GW - 28

REPORTS

YEAR(S):

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35MM DRAWINGS

GW-28

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16

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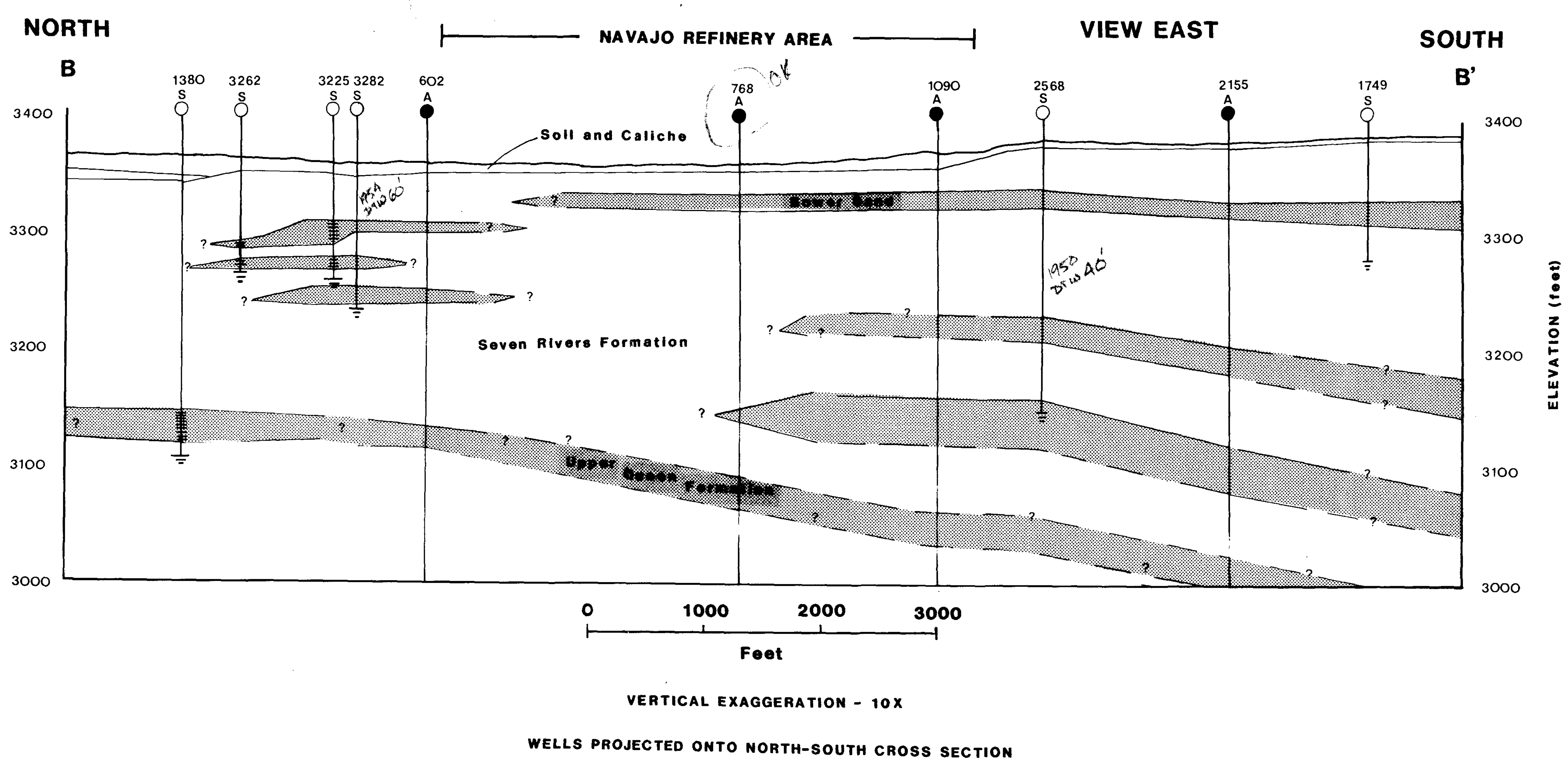

FIGURE 4-3

OIL CONSERVATION DIVISION
DEC 11 1984
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Geoscience Consultants, Ltd.

CROSS SECTIONS NAVAJO REFINING COMPANY AND ARTESIA, NEW MEXICO AREA

CLIENT: NAVAJO REFINING CO.
DATE: 10/11/84
DRAWN BY: Anita Larson
CHECKED BY: Randy Hicks AAG 12-3-84
REVISED:
SCALE: 1:22,000(H) 1:1200(V)

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
CERTIFICATE NUMBER 6421
AIPG
ALBERTO A. GUTIERREZ
CERTIFIED PROFESSIONAL GEOLOGIST

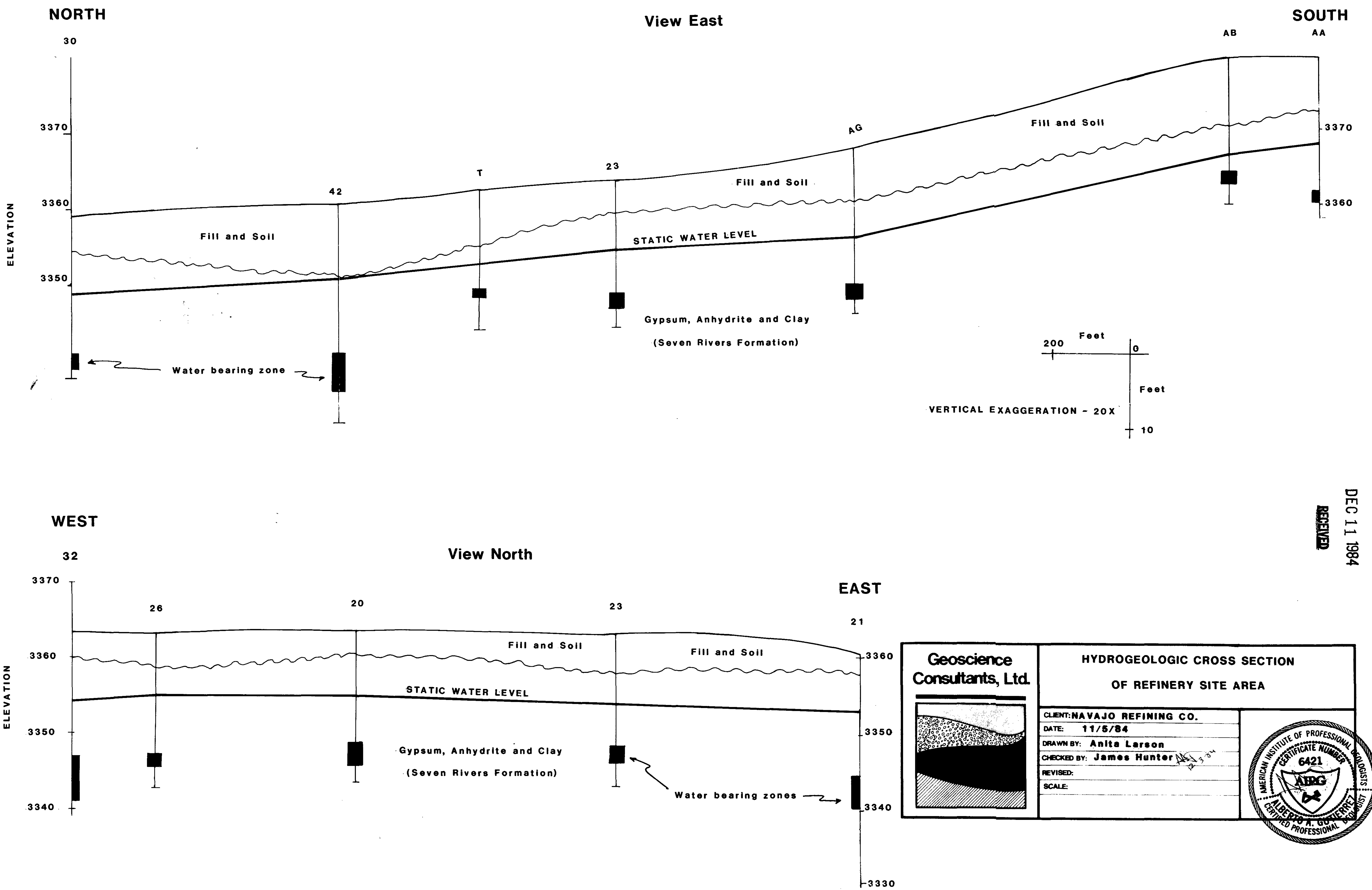

FIGURE 4-6

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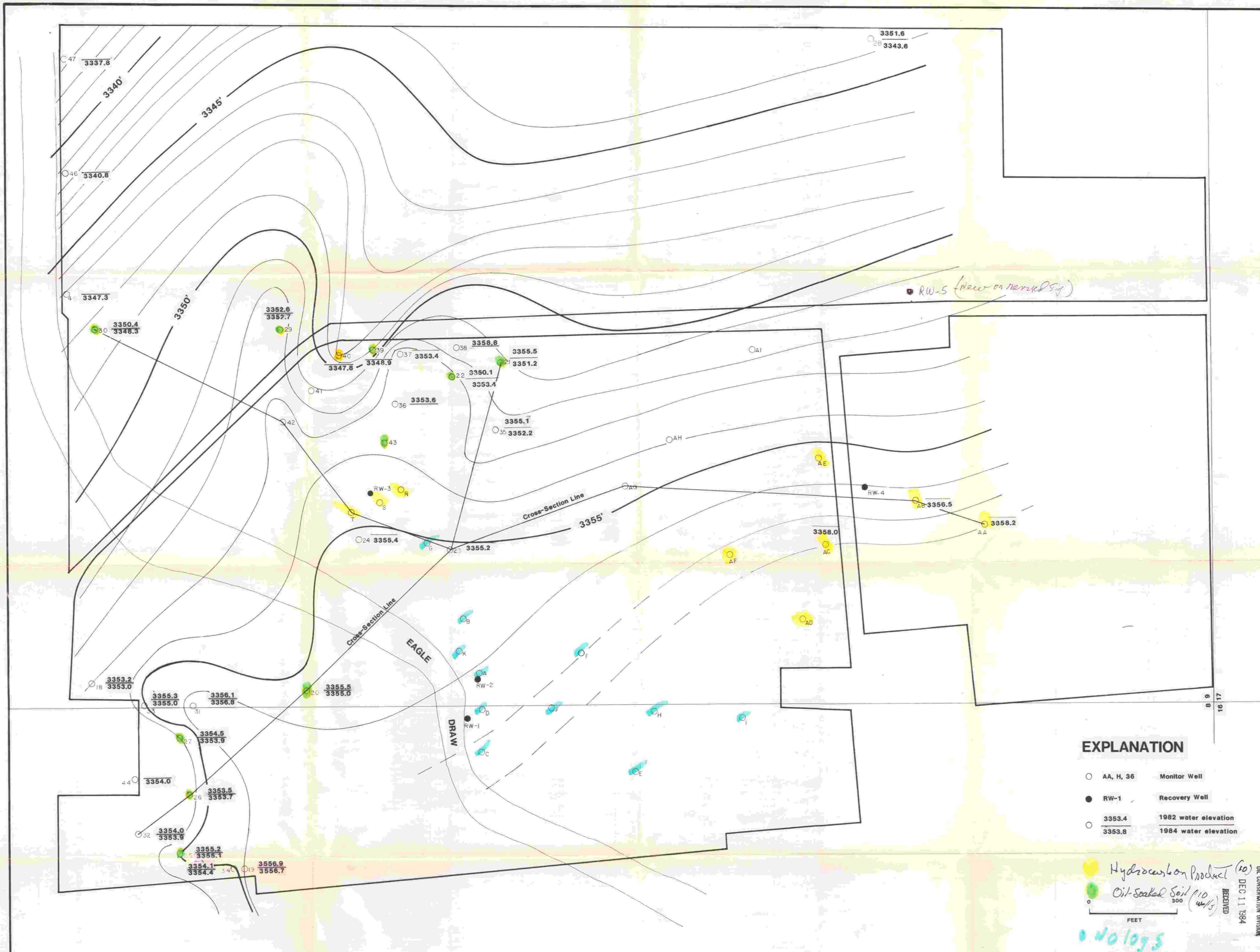
DEC 11 1984
OIL CONSERVATION DIVISION



OIL CONSERVATION DIVISION
RECEIVED
DEC 11 1984

0 W0 1095

Geoscience Consultants, Ltd.	POTENTIOMETRIC SURFACE SHALLOW PERCHED AQUIFER NAVAJO REFINING COMPANY ARTESIA, NEW MEXICO
CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 9, 1984
DRAWN BY:	James Hunter
CHECKED BY:	AAG 12/3/84
REVISED:	
SCALE:	1 inch equals 150 feet

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
CERTIFICATE NUMBER 6421
AIPG
ALBERTO A. GUTIERREZ
CERTIFIED PROFESSIONAL GEOLOGIST

FIGURE 4-7

OCD file copy

Geoscience Consultants, Ltd.

