0.00	564	15.91	1150	23.94	43.48	42.83	0.75
TMD-GW-MW-16	C930211/W00190	26-Jan-93		403	17.53	375	6.15	0	0.00	0	0.00	457	12.89	1360	28.32	49.81	47.36	2.52
TMD-GW-MW-20	C930223/W00269	26-Jan-93		752	32.71	438	7.18	0	0.00	0	0.00	552	15.57	4860	101.19	124.12	123.94	0.07
TMD-GW-MW-21	C930224/W00270	26-Jan-93		432	18.79	381	6.25	0	0.00	0	0.00	518	14.61	3340	69.54	87.43	90.40	-1.67
TMD-GW-MW-45	C922354/15667	14-Nov-92		372	16.18	402	6.59	0	0.00	0	0.00	671	18.93	1780	37.06	59.01	62.58	-2.94
TMD-GW-MW-46	C922359/15671	15-Nov-92		471	20.49	458	7.51	0	0.00	0	0.00	636	17.94	2580	53.72	73.36	79.17	-3.81
NMD-EC-SW-1	C922349/15663	14-Nov-92		489	21.27	373	6.11	0	0.00	0	0.00	540	15.23	3630	75.58	91.67	96.92	-2.78

presented in Section 9.0, the water quality of the near-surface saturated zone exceeded federal and state secondary standards for chloride, fluoride, sulfate, and TDS at all locations sampled. Secondary drinking water standards are applied for constituents that generally impart aesthetic impacts such as taste or odor, or increase salt concentrations in the water. They also may cause minor stomach irritation (sulfates), mottling of teeth (fluorides) or staining of clothes and fixtures (iron and manganese).

6.2.2.3.2 Domestic Wells

Three domestic water wells north of Three-Mile Ditch were also sampled during the RFI Phase II investigation. Their locations are shown on Figure 4, Sheet C. Several additional wells used for irrigation were scheduled for testing, but access was not available owing to cessation of the growing season. Except for one well, TMD-GW-3368 (Chase Farms), that was resampled for the analysis of volatile organic compounds, the domestic wells were sampled only once during the RFI.

The groundwater physical parameters measured at the time of sampling are shown in Table 13. No volatile or semivolatile constituents were detected in the analyzed samples collected during the Phase II investigation.

Results of sampling for heavy metals and water chemistry are shown in Tables 14 and 15, respectively. No heavy metals were detected except for nickel at concentrations below federal and state standards in the three wells. All secondary (aesthetic) standards were exceeded except for chloride (one well) and fluoride (three wells). Although used for general household purposes, the domestic wells are not all used for drinking-water sources because of the naturally occurring salt content.

Table 13. Groundwater indicator parameters at the time of field sampling of domestic wells near Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Table 13. Groundwater indicator parameters at the time of field sampling of domestic wells near Three-Mile Ditch , Navajo Refinery, RFI Phase II.

Well sample	Laboratory number	Date sampled	Time sampled	pH	Conductivity (µmhos/cm at 25°C)
TMD-GW-3282-1 (Simmons)	C922346/15660	11/15/92	NA	6.8	1400
TMD-GW-3368-1 (Chase Farms)	C922347/15661	11/14/92	1200	6.5	3450
TMD-GW-6650-1 (McLurg)	C922348/15662	11/14/92	1510	6.5	3900

NA = Not available.

Table 14. Results of metals analyses (mg/L), groundwater sampling of domestic wells near Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Table 14. Results of metals analyses (mg/L), groundwater sampling of domestic wells near Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Well sample identification	Laboratory number	Date sampled Detection level	Total As 0.005	Total Cr 0.02	Total Pb 0.02	Total Ni 0.01
TMD-GW-3282-1 (Simmons)	C922346/15660	15-Nov-92	ND	ND	ND	0.07
TMD-GW-3368-1 (Chase Farms)	C922347/15661	14-Nov-92	ND	ND	ND	0.06
TMD-GW-6650-1 (McLurg)	C922348/15662	14-Nov-92	ND	ND	ND	0.06

Table 15. Results of inorganic water analyses, groundwater sampling of domestic wells near Three-Mile Ditch, Navajo Refinery, RFI Phase II.

Table 15. Results of inorganic water quality analyses, groundwater sampling of domestic wells near Three-Mile Ditch, Navajo Refinery, RFI Phase II.

				pH (Laboratory)	Electrical Conductivity at 25°C (Laboratory)	Total dissolved solids at 180°C	Total calcium	Total alkalinity	Total hardness	Flouride	Calcium	Calcium	Magne-sium	Magne-sium	Potas-sium	Potas-sium
Well sample ID	Laboratory no.	Date sampled	Detection Level Units	0.1 (s.u.)	1 (µmhos/cm)	1 (mg/L)	1 (mg/L)	1 (mg/L)	1 (mg/L)	0.1 (mg/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)
TMD-GW-3282-1 (Simmons)	C922346/15660	15-Nov-92		7.4	1620	1250	1170	149	837	0.8	225	11.23	67	5.51	5.2	0.13
TMD-GW-3368-1 (Chase Farms)	C922347/15661	14-Nov-92		7.0	3790	3090	2870	179	1880	0.6	483	24.10	163	13.40	4.1	0.13
TMD-GW-6650-1 (McLurg)	C922348/15662	14-Nov-92		7.2	4320	3800	3580	164	2230	0.5	637	31.79	156	12.83	4.9	0.13

Table 15. Continued.

			Detection Level	Sodium	Sodium	HCO_3	HCO_3	CO_3	CO_3	OH	OH	Chloride	Chloride	SO_4	SO_4	Cation sum	Anion sum	Percent difference
Well sample ID	Laboratory no.	Date sampled	Units	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	(meq)	(meq)	(%)
TMD-GW-3282-1 (Simmons)	C922346/15660	15-Nov-92		38	1.65	182	2.98	0	0.00	0	0.00	37	1.04	709	14.76	18.52	18.78	-0.70
TMD-GW-3368-1 (Chase Farms)	C922347/15661	14-Nov-92		190	8.26	218	3.57	0	0.00	0	0.00	390	11.00	1530	31.86	45.89	46.43	-0.58
TMD-GW-6650-1 (McLurg)	C922348/15662	14-Nov-92		272	11.83	199	3.26	0	0.00	0	0.00	304	8.58	2110	43.93	56.58	55.77	0.72

7.0 REVIEW OF PHASE I INVESTIGATION — EVAPORATION PONDS

The following sections include a review of the data presented in the RFI Phase I Report for soils and groundwater in the vicinity of the evaporation ponds. Summary data tables from the Phase I Report are included in Appendix D. The worth of the Phase I data and related analytical problems are discussed subsequently in Section 9.2.

7.1 SOILS

During the RFI Phase I investigation, surficial soil samples were collected from the evaporitic crust at six unvegetated areas near the evaporation pond berms.

Analytical results for volatile and semivolatile organic compounds from the surficial soil samples indicated no detections other than two occurrences of the common laboratory contaminant bis(2-ethylhexyl)phthalate (RFI Phase I Report, table 6.5). Any impact of oil and grease and of metals was insignificant (RFI Phase I Report, table 6.6), with relatively elevated concentrations of arsenic, chromium, lead, nickel, and zinc restricted to sample NEP-SS-005-01. Because the samples were collected only at the surface, the relationship of any metals concentrations to depth can not be made.

7.2 GROUNDWATER

A plume of organic contaminants extending approximately 3,000 ft downgradient (south) of Pond 1 was indicated from the analysis of samples taken in 1989 from groundwater monitor wells and piezometers in that area. The plume was first detected with an extent of 2,000 ft in a 1986 investigation conducted by Geoscience Consultants, Ltd. The plume consisted primarily of toluene, ethylbenzene, and xylenes, with maximum concentrations of 0.280, 0.656, and 0.203 mg/L, respectively (RFI Phase I Report, table 6.1). The maximum detected concentration of benzene was 0.051 mg/L in MW-4. Low concentrations of other organic compounds were detected sporadically (RFI Phase I Report, table 6.2).

The presence of low concentrations of volatile organic compounds in the vicinity of Pond 1 was confirmed during the Phase I investigation (RFI Phase I Report, table 6.10) in three of the five monitor wells to the south of the ponds (MW-3, MW-4, and MW-6) and in one well to the southeast (OCD-8). The detections were limited to benzene (one detection at 0.041 mg/L), toluene (one detection at 0.013 mg/L), ethylbenzene (two detections at 0.011 and 0.032 mg/L), xylenes (two detections at 0.019 and 0.023 mg/L), and 2-hexanone (three detections at 0.012, 0.014, and 0.023 mg/L). The values for toluene, ethylbenzene, and xylenes from the Phase I analysis were generally 1 order of magnitude less than those reported from the previously collected data.

Only three minor concentrations of semivolatiles were detected in the Phase I analysis (RFI Phase I Report, table 6.11).

Concentrations of arsenic, barium, cadmium, chromium, lead, nickel, silver, and zinc above minimum detection levels were found in the RFI Phase I analysis of groundwater samples from wells immediate to the pond complex, with the majority of the detections from wells downgradient from the pond (RFI Phase I Report, table 6.12 [Appendix D]). An elevated concentration of barium was found in groundwater sampled at background monitor well EPA-1, but arsenic and nickel were also detected. The maximum constituent concentrations found in groundwater were total arsenic of 0.23 mg/L at OCD-5, total barium of 0.25 mg/L at EPA-1, total cadmium of 0.024 mg/L at OCD-3, total chromium of 1.0 mg/L at MW-1, total lead of 0.117 mg/L at MW-7, total nickel of 0.13 mg/L at MW-1, total silver of 0.03 mg/L at MW-5, and total zinc of 0.15 mg/L at OCD-6. The elevated metals concentrations at MW-1 were attributed in the Phase I Report primarily to the materials in Three-Mile Ditch. However, the samples collected for metals analysis were moderately to highly turbid, and none was filtered to collect dissolved metals and thereby avoid the introduction of analytical bias. Additionally, degradation of the steel casing is the likely cause of the high chromium and nickel values, as discussed further in Section 9.0.

The analytical values of several inorganic compounds and TDS for the groundwater samples from the vicinity of the evaporation ponds and from background monitor well EPA-1 varied extremely (RFI Phase I Report, table 6.13). Fluoride is anomalously high in monitor wells OCD-1 and OCD-4, at 4.12 and 5.56 mg/L, respectively. Sulfate values exceeded the background concentration of 1,220 mg/L in 13 wells, with a maximum value of 3,870 mg/L in monitor well OCD-2. Values of TDS range up to 15,800 mg/L, as measured in monitor well MW-5.

Aquifer characteristics determined from a series of aquifer tests in the wells installed in the area at the evaporation ponds yielded values of hydraulic conductivity that ranged from 1.26×10^{-5} to 3.12×10^{-4} ft/second (8.19 to 201 gpd/ft^2) for assumed aquifer thicknesses of 200 and 100 ft, respectively (RFI Phase I Report, table 6.14). The average groundwater velocity was calculated to range from 2.0 to 49.19 ft/yr.

8.0 RFI PHASE II INVESTIGATION — EVAPORATION PONDS

8.1 SOILS AT EVAPORATION POND 1

As part of the Navajo RFI Phase II activities, an investigation was conducted at Evaporation Pond 1 in order to characterize the soils within the unit. The following sections detail sample collection locations, collection methods, and laboratory analytical results.

8.1.1 Soil and Sediment Investigation Procedures

8.1.1.1 Trench Location and Excavation

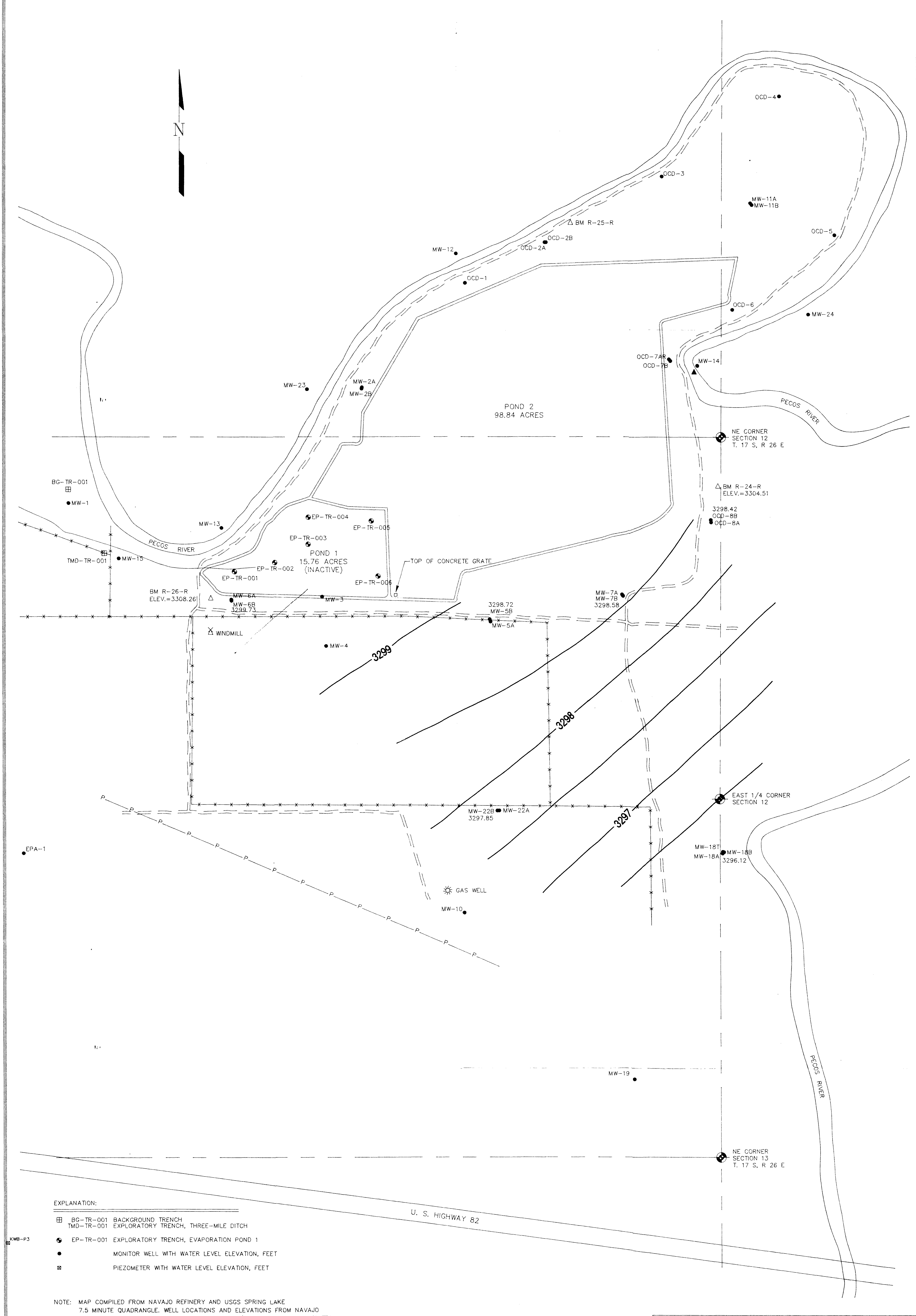
The sample trench locations for Evaporation Pond 1 are shown in Figure 6. The Phase II workplan called for the excavation of six sample trench locations within the unit, including three trenches at various locations around the unit periphery and three trenches within the inner zone of the unit, where the sludge materials were assumed to have undergone sufficient biodegradation to permit ready access by foot and vehicle. However, upon inspection of the unit it was apparent that the unstable sludge materials within the inner peripheral area of the unit would not permit safe access to the selected sample areas. Following consultation with EPA contract personnel onsite, the planned periphery trenches were relocated to accessible areas chosen as close to the unit periphery as possible. However, a single grab sample of sludge materials (EP-TR-006-05) was obtained from the unit periphery at sample trench location EP-TR-006 by positioning the trackhoe as close to the unit periphery as possible and extending the trackhoe bucket into surficial sludge materials within the unit.

Six trench excavations were completed at Evaporation Pond 1 during the Phase II investigation.

8.1.1.2 Soil Sampling and Analysis from Trench Excavations

Upon excavation of each trench to a depth of 4 ft, samples were collected at depths of 1 and 3 ft. Additional samples were obtained from the trackhoe bucket at a depth of 6 ft, as previously described for the Three-Mile Ditch trench sampling activities in Section 6.1.1.2, "Soil Sampling and Analysis from Trench Excavations." Groundwater was not encountered prior to a depth of 9 ft in any of the Evaporation Pond 1 trenches. Therefore, samples were also obtained at a depth of 9 ft. For three of the six pond trenches (EP-TR-001 through -003), groundwater was

Figure 6. Location map for trenches, monitor wells, and piezometers, Evaporation Pond Area, RFI Phase II.



EXPLANATION:

⊞ BG-TR-001 BACKGROUND TRENCH
TMD-TR-001 EXPLORATORY TRENCH, THREE-MILE DITCH

◐ EP-TR-001 EXPLORATORY TRENCH, EVAPORATION POND 1

● MONITOR WELL WITH WATER LEVEL ELEVATION, FEET

⊠ PIEZOMETER WITH WATER LEVEL ELEVATION, FEET

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES, WATER LEVELS MEASURED 2/8-10/93.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

CONTOUR INTERVAL 0.5 FEET

KWBES

prepared for:
Navajo

Deep groundwater potentiometric map,
February, 1993,
Evaporation Pond Area, RFI Phase II.

PROJECT:	622092005-110 (NAV-BIG)		
LOCATION:	ARTESIA, NEW MEXICO		
APPR:		DATE:	04/14/93
DRAWN BY:	JW	SCALE:	AS SHOWN
DATE:	02/25/93	FIGURE:	15

encountered at depths sufficiently greater than 9 ft to allow the collection of a fifth sample immediately above groundwater, at a depth of 11 ft or greater. The excavation of each trench was considered complete to final depth upon reaching groundwater. The various intervals sampled and depth to groundwater at each trench were recorded in the field logbook.

Samples collected from the Evaporation Pond 1 trenches were analyzed for the parameters listed in Section 6.1.1.2, following the same collection procedures.

8.1.1.3 Equipment Decontamination

In order to avoid cross-contamination, all hand-operated soil sampling equipment (e.g., spatulas, scoops, bowls, augers) was thoroughly decontaminated prior to reuse. Decontamination consisted of a Liquinox^{TM} soap wash followed by successive rinses with drinking-quality water and distilled water. All trenching equipment used at Evaporation Pond 1 that may have come in contact with waste materials and soils within the unit was steam-cleaned between excavations. All decontamination solutions were discharged into containers for disposal to the refinery wastewater treatment system. Any disposable materials that may have been contaminated were collected and placed in appropriate containers for proper disposal.

8.1.2 Results

Laboratory analytical results for the soil samples from the trenches installed at Evaporation Pond 1 are included in Appendix I of this report. The analytical data are presented in the following summary tables, and a vertical profile description of soils within each trench are included in Appendix E-2.

The same six volatile constituents detected in various samples obtained from the trenches at Three-Mile Ditch were also observed in the Evaporation Pond 1 trench samples, along with two additional constituents (carbon disulfide and 2-butanone). The constituents detected, number of detection events, and concentration ranges (mg/kg) were acetone — 17 detections: 0.028 to 0.556; benzene — one detection: 0.030; ethylbenzene — seven detections: 0.052 to 2.34; methylene chloride — six detections: 0.008 to 0.122; toluene — seven detections: 0.032 to 3.06; total xylenes — eight detections: 0.007 to 6.51; 2-butanone — two detections: 0.033 and 0.127; and carbon disulfide — one detection: 0.033 (Table 16).

In contrast to trends observed for other volatile constituents, the occurrence and concentration levels observed for acetone and methylene chloride in these trench samples do not appear to be correlated with sample depth. Because acetone and methylene chloride are both recognized as common laboratory contaminants, these results suggest that detection events for these two constituents are best explained as laboratory contamination artifacts.

Table 16. RFI Phase II soil sampling, Evaporation Pond 1 — oil and grease and volatile organic compounds (mg/kg).

Table 16. RFI Phase II soil sampling, Evaporation Pond 1 — oil and grease and volatile organic compounds (mg/kg).

Sample	Sample depth (ft)	Oil and grease (%)	Acetone	Benzene	Ethyl-benzene	Methylene chloride	Toluene	Xylenes (total)
EP-TR-001-01	1	8.27	0.387	0.03	0.443	< 0.028	0.622	2.05
EP-TR-001-02	3	1.11	0.437	< 0.034	0.128	< 0.034	0.082	0.484
EP-TR-001-03	6	0.4	0.295	< 0.025	0.052	< 0.025	0.032	0.159
EP-TR-001-04	9	0.06	0.176	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
EP-TR-001-05	13	< 0.05	< 0.012	< 0.006	< 0.006	0.014	< 0.006	< 0.006
EP-TR-002-01	1	18.49	< 0.391	< 0.196	0.59	< 0.196	0.376	1.57
EP-TR-002-02 [b]	3	0.96	0.442	< 0.007	0.488	< 0.007	0.083	1270
EP-TR-002-03 [c]	6	0.08	0.556	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EP-TR-002-04	9	0.08	0.043	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
EP-TR-002-05	13	< 0.05	< 0.014	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EP-TR-003-01	1	7.05	< 0.061	< 0.031	< 0.031	< 0.031	< 0.031	0.264
EP-TR-003-02	3	< 0.05	0.228	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EP-TR-003-03	3 (duplicate)	0.26	0.189	< 0.007	< 0.007	0.015	< 0.007	< 0.007
EP-TR-003-04	6	0.05	< 0.014	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EP-TR-003-05	11	<0.05	0.033	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
EP-TR-004-01	1	16.07	< 0.314	< 0.157	0.332	< 0.157	< 0.157	< 0.157
EP-TR-004-02	3	0.10	0.079	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
EP-TR-004-03	6	< 0.05	0.184	< 0.034	< 0.034	< 0.034	< 0.034	< 0.034
EP-TR-004-04	9	< 0.05	< 0.012	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
EP-TR-005-01	1	0.19	< 0.012	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
EP-TR-005-02	3	0.11	0.264	< 0.007	< 0.007	<7	< 0.007	< 0.007
EP-TR-005-03	6	0.13	0.235	< 0.007	< 0.007	91	< 0.007	< 0.007
EP-TR-005-04	9	0.10	0.172	< 0.006	< 0.006	0.122	< 0.006	< 0.006
EP-TR-006-01	1	12.56	< 0.263	< 0.132	< 0.132	< 0.132	0.147	< 0.132
EP-TR-006-02	3	0.12	0.7	< 0.032	< 0.032	0.147	< 0.032	< 0.032
EP-TR-006-03	6	0.05	0.054	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EP-TR-006-04	9	< 0.05	0.028	< 0.006	< 0.006	0.008	< 0.006	< 0.006
EP-TR-006-05	0-1	18.61	< 4.320	< 2.160	2.34	< 2.160	3.06	6.51

a = Trackhoe bucket grab sample of pond surface sludges adjacent to trench EP-TR-006.
b = 2-butanone (0.127 mg/kg) and carbon disulfide (0.033 mg/kg) also detected.
c = 2-butanone (146 mg/kg) also detected.

Detectable levels of oil and grease in the soil samples were observed generally to decrease markedly at sample depths below the 1-ft collection depth. Oil and grease concentrations in samples collected at the 1-ft depth ranged from 0.19% to 18.49%, with an average value of 10.4% (Table 16). Oil and grease levels at the 3-ft sample depth were also observed to be at or near a concentration of 1% at trenches EP-TR-001 and EP-TR-002. The location of those trenches was nearest to the former influent point to Evaporation Pond 1 (Figure 6).

Two semivolatile constituents, di-n-butyl phthalate and phenanthrene, were detected in various soil samples from Evaporation Pond 1 (Appendix I). Di-n-butyl phthalate was detected in 11 samples at concentrations ranging from 1.6 to 8.6 mg/kg, whereas only one detection was made of phenanthrene at a value of 13 mg/kg. Phthalate compounds are common laboratory contaminants, and are generally recognized as unreliable indicators of hydrocarbon contamination in environmental samples (Sullivan et al., 1993).

The data for pH, electrical conductivity, and total metals are presented in Table 17. Soil pH and electrical conductivity values for the trench samples at Evaporation Pond 1 averaged 8.2, and 6.0 mmhos/cm, respectively. The data for total metals concentrations revealed that significant accumulation levels for the metals of concern were measured only in soils at the 1-ft sample depth. Maximum and average concentration levels, respectively, in the Evaporation Pond 1 samples at the 1-ft sample interval, in mg/kg, were arsenic — 39.9 and 24.8; chromium — 1,011 and 397; lead — 389 and 124; nickel — 37 and 22.5; and zinc — 434 and 198 (Table 17).

All trench soil samples collected at Evaporation Pond 1 underwent TCLP analysis. None of the trench samples yielded leachate concentrations in excess of the specified regulatory limits for the selected TC constituents.

8.2 SUBSURFACE GAS

A well point investigation to measure headspace vapors from the degassing of groundwater was performed from 16 November to 4 December 1992 to approximate the lateral extent of the hydrocarbon plume extending south of Evaporation Pond 1 and to aid in the placement of monitor wells associated with monitoring this plume. The following sections present a discussion of the methods employed in the investigation.

8.2.1 Well Point Installation

Prior to the installation of the well points, a grid with a 500-ft spacing was established for the area south of Evaporation Pond 1. In addition, a background location was selected southwest of the pond and adjacent to monitor well EPA-1. Well points consisting of steam-cleaned 6-ft

Table 17. RFI Phase II soil sampling, Evaporation Pond 1 — pH, electrical conductivity, and total metals concentrations (mg/kg).

Table 17. RFI Phase II soil sampling, Evaporation Pond — pH, electrical conductivity, and total metals concentrations (mg/kg).

Sample	Sample depth (ft)	pH	Electrical conductivity (mmhos/cm)	Arsenic	Chromium	Lead	Nickel	Zinc
EP-TR-001-01	1	8.5	2.9	26.1	74	389	21	54
EP-TR-001-02	3	8.5	4.9	3.9	29	17	26	64
EP-TR-001-03	6	7.5	6.4	7.6	17	7	24	44
EP-TR-001-04	9	7.6	5.0	2.2	16	4	23	25
EP-TR-001-05	13	8.1	2.6	2.4	16	1	20	36
EP-TR-002-01	1	8.3	3.6	38.6	1011	93	37	303
EP-TR-002-02	3	8.8	2.8	1.8	19	10	21	49
EP-TR-002-03	6	7.5	6.1	8.6	17	6	24	41
EP-TR-002-04	9	7.9	5.3	4	16	5	28	37
EP-TR-002-05	13	7.9	5.3	9.9	16	6	31	42
EP-TR-003-01	1	8.1	3.1	22.6	633	73	14	434
EP-TR-003-02	3	7.8	5.8	9.1	30	14	23	57
EP-TR-003-03	3 (duplicate)	7.7	6.5	10.3	26	12	22	55
EP-TR-003-04	6	7.7	5.0	7.1	24	7	14	53
EP-TR-003-05	11	7.7	4.0	3.3	20	6	10	32
EP-TR-004-01	1	8.2	8.0	19.7	398	28	12	194
EP-TR-004-02	3	9.1	3.3	1.4	14	4	7	21
EP-TR-004-03	6	9.5	2.7	8.7	34	14	22	73
EP-TR-004-04	9	8.2	1.9	3.1	9	3	5	37
EP-TR-005-01	1	7.6	6.6	1.6	32	9	14	40
EP-TR-005-02	3	8.5	6.4	1.5	19	7	13	33
EP-TR-005-03	6	9.4	4.2	3.9	25	11	18	48
EP-TR-005-04	9	8.7	5.1	11.6	26	8	14	38
EP-TR-006-01	1	7.7	7.0	39.9	235	153	37	161
EP-TR-006-02	3	9.1	3.9	2.4	29	9	13	63
EP-TR-006-03	6	7.6	6.3	6.5	18	4	10	31
EP-TR-006-04	9	8.7	2.6	2.2	12	7	10	31
EP-TR-006-05 [a]	1	8.6	6.0	16.1	320	36	14	320

a = Trackhoe bucket grab sample of pond surface sludges adjacent to trench EP-TR-006.

joints of 1/2-in. steel pipe equipped with expendable conical tips were installed at each grid point. Installation was accomplished by utilizing a drill rig to hydraulically push the well points into the ground to the desired depth. The depth of insertion of the individual well points was determined during installation from the obvious reduction in downward force that occurs upon contact with saturated material. Once the proper depth was obtained, a well point would be withdrawn 6 in. to allow the groundwater to move into the annulus of the pipe.

Once each well point was installed, a threaded steel cap was used to seal the pipe and prevent the transfer of ambient air into the pipe. The elevation of the well points was then surveyed and recorded. This information was later used to determine the groundwater flow direction of the uppermost water-bearing zone.

8.2.2 Well Point Sampling

The water level was allowed to equilibrate in the installed pipes for at least 12 hours. A steel tape marked with chalk was then lowered into the pipe to determine the depth of water at that well point. The well point was then sampled by inserting polypropylene tubing into the well and using a peristaltic pump to withdraw the water. Approximately 400 ml of water was collected in a glass 1-L bottle or a quart jar. To minimize subsequent gas loss, clean aluminum foil was placed over the mouth of the container before it was sealed. The sealed container was shaken vigorously for 2 minutes and then allowed to sit for a minimum of 5 minutes. The lid was removed and flame ionization detector (FID) and photoionization detector (PID) probes were inserted into the container to draw headspace air from the container until the concentrations of volatile organic compounds were depleted. The maximum headspace reading for each instrument was recorded in the field logbook.

After all well points had been screened with the PID and FID, three locations were selected for collecting groundwater samples for laboratory analysis. The locations represent the range of PID and FID values found during the screening. The samples were withdrawn using the polypropylene tubing and peristaltic pump as described previously. Two 40-ml samples were collected at each location, preserved with HCl to a pH of <2.0, and packed on ice in an insulated container. The samples were recorded in the field logbook and on chain-of-custody forms, as previously detailed in Section 6.2.1.3, "Groundwater Sample Collection," and submitted to the laboratory for the analysis of benzene, toluene, ethylbenzene, and xylenes (BTEX) by EPA Method SW-8020.

8.2.3 Well Point Sampling Results

Results of the well point sampling event for subsurface gas are presented in Table 18. The well point sampling results, PID and FID readings, and contoured groundwater levels are included as Figures 7, 8, and 9, respectively.

Detectable hydrocarbon concentrations indicative of a hydrocarbon plume emanate from the vicinity of the southeast corner of Evaporation Pond 1 and the southwest corner of Pond 2. Detectable concentrations extend in a southeasterly direction for a distance of approximately 4,000 ft. Maximum PID concentrations detected are in excess of 50 ppm while several FID concentrations exceeded 1,000 ppm. Zones of highest PID and FID concentrations generally coincide and are limited to a distance of about 1,500 ft southeast of the Pond 1/Pond 2 intersection with a maximum width of 1,500 ft. Increased PID/FID readings in the vicinity of the gas well indicate that a second plume could be associated with the gas well immediately north of MW-10. Older gas wells in the state have been found to leak varying amounts of gas around the outside of the casing due to cement breakdown or casing problems. This could produce the 10-fold elevated FID levels seen downgradient from the well, although near-surface changes in lithology or multiple releases of hydrocarbon constituents could produce the lobe-shaped plume contours in that area.

One of three water samples taken during the well point sampling detected benzene at a concentration of 0.0285 mg/L in a well point at 1,000 ft. south and 500 ft east on the grid. This location is approximately 900 ft south-southeast of the south corner intersection of ponds 1 and 2. The second water detection of benzene, which occurred at the lower limit of the laboratory analytical equipment (0.0005 mg/L), was along the center line at point 4,000 ft south. Levels for the other volatile constituents varied but were generally low. Xylene at a concentration of 0.0987 mg/L at a location 1000 ft. south, 500 ft. east was the highest value analyzed.

Monitor wells were subsequently positioned in areas of the plume where landowner permission was obtained to verify the results of this investigation and to monitor plume movement. A discussion of the installation of these wells was presented in Section 8.3.1.1.

8.3 GROUNDWATER

8.3.1 Groundwater Investigation Procedures

The objectives of the groundwater investigation program at the evaporation ponds were to determine the lateral and vertical extent and concentration of any contamination impacting on groundwater and to facilitate future decision making. As described in Section 8.2.1, a well

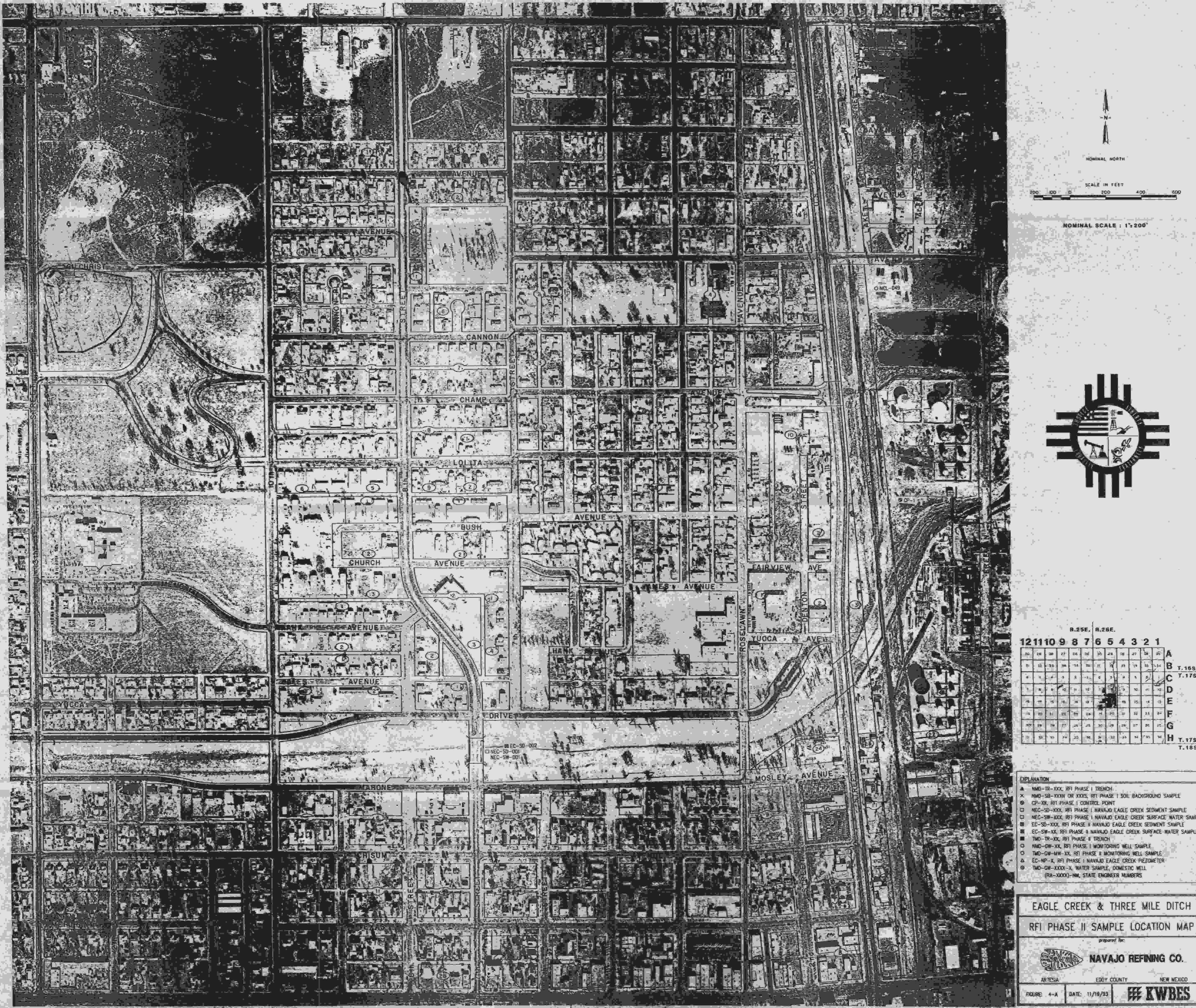
Table 18. Well point sampling results for subsurface gas survey at Evaporation Pond 1.

Table 18. Well point sampling results for subsurface gas survey at Evaporation Pond 1.

Location(ft)	Depth towater (ft)	Maximum reading (ppm) (PID)	Maximum reading (ppm) (FID)	Benzene [a] (mg/L)	Toluene [a] (mg/L)	Ethyl-benzene [a] (mg/L)	p,m-Xylene [a] (mg/L)	o-Xylene [a] (mg/L)
0S, 500W	8.62	6.5	150	—	—	—	—	—
500S, 0W	7.80	63.0	1200	—	—	—	—	—
500S, 500E	6.60	30.0	2000	—	—	—	—	—
500S, 500W	4.50	0.0	150	—	—	—	—	—
500S, 1000W	6.91	1.6	85	—	—	—	—	—
1000S, 0W	7.50	65.0	2500	—	—	—	—	—
1000S, 500E	6.58	66.0	3000	0.0285	0.0028	0.0066	0.0048	0.0987
1000S, 500W	9.67	2.0	2000	—	—	—	—	—
1000S, 1000E	6.17	88.0	400	—	—	—	—	—
1000S, 1000W	7.01	2.0	90	—	—	—	—	—
1000S, 2000E	7.33	32.0	60	—	—	—	—	—
1000S, 2500E	7.67	0.0	30	—	—	—	—	—
1000S, 3000E	8.25	0.0	70	—	—	—	—	—
1500S, 500E	6.40	27.0	300	—	—	—	—	—
1500S, 500W	6.95	0.0	30	—	—	—	—	—
1500S, 1000E	5.76	122.0	400	—	—	—	—	—
1500S, 1000W	7.67	0.0	1	—	—	—	—	—
1500S, 1500W	7.08	0.0	1	—	—	—	—	—
1500S, 2000E	7.71	16.0	50	—	—	—	—	—
2000S, 0W	9.46	0.0	40	—	—	—	—	—
2000S, 500E	6.09	29.0	150	—	—	—	—	—
2000S, 500W	6.75	0.0	20	—	—	—	—	—
2000S, 1000E	7.00	4.0	2	—	—	—	—	—
2000S, 1000W	4.75	0.0	1	—	—	—	—	—
2000S, 1500E	7.46	4.0	9	—	—	—	—	—
2000S, 2000E	6.25	0.0	15	—	—	—	—	—
2500S, 0W	9.38	16.0	300	—	—	—	—	—
2500S, 500E	6.67	44.0	30	—	—	—	—	—
2500S, 500W	6.00	4.0	105	—	—	—	—	—
2500S, 1000E	7.12	4.0	5	—	—	—	—	—
2500S, 1000W	—	0.0	0	—	—	—	—	—
2500S, 2000E	5.92	4.0	100	ND	0.0011	0.0005	0.0009	0.0128
3000S, 0W	6.67	16.0	250	—	—	—	—	—
3500S, 0W	9.15	8.0	80	—	—	—	—	—
3500S, 500E	10.67	0.0	9	—	—	—	—	—
3500S, 500W	5.42	0.0	0	—	—	—	—	—
4000S, 0W	4.33	0.0	3	0.0005	0.0018	0.0006	0.001	0.0005
4500S, 0W	—	0.0	0	—	—	—	—	—
Background								
BKG-WP-EPA-1	10.04	0.0	2	—	—	—	—	—
BKG-EPA-1 [b]	9.52	0.0	2	ND	ND	ND	ND	ND

ND = Not detected at 0.0005 mg/L.
a = Analysis by EPA Method SW-8020, results not confirmed by mass spectrometer.
b = Sample obtained from monitor well EPA-1 on 11/18/92.

Figure 7. Well point survey, PID contour map, November 1992, Evaporation Pond Area, RFI Phase II.