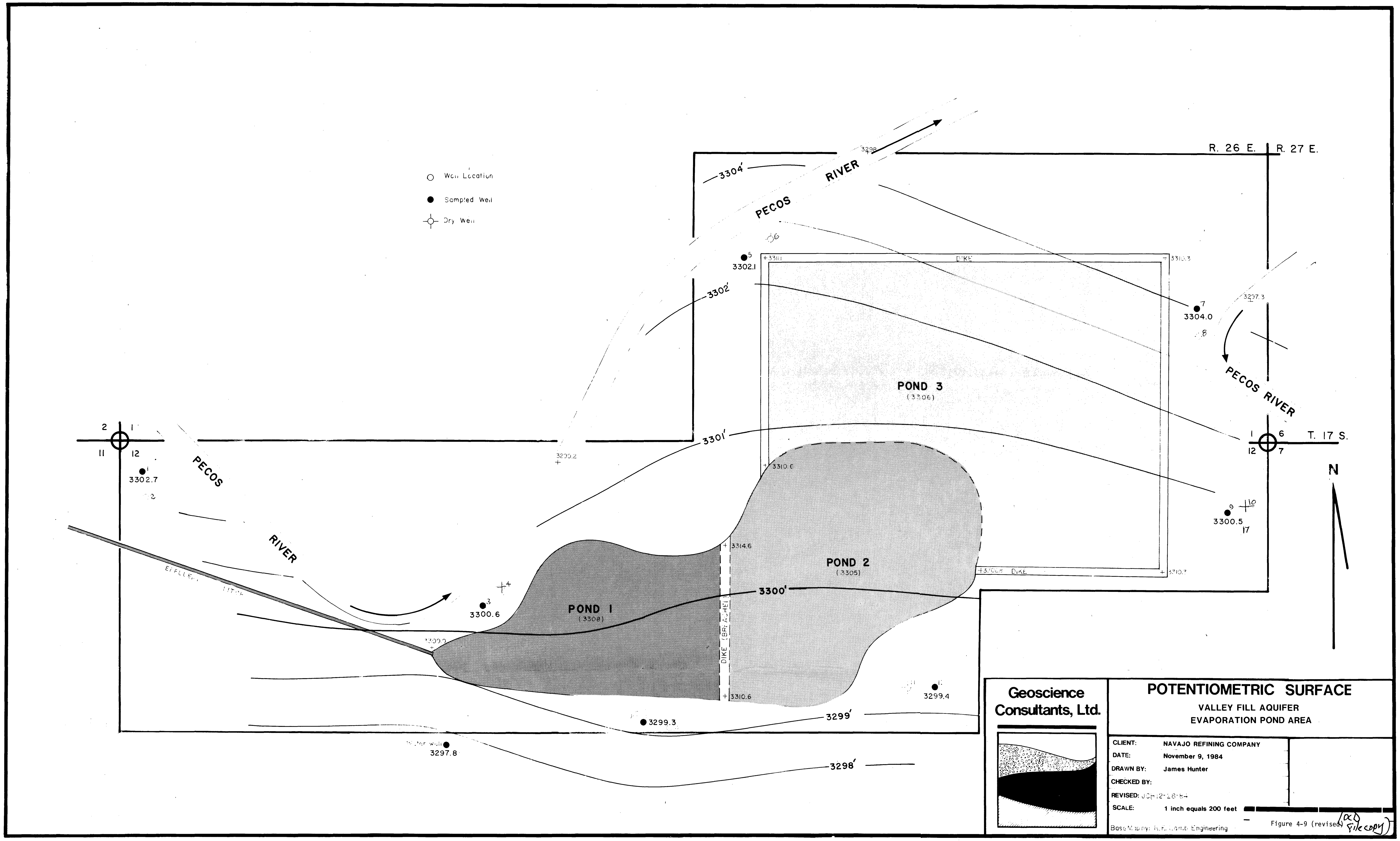
POTENTIOMETRIC SURFACE

VALLEY FILL AQUIFER
EVAPORATION POND AREA

CLIENT:	NAVAJO REFINING COMPANY
DATE:	November 9, 1984
DRAWN BY:	James Hunter
CHECKED BY:	12/3/84
REVISED:	
SCALE:	1 inch equals 200 feet

FIGURE 4-9 (ocd File copy)

OIL CONSERVATION DIVISION
RECEIVED
DEC 11 1984



POTENTIOMETRIC SURFACE
VALLEY FILL AQUIFER
EVAPORATION POND AREA

Geoscience Consultants, Ltd.

CLIENT: NAVAJO REFINING COMPANY
DATE: November 9, 1984
DRAWN BY: James Hunter
CHECKED BY:
REVISED: JCH 12-28-84
SCALE: 1 inch equals 200 feet
Base Map by: R.E. Lamb Engineering
Figure 4-9 (revised) (OCD file copy)

NAVAJO REFINING CO., INC.

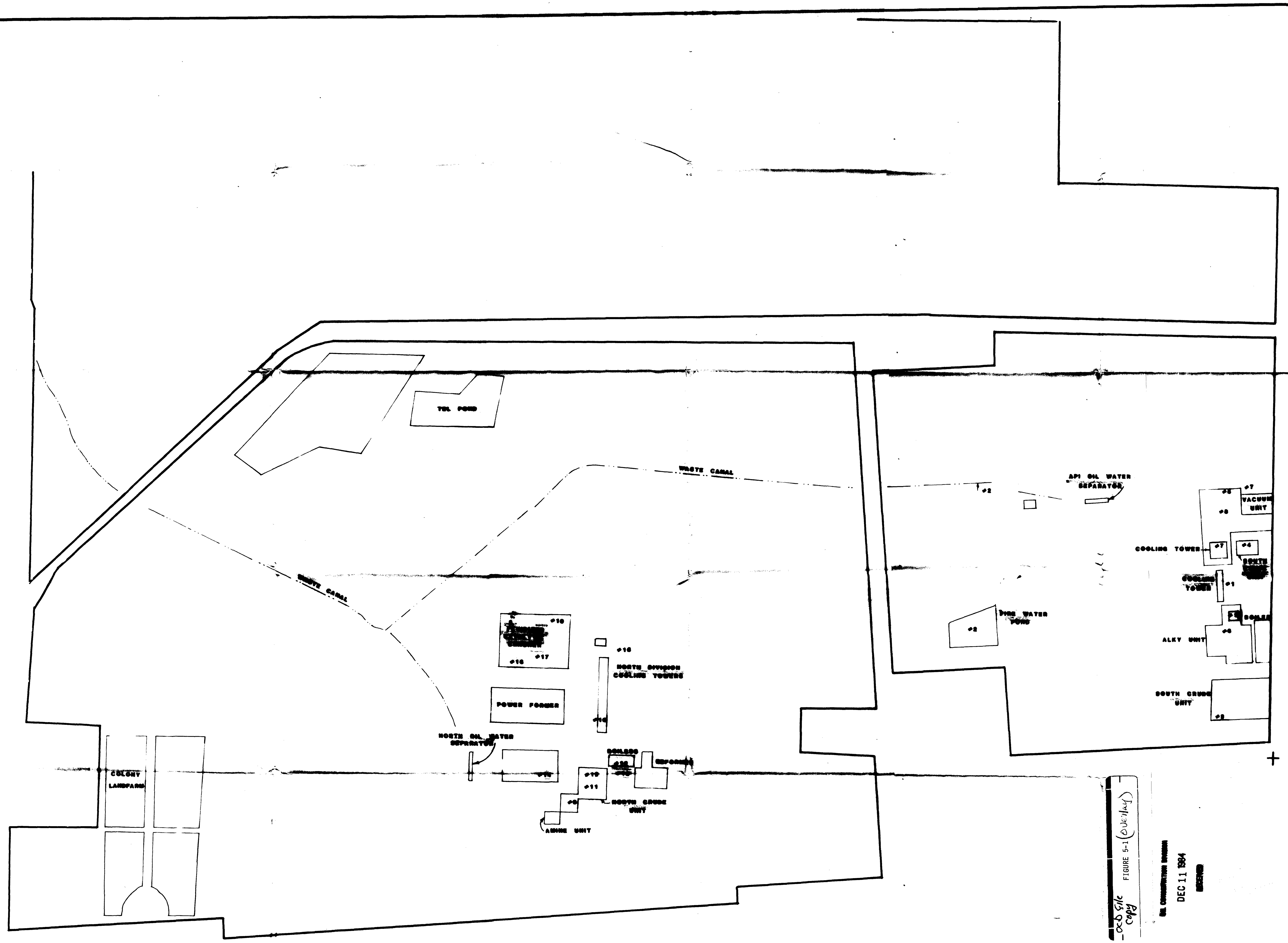
PROPOSED 12" PIPELINE
SITUATE WITHIN
SECTIONS 9 & 10, T 17 S, R 26 E, N.M.P.M.,
EDDY COUNTY, NEW MEXICO

SURVEY & MAPPING BY JOHN WEST ENGINEERING, HOBBS, N.M.

Sheet 2 of 3

PLATE 1-SINGLE PLAN AND PROFILE-FULL LINE

Revd 8/18/86 OCD/



OCD file copy

FIGURE 5-1 (overlay)

DEC 11 1984

Geoscience Consultants, Ltd.

[redacted]

CLIENT: [redacted]

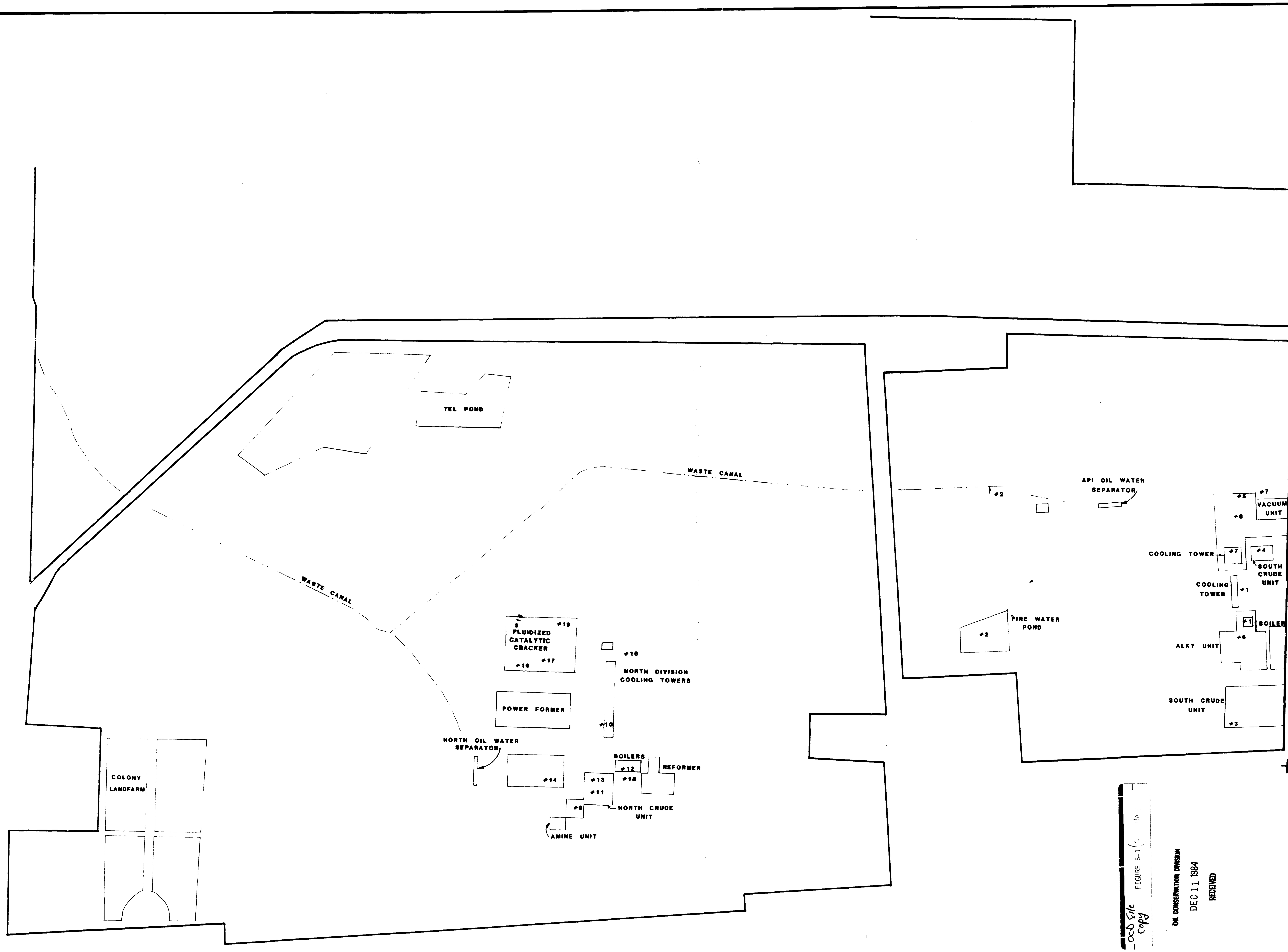
DATE: [redacted]

DRAWN BY: [redacted]

CHECKED BY:

REVISED:

SCALE: [redacted]



_ocd file copy

FIGURE 5-1

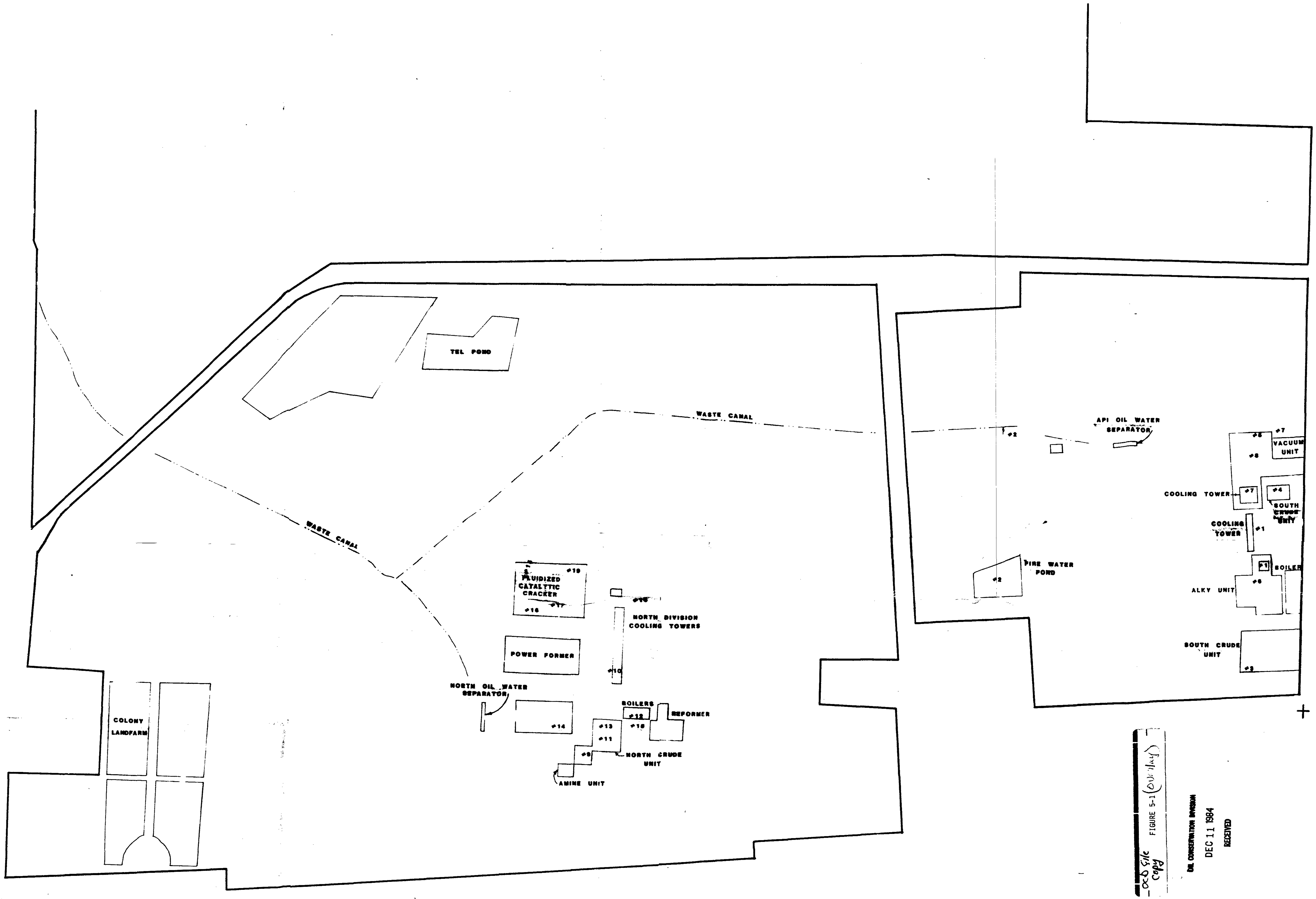
OIL CONSERVATION DIVISION
DEC 11 1984
RECEIVED

Geoscience Consultants, Ltd.

**LOCATION OF PROCESS UNITS AND DISCHARGE POINTS
OVERLAY FOR AERIAL PHOTOGRAPH**

CLIENT: Navajo Refining Company
DATE: [illegible]
DRAWN BY: Randall Hicks
CHECKED BY:
REVISED:
SCALE: 1:1000

Figure 5-1 (OCD File Copy)



OCD file copy

FIGURE 5-1 (overlay)

OIL CONSERVATION DIVISION
DEC 11 1984
RECEIVED

Geoscience Consultants, Ltd.

LOCATION OF PROCESS UNITS
OVERLAY FOR AERIAL

CLIENT: Navajo Refining Company
DATE: [illegible]
DRAWN BY: [illegible]
CHECKED BY:
REVISED:
SCALE: 1:1500

FIGURE 5-2 (Tech file copy)

FIGURE 5-2 (old file copy)

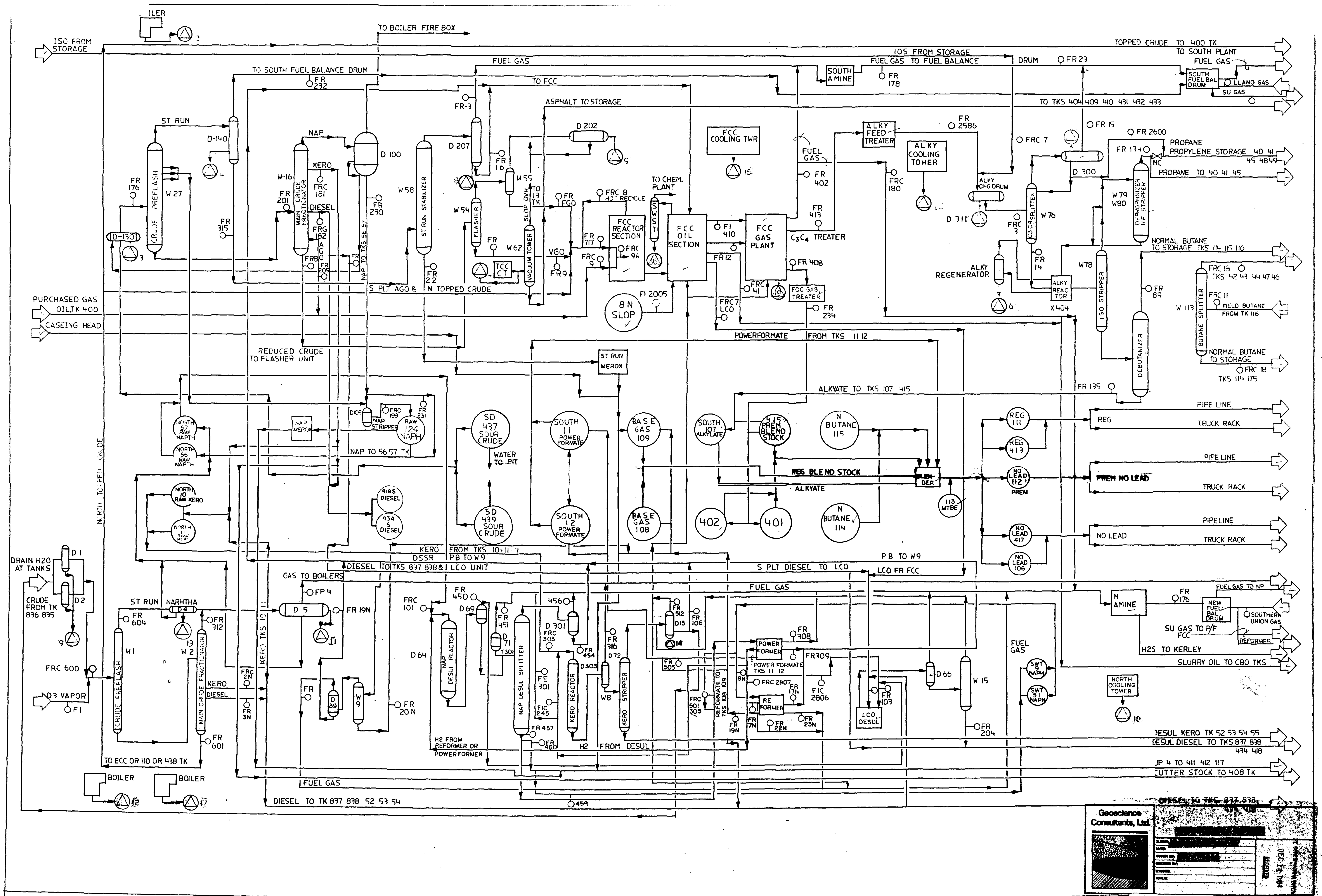

ISO FROM STORAGE
TO BOILER FIRE BOX
TOPPED CRUDE TO 400 TK
TO SOUTH PLANT
FUEL GAS
IOS FROM STORAGE
FUEL GAS TO FUEL BALANCE
DRUM
FR 23
SOUTH AMINE
FR 178
SOUTH FUEL BAL DRUM
LLANO GAS
SU GAS
TO SOUTH FUEL BALANCE DRUM
FR 232
TO FCC
ASPHALT TO STORAGE
TO TKS 404 409 410 431 432 433
ST RUN
D-140
NAP
D 100
D 207
D 202
CRUDE PREFLASH
W 27
FR 176
FR 315
D-130
MAIN CRUDE FRACTIONATOR
W-16
KERO
FRC 181
DIESEL
FRG 182
AGO
FR 209
FR 201
FR 230
NAP TO TKS 56 57
W 58
ST RUN STABILIZER
FR 22
W 54
FLASHER
W 55
TO 13 TK
SLOP OVH
W 62
VACUUM TOWER
TCC CT
VGO
FR 9
FR FGO
FR 717
FRC 9
FRC 8
HCO RECYCLE
FCC REACTOR SECTION
FRC 9A
TO CHEM. PLANT
SWST
FCC OIL SECTION
FI 410
FR 12
FCC GAS PLANT
FR 413
C_3C_4 TREATER
FR 408
FCC GAS TREATER
FR 234
FRC 7 LCO
FRC 41
FCC COOLING TWR
FUEL GAS
FR 402
ALKY FEED TREATER
FR 2586
ALKY COOLING TOWER
FRC 180
FRC 7
ALKY CHG DRUM
D 311
FR 15
FR 2600
FR 134
PROPANE
PROPYLENE STORAGE 40 41 45 4849
PROPANE TO 40 41 45
D 300
C3 C4 SPLITTER
W 76
W 79
W 80
DEPROPANIZER HF STRIPPER
ALKY REGENERATOR
ALKY REACTOR
X 404
W 78
ISO STRIPPER
NORMAL BUTANE TO STORAGE TKS 114 115 116
FRC 16
TKS 42 43 44 47 46
FRC 11
FIELD BUTANE FROM TK 116
W 113
BUTANE SPLITTER
DEBUTANIZER
FR 89
NORMAL BUTANE TO STORAGE
FRC 18
TKS 114 175
FR 135
PURCHASED GAS
OIL TK 400
CASEING HEAD
S PLT AGO & N TOPPED CRUDE
FI 2005
8 N SLOP
POWERFORMATE
FROM TKS 11 12
REDUCED CRUDE TO FLASHER UNIT
ST RUN MEROX
ALKYATE TO TKS 107 415
NORTH 57 RAW NAPTH
NORTH 56 RAW NAPTH
NAP MEROX
NAP STRIPPER
FRC 199
FR 231
RAW 124 NAPH
NAP TO 56 57 TK
SD 437 SOUR CRUDE
WATER TO PIT
SOUTH 11 POWER FORMATE
BASE GAS 109
SOUTH 107 ALKYLATE
415 PREM BLEND STOCK
N BUTANE 115
REG BLEND STOCK
BLENDER
ALKYATE
113 MTBE
REG 111
REG 413
NO LEAD 112 PREM
REG
PIPE LINE
TRUCK RACK
PREM NO LEAD
NORTH 10 RAW KERO
NORTH 11 RAW KERO
418S DIESEL
434 S DIESEL
SD 439 SOUR CRUDE
SOUTH 12 POWER FORMATE
BASE GAS 108
402
401
N BUTANE 114
NO LEAD 417
NO LEAD 106
NO LEAD
PIPELINE
KERO FROM TKS 10+11
DSSR PB TO W9
PB TO W9
DIESEL TO TKS 837 838 & LCO UNIT
S PLT DIESEL TO LCO
LCO FR FCC
FUEL GAS
N AMINE
FR 176
FUEL GAS TO NP
NEW FUEL BAL. DRUM
SOUTHERN UNION GAS
SU GAS TO P/F FCC
REFORMER
H2S TO KERLEY
SLURRY OIL TO CBO TKS
DRAIN H2O AT TANKS
D 1
D 2
CRUDE FROM TK 836 835
FRC 600
D3 VAPOR
FI
ST RUN
NARHTHA
D 4
FR 604
FR 312
W 1
W 2
CRUDE PREFLASH
MAIN CRUDE FRACTIONATOR
KERO
DIESEL
FR 601
FRC 2N
FR 3N
KERO TKS 10 11
GAS TO BOILERS
FP 4
D 5
FR 19N
D 39
W 9
FR 20 N
FRC 101
FR 450
D 69
D 64
NAP DESUL REACTOR
FR 451
D 71
T 301
NAP DESUL SPLITTER
456
D 301
FRC 303
FR 454
D 303
FE 301
FIC 245
KERO REACTOR
FR 316
D 72
W 8
KERO STRIPPER
FR 457
FR 460
H2 FROM REFORMER OR POWERFORMER
H2 FROM DESUL
FR 512
D 15
FR 106
FR 505
FRC 501 305
REFORMATE TO TKS 108 109
FR 19N
POWER FORMER
FR 308
POWER FORMATE TKS 11 12
FR 309
FRC 2807
FR 17N
FIC 2806
RE FORMER
FR 7N
FR 22N
FR 23N
LCO DESUL
FR 103
D 66
W 15
FR 204
FUEL GAS
SWT S NAPH
SWT S1 NAPH
NORTH COOLING TOWER
DESUL KERO TK 52 53 54 55
DESUL DIESEL TO TKS 837 838 434 418
JP 4 TO 411 412 117
CUTTER STOCK TO 408 TK
DIESEL TO TKS 837 838 434 418
TO ECC OR 110 OR 438 TK
BOILER
FUEL GAS
DIESEL TO TK 837 838 52 53 54
459
NORTH TOPPED CRUDE
Geoscience Consultants, Ltd.
[redacted]
DEC 11 1984