EXPLANATION

- ▲ NMD-TR-XXX, RFI PHASE I TRENCH
- × NMD-SB-XXXN OR XXXS, RFI PHASE I SOIL BACKGROUND SAMPLE
- ⊕ CP-XX, RFI PHASE I CONTROL POINT
- ☐ NEC-SD-XXX, RFI PHASE I NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ☐ NEC-SW-XXX, RFI PHASE I NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
- ☒ EC-SD-XXX, RFI PHASE II NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ☒ EC-SW-XX, RFI PHASE II NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
- ■ TMD-TR-XX, RFI PHASE II TRENCH
- ○ NMD-GW-XX, RFI PHASE I MONITORING WELL SAMPLE
- ○ TMD-GW-MW-XX, RFI PHASE II MONITORING WELL SAMPLE
- △ EC-NP-X, RFI PHASE I NAVAJO EAGLE CREEK PIEZOMETER
- ⊙ TMD-GW-XXXX-X, WATER SAMPLE, DOMESTIC WELL
  (RA-XXXX)-NM, STATE ENGINEER NUMBERS

EAGLE CREEK & THREE MILE DITCH

RFI PHASE II SAMPLE LOCATION MAP

prepared for:

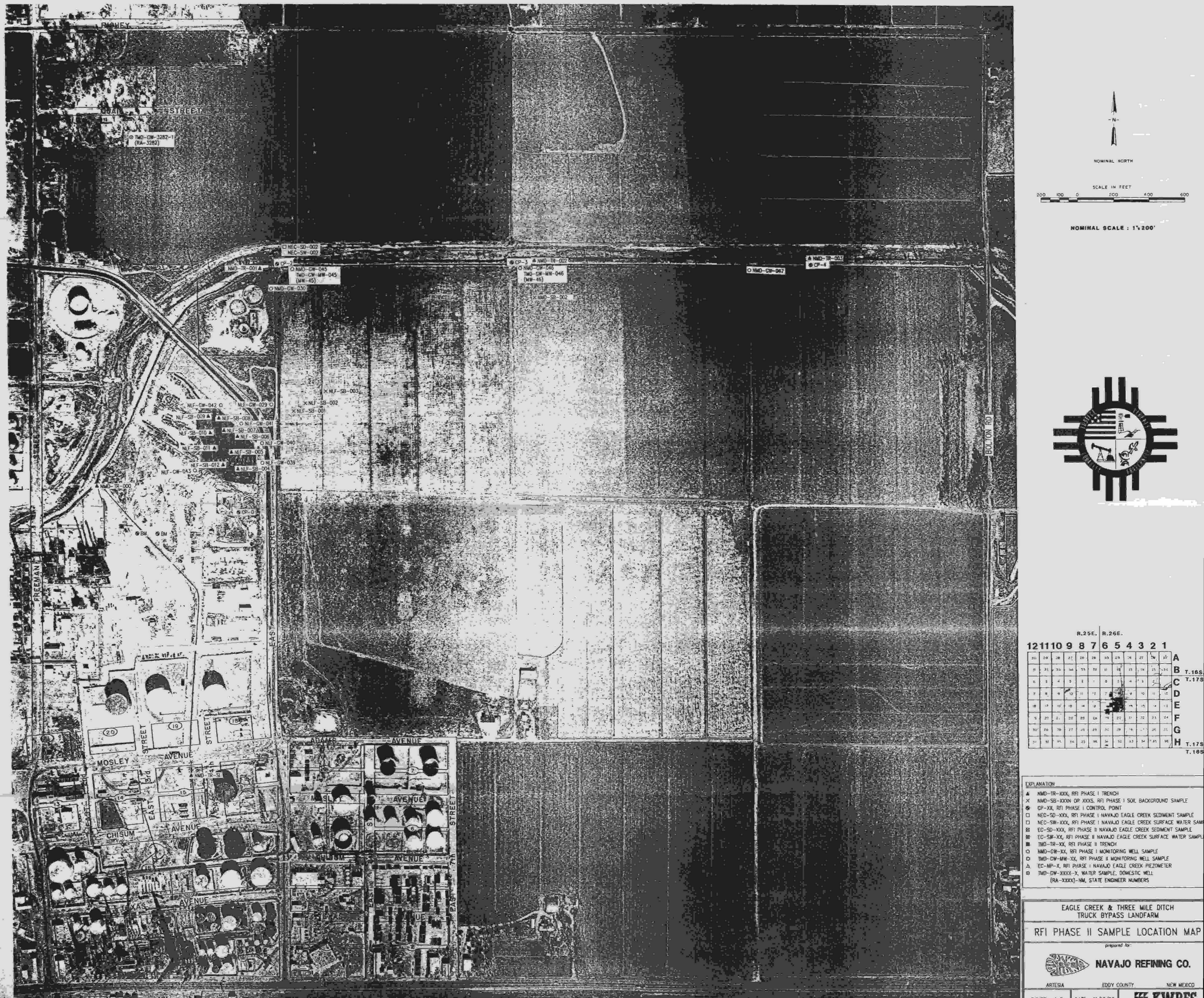
NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

FIGURE: 4-A DATE: 11/19/93 KWBES

RATIO - RECTIFIED PHOTOBASE MAP
PREPARED FROM AERIAL PHOTOGRAPHY
EXPOSED 12-17-85 BY THOMAS R. MANN
& ASSOCIATES, INC., ALBUQUERQUE, N.M.

Figure 8. Well point survey, FID contour map, November 1992, Evaporation Pond Area, RFI Phase II.



EXPLANATION

- ▲ NMD-TR-XXX, RFI PHASE I TRENCH
- × NMD-SB-XXXN OR XXXS, RFI PHASE I SOIL BACKGROUND SAMPLE
- ⊕ CP-XX, RFI PHASE I CONTROL POINT
- □ NEC-SD-XXX, RFI PHASE I NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- □ NEC-SW-XXX, RFI PHASE I NAVAJO EAGLE CREEK SURFACE WATER SAM
- ⊠ EC-SD-XXX, RFI PHASE II NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ⊠ EC-SW-XX, RFI PHASE II NAVAJO EAGLE CREEK SURFACE WATER SAMPL
- ■ TMD-TR-XX, RFI PHASE II TRENCH
- ○ NMD-GW-XX, RFI PHASE I MONITORING WELL SAMPLE
- ⊖ TMD-GW-MW-XX, RFI PHASE II MONITORING WELL SAMPLE
- △ EC-MP-X, RFI PHASE I NAVAJO EAGLE CREEK PIEZOMETER
- ⊙ TMD-GW-XXXX-X, WATER SAMPLE, DOMESTIC WELL
  (RA-XXXX)-NM, STATE ENGINEER NUMBERS

EAGLE CREEK & THREE MILE DITCH
TRUCK BYPASS LANDFARM

RFI PHASE II SAMPLE LOCATION MAP

prepared for:

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

FIGURE: 4-B DATE: 11/19/93 KWBES

RATIO - RECTIFIED PHOTOBASE MAP
PREPARED FROM AERIAL PHOTOGRAPHY
EXPOSED 12-17-85 BY THOMAS R. MANN
& ASSOCIATES, INC., ALBUQUERQUE, N.M.

Figure 9. Well point survey, groundwater elevations, November 1992, Evaporation Pond Area, RFI Phase II.

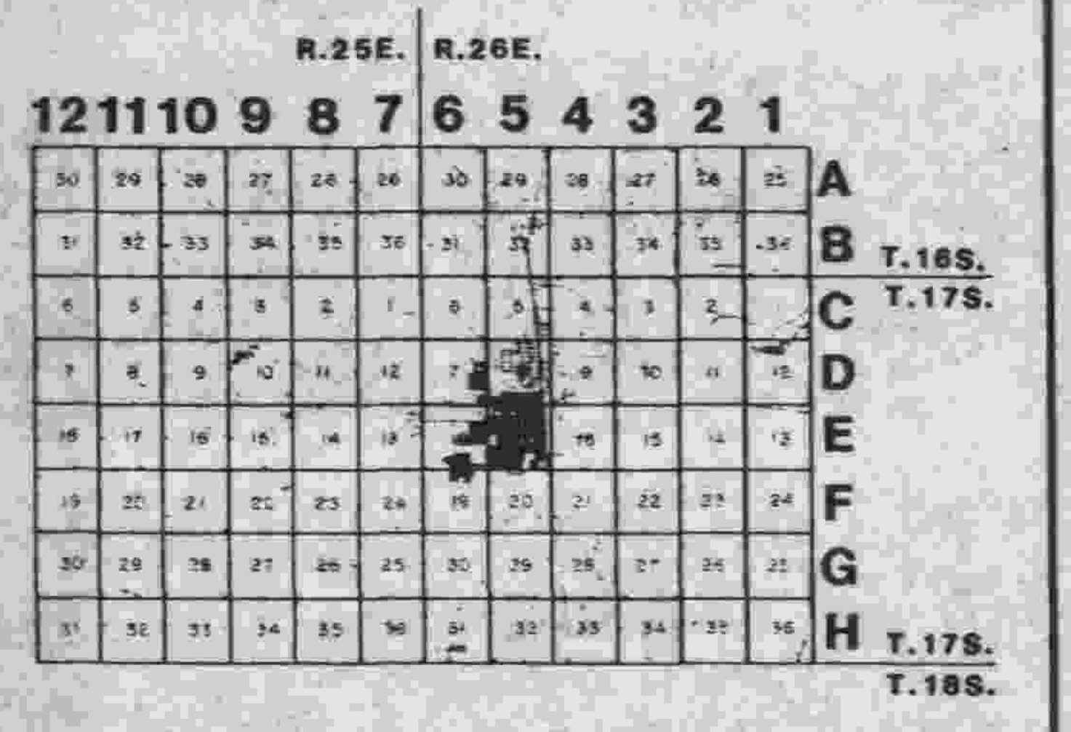
-N-

NOMINAL NORTH

SCALE IN FEET

200 100 0 200 400 600

NOMINAL SCALE : 1"=200'



EXPLANATION

- ▲ NMD-TR-XXX, RFI PHASE I TRENCH
- × NMD-SB-XXXN OR XXXS, RFI PHASE I SOIL BACKGROUND SAMPLE
- ⊕ CP-XX, RFI PHASE I CONTROL POINT
- ☐ NEC-SD-XXX, RFI PHASE I NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ☐ NEC-SW-XXX, RFI PHASE I NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
- ☒ EC-SD-XXX, RFI PHASE II NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ☒ EC-SW-XX, RFI PHASE II NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
- ■ TMD-TR-XX, RFI PHASE II TRENCH
- ○ NMD-GW-XX, RFI PHASE I MONITORING WELL SAMPLE
- ○ TMD-GW-MW-XX, RFI PHASE II MONITORING WELL SAMPLE
- △ EC-NP-X, RFI PHASE I NAVAJO EAGLE CREEK PIEZOMETER
- ⊙ TMD-GW-XXXX-X, WATER SAMPLE, DOMESTIC WELL
  (RA-XXXX)-NM, STATE ENGINEER NUMBERS

EAGLE CREEK & THREE MILE DITCH

RFI PHASE II SAMPLE LOCATION MAP

prepared for:

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

FIGURE: 4-C DATE: 11/19/93 KWBES

RATIO - RECTIFIED PHOTOBASE MAP
PREPARED FROM AERIAL PHOTOGRAPHY
EXPOSED 12-17-85 BY THOMAS R. MANN
& ASSOCIATES, INC., ALBUQUERQUE, N.M.

point sampling investigation was performed first to approximate the lateral extent of contamination and aid in the placement of the monitor wells. The procedures followed for drilling and sampling monitor wells and borings are identical to those described in Section 6.2.1, "Groundwater Investigation Procedures," for the investigation at Three-Mile Ditch. The groundwater investigation at the evaporation ponds also involved the use of hydrogeological techniques, as described in Section 8.3.1.2.

8.3.1.1 Monitor Well Installation

Nineteen monitor wells (including a replacement well and a well located in proximity to the lower end of the effluent ditch) were completed in the vicinity of Evaporation Pond 1 (Figure 6) during December 1992 and January 1993 to provide information on water levels and quality from surficial and deeper groundwater within the valley fill alluvium. Ten shallow monitor wells were completed south of the ponds and on the east side of the Pecos River. Nine deeper wells, identified with the suffix letter B (e.g., MW-2B), are surface-cased to isolate the deeper groundwater from the surficial zone within the aquifer. An additional nest of one test well and two monitor wells was installed in an area southeast of the pond for an aquifer test (Section 8.3.2.2, "Aquifer Testing"). Several wells tentatively located south and east of MW-4 were not installed due to the inability of Navajo to obtain access to drill and complete the wells.

The wells installed in the shallower groundwater zone were drilled, logged, completed, and developed as described in Section 6.2.1.1, "Drilling Procedures." Installation was performed by Pool Environmental Drilling, as previously identified, and by Precision Engineering, an environmental drilling firm headquartered in Las Cruces, New Mexico. The Precision Engineering drillers used a CME 75 Hi-Torque hollow-stem dry auger rig mounted on a four-wheel-drive truck.

Installation of the deep wells required different techniques to address the difficulties in boring and sampling in heaving sands at depths of 30 to 50 ft in the valley fill alluvium. Borings began using the procedures previously described, which were followed until heaving sands pushed into the augers when the recovery barrel was retrieved. The depth of occurrence of the heaving sands varied from 9 to 20 ft below the ground surface. At this point, the drillers replaced the recovery barrel with a center bit and ran it in advance of the augers. As the boring advanced with the center bit, the geologist selected intervals to be sampled using a split-spoon sampler based on changes in the cuttings, auger feed rate, and hydraulic drawdown pressure.

Total depth of the boring was determined by continuing boring for at least 30 ft below the deepest contaminated zone because no confining layer was found below the first transmissive zone. Contaminated zones were identified by appearance and odor. Once total depth was achieved, the 4.25-in.-I.D. augers were replaced with 8.25-in.-I.D. augers to overdrill the boring to a depth approximately 15 ft short of total depth. A wooden knockout plug was inserted in the lead auger to keep soil from pushing into the auger annulus. The augers were then removed and 10-in.-O.D. schedule 40 PVC casing was placed in the boring to act as surface casing. The 20-ft sections of PVC casing were connected using stainless-steel screws while a section was suspended in the hole. The rig kelley was used to press the PVC casing the last few feet to total depth. A seal was installed between the PVC casing and the boring wall by using a tremie pipe to pump a slurry of cement and 5% bentonite into the annulus. The tremie pipe was placed a few feet above the bottom of the casing to avoid pumping grout into the zone to be screened.

The grout was allowed to cure for at least 24 hours before the rig was set back over the hole. The 4.25-in. augers were rigged with a wood knockout plug and quickly advanced to the total depth of the boring. The wood plug was then knocked out by lowering the drill rod through the auger casing, and 2-in. PVC casing with a 10-ft screened section was placed within the surface casing. Silica sand was placed in the annulus between the auger and the 2-in. PVC casing to form a sand pack, and the auger was pulled slowly from the hole to ensure proper placement of the sand pack. The problems with heaving sands ended once the lead auger was pulled into the 10-in. surface casing, and the remainder of the auger sections could be pulled quickly. The sand pack was extended for a few feet into the surface casing, and then a bentonite seal was placed using either slurry or dry-pellet methods. After a short hydration period, concrete was pumped into the annulus between the surface casing and the 2-in. well casing to provide an anchor and seal. Surface completion for the deep wells was the same as previously described in Section 6.2.1.1.3, "Well Construction."

A tremie pipe was then placed down the annulus between the PVC casing and the boring wall to pump a slurry of cement and 5% bentonite around the casing to provide a seal.

8.3.1.2 Hydrogeologic Techniques and Parameters

This subsection reviews the procedures used for characterizing the groundwater system associated with the evaporation ponds. These procedures include groundwater elevation measurements and the determination of various aquifer parameters related to flow velocity and the transport of dissolved-phase contaminants.

A well discharge rate is obtained by measuring the time necessary for the pumped groundwater to fill a container of known volume. This rate was recorded in the logbook in gallons per minute (gpm). Other hydrologic parameters such as hydraulic conductivity, transmissivity, and similar characteristics were obtained as necessary from the tests described herein or from the extensive hydrogeologic literature available for the site.

An aquifer, or pump, test was conducted to quantify key hydraulic parameters such as transmissivity and hydraulic conductivity. The test was performed using an observation well, which is the preferred approach to overcome small variations in pumping and friction losses in the pumped well.

Conducting the pump test required the temporary installation of a 2-in.-diameter electric submersible pump (Grunfos Redi-Flo 2) with the associated plumbing in the pumping well in order to withdraw water from the pumping well. The limited discharge of withdrawn water to a nearby field during the test was not considered detrimental to test results because the fine-grained nature of the surface soils minimized the downward seepage of the water. Also, the results of the monitor well sampling showed that, at most, only trace levels of dissolved organics were present in the monitor wells. Power to the electric pump was supplied by a gasoline-powered generator. A pump controller and a flow meter were used to regulate and determine the pumping rate during the test.

An automated electronic data logging system (*in situ* Hermit 2000 data logger equipped with *in situ* submersible pressure transducers) was used to collect water-level measurements in the pumping and observation wells during the test. The pressure transducers in the observation wells were placed at a depth within the screened interval of the casing, below the expected level of drawdown. The pressure transducer in the pumping wells was placed a few feet above the top of the pump but below the expected level of drawdown.

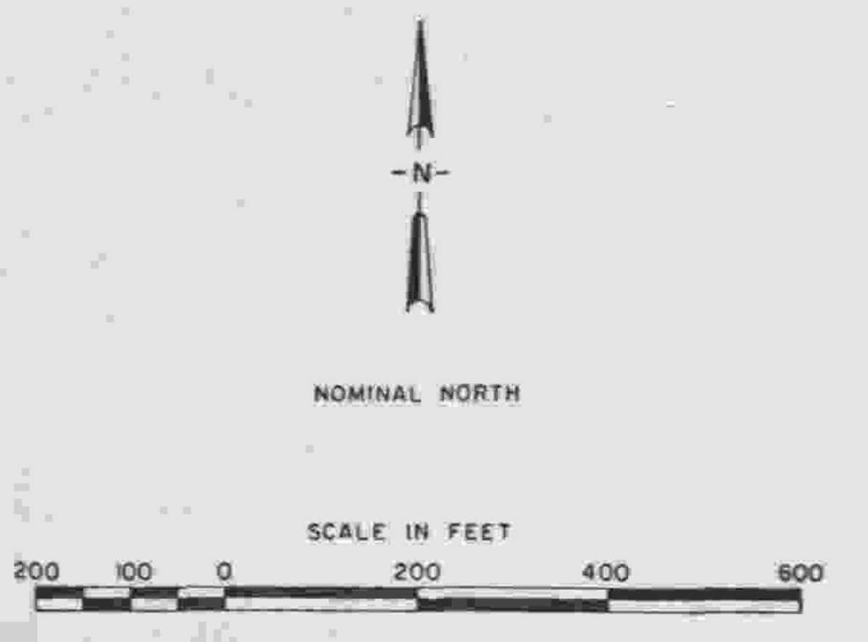
Prior to the start of test pumping, the maximum pumping rate was determined by performing a step-drawdown test. During a step-drawdown test, the well is pumped at progressively higher rates until it is determined that the water-bearing zone can not produce the volumes of water necessary to maintain a higher pumping rate (i.e., the level of drawdown is such that the water level is drawn below the pressure transducer).

The results of the aquifer test were analyzed using standard hydrogeological methods utilized by experts in the groundwater profession.

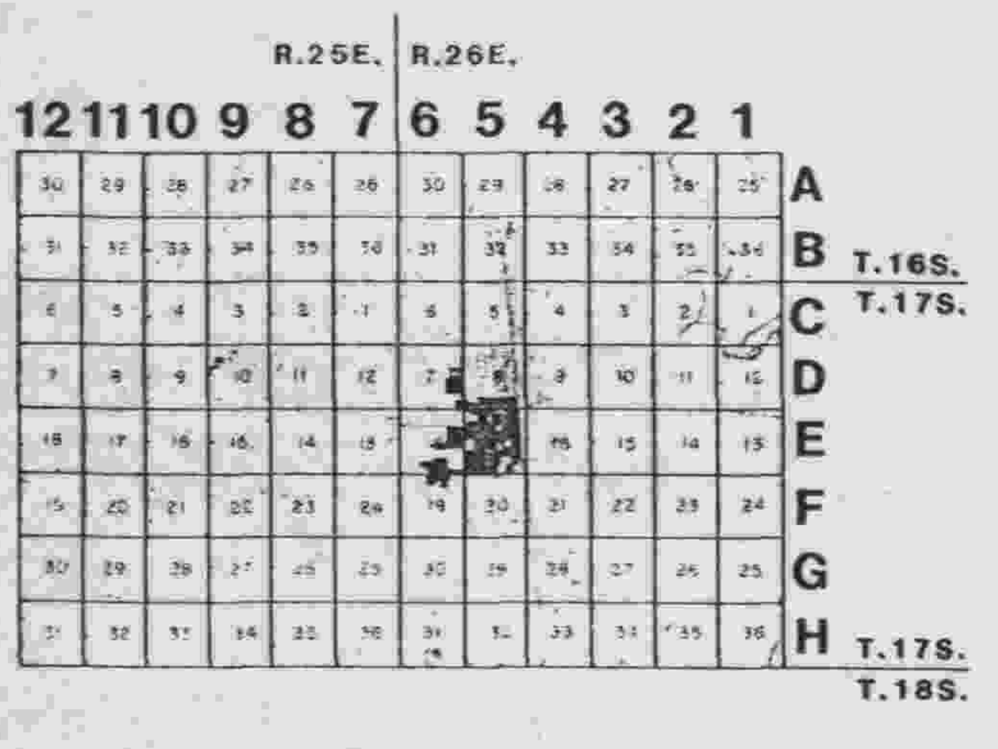
8.3.2 Results

8.3.2.1 Results of the Drilling Program

The generalized stratigraphy developed from the well logs compiled for the 21 monitor wells and the one test well installed in the area around Evaporation Ponds 1 and 2 during the RFI Phase II field investigation indicates an environment of deposition typical for meandering rivers. As seen in Figure 10, the ponds are located within a current meander loop of the Pecos River.



NOMINAL SCALE : 1"=200'



EXPLANATION

- ▲ NMD-TR-XXX, RFI PHASE I TRENCH
- × NMD-SB-XXXN OR XXXS, RFI PHASE I SOIL BACKGROUND SAMPLE
- ⊕ CP-XX, RFI PHASE I CONTROL POINT
- ☐ NEC-SD-XXX, RFI PHASE I NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ☐ NEC-SW-XXX, RFI PHASE I NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
- ☒ EC-SD-XXX, RFI PHASE II NAVAJO EAGLE CREEK SEDIMENT SAMPLE
- ☒ EC-SW-XX, RFI PHASE II NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
- ■ TMD-TR-XX, RFI PHASE II TRENCH
- ○ NMD-GW-XX, RFI PHASE I MONITORING WELL SAMPLE
- ○ TMD-GW-MW-XX, RFI PHASE II MONITORING WELL SAMPLE
- △ EC-NP-X, RFI PHASE I NAVAJO EAGLE CREEK PIEZOMETER
- ⊙ TMD-GW-XXXX-X, WATER SAMPLE, DOMESTIC WELL
  (RA-XXXX)-NM, STATE ENGINEER NUMBERS

EAGLE CREEK & THREE MILE DITCH

RFI PHASE II SAMPLE LOCATION MAP

prepared for:

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

FIGURE: 4-D	DATE: 11/19/93	KWBES

RATIO - RECTIFIED PHOTOBASE MAP
PREPARED FROM AERIAL PHOTOGRAPHY
EXPOSED 12-17-85 BY THOMAS R. MANN
& ASSOCIATES, INC. ALBUQUERQUE, N.M.

TRM

Figure 10. Location of stratigraphic cross sections, Evaporation Pond Area, RFI Phase II.

The near-surface geology consists predominantly of fine- to medium-grain, well-graded sands exhibiting increasing grain sizes with depth and interbedded in the upper 20 ft of the section with thin clayey zones. The clayey materials resulted from overbank deposition and are thickest near the cutbanks of the river, as found in monitor well OCD-8B and the MW-18 three-well nest (Appendix F). The thick gravel zones found below 27 ft in depth in monitor wells MW-18B, MW-18T, MW-22B, and OCD-8B are indicative of channel deposits. The variation in the stratigraphic record among the wells is illustrated by the north-south and two east-west stratigraphic cross sections shown in Figures 11 through 13.

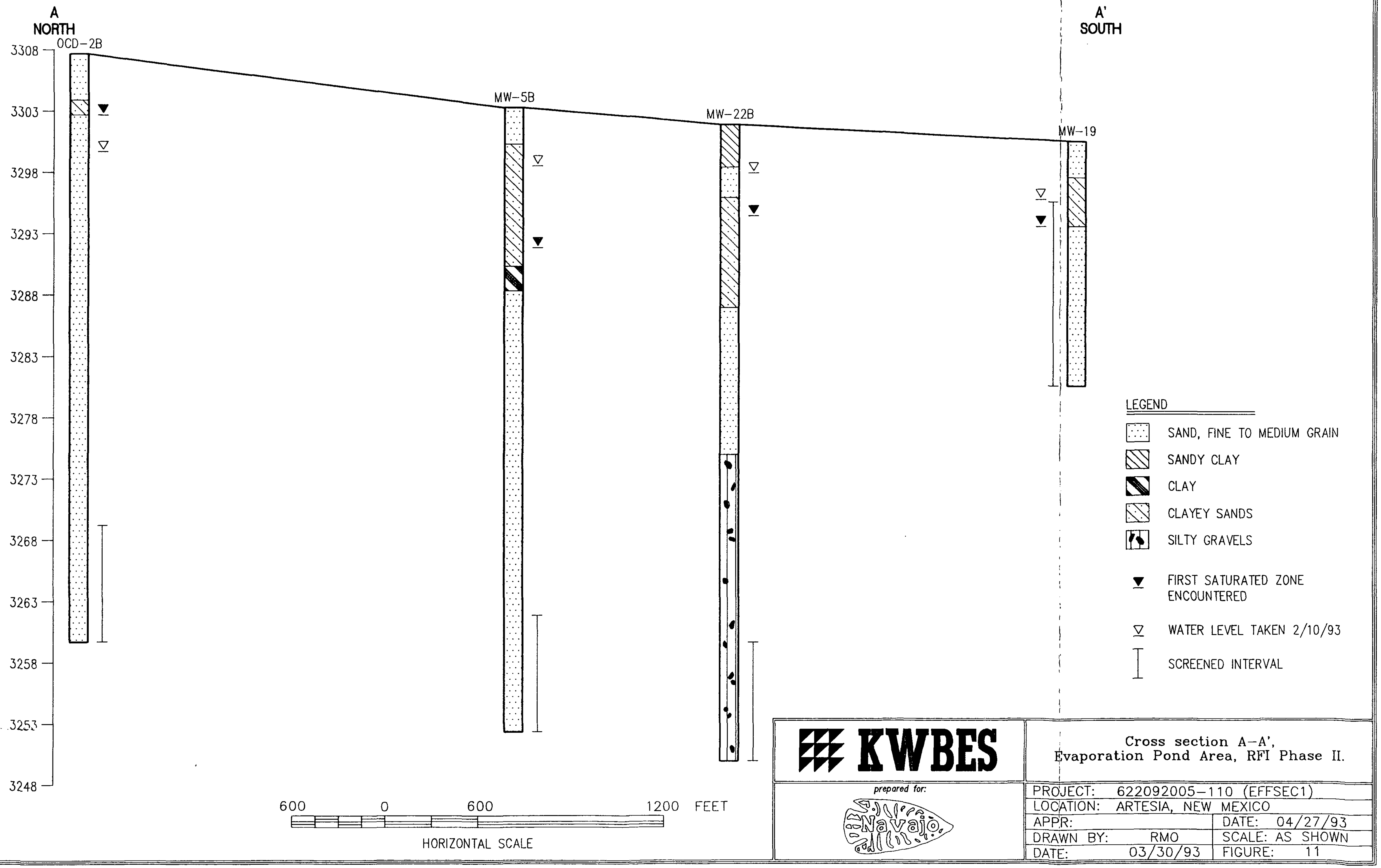
The depth to the first saturated zone ranged from 14.5 ft below the ground surface at MW-6B, which was installed on top of earthen fill, to 3.5 ft below the surface at MW-11A and MW-11B located on the low-lying flat area northeast of Evaporation Pond 2. The average measured depth to water was approximately less than 10 ft below grade.

MW-17 was installed as a background well on a topographic high to the north of MW-16, one of the four Phase II wells installed along Three-Mile Ditch. The well log description for this well is sands and sandy clays with a depth of 19 ft to the first zone of saturation. The location of this well is shown on Figures 1 and 5B.

8.3.2.2 Groundwater Movement

Depth-to-water measurements in the monitor wells and in one piezometer in the vicinity of the evaporation ponds were made between 8 and 10 February 1993. Additionally, the river water-level elevation was measured during that period by the land surveyors determining the location and elevations of the new and existing monitor wells during those dates. Water-level elevations were calculated by subtracting the depth-to-water readings from the elevations surveyed for the top of the well casings (Table 19). New and existing well locations and water-level elevations were plotted on a 1:3600 (1 in. = 300 ft) base map prepared from the earlier RFI Phase I report and the USGS Spring Lake 7.5-minute quadrangle topographic map. Water-level contour lines were drawn at 0.5-ft intervals in the mapped area. The resulting potentiometric map is shown as Figure 14. Surface water elevations were used to estimate the groundwater-level elevations in the vicinity of the active pond and along the reach of the Pecos River adjacent to the ponds. A pond water elevation of 3,310 ft. was measured from the concrete grate at the effluent pipeline discharge culvert at the southwest corner of Pond 2. River stage was measured opposite well OCD-7B. Surface water elevations upriver from the measurement point were estimated using a gradient of 0.323 ft per 10,000 ft of river distance (0.0000323 ft/ft). The gradient per river distance is significantly flatter than either the 0.00062 ft/ft gradient measured directly from the map at the points where the 3,300 and 3,290 ft contour lines intersect the river or the gradient of the local land surface topographic gradient (0.0013 ft/ft)

Figure 11. Cross section A-A, Evaporation Pond Area, RFI Phase II.



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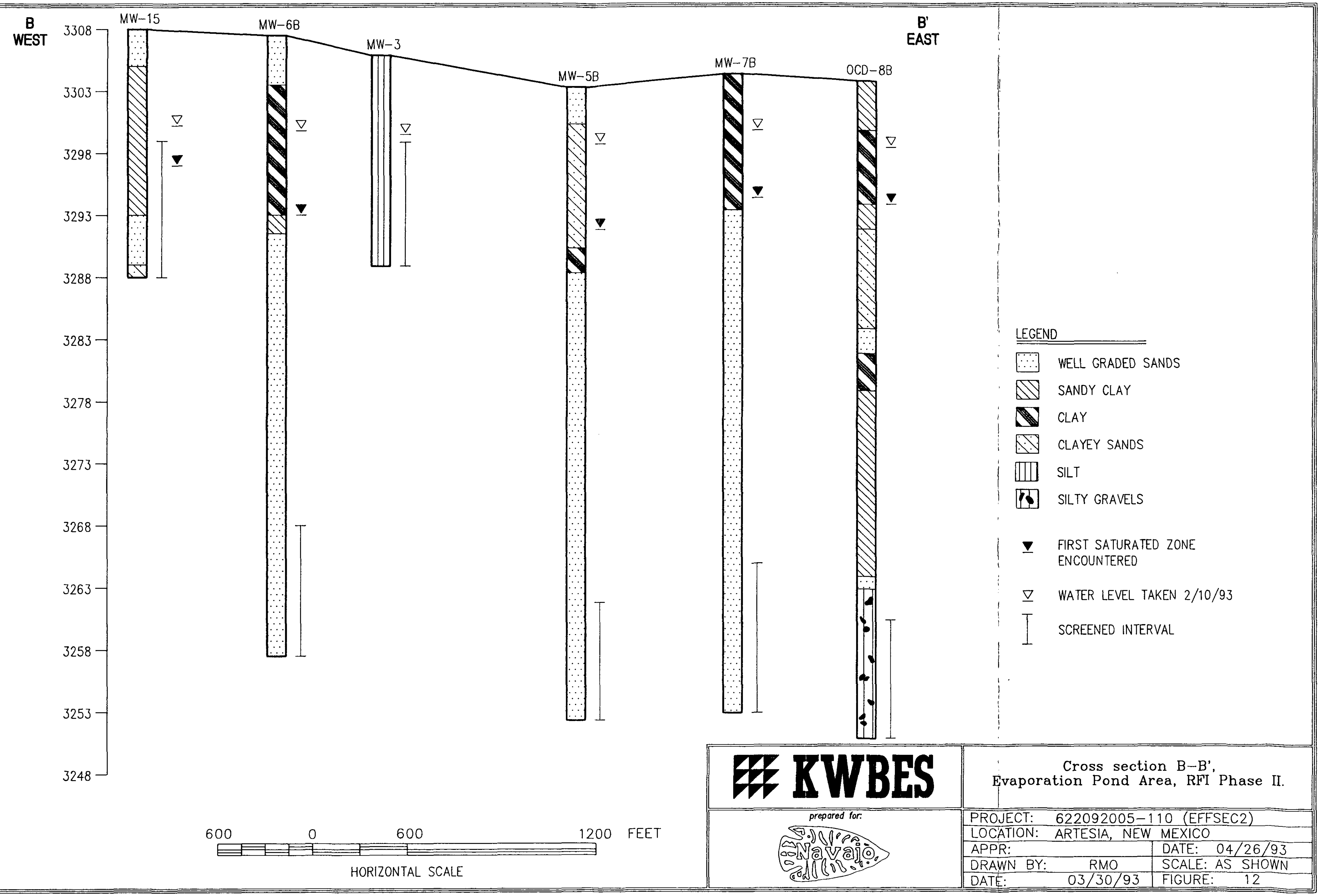
Navajo

Cross section A-A',
Evaporation Pond Area, RFI Phase II.

PROJECT: 622092005-110 (EFFSEC1)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/27/93
DRAWN BY: RMO	SCALE: AS SHOWN
DATE: 03/30/93	FIGURE: 11

Figure 12. Cross section B-B, Evaporation Pond Area, RFI Phase II.



KWBES

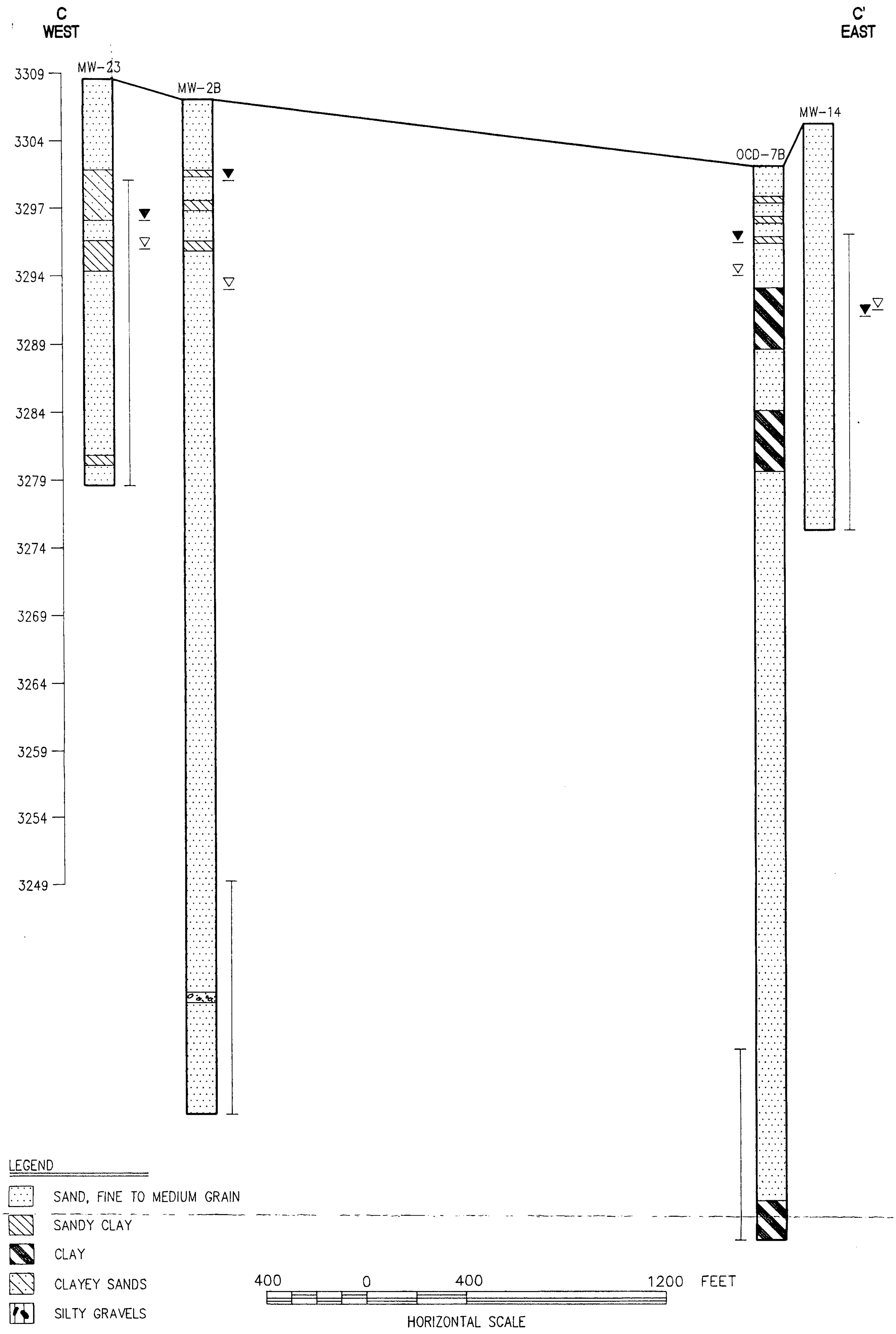
prepared for:

Navajo

Cross section B-B',
Evaporation Pond Area, RFI Phase II.

PROJECT: 622092005-110 (EFFSEC2)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 04/26/93
DRAWN BY: RMO	SCALE: AS SHOWN
DATE: 03/30/93	FIGURE: 12

Figure 13. Cross section C-C, Evaporation Pond Area, RFI Phase II.



LEGEND

- ⬚ SAND, FINE TO MEDIUM GRAIN
- ▨ SANDY CLAY
- ▨ CLAY
- ▨ CLAYEY SANDS
- ▨ SILTY GRAVELS

- ▼ FIRST SATURATED ZONE ENCOUNTERED
- ▽ WATER LEVEL TAKEN 2/10/93
- I SCREENED INTERVAL

KWBES

prepared for:

Navajo

Cross section C–C',
Evaporation Pond Area, RFI Phase II.