FIGURE 5-2

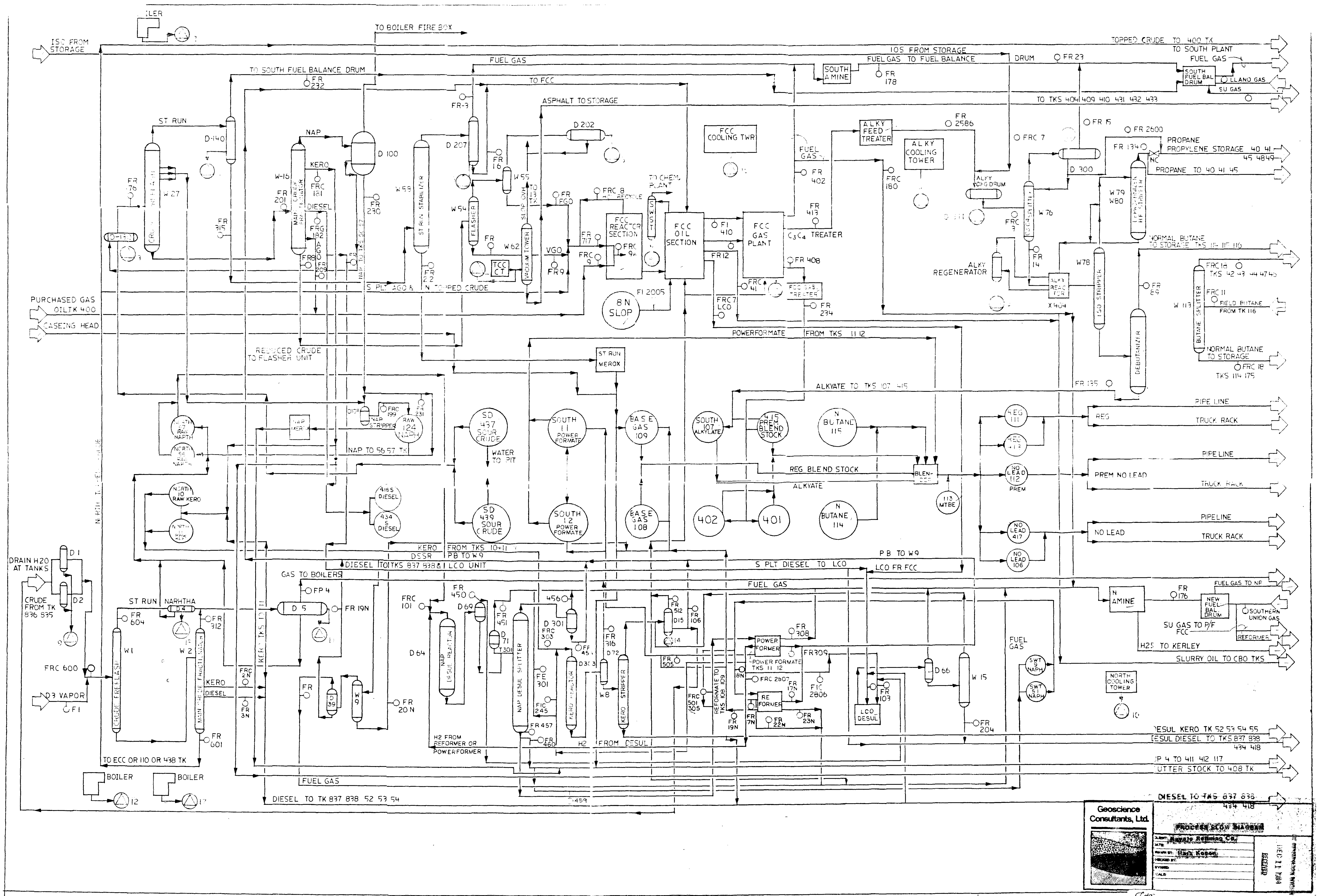


FIGURE 5-2 (OCD file copy)

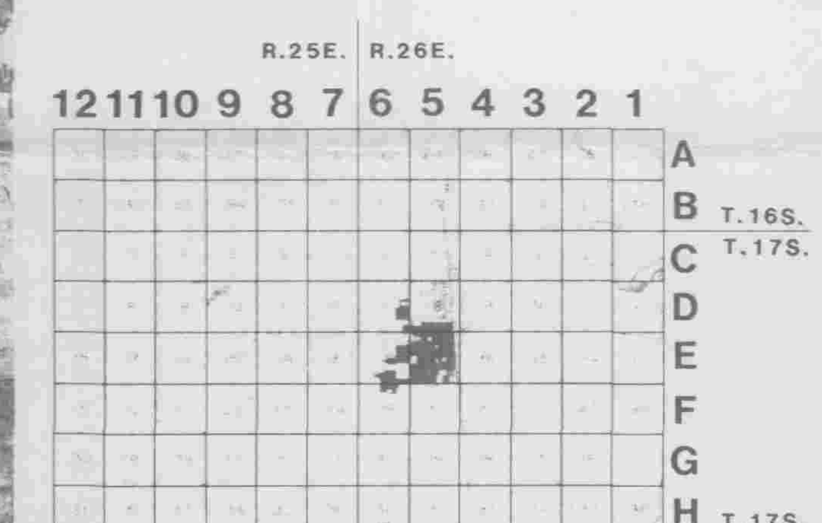
N

NOMINAL NORTH

SCALE IN FEET

200 100 0 200 400 600

NOMINAL SCALE : 1"=200'



EAGLE CREEK & 3 MILE DITCH

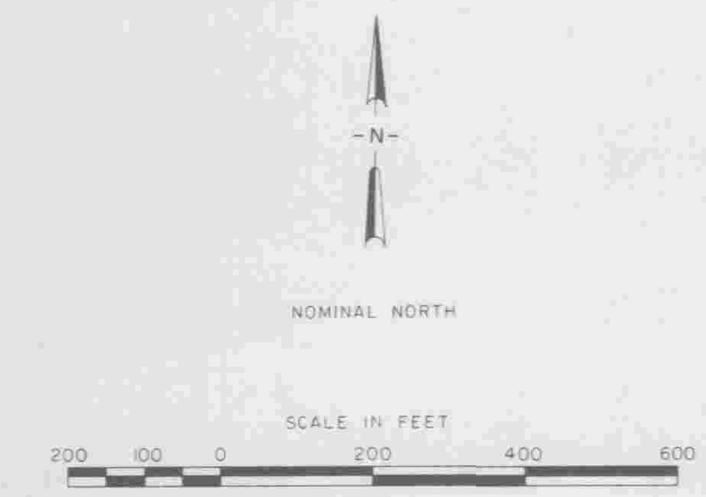
SAMPLE LOCATION MAP

NAVAJO REFINING CO.

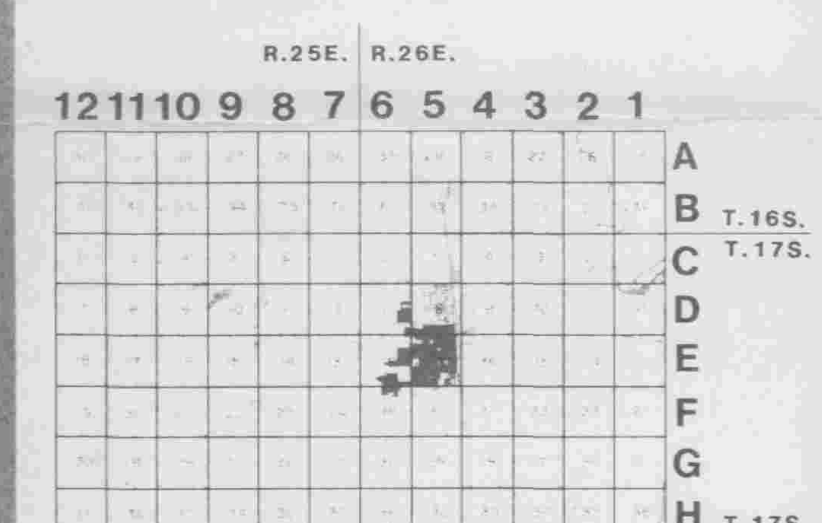
ARTESIA EDDY COUNTY NEW MEXICO

PREPARED FOR MARIAH ASSOCIATES
BY McFARLAND ENGINEERING

RFI DRAWING NO. 1	JOB NO. 90149	DATE SEPT. 1990	90-33-D-1



NOMINAL SCALE : 1"= 200'



EAGLE CREEK & 3 MILE DITCH
TRUCK BYPASS LANDFARM

SAMPLE LOCATION MAP

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

PREPARED FOR MARIAH ASSOCIATES
BY McFARLAND ENGINEERING

RFI DRAWING NO. 2	JOB NO. 90149	DATE SEPT. 1990	90-33-D-2

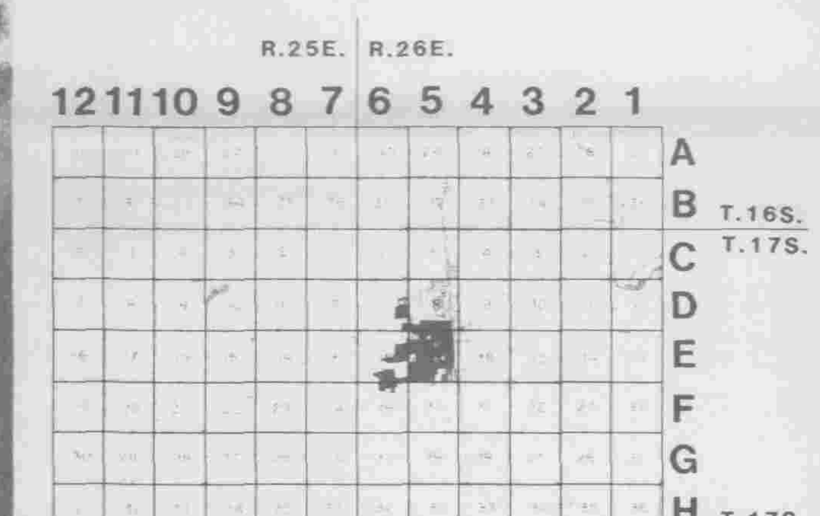
N

NOMINAL NORTH

SCALE IN FEET

200 100 0 200 400 600

NOMINAL SCALE : 1"= 200'



EAGLE CREEK & 3 MILE DITCH

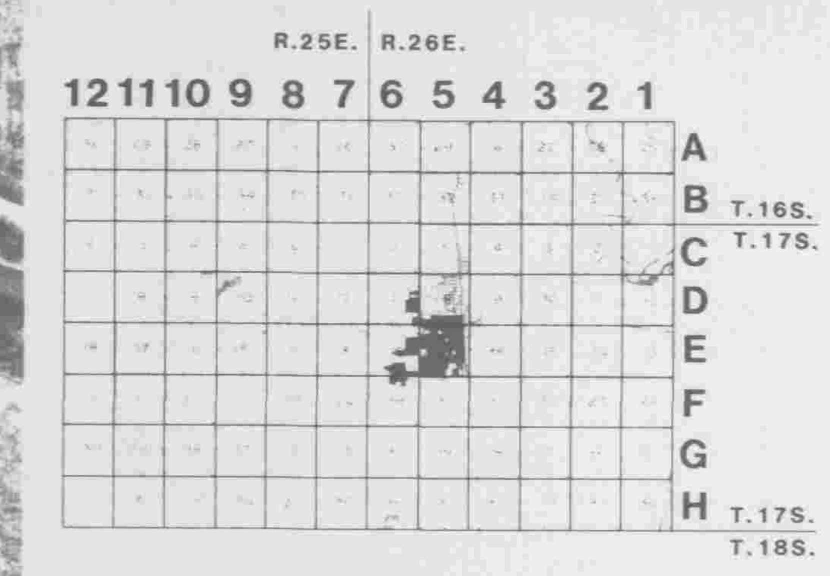
SAMPLE LOCATION MAP

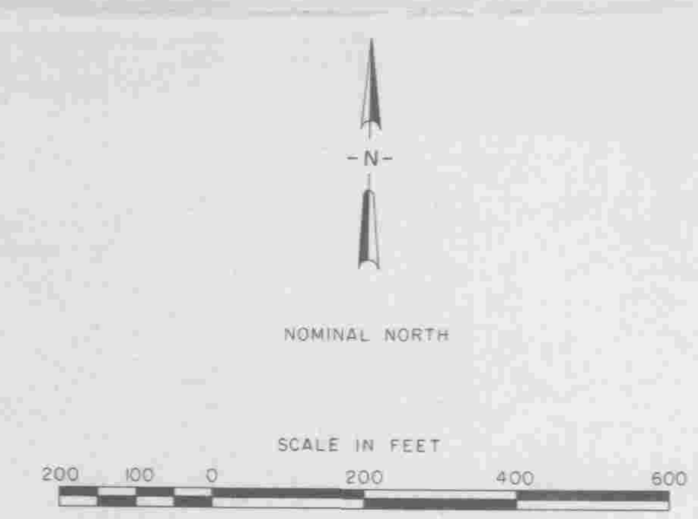
NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

PREPARED FOR MARIAH ASSOCIATES
BY McFARLAND ENGINEERING

RFI DRAWING NO.	JOB NO.	DATE	
3	90149	SEPT. 1990	90-33-D-3





NOMINAL SCALE : 1"=200'

EAGLE CREEK & 3 MILE DITCH

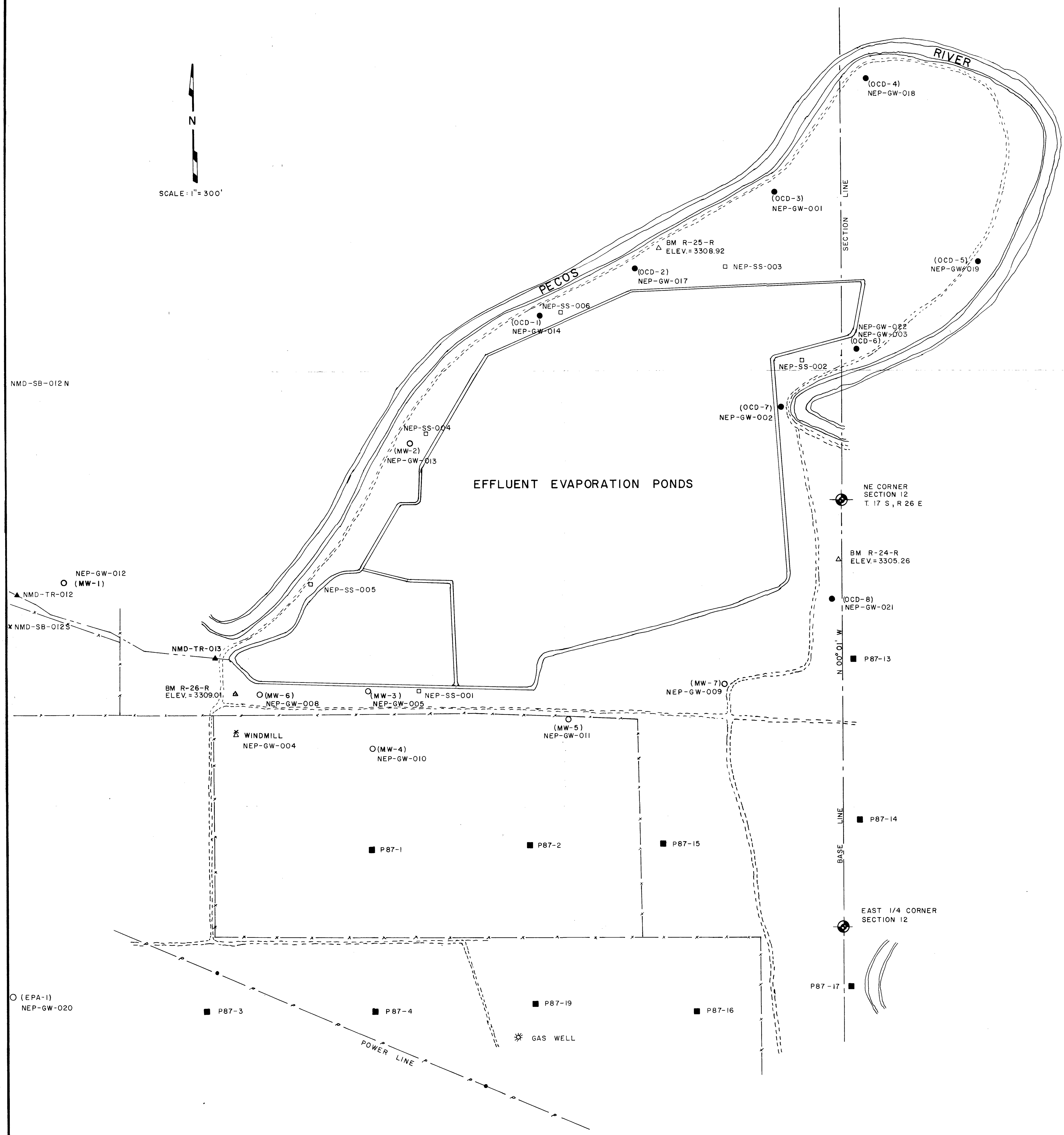
SAMPLE LOCATION MAP

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

PREPARED FOR MARIAH ASSOCIATES
BY McFARLAND ENGINEERING

RFI DRAWING NO. 4	JOB NO. 90149	DATE SEPT. 1990	90-33-D-4



NOTE: ELEVATIONS ON WELLS ARE FROM U.S.G.S. B.M. AT RAILROAD DEPOT IN ARTESIA. THEY ARE 0.40 FEET HIGHER THAN THE U.S.B.R. ELEVATIONS SHOWN ON R-24-R, R-25-R, AND R-26-R.

EVAPORATION PONDS

SAMPLE LOCATION MAP

NAVAJO REFINING CO.

ARTESIA EDDY COUNTY NEW MEXICO

PREPARED FOR MARIAH ASSOCIATES

BY McFARLAND ENGINEERING

RFI DRAWING NO. 5	JOB NO. 90149	DATE SEPT. 1990	10-32-D-5

N. R

HICKS – HOGBACK UNIT
EPA TRIP
3/22/88

HICKS - HOGBACK UNIT
EPA TRIP
3/22/88

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LIST OF APPENDICES

1.0 EXECUTIVE SUMMARY

1.1 PURPOSE

Mariah Associates, Inc. (Mariah) conducted the Resource Conservation Recovery Act (RCRA) facility investigation (RFI) Phase I for Navajo (Navajo) Refining Company, a petroleum refinery located in Artesia, New Mexico. The RFI encompassed three solid waste management units on the refinery site: 1) the Truck Bypass Landfarm, 2) the Three-Mile Ditch and Eagle Creek, and 3) the evaporation ponds. The purpose of the Navajo RFI Phase I was to determine the nature and extent of hazardous waste or constituent releases from solid waste management units (SWMUs) and to provide rationale for proposal of a RFI Phase II investigation.

1.2 SITE DESCRIPTION/HISTORY

Navajo operates a petroleum refinery on the eastern edge of Artesia, New Mexico. The plant facilities are in the W½ of Section 9, Township 17 South, Range 26 East. The refinery has been in operation for approximately 50 years and had several previous owners. Primary products include gasoline, diesel fuel, aviation fuels, and paving asphalts. The current production level is approximately 40,000 barrels per day.

The Truck Bypass Landfarm SWMU is approximately three acres in plan and is located adjacent to East 5th Street, immediately east of the central part of the refinery facility. Landfarm operations began in 1980. Nonhazardous solid wastes being deposited at the landfarm include unleaded tank bottoms (40 tons/year), separated wastewater and spilled hydrocarbons (80 tons/year), and hydrocarbon contaminated materials (40 tons/year). The landfarm is partially surrounded by a 1.5-ft dike to prevent surface water runoff. The landfarm site is immediately underlain by silty loams of moderately slow permeability. Shallow ground water occurs in 0.5-4.0-ft thick saturated zones approximately 12-25 feet below land surface (BLS). Ground water flows in an easterly direction.

Eagle Creek is an ephemeral stream that courses east through the refinery facility, approximately three miles to the Pecos River. To convey process wastewater to the evaporation pond complex, Navajo and its predecessors operated an unlined effluent ditch (Three-Mile Ditch), which parallels Eagle Creek for approximately 2.5 miles before turning south to the evaporation ponds. Use of the ditch was discontinued in 1987 when Navajo installed a polyethylene pipeline for wastewater discharge.

Refinery sludges that accumulated at the base of Three-Mile ditch were periodically removed and placed on the berms along either side. The creek and ditch traverse flat, irrigated croplands. Gradients are slightly lower on the eastern end where they enter the Pecos River floodplain. The ditch and creek are situated on silt, silty clay, and sandy loams which are moderately permeable and have high water-holding capacity. The shallow ground water table varies from approximately five to 10 ft BLS, and flow is generally eastward.

The evaporation pond complex is approximately three miles east of the facility, directly adjacent to the Pecos River. Historically, process wastewater was conveyed through Three-Mile Ditch and discharged to pond #1. Use of the pond #1 was discontinued in September 1987. The current pond complex has a surface area of approximately 85 acres; the inactive pond #1 covers approximately 16 acres. The evaporation ponds are unlined, contained by 10 ft high earthen dikes, and constructed on the Pecos River floodplain in soils of low to moderate permeability. The shallow ground water table is approximately six feet BLS, and flow is generally southward except where mounding is expected from local, pond influenced recharge.

1.3 INVESTIGATION SYNOPSIS

Soil, stream sediment, surface water, and ground water samples were collected from areas potentially affected by releases from each SWMU. Samples were analyzed by Professional Services Industries Laboratory in Deerfield, Texas, according to an analytical scheme specified in the Navajo RFI (Phase I) Work Plan.

The environmental setting for each SWMU was determined through the review of previous studies augmented by field observations and the analysis of physical data obtained in this study. Historical water quality results were synthesized and reviewed to identify past problems and document trends.

Specific tasks undertaken during the field investigation of each SWMU are summarized below:

Truck Bypass Landfarm SWMU

- Collection and description of samples from 12 10-ft deep soil borings
- Collection of ground water samples, measurement of physical parameters, and water levels from six monitor wells

Three-Mile Ditch/Eagle Creek SWMU

- Collection of soil samples, description, and monitoring of organic vapor levels in 15 regularly spaced backhoe trenches along Three-Mile Ditch
- Collection and description of samples from five shallow background soil borings
- Collection of ground water samples, measurement of physical parameters, and water levels from five monitor wells
- Collection of surface water samples and measurement of physical parameters at five sites along Eagle Creek

- Collection and description of stream sediments at five sites along Eagle Creek

Evaporation Ponds SWMU

- Collection and description of six surface soil samples near the ponds perimeter
- Installation and description of one background monitor well
- Collection of ground water samples, measurement of physical parameters, and water levels from 16 monitor wells
- Measurement of water levels in three shallow piezometers
- Determination of aquifer characteristics via slug tests on five monitor wells

1.4 FINDINGS

Results from this study, judged to represent significant environmental impacts, are listed below.