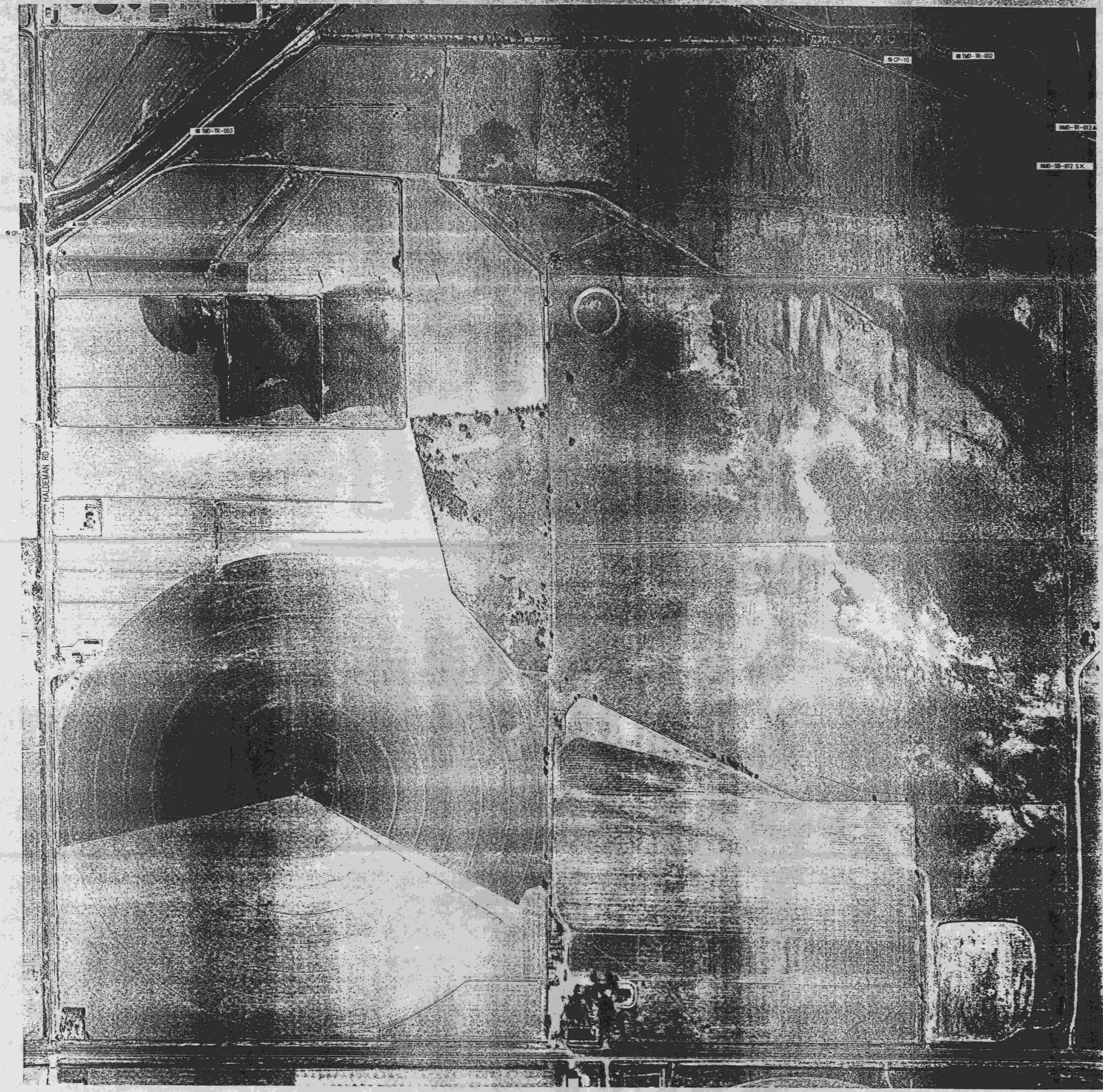
PROJECT: 622092005–110 (EFFSEC3)
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 04/26/93
DRAWN BY: RMO
SCALE: AS SHOWN
DATE: 03/31/93
FIGURE: 13

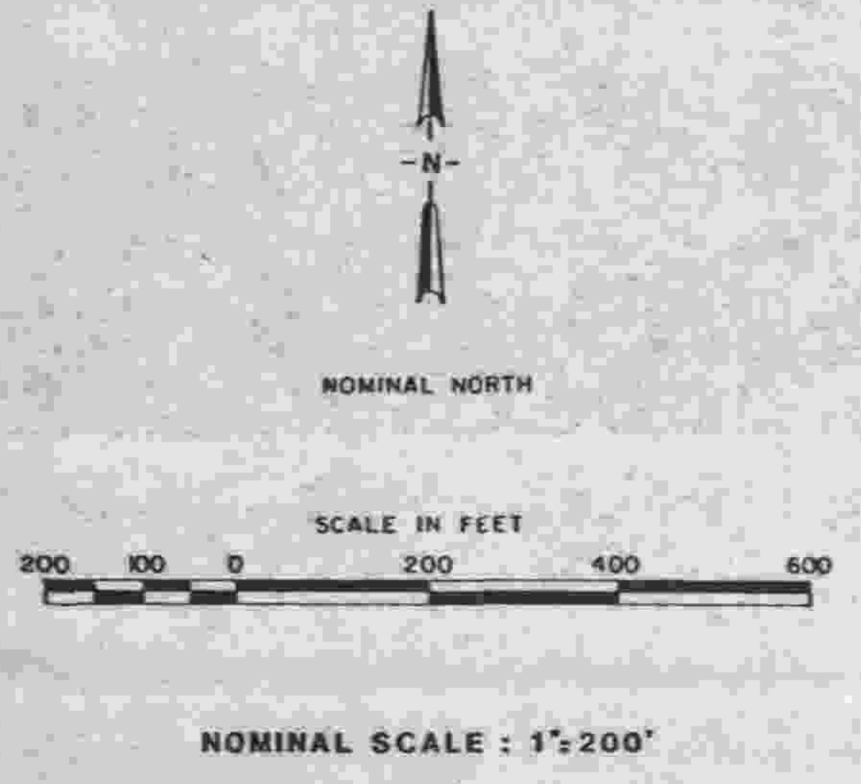
Table 19. Water-level elevations at monitor wells in the vicinity of Navajo evaporation ponds, February 1993.

Table 19. Water level elevations at monitor wells in the vicinity of Navajo evaporation ponds, February 1993.

Well	Surveyed elevation (ft)	Depth to water (ft)	Water elevation (ft)
MW-1	3311.6	10.25	3301.35
MW-2A	3309.8	8.32	3301.48
MW-2B	3309.29	9.36	3299.93
MW-3	3307.28	7.85	3299.43
MW-4	3309.65	10.4	3299.25
MW-5A	3305.87	7.64	3298.23
MW-5B	3305.94	7.22	3298.72
MW-6A	3310.71	11.01	3299.7
MW-6B	3310.59	10.86	3299.73
MW-7A	3304.73	6.52	3298.21
MW-7B	3306.3	7.72	3298.58
MW-10	3301.3	4.28	3297.02
MW-11A	3307.46	8.81	3298.65
MW-11B	3307.55	8.76	3298.79
MW-12	3310.03	10.15	3299.88
MW-13	3311.55	11.27	3300.28
MW-14	3308.78	11.42	3297.36
MW-15	3310.93	10.65	3300.28
MW-17	3320.38	14.64	3305.74
MW-18A	3305.36	9.53	3295.83
MW-18B	3305.58	9.46	3296.12
MW-18P	3305.62	NA	NA
MW-19	3303.09	7.3	3295.79
MW-22A	3304.3	6.75	3297.55
MW-22B	3304.46	6.61	3297.85
MW-23	3311.26	10.85	3300.41
MW-24	3309.65	11.87	3297.78
OCD-1	3311.11	9.58	3301.53
OCD-2A	3310.99	11.23	3299.76
OCD-2B	3309.9	10.07	3299.83
OCD-3	3311.19	12.23	3298.96
OCD-4	3309.95	11.66	3298.29
OCD-5	3308.31	10.22	3298.09
OCD-6	3308.19	10.22	3297.97
OCD-7AR	3307.05	7.89	3299.16
OCD-7B	3307.15	8.21	3298.94
OCD-8A	3305.6	8.33	3297.27
OCD-8B	3306.08	7.66	3298.42
EPA-1	3308.04	8.99	3299.05
Concrete grate	3310.32		3310.32
River water level (near OCD-7)	3297.2		3297.2

Note: Water level measured February 8 — 10, 1993.
NA: Not available.





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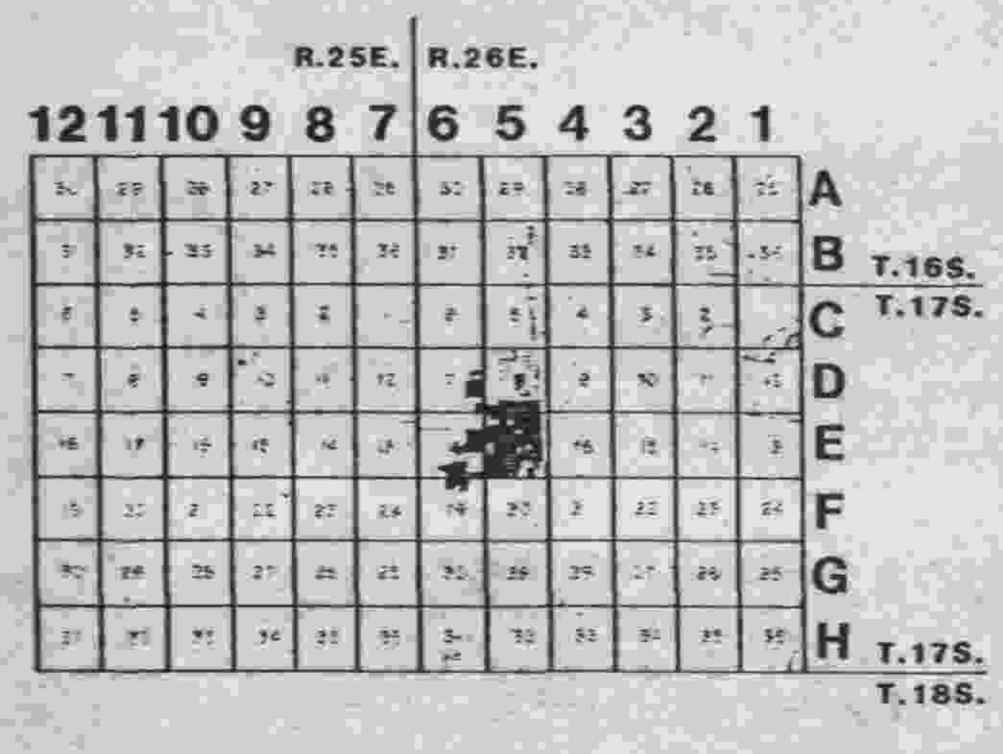

EXPLANATION

- ▲ NMD-TR-XXX, RFI-PHASE I TRENCH
- × NMD-SB-XXXN OR XXXS, RFI PHASE I SOIL BACKGROUND SAMPLE
- ● CP-XX, RFI PHASE I CONTROL POINT
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- □ NEC-SW-XXX, RFI PHASE I NAVAJO EAGLE CREEK SURFACE WATER SAMPLE
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- ■ TMD-TR-XX, RFI PHASE II TRENCH
- ○ NMD-GW-XX, RFI PHASE I MONITORING WELL SAMPLE
- ○ TMD-GW-MW-XX, RFI PHASE II MONITORING WELL SAMPLE
- △ EC-NP-X, RFI PHASE I NAVAJO EAGLE CREEK PIEZOMETER
- ⊙ TMD-GW-XXXX-X, WATER SAMPLE, DOMESTIC WELL
  (RA-XXXX)-NM, STATE ENGINEER NUMBERS

EAGLE CREEK & THREE MILE DITCH

RFI PHASE II SAMPLE LOCATION MAP

prepared for:

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

FIGURE: 4-E DATE: 11/19/93 KWBES

RATIO - RECTIFIED PHOTOBASE MAP
PREPARED FROM AERIAL PHOTOGRAPHY
EXPOSED 12-17-85 BY THOMAS R. MANN
& ASSOCIATES, INC., ALBUQUERQUE, N.M.

TRM

Figure 14. Shallow groundwater potentiometric map, February 1993, Evaporation Pond Area, RFI Phase II.

south of the ponds and north of U.S. Highway 82. As can be seen from the map, the river meanders in the vicinity of the ponds, which causes the wide variation in gradient.

Groundwater flow direction is perpendicular to the potentiometric contours. Examination of the potentiometric map shows regional groundwater movement to be southeasterly with a gradient of 0.00088 ft/ft in the area between MW-10 and MW-19, and 0.00118 in the area of MW-5 and MW-18. Closer to Evaporation Pond 1 the contours steepen and follow the pond outline. Also, the contours were drawn to cross the river at elevations calculated using the 0.323 ft per 10,000 ft river distance relationship discussed previously. River water-level elevations are about 7 to 8 ft beneath the level of the adjacent banks because the channel has been severely incised as a result of past erosion. Comparison of the river, groundwater, and topographic gradients reveals that the near-surface groundwater gradient is much closer to the local topographic gradient than to the river gradient.

At those locations and times of the year when the elevation of the groundwater is higher than the elevation of the adjacent river section, groundwater movement is toward the river. The measurements show the river to be a gaining stream in the area of this map. This is consistent with the discussion by Welder (1983, p. 13) that the river generally receives groundwater flow from the valley fill aquifer along the section of river from north of Roswell to a location about 1 mile south of the Highway 82 bridge.

The Phase II installation of the 10 deep monitor wells (completed from 35 to 50 ft in depth) enabled the measurement of vertical gradients and estimation of the direction of movement and gradient of the deeper water. Differences in vertical potentiometric levels are determined by comparing water-level elevations in the shallow "A" well and the deeper "B" well. Vertical gradients were determined by dividing the difference in water-level elevations by the vertical separation between the base of the "A" screen and the top of the "B" screen, a distance that varied between 14 and 26 ft depending on the measured depth of the original "A" well. The vertical gradients for each well pair are only approximated because screened intervals for both the "A" and "B" wells were up to 15 ft long and the water-level measured in each screened interval is an integrated value for that interval.

The differences in water levels between the "A" and "B" pairs for the February and November 1993, measurements are shown in Table 20A and 20B together with the associated vertical gradient. Upward vertical gradients were measured in eight of the 10 well pairs in February and seven of the 10 well pairs in November. Agreement was good between the two sets of readings except for a discrepancy in data for OCD-2. This well had a marginally upward gradient measured in February and a strong downward gradient in November. The suspected reason is an error in one of the four depth to water readings for this well pair. If it follows the

Table 20A. Vertical gradients in the vicinity of Navajo evaporation ponds, February 1993.

Table 20A. Vertical gradients in the vicinity of Navajo evaporation ponds, February 1993.

Well	Top of casing elevation (ft)	Depth-to-water (ft)	Groundwater elevation (ft)	Difference in groundwater elevation (ft) [c]	Vertical separation (ft) [d]	Vertical gradient (ft/ft) [e]
MW-2A	3309.8 [a]	8.32	3301.48	-1.55	21.0	-0.074
MW-2B	3309.29	9.36	3299.93			
MW-5A	3305.87 [a]	7.64	3298.23	0.49	23.0	0.021
MW-5B	3305.94	7.22	3298.72			
MW-6A	3310.71 [a]	11.01	3299.70	0.03	26.0	0.001
MW-6B	3310.59	10.86	3299.73			
MW-7A	3304.73 [a]	6.52	3298.21	0.37	20.0	0.018
MW-7B	3306.30	7.72	3298.58			
MW-11A	3307.46	8.81	3298.65	0.14	16.0	0.009
MW-11B	3307.55	8.76	3298.79			
MW-18A	3305.36	9.53	3295.83	0.29	17.5	0.017
MW-18B	3305.58	9.46	3296.12			
MW-22A	3304.30	6.75	3297.55	0.30	22.5	0.013
MW-22B	3304.46	6.61	3297.85			
OCD-2A	3310.99	11.23	3299.76	0.07	14.0	0.005
OCD-2B	3309.90	10.07	3299.83			
OCD-7AR	3307.05	7.89	3299.16	-0.22	24.0	-0.009
OCD-7B	3307.15	8.21	3298.94			
OCD-8A	3306.66 [b]	8.33	3298.33	0.09	19.0	0.005
OCD-8B	3306.08	7.66	3298.42			

a = Elevation at the top of the steel cap minus the cap thickness (0.02 ft).
b = Top of the steel protective casing rather than the top of the PVC well casing.
c = Groundwater elevation in the upper well minus the groundwater elevation in the lower well.
d = Vertical separation between the base of the upper well screen and the top of the lower well screen.
e = Difference in groundwater elevation divided by the vertical separation; negative values indicate a downward gradient.

Table 20B. Vertical gradients in the vicinity of Navajo evaporation ponds, November 1993.

Table 20B. Vertical gradients in the vicinity of Navajo evaporation ponds, November 1993.

Well	Top of casing elevation (ft)	Depth-to-water (ft)	Groundwater elevation (ft)	Difference in groundwater elevation (ft) [c]	Vertical separation (ft) [d]	Vertical gradient (ft/ft) [e]
MW-2A	3309.8 [a]	10.01	3299.79	-1.44	21.0	-0.069
MW-2B	3309.29	10.94	3298.35			
MW-5A	3305.87 [a]	8.45	3297.42	0.46	23.0	0.020
MW-5B	3305.94	8.06	3297.88			
MW-6A	3310.71 [a]	12.56	3298.15	0.03	26.0	0.001
MW-6B	3310.59	12.41	3298.18			
MW-7A	3304.73 [a]	7.22	3297.51	0.38	20.0	0.019
MW-7B	3306.30	8.41	3297.89			
MW-11A	3307.46	9.07	3298.39	0.12	16.0	0.008
MW-11B	3307.55	9.04	3298.51			
MW-18A	3305.36	10.68	3294.68	0.28	17.5	0.016
MW-18B	3305.58	10.62	3294.96			
MW-22A	3304.30	7.65	3296.65	0.30	22.5	0.013
MW-22B	3304.46	7.51	3296.95			
OCD-2A	3310.99	12.26	3298.73	-0.34	14.0	-0.024
OCD-2B	3309.90	11.51	3298.39			
OCD-7AR	3307.05	8.33	3298.72	-0.37	24.0	-0.015
OCD-7B	3307.15	8.80	3298.35			
OCD-8A	3306.66 [b]	8.93	3297.73	0.03	19.0	0.002
OCD-8B	3306.08	8.32	3297.76			

a = Elevation at the top of the steel cap minus the cap thickness (0.02 ft).
b = Top of the steel protective casing rather than the top of the PVC well casing.
c = Groundwater elevation in the upper well minus the groundwater elevation in the lower well.
d = Vertical separation between the base of the upper well screen and the top of the lower well screen.
e = Difference in groundwater elevation divided by the vertical separation; negative values indicate a downward gradient.

pattern seen in MW-2A/B and OCD-7AR/B, the November value more likely approximates the correct reading because OCD-2, located between the pond and the river, is closer to the pond than most other wells and intercepts the groundwater mound created by the pond. Monitor wells at the MW-2 and OCD-7 sites, located immediately adjacent to the active pond, had downward (negative) gradients of -0.074 and -0.009 ft/ft, respectively. The other eight well pairs had upward (positive) gradients ranging between 0.001 ft/ft (MW-6) and 0.021 ft/ft (MW-5). The MW-18 and MW-22 well pairs located away from the immediate hydraulic influence of the pond had upward gradients of 0.017 and 0.013 ft/ft, respectively.

A deep groundwater potentiometric map (Figure 15) was prepared using the water level elevations in the "B" wells south of the ponds. The groundwater flow direction for the deep wells also is southeastward with a gradient of about 0.00125 ft/ft. This value is only slightly higher than the shallow gradients and is about equal to the land surface topographic gradient measured for the area south of the ponds. One reason the shallow gradient may be flatter than the deep gradient is that the river gradient in the vicinity of the ponds is flatter, as reported previously. However, this description is based on only one set of measurements and additional seasonal measurements will be necessary to verify the exact relationship between the shallow and deep zones.

8.3.2.3 Aquifer Testing

An aquifer test was conducted on 27 January 1993 to determine the hydraulic properties of the deep saturated zone in the vicinity of the Navajo Refinery evaporation ponds. Well MW-18B was the pumping well and MW-18T, a temporary well installed 9 ft west of the pumping well, served as the observation well during the aquifer test. Monitor well MW-18A, a shallow well located about 10 ft from MW-18B, served as a secondary observation well during the test. MW-18T was completed at the same depth as MW-18B and screened over the same interval. The three wells were installed on private property south of Evaporation Pond 2 and adjacent to the west bank of the Pecos River (Figure 6). The completion details of the wells are presented in Table 21, and the well completion diagrams and boring logs are included in Appendix F. The following sections document the test procedures and present the results of the aquifer test.

Table 21. Wells used during the aquifer test in the vicinity of the Navajo Refinery evaporation ponds.

	Pumping well MW-18B	Primary observation well MW-18T	Secondary observation well MW-18A
Total depth (ft)	47	47	20
Screened interval (ft)	37-46.5	37-46.5	10-19.5
Casing diameter (in.)	2	2	2

Figure 15. Deep groundwater potentiometric map, February 1993, Evaporation Pond Area, RFI Phase II.

EXPLANATION

KWB-7 ⊕	Monitor well location
RW-1 ■	Recovery well location
NP-2 ⊠	Piezometer location
◎	Section corner
	Pecan trees

NOTE: Map compiled from USGS Artesia 7.5 Minute Quadrangle, Navájo Refinery and NM State Highway Department Aerial Mapping, well locations surveyed 2/93, Jaquess & Associates.

LOCATION: T17S, R26E, NMPM,
Eddy County, New Mexico

KWBES

prepared for:

Navajo

Groundwater potentiometric map, February 1993, Three-Mile Ditch, refinery to Bolton Road Area, RFI Phase II.

PROJECT: 622093004-110 (BASE2)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 11/22/93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 4/21/92	FIGURE: 5A

8.3.2.3.1 Test Procedures

The aquifer test consisted of three phases of data collection: pumping, recovery, and background. The data collected during these three phases are presented in Appendix G. Prior to the pumping phase, the water levels in both the pumping well and observation well were monitored in order to verify that the water levels were static. During the pumping phase, water-level measurements were collected from the three wells while water was removed from the pumping well at a rate of 4.3 gpm. Data recording began at the onset of the pumping, at 09:17:41 on 27 January, and continued for 1,020 minutes (17 hours), at which time the pumping was stopped. The recovery phase began at 02:33:38 on 28 January and continued for 360 minutes (6 hours). Water-level measurements were collected from the three wells during this phase. The data collected during the pumping and recovery phases were subsequently evaluated to determine the hydraulic properties of the upper aquifer. The background phase began at 08:33:38 on 28 January and continued for 1420 minutes (23.7 hours). Water-level measurements were collected from both the pumping well and the observation wells during this phase. Data collected during this third phase were useful in determining if barometric pressure changes may have influenced the water levels in the wells during the test.

8.3.2.3.2 Test Results

At a constant pumping rate of approximately 4.3 gpm, maximum drawdowns of 4.23, 0.35, and 0.09 ft were recorded for MW-18B, MW-18T, and MW-18A, respectively. Because the water-level change in MW-18A was insignificant for use in the analytical calculations, pumping and recovery data from this shallow well were not used to determine the aquifer properties. The background water levels recorded immediately following the pump test fluctuated only slightly (less than 0.02 ft) in the pumping and observation wells during the 24-hour period. There were no obvious large-scale fluctuations (such as diurnal pressure changes) observed during the background period and, thus, no adjustment to the pumping or recovery data was necessary.

Analytical methods used to evaluate the results of the pumping and recovery data required graphing of the test data, with time values plotted on the horizontal axis and drawdown plotted on the vertical axis. These plots were then used to determine the transmissivity and storage coefficient of the saturated zone. The hydraulic conductivity of the saturated zone was then obtained by dividing the transmissivity by the screened interval (assumed equal to producing-zone thickness). The analytical methods utilized to evaluate the aquifer test data are discussed in the following section. The plots of the pumping and recovery data, as well as the background data, are included in Appendix G.

Pumping Phase

The drawdown data obtained during the pumping phase of the aquifer test were analyzed using the Hantush-Jacob leaky aquifer analytical method (Fetter, 1988), which utilizes a curve-matching procedure to determine the transmissivity and storativity of a given aquifer based upon the behavior of the aquifer when subjected to stress (pumping). This methodology requires plotting water-level changes (drawdown) versus elapsed time on a logarithmic scale. The resulting "drawdown curve" is then compared to the type curves for a leaky aquifer system by overlaying the two graphs. The type curves are a logarithmic plot of the well function $W(u, r/B)$ versus $1/u$, where u is a unitless variable known as the well constant. The well constant is related to the transmissivity and storativity of the aquifer. Once the time/drawdown curve is matched with a given type curve, the two curves are superimposed on each other and a random point, referred to as the match point, is selected on the two graphs. Once the values of drawdown and time at the match point are determined from the time/drawdown curve, and the values of $W(u, r/B)$ and $1/u$ at the match point are determined from the type curve, the transmissivity of the aquifer is calculated according to the following equation:

$$T = 15.3Q/s\ W(u,r/B)$$

where:

T = aquifer transmissivity (ft^2/day)
Q = pumping rate (gpm)
$W(u, r/B)$ = well function (unitless)
s = drawdown (ft)

Transmissivity values are presented in this report in gallons per day per foot (gpd/ft = ft^2/day x 7.48 gallons/ft^3).

Once the transmissivity has been determined, the hydraulic conductivity of the aquifer can be calculated using the transmissivity and the thickness of the transmissive zone. For a confined aquifer, the height of the well screen is assumed to equal the thickness of the transmissive zone of the aquifer through which water is flowing during the test. The hydraulic conductivity is calculated from the equation

$$K = T/b$$

where:

K = hydraulic conductivity (ft/day)
b = thickness of the transmissive zone (assumed to equal the thickness of the screened interval, ft)

Hydraulic conductivity values are presented in this report in gpd/ft^2.

The storativity of the aquifer can also be determined from the transmissivity and the pumping data using the equation

$$S = Ttu/360r^2$$

where:

S = aquifer storativity (unitless)
t = time since pumping started (days)
u = well constant (unitless)
r = distance from the pumping well to the observation well (ft)

The upper aquifer in the vicinity of the evaporation ponds is considered unconfined. However, the correlation between the drawdown curves and the leaky aquifer type curves together with the minimal response recorded in MW-18A to pumping indicate that the aquifer in the immediate vicinity of MW-18 is partially confined. This is further confirmed by examination of the drilling log for MW-18B which shows a 1 ft thick stiff clay zone at a depth of 27 ft. The vertical conductivity of the "confining zone," which in this case is the portion of the aquifer overlying the top of the well screen, can then be calculated according to the following equation:

$$K' = [Tb'(r/B)^2]/r^2$$

where:

K' = vertical hydraulic conductivity (ft/day)
b' = thickness of the overlying confining zone (ft)
r/B = type curve matched to drawdown curve (unitless)

The seepage velocity of the groundwater system can be determined from the hydraulic conductivity, hydraulic gradient, and effective porosity of the aquifer. The hydraulic gradient is typically measured from a groundwater contour map or a potentiometric surface map. The groundwater-flow gradient of 0.001 ft/ft present in the area south of the evaporation ponds was thus used in the calculation of seepage velocity. The effective porosity can be estimated from the intrinsic porosity of the aquifer. Although the intrinsic porosity is the actual pore volume of the aquifer matrix, it is usually not representative of the actual porosity that governs the flow of water through the matrix because of the influence of isolated pore spaces, grain angularity, and other factors. The effective porosity of the aquifer is a corrected porosity that more closely represents true flow conditions. Effective porosity can be several orders of magnitude lower than the intrinsic porosity in consolidated aquifers, but the effective porosity of an unconfined alluvial aquifer is typically 10% to 100% of the intrinsic porosity (Fetter, 1988), which is usually 25% to 30% in alluvial sediments. In the absence of site-specific porosity data, the effective porosity was assumed to be 20%, which is representative of porosities found in this lithologic environment. Thus, the seepage velocity of the groundwater system south of the evaporation ponds was calculated using an effective porosity of 20% according to the following equation:

$$v = Ki/n_e$$

where:

v = seepage velocity (ft/yr)
i = hydraulic gradient (ft/ft)
n_e = effective porosity (unitless)

Analysis of the pumping data according to the Hantush-Jacob leaky aquifer method yielded an aquifer transmissivity of 162 gpd/ft for pumping well MW-18B and 1,970 gpd/ft for observation well MW-18T. These values of transmissivity yield values of hydraulic conductivity of 17.1 and 207 gpd/ft^2 for MW-18B and MW-18T, respectively. An aquifer storativity of 0.002 was determined from the MW-18T values. Storativity and vertical conductivity can not be determined for a pumping well. The seepage velocity of the groundwater system was determined to be 4.18 and 50.6 ft/yr from MW-18B and MW-18T, respectively. The results of the analysis are summarized in Table 22.

Table 22. Summary of aquifer test results.

Well	Screened interval (ft)	Transmissivity (gpd/ft)	Hydraulic conductivity (gpd/ft^2)	Storativity	Seepage velocity (ft/yr)
Pumping Data — Hantush-Jacob leaky aquifer method					
MW-18B	9.5	162	17.1	—	4.18
MW-18T	9.5	1,970	207	0.002	50.6
Recovery Data — Theis recovery method					
MW-18B	9.5	50	5.26	—	1.29
MW-18T	9.5	2,124	224	—	54.7

Analysis of the pumping data from MW-18T yielded a vertical hydraulic conductivity of 311 gpd/ft^2 for the upper portion of the aquifer. The value is about 50% greater than the maximum horizontal hydraulic conductivity determined for the aquifer. This condition of equivalent vertical and horizontal values of hydraulic conductivity is indicative of a homogeneous aquifer. However, the response of the wells to pumping, as demonstrated by the shape of the drawdown curves for data from early within the test, indicates that the aquifer is partially "confined" by a leaky, upper confining zone in the immediate vicinity of the measured wells. Under these conditions the vertical hydraulic conductivity is expected to be from 50% to more than 1 order of magnitude less than the horizontal hydraulic conductivity. As a result, this value of vertical hydraulic conductivity is considered erroneous, and was not used for estimating groundwater migration in this report. Erroneously high vertical conductivity values may be the result of vertical flow through the sand pack in the observation well during the pumping phase. Heaving aquifer sands pushing upward into the borehole during well completion extended the sand pack in MW-18T above the optimal position in the aquifer.

Recovery Phase

The recovery phase of the test was analyzed using the Theis recovery method (Fetter, 1988). This method, which is also a graphical solution, requires plotting residual drawdown (s') versus the time ratio (t/t') on a semilog scale. The time ratio is the time since pumping started (t) divided by the time since pumping stopped (t'). Plotting the data in this way yields a recovery curve with a distinct straight-line portion that occurs early in the recovery phase. The change in residual drawdown that occurs during one log cycle on the straight-line portion of the curve is then determined from the recovery curve. The aquifer transmissivity is thus calculated using the Cooper-Jacob equation:

$$T = 35Q/s$$

where:

Δs = change in residual drawdown in one log cycle (ft)

After determining the aquifer transmissivity, the hydraulic conductivity of the aquifer and the groundwater seepage velocity were calculated using the equations presented in the previous section for a hydraulic gradient of 0.001 ft/ft and an effective porosity of 20%.

Analysis of the recovery data according to the Theis recovery method yielded aquifer transmissivity values of 50 and 2,124 gpd/ft for MW-18B and MW-18T, respectively. These transmissivity values yielded values of hydraulic conductivity of 5.26 and 224 gpd/ft^2 for MW-18B and MW-18T, respectively. The aquifer storativity and vertical conductivity can not be determined using the Theis recovery method. The seepage velocity of the groundwater system was determined to be 1.29 and 54.7 ft/yr from MW-18B and MW-18T, respectively.

The results of the aquifer tests at the evaporation ponds showed significant differences between aquifer characteristics for the pumping well, MW-18B, and the observation well, MW-18T. The values of transmissivity determined from the pumping well data were about three times greater for the pumping phase that for the recovery phase in the well. The values of transmissivity determined from the observation well data were about the same for both the pumping and recovery phases and about 10 times greater than those determined from both the pumping and recovery phases of the pumping well data. The reason for this difference was first believed to be poor communication between the pumping and observation wells, which would make the pumping well data more representative of actual well conditions. However, the seepage velocities calculated from the hydraulic conductivity values indicate that the observation well values are more representative of the documented field conditions. The average seepage velocities were 2.74 and 52.7 ft/yr for MW-18B and MW-18T, respectively. Assuming a travel time of 60 years, which is the approximate number of years that the evaporation ponds have been in service, these velocities yield distances of 164 and 3,160 ft, respectively. The latter value, derived from the observation well data, corresponds well with the approximate 3,000-ft extent of groundwater impacts south of the evaporation ponds, as indicated during previous groundwater investigations (Section 7.2 and Appendix D) and the Phase II subsurface soil gas survey. The variance between the results obtained from the two wells may be related to the amount of development of the pumping well. Although the well was purged until clear of sediment and turbidity, fine-grained material remaining in the outer portion of the sand pack may be preventing the efficient movement of water into the wellbore.

The values determined for transmissivity, hydraulic conductivity, and seepage velocity from the pumping and recovery phases of the aquifer test correspond with values previously determined by Mariah Associates for the RFI Phase I investigation at the Navajo Refinery (Table 23). In September 1990, Mariah personnel conducted two slug tests each on monitor wells MW-4, MW-6A, MW-7A, OCD-3, and EPA-1 in the vicinity of the evaporation ponds. The values determined for MW-18B fall at the lower end of the range of the Phase I slug test values, whereas the values determined for MW-18T fall at the upper end.

Table 23. Summary of RFI Phase I single-well aquifer tests.

Well	Screened interval (ft)	Test number	Transmissivity[a] (gpd/ft)	Hydraulic conductivity (gpd/ft^2)	Seepage velocity (ft/yr)
MW-4	10	1	754	75.4	18.45
		2	542	54.2	13.26
MW-6A	10	1	2,010	201	49.19
		2	297	29.7	7.27
MW-7A	10	1	200	20.0	4.89
		2	81.9	8.19	2.00
OCD-3	18.5	1	274	14.8	3.63
		2	318	17.2	4.19
EPA-1	10	1	197	19.7	4.83
		2	148	14.8	3.63

[a] = Calculated from the Phase I data as the product of hydraulic conductivity and the length of the screened interval.

A pump test conducted in the vicinity of Evaporation Pond 1 by Geoscience Consultants, Ltd., in 1986 is also reported in the RFI Phase I Report as yielding a transmissivity of 6,240 gpd/ft, hydraulic conductivity of 250 gpd/ft^2, and storativity of 0.20. Although the value for hydraulic conductivity is similar to those determined for MW-18T, the 1986 transmissivity value is about three times greater than the largest transmissivity value determined for MW-18T and the storativity is two orders of magnitude higher than the storativity determined for MW-18T. The test analysis method used by Geoscience Consultants is not known nor are the data from the 1986 test included in the RFI Phase I Report.

8.3.2.4 Groundwater Quality

Results of the RFI Phase II groundwater sampling of the monitor wells, a windmill used for stock watering, and surface water in the Pecos River are presented in this section, with the data included in Appendix I. Results from prior sampling events and from the RFI Phase I study (as reviewed in Section 7.2) are in Appendix D. Results from MW-15 and MW-1, which are located adjacent to Three-Mile-Ditch, are included in the data presentations for both Three-Mile Ditch and the evaporation ponds. Field parameters of pH, conductivity, and temperature were measured at each monitor well sampled. As described in the protocol in Section 6.2.1.3, "Groundwater Sample Collection," sampling was performed after these field parameters had stabilized during pumping. The final readings taken for samples from the monitor wells are shown in Table 24.

Sampling of the existing and new monitor wells installed in the vicinity of the evaporation ponds for volatile organic compounds detected target compounds in several wells south (downgradient) of Ponds 1 and 2. With the exception of an elevated level of carbon disulfide in MW-06B, all detected compounds are at concentrations less than 0.050 mg/L. The constituents detected in volatiles testing together with their respective practical quantitation limits (PQLs) are presented in Table 25. As will be discussed in Section 9.0, the shallow groundwater in the vicinity of the ponds is naturally unsuitable for human consumption, but drinking-water standards for the detected compounds are presented for comparison purposes where they have been established.

Benzene at concentrations between 0.009 and 0.021 mg/L was detected in wells MW-3, 4, MW-5A, MW-6B and OCD-7B. The MCL for benzene set by the EPA under the Safe Drinking Water Act is 0.005 mg/L. In New Mexico, the state Water Quality Control Commission (WQCC) health standard for benzene in groundwater is 0.010 mg/L.

Ethylbenzene was detected in wells MW-3, MW-4, MW-5A, and MW-6A in concentrations between 0.006 and 0.019 mg/L. The MCL for ethylbenzene is 0.700 mg/L whereas the WQCC health standard for ethylbenzene in groundwater is 0.750 mg/L. EPA has proposed an MCL of 0.030 mg/L as a recommended aesthetic standard.

Levels of toluene between 0.006 and 0.028 mg/L were found in monitor wells MW-3, MW-4, MW-5A, MW-6A, and MW-6B. The MCL for toluene is 1.0 mg/L whereas the New Mexico health

Table 24. Groundwater and surface water indicator measurements at the time of field sampling, Evaporation Pond area, Navajo Refinery, RFI Phase II.

Table 24. Groundwater and surface water indicator measurements at the time of field sampling, Evaporation Pond area, Navajo Refinery, RFI Phase II.

Well number	Laboratory number	Date sampled	Time sampled	pH	Conductivity (μmhos/cm at 25°C)	Temperature (°C)	Dissolved oxygen
NEP-GW-OCD-1	C922324/15649	11/13/92	1305	7.12	13,000	19.9	NA
NEP-GW-OCD-2A	C922357/15669	11/15/92	1255	7.07	14,000	NA	NA
NEP-GW-OCD-2B	C930134/W00057	1/21/93	1445	7.79	13,000	19.2	1.25
NEP-GW-OCD-3	C922358/15670	11/16/92	900	6.89	15,000	19.1	NA
NEP-GW-OCD-4-1		11/16/92	1500	7.18	17,500	20.4	NA
NEP-GW-OCD-4-1	C922398/15727	12/12/92	1624	7.41	20,000	19.8	NA
NEP-GW-OCD-5	C922399/15728	11/17/92	1230	7.05	17,000	19.7	NA
NEP-GW-OCD-6-1		11/16/92	1640	6.99	13,000	19	NA
NEP-GW-OCD-6-1	C922400/15729	12/12/92	1525	7.25	14,000	18.9	NA
NEP-GW-OCD-7A	C922389/15720	11/18/92	1105	7.13	13,000	18	NA
NEP-GW-OCD-7AR	C930104/W00054	1/19/93	1610	7.04	9,700	15.9	NA
NEP-GW-OCD-7B	C930279/W00345	1/30/93	1100	8.32	5,150	15.7	NA
NEP-GW-OCD-8A	C922393/15723	11/17/92	1555	6.88	11,750	21.1	NA
NEP-GW-OCD-8B	C930203/W00182	1/23/93	1055	6.94	6,500	18.9	0.15
NEP-GW-MW-01-01	C922278/15632	11/10/92	1725	7.10	15,000	19.6	NA
NEP-GW-MW-02A	C922280/15633	11/10/92	NA	7.29	10,500	20.3	NA
NEP-GW-MW-02B	C922653/16029	12/16/92	810	7.25	3,400	16.4	NA
NEP-GW-MW-02B		1/20/93	1200	NA	NA	NA	0.3
NEP-GW-MW-03	C922322/15647	11/12/92	1350	7.06	7,500	21.4	NA
NEP-GW-MW-04	C922333/15644	11/12/92	945	6.97	7,000	18.8	NA
NEP-GW-MW-05A	C922334//15645	11/11/92	1645	7.04	26,500	19.1	NA
NEP-GW-MW-05B	C930136/W00059	1/22/93	1030	6.75	7,400	18.2	0.25
NEP-GW-MW-06A	C922323/15648	11/12/92	1655	7.30	4,500	20.9	NA
NEP-GW-MW-06B	C930278/W00344	1/30/93	1000	8.62	5,450	18.8	NA
NEP-GW-MW-07A	C922281/15634	11/11/92	1150	7.07	13,500	19.7	NA
NEP-GW-MW-07B	C930106/W00056	1/21/93	1115	7.10	9,600	18.1	0.7
NEP-GW-MW-10	C922390/15721	11/18/92	1315	6.99	5,600	18.2	NA
NEP-GW-MW-11A	C922567/15975	12/12/92	1204	7.19	24,000	18.7	NA
NEP-GW-MW-11B	C930205/W00184	1/23/93	1510	6.95	19,000	18.6	0.15
NEP-GW-MW-12	C922658/16033	12/18/92	900	7.32	23,000	17.6	NA
NEP-GW-MW-13	C922659/16034	12/18/92	935	7.73	4,600	17.7	NA
NEP-GW-MW-14	C922655/16031	12/17/92	1530	7.35	16,000	17.7	NA
TMD-GW-MW-15	C930105/W00055	1/20/93	1710	7.41	3,500	19.3	0.6
NEP-GW-MW-17	C930209/W00189	1/26/93	1345	7.04	2,200	18.8	NA
NEP-GW-MW-18A	C930207/W00187	1/25/93	1735	7.06	15,000	17.5	1.45
NEP-GW-MW-18B	C930602/W01466	1/25/93	NA	7.05	7,000	18.4	NA
NEP-GW-MW-19	C930208/W00188	1/26/93	950	6.91	6,500	17.3	0.1
NEP-GW-MW-22A	C930282/W00347	1/29/93	1100	7.50	4,300	16.9	0.15
NEP-GW-MW-22B	C930283/W00348	1/29/93	1315	7.06	4,900	18	0.2
NEP-GW-MW-23	C930229/W00271	1/28/93	1045	7.03	14,000	17.3	0.45
NEP-GW-MW-24	C93028/W00346	1/28/93	1430	7.27	16,000	19.3	0.15
NEP-GW-EPA-1	C922391/15722	11/18/92	1010	7.00	4,700	17.6	NA

NA = Not analyzed.

Table 25. Volatile organic compounds detected during field sampling, Evaporation Pond area, Navajo Refinery, RFI Phase II.

Table 25. Volatile organic compounds detected during field sampling, Evaporation Pond area, Navajo Refinery, RFI Phase II.

			Acetone		Benzene		2-Butanone (MEK)		Carbon disulfide		Ethylbenzene		Methylene chloride		Toluene		Xylenes (total)	
Well ID	Laboratory	Date sampled	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)	Result (mg/L)	PQL (mg/L)
Evaporation Pond	C922424	11/20/92	0.092	0.010	0.043	0.005			0.032	0.005	0.016	0.005			0.061	0.005	0.045	0.005
MW-03	C922322	11/12/92			0.017	0.005					0.016	0.005			0.021	0.005	0.025	0.005
MW-04	C922333	11/12/92			0.021	0.005					0.019	0.005			0.009	0.005	0.032	0.005
MW-05A(Field Duplicate)	C922335	11/11/92			0.013	0.005					0.006	0.005			0.028	0.005	0.008	0.005
MW-06A	C922323	11/12/92									0.007	0.005			0.006	0.005	0.014	0.005
MW-06B	C930278	1/30/93			0.009	0.005	0.048	0.010	0.117	0.005					0.006	0.005		
MW-12	C922658	12/18/92											0.007	0.005				
MW-14	C922655	12/17/92											0.020	0.005				
OCD-7B	C930279	1/30/93			0.009	0.005												
Windmill	C922656	12/17/92											0.010	0.005				

PQL = Practical quantitation limit.

standard in groundwater is 0.750 mg/L. The proposed EPA secondary, aesthetic standard for toluene is 0.040 mg/L.

Xylenes were detected in MW-3, MW-4, MW-5A, and MW-6A at concentrations between 0.008 and 0.032 mg/L. The drinking-water MCL for total xylenes is 10 mg/L, with a proposed MCL of 0.020 mg/L as a recommended aesthetic standard. In New Mexico, the WQCC health standard for total xylenes in groundwater is 0.62 mg/L. Figure 16 is a map showing the distribution of the BTEX volatiles in the evaporation pond area.

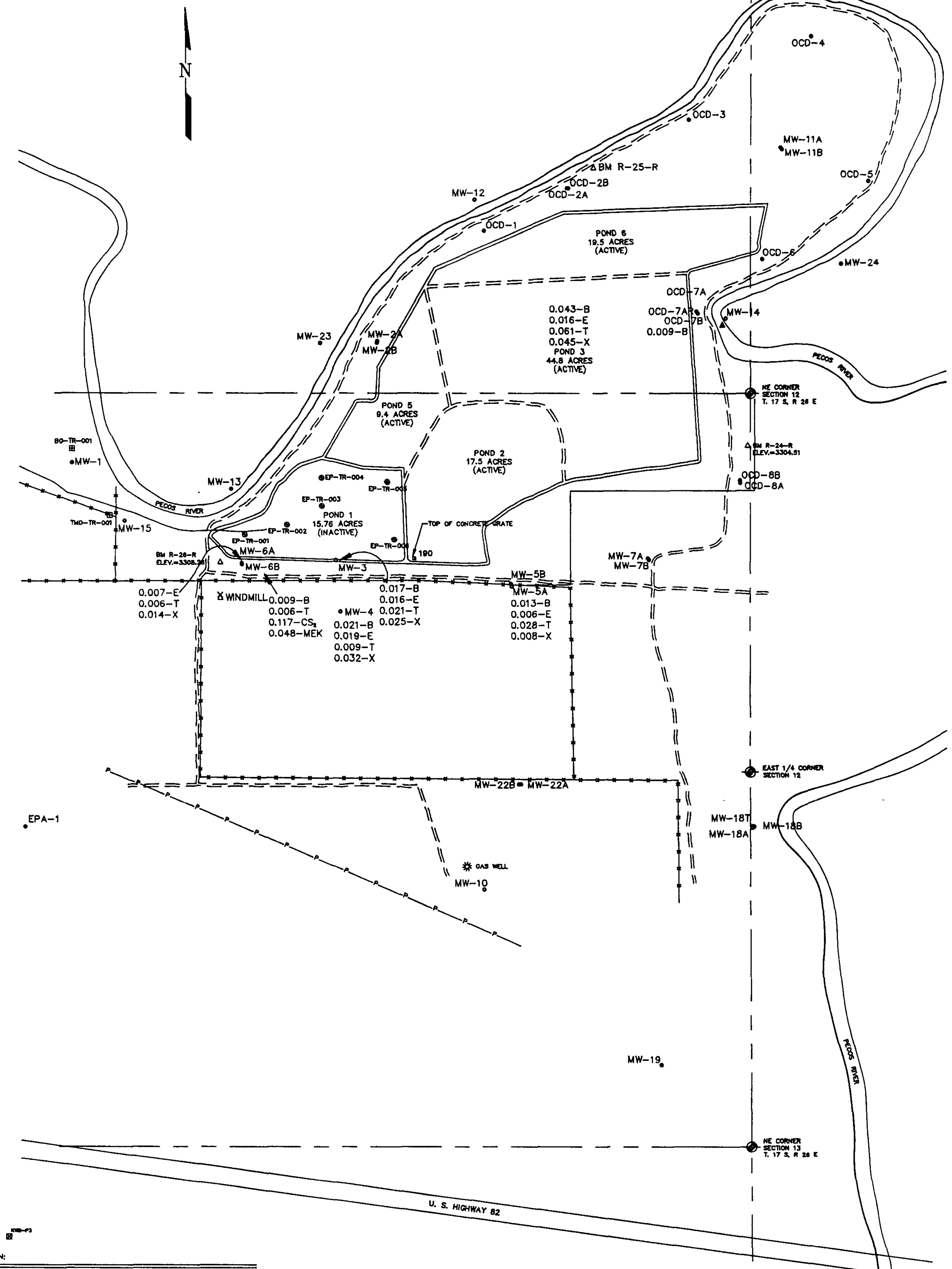
The PQL for the four aromatic BETX compounds listed in the preceding was 0.005 mg/L except for 0.050 mg/L at OCD-1 for which the sample required dilution because of matrix interference. However, analysis of the OCD split sample taken by PRC, Inc., EPA's contractor, did not result in BETX detections at levels of 0.010 mg/L or carbon disulfide at 0.001 mg/L. Results of the EPA contractor sampling are included in Appendix J.

In addition to xylenes, MW-6B had detections of carbon disulfide at 0.117 mg/L and 2-butanone (MEK) at 0.048 mg/L. No federal or state water quality standards exist for either of these compounds although possible standards for water and leachate are presented and discussed in Section 9.0.

The only other volatile target compound identified was methylene chloride, which was detected in several monitor wells and in the pond windmill at concentrations between 0.006 and 0.020 mg/L and in several method blanks at levels of 0.006 to 0.037 mg/L. Detections of methylene chloride appear to be related more to the consecutive laboratory sample numbers rather than sample origin. This relationship together with the detections of methylene chloride in laboratory method blanks and the fact that methylene chloride is a common laboratory contaminant should eliminate the compound from consideration as a groundwater contaminant unless subsequent sampling verifies its presence. 1,1,2,2,-tetrachloroethane, a volatile specifically listed in EPA's approval of the RFI Phase II Workplan, was not detected in any of the samples. Results of the quality control procedures and complete data results for all analyses can be found in Appendix I.

Semivolatile constituent detections were limited to the phthalates found in six samples at levels between 0.021 and 0.078 mg/L. The semivolatile organic compounds detected during groundwater sample testing and the associated PQLs are presented in Table 26. Again, detections were more related to consecutive laboratory sample numbers than to any other factor. As discussed in Section 9.0 phthalates are common laboratory contaminants and unlikely to be found in groundwater. Neither 2,4-dinitrotoluene or 2,6-dinitrotoluene, two semivolatiles specifically listed in EPA's approval of the RFI Phase II Workplan, were detected in any of the samples. At two locations, the PQL was elevated above PQLs employed for other

Figure 16. Map of volatile organic compounds, Evaporation Pond Area, RFI Phase II.



EXPLANATION:

⊞ BG-TR-001 TMD-TR-001	BACKGROUND TRENCH EXPLORATORY TRENCH, THREE-MILE DITCH
● EP-TR-001	EXPLORATORY TRENCH, EVAPORATION POND 1
∘ MW-10	MONITOR WELL
⊠	PIEZOMETER
0.012-B	BENZENE CONCENTRATION (mg/l)
0.012-E	ETHYLBENZENE CONCENTRATION (mg/l)
0.012-T	TOLUENE CONCENTRATION (mg/l)
0.012-X	XYLENE CONCENTRATIONS (mg/l)
0.117-CS_2	CARBON DISULFIDE CONCENTRATION (mg/l)
0.048-MEK	2-BUTANNONE CONCENTRATION (mg/l)
	PRACTICAL QUANTITATION LIMIT 0.005 mg/l

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

800 0 800 2400 FEET

KWBES

Map of benzene, ethylbenzene, toulene, and xylene volatiles, Evaportion Pond Area, RFI Phase II.

prepared for:

Navajo

PROJECT: 622092005-110 (NAVSAMP)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-29-93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 4-27-93	FIGURE: 16

Table 26. Semivolatile organic compounds detected during field sampling, Evaporation Pond area, Navajo Refinery, RFI Phase II.

Table 26. Semivolatile organic compounds detected during field sampling, Evaporation pond area, Navajo Refinery, RFI Phase II.

Well ID	Laboratory number	Date sampled	B2EP Result (µg/L)	B2EP PQL (µg/L)	DNBP Result (µg/L)	DNBP PQL (µg/L)	DM24 Result (µg/L)	DM24 PQL (µg/L)
MW-2B	C922653	12/16/92	28	25				
MW-14	C922655	12/17/92			66	25		
MW-14 (Field Dup)	C922654	12/17/92			78	25		
MW-20	C930223	1/26/93			27	25		
OCD-8B	C930203	1/23/93	35	25				
OCD-8B (Field Dup)	C930204	1/23/93	21	20				
Evaporation Pond	C922424	11/20/92					180	50

PQL = Practical Quantitative Limit
B2EP = bis(2-Ethylhexyl)phthalate
DNBP = Di-n-butyl phthalate
DM24 = 2,4-Dimethylphenol
MN1 = 1-Methylnaphthalene
MN2 = 2-Methylnaphthalene
NAPH = Naphthalene

sample locations because dilution of the sample was necessary owing to matrix interference. The sample at MW-4 had the highest PQL, but the split sample analyzed by PRC did not report detection of any target compounds (Appendix J). Results of the quality control procedures and complete data results for all analyses can be found in Appendix I.

No volatile or semivolatile organic priority pollutants were found in the monitor wells across the river except for methylene chloride and di-n-butyl phthalate in MW-14. Both constituents are common laboratory contaminants, as discussed above, and not components of past or present Navajo effluent discharges. Laboratory analysis of the water samples did show a small number of unidentifed hydrocarbon compounds in the wells across the river, with the highest number showing in well MW-14 which is southeast and downgradient of active evaporation ponds 3 and 6. The number of detections and approximate total concentrations of unidentified hydrocarbons for these wells are shown in Table 27. Further discussion of unidentified hydrocarbons is presented in Section 8.3.3.2.

Table 27. Detection of unidentified hydrocarbons in monitor wells across the Pecos River.

Monitor Well	Volatiles (Method 8240)		Semivolatiles (Method 8270)	
	Number of Detections	Total Est. Conc. (mg/L)	Number of Detections	Total Est. Conc. (mg/L)
MW-12	1	0.074	2	0.030
MW-13	ND	--	Present	No est.
MW-14	6	0.393	5	0.170
MW-14 (dup)	7	0.394	5	0.170
MW-23	2	0.255	1	0.059
MW-24	ND	--	3	35

The pond windmill is close to the evaporation pond inlet and south of Three-Mile Ditch. However, it did not show evidence of volatile or semivolatile organic contamination although, one unknown volatile hydrocarbon was detected at a low concentration. Although south of the ponds, the windmill is located off-gradient from all but the uppermost end of Pond 1. FID measurements of the area made during the investigation indicated slightly elevated levels south of the windmill but much less than those detected southeast of Pond 1. This most likely indicates the presence of low level residual hydrocarbons remaining in the groundwater after contact with ditch seepage during the time of use and subsequently transported downgradient.

A total of 53 samples were collected for metals analysis from 40 groundwater locations in the vicinity of the evaporation ponds. The difference between the number of samples and locations represents 13 samples that were field or laboratory duplicates. Metals analyses for total and dissolved arsenic, chromium, lead, and nickel are presented in Table 28 together with

Table 28. Results of metals analyses, Evaporation Pond area, Navajo Refinery, RFI Phase II.

Table 28. Results of metals analyses, Evaporation Ponds, Navajo Refinery, RFI Phase II.

Well sample identification	Laboratory number	Date samples	TAS [a]	TAS [b]	TAS [c]	DAS [d]	TCR [e]	DCR [f]	TPB [g]	DPB [h]	TNI [i]	TNI [j]	DNI [k]	pH	EC [l]
NEP-GW-EPA-1	C922391/15722	18-Nov-92	ND	ND		ND	ND	ND	ND	ND	0.08	ND	0.06	7.2	5340
NEP-GW-MW-01-01	C922278/15632	10-Nov-92	0.02	0.023	0.01	ND	3.65	ND	ND	ND	0.35	0.22	0.2	7.5	14900
NEP-GW-MW-01-01 (Lab Dup)	C922278/15635	10-Nov-92	0.022			ND	3.62	ND	ND	ND	0.34		0.18	7.5	14900
NEP-GW-MW-02A	C922280/15633	10-Nov-92	0.087	0.117	0.09	0.073	0.1	ND	ND	ND	0.12	ND	0.1	7.4	11300
NEP-GW-MW-02B	C922653/16029	16-Dec-92	ND	ND		ND	ND	ND	ND	ND	0.04		ND	7.4	3430
NEP-GW-MW-02B (Lab Dup)	C922653/16036	16-Dec-92	ND			ND	ND	ND	ND	ND	0.03		ND	7.4	3430
NEP-GW-MW-03	C922322/15647	12-Nov-92	0.078	0.096		0.054	0.03	ND	ND	ND	0.12	0.04	0.08	7.3	7220
NEP-GW-MW-04	C922333/15644	12-Nov-92	0.08	0.112	0.136	0.069	ND	ND	ND	ND	0.11	ND	0.07	7.3	7610
NEP-GW-MW-04 (Lab Dup)	C922333/15651	12-Nov-92	0.085			0.071	ND	ND	ND	ND	0.09		0.07	7.3	7620
NEP-GW-MW-05A	C922334/15645	11-Nov-92	0.074	0.089		0.063	0.03	ND	ND	ND	0.27	0.12	0.25	7.2	28000
NEP-GW-MW-05A (Fld Dup)	C922335/15646	11-Nov-92	0.077			0.062	0.02	ND	ND	ND	0.26		0.26	7.2	28100
NEP-GW-MW-05B	C930136/W00059	22-Jan-93	0.131	0.15	0.162	0.106	ND	ND	ND	ND	ND		ND	7.1	9310
NEP-GW-MW-06A	C922323/15648	12-Nov-92	0.065			0.03	0.05	ND	ND	ND	0.11	0.04	0.04	7.4	4950
NEP-GW-MW-06B	C930278/W00344	30-Jan-93	0.021	0.02		0.016	ND	ND	ND	ND	ND		ND	11.9	6410
NEP-GW-MW-07A	C922281/15634	11-Nov-92	0.038	0.037	0.05	0.03	0.07	ND	ND	ND	0.13	ND	0.09	7.2	13900
NEP-GW-MW-07B	C930106/W00056	21-Jan-93	0.014	0.013	0.016	0.011	ND	ND	ND	ND	ND		ND	7.5	10700
NEP-GW-MW-10	C922390/15721	18-Nov-92	0.011	0.011		0.007	0.02	ND	ND	ND	0.09		0.07	7.2	6190
NEP-GW-MW-11A	C922567/15975	12-Dec-92	ND	ND		ND	ND	ND	ND	ND	0.19		0.18	7.1	23700
NEP-GW-MW-11B	C930205/W00184	23-Jan-93	ND	ND		ND	ND	ND	ND	ND	0.01		ND	7.3	20500
NEP-GW-MW-12	C922658/16033	18-Dec-92	ND	ND		ND	0.02	ND	ND	ND	0.05		ND	7.2	18700
NEP-GW-MW-13	C922659/16034	18-Dec-92	ND	ND		ND	ND	ND	ND	ND	0.03		ND	7.5	5180
NEP-GW-MW-14	C922655/16031	17-Dec-92	0.012	0.012		0.01	ND	ND	ND	ND	0.04		ND	7.4	11200
NEP-GW-MW-14 (Fld Dup)	C922654/16030	17-Dec-92	0.01			0.007	0.02	ND	ND	ND	0.03		ND	7.3	10900
TMD-GW-MW-15	C930105/W00055	20-Jan-93	0.01	0.006		0.006	0.03	ND	ND	ND	ND		ND	7.5	3590
NEP-GW-MW-17	C930209/W00189	26-Jan-93	ND	ND		ND	ND	ND	ND	ND	0.01		0.01	7.7	2600
NEP-GW-MW-18A	C930207/W00187	25-Jan-93	ND	ND		ND	ND	ND	ND	ND	0.03		0.01	7.3	16400
NEP-GW-MW-18B	C930602/W01466	11-Mar-93	ND	ND			0.02		ND		ND			7.7	4650
NEP-GW-MW-18B (Lab Dup)	C930602/W1467	11-Mar-93	ND				0.02		ND		ND			7.7	4640
NEP-GW-MW-19	C930208/W00188	26-Jan-93	ND	ND		ND	ND	ND	ND	ND	0.01		ND	7.6	7280
NEP-GW-MW-22A	C930282/W00347	29-Jan-93	0.013	0.013		0.011	ND	ND	ND	ND	ND		ND	7.4	5750
NEP-GW-MW-22A (Fld Dup)	C930284/W00349	29-Jan-93	0.014			0.011	ND	ND	ND	ND	0.02		ND	7.4	5790
NEP-GW-MW-22B	C930283/W00348	29-Jan-93	0.007	0.008		0.005	ND	ND	ND	ND	0.01		0.01	7.1	6180
NEP-GW-MW-22B (Lab Dup)	C930283/W00351	29-Jan-93	0.008			0.005	ND	ND	ND	ND	ND		ND	7.1	6180
NEP-GW-MW-23	C930229/W00271	28-Jan-93	0.007	0.008		0.006	ND	ND	ND	ND	ND		ND	7.2	15900
NEP-GW-MW-23 (Lab Dup)	C930229/W00274	28-Jan-93	0.007			0.006	ND	ND	ND	ND	ND		ND	7.2	15900
NEP-GW-MW-24	C930281/W00346	28-Jan-93	ND	ND		ND	ND	ND	ND	ND	ND		ND	7.3	16300
NEP-GW-OCD-1	C922324/15649	13-Nov-92	0.097	0.115	0.154	0.071	0.06	ND	0.03	ND	0.16	0.05	0.11	7.2	14200
NEP-GW-OCD-2A	C922357/15669	15-Nov-92	0.067	0.084		0.043	0.04	ND	ND	ND	0.15	ND	0.12	7	15400
NEP-GW-OCD-2B	C930134/W00057	21-Jan-93	0.007	0.005	0.018	0.006	ND	ND	ND	ND	0.01		ND	7.3	14700
NEP-GW-OCD-2A (Lab Dup)	C922357/15673	15-Nov-92	0.069			0.043	0.04	ND	ND	ND	0.14		0.13	7	15400
NEP-GW-OCD-3	C922358/15670	16-Nov-92	0.021	0.022		ND	0.19	ND	0.06	ND	0.28	0.09	0.12	7.1	17300
NEP-GW-OCD-4-1	C922398/15727	16-Nov-92	0.015	0.017		0.005	ND	ND	ND	ND	0.15		0.11	7.2	19000

Table 28. Continued.

Well sample identification	Laboratory number	Date samples	TAS[a]	TAS[b]	TAS[c]	DAS[d]	TCR[e]	DCR[f]	TPB[g]	DPB[h]	TNI[i]	TNI[j]	DNI[k]	pH	EC[l]
NEP-GW-OCD-5	C922399/15728	16-Nov-92	0.008	0.008		0.007	ND	ND	ND	ND	0.13	ND	0.12	7.2	17800
NEP-GW-OCD-5 (Fld Dup)	C922394/15724	17-Nov-92	0.009			0.008	ND	ND	ND	ND	0.12		0.12	7.2	17900
NEP-GW-OCD-5 (Dup of Fld D)	C922394/15731	17-Nov-92	0.008			0.007	ND	ND	ND	ND	0.13		0.12	7.2	17900
NEP-GW-OCD-6-1	C922400/15729	16-Nov-92	0.036	0.048		0.028	ND	ND	ND	ND	0.14	ND	0.13	7.1	14500
NEP-GW-OCD-7 (Fld Blank)	C922395/15725	18-Nov-92	ND				ND		ND		0.04				
NEP-GW-OCD-7A	C922389/15720	18-Nov-92	0.021	0.023		0.012	0.02	ND	ND	ND	0.15		0.13	7.3	13300
NEP-GW-OCD-7A R	C930104/W00054	19-Jan-93	0.175			0.154	0.02	ND	ND	ND	0.02		0.02	7.3	10500
NEP-GW-OCD-7B	C930279/W00345	30-Jan-93	0.005	0.005		ND	ND	ND	ND	ND	0.01		ND	7.6	6110
NEP-GW-OCD-8A	C922393/15723	17-Nov-92	0.032	0.037		0.019	ND	ND	ND	ND	0.12	ND	0.11	7	12400
NEP-GW-OCD-8B	C930203/W00182	23-Jan-93	ND	ND		ND	ND	ND	ND	ND	0.02		ND	7.3	7490
NEP-GW-OCD-8B (Fld Dup)	C930204/W00183	23-Jan-93	ND			ND	ND	ND	ND	ND	0.03		0.01	7.7	7270
Pecos River at OCD 7	C922425/W01464	20-Nov-92												7.3	7080
NEP-Windmill	C922656/16032	17-Dec-92	ND	ND		ND	ND	ND	ND	ND	0.02		ND	7.4	6610
Evaporation Pond at OCD-7	C922424/15745/W01463	20-Nov-92	0.167				ND		ND		0.06			7.6	10900

Key	**Test description/method**	**Detection limits**
a	Total arsenic — Method 7061	0.005
b	Total arsenic — Method 7061 — Verification	0.005
c	Total arsenic — Method 7060 — Verification	0.005
d	Dissolved arsenic — Method 701	0.01
e	Total chromium — Method 7191	0.02
f	Dissolved chromium — Method 7191	0.02
g	Total lead — Method 7421	0.02
h	Dissolved lead — Method 7421	0.02
i	Total nickel — Method 7520	0.01
j	Total nickel — Method 7520 — verification	0.05
k	Dissolved nickel — Method 7520	0.01
l	Electrical conductivity, µmhos/cm at 25 ° C	

ND = Not detected.

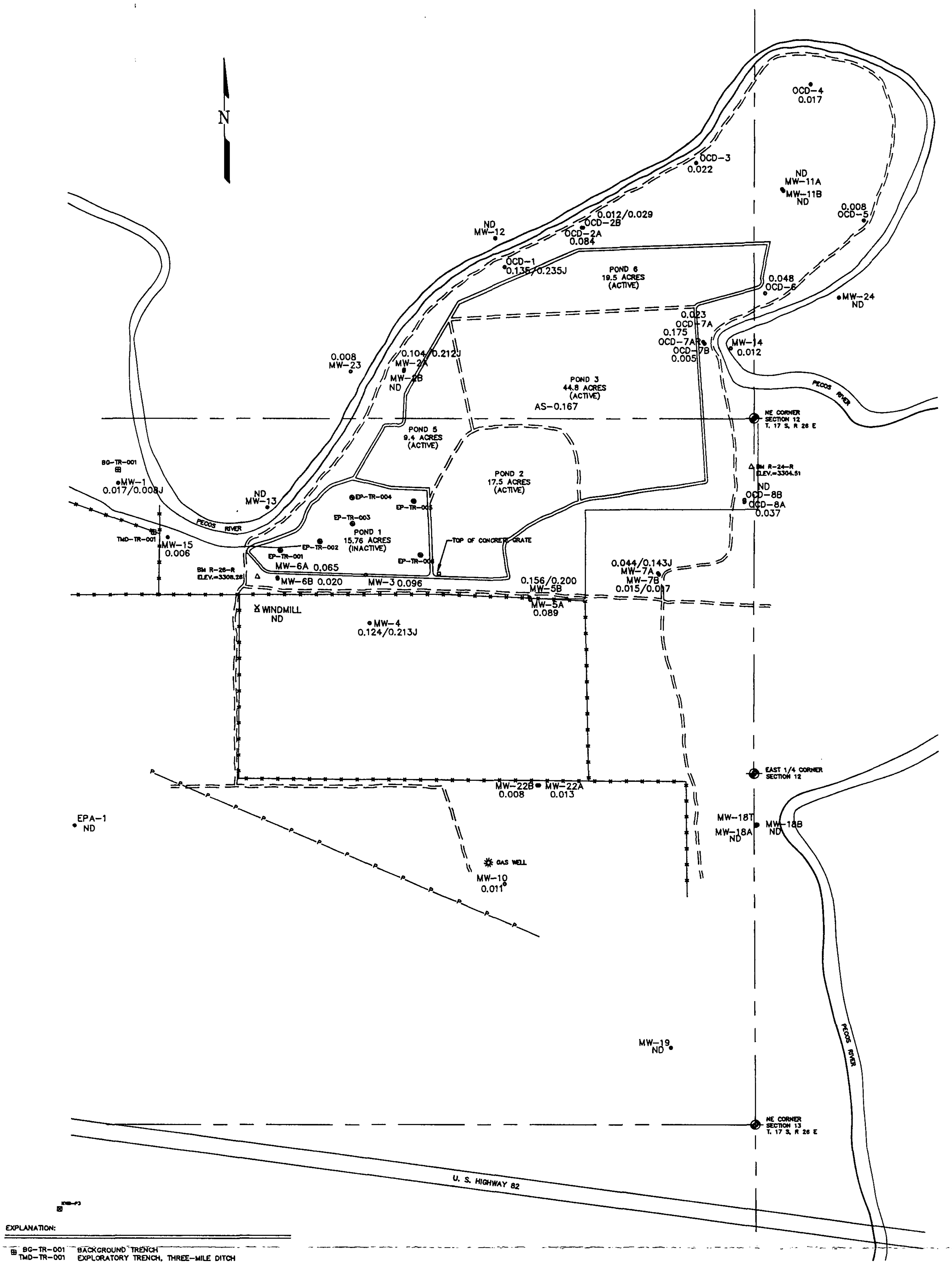
Standards	**EPA Drinking Water (mg/L)**	**NMWQCC Groundwater**
As	0.05	0.1
Cr	0.1	0.5
Pb	0.015 (Action level)	0.05
Ni	0.1	0.2 (irrigation)

EPA drinking water and New Mexico groundwater quality standards. The EPA MCL for lead is an action level requiring treatment at the tap if exceeded in drinking water. In New Mexico nickel is an irrigation standard, not a human-health standard. The other standards shown are human-health standards in water. Because New Mexico groundwater protection regulations require measurements be made on a dissolved (vs. total) sample, all samples, except for well MW-18B, were filtered in the field using a 0.45-micron dedicated filter, as described in Section 6.2.1.3, "Groundwater Sample Collection." MW-18B was not sampled during the January investigation and an unfiltered sample was obtained during a subsequent visit in March. Verification analyses were performed on some preserved samples of arsenic and nickel from some wells because examination of the preliminary analysis results and comparison with draft results from PRC, Inc., EPA's onsite contractor during water quality sampling, indicated possible testing problems may have occurred at either of the analytical laboratories during processing the samples. Further discussion of this issue can be found in Section 9.0.

The results of verification analyses for total arsenic samples collected in the evaporation pond area showed exceedances of the EPA MCL of 0.05 mg/L for total arsenic at nine of 40 groundwater sample locations. The New Mexico groundwater standard of 0.10 mg/L is exceeded at only two locations (MW-5B, OCD-7AR) in the dissolved samples. Figure 17 is a map of the average of the verification analyses for total arsenic in the evaporation pond area. Total arsenic exceeded the New Mexico groundwater standard in two of the initial samples and in four of the arsenic verification analyses. A combined total of five samples exceeded the New Mexico standard. Analyses for dissolved arsenic generally showed a 15% to 35% reduction in the metal from the nonfiltered sample, but the result was not reduced to detection levels.

Numerous MCL exceedances for nickel were observed in samples collected in November through early December 1992. At the time, laboratory QA/QC procedures indicated acceptable values were being obtained in duplicate samples and with spiked samples. However, beginning in mid-December, more recently collected samples from the newly installed monitor wells showed a decline in that could not be readily explained. The results from selected samples chosen for reanalysis were significantly lower than those originally reported. No obvious reason is known for the difference in results, although it may be related to the operation of the equipment and resultant matrix interference owing to the salinity of the samples. At the conclusion of the limited retesting, the November and December samples with results significantly above detection levels were resubmitted for analysis. The revised analyses show total nickel below the federal standard of 0.1 mg/L in all but two of the samples that were reanalyzed. However, those two samples were from wells with stainless-steel casing suspected of having corroded. The samples field filtered to obtain dissolved samples for analysis were

Figure 17. Map of arsenic concentrations, Evaporation Pond Area, RFI Phase II.



EXPLANATION:

⊞ BG-TR-001 TMD-TR-001	BACKGROUND TRENCH EXPLORATORY TRENCH, THREE-MILE DITCH
● EP-TR-001	EXPLORATORY TRENCH, EVAPORATION POND 1
● MW-4 0.124/0.213J	MONITOR WELL WITH TOTAL ARSENIC CONCENTRATION (mg/l), KWBES/PRC SPLIT SAMPLE (WHERE PERFORMED)
⊠	PIEZOMETER
J	ESTIMATED VALUE
ND	NOT DETECTED AT 0.005 (mg/l)

800 0 800 2400 FEET

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

NOTE: KWBES ARSENIC CONCENTRATION SHOWN IS THE VERIFICATION ANALYSIS OR AVERAGE OF TWO VERIFICATION ANALYSES; IF NO VERIFICATION ANALYSIS WAS PERFORMED, VALUE SHOWN IS ORIGINAL CONCENTRATION.

KWBES

prepared for:

Navajo

Map of arsenic concentrations, Evaporation Pond Area, RFI Phase II.

PROJECT: 622092005-110 (NAVSAMP)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 11-20-93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 4-27-93	FIGURE: 17

not retested. For the original analyses, dissolved nickel concentrations were reported at levels about 70% to 90% of the value obtained for the total nickel concentration. As with arsenic, field filtration of the samples did not eliminate the majority of the nickel in this environment. Further discussion of the differences between the KWBES and PRC split sample analyses is presented in Section 9.0.

Total chromium was at or exceeded the EPA MCL in three wells and was detected in 13 others. The highest exceedance occurred in MW-1 with a concentration of 3.65 mg/L related to casing deterioration. The other exceedances occurred in MW-2A (0.10 mg/L) and OCD-3 (0.19 mg/L). Total lead at levels of 0.03 and 0.06 mg/L was detected in OCD-1 and OCD-3, respectively. Both wells have a TDS concentration of greater than 10,000 mg/L. However, chromium and lead did not move through the 0.45-micron field filter and no detections of dissolved chromium and lead in were observed in any of the filtered samples collected in the area of the evaporation ponds.

Laboratory analytical results for metals in the five wells across the river show levels of arsenic, chromium, and nickel elevated above minimum detection levels in one or more wells. Arsenic, total chrome, and nickel were detected in MW-14 at 0.012 mg/L, 0.02 mg/L, and 0.04 mg/L, respectively. Nickel was detected in two other wells and chrome in one other well. Chrome and nickel were not detected in filtered samples from any of the five wells. None of the filtered or total samples exceeded MCL for metals.

The laboratory analytical data for the inorganic water quality constituents and indicator constituents for groundwater in the vicinity of the Evaporation Pond are shown in Table 29. In addition to the major constituents, the minor constituent fluoride, measured and calculated values of TDS, cation-anion totals, and percent difference are shown. The latter three values provide a rapid check of completeness and accuracy of the water analysis. For good-quality, low-TDS water, a percent difference of 1% to 2% is easily obtained. For wastewater and high-TDS water that can cause analytical instrument interference, a 5% difference may be acceptable. Although discussion and interpretation of these results are presented in Section 9.2.3, the water quality of the near-surface saturated zone exceeded federal and state secondary (aesthetic) standards for chloride, sulfate, and TDS at all locations sampled except for chloride at MW-17. The EPA MCL for fluoride of 4.0 mg/L was exceeded at wells MW-2A, OCD-1, and OCD-7A and -7AR. An additional six wells had concentrations above the aesthetic concentration of 2 mg/L but less than the MCL.

Table 29. Results of inorganic water quality analyses, Evaporation Pond area, Navajo Refinery, RFI Phase II.

Table 29. Results of inorganic water quality analyses, Evaporation Pond, Navajo Refinery, RFI Phase II.

Well sample ID	Laboratory no.	Date sampled	Detection level Units	pH (Laboratory)	Electrical Conductivity at 25°C (Laboratory)	Total dissolved solids at 180°C	Total calcium	Total alkalinity	Total hardness	Flouride	Calcium	Calcium	Magne-sium	Magne-sium	Potas-sium	Potas-sium
				0.1 (s.u.)	1 (µmhos/cm)	1 (mg/L)	1 (mg/L)	1 (mg/L)	1 (mg/L)	0.1 (mg/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)
NEP-GW-EPA-1	C922391/15722	18-Nov-92		7.2	5340	3750	3670	167	1960	0.8	495	24.70	176	14.47	7.1	0.18
NEP-GW-MW-01-01	C922278/15632	10-Nov-92		7.5	14900	11200	10500	406	3880	1.1	764	38.12	480	39.47	14.0	0.36
NEP-GW-MW-01-01 (Lab Dup)	C922278/15635	10-Nov-92		7.5	14900	11300	NA	408	NA	1.1	769	NA	480	NA	16.0	NA
NEP-GW-MW-02A	C922280/15633	10-Nov-92		7.4	11300	8430	8430	523	1980	9.9	573	28.59	134	11.02	14.0	0.36
NEP-GW-MW-02B	C922653/16029	16-Dec-93		7.4	3430	2500	2320	160	1220	1.2	304	15.17	112	9.21	20.0	0.51
NEP-GW-MW-02B (Lab Dup)	C922653/16036	16-Dec-92		7.4	3430	2540	NA	160	NA	1.2	300	NA	112	NA	18.0	NA
NEP-GW-MW-03	C922322/15647	11-Nov-92		7.3	7220	5310	4570	285	1630	3.0	457	22.80	119	9.79	12.0	0.31
NEP-GW-MW-04	C922333/15644	12-Nov-92		7.3	7610	5360	5080	234	1410	1.8	370	18.46	119	9.79	5.5	0.15
NEP-GW-MW-04 (Lab Dup)	C922333/15651	12-Nov-92		7.3	7620	5360	NA	233	NA	1.8	376	NA	121	NA	5.0	NA
NEP-GW-MW-05A	C922334/15645	11-Nov-92		7.2	28000	24300	22300	423	5650	3.3	585	29.19	1020	83.88	9.0	0.23
NEP-GW-MW-05A (Fld Dup)	C922335/15646	11-Nov-92		7.2	28100	24400	22200	427	5640	3.3	579	28.89	1020	83.88	9.3	0.23
NEP-GW-MW-05B	C930136/W00059	22-Jan-93		7.1	9310	7350	7160	328	2460	1.5	650	32.44	204	16.78	13.0	0.33
NEP-GW-MW-06A	C922323/15648	12-Nov-92		7.4	4950	3540	3300	136	1090	2.7	282	14.07	93	7.65	3.5	0.10
NEP-GW-MW-06B	C930278/W00344	30-Jan-93		11.9	6410	3800	3660	428	1620	0.4	648	32.34	1	0.08	27.0	0.69
NEP-GW-MW-07A	C922281/15634	11-Nov-92		7.2	13900	11500	11000	302	2780	1.4	471	23.50	389	31.99	12.0	0.31
NEP-GW-MW-07B	C930106/W00056	21-Jan-93		7.5	10700	9220	7980	293	1670	1.4	547	27.30	74	6.09	14.0	0.36
NEP-GW-MW-10	C922390/15721	18-Nov-92		7.2	6190	4400	4380	223	1340	1.1	417	20.81	72	5.92	7.4	0.18
NEP-GW-MW-11A	C922567/15975	12-Dec-92		7.1	23700	16100	15200	331	3980	1.0	964	48.10	384	31.58	31.0	0.79
NEP-GW-MW-11B	C930205/W00184	23-Jan-93		7.3	20500	14000	13600	217	5950	0.9	961	47.95	317	26.07	41.0	1.05
NEP-GW-MW-12	C922658/16033	18-Dec-92		7.2	18700	13500	12400	358	4470	1.1	788	39.32	608	50.00	19.0	0.49
NEP-GW-MW-13	C922659/16034	18-Dec-92		7.5	5180	3630	3370	254	1340	0.7	352	17.56	112	9.21	17.0	0.43
NEP-GW-MW-14	C922655/16031	17-Dec-93		7.4	11200	8230	7780	405	2320	1.0	456	22.75	288	23.68	18.0	0.46
NEP-GW-MW-14 (Fld Dup)	C922654/16030	17-Dec-93		7.3	10900	7890	7550	396	2260	1.0	444	22.16	280	23.03	21.0	0.54
TMD-GW-MW-15	C930105/W00055	20-Jan-93		7.5	3590	2790	2670	150	1190	1.1	308	15.37	102	8.39	11.0	0.28
NEP-GW-MW-17	C930209/W00189	26-Jan-93		7.7	2600	2230	2020	121	1370	1.1	387	19.31	99	8.14	13.0	0.33
NEP-GW-MW-18A	C930207/W00187	25-Jan-93		7.3	16400	12600	11900	286	4530	1.6	721	35.98	664	54.61	30.0	0.77
NEP-GW-MW-18B	C930602/W01466	11-Mar-93		7.7	4650	3710	3550	164	2110	1.1	588	29.34	157	12.91	17.0	0.43
NEP-GW-MW-18B (Lab Dup)	C930602/W1467	11-Mar-94		7.7	4640	3710	NA	164	NA	1.1	577	NA	154	NA	16.0	NA
NEP-GW-MW-19	C930208/W00188	26-Jan-93		7.6	7280	5720	5150	210	2790	0.9	745	37.18	226	18.59	10.0	0.26
NEP-GW-MW-22A	C930282/W00347	29-Jan-93		7.4	5750	4410	4220	159	1520	1.5	421	21.01	114	9.38	6.0	0.15
NEP-GW-MW-22A (Fld Dup)	C930284/W00349	29-Jan-93		7.4	5790	4400	4290	159	1560	1.5	434	21.66	117	9.62	7.0	0.18
NEP-GW-MW-22B	C930283/W00348	29-Jan-93		7.1	6180	4700	4510	213	1720	1.0	461	23.00	139	11.43	4.0	0.10
NEP-GW-MW-22B (Lab Dup)	C930283/W00351	29-Jan-93		7.1	6180	4720	NA	212	NA	1.0	464	NA	139	NA	5.0	NA
NEP-GW-MW-23	C930229/W00271	28-Jan-93		7.2	15900	11700	10500	349	3890	0.8	988	49.30	347	28.54	14.0	0.36
NEP-GW-MW-23 (Lab Dup)	C930229/W00274	28-Jan-93		7.2	15900	11700	NA	349	NA	0.8	986	NA	342	NA	14.0	NA
NEP-GW-MW-24	C930281/W00346	28-Jan-93		7.3	16300	11600	10786	242	2951	1.0	787	39.27	240	19.74	38.0	0.97
NEP-GW-OCD-1	C922324/15649	13-Nov-92		7.2	14200	10300	8570	526	1860	5.7	487	24.30	156	12.83	7.2	0.18
NEP-GW-OCD-2A	C922357/15669	15-Nov-92		7.0	15400	11800	10900	404	2780	1.2	565	28.19	333	27.38	8.1	0.20
NEP-GW-OCD-2A (Lab Dup)	C922357/15673	15-Nov-92		7.0	15400	11700	NA	394	NA	1.2	567	NA	313	NA	9.0	NA
NEP-GW-OCD-2B	C930134/W00057	21-Jan-93		7.3	14700	11600	11100	408	4140	0.9	844	42.12	494	40.63	13.0	0.33
NEP-GW-OCD-3	C922358/15670	16-Nov-92		7.1	17300	11600	10300	281	3340	0.9	922	46.01	268	22.04	29.0	0.74
NEP-GW-OCD-4-1	C922398/15727	16-Nov-92		7.2	19000	13100	11800	197	2790	0.9	724	36.13	240	19.74	50.0	1.28
NEP-GW-OCD-5	C922399/15728	16-Nov-92		7.2	17800	12400	12000	199	3070	1.0	847	42.27	232	19.08	37.0	0.95
NEP-GW-OCD-5 (Fld Dup)	C922394/15724	17-Nov-92		7.2	17900	12400	11900	202	3050	1.0	846	42.22	228	18.75	36.0	0.92
NEP-GW-OCD-5 (LabDup of Fld D)	C922394/15731	17-Nov-92		7.2	17900	12400	NA	205	NA	1.0	849	NA	225	NA	36.0	NA
NEP-GW-OCD-6-1	C922400/15729	16-Nov-92		7.1	14500	10900	10400	495	2550	2.9	675	33.68	210	17.27	15.0	0.38
NEP-GW-OCD-7A	C922389/15720	18-Nov-92		7.3	13300	10300	9570	564	2670	4.1	620	30.94	274	22.53	8.5	0.23
NEP-GW-OCD-7A R	C930104/W00054	19-Jan-93		7.3	10500	8350	7940	511	2390	6.6	652	32.53	186	15.30	14.0	0.36
NEP-GW-OCD-7B	C930279/W00345	30-Jan-93		7.6	6110	5060	4840	141	1850	1.2	547	27.30	117	9.62	10.0	0.26
NEP-GW-OCD-8A	C922393/15723	17-Nov-92		7.0	12400	9670	9050	434	2850	2.5	633	31.59	308	25.33	11.0	0.28
NEP-GW-OCD-8B	C930203/W00182	23-Jan-93		7.3	7490	5400	5240	164	2930	0.9	834	41.62	207	17.02	12.0	0.31
NEP-GW-OCD-8B (Fld Dup)	C930204/W00183	23-Jan-93		7.7	7270	5270	5130	163	2840	0.9	807	40.27	202	16.61	14.0	0.36
NEP-Navajo Effluent	C930367/W00731	11-Feb-93		8.9	9300	7348	4840	829	279	151.0	21	1.05	55	4.52	22.0	0.56
Evaporation Pond at OCD 7	C922424/15745	16-Nov-92		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Evaporation Pond at OCD 7	C922424/15745/W0 1463	16-Nov-92		7.6	10900	7080	6620	534	354	36.3	46	2.30	58	4.77	67.0	1.31
NEP-Windmill	C922656/16032	17-Dec-92		7.4	6610	4740	4450	163	1530	1.1	316	15.77	180	14.80	14.0	0.36
Pecos River at OCD 7	C922425/W01464	16-Nov-92		7.3	7080	5110	4735	165	2190	0.9	571	28.49	186	15.30	13.0	0.33

Table 29. Continued.