1) Monitor wells near the Truck Bypass Landfarm contain up to four feet of floating product. since this plume has been documented upgradient of the landfarm, it is unlikely that landfarm operations significantly degrade water quality.

2) Samples from three monitor wells adjacent to Three-Mile Ditch contain high levels of chromium and lead (0.10, 2.27, 3.99 mg/l chromium and 1.83 mg/l lead). Shallow ground water quality appears to be significantly degraded due to releases from nearby ditch sludges. Visually contaminated soils were present at or below the water table in several trenches.

3) Selected ground water samples from the evaporation pond area contain low-level metals anomalies (nine) from 0.1 to .23 mg/l arsenic, (one) 0.117 mg/l lead, (one) 0.13 mg/l nickel and two from 0.18 to 1.0 mg/l chromium. Low-level concentrations 11-41 ug/l) of the volatile compounds benzene, toluene, ethyl benzene, xylene, and 2-hexanone were also found in samples from five monitor wells.

4) One of five sediment samples collected from Eagle Creek contained a significant lead concentration (69.3 mg/kg lead).

5) Soil samples collected from the Truck Bypass Landfarm record no significant impact below four feet except for one sample (NLF-SB-011-04) which contains low levels of various volatile and semivolatile compounds.

Shallow ground water evaluated in this study generally is of poor quality (high TDS). No public drinking water source is endangered because the potable aquifer is at depth with considerable artesian head. The shallow aquifer in the area of the refinery and along the ditch is not used for any known purpose. The shallow aquifer in the area of the evaporation ponds is used only on a limited basis for the watering of stock.

2.0 SITE BACKGROUND

2.1 INTRODUCTION

Navajo operates a 40,000 barrel per day petroleum refinery on the eastern edge of Artesia, New Mexico (Plates 1 and 2, Figure 2.1). Primary products include gasoline, diesel fuel, aviation fuels, and paving asphalts. Process water is obtained from wells completed in the San Andres aquifer. The plant facilities are located in the W 1/2 of Section 9, Township 17 South, Range 26 East. Refinery wastewater once flowed through a conveyance ditch which crossed Sections 9, 10, 11, 2, and 12, T17S, R26E; was discharged to evaporation ponds in Sections 1 and 12, T17S, R26E; and was discharged to evaporation ponds in Sections 1 and 12, T17S, R26E, and the SW 1/4 of Section 1, T17S, R27E. The use of the conveyance ditch was discontinued in September 1987, when Navajo completed the construction of a primary wastewater treatment plant and effluent pipeline. The evaporation ponds now receive approximately 650,000 gallons per day of treated wastewater through the effluent pipeline.

Artesia has an elevation of 3370 ft above mean sea level (amsl). The surrounding area is used mainly for farming and ranching. The major crops are cotton, alfalfa, and pecans. Most farms are heavily irrigated.

2.2 PURPOSE AND SCOPE

The Navajo refinery (U.S. Environmental Protection Agency [EPA] ID No. NMD 048918817) located in Artesia, New Mexico, is regulated under the RCRA and the Hazardous and Solid Waste Amendments (HSWA). One of the major provisions of HSWA (Section 3004-6) requires corrective action for releases of hazardous waste

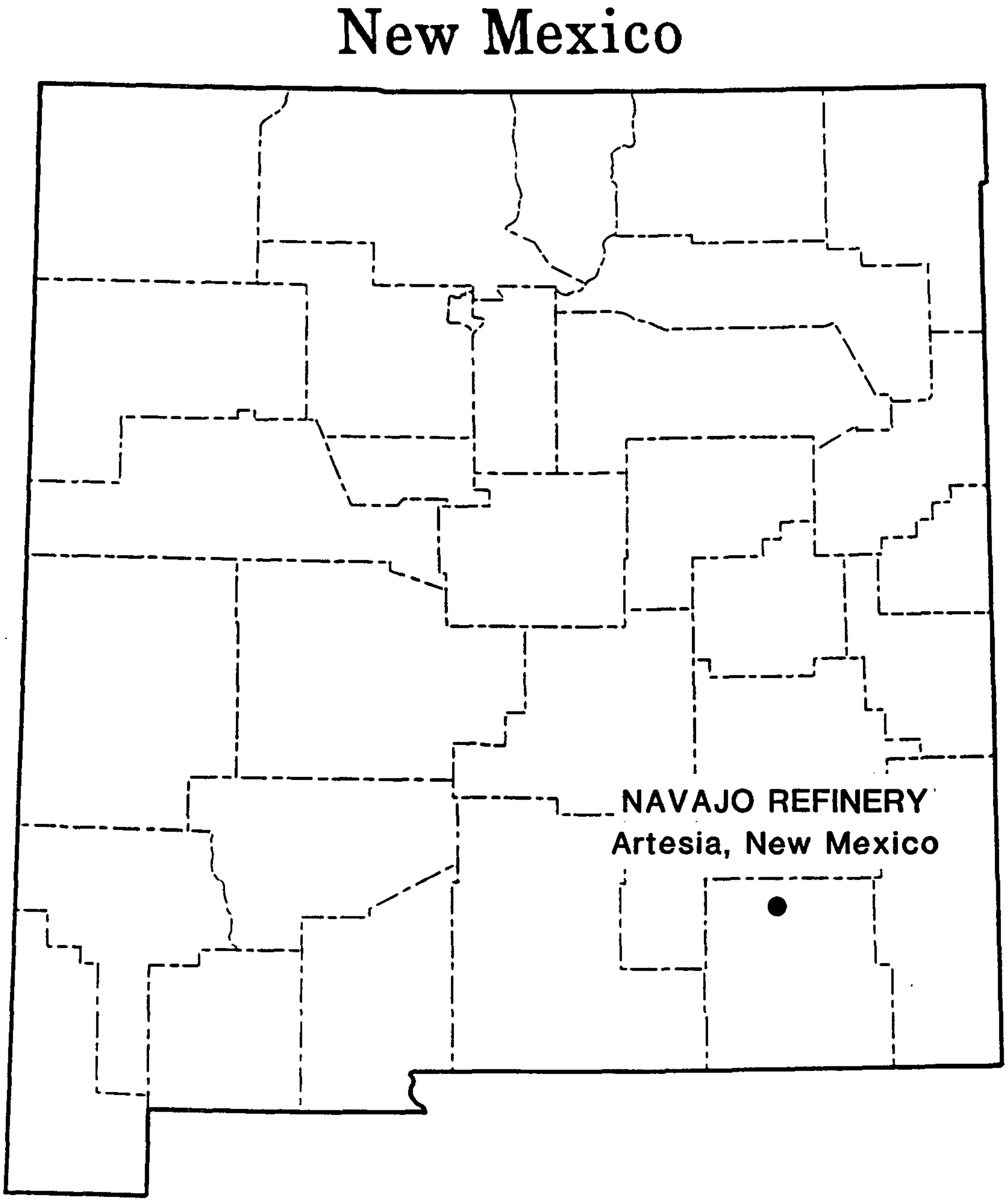


Figure 2.1 Site Location Map, RFI Phase I Report, Navajo Refining Company, October 1990.

or constituents from SWMUs which are suspected to be sources of releases to the environment. The EPA conducted a Preliminary Review (PR) of all SWMUs at the Navajo refinery. Based on that review and additional information, the EPA determined that an RFI on SWMUs at the facility was necessary. The purpose of the RFI Phase I investigation was to determine the nature and extent of releases of hazardous waste or constituents from SWMUs identified in the permit and to provide the rationale for proposing the RFI Phase II.

Soil, stream sediment, surface water, and ground water samples were collected from areas potentially affected by releases from each SWMU. Samples were analyzed by Professional Services Industries Laboratory in Deerfield, Texas, according to an analytical scheme specified in the Navajo RFI (Phase I) Work Plan. Analytical parameters and contract required detection limits (CRDLs) are listed in Tables 2.1-2.4. EPA or Work Plan specified protocol was followed for sampling and analysis except where noted.

The environmental setting for each SWMU was determined through the review of previous studies augmented by field observations and the analysis of physical data obtained in this study. Historical water quality results were synthesized and reviewed to identify past problems and document trends.

Specific tasks undertaken during the field investigation of each SWMU are summarized below:

<u>Truck Bypass Landfarm SWMU</u>

- Collection and description of samples from 12 10-ft deep soil borings
- Collection of ground water samples, measurement of physical parameters, and water levels from six monitor wells

Table 2.1 Volatile HSL Analytical Parameters, EPA Method 8240, RFI Phase I Report, Navajo Refining Company, October 1990.

Compound	Rpt Limit Solids mg/kg	Rpt Limit Water ug/l
Chloromethane	0.3	10
Bromomethane	0.3	10
Vinyl chloride	0.3	10
Chloroethane	0.3	10
Dichloromethane	0.3	10
Acetone	0.3	10
Carbon disulfide	0.3	10
1,1-Dichloroethene	0.3	10
1,1-Dichloroethane	0.3	10
2-Butanone	0.3	10
Trans-1,2-dichloroethene	0.3	10
Chloroform	0.3	10
1,2-Dichloroethane	0.3	10
1,1,1-Trichloroethane	0.3	10
Carbon tetrachloride	0.3	10
Bromodichloromethane	0.3	10
1,2-Dichloropropane	0.3	10
Vinyl acetate	0.3	10
Cis-1,3-dichloropropene	0.3	10
Trichloroethane	0.3	10
Dibromochloromethane	0.3	10
1,1,2-Trichloroethane	0.3	10
Benzene	0.3	10
Trans-1,3-dichloropropene	0.3	10
2-Chloroethyl vinyl ether	0.3	10
Bromoform	0.3	10
2-Hexanone	0.3	10
4-Methyl-2-pentanone	0.3	10
Tetrachloroethene	0.3	10
1,1,2,2-Tetrachloroethane	0.3	10
Toluene	0.3	10
Chlorobenzene	0.3	10
Ethylbenzene	0.3	10
Styrene	0.3	10
Total xylenes	0.3	10

Table 2.2 Semivolatile HSL Analytical Parameters, EPA Method 8270, RFI Phase I Report, Navajo Refining Company, October 1990.

Compound	Rpt Limits Solids mg/kg	Rpt Limits Water ug/l
Acenaphthene	0.66	10
Acenaphthylene	0.66	10
Anthracene	0.66	10
Benzoic acid	3.30	10
Benzo(a)anthracene	0.66	10
Benzo(b)fluoranthene	0.66	10
Benzo(k)fluoranthene	0.66	10
Benzo(g,h,i)perylene	0.66	10
Benzo(a)pyrene	0.66	10
Benzyl alcohol	1.30	10
Bis(2-chloroethoxy)methane	0.66	10
Bis(2-chloroethyl)ether	0.66	10
Bis(2-chloroisopropyl)ether	0.66	10
Bis(2-ethylhexyl)phthalate	0.66	10
4-Bromophenyl phenyl ether	0.66	10
Butyl benzyl phthalate	0.66	10
4-Chloroaniline	1.30	20
2-Chloronaphthalene	0.66	10
4-Chloro-3-methylphenol	0.66	10
2-Chlorophenol	0.66	10
4-Chlorophenyl phenyl ether	0.66	10
Chrysene	0.66	10
Dibenz(a,h)anthracene	0.66	10
Dibenzofuran	0.66	10
Di-n-butyl phthalate	0.66	10
1,3-Dichlorobenzene	0.66	10
1,4-Dichlorobenzene	0.66	10
1,2-Dichlorobenzene	0.66	10
3,3-Dichlorobenzidine	1.30	20
2,4-Dichlorophenol	0.66	10
Diethylphthalate	0.66	10
2,4-Dimethylphenol	0.66	10
Dimethylphthalate	0.66	10
4,6-Dinitro-2-methylphenol	3.30	60

Table 2.2 (Continued).

Compound	Rpt Limits Solids mg/kg	Rpt Limits Water ug/l
2,4-Dinitrophenol	0.66	10
2,4-Dinitrotoluene	0.66	10
2,6-Dinitrotoluene	0.66	10
Di-n-octylphthalate	0.66	10
Fluoranthene	0.66	10
Fluorene	0.66	10
Hexachlorobenzene	0.66	10
Hexachlorobutadiene	0.66	10
Hexachlorocyclopentadiene	0.66	10
Hexachloroethane	0.66	10
Indeno(1,2,3-cd)pyrene	0.66	10
Isophorone	0.66	10
2-Methylnaphthalene	0.66	10
2-Methylphenol	0.66	10
4-Methylphenol	0.66	10
Naphthalene	0.66	10
2-Nitroaniline	3.30	60
3-Nitroaniline	3.30	60
4-Nitroaniline	3.30	60
Nitrobenzene	0.66	10
2-Nitrophenol	0.66	10
4-Nitrophenol	3.30	60
N-Nitrosodiphenylamine	0.66	10
N-Nitrosodipropylamine	0.66	10
Pentachlorophenol	3.30	60
Phenanthrene	0.66	10
Phenol	0.66	10
Pyrene	0.66	10
1,2,4-Trichlorobenzene	0.66	10
2,4,5-Trichlorophenol	0.66	10
2,4,6-Trichlorophenol	0.66	10

Table 2.3 Metals HSL Analytical Parameters, EPA 7000 Series, RFI Phase I Report, Navajo Refining Company, October 1990.