Well sample ID	Laboratory no.	Date sampled	Detection level Units	Sodium	Sodium	HCO_3	HCO_3	CO_3	CO_3	OH	OH	Chloride	Chloride	SO_4	SO_4	Cation sum	Anion sum	Percent difference
				1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	1 (mg/L)	(meq/L)	(meq)	(meq)	(%)
NEP-GW-EPA-1	C922391/15722	18-Nov-92		480	20.88	204	3.34	0	0.00	0	0.00	989	27.90	1420	29.56	60.23	60.80	-0.47
NEP-GW-MW-01-01	C922278/15632	10-Nov-92		2130	92.65	495	8.11	0	0.00	0	0.00	3750	105.78	3020	62.88	170.60	176.77	-1.78
NEP-GW-MW-01-01 (Lab Dup)	C922278/15635	10-Nov-92		2130	NA	NA	NA	NA	NA	NA	NA	3740	NA	3010	NA	NA	NA	NA
NEP-GW-MW-02A	C922280/15633	10-Nov-92		2170	94.39	638	10.46	0	0.00	0	0.00	2120	59.8	3180	66.21	134.36	134.47	-0.78
NEP-GW-MW-02B	C922653/16029	16-Dec-93		268	11.66	195	3.20	0	0.00	0	0.00	497	14.02	1020	21.24	36.55	38.46	-2.55
NEP-GW-MW-02B (Lab Dup)	C922653/16036	16-Dec-92		268	NA	NA	NA	NA	NA	NA	NA	498	NA	1020	NA	NA	NA	NA
NEP-GW-MW-03	C922322/15647	11-Nov-92		975	42.41	348	5.70	0	0.00	0	0.00	1820	51.34	1020	21.24	75.31	78.28	-1.93
NEP-GW-MW-04	C922333/15644	12-Nov-92		1180	51.33	285	4.67	0	0.00	0	0.00	1380	38.93	1880	39.14	79.73	82.74	-1.85
NEP-GW-MW-04 (Lab Dup)	C922333/15651	12-Nov-92		1170	NA	NA	NA	NA	NA	NA	NA	1410	NA	1870	NA	NA	NA	NA
NEP-GW-MW-05A	C922334/15645	11-Nov-92		5250	228.36	516	8.46	0	0.00	0	0.00	5410	152.61	9770	203.41	341.66	364.48	-3.23
NEP-GW-MW-05A (Fld Dup)	C922335/15646	11-Nov-92		5150	224.01	520	8.52	0	0.00	0	0.00	5470	154.30	9740	202.79	337.01	365.61	-4.07
NEP-GW-MW-05B	C930136/W00059	22-Jan-93		1600	69.60	400	6.56	0	0.00	0	0.00	1760	49.65	2730	56.84	119.15	113.05	2.63
NEP-GW-MW-06A	C922323/15648	12-Nov-92		700	30.45	166	2.72	0	0.00	0	0.00	654	18.45	1490	31.02	52.27	52.19	0.08
NEP-GW-MW-06B	C930278/W00344	30-Jan-93		574	24.97	0	0.00	37	1.22	125	7.33	968	27.31	1180	24.57	58.08	60.43	-1.98
NEP-GW-MW-07A	C922281/15634	11-Nov-92		2930	127.45	368	6.03	0	0.00	0	0.00	2750	77.57	4260	88.69	183.25	172.29	3.08
NEP-GW-MW-07B	C930106/W00056	21-Jan-93		1990	86.56	357	5.85	0	0.00	0	0.00	1880	53.03	3300	68.71	120.31	127.59	-2.94
NEP-GW-MW-10	C922390/15721	18-Nov-92		970	42.19	272	4.46	0	0.00	0	0.00	982	27.70	1800	37.48	69.10	69.64	-0.39
NEP-GW-MW-11A	C922567/15975	12-Dec-92		3860	167.90	404	6.62	0	0.00	0	0.00	7108	200.51	2610	54.34	248.37	261.47	-2.57
NEP-GW-MW-11B	C930205/W00184	23-Jan-93		3410	148.33	265	4.34	0	0.00	0	0.00	5950	167.84	2790	58.09	223.40	230.27	-1.51
NEP-GW-MW-12	C922658/16033	18-Dec-92		2560	111.35	437	7.16	0	0.00	0	0.00	4980	140.48	3250	67.67	201.16	215.31	-3.40
NEP-GW-MW-13	C922659/16034	18-Dec-92		596	25.92	310	5.08	0	0.00	0	0.00	914	25.78	1230	25.61	53.12	56.47	-3.06
NEP-GW-MW-14	C922655/16031	17-Dec-93		1720	74.82	493	8.08	0	0.00	0	0.00	2150	60.65	2900	60.38	121.71	129.11	-2.95
NEP-GW-MW-14 (Fld Dup)	C922654/16030	17-Dec-93		1650	71.77	483	7.92	0	0.00	0	0.00	2080	58.67	2830	58.92	117.50	125.51	-3.30
TMD-GW-MW-15	C930105/W00055	20-Jan-93		447	19.44	182	2.98	0	0.00	0	0.00	564	15.91	1150	23.94	43.48	42.83	0.75
NEP-GW-MW-17	C930209/W00189	26-Jan-93		109	4.74	147	2.41	0	0.00	0	0.00	122	3.44	1220	25.40	32.52	31.25	1.99
NEP-GW-MW-18A	C930207/W00187	25-Jan-93		2420	105.26	348	5.70	0	0.00	0	0.00	3930	110.86	3950	82.24	196.62	198.80	-0.55
NEP-GW-MW-18B	C930602/W01466	11-Mar-93		356	15.48	200	3.28	0	0.00	0	0.00	661	18.65	1670	34.77	58.16	56.70	1.27
NEP-GW-MW-18B (Lab Dup)	C930602/W1467	11-Mar-94		353	NA	NA	NA	NA	NA	NA	NA	668	NA	1690	NA	NA	NA	NA
NEP-GW-MW-19	C930208/W00188	26-Jan-93		718	31.23	256	4.20	0	0.00	0	0.00	1370	38.65	1950	40.60	87.26	83.45	2.23
NEP-GW-MW-22A	C930282/W00347	29-Jan-93		799	34.75	193	3.16	0	0.00	0	0.00	835	23.55	1950	40.60	65.29	67.31	-1.52
NEP-GW-MW-22A (Fld Dup)	C930284/W00349	29-Jan-93		809	35.19	193	3.16	0	0.00	0	0.00	844	23.81	1990	41.43	66.65	68.40	-1.30
NEP-GW-MW-22B	C930283/W00348	29-Jan-93		830	36.10	259	4.25	0	0.00	0	0.00	983	27.73	1970	41.02	70.63	73.00	-1.65
NEP-GW-MW-22B (Lab Dup)	C930283/W00351	29-Jan-93		827	NA	NA	NA	NA	NA	NA	NA	983	NA	1950	NA	NA	NA	NA
NEP-GW-MW-23	C930229/W00271	28-Jan-93		2180	94.82	425	6.97	0	0.00	0	0.00	4240	119.61	2570	53.51	173.02	180.09	-2.00
NEP-GW-MW-23 (Lab Dup)	C930229/W00274	28-Jan-93		2160	NA	NA	NA	NA	NA	NA	NA	4260	NA	2660	NA	NA	NA	NA
NEP-GW-MW-24	C930281/W00346	28-Jan-93		2500	108.74	295	4.84	0	0.00	0	0.00	4170	117.63	2910	60.59	168.72	183.06	-4.08
NEP-GW-OCD-1	C922324/15649	13-Nov-92		2230	97.00	642	10.52	0	0.00	0	0.00	1930	54.44	3450	71.83	134.31	136.79	-0.91
NEP-GW-OCD-2A	C922357/15669	15-Nov-92		2510	109.18	493	8.08	0	0.00	0	0.00	3220	90.83	3990	83.07	164.95	181.98	-4.91
NEP-GW-OCD-2A (Lab Dup)	C922357/15673	15-Nov-92		2600	NA	NA	NA	NA	NA	NA	NA	3200	NA	3980	NA	NA	NA	NA
NEP-GW-OCD-2B	C930134/W00057	21-Jan-93		2320	100.91	498	8.16	0	0.00	0	0.00	3710	104.65	3450	71.83	183.99	184.64	-0.18
NEP-GW-OCD-3	C922358/15670	16-Nov-92		2330	101.35	281	4.61	0	0.00	0	0.00	4130	116.50	2520	52.47	170.14	173.58	-1.00
NEP-GW-OCD-4-1	C922398/15727	16-Nov-92		3120	135.71	240	3.93	0	0.00	0	0.00	4500	126.94	3010	62.67	192.86	193.54	-0.18
NEP-GW-OCD-5	C922399/15728	16-Nov-92		3030	131.80	243	3.98	0	0.00	0	0.00	4720	133.15	2980	62.04	194.10	199.17	-1.29
NEP-GW-OCD-5 (Fld Dup)	C922394/15724	17-Nov-92		2930	127.45	246	4.03	0	0.00	0	0.00	4760	134.27	3000	62.46	189.34	200.76	-2.93
NEP-GW-OCD-5 (LabDup of Fld D)	C922394/15731	17-Nov-92		2970	NA	NA	NA	NA	NA	NA	NA	4780	NA	2990	NA	NA	NA	NA
NEP-GW-OCD-6-1	C922400/15729	16-Nov-92		2550	110.92	603	9.89	0	0.00	0	0.00	3000	84.63	3670	76.41	162.25	170.93	-2.61
NEP-GW-OCD-7A	C922389/15720	18-Nov-92		2120	92.21	687	11.26	0	0.00	0	0.00	2480	69.96	3730	77.66	145.91	158.88	-4.26
NEP-GW-OCD-7A R	C930104/W00054	19-Jan-93		1950	84.82	623	10.21	0	0.00	0	0.00	2040	57.55	2800	58.30	133.01	126.06	2.68
NEP-GW-OCD-7B	C930279/W00345	30-Jan-93		813	35.36	172	2.82	0	0.00	0	0.00	690	19.46	2570	53.51	72.54	75.79	-2.19
NEP-GW-OCD-8A	C922393/15723	17-Nov-92		1930	83.95	529	8.67	0	0.00	0	0.00	2290	64.60	3620	75.37	141.15	148.64	-2.58
NEP-GW-OCD-8B	C930203/W00182	23-Jan-93		651	28.32	200	3.28	0	0.00	0	0.00	1630	45.98	1810	37.68	87.27	86.94	0.19
NEP-GW-OCD-8B (Fld Dup)	C930204/W00183	23-Jan-93		628	27.32	199	3.26	0	0.00	0	0.00	1580	44.57	1800	37.48	84.56	85.31	-0.44
NEP-Navajo Effluent	C930367/W00731	11-Feb-93		1290	56.11	1011	16.57	0	0.00	0	0.00	1920	54.16	1034	21.53	62.24	92.26	-19.43
Evaporation Pond at OCD 7	C922424/15745	16-Nov-92		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Evaporation Pond at OCD 7	C922424/15745/W01463	16-Nov-92		2000	86.99	651	10.67	0	0.00	0	0.00	2180	61.50	1950	40.60	95.77	112.77	-8.15
NEP-Windmill	C922656/16032	17-Dec-92		872	37.93	199	3.26	0	0.00	0	0.00	1190	33.57	1780	37.06	68.86	73.89	-3.52
Pecos River at OCD 7	C922425/W01464	16-Nov-92		733	31.88	201	3.30	0	0.00	0	0.00	1470	41.47	1660	34.56	76.00	79.32	-2.14

8.3.3 Groundwater Modeling

The RFI workplan did not originally include a groundwater modeling component. Other than the preparation of potentiometric maps to determine direction of groundwater movement and the determination of seepage velocities for time-of-travel calculations, no groundwater flow calculations were expected to be performed as part of this study. However, the finding of significant and consistent upward vertical gradients in the shallow subsurface, the lack of notable contamination in a monitoring well where it was expected, and the availability of hydrologic data from this and earlier reports led to the decision to proceed with the use of a simple and accepted groundwater model.

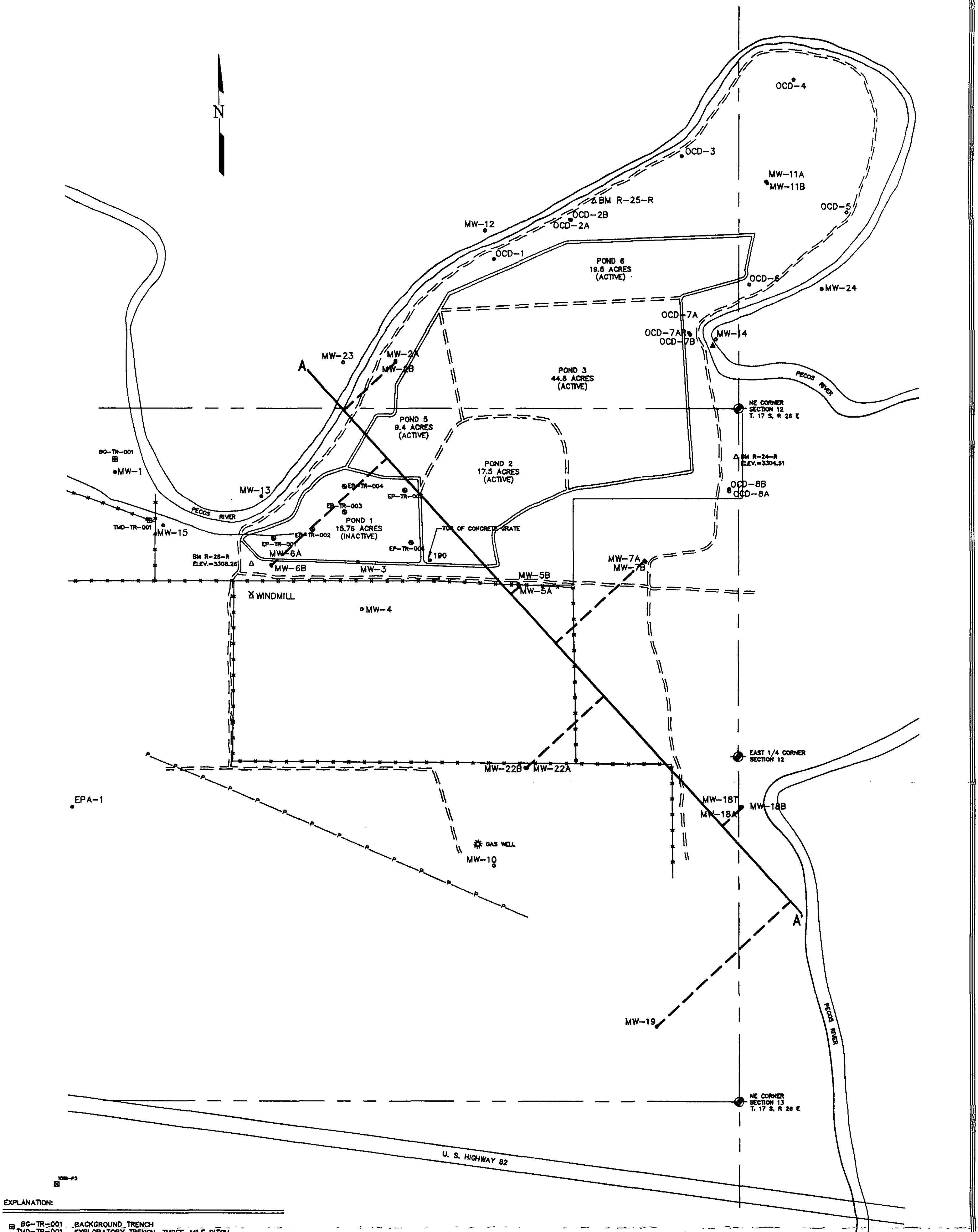
8.3.3.1 Modeling Approach

A straightforward mathematical modeling approach was applied to the hydrologic conditions found to exist at the pond to model fluid movement and pathways. An interactive microcomputer-based model was used for estimating the fluid path lines in the flow domain. This saturated-flow model, GWPATH (Version 4.0), computes and displays the flow path of a particle for which the initial location can be anywhere in a two-dimensional domain. The program is based on Darcy's law for incompressible fluids. For inputs, the model requires hydraulic conductivity, in the principal coordinate directions, and the effective porosity. Aquifer properties can be input for homogeneous conditions or for spatially varying conditions. The model allows the properties of the aquifer to be input at each node if necessary. Hydraulic head must also be input over the entire flow domain. Sources and sinks are located as an input. A more complete discussion of the computer modeling methodology is presented in Appendix H.

8.3.3.2 GWPATH Modeling Results

Figure 18 is the location of the cross-section used to model the groundwater flow. The cross-section is oriented generally northwest-southeast in the direction of horizontal surface flow. Figure 19 shows the horizontal and vertical coordinate system and resultant path line particle map. The pond location and the initial particle position are all designated, as well as the positions of monitoring wells pairs MW-2, MW-5, MW-7, MW-18, and MW-22. Aquifer properties, including the hydraulic gradient and hydraulic conductivity, were determined from field measurements. The procedures for obtaining these data were presented earlier in Section 8.3.1 and the resultant values were presented in Section 8.3.2. Note that these data include horizontal hydraulic conductivities with a range of values. Vertical conductivities, which were

Figure 18. Cross section location for vertical groundwater flow model, Evaporation Pond Area, RFI Phase II.



EXPLANATION:

⊞ BG-TR-001	BACKGROUND TRENCH
TMD-TR-001	EXPLORATORY TRENCH, THREE-MILE DITCH
● EP-TR-001	EXPLORATORY TRENCH, EVAPORATION POND 1
○ MW-10	MONITOR WELL
⊠	PIEZOMETER

NOTE: MAP COMPILED FROM NAVAJO REFINERY AND USGS SPRING LAKE 7.5 MINUTE QUADRANGLE. WELL LOCATIONS AND ELEVATIONS FROM NAVAJO REFINERY CONTROL. WELL LOCATIONS SURVEYED 2/93, JAQUESS & ASSOCIATES.

LOCATION T 17 S, R 26 E, NMPM, EDDY COUNTY, NM

KWBES

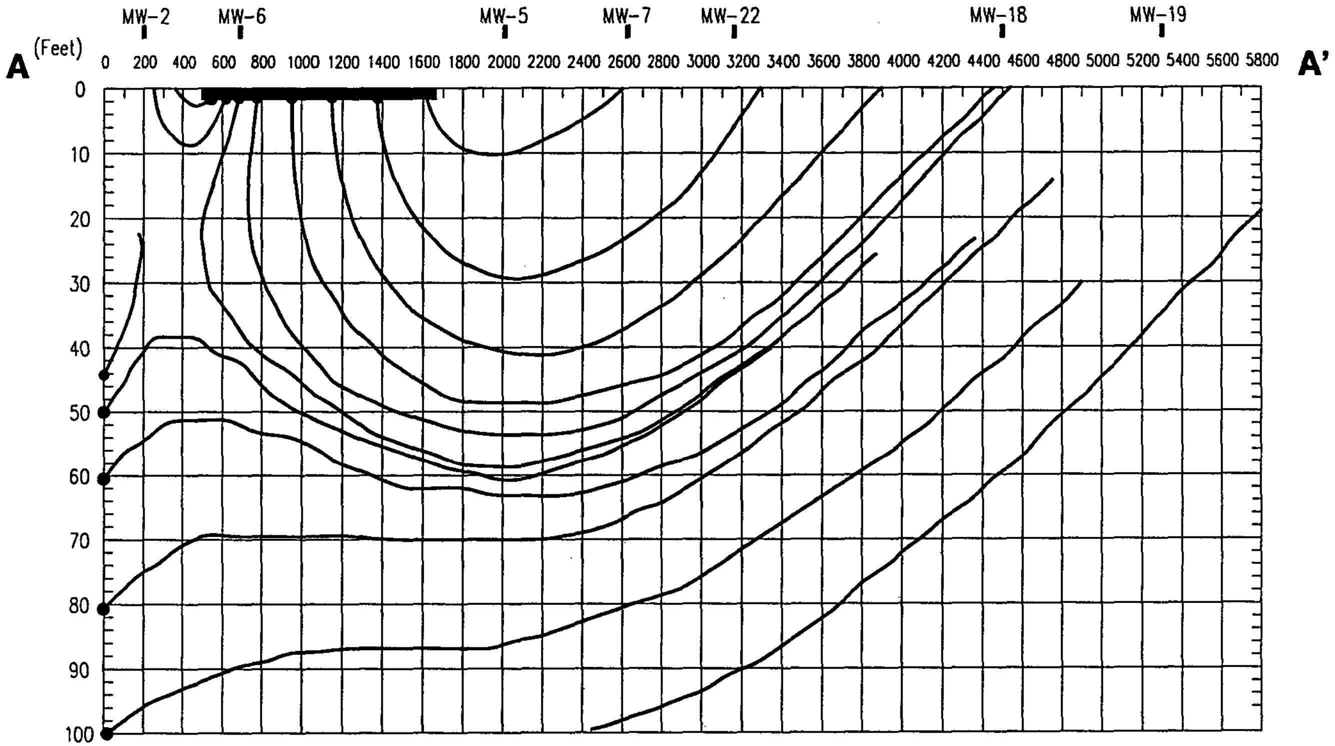
Cross section location for vertical groundwater flow model, Evaporation Pond Area, RFI Phase II.

prepared for:

Navajo

PROJECT: 622092005-110 (NAVSAMP)	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-29-93
DRAWN BY: JW	SCALE: AS SHOWN
DATE: 4-27-93	FIGURE: 18

Figure 19. Vertical groundwater flow model — particle tracking map for 60 years, Evaporation Ponds 1 and 2, RFI Phase II.



EXPLANATION

▬ SURFACE IMPOUNDMENT

/ FLOW PATH

● INITIAL PARTICLE POSITION

MW-2 MONITOR WELL LOCATION

KWBES

prepared for:

Navajo

Vertical groundwater flow model – particle tracking map for 60 years, Evaporation Ponds 1 and 2, RFI Phase II.

PROJECT: 622092005-110 (GWMODEL)
LOCATION: ARTESIA, NEW MEXICO
APPR: DATE: 04/14/93
DRAWN BY: JW SCALE: NONE
DATE: 11/22/93 FIGURE: 19

typically less than the horizontal values by an order of magnitude or more, were selected after reviewing the results of hydraulic conductivity testing from this study and the results reported in the RFI Phase I Report. Hydraulic heads were obtained from monitor well values presented previously in Table 20. Because the wells are not all screened at the same topographic elevation, the input data include head values from different lateral and vertical locations. The hydraulic head input data file was prepared using these data in the USGS flow model MODFLOW.

Figure 19 shows the resultant flow paths of the hypothetical particles from their initial locations over a time period of 60 years. The figure illustrates a situation in which there is downward flow from the pond superimposed on a domain that is generally moving vertically upward. Thus, the flow is initially downward directly beneath the pond, and rises laterally in the downgradient direction. There is a surface upon which particles move neither upward or downward. Here, motion is lateral and follows the regional gradient away from the influence of the pond. Thus, a particle moves off the vertically static surface to a region in which flow is again upward.

From Figure 19, it is clear why under the given conditions, only a minimal number of contaminant particles are able to migrate downward to the elevation where MW-2B is screened. Because of the confined effect of the vertical and horizontal gradients and conductivity, the lower zone in the vicinity of MW-2 remains largely uncontaminated in spite of local downward movement in upper zones that are significantly influenced by the pond. The particle flow map also shows how flow will influence the movement of particles upward toward a discharge area southeast of the ponds. In conclusion, flow physics and a strong vertical gradient explain the localized flow regimen and absence of expected high contamination levels in monitoring well MW-2B.

The flow physics also explain the occurrence of unidentified hydrocarbons across the Pecos River which would normally be considered a hydrologic barrier. Groundwater movement is perpendicular to the hydrologic gradient and in the vicinity of the ponds, an artificial gradient has been imposed because of the hydraulic head due to the pond water. The pond causes a groundwater mound with groundwater flowing away from the mound radially and vertically. At some distance from the pond, flow comes into equilibrium with the naturally occurring conditions, and movement along the direction of the preexisting gradient is resumed. The combined hydraulic impacts physically cause movement of water in directions normally unanticipated, This movement is shown graphically on Figure 19, and includes movement upstream and under the river.

9.0 DISCUSSION

In order to assist in the interpretation of analytical data for samples obtained from Three-Mile Ditch and the evaporation ponds at the Navajo Refinery, a summary table containing health-based concentration criteria, MCLs set under the Safe Drinking Water Act, and New Mexico groundwater quality standards for selected constituents was developed (Table 30). The health-based concentrations are derived from two EPA-proposed rules (55 *FR* 30798, 27 July 1990; and 57 *FR* 21450, 20 May 1992) that set forth health-based contaminant concentration levels for use in the assessment of contaminated media and contaminated media and waste, respectively, and an EPA Region 3 memorandum specifying guidance for the establishment of action levels in corrective action permits for soil and water media (Region 3 memorandum, 11/23/92). For both sets of proposed regulations, and the Region 3 guidance memorandum, permissible constituent concentration limits for carcinogens are based on lifetime exposure scenarios (70 years) and an excess cancer risk ranging from 10^{-5} to 10^{-6}. For systemic toxicants, reference doses were used in conjunction with standard constituent ingestion rates to determine maximum constituent concentrations that would not produce deleterious effects in a sensitive individual over a lifetime of exposure.

The constituents selected for inclusion in Table 30 include the inorganic constituents of concern for Three-Mile Ditch as well as all of the organic constituents reported at detectable levels in the following data sets:

- RFI Phase I Investigation — Mariah Associates, Inc. (Appendix D)
- RFI Phase II Investigation — K. W. Brown Environmental Services (Appendix I)
- RFI Phase II Investigation (split samples) — PRC, Inc. (Appendix J)

9.1 THREE-MILE DITCH

9.1.1 Soils

The RFI Phase II soils investigation for Three-Mile Ditch was, in part, designed to confirm the findings of the previous soils investigation for the unit, which were presented in the 1990 Navajo RFI Phase I Report (Appendix D). A comparison of the RFI Phase I and Phase II data and their potential implications are discussed herein.

Table 30. Health-based criteria proposed by the EPA for various metals and organic compounds in environmental media(soils concentrations in mg/kg, water and leachate concentrations in mg/L).

Table 30. Health-based criteria proposed by the EPA for various metals and organic compounds detected in environmental media in Three-Mile Ditch and Pond 1 (soils concentrations in mg/kg, water and leachate concentrations in mg/L.)

Constituent	Proposed 55 FR 30798 ^{a}		Proposed 57 FR 21450 ^{b}		USEPA Region 3 Corrrective Action Permits Action Level Guidance(d)		Drinking water MCL	New Mexico groundwater standard
	Soil	Water	Soil	Leachate ^{c}	Soil	Water		
Metals								
Arsenic	80	0.05^e	20	0.5	20	0.05	0.05	0.1
Chromium	400	0.05	400	1.0	400	0.1	0.1	0.05
Lead	500^f	0.05^f	500	0.15	500	0.015	AL = 0.015	0.05
Nickel	2000	0.7	1000	1.0	1000	0.1	0.1	I = 0.2
Zinc	16,000^g	7.0^g	1000	70	1000	7.0	5^i	10.0^i
Volatile organic compounds								
Acetone	8000	4.0	1000	40	1000	4.0	-	-
Benzene	24^g	0.005^e	40	0.05	40	0.005	0.005	0.01
2-butanone (MEK)	4000	2.0	1000	20	1000	2.0	-	-
Carbon disulfide	8000	4.0	1000	40	1000	4.0	-	-
Chloromethane	-	-	-	-	-	-	-	-
Ethylbenzene	8000	4.0	1000	7.0	1000	0.7	0.7	0.75
1,1,2,2-tetrachloroethane	40	0.002	6.0	0.002	6.0	0.0002	-	0.01
Methylene chloride	90	0.005	-	-	100	0.005	0.005	0.1
Toluene	20000	10	1000	10	1000	1.0	1	0.75
Trichloroethylene	60	0.005^e	100	0.5	100	0.005	0.005	0.1
Xylenes	160,000	70	1000	100	1000	10	10	0.62

Note: AL = action level that, if exceeded, requires water treatment.

I = irrigation standard.

a = Proposed rule: Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (27 July 1990).

b = Proposed rule: Identification and Listing of Hazardous Waste (20 May 1992).

c = Regulatory leachate concentration yielded by the Toxicity Characteristic Leachate Procedure modeled assuming municipal landfill disposal.

d = 11/23/92 EPA Region 3 memorandum from Mary Beck, General States Permits Section to Carolyn Loomis, Corrective Action Programs Branch

e = Maximum contaminant level promulgated under the Safe Drinking Water Act.

f = Based on values calculated using the EPA Lead Uptake/Biokinetic Model, Version 0.4.

g = Calculated according to methods in Appendix E, Corrective Action for Solid Waste Management Units at Hazardous Waste Management facilities (27 July 1990); reference dose or carcinogenic slope factor obtained from EPA Health Effects Summary Table (HEAST), 1991.

h = RfD derived from LD50 listed in Registry of Toxic Effects of Chemical Substances, Department of Health, Education and Human Services.

i = Not health-based, but a recommended aesthetic standard.

j = Standard applicable to the sum of naphthalene and monomethylnapthalene isomers.

Table 30. Continued.

Constituent	Proposed 55 FR 30798 [a]		Proposed 57 FR 21450 [b]		USEPA Region 3 Corrrective Action Permits Action Level Guidance[d]		Drinking water MCL	New Mexico groundwater standard
	Soil	Water	Soil	Leachate [c]	Soil	Water		
Semivolatile organic compounds								
Acenaphthene	4800 [g]	2.1 [g]	1000	20	1000	2.0	-	-
Anthracene	24000 [g]	107 [g]	-	-			-	-
Benzo(a)anthracene	-	-	0.5	0.001	0.05	0.0001	-	-
Benzo(b)fluoranthene	-	-	0.1	0.002	1.0	0.0002	-	-
Benzo(g,h,i)perylene	-	-	-	-			-	-
Benzo(a)pyrene	0.06 [g]	0.000003 [g]	0.2	0.002	0.2	0.0002	0.0002	0.0007
Bis(2-chloroisopropyl) ether	100 [g]	0.005 [g]	-	-	20	0.0005	-	-
Bis(2-ethylhexyl)phthalate	50	0.003	80	0.04	80	0.004	-	-
Butyl benzyl phthalate	20,000	7.0	1000	1.0	1000	0.1	-	-
Carbazole	-	-	-	-			-	-
4-chloroaniline	320 [g]	0.14 [g]	300	1.0	300	0.1	-	-
4-chloronaphthalene	-	-	-	-			-	-
4-chloro,3-methylphenol	-	-	-	-			-	-
2-chlorophenol	400 [g]	0.2 [g]	400	2.0	400	0.2	-	-
Chrysene	-	-	10	0.002	10	0.0002	-	-
Cresols (total)	40000 [g]	19.2 [g]	1000	20	1000	2.0		
Dibenzofuran	800 [g]	0.35 [g]	-	-			-	-
Di-n-butylphthalate	8000	4.0	1000	40	1000	4.0	-	-
Diethtyl phthalate	60000	30	1000	300	1000	30.0	-	-
2,4-dimethylphenol	1600 [g]	0.7 [g]	-	-	1000	0.7	-	-

Note: AL = action level that, if exceeded, requires water treatment.

I = irrigation standard.

a = Proposed rule: Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (27 July 1990).

b = Proposed rule: Identification and Listing of Hazardous Waste (20 May 1992).

c = Regulatory leachate concentration yielded by the Toxicity Characteristic Leachate Procedure modeled assuming municipal landfill disposal.

d = 11/23/92 EPA Region 3 memorandum from Mary Beck, General States Permits Section to Carolyn Loomis, Corrective Action Programs Branch

e = Maximum contaminant level promulgated under the Safe Drinking Water Act.

f = Based on values calculated using the EPA Lead Uptake/Biokinetic Model, Version 0.4.

g = Calculated according to methods in Appendix E, Corrective Action for Solid Waste Management Units at Hazardous Waste Management facilities (27 July 1990); reference dose or carcinogenic slope factor obtained from EPA Health Effects Summary Table (HEAST), 1991.

h = RfD derived from LD50 listed in Registry of Toxic Effects of Chemical Substances, Department of Health, Education and Human Services.

i = Not health-based, but a recommended aesthetic standard.

j = Standard applicable to the sum of naphthalene and monomethylnapthalene isomers.

Table 30. Continued

Constituent	Proposed 55 FR 30798[a]		Proposed 57 FR 21450[b]		USEPA Region 3 Corrrective Action Permits Action Level Guidance[d]		Drinking water MCL	New Mexico groundwater standard
	Soil	Water	Soil	Leachate[c]	Soil	Water		
Semivolatiles organic compounds (cont.)								
2,4-dinitrotoluene	1.0[g]	0.00005[g]	2	0.0005	2.0	0.00005	-	-
2,6-dinitrotoluene	1.0[g]	0.00005[g]	2	0.0005	2.0	0.00005	-	-
Fluoranthene	3200[g]	1.4[g]	1000	10	1000	1.0	-	-
Fluorene	3200[g]	1.4[g]	1000	10	1000	1.0	-	-
2-methylnaphthalene	1000[g]	0.4[g]	-	-	-	-	-	-
Naphthalene	320[g]	0.14[g]	1000	10	1000	1.0	-	0.03[j]
4-nitrophenol	-	-	-	-	-	-	-	-
2-nitroaniline	-	-	-	-	-	-	-	-
Phenanthrene	1,600[g,h]	0.7[g,h]	-	-	40	0.002	-	-
Pyrene	2400[g]	1.1[g]	1000	10	1000	1.0	-	-

Note: AL = action level that, if exceeded, requires water treatment.

I	=	irrigation standard.
a	=	Proposed rule: Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (27 July 1990).
b	=	Proposed rule: Identification and Listing of Hazardous Waste (20 May 1992).
c	=	Regulatory leachate concentration yielded by the Toxicity Characteristic Leachate Procedure modeled assuming municipal landfill disposal.
d	=	11/23/92 EPA Region 3 memorandum from Mary Beck, General States Permits Section to Carolyn Loomis, Corrective Action Programs Branch
e	=	Maximum contaminant level promulgated under the Safe Drinking Water Act.
f	=	Based on values calculated using the EPA Lead Uptake/Biokinetic Model, Version 0.4.
g	=	Calculated according to methods in Appendix E, Corrective Action for Solid Waste Management Units at Hazardous Waste Management facilities (27 July 1990); reference dose or carcinogenic slope factor obtained from EPA Health Effects Summary Table (HEAST), 1991.
h	=	RfD derived from LD50 listed in Registry of Toxic Effects of Chemical Substances, Department of Health, Education and Human Services.
i	=	Not health-based, but a recommended aesthetic standard.
j	=	Standard applicable to the sum of naphthalene and monomethylnapthalene isomers.

The RFI Phase I and Phase II analytical data for volatile organic compounds in the Three-Mile Ditch trench samples are generally consistent in that the BTEX constituents occur at the highest rates of frequency and neither data set exhibits concentrations of volatile organic compounds at concentrations that exceed health-based levels (Tables 4 and 30 and Appendix D). Only four volatile organic compounds were detected in one data set but not observed in the other set:

- 1,1,2,2-tetrachloroethane — four detections in the Phase I data set
- chloromethane — one detection in the Phase I data set
- acetone — two detections in the Phase II data set
- methylene chloride — two detections in the Phase II data set

The results of TCLP analysis of the Phase II soil samples from Three-Mile Ditch are summarized in Table 31. None of the volatile organic compounds analyzed in the soil leachate extracts exceeded hazardous waste regulatory levels under the TC rule.