Constituent	Rpt Limit Solids mg/kg	Rpt Limit Water mg/l
Antimony	0.50	0.01
Arsenic		0.01
Barium		0.10
Beryllium	0.30	0.001
Cadmium	0.30	0.001
Lead	0.50	0.01
Mercury	0.05	0.001
Chromium	0.30	0.01
Nickel		0.01
Selenium	0.50	0.01
Silver	0.50	0.01
Zinc		0.01
Oil & Grease	0.01%	0.01%

Table 2.4 Inorganics Analytical Parameters, RFI Phase I Report, Navajo Refining Company, October 1990.

Constituent	Rpt Limit Water mg/l
Chloride	1.0
Sulfate	1.0
Bicarbonate	1.0
Fluoride	0.020

Three-Mile Ditch/Eagle Creek SWMU

- Collection of soil samples, description, and monitoring of organic vapor levels in 15 regularly spaced backhoe trenches along Three-Mile Ditch

- Collection and description of samples from five shallow background soil borings

- Collection of ground water samples, measurement of physical parameters, and water levels from five monitor wells

- Collection of surface water samples and measurement of physical parameters at five sites along Eagle Creek

- Collection and description of stream sediments at five sites along Eagle Creek

Evaporation Ponds SWMU

- Collection and description of six surface soil samples near the pond perimeter

- Installation and description of one background monitor well

- Collection of ground water samples, measurement of physical parameters, and water levels from 16 monitor wells

- Measurement of water levels in three shallow piezometers

- Determination of aquifer characteristics via slug tests on five monitor wells

2.3 PROCESS DESCRIPTION AND WASTEWATER CHARACTERISTICS

A petroleum refinery is a complex combination of interdependent operations engaged in separating crude molecular constituents, molecular cracking, molecular rebuilding, and solvent finishing to produce petroleum-derived products. Several distinct processes are utilized by the industry for refining crude petroleum and its fractionation products. An EPA survey of the petroleum refining industry, conducted during 1977, identified over 150 separate processes being used and many more process combinations that may be employed at any individual refinery.

Each process is a series of unit operations which cause chemical and/or physical changes in the feedstock or product. In the commercial synthesis of a single product from a single feedstock, there are sections of the process associated with the preparation of the feedstock, the chemical reaction, the separation of reaction products, and the final purification of the desired product.

At the Navajo facility in Artesia, New Mexico, the major refining processes are:

1) Crude oil fractionation (with vacuum fractionation)
2) Fluidized catalytic cracking
3) Alkylation
4) Reforming
5) Desulfurization

Associated with these processes are several auxiliary activities. These activities do not directly result in conversion of crude oil to product nor result in complex chemical changes in the product. Instead, they separate impurities from the feedstocks and products, or are required for other aspects of the operation and maintenance of refinery.

The auxiliary units are:

1) Boilers
2) Cooling towers
3) Storage tanks

4) Water purification and wastewater facilities

5) Desalting units

6) Drying and sweetening units

The North Division of the Navajo refinery processes New Mexico intermediate crude whereas the South Division processes sour crude. The Artesia facility can process a total of about 40,000 barrels of crude per day with the South Division producing about three-fourths of the total.

Each process or auxiliary unit operation has different water usages associated with it, and the nature and quantity of wastewater produced by the units vary according to the process involved. The final aqueous effluent of the Artesia refinery is a blend of process and auxiliary waste streams as well as some additional wastewater produced during general cleanup at the facility. The relative flow volumes from the different units are:

Cooling Towers	55%
Boiler Blowdown	20%
Desalter	13%
Process Units and Water Softener	12%

The total effluent discharge averages 1.0 cubic feet per second (cfs) or about 650,000 gallons per day (Navajo 1990).

A brief description of each process and its wastewater characteristics is provided below.

2.3.1 Crude Oil Fractionation

Fractionation serves as the basic refining process for the separation of crude petroleum into intermediate fractions of specific boiling point ranges. Fractionation is a thermal distillation process which, at the South Crude Unit, yields gas, straight run gasoline, naptha, kerosene, diesel, atmospheric gas oil, and reduced crude. Reduced crude is transferred to the associated vacuum unit where it is further fractionated into asphalt and vacuum gas oil.

In the North Crude Unit, where New Mexico intermediate crude is processed, the product streams consist of gas, straight run gasoline, naptha, kerosene, diesel, and topped crude. Wastewater produced from the crude units contains ammonia, sulfides, chlorides, oil, and phenols. All waste streams that have contacted crude or product (contact wastewater) and contain oil are routed to API oil-water separators located in the North and South plants, respectively. Once oil has been skimmed from the wastewater entering each of the respective API separators, the wastewater proceeds via pipeline to the refinery's wastewater treatment plant. Effluent from the wastewater treatment plant is then conveyed by pipeline to a series of evaporation ponds located approximately three miles from the refinery.

2.3.2 Fluidized Catalytic Cracking

A fluidized catalytic cracking process is employed at Navajo. Catalytic cracking involves at least four types of reactions:

1) Thermal decomposition
2) Primary catalytic reactions at the catalyst surface
3) Secondary catalytic reactions between the primary products
4) Removal of products which may be polymerized from further reactions by adsorption into the surface of a fluidized bed of catalyst as coke

The catalysts are in the form of powder for the fluidized unit. A catalyst is lifted into the reactor area by the incoming oil feed which, in turn, is vaporized upon contact. Vapors from the reactors pass up through a cyclone separator which removes most of the entrained catalyst. These vapors then enter the fractionator, where the desired products are removed and heavier fractions recycled to the reactor.

The major wastewater constituents resulting from catalytic cracking operations are oil, sulfides, phenols, cyanides, and ammonia. These produce an alkaline wastewater and high BOD and COD concentrations. Sulfide and phenol concentrations in the wastewater can be significant.

2.3.3 Alkylation

Alkylation is the reaction of an isoparaffin (usually isobutane) and an olefin (butylenes) in the presence of hydrofluoric acid as a catalyst at carefully controlled temperatures and pressures to produce a high-octane alkylate for use as a gasoline blending component. The reaction products are separated in a catalyst recovery unit, from which the catalyst is recycled. The hydrocarbon stream is passed through a caustic after going to the fractionation section.

The wastewater from the alkylation unit is an acidic solution containing some suspended solids, oil, dissolved solids, fluoride, and phenols. The waste stream is discharged to the neutralizing sewer and is treated to raise the pH prior to discharge to the API oil-water separator.

2.3.4 Reforming

Reforming converts low-octane naphtha to high-octane gasoline blending stock. At Navajo the reformers do not produce a waste stream. Feed stocks are hydrotreated to remove sulfur and nitrogen compounds prior to charging to the reformer since the extremely expensive platinum catalysts used in the unit are readily contaminated and ruined by the sulfur and nitrogen compounds. The predominant reaction during reforming is the dehydrogenation of naphthenes. Important secondary reactions are the isomerization, cyclization, and cracking of paraffins. All reactions result in high-octane products.

2.3.5 Desulfurization

Desulfurization is primarily used to remove sulfur compounds and other impurities from gasoline, kerosene, jet fuels, and diesel fuel. The wastewater typically consists of sulfidic compounds. This waste stream is routed to the oil-water separator.

2.3.6 Boilers

Steam is consumed throughout the refining process and is generated in boilers at the North and South Divisions. To assure proper operation of the boilers, a certain amount of boiler water must be discharged (blowdown) and treated water added as makeup.

2.3.7 Cooling Towers

Water used for cooling process streams throughout the facility is cooled by towers in both the North and South Divisions and comprises most of the water usage at the facility. A significant amount of water is lost by evaporation in the cooling towers resulting in an increased concentration of dissolved solids in the cooling water over time. Blowdown from cooling towers passes through the oil-water separators.

2.3.8 Storage Tanks

Storage of crude and product typically permits some separation of any water or suspended solids entrained in the fluid. These wastes, removed from the tank bottoms, contain emulsified oil, phenols, iron, sulfide, and other constituents depending upon the nature of the material stored in a particular tank. This liquid is removed to the oil-water separators by vacuum trucks. The volume of effluent from this source is very small.

2.3.9 Water Purification System

Pure water must be supplied to the boiler units as well as some process systems. Backwash from the purification system contains dissolved solids removed from the water supply system. The water purification system is basically a water softener and produces a periodic waste stream enriched in dissolved solids.

2.3.10 Desalters

All produced crude contains some formation (connate) water and suspended solids. Because southeast New Mexico crude is generally found in marine formation, this water is highly saline. Desalters remove the saline fluid and suspended solids from the crude by passing crude (with some added water) through an electrostatic field which acts to agglomerate the dispersed brine droplets.

Wastewater can contain high dissolved solids, phenols, (depending upon crude type), ammonia, and sulfides. This contact wastewater is discharged to the oil-water separator. This waste stream contributes significantly to the total effluent volume.

2.3.11 Washdown and Storm Water

A certain amount of wash water is intermittently utilized for general cleanup of the facility. This activity occurs within the concrete lined process areas. All areas drain to the wastewater treatment plant and into the pipeline to the evaporation ponds.

2.3.12 Produced Water from Oil Recovery System

In those oil recovery wells that produce water, the recovery system pumps water from below the oil-water interface to create a gradient so the oil will flow toward the skimmer pump in the trench. The produced water from the oil recovery system is discharged to the wastewater treatment plant.

3.0 ENVIRONMENTAL SETTING

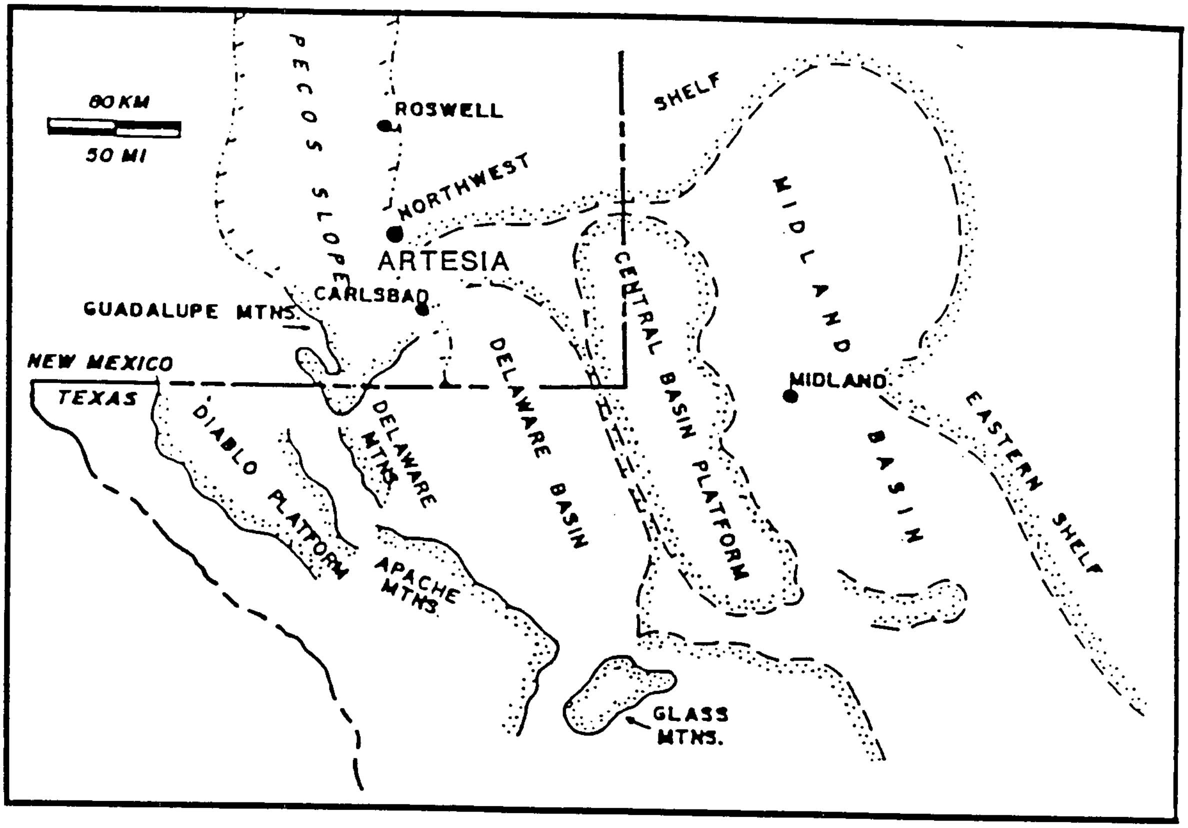
3.1 REGIONAL GEOLOGY

Most of the information contained in Section 3.0 is taken from previously published sources. Although the data are generally deemed reliable, it was beyond the scope of this investigation to validate such information as regional geology and the hydrogeologic conditions present below the first 25 ft of the site subsurface. Nevertheless, there appear to be sufficient data to serve as the foundation of this RFI. The text of this section was retrieved wholly from a hydrogeologic assessment report prepared by IT Corporation for Navajo with editing from Navajo and Mariah. Mariah accepts no responsibility for the interpretation presented herein.

The Navajo facility and the city of Artesia are located in southeast New Mexico on the Northwest Shelf of the Permian Basin, a large, sedimentary basin which developed primarily between Early Pennsylvanian and Late Permian time (Hiss 1975). Southeast of the Northwest Shelf, strata grade into the Permian Reef facies and farther south into the Delaware Basin (Figure 3.1).

Shelf deposits present in the Navajo refinery area consist of dolomite, siltstone, mudstone, limestone, and evaporites typical of a back reef sedimentary environment and have been named the Artesia Group, belonging to the Guadalupian Series (Kelley 1971). The Artesia Group consists of, in descending stratigraphic order, the Tansill, Yates, Seven Rivers, Queen, and Grayburg Formations (Table 3.1).

Underlying the Artesia Group, the Leonardian San Andres and Yeso Formations overlie Precambrian strata. Subsequent deposits have been removed by erosion in the vicinity of Artesia leaving the Artesia Group and a mantel of Quaternary deposits present at the



FROM: Ward, R.F. et al., 1986

Figure 3.1 Regional Geologic Provinces.

Table 3.1 General Stratigraphy of the Permian Basin.

Age	Formations and Members	Thick (ft)	Description
Holocene and Pleistocene	Assorted surficial deposits	0-300	Valley alluvium, terrace and pediment gravel, caliche soils, aeolian sand, traverine
Pleistocene-Pliocene	Gatuna Formation	0-200	Sandstone, sand gravel, siltstone, limestone, red, brown, tan, gray, yellowish
Oligocene	Sierra Blanca Volcanics	700-4,000	-- breccia and -- ; -- flows
Paleocene	Cub Mountain Formation	500-2,000	Sandstone, mudstone, conglomerate, arcose: white, buff, lavender, purple, maroon
Cretaceous	Mesa Verde Formation	500-1,500	Sandstone, shale, coal, conglomerate: buff, gray, black
	Mancos Shale	400-700	Shale, siltstone, with local thin sandstone and limestone: black, grayish-black
	Dakota Sandstone	100-150	Sandstone, conglomerate, black shale: gray to tan
Upper Triassic	Chinle Shale	0-300	Mudstone with some claystone and thin sandstone: reddish brown
	Santa Rosa Sandstone	0-300	Sandstone, conglomerate, mudstone: brown, buff, lavender
	Dewey Lake Formation	200-250	Sandstone, siltstone: orange-brown: commonly laminated
	Rusclar Formation: Upper Member	150-200	Dolomite, gypsum, mudstone, white, red-brown, green, gray, deep orange: magenta dolomite at base
	Lower Member	100-250	Dolomite, gypsum, mudstone, sandstone: white, red-brown, gray, green: salt in subsurface: Culabra dolomite at base
	Salado Formation	0-2,500	Gypsum, mudstone, thin local dolomite: white, red, brown, green, deep orange: breccia residue at surface, thick salt, potash in subsurface
	Castile Formation Upper Member* (surface)	1,000=	Gypsum, (anhydrite), salt: white, gray
	Lower Member (surface)	1,000=	Laminated gypsum (anhydrite) and limestone, laminated limestone, laminated gypsum: gray, black, white
	Tanall Formation	200-300	Dolomite and siltstone (south); dolomite, gypsum, and anhydrite (north); Ococillo -- tongue near exposed top
	Yates Formation	250-350	Siltstone, sandstone, dolomite, limestone and gypsum (south); gypsum, siltstone and thin dolomite (north)
	Seven Rivers Formation	450-600	Dolomite, siltstone (south); gypsum and siltstone (north)
	Queen Formation	200-400	Dolomite, siltstone (south); gypsum, red mudstone, dolomite (north): Shamrock member near top
	Grayburg Formation	250-450	Dolomite and sandstone (south); gypsum, mudstone, dolomite (north)
	San Andres Formation: Fourmile Draw Member	0-700	Dolomite, gypsum, reddish mudstone: sandstone locally at top: thin-bedded
	Bonney Canyon Member	0-300	Dolomite, local limestone: gray, light-gray, local black: thin-bedded
	Rio Bonito Member	250-350	Dolomite, limestone, sandstone (Glorieta): gray, brownish gray: thick-bedded
	Yeso Formation	0-1,400	Sandstone, siltstone, dolomite, gypsum: tan, red-yellow, gray, white
Precambrian	Svenite, --, and diabase		

* Delaware basin faces only
\+ Reef faces only

MODIFIED FROM KELLEY (1971).

site. Younger Ochoan sediments, primarily the Rustlen, Salado, and Castile Formations, crop out east and south of the area.

Structure contour maps developed by Kelley (1971) indicate a dip of the Northwest Shelf units eastward at approximately 50 to 60 ft per mile. Kelley (1971) recognized only two structural features in the vicinity of Artesia: the K-M fault and the Artesia-Vacuum Arch. The K-M normal fault, which Kelley (1971) inferred from subsurface structure contouring, is down-thrown on the southeast side a maximum of 200 ft. The fault trends north-east and passes about four miles northwest of Artesia. The Artesia-Vacuum Arch is a gentle anticline, trending east-northwest, which passes about six miles southeast of Artesia. The Arch is primarily a subsurface feature, seen only in the Chalk Bluff hills east of Artesia.

3.2 LOCAL GEOLOGY

3.2.1 Stratigraphy

The Navajo refinery is located on the Northwest Shelf of the Permain Basin (Figure 3.1). In this region, deposits are comprised of approximately 250 ft of Quaternary (and late Tertiary?) alluvium unconformably overlying approximately 2,000 ft of Permian clastic and carbonate rocks. These Permian deposits unconformably overlie Precambrian syenite, gneiss, and diabase crystalline rocks (Kelley 1971).

3.2.1.1 Surficial Soils

The Artesia region is located on a broad, gently sloping plateau that has developed as a result of in situ weathering of flat-lying carbonate and evaporatic bedrock. Localized areas of valley fill (Pecos River Valley and major arroyos) form the only other major substrate. Soil properties vary as a result of differing parent materials, grain size, land slope, and available moisture. Plates 2 and 3 show the distribution of soil types in the Artesia area.

3.2.1.2 Quaternary Alluvium

The Quaternary alluvium in the refinery area is comprised of clays, silts, sands, and gravels deposited in the Pecos River Valley (Welder 1983). These valley fill deposits extend in a north-south belt approximately 20 miles wide, generally west of the Pecos River. The thickness of the valley fill varies from a thin veneer on the western margins of the Pecos River Valley to a maximum of 300 ft in several depressions, one located beneath the refinery (Welder 1983). These depressions have resulted from dissolution of the underlying Permian carbonates and evaporates (Lyford 1973).

Lyford (1973) described the sedimentology and mineralogy of the valley fill deposits and, based on these descriptions, divided the valley fill into three units: the uppermost carbonate gravel unit, the interbedded clay unit, and the underlying quartzose unit.

Carbonate Gravel Unit

The carbonate gravel unit consists of coarse-grained carbonate gravel deposits along major tributaries to the Pecos River which grade into brown calcareous silts or caliche zones in the interstream region (Lyford 1973). The carbonate gravel unit includes the Lakewood, Orchard Park, and Blackdome terrace deposits of Fieldler and Nye (1933) as well as Holocene and Pleistocene Pecos River alluvial deposits. The Lakewood terrace is comprised of Holocene deposits of brown silt interbedded with lenses of gravel and sand. The Lakewood terrace is confined to the area immediately adjacent to the river and rises approximately 20 to 30 ft above the present Pecos River floodplain with a maximum thickness of 50 ft (Morgan 1938). The Lakewood terrace is underlain by Pleistocene "younger" alluvium deposited by the Pecos River and its tributaries (Hendrickson and Jones 1952). The younger alluvium is approximately 40 ft thick beneath the Lakewood terrace and decreases to a five- to 20-ft thick veneer on the flanks of the river valley where it overlies the Pleistocene Orchard Park and Blackdom terraces (Hendrickson and Jones 1952).

The Orchard Park terrace is generally less than 20 ft thick in the refinery area and is comprised of silt interbedded with poorly sorted lenses of pebbles in a silt and sand matrix. Caliche commonly occurs in the upper layers (Morgan 1938). The terrace surface gently rises between five and 25 ft in elevation above the Lakewood terrace (Kelley 1971). The Blackdom terrace is about 30 to 60 ft in elevation above the Orchard Park terrace (Hendrickson and Jones 1952). However, the deposits associated with the Blackdom terrace are generally less that 20 ft thick. The Blackdom terrace deposits are coarser-grained than the deposits associated with the Orchard Park and Lakewood terraces (Morgan 1938). In addition, the caliche soils have a higher density than those developed on the Orchard Park terrace (Kelley 1971). The primary refinery operations are immediately underlain by a thin veneer of young alluvium overlying the Orchard Park terrace deposits.

Clay Unit

The clay unit described by Lyford (1973) is not laterally continuous throughout the valley fill deposits but occurs in isolated lenses overlying the quartzose unit. The clay unit is comprised of light to medium gray clays and silts deposited in localized ponds and lakes. These ponds and lakes may have formed in conjunction with dissolution and collapse of the underlying Permian rocks (Lyford 1973).

Quartzose Unit

The quartzose unit consists primarily of fragments of quartz and igneous rocks cemented by calcium carbonate (Lyford 1973). This unit is laterally continuous throughout the Pecos River Valley and is generally less than 250 ft thick. The quartzose unit unconformably overlies Permian rocks and is correlative with the quartzose conglomerate of Fieldler and Nye (1933) and Morgan (1938).

3.2.1.3 Permian Artesian Group

The Permian Artesian Group is comprised of five formations -- in descending order, the Tansill, Yates, Seven Rivers, Queen, and Grayburg Formations (Table 3.1; Kelley 1971). The Tansill, Yates, and Seven Rivers Formations are not present in the subsurface beneath the refinery (Welder 1983). Reports prepared by various contractors for Navajo have discrepancies regarding the presence and depth to the Permian sediments of the Seven Rivers and Queen Formations. Geoscience Consultants, Ltd. (1984) states that the Seven Rivers Formation is 15 to 20 ft below the surface at the Navajo refinery; no data are provided in this report to support this conclusion. Kinney (1985) states that the subsurface, below a 15- to 20-ft thick soil layer, under Artesia is the lower half of the Seven Rivers Formation; no data are provided in this report to support this conclusion. Geoscience Consultants, Ltd. (1987) again reports the Seven Rivers Formation at depth in the refinery area. A thorough evaluation of all available borehole logs, in this review, provided no evidence that the Seven Rivers Formation is present (at any depth) beneath the refinery. All lithologic logs of wells completed in the refinery area describe unconsolidated alluvial materials to depths of 200 to 250 ft. Morgan (1938) reviewed lithologic logs and concluded that the valley fill under Artesia extends to a depth of about 200 ft. Lyford (1973), based on microscopic examination of drill cuttings from water and oil wells in the area, also concluded that the valley fill extends 200 to 250 ft below the Artesia area.

Queen Formation

The Queen Formation was named by Crandall (1979) from exposures near Queen in the Guadalupe Mountains, which conformably overly the Grayburg Formation. Lithologies of the Queen Formation are similar to those of the Grayburg Formation with the principal difference being a higher proportion of clastics in the Queen. The Queen Formation ranges from 200 to 400 ft thick and is a time equivalent of the Goat Seep and Cherry Canyon Formations.

Grayburg Formation

The Grayburg Formation, named by Dickey (1940) for a location along the Huapache monocline and in the adjoining Guadalupe Mountains, consists primarily of very light tan dolomite and calcareous dolomite with interstratified fine-grained sandstone. The formation grades northward into dolomite, gypsum, and mudstone (Kelley 1971). The Grayburg Formation grades conformably into the overlying Queen Formation and is thought to disconformably overlie the San Andres Formation.

3.2.1.4 Permian San Andres Formation

The oldest of the Permian units discussed in this report is the San Andres Formation. According to Kinney (1968) the upper portion