The analytical results for the soils samples are confirmed by the lack of detectable concentrations of volatile organic compounds on the EPA's Target Compound List in the data from groundwater samples obtained from monitor wells adjacent to the unit except at MW-45, which is in the transition area from the refinery process area to along the ditch. Thus, all of the available analytical data from Phase I and Phase II indicate that any volatile organic compounds in Three-Mile Ditch are present only at relatively low concentrations and remain strongly adsorbed to the soil matrix. Based on the analytical results for both total volatile constituents and TCLP analyses, it is reasonable to conclude that the desorption of volatile organics to the water phase will be a slow process. As residual organic compounds gradually partition into the water phase at trace concentrations, the processes of biodegradation and attenuation are well known to greatly minimize the possibility of significant accumulations and migration of the volatile organic compounds in groundwater.

Furthermore, the likelihood of any ditch materials containing volatile organic compounds migrating from the unit is also low. At the western end of the unit near the refinery, the original unit base is covered with overlying sediment material and remains contained within the original containment berms. To the east of the refinery, the containment berms have been pushed into the ditch, burying the contents of the ditch under several feet of soil.

In summary, no evidence has been identified to indicate that volatile organic compounds present within Three-Mile Ditch currently pose or will pose a significant risk to human health and the environment.

Table 31. Summary of soil sample TCLP data for volatile organic compounds, Three-Mile Ditch.

Table 31. Summary of soil sample TCLP data for volatile organic compounds, Three-Mile Ditch.

Volatile organic compound	Number of detections [a]	Maximum analytical concentration (mg/L)	TC regulatory concentration (mg/L)
Trichloroethylene	1	0.019	0.5
Carbon disulfide	1	0.008	-
Ethylbenzene	3	0.047	-
Methylene chloride [b]	13	0.245	-
Toluene	3	0.038	-
m,p-xylenes	4	0.075	-
o-xylene	3	0.035	-

a = Total out of a possible maximum of 13 samples.
b = Detected in accompanying method blanks for all Three-Mile Ditch TCLP data for soil samples.

A comparison of the Three-Mile Ditch soil sample analyses for semivolatile organic compounds from the RFI Phase I and Phase II investigations reveals significant differences between the two data sets. Numerous detections for various semivolatile organic compounds, typically in the low mg/kg range (Appendix D), were reported from the RFI Phase I investigation of the unit. In contrast, only four semivolatile constituents were reported for the Phase II trench samples taken from the unit (Table 5). Of those four constituents, fluorene and 2-methylnaphthalene were detected only in sample TMD-TR-001-01. Phenanthrene was detected in four samples, and di-n-butyl phthalate, a common laboratory contaminant, was reported for six samples. However, the PQLs achieved for the semivolatile organic compounds during the analysis of the Phase II soil samples were generally higher than those employed for the Phase I soil sample analysis. The analytical results from the split soil samples collected by EPA representatives (PRC, Inc.) during RFI Phase II activities are generally consistent with the RFI Phase I soil sampling results. Therefore, the level of agreement between the analytical results of the RFI Phase I soils investigation and the Phase II split samples obtained by PRC suggests that those two data sets are generally indicative of the status of semivolatile organic compound contamination within the unit.

Seven semivolatile organic compounds were detected in the Phase I and Phase II analyses from various Three-Mile Ditch soil samples at concentrations exceeding the health-based criteria presented in Table 30: benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, chrysene, 2,4-dinitrotoluene (Phase I only), 2,6-dinitrotoluene(Phase I only), and phenanthrene. Other semivolatile constituents were also sporadically detected in the unit soil samples, although these additional constituents were reported at concentrations well below the health-based levels. None of the semivolatile compounds detected in the unit soil samples was reported in groundwater samples collected from monitoring wells adjacent to the unit. The apparent absence of semivolatile organic compounds in groundwater is not unexpected, because semivolatile compounds generally possess low water-solubility characteristics.

In contrast to the RFI Phase II soil sample results of Three-Mile Ditch for total semivolatiles, a laboratory PQL of 0.010 mg/L was achieved, permitting the evaluation of very low levels of semivolatile constituents in TCLP leachate samples. The results of Phase II TCLP testing of soil samples did not reveal detectable levels for any of the designated TC semivolatile compounds. Several other semivolatile constituents that do not have concentration limits specified in the TC rule were detected in the TC leachate extracts (Appendix I); however, with the exception of two samples that yielded naphthalene leachate concentrations of 0.039 and 0.067 mg/L (the New Mexico groundwater standard is 0.03 mg/L), and three samples that yielded phenanthrene concentrations of 0.029, 0.023 and 0.020 mg/l, semivolatile leachate concentrations were well below the available health-based criteria for both waste leachate and/or drinking-quality water set forth in Table 30. Considering the fact that the TCLP procedure incorporates an additional 100-fold dilution factor in establishing allowable leachate contaminant levels, it is apparent that the observed leachate concentrations obtained for the semivolatile constituents not regulated under the TC rule do not constitute cause for concern.

The findings of the RFI Phase I soils investigation of Three-Mile Ditch indicated that arsenic, chromium, and lead were present at several areas in the unit at concentrations that exceed their health-based criteria, as given in Table 30. However, the subsequent RFI Phase II analytical results for the metals of concern do not verify this indication from the Phase I soils investigation. Maximum metals concentrations obtained for the Phase II soil samples were significantly lower than the maximum values reported for the Phase I samples. The Phase I and Phase II sample locations are not identical, and the Phase I soils investigation of the ditch does not indicate a uniform distribution of high (e.g., exceeding health-based criteria of Table 30) concentrations of arsenic, chromium, and lead throughout the unit. Therefore, it is concluded that areas of the ditch exhibiting high concentrations of arsenic, chromium, and lead are not widespread, but are instead localized occurrences. In addition, the RFI Phase I data show that maximum accumulations for these metals were usually found in the upper portion of the contaminated soil profile within the unit, typically located well above the existing water table.

The TCLP analysis of soil samples collected from Three-Mile Ditch during the Phase II field activities resulted in no concentration exceedances in leachate for the metals of concern. The soils in the vicinity of the unit generally possess physical and chemical properties (high clay content, high pH) associated with a high metal fixation capacity (see Anderson et al., 1983; Lindsay, 1979). Evidence of groundwater contamination caused by metal constituents in the vicinity of the unit is limited to the detection of chromium and nickel in monitor wells MW-8 and MW-9. However, as discussed separately (Section 9.1.3.2.2), the chromium and nickel detections reported for those wells are evidently artifacts caused by corrosion of the stainless-steel well casing. The analytical results of samples from MW-21, which was recently installed between MW-8 and MW-9 (Figure 4), refute the reported groundwater contamination by chromium and nickel (Table 32).

The comparison of all available RFI Phase I and Phase II soil analytical data for Three-Mile Ditch with the health-based criteria presented in Table 30 indicates that nickel and zinc may be eliminated as constituents of concern for the unit. Although localized areas of elevated soil nickel and zinc concentrations appear to be present within the unit, these levels are well below the health-based concentration criteria. Further, the RFI Phase I groundwater investigation did not provide any evidence that zinc was a constituent of concern for groundwater in the vicinity of the unit. With the exception of the apparent artifact data from MW-8 and MW-9, no evidence exists to indicate that nickel contamination of groundwater in the vicinity of the ditch is an issue of concern.

Table 32. Comparison of metals sampling of groundwater from wells cased in stainless-steel (MW-8 and MW-9) and cased in PVC (MW-21) with the composition of the stainless-steel.

Sample ID:	TMD-GW-MW-8	TMD-GW-MW-9	TMD-GW-MW-21	Well casing (MW-9)
Laboratory number:	C922352/15665	C922353/15666	C930224/W00270	0493H01400
Date Sampled	11/14/92	11/14/92	01/26/93	03/10/93
Units (except pH):	mg/L	mg/L	mg/L	mg/kg
Field pH (S.U.)	6.93	6.97	6.85	
Total iron	27.10	116.70	1.91	700,000
Total chromium	2.26	18.42	<0.02	180,000
Total nickel	0.74	8.04	<0.01	78,000
Total manganese	1.08	4.72	0.54	12,000
Total copper	0.08	0.32	0.02	2,600
Total molybdenum	0.08	0.41	<0.05	2,000

9.1.2 Eagle Creek Sediments

The two sediment samples collected from Eagle Creek during the Phase II investigation provided confirmation of the sampling results from the Navajo RFI Phase I investigation. Analytical results from the Phase I sediment samples collected from Eagle Creek at five locations revealed no evidence of environmental contamination that could be attributed to Three-Mile Ditch. Metal constituents were all within normal limits. No volatile organic compounds were detected, and low levels of two phthalate compounds (a common laboratory contaminant) were reported as the sole detected semivolatile compounds in one of the sediment samples (Appendix D).

Analytical results from the two RFI Phase II sediment samples similarly evidence that the creek is not impacted by contaminants migrating from Three-Mile Ditch. In the present Phase II study, metal constituent concentrations in a creek sediment sample obtained in the vicinity of the unit were less than those obtained at a representative background location upgradient of the unit, and there is no evidence to indicate that waste constituents from the unit have exerted an environmental impact on the adjacent Eagle Creek. Although the Phase II samples exhibited detectable levels of oil and grease (0.05% and 0.13%), oil and grease concentrations of this magnitude are not unusual for organic-rich sediment materials, such as those collected from Eagle Creek. As discussed previously in Section 5.2, "Eagle Creek Sediments," Eagle Creek is the major stormwater conveyance for the city of Artesia and the surrounding area.

9.1.3 Groundwater

9.1.3.1 Groundwater Occurrence and Movement

Shallow groundwater occurs at depths between 8 and 15 ft below the land surface along the length of Three-Mile Ditch. The near-surface geology determined from the drilling program consists of sands and sandy fines near the river, grading to sandy clays and clays at MW-16, approximately 4,500 ft upgradient. Farther upgradient, the subsurface material was mainly clayey fines but with abundant, well-rounded gravel at depth.

A series of piezometers and monitor wells was installed about one mile east of the refinery process area to determine groundwater flow direction and quality in the area east of Bolton Road. Information collected from the newly installed borings, together with data from the existing wells, shows that groundwater movement is essentially parallel to the ditch and Eagle Creek in this area. At locations east of MW-9 and toward the river, the lack of subsurface information prevented the determination of specific flow directions, but the direction of flow most likely follows the topographic gradient of the ditch and creek.

Although Eagle Creek drains a large watershed to the west of Artesia, it is an intermittent stream that flows only in response to nearby precipitation and runoff from the urbanized area of Artesia. However, at some times during the year, the groundwater surface is sufficiently elevated to intersect the base of the channel and provide for temporary pools in the channel bottom. In November 1992, pools opposite MW-8 were observed to support cattails, insects, and a small minnow population. But in February 1993, groundwater levels had declined to below the channel bottom and the pools were dry and devoid of life.

The nearest active water wells to the ditch are north of Eagle Creek at a minimum distance of about one-quarter mile. However, the generally easterly flow of groundwater together with the fact that the wells are completed in deeper zones, at depths exceeding 100 ft, eliminates them as potential receptors. In the vicinity of Three-Mile Ditch, no other wells are known to be located farther east and the shallow subsurface water is generally of poor quality with TDS ranging from 3,740 to 8,460 mg/L in the monitor wells located adjacent to the ditch and along Eagle Creek.

9.1.3.2 Groundwater Quality

9.1.3.2.1 Volatile and Semivolatile Organic Compounds

Analyses of groundwater from existing and newly installed monitor wells and nearby domestic water wells did not detect volatile or semivolatile organic compounds except for low concentrations of two volatiles detected in MW-45 and the methylene chloride artifacts observed in MW-8, MW-9, and MW-45. Because it is downgradient of documented product releases and hydrocarbon contamination in the refinery process area (Figure 5A), the low levels of organics detected in MW-45 are thought to be related to these activities and not residual contamination from ditch operations. Although the water in wells along the ditch was frequently observed to have a strong odor and some unidentifiable volatile and semivolatile hydrocarbons were detected by the mass spectrometer at low concentrations, no target compounds other than those mentioned previously were detected.

9.1.3.2.2 Selected Metals

In the absence of contamination by organic compounds, metals become the focus of concern. The RFI Phase I investigation found significant groundwater impacts from metals in monitor wells MW-8 and MW-9, located between Three-Mile Ditch and Eagle Creek east of Bolton Road. This area was the focus of intense study during the RFI Phase II investigation with the excavation of an additional trench, resampling of existing monitor wells, and the installation of piezometers and additional monitor wells. Along Three-Mile Ditch the focus of resampling was at MW-8 and MW-9, both of which had total chromium levels in excess of 2 mg/L in RFI Phase I, and at MW-1 at the lower end of the ditch above Pond 1, which had a concentration of 1.0 mg/L. Results of the Phase II sampling confirmed high chromium and nickel concentrations with the total of chromium and nickel concentrations in MW-9 exceeding 26 mg/L. These levels were 4 to 5 times the levels observed in the October 1990 sampling. Chromium and nickel are both components of stainless steel and the excessive levels were thought to be a result of decomposition of the well screen owing to the naturally high concentrations of salts in the shallow groundwater. Research into the composition of common stainless steels reveals that in addition to iron, chromium, and nickel, common additives include copper, manganese, and copper (Budinski, 1989). Preserved groundwater samples previously obtained from stainless-steel wells MW-8 and MW-9 and from newly installed PVC-cased well MW-21 were reanalyzed for these additional constituents. The results of the analyses, presented in Table 32, show elevated metals in the stainless-steel wells and levels at or below detection in the PVC well except for iron and manganese. To compare these results with the actual composition of the metal in the well, a piece of the casing was removed and submitted to the laboratory for digestion and analysis. These results are also shown in Table 32.

The groundwater in the area of the ditch is not overly acidic; values of pH in all water samples are at or only slightly below neutral values of pH = 7. Examination of the metals analyses shows that the relative order of constituent concentrations is maintained among those samples having elevated metals levels whereas only iron and manganese are present above detection levels in the PVC well. However, the occurrence of iron and manganese at these levels in groundwater in a PVC well is usually an indication of a reduced or anoxic environment. Such an environment is commonly found in areas having an abundance of organic material undergoing decomposition and where available oxygen is consumed through biological or chemical processes.

Although designed to resist corrosion, stainless steels are most effective in oxidizing environments and in the absence of chloride solutions (Budinski, 1989). In addition to indications of a reduced or anoxic environment, chlorides are naturally present in groundwater at levels above 500 mg/L in those areas of the ditch where the metal-cased wells are located.

Based on this information, the RFI Phase II results support the conclusion that the chromium and nickel observed in these two wells is the result of well corrosion and not groundwater contamination from the ditch or ditch materials.

However, as measured by chromium and nickel concentrations, the magnitude of the corrosion appears most severe in the ditch area and was not observed to greatly impact the stainless-steel wells in the vicinity of the ponds with the exception of MW-1. The reduced occurrence of corrosion is most likely the result of the presence of increased levels of unidentified and non-target compound hydrocarbons observed in the groundwater immediately adjacent to Ponds 1 and 2. Although it does not exhibit free product or oil, water in some of the wells foamed and coated bailers and pump hose with a residue. Similar coatings surrounding bare metal in the steel casings could act as an inhibitor by impeding direct contact of the water and the metal, thereby restricting the flow of electrons between the water and the casing that is necessary for corrosion to occur. An additional explanation could be the lack of oxygen caused by the high level of total organics in the subsurface. An oxygen deficiency would be much more pronounced in the area of the ponds than at the ditch where ditch impacts are minimal.

9.1.3.2.3 Water Chemistry

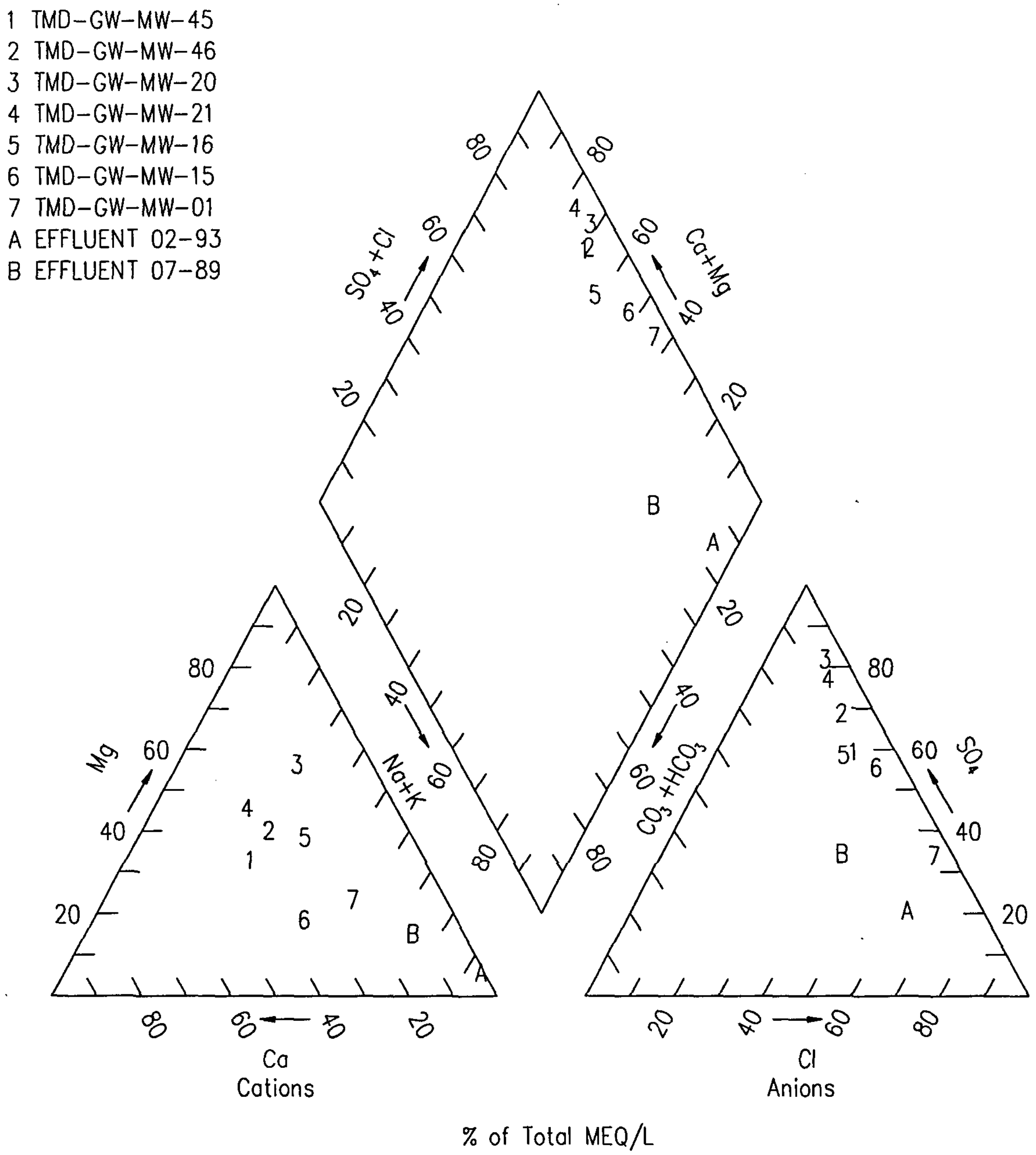
Examination of the water chemistry of the groundwater in the vicinity of the ditch and interpretation of the relationships among and between samples can provide support for a hypothesis that the mixing of groundwater has or has not occurred for a specific sample. For example, among three samples, one of which is an effluent known to have a high chloride concentration, detection of a high chloride concentration in a second sample relative to the third sample could lead to the conclusion that the second sample was impacted by the high chloride source. However, such a determination depends not only on the direction of groundwater flow, but on the total salt concentration of the sample and the relative concentrations of the individual constituents.

Various methodologies can be used to demonstrate chemical relationships between groundwater from differing sources. Examples include bar and pie charts and radial and Stiff diagrams. Although each method can demonstrate graphically the makeup of individual samples, comparison among samples is difficult. Use of the Piper trilinear diagram overcomes these deficiencies by providing information on the major ionic components of a water sample and directly comparing component composition with those of other samples (Hem, 1989). Because complete water chemistry data were collected during the investigation, the Piper method is used herein, together with the volatiles and metals analyses, to demonstrate the lack of contamination between effluent carried in Three-Mile Ditch and shallow and deep groundwater in the immediate vicinity of the ditch.

A Piper diagram has two triangular and one diamond-shaped field for plotting sample constituent concentrations and for observing similarities or differences between samples. The left and right triangles show the cation and anion composition of the sample, respectively, whereas the center diagram is the projection of the major cation-anion groups. Although sample points may have a similar cation or anion composition in one of the two triangles (as determined by position relative to the vertices), it is necessary for the points to be located in the same relative position in all three plots for the samples to be considered from the same source. Possible sample mixing is evidenced by the placement of a point on a straight line between two other points in each of the three fields. However, mixing is physically possible only when groundwater movement is in a direction that will allow such mixing. Initial and resultant mixing concentrations can be shown on the diagram through the use of concentration circles, with the radii of the circles proportional to the concentration. For clarity, concentration circles are eliminated from the figures shown here; they can be drawn using either TDS values or the cation-anion sums shown in Table 29.

Two Piper diagrams are presented and discussed to show the lack of mixing between the various sources. Figure 20 shows the relative concentrations of constituents in water samples in the monitor wells along the ditch beginning with MW-45 and continuing to MW-15 near the entrance to now-inactive Pond 1. Water concentrations from MW-8 and MW-9 are not shown because they are almost identical to that of MW-21 and overlay that point in the diagram. The 1989 effluent analysis is from a sampling of the outfall to the ponds by the New Mexico Oil Conservation Division. It is a reasonable assumption that water chemistry composition of the pre-1989 effluent was similar to composition range shown here because the major reduction in water use and changes in the nonorganic composition of the wastewater are occurring presently. Prior to 1993, most treatment was related to organics reduction.

Figure 20. Trilinear mixing diagram, Three-Mile Ditch, RFI Phase II, April 1993.



KWBES

Trilinear mixing diagram, Three Mile Ditch, RFI Phase II, April 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI) TMDITCH	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-27-93
DRAWN BY: JW	SCALE:
DATE:	FIGURE: 20

Mixing is best demonstrated in Figure 20 by comparing the water sampled from wells MW-45, MW-46, and MW-20. All three points plot on a straight line in the three fields. In the cation triangle a decrease in calcium composition and a related increase in the percentage of magnesium are observed. In the anion triangle, the carbonate-bicarbonate percentage also decreases relative to chloride and sulfate. Relationships in both fields imply the deposition of calcium carbonate. Field evidence supports the occurrence of deposition because caliche is observed in the area of the wells.

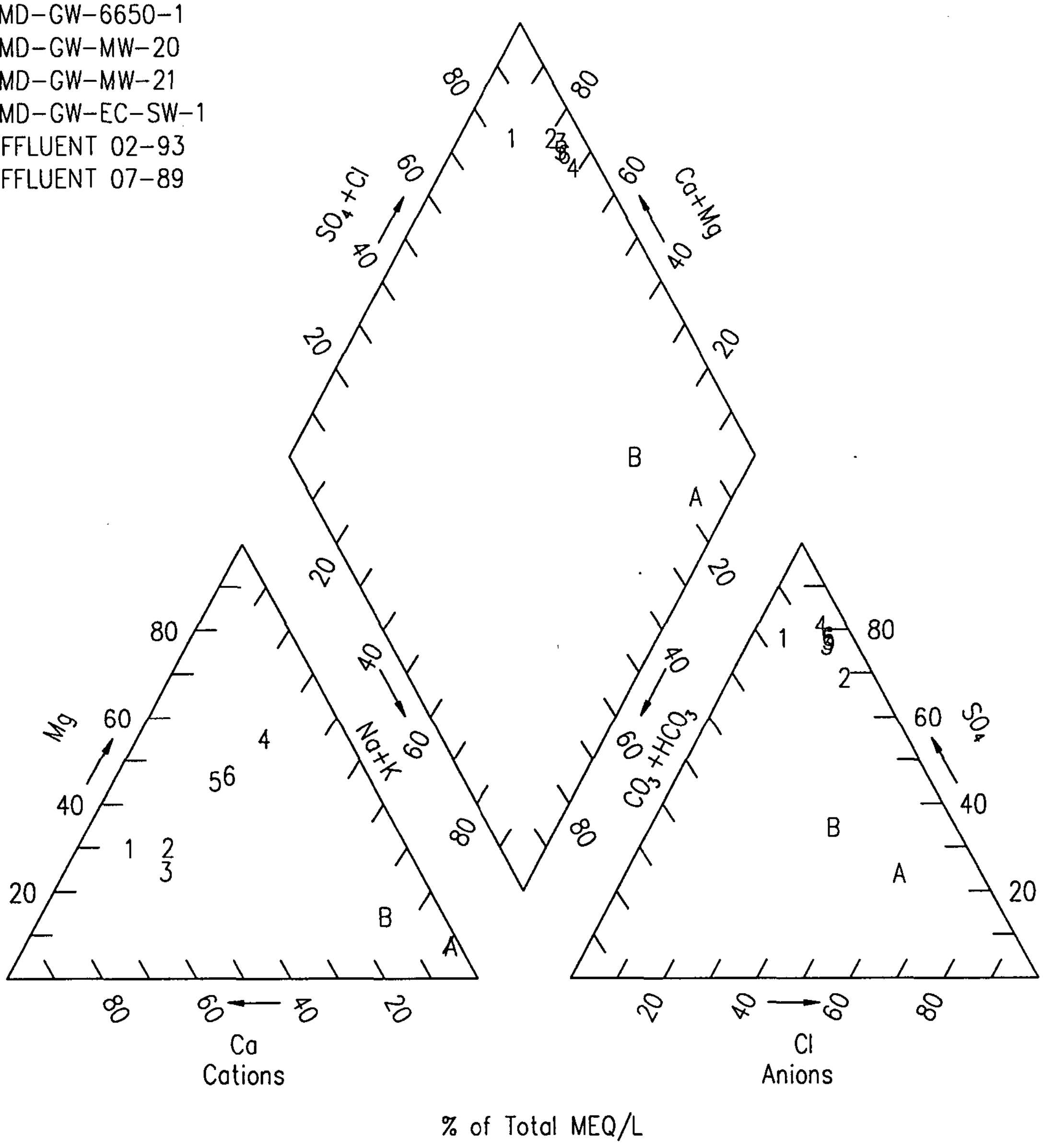
Similarly, the lack of straight lines between the two effluent samples and any of the water sources on the diagram indicates the absence of mixing. The apparent placement of MW-1 in the cation field between the two effluent samples and MW-46 is only a coincidence because salt concentrations in MW-1 are determined by proximity to the Pecos River and evapotranspiration rather than to the effluent, as demonstrated in a later discussion. The diagrams graphically demonstrate that the effluent sources have had no obvious impact on the water chemistry of groundwater adjacent to the ditch. They offer support to the results of the organic and metal analyses presented previously that show that any current groundwater impacts of past ditch use are at most minimal.

Figure 21 presents a similar diagram for the domestic water wells sampled during the RFI Phase II portion of the study. As shown on the figure, three differing types of water chemistry are determined by their relative positions on the diagram. The domestic wells are located in the lower left center of the cation triangle, whereas the ditch monitor wells are in the upper center. The ditch wells have less calcium and more magnesium than the water wells. The two effluent samples with high sodium values are in the lower right of the triangle. In the anion triangle, both the domestic wells and the monitor wells are located in the sulfate corner of the triangle, whereas the effluent samples are toward the chloride end. In the center diamond, the effluent samples are isolated from the other six samples.

The domestic water wells sampled are shown on Figure 4 . The water wells are not completed in the same shallow zones bearing the near-surface water found in the ditch wells. Also, they are north of both Three-Mile Ditch and Eagle Creek and the general direction of groundwater movement is easterly. Well TMD-GW-3368 is the easternmost well known to be located between the refinery process area and the river in the general vicinity of the ditch and Eagle Creek. The available information, including interpretation of the previously referenced Figure 21, demonstrates that this water well and others located to the west and north of Eagle Creek are at minimal risk from contamination by any materials remaining in the ditch.

Figure 21. Trilinear mixing diagram, domestic wells, RFI Phase II, April 1993.

1 TMD-GW-3282-1
2 TMD-GW-3368-1
3 TMD-GW-6650-1
4 TMD-GW-MW-20
5 TMD-GW-MW-21
6 TMD-GW-EC-SW-1
A EFFLUENT 02-93
B EFFLUENT 07-89



KWBES

Trilinear mixing diagram, domestic wells, RFI Phase II April 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI) TMDCOMP
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 21

Likewise the shallow groundwater in the vicinity of the ditch, as shown in Table 29, has high naturally occurring TDS concentrations that make it unusable except for occasional stock use. Not withstanding the lack of current use, there is no evidence to support widespread contamination of the groundwater as a result of past ditch use and no evidence (as supported by the TCLP test results) that existing sediments are contributing or will contribute to groundwater degradation in the ditch area.

9.2 EVAPORATION PONDS

9.2.1 Soils at Evaporation Pond 1

The RFI Phase II soil sample data for Evaporation Pond 1 revealed that any occurrences of volatile organic compounds are most likely found at relatively low concentrations in the first few feet of soil near the influent point to the unit. No volatile constituents were detected at concentrations that exceeded (or even approached) the health-based soil criteria presented in Table 30. Further, TCLP analysis of the Pond 1 soil samples did not yield any exceedances for TC volatile constituents (Table 33).

As was the case for the semivolatile constituent analysis of Phase II soil samples from Three-Mile Ditch, the detection limits achieved for semivolatile constituents in the Pond 1 soil samples collected as part of the Phase II investigation were generally too high to detect semivolatile constituents that may have been present in the mg/kg range. Several split soil samples collected by the onsite EPA representatives (PRC, Inc.) during RFI Phase II activities yielded semivolatile constituent concentrations that were generally consistent with the analytical findings for the RFI Phase I investigation of Three-Mile Ditch. It is a reasonable conclusion that the presence of semivolatile organic constituents in the soils of Evaporation Pond 1 are correlated with soil oil and grease concentrations, and that the extent of semivolatile contamination in the unit is generally similar to the levels observed in the soils of Three-Mile Ditch.

The laboratory PQLs achieved for the TCLP analysis of soil samples from Evaporation Pond 1 were all well below the minimum concentrations required to evaluate all TC-regulated semivolatile constituents. With the exception of three samples, a PQL of 0.010 mg/L was achieved for the Pond 1 soil samples. For the remaining samples, one possessed a PQL of 0.020 mg/L, whereas two others had a PQL of 0.060 mg/L. The TCLP analysis for semivolatile constituents in the soil samples from Evaporation Pond 1 failed to yield any exceedances for semivolatile constituents regulated under the TC rule. Of the semivolatile constituents not regulated under the TC rule that were analyzed for in the TCLP leachate extracts,

Table 33. Summary of soil sample TCLP data for volatile organic compounds, Evaporation Pond 1.

Table 33. Summary of soil sample TCLP data for volatile organic compounds, Evaporation Pond 1.

Volatile organic compound	Number of detections [a]	Maximum analytical concentration (mg/L)	TC regulatory concentration (mg/L)
Benzene	1	0.014	0.5
Trichloroethylene	4	0.038	0.5
Acetone	8	0.088	-
Ethylbenzene	4	0.019	-
Methylene chloride [b]	26	0.177 (1)	-
Toluene	5	0.026	-
m,p-xylenes	4	0.033	-
o-xylene	4	0.015	-

a = Total out of a possible maximum of 28 samples.
b = Detected in either accompanying daily blanks or method blanks for all Evaporation Pond 1 TCLP data for soil samples.

phenanthrene was the only constituent detected at concentrations in exceedance of the available health-based criteria for water or leachate presented in Table 30. Considering the fact that the TCLP procedure incorporates an additional 100-fold dilution factor in establishing allowable leachate contaminant levels, it is apparent that the observed leachate concentrations obtained for semivolatile constituents not regulated under the TC rule do not constitute cause for concern.

The RFI Phase II analytical data for Pond 1 soil samples indicated that, as was true for Three-Mile Ditch, arsenic, chromium, and lead are the primary metals of concern. The data suggested that concentrations for those three constituents were elevated beyond general background levels in the upper soil profile (upper 1-ft interval). The analytical data for arsenic and chromium revealed several exceedances of the health-based concentration criteria for those metals (Table 30). However, the data also indicated that excessively high soil concentrations for those two constituents are not widespread throughout the unit, but are localized occurrences in the upper soil profile.

9.2.2 Subsurface Gas

Information derived from the subsurface gas investigation correlated well with analytical results from new and existing monitor wells installed south of the pond area. The detection of volatile aromatic compounds was limited to MW-4, inside the highest PID contour as illustrated in Figure 7 . Wells located in areas with PID concentrations of less than 50 ppm did not have identifiable organic compounds, including BTEX, at levels above the 0.005 mg/L detection limit. Likewise, testing of the wells showed that the water sampled, although not containing measurable BTEX, did contain hydrocarbon-type compounds that imparted an odor and color to the water and foamed when shaken. This water was limited to an area outlined by the FID readings, and most likely contained slightly soluble hydrocarbon compounds with sulfur and nitrogen components. Like other hydrocarbons, these compounds have carbon bonds capable of being ionized by the detectors.

9.2.3 Groundwater

9.2.3.1 Groundwater Occurrence and Movement

The drilling of the deep wells, measurement of the horizontal and vertical gradients, mapping of the shallow and deep potentiometric surfaces, aquifer testing, and groundwater modeling provide sufficient evidence to demonstrate that the hydrologic system in the vicinity of the evaporation ponds is discharging groundwater vertically upward and that groundwater moves laterally in a southeasterly direction toward the Pecos River crossing at U.S. Highway 82 and areas heavily vegetated with salt cedar located immediately adjacent to the highway. Water not consumed by vegetation is evaporated or discharged into the Pecos River.

The near-surface geology to a depth of at least 50 ft is mostly fine- to medium-grained sands with generally thin clayey zones interbedded in the upper 20 ft. The clay zones appear to be discontinuous with no single confining zone detected. The apparent uniformity of the sediments allows fairly complete mixing of groundwater in the subsurface and also facilitates the transport of constituents.

The February 1993 measurement of water-level elevation differences between the shallow and deep wells produced upward (positive) vertical gradients everywhere except for -0.074 ft/ft at MW-2 and -0.009 ft/ft at OCD-7, which are within 100 ft of the pond berms and are the well pairs closest to the pond. Because of the approximately 11-ft elevation difference in hydraulic head between the maximum elevation of the pond and the adjacent groundwater, gradients closest to the pond would be expected to be negative. At all other locations, gradients were positive, with well pairs MW-5, MW-7, MW-18, and MW-22, located on the south of the side of the ponds, having positive gradients greater than 0.01 ft/ft. November 1993 measurements verified the upward vertical gradient. The upward gradient observed during this study is regional in nature. Upward discharge of water from the shallow aquifer along the Pecos River from the vicinity of Acme (north of Roswell) to about one mile south of the Highway 82 bridge has been documented by the USGS and the New Mexico State Engineer Office (Welder, 1983).

Shallow and deep horizontal potentiometric maps (Figures 14 and 15) show movement southeasterly at gradients of 0.00088–0.00118 and 0.00125 ft/ft, respectively. The direction of movement is toward an area in the vicinity of Highway 82 just west of the river that is shown on the USGS Spring Lake 7.5-minute topographic quadrangle as marshy. Immediately south of the highway and extending at least several miles to the south is an area heavily overgrown with salt cedar, a phreatophyte that consumes large amounts of water in the summer months. As water is consumed, the dissolved salts remain behind and contribute to the poor water quality of the near-surface water and cause localized areas of salt-impacted soils. The negative impact of phreatophytes on groundwater in this reach of the Pecos River has been studied by both state and federal investigators (Mower et al; 1964).

The particle flow map (Figure 19) resulting from the groundwater modeling described in Section 8.3.3 provides a graphical picture of the interaction of groundwater moving upward from the valley fill aquifer with water seepage from the evaporation pond. Although some zones appear to undergo little mixing, movement of water into and out of the cross section can not be seen because the model is two dimensional. Slight variations in actual vertical or horizontal gradients or hydraulic conductivity will cause particle movement to deviate from the paths shown. However the overall effect will cause groundwater to move upward toward the discharge zone, where it will be consumed through evaporation and transpiration. With use of the map and available geologic, hydrologic, and chemical data, predictions regarding locations of future impact of the seepage water can be offered. For example, the model shows that not all flow paths have reached the surface discharge area even after 60 years. During the remaining time necessary for a particle to reach the surface, the model can show locations of intermediate zones subject to degradation as the contaminant front passes through the area. Therefore, the first detection of constituents in a monitor well should not immediately be a cause for concern if the location of the well is in the predicted path of the mobile contaminants. Such detection should be looked upon as verification of the utility of the program and its ability to accurately represent subsurface flow.

9.2.3.2 Groundwater Quality

9.2.3.2.1 Volatile Organic Compounds

The results of testing for volatile organic compounds in the area of the evaporation ponds were not greatly different from the majority of results from earlier studies (RFI Phase I Report, tables 6.4 and 6.10). Low concentrations of volatile aromatic hydrocarbons were detected in several monitor wells located on the south side of the ponds. Of the volatiles observed in existing wells MW-3, MW-4, MW-5A, and MW-6A and newly installed wells MW-6B and OCD-7B, only benzene exceeded current federal or state standards. However, there were just four benzene exceedances, and the maximum level detected was only 0.021 mg/L, slightly more than 4 times the federal standard and twice the New Mexico groundwater standard. The highest concentration of a BTEX constituent detected was xylene at 0.032 mg/L in MW-4. None of the other volatiles exceeded standards or the health-based levels shown on Table 29. Results for the volatile hydrocarbons were previously presented in Table 25 and shown in Figure 16.

The results of these tests were compared with those from the RFI Phase I study to determine trends. Detections occurred in most of the same wells as in the earlier study. The Phase I study identified MW-3, MW-4, MW-6A, OCD 3, and OCD-8A as having low levels of volatiles with benzene at the highest value of 0.041 mg/L in MW-3. As reported previously, similar low levels were detected in the current investigation. Also, no detections were found in OCD-3 and OCD-8. (The Phase I values reported for OCD-3 are apparently the result of a transcription error, because the values do not appear in table 6-10, p. 6-49 of the RFI Phase I Report, and only on associated figure 6.14. They are identical to values reported for MW-4). MW-6B and OCD-7B, two wells installed for the current study, also had detections of low levels of hydrocarbons.

Although the testing results were generally comparable to earlier analyses by several different laboratories utilized by the New Mexico Oil Conservation Division, major differences were observed between individual BTEX components in several samples. For example, the New Mexico Scientific Laboratory Division (SLD) reported an m-xylene concentration of 1.720 mg/L in a sample from MW-4 taken on 12 November 1987 and analyzed by SW-846 Method 8020. Concentrations of the o- and p-xylene constituents were only 0.032 and 0.015 mg/L, respectively. After requesting verification, the SLD reported on 22 December 1987 that the value was not confirmed by mass spectrometer analysis.

This and other anomonlously high results may be questionable owing to the lack of confirmation by mass spectrometer analysis. Standard EPA laboratory Method 8020 can falsely identify BTEX constituents in samples containing other hydrocarbons. Numerous aliphatic hydrocarbons can co-elute simultaneously with BTEX, and the PID used to measure concentrations is incapable of discerning between BTEX compounds and the co-eluting aliphatic hydrocarbons. SW-846 recommends the use of a second confirmatory method to resolve concentrations of aromatic hydrocarbons in complex samples (Robbins et al., 1993).

A second example of questionably high concentrations could be the BETX concentration maps prepared by Geoscience Consultants and presented in Figures 6.2 through 6.7 of the RFI Phase I Report. The xylene concentrations reported at several shallow piezometers in the area south of the ponds are at concentrations 1 order of magnitude higher than those reported in the current study. MW-22A and MW-22B installed during this study are located between the piezometers with the highest reported xylene concentrations, P87-2 (0.453 mg/L) and P87-19 (0.342 mg/L). Analysis of samples from both wells did not detect BTEX at concentrations above the PQL of 0.005 mg/L although other unidentified hydrocarbons were determined to be present. Care must be taken to confirm suspected detections to avoid the misidentification of aliphatic hydrocarbons as aromatic hydrocarbons that have health-based regulatory limits.

9.2.3.2.2 Semivolatile Organic Compounds

The extensive testing conducted for semivolatile organic compounds in groundwater in the area of the evaporation ponds did not result in any semivolatile constituent detections except for phthalates found in six samples at levels between 0.021 and 0.078 mg/L. The detections appeared related more to the consecutive laboratory sample numbers than to any other factor. As discussed previously, phthalates are common laboratory contaminants and not likely to be found in groundwater. Testing results also were negative for 2,4-dinitrotoluene and 2,6-dinitrotoluene, two semivolatiles specifically listed in EPA's approval of the RFI Workplan. Summary information on semivolatile detections in the evaporation pond area was provided in Table 26. Complete data results are provided in Appendix I.

9.2.3.2.3 Selected Metals

Verification analyses for arsenic and nickel were performed after comparison of preliminary analysis results with draft results from PRC, Inc., EPA's onsite contractor, indicated possible analytical problems with these two constituents. PRC's arsenic concentrations were generally higher than those reported by Inter-Mountain Laboratories (IML), the KWBES contractor, whereas IML reported higher levels of nickel in samples. Comparison of the results of the arsenic and nickel verifications is shown in Table 34. Arsenic levels for KWBES and PRC split samples are shown on Figure 17.

Examination of the information presented in the table indicates that Method 7060 (direct electrothermal atomic absorption spectrometric) results from IML are generally higher than the Method 7061 (gaseous hydride, atomic absorption spectrometric) results. Further, PRC's draft results using Method 7060 are higher than IML's results. The reasons for the variations are not clear, but several points can be made with the available information. First, review of the QA/QC supplied with the analyses reveals acceptable handling of the sample duplication and spiked samples by IML with no obvious variation in the results of the duplicate analysis. Second, the simpler, alternate method (7060) is adequate in the documented absence of interference (Standard Methods, 17th edition, 1989). The differences in the methods were greatest for samples from monitor wells known to have at least some hydrocarbon impacts (e.g., MW-2A, MW-4, OCD-2B), including elevated BTEX and/or strong hydrocarbon odor, discoloration, and foaming. Levels of dissolved solids for some of these wells also were above 10,000 mg/L, which could be expected to cause salt-related interference. Finally, arsenic is a difficult element to analyze accurately and serious variability can occur between laboratories because of these difficulties. Variations in results of arsenic analyses between laboratories were reported to range from 12% to 72% at arsenic concentrations from 0.010 to 0.227 mg/L (Standard Methods, 1989). Therefore, some of the discrepancies between analytical results may be explained by interlaboratory variability.

Comparison of the current results with those presented in the RFI Phase 1 Report (Appendix D, Table 6.12) indicates that elevated levels of arsenic were reported for many of the same monitor wells. However, the Phase II study results did not include finding highly elevated arsenic levels in OCD wells 4 and 5 north and east of Pond 2, as was reported in the RFI Phase I Report, nor in newly installed wells MW-11A or B. Monitor wells in this area (originally installed for future pond expansion) do not appear impacted by the ponds, but have concentrated levels of salts resulting from the large amount of water lost to evaporation and transpiration, especially in the summer. A Phase I duplicate sample for OCD-4 resulted in a concentration decrease from 0.21 to 0.005 mg/L, which emphasizes the analytical difficulties with arsenic in high salt environments.

Table 34. Comparison of Arsenic and Nickel sampling and verification, RFI Phase II.

Table 34. Comparision of Arsenic and Nickel sampling and verification, RFI, Phase II.

Well Sample Identification	Lab. Number (Units)	Date Sampled	TAs (Initial) (mg/L)	TAs (Verif.) (mg/L)	TAs (7060) (mg/L)	As, PRC Value (mg/L)	TNi (Initial) (mg/L)	TNi (Verif) (mg/L)	PRC Value (mg/L)	EC (µmho/cm)
NEP-GW-MW-01	C922278/15632	11/10/92	0.020	0.023	0.010	0.008(J)	0.35	0.22	0.284	14,900
NEP-GW-MW-02A	C922280/15633	11/10/92	0.087	0.117	0.090	0.212(J)	0.12	ND	0.040(U)	11,300
NEP-GW-MW-04	C922333/15644	11/12/92	0.080	0.112	0.136	0.213(J)	0.11	ND	0.040(U)	7,610
NEP-GW-MW-05B	C930136/W00059	1/22/93	0.131	0.150	0.162	0.200	ND	NA	0.040(U)	9,310
NEP-GW-MW-07A	C922281/15634	11/11/92	0.038	0.037	0.050	0.143(J)	0.13	ND	0.040(U)	13,900
NEP-GW-MW-07B	C930106/W00056	1/21/93	0.014	0.013	0.016	0.017	ND	NA	0.040(U)	10,700
NEP-GW-OCD-01	C922324/15649	11/13/92	0.097	0.115	0.154	0.235(J)	0.16	0.05	0.040(U)	14,200
NEP-GW-OCD-02B	C930134/W00057	1/21/93	0.007	0.005	0.018	0.029	0.01	NA	0.040(U)	14,700
TMD-GW-MW-08	C922352/15665	11/14/92	0.014	0.014	0.027	0.008(J)	0.74	0.71	0.527	6,510
TMD-GW-MW-09	C922353/15666	11/14/92	0.021	0.025	0.015	0.018(J)	8.04	9.02	6.040	6,720
TMD-GW-MW-45	C922354/15667	11/14/92	0.009	0.008	0.011	0.011(J)	0.10	ND	0.040(U)	5,050

TAs(Initial) = Total Arsenic, initial analysis, method 7061, detection limit=0.005 (mg/L).
TAs(Verif) = Total Arsenic, verification analysis, method 7061, detection limit=0.005 (mg/L).
TAs(7060) = Total Arsenic, verification analysis, method 7060, detection limit=0.005 (mg/L).
As, PRC = Total Arsenic, PRC Value, method 7060.
TNi(Initial) = Total Nickel, initial analysis, method 7520, detection limit=0.01 (mg/L).
TNi(Verif) = Total Nickel, verification analysis, method 7520, detection limit=0.05 (mg/L).
Ni, PRC = Total Nickel, PRC Value, method 7520.
ND = Not detected.
NA = Not analyzed.
(J) = Estimated concentration.
(U) = Undetected at practical quantitation limit listed.
EC = Laboratory electrical conductivity, µmhos/cm at 25°C .

Water in the immediate area of the ponds is essentially unusable owing to the high natural concentration of salts. Although there is some limited use of poor-quality water for livestock on the west side of the ponds, which is upgradient from the site, the combination of a groundwater discharge area and high natural concentrations of salts eliminate the possibility of the high arsenic levels impacting usable ground water supplies and potential receptors.

Chromium was highly elevated in one well, MW-1, probably because of the corrosion of the stainless-steel casing. As at other Three-Mile Ditch wells, a newly installed PVC-cased well nearby (MW-15) did not document a problem with the metal. The PVC-cased well, OCD-3, which had TDS content of more than 17,300 mg/L, had a concentration of 0.19 mg/L in the total metals sample. No chromium was detected in the filtered sample and a total chromium sample obtained during the Phase I sampling reported a concentration of less than 0.05 mg/L. Although the elevated level is not a problem owing to the lack of potential receptors, several other metal constituents were found to be elevated during this investigation and the well is recommended for confirmatory resampling. OCD-3 is located near an area of the pond that was constructed less than 8 years ago, about the time the use of chrome in petroleum industry operations was decreasing.

The RFI Phase I Report listed two relatively elevated levels of lead (0.27 and 0.117 mg/L) in MW-2 and MW-7, respectively. The Phase II study did not detect lead in either of these two wells. Total lead was found in two PVC-cased wells with the highest concentration at 0.06 mg/L in OCD-3. Again, no dissolved concentrations of lead were detected in the filtered samples. Results of water analyses at the beginning of the project showed anomonlously high levels of nickel in wells that otherwise appeared unimpacted. Verification was requested by reanalysis of preserved samples from several wells (Tables 28 and 34). The results were uniformly lower except in the three stainless-steel wells along the ditch, where elevated nickel resulted from suspected casing corrosion. Not all of the samples were chosen for reanalysis; priority was given to those located near the pond or those having the highest values. The source of the discrepancies was an equipment problem that did not remove background noise and allowed the reading of spurious signals.

9.2.3.2.4 Water Chemistry

Inorganic water chemistry data collected during the RFI Phase II study were examined to provide information regarding the impact of the pond chemistry on the local hydrologic environment. Analysis of groundwater samples from the monitor wells in the vicinity of the ponds indicates that the groundwater at some locations has been impacted by seepage discharge from the ponds. Information supporting this conclusion included the detection of the types of hydrocarbons found in the pond and elevated levels of some inorganic constituents above levels found in groundwater upgradient of the pond. However, some of the elevated levels could be the result of concentration of the naturally occurring salts as shallow groundwater in the alluvium evaporates or is used in plant transpiration. The installation of the deeper monitor wells also allows comparison of the deeper groundwater with that at shallow depths.

Because complete information on the major water constituents was collected at the time of sampling for target compounds, an analysis of the types of water present could be performed that would be useful in interpretation of hydrologic conditions at the site. The Piper trilinear diagram (Hem, 1989) was the method of analysis chosen to represent the various types of water likely to be present in the area. A description of method and its use was provided in the discussion of water chemistry at Three-Mile Ditch (Section 9.1.3.2.3) and will not be reviewed here.

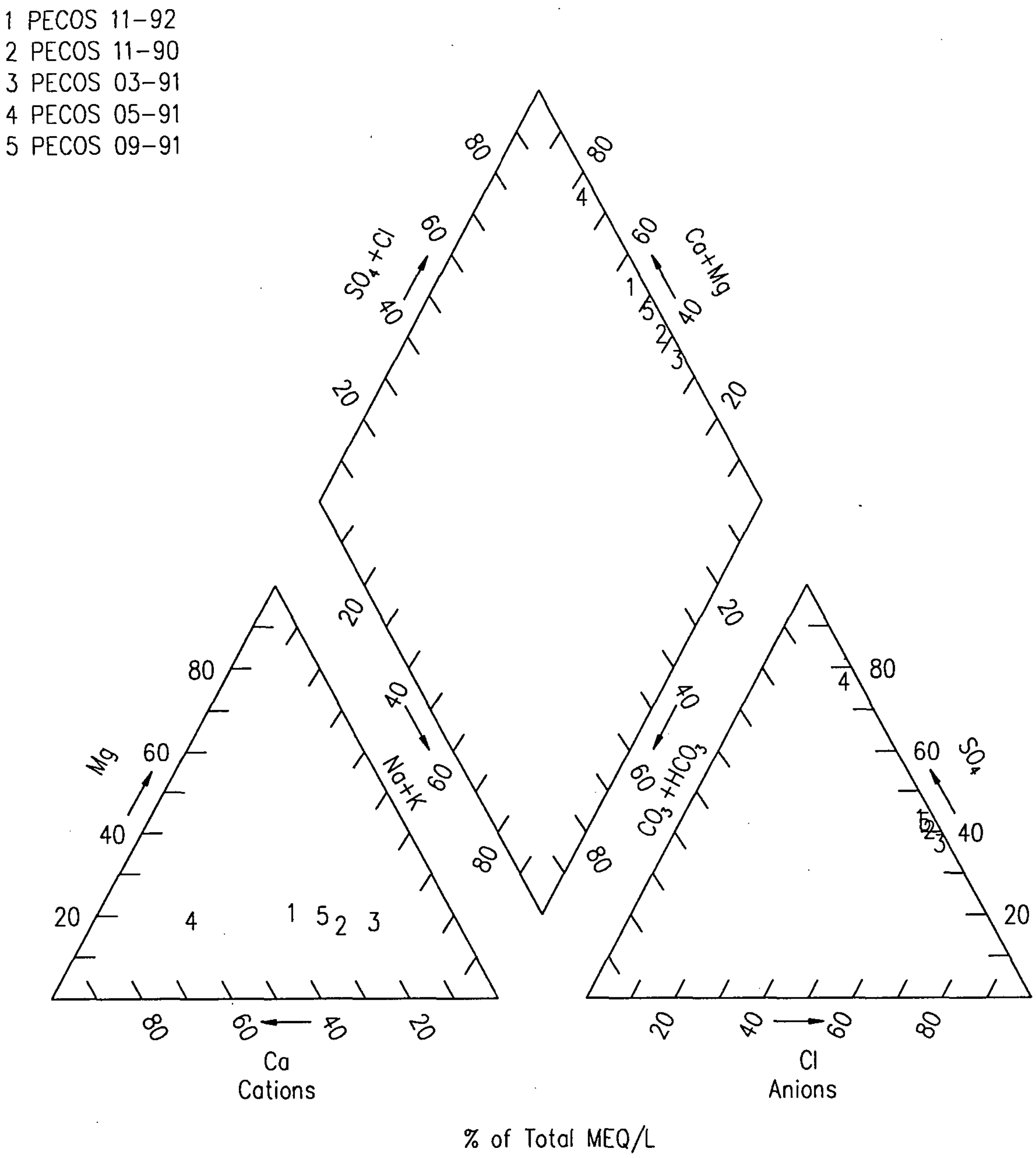
Several sources of water with apparent differences in composition were compared to establish their attributes so that interpretations could be performed. These included monitor wells installed during this and earlier evaporation ponds studies, the Pecos River, a windmill in operation immediately southwest of the ditch entrance to Pond 1, and the effluent currently present in the active pond. Because 46 individual samples were available for comparison, differing combinations of sources were plotted on the diagrams for clarity of interpretation. Of the multitude of combinations available, 12, representing the Pecos River water, background water, and the shallow-deep monitor well pairs, were chosen for presentation and inclusion in this report. For each of the 12 diagrams (Figures 22 through 33) a summary description and interpretation of the most important water chemistry characteristics are provided in the following.

- The quality of the Pecos River varies greatly during a typical year (Figure 22). In March 1991, the composition was greater than 60% sodium chloride with a TDS concentration of 6,670 mg/L. By contrast, two months later, in likely response to upstream flow releases for irrigation, the composition was 80% calcium-magnesium sulfate with a TDS of 3,230 mg/L.

- The concentration of the background groundwater in the vicinity of the ponds is similarly variable and distinctly different from the water in the active pond. The unimpacted water in the shallow subsurface has a composition ranging from that of the Pecos River in March 1991 (Figure 22) to a better quality, calcium sulfate water type in the alluvium farther west of the river channel (Figure 23). TDS concentrations range from greater than 10,000 mg/L for water with a composition similar to river water, to 2,072 mg/L for water in sediment on the periphery of the floodplain alluvium.

- MW-1, MW-15, and the windmill adjacent to Evaporation Pond 1 do not appear to be impacted by the currently active pond, and do not show clear evidence of having been impacted by salt in the past (Figure 23). TDS concentrations at MW-1, MW-15, and the windmill are 10,565, 2,733, and 4,516 mg/L, respectively.

Figure 22. Trilinear mixing diagram, Pecos River, RFI Phase II, April 1993.



KWBES

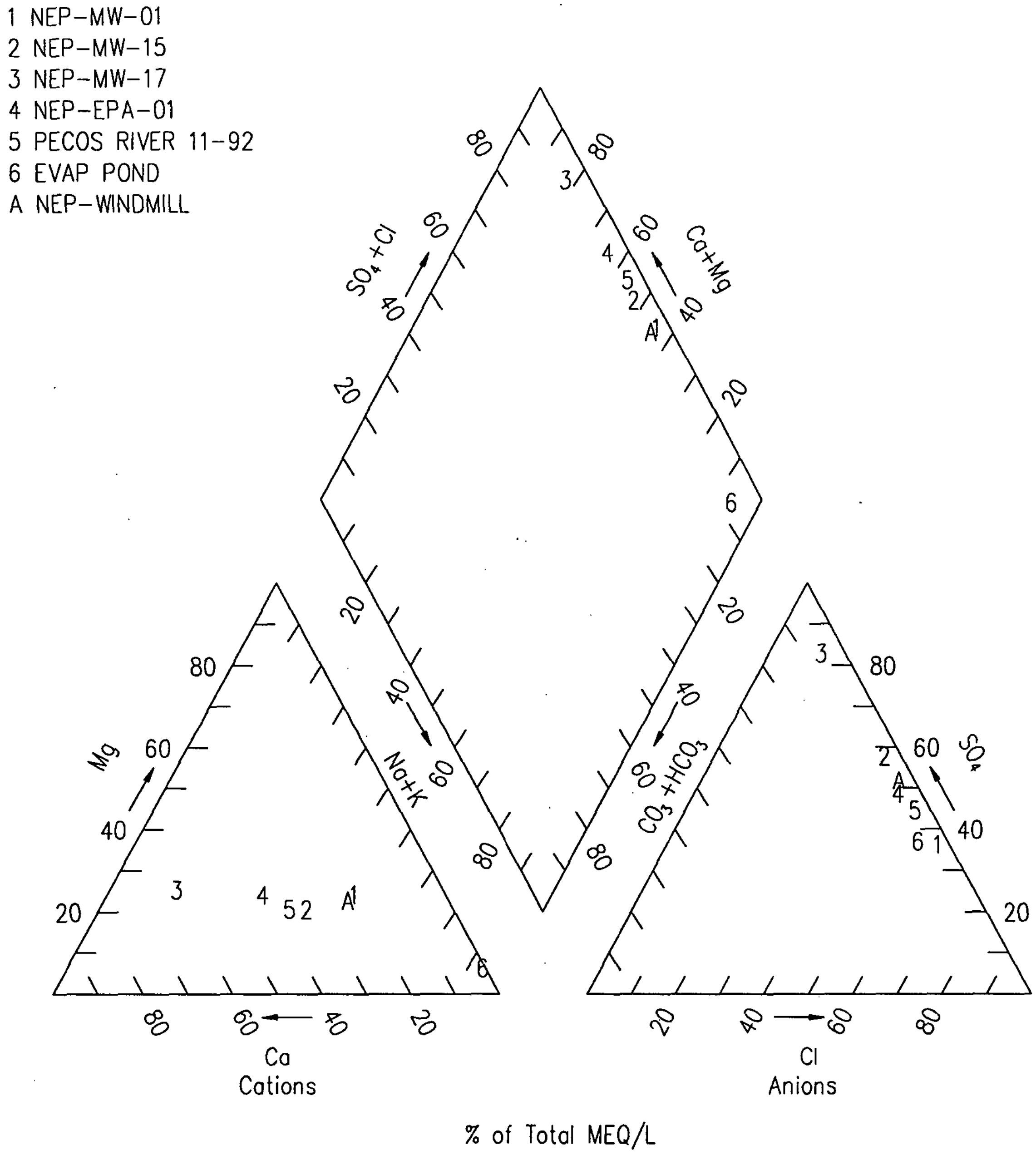
Trilinear mixing diagram, Pecos River, RFI Phase II, April 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI)PECOS-RIVER	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-27-93
DRAWN BY: JW	SCALE:
DATE:	FIGURE: 22

Figure 23. Trilinear mixing diagram, pond windmill background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

Trilinear mixing diagram, pond windmill background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

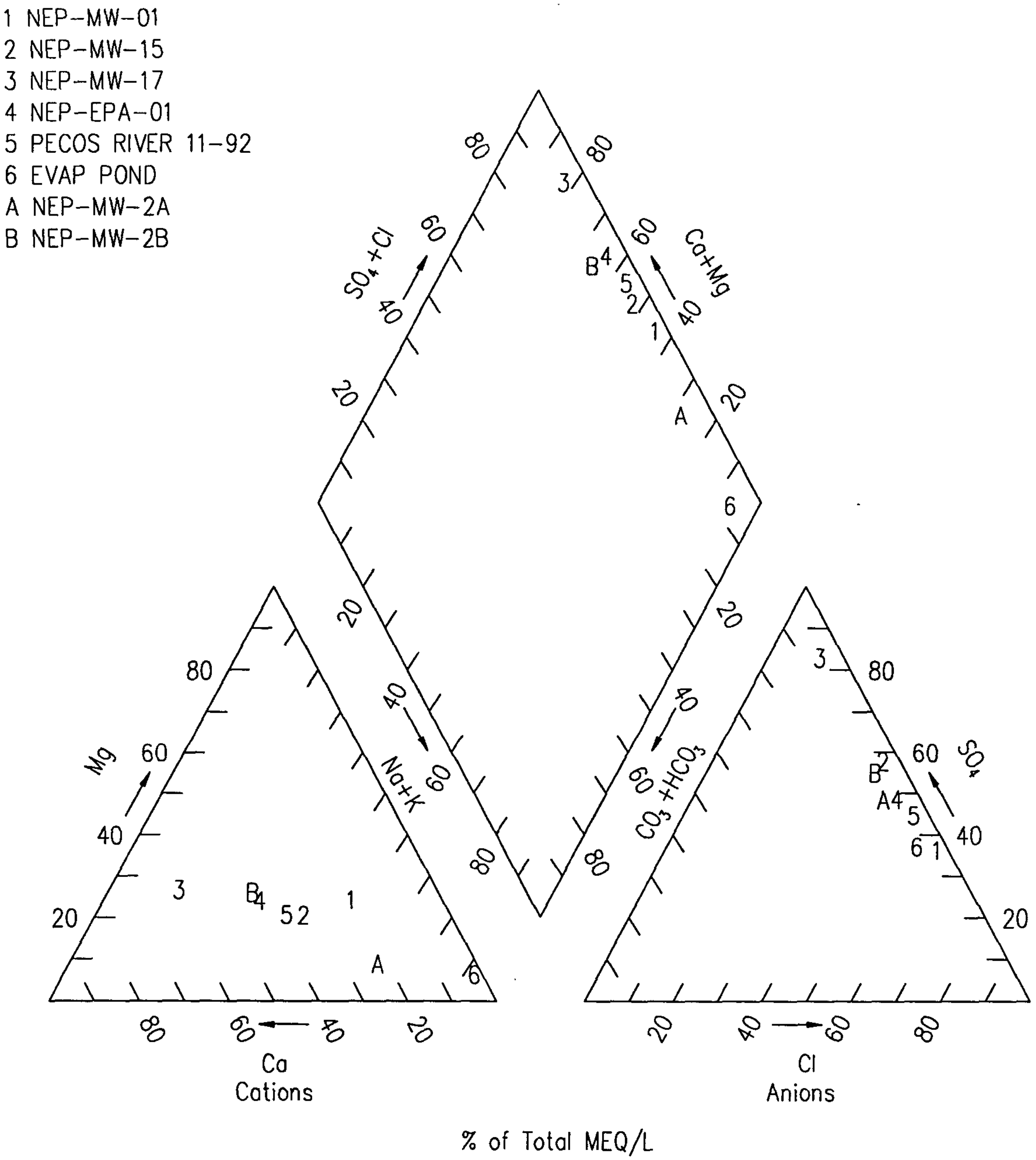
prepared for:

Navajo

PROJECT: 622092005-110 (TRI)POND-WINDMILL
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 23

- In Figure 24, the location of shallow well MW-2A on the diagram, with respect to the evaporation pond, indicates salt impact from the pond. However, deeper well MW-2B shows no evidence of salt impact, which is supported by the metal chemical analyses and a lack of notable organic constituents. Although the measured vertical gradient is downward, the lack of observed salt and major organic impacts provides credence to the groundwater flow model (Figure 19).
- Both the shallow and deep wells at MW-5 show evidence of salt impact, with the deeper well MW-5B less affected than the shallow well (Figure 25). Analytical results of BTEX slightly elevated above detection levels in MW-5A and elevated arsenic in MW-5B support the interpretation.
- In Figure 26, shallow well MW-6A, located immediately adjacent to the entrance to inactive Pond 1, appears only slightly salt impacted although low concentrations of BTEX were detected. Although deep well MW-6B appears unaffected by salts, low concentrations of several volatiles were detected. Owing to the relatively high transmissivity of the lower zones, and the lack of fluids in Pond 1, the water in the impacted zone may be undergoing replacement with better quality deeper groundwater.
- In contrast to MW-2B on the north side, both MW-7A and MW-7B are salt impacted (Figure 27). The general direction of groundwater flow in this area is southeast and the wells are directly downgradient from the pond. The most likely reason that elevated levels of target compounds are not seen in the MW-7 pair is that Pond 1 to the west received most of the hydrocarbon waste materials prior to its inactivation in 1987.
- Owing to their location on the center plot, both MW-11A and MW-11B would appear to be impacted by the pond (Figure 28). However, no detections of contaminants such as BTEX or arsenic were seen. Additionally, the section of Pond 2 closest to the wells only was completed in 1987. The composition of the shallow and deep water is primarily chloride with relative proportions greater than the existing concentrations of the effluent water. Therefore, the pond is not the likely source of water in these two wells.
- MW-18 wells are located within about 100 ft of the river. The composition of the water in MW-18A (Figure 29) is approximately the same as the river water shown on Figure 22 and it is also similar to the water of MW-1, also located near the river. MW-18B water composition is similar to that of MW-2B. However, MW-18A and MW-18B are in the particle flow path as shown on Figure 19. Although downgradient from the pond, the predicted salt impact in MW-18A may not be severe because of the distance from the source and the attenuation of constituents that will occur through groundwater mixing. The particle flow model predicts little or no groundwater impact at MW-18B.
- MW-22A and MW-22B (Figure 30) are directly downgradient from Pond 1 and in the zone of possible impacts as delineated by the subsurface gas survey (Figures 7 and 8), detection of unidentified organic compounds in the well pair, and the groundwater flow model (Figure 19). The degree of salt impact from the ponds is uncertain because the points plot on the edge of the zone delineated by the composition of Pecos River water. However, water in most deep monitor wells that appears unaffected by the pond has a composition that tends toward calcium sulfate and plots closer to the upper vertex in the diagram's center diamond.
- OCD-2A appears to be salt impacted, but OCD-2B is likely not (Figure 31). The vertical gradient at this location is only slightly upward, and the composition of the deep water appears to be similar to that of MW-1 and unlike the water of MW-2B and MW-18B. The well pair is located beside the river on the northeast side of Pond 2 and in the vicinity of the MW-11 pair. This section of the pond has been in use only since 1987. The deep water quality may deteriorate to the east because of a change in lithology. The valley fill alluvium thins and ends less than one-half mile to the east and is replaced by the rock outcrops of the gypsiferous Seven Rivers Formation. Also, any deep saline water from

Figure 24. Trilinear mixing diagram, MW-2A, -2B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

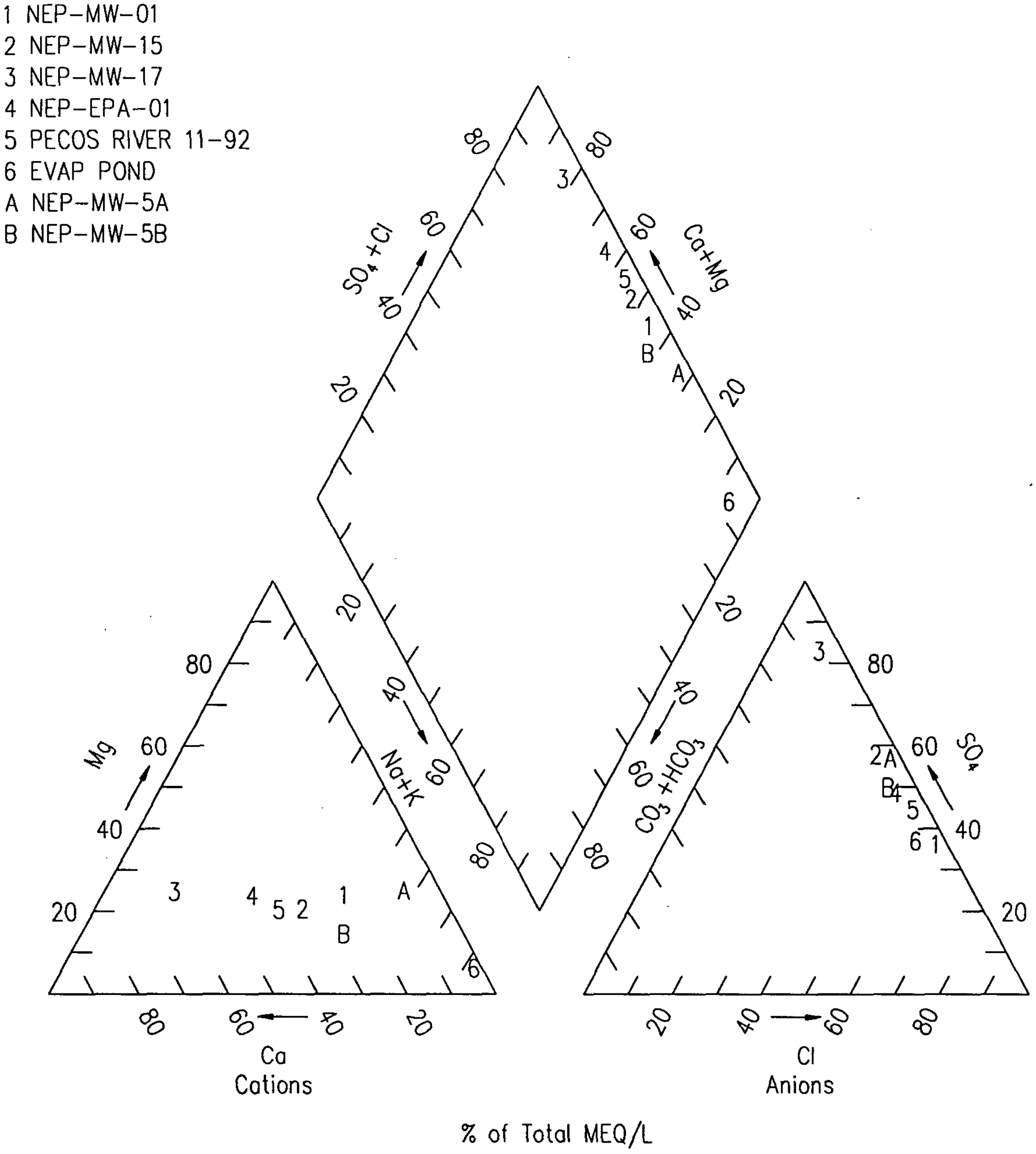
Trilinear mixing diagram, MW-2A,-2B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI)MW-2A-2B
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 24

Figure 25. Trilinear mixing diagram, MW-5A, -5B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

Trilinear mixing diagram, MW-5A, -5B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

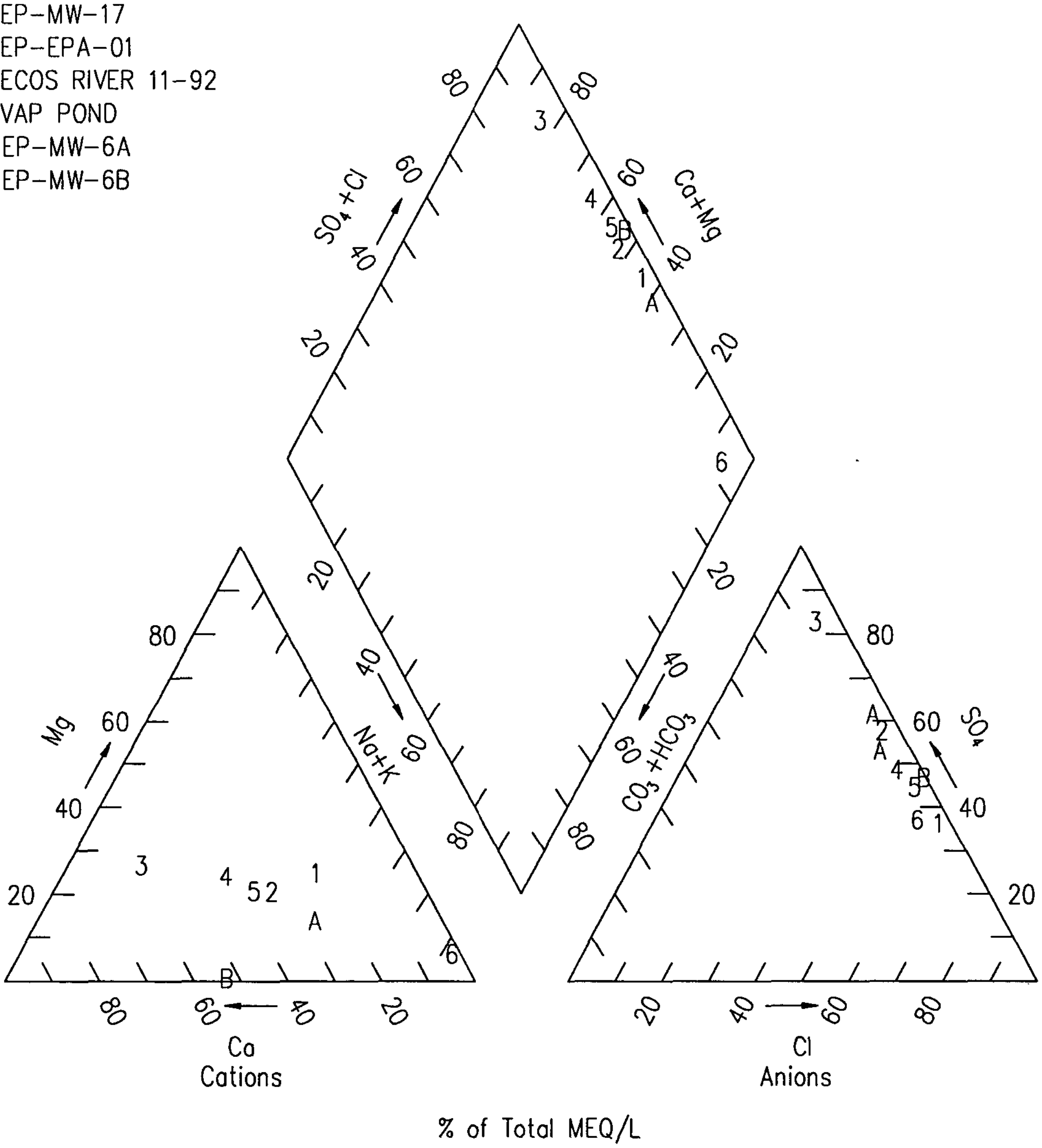
prepared for:

Navajo

PROJECT: 622092005-110 (TRI)MW-5A-5B	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-27-93
DRAWN BY: JW	SCALE:
DATE:	FIGURE: 25

Figure 26. Trilinear mixing diagram, MW-6A, -6B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.

1 NEP-MW-01
2 NEP-MW-15
3 NEP-MW-17
4 NEP-EPA-01
5 PECOS RIVER 11-92
6 EVAP POND
A NEP-MW-6A
B NEP-MW-6B



KWBES

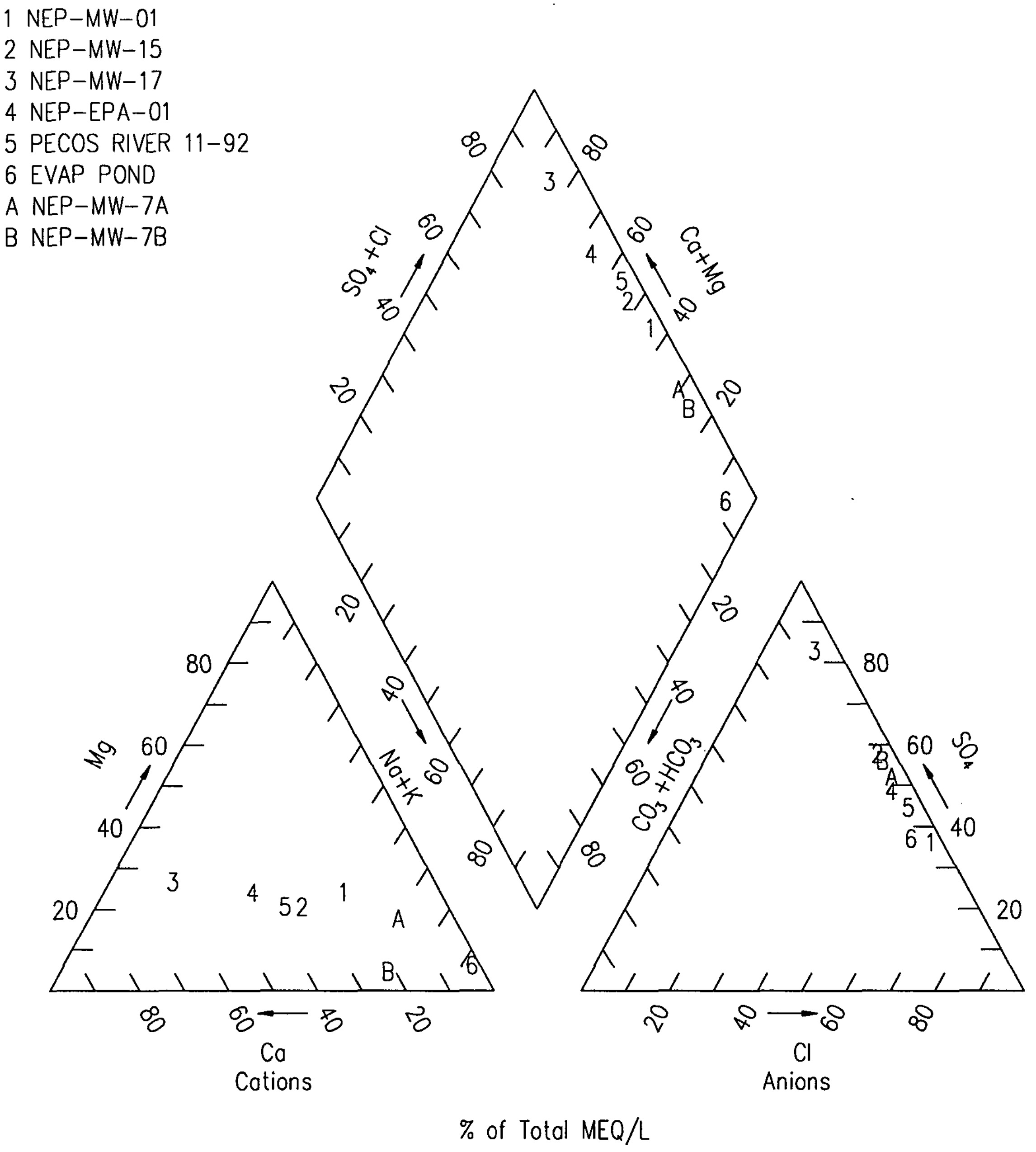
Trilinear mixing diagram, MW-6A, -6B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI)MW-6A-6B
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 26

Figure 27. Trilinear mixing diagram, MW-7A, -7B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



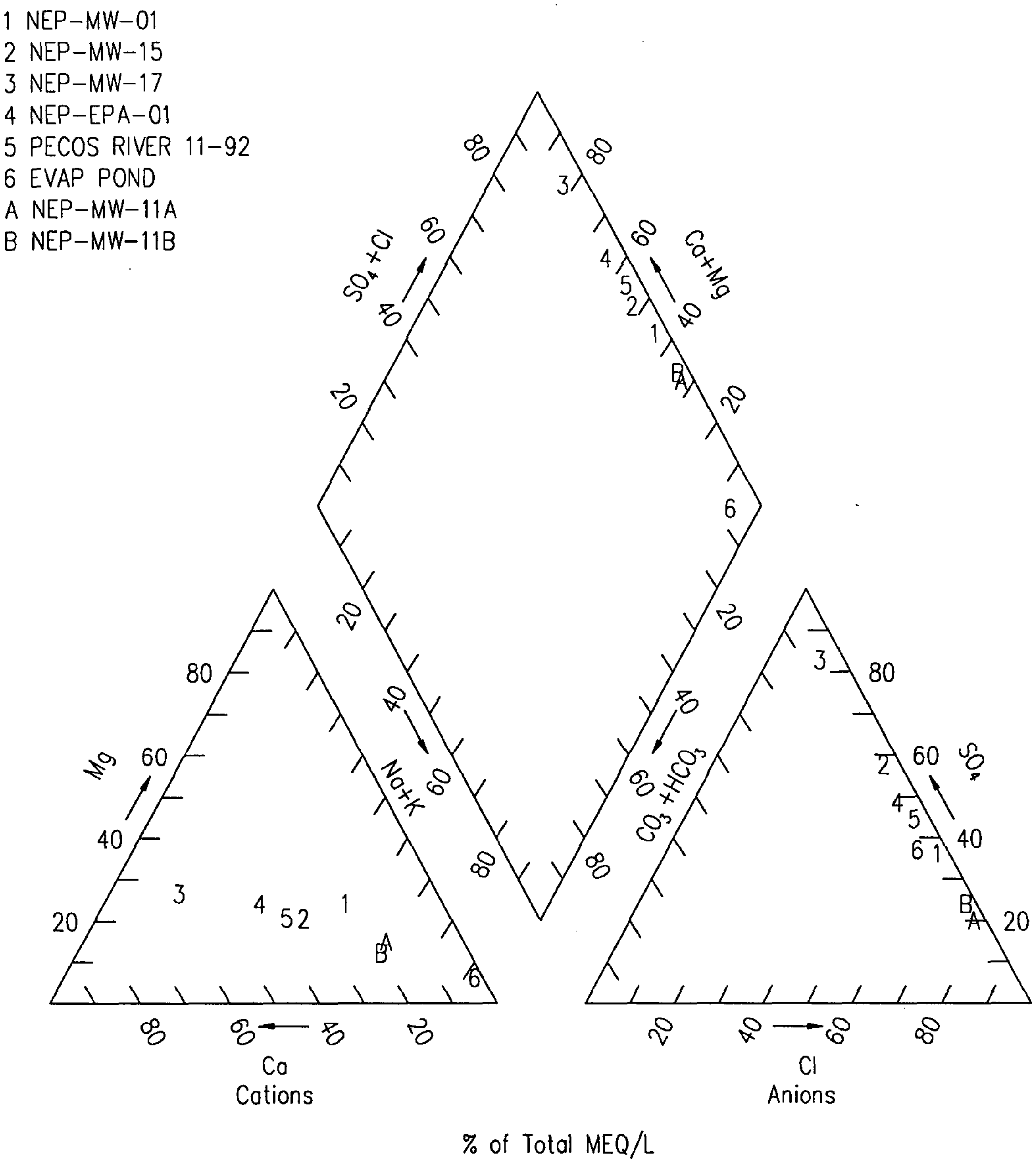
KWBES

Trilinear mixing diagram, MW-7A, -7B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for: Navajo

PROJECT: 622092005-110 (TRI)MW-7A-7B
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 27

Figure 28. Trilinear mixing diagram, MW-11A, -11B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

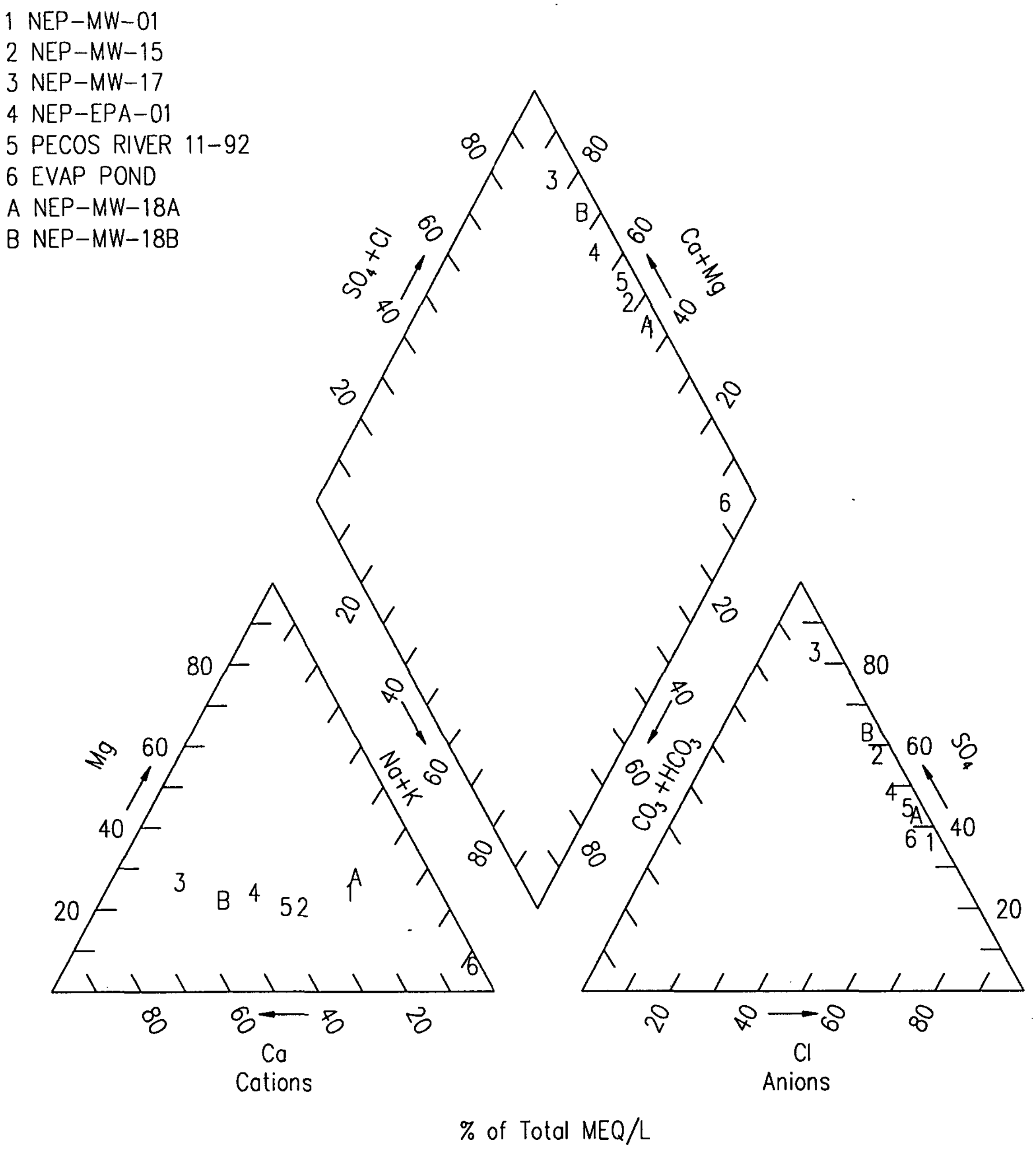
Trilinear mixing diagram, MW-11A, -11B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI)MW-11A-11B
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 28

Figure 29. Trilinear mixing diagram, MW-18A, -18B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

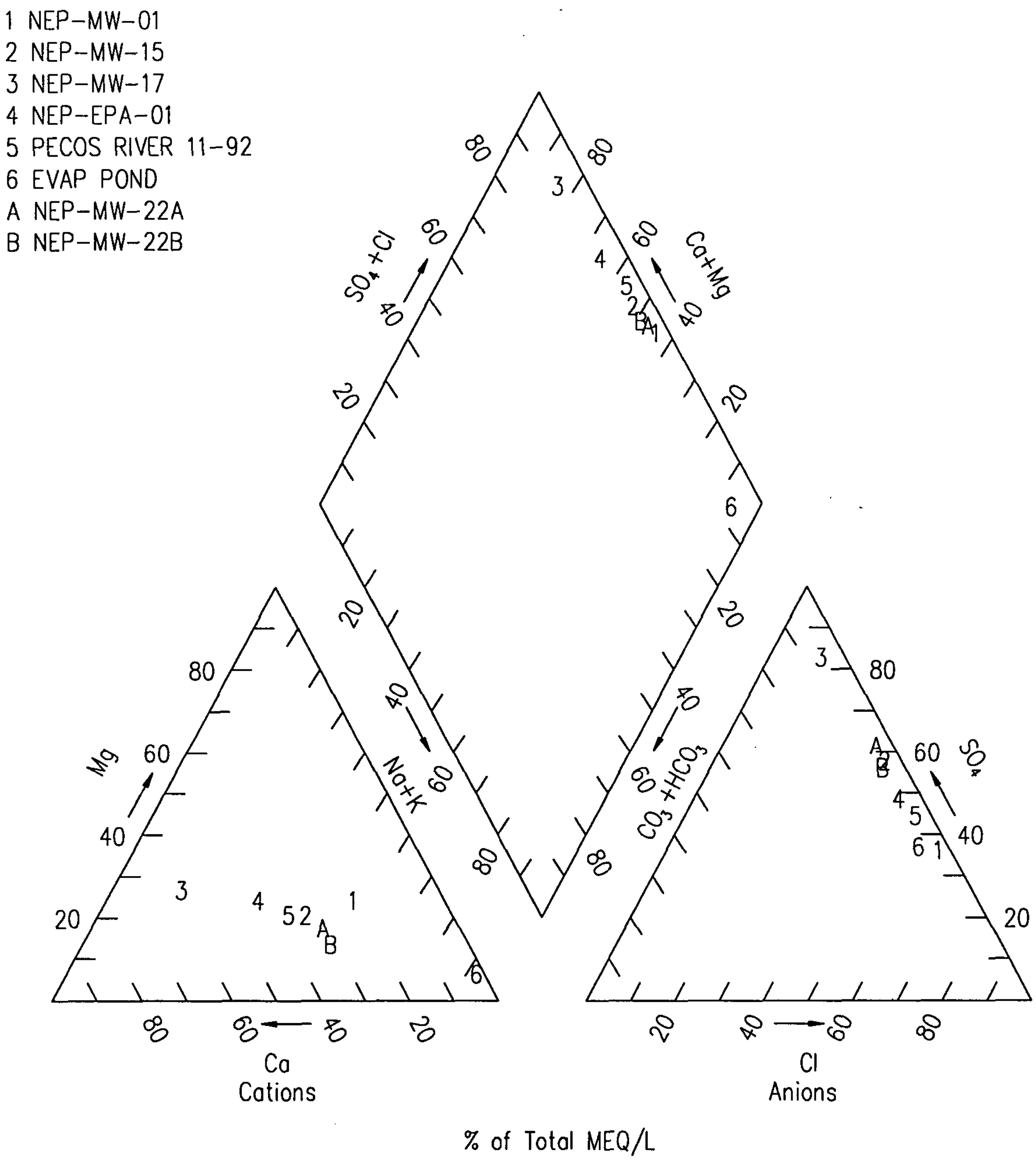
Trilinear mixing diagram, MW–18A, –18B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT:	622092005–110 (TRI)MW–18A–18B		
LOCATION:	ARTESIA, NEW MEXICO		
APPR:		DATE:	4–27–93
DRAWN BY:	JW	SCALE:	
DATE:		FIGURE:	29

Figure 30. Trilinear mixing diagram, MW-22A, -22B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

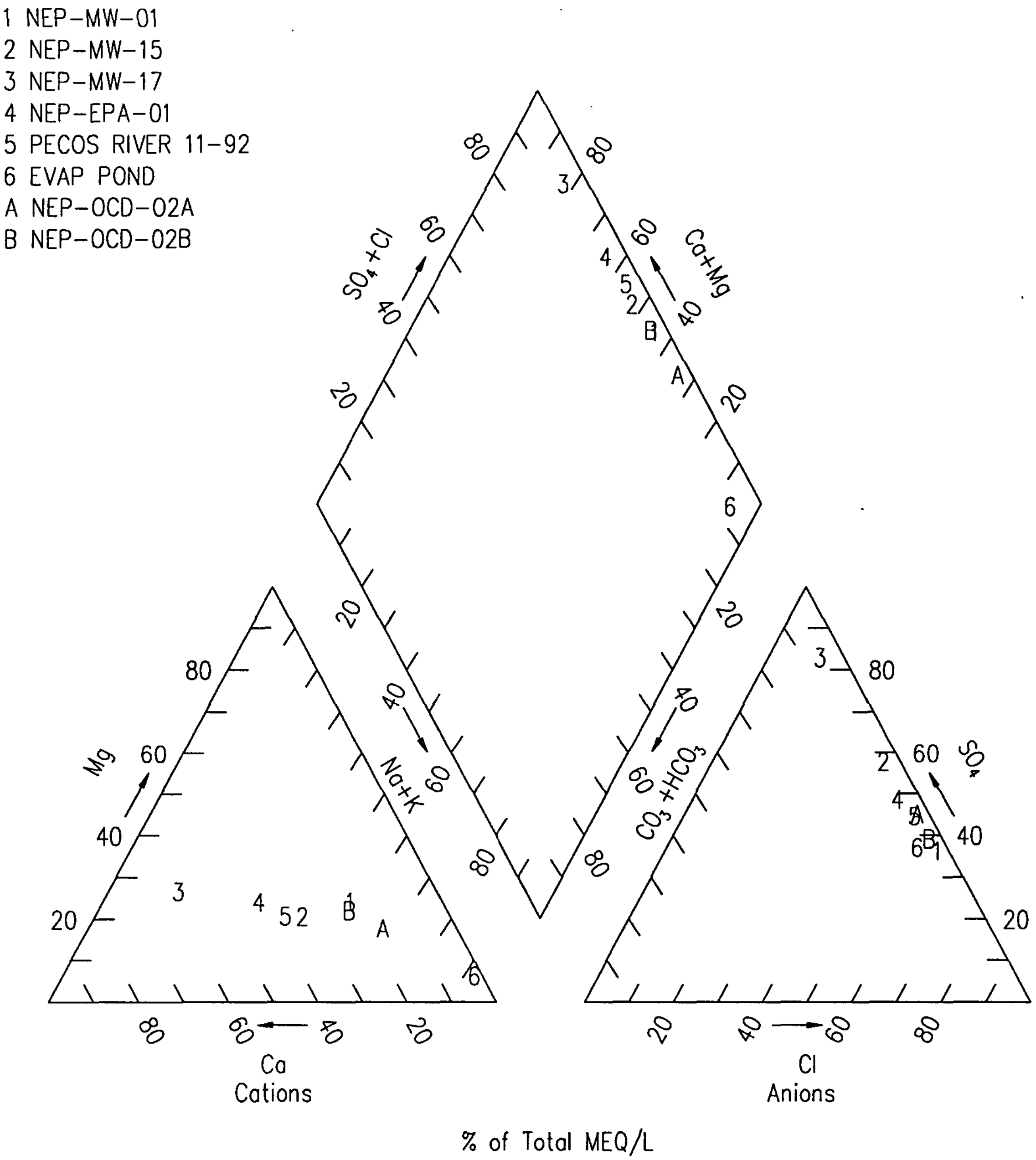
Trilinear mixing diagram, MW-22A, -22B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI)MW-22A-22B	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-27-93
DRAWN BY: JW	SCALE:
DATE:	FIGURE: 30

Figure 31. Trilinear mixing diagram, OCD-2A, -2B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

Trilinear mixing diagram, OCD-2A, -2B background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI) OCD-2A-2B	
LOCATION: ARTESIA, NEW MEXICO	
APPR:	DATE: 4-27-93
DRAWN BY: JW	SCALE:
DATE:	FIGURE: 31

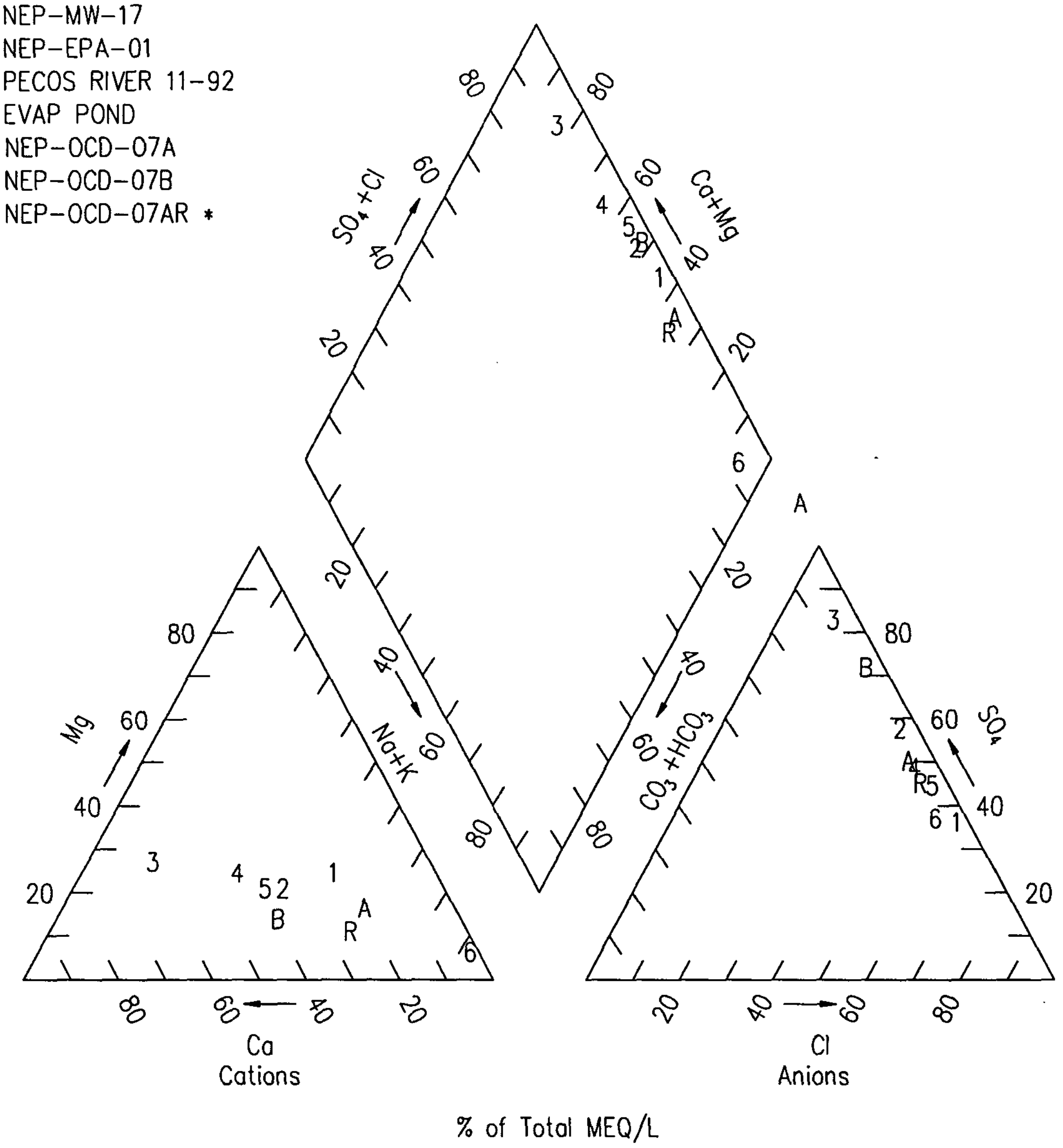
the San Andres Formation would migrate upward on this side of the valley because movement to the east is blocked by the much less permeable rocks.

- OCD-7AR (the replacement well for damaged OCD-7A) and OCD-7B are located within 50 ft of Pond 1 with OCD-7AR showing impact by pond salts (Figure 32). Water in OCD-7B may be undergoing a compositional change because the sodium percentage is increased over nonimpacted deep wells but the predominant anion is still sulfate. Of the monitor wells, only the MW-2 and OCD-7 pairs have downward vertical gradients. However, the result of both pairs of wells being in proximity to the pond is quite different. The OCD-7 pair is immediately beside and downgradient of the pond, and the movement of pond liquids is in the direction of the well pair. Although the gradient at MW-2 is also downward, the well pair is located slightly farther from the pond. Impacted water at depth does not exist upgradient of MW-2B and the natural direction of groundwater flow is toward the source of contaminated water.
- OCD-8A appears slightly impacted by the pond, but OCD-8B does not (Figure 33). Although downgradient from the pond, no sign of an impact is seen in OCD-8B, and the water has the characteristics of the water seen in MW-2B and MW-18B. A reasonable explanation can be found by examining the drilling logs. This well is one of the few deep wells where significant zones of clay and sandy clay are found. If these are continuous in the direction of the pond, they may provide localized barriers to the downward migration of fluids. Also, this section of the pond is less than 20 years old and if deep migration is restricted by clays, it may not yet have progressed to the point where it has reached the monitor well.

The preceding information on water characteristics was derived from examination of the trilinear diagrams and used to verify the reasonableness of the particle flow tracking model. The mathematical flow model is used to duplicate existing flow conditions. Interpretation of the geochemical characteristics of the groundwater provides information that supports the predictions made by the model. Together they provide strong evidence that the impacts of past and continued use of the ponds will be limited to the area of the ponds and to the area of poor-quality groundwater that exists near the surface and downgradient of the site.

Figure 32. Trilinear mixing diagram, OCD-7A, -7B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.

1 NEP-MW-01
2 NEP-MW-15
3 NEP-MW-17
4 NEP-EPA-01
5 PECOS RIVER 11-92
6 EVAP POND
A NEP-OCD-07A
B NEP-OCD-07B
R NEP-OCD-07AR *



* OCD-07AR IS A REPLACEMENT FOR DAMAGED OCD-07A

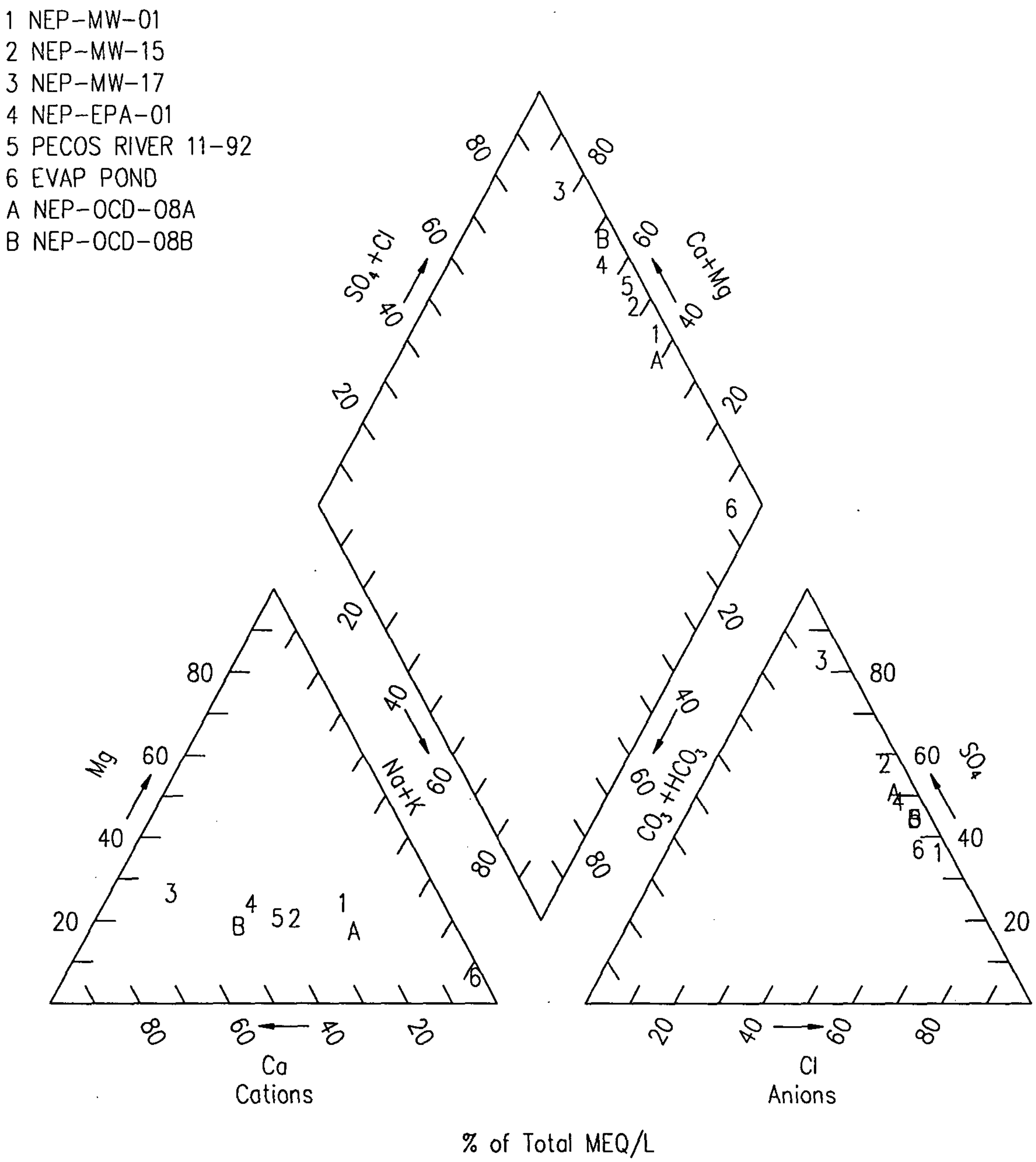
KWBES

Trilinear mixing diagram, OCD-7A, -7B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:
Navajo

PROJECT: 622092005-110 (TRI) OCD-7A-7B
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 32

Figure 33. Trilinear mixing diagram, OCD-8A, -8B, background wells, Pecos River, evaporation pond, RFI Phase II, April 1993.



KWBES

Trilinear mixing diagram, OCD-8A, -8B, background wells, Pecos River, evaporation pond, RFI Phase II, April, 1993.

prepared for:

Navajo

PROJECT: 622092005-110 (TRI) OCD-8A-8B
LOCATION: ARTESIA, NEW MEXICO
APPR:
DATE: 4-27-93
DRAWN BY: JW
SCALE:
DATE:
FIGURE: 33

10.0 CONCLUSIONS

10.1 THREE-MILE DITCH

All of the available data associated with Three-Mile Ditch indicate that the unit does not pose a present or future significant threat to human health or the environment. No verifiable information exists to suggest that residual organic constituents contained within the unit present the likelihood for significant contamination of shallow groundwater (i.e. above conservatively calculated health-based levels). This conclusion is based on the following evidence obtained during the RFI Phase II study:

- TCLP evaluation of the soil samples collected from the unit demonstrates that, even under the extreme leaching conditions posed by that analytical procedure, organic constituents remain strongly sorbed to the soil matrix, which indicates that they are essentially immobile.
- Organic constituents that may incrementally desorb from the soil can be expected to undergo biodegradation and dispersion processes that will further minimize the potential for their accumulation in the water phase.
- The metal constituents of arsenic, chromium, and lead present within the unit are not widely distributed, but occur in localized concentrations. Furthermore, these metals are also strongly sorbed to the soil matrix, as demonstrated by the TCLP leaching test.
- The exceedingly high level of lead found in MW-45 during the earlier study was not verified; the level detected during this investigation is at the state and former federal drinking water standard for lead.
- Based on the Phase I and II soil results for nickel and zinc, and the lack of credible evidence for nickel or zinc in the groundwater, it can be concluded that neither nickel nor zinc poses an environmental problem in or adjacent to Three-Mile Ditch.
- Except for the detection of methylene chloride, an apparent laboratory artifact, the groundwater investigation in the vicinity of the ditch did not detect the presence of Appendix VIII hazardous volatile organic compounds in any well except MW-45, a well adjacent to an area of the refinery known to have had underground releases from product storage tanks and lines. Volatiles detected in this well were below drinking water standards or health-based criteria. No Appendix VIII hazardous semivolatile organic compounds were detected in the wells in the vicinity of Three-Mile Ditch.
- Significant levels of chromium and nickel detected in groundwater during the previous study were not verified by analyses from the newly installed monitor wells. The source of contamination, as indicated by additional metals testing of the groundwater and metal well casing, was the corrosion of the stainless-steel casing likely caused by naturally occurring salts in the groundwater.
- The direction of groundwater movement is parallel to the ditch eastward from the refinery to the river. In the area of the refinery, the most permeable shallow water-bearing zones are discontinuous and grade into clays and other finer grained materials.

In the area of the river, the deposits typically consist of sands and other floodplain soils.

- The intersection of groundwater with the bottom of Eagle Creek during periods of high groundwater levels is evidenced by the formation of pools that support a variety of aquatic life forms. During infrequent storm events, runoff in Eagle Creek infiltrates into adjacent shallow permeable zones. For the remainder of the year, the channel is dry. The RFI Phase I study found no evidence of sediment contamination from the ditch. Limited sampling conducted during this study confirms that result.
- The natural quality of the groundwater along the route of the former ditch is high in TDS and has elevated levels of calcium, chloride, and sulfate. Because of its poor quality, the shallow water in the immediate vicinity of the ditch is not used. Any future use would most likely be limited to livestock in the alluvial plain west of the river. However, as determined by analysis of samples from the monitor wells, this water is also of poor quality.
- In the area of the ditch, water wells completed for domestic or irrigation use are completed in one of two zones at depths of from 100 to 300 ft or from about 700 to 1,100 ft. The nearest known usable wells in the proximity of Three-Mile Ditch are located about one-quarter mile north of the ditch and are completed in one of these two water-bearing zones.
- A comparison was made of the chemistry of the inorganic constituents of the current and past effluent, of shallow groundwater along the ditch, and of groundwater used for domestic purposes from the several water wells closest to the ditch. The chemical data were examined using a graphical technique to determine if water from the three sources were alike, different, or a mixture of one or more of the sources. There was no evidence to indicate that the water was from a common source or a mixture of sources, although the RFI reports determined that waste from the ditch has contacted groundwater at certain locations along the ditch. The comparisons offer support to the results of the organic and metal analyses presented previously that show that any current groundwater impacts of past ditch use are at most minimal.

Based on these Phase II study results, it can be further concluded that no reliable evidence exists to indicate that any residual metal constituents present within the unit are migrating or have the potential to migrate from the unit. The primary environmental issue associated with long-term management of the unit is the sporadic occurrence within the unit of the metal constituents arsenic, chromium, and lead at levels that may be deemed excessive from the perspective of direct, sustained exposure.

However, the privately owned lands in the vicinity of the unit are currently limited to agricultural use, and the potential for direct and extensive human exposure to soil-borne contamination is low. Even if land usage in the vicinity of the unit changed, the relatively narrow and confined configuration of the ditch unit limits the probability that its contents would be disturbed to a significant extent. In addition, because the quality of the shallow groundwater underlying the unit is extremely poor, it is essentially unusable. Furthermore, there do not appear to be any existing or potential receptors for the prevailing shallow groundwater aquifer present below the unit.

In contrast, excavation and transport of soils from the unit can be expected to significantly increase the potential short-term human exposure to personnel involved in excavation and transport of excavated soils. In addition, if the excavated materials were transported to Evaporation Pond 1, the potential exposure to other environmental receptors via surface pathways could also be expected to increase because the excavated materials would be spread over the wide surface area of Evaporation Pond 1.

All available evidence indicates that the level of potential risk to human health and the environment posed by residual contaminants within the former Three-Mile Ditch wastewater conveyance will be relatively small. The degree of risk does not seem to justify the major effort and costs associated with the excavation and removal of contaminated soils from the unit. Thus, it is in the best interest of human health and the environment to allow Navajo Refining Company to prioritize resource allocations to other needs that present greater environmental benefits.

10.2 EVAPORATION PONDS

10.2.1 Soils of Evaporation Pond 1

The soil sample analytical results for Evaporation Pond 1 indicate that residual soil contaminants in the unit do not appear to pose a significant environmental risk to groundwater in the vicinity of the unit. Evidence supporting this conclusion is briefly summarized below:

- The data suggest that localized occurrences of excessive concentrations of metal constituents may be present within the soils of Evaporation Pond 1, but excessive levels of arsenic, chromium, and lead (the metals of concern) are not widespread within the unit. Excessive levels are considered to be levels elevated above various health-based criteria (presented in Section 9.0) or levels otherwise potentially capable of yielding leachate at levels regulated under the TC.

- Evaluation of the contamination profile within the soils of Evaporation Pond 1 reveals a distinct trend in which the concentration of organic constituents diminishes abruptly with increasing depth within 3 ft or less below the surface. A similar trend was even more highly developed for metal constituents. Metal concentrations observed at all sample intervals below a 1-ft sample depth yielded metal concentrations either at background levels or only slightly elevated above background metal concentrations.

- Nickel and zinc should be removed from consideration as potential constituents of concern at this unit. All available data indicated that neither of these constituents poses a current or potential future environmental problem in or adjacent to Evaporation Pond 1.

- Continued mechanical mixing and aeration of surface soils in Evaporation Pond 1 will enhance the degradation of residual organic constituents and the fixation of metal constituents. A comparison of sample EP-TR-006-005 (consisting of undisturbed Pond 1 waste materials) with other Pond 1 soil samples collected at a 1-ft sample depth in areas previously subject to mechanical mixing provides evidence to demonstrate that residual hydrocarbon constituents within the unit can be effectively remediated by this method.

10.2.2 Groundwater

The evaporation ponds have continuously received refinery wastewater for more than 50 years. However, the wastewater has received increasing levels of treatment only within the past 10 years. Therefore, extensive studies to characterize the groundwater in the vicinity of the evaporation ponds have been conducted. The field and analytical studies conducted for this phase of the investigation found only several organic and inorganic constituents of health-based concern elevated above detection levels. Except for highly elevated levels of metals resulting from the probable corrosion of stainless-steel casing in one well (MW-1), exceedance of health-based standards was minimal relative to the waste types, concentrations and length of time the pond system has operated. These analytical results strongly support a finding that the location of the ponds in an area with naturally high concentrations of salts at the surface has limited the impact of many years of pond use. The major conclusions of the Phase II investigation that support minimal health-related groundwater impacts are summarized in the following:

- Extensive testing of groundwater for volatile organic compounds listed on EPA's Target Compound List detected six compounds (not including methylene chloride) present in only six wells in the immediate vicinity of the ponds.
- The only organic constituent that exceeded EPA health-based standards was benzene, which was found in five wells. The maximum concentration was 0.021 mg/L, which is slightly greater than 4 times the detection limit and drinking water standard of 0.005 mg/L.
- The maximum concentration for any volatile organic compound was 0.117 mg/L of carbon disulfide found in MW-6B, which is immediately adjacent to the inactive Pond 1. The other four compounds detected were ethylbenzene, toluene, xylene, and 2-butanone (MEK) at individual levels less than 0.048 mg/L.
- Methylene chloride detections were considered laboratory artifacts based on detection in quality control method blanks and lack of detection in the evaporation pond.
- No semivolatile organic compounds were detected in the groundwater samples except for phthalates, which are a common laboratory contaminant. These semivolatile compounds were not found in the evaporation pond.
- Unidentified volatile and semivolatile organic constituents were detected at low concentrations in several monitoring wells along the Pecos River across from the evaporation ponds. Natural and pond-caused hydraulic gradients combine to cause fluid movement east and north under the river. Water levels in wells across the river are higher than the river surface demonstrating the persistence of the upward gradient.
- Arsenic concentrations exceeded the EPA health-based standards at nine monitor wells immediately adjacent to the ponds, but only two of the wells exceeded the New Mexico groundwater standard. The maximum exceedance was slightly greater than 3 times the EPA standard of 0.05 mg/L.
- Total lead exceeded the EPA drinking water action level in two PVC-cased wells and total chromium exceeded the EPA standard in one PVC-cased well. The analysis of filtered samples did not detect either constituent. The minimum EC for these wells was 14,200 µmhos/cm.

- Chromium and nickel were significantly elevated in a stainless-steel cased well upgradient from the ponds. As in the Three-Mile Ditch wells, the source of this contamination is believed to be severe corrosion of the well casing.
- Nickel appeared elevated in several PVC-cased wells sampled during the early portion of the project. The performance of verification testing of selected samples determined that these initial test results were elevated. Retesting of several PVC-cased well samples resulted in uniformly low detections.
- As summarized in the RFI Phase I Report, a 1987 well point groundwater survey of the area south of the ponds reported individual BTEX constituents of several hundred micrograms per liter. However, monitor wells newly completed at the southern end of the apparent zone of high concentrations found the water discolored, foamy, and odoriferous but elevated levels of the reported hydrocarbons were not detected. The discrepancy may result from the incorrect identification by the PID instrument of hydrocarbon compounds with chromatography retention times similar to those of the BTEX compounds.
- An RFI Phase II subsurface headspace vapor survey in the area south of the ponds provided a tentative delineation of the extent of potentially hydrocarbon-impacted groundwater, but due to landowner restrictions, monitor wells were not installed at the locations of highest vapor concentrations to determine contaminant concentrations.
- Monitor well sampling did not verify the presence of EPA target compounds, except in the area immediately to the south and east of Pond 1. Therefore, any impact outside that area appears to be limited to the presence of odor, foaming and discoloration, which is probably the result of slightly soluble organic compounds together with odoriferous sulfur and nitrogen constituents.
- Existing and new monitor wells document the very poor quality of shallow groundwater at locations close to the river and away from the direct influence of the pond.
- Some of the dissolved salt concentrations in the groundwater at river locations unimpacted by the ponds were in excess of 10,000 mg/L. Analyses by the USGS show river water during certain months of the year approaches these concentrations.
- Installation of shallow and deep pairs of groundwater monitoring wells away from the direct influence of the active pond provided information on subsurface groundwater movement and documented the existence of a significant upward vertical gradient in the vicinity of the ponds that limits the downward migration of pond seepage water. This finding collaborates area-wide hydrologic studies published by the USGS and the New Mexico State Engineer Office.
- Groundwater elevation measurements of the shallow and deep monitor wells show the horizontal movement of groundwater to a discharge area south and east of the ponds in the vicinity of U.S. Highway 82. The area is identified on local topographic maps and was verified as being a marshy area heavily populated with salt cedar, considered nuisance vegetation.
- Naturally occurring salts in water discharged from depth to the surface are concentrated as a result of direct surface evaporation and high transpiration by salt-tolerant plants growing in this and other marshy areas adjacent to the Pecos River. Water not evaporated or consumed by vegetation is discharged into the Pecos River during times of low flow.
- Limited sampling of the Pecos River during the Phase II study did not detect elevated levels of constituents that could be attributed to Navajo Refinery practices. The historically poor-quality water in the river has been documented by state and federal agencies.

- The area in the vicinity of the ponds serves as a regional groundwater discharge location that minimizes the possibility that seepage from the pond will migrate to better quality aquifers used for drinking water or irrigation sources.
- Using field-derived information on the local geology, hydraulic conductivity, and horizontal and vertical gradients, a groundwater flow model was developed to replicate the horizontal and vertical groundwater movement in the study area.
- The groundwater model demonstrates limited downward migration of pond constituents before upward gradients cause flow to turn upward. The southeastward horizontal gradient directs groundwater movement to the naturally salty discharge area.
- The upward gradient could be impacted by pumping of deeper, better quality groundwater in the vicinity of the ponds, but water rights allowing such pumping are not available from the State Engineer due to prior appropriation and water flow contractual obligations with Texas.
- A comparison of the chemistry of the inorganic constituents of the current effluent, of groundwater in the pond monitor wells, and of groundwater in the valley fill alluvium determined that the groundwater in the shallow monitor wells immediately adjacent to the pond and the deeper monitor wells on the south side of the pond had characteristics indicating partial mixing of the groundwater with pond water.
- Although there are unidentified volatile and semivolatile hydrocarbons in the wells, there is no indication that the groundwater sampled from the deeper monitor wells adjacent to the upgradient, north side of the pond has been salt impacted by the pond. Additionally, unlike deep wells on the south side of the pond, there is an absence of target compounds in the north side deep wells. These results are consistent with the information presented by the groundwater model indicating limited downward migration of pond constituents in the area beneath the pond and eventual upward movement to the naturally poor-quality groundwater discharge area at the surface.
- The shallow groundwater in the vicinity of the ponds, as well as the water of the Pecos River, is naturally high in TDS. The salty content of the river water makes it unusable for domestic uses and the salty nature of the shallow groundwater renders it unusable for domestic, agricultural, or industrial purposes.

The Phase II study demonstrated that seepage of wastewater historically discharged to the ponds remains in the shallow subsurface and migrates and mixes with naturally poor quality groundwater. This poor quality groundwater is unusable for drinking, agricultural or industrial use. As a result, no potential environmental receptors for hydrocarbon-impacted groundwater exist downgradient of the ponds.

Currently implemented modifications to wastewater treatment system at the refinery will reduce effluent quantity and improve the quality discharged to the ponds. Therefore, recommended follow-up actions during continued use of the evaporation ponds include routine monitoring of the effluent stream and groundwater in the downgradient monitor wells for constituents known or likely to be in the discharge, and the measurement of water levels in the monitor wells to verify vertical and horizontal gradients and groundwater movement.

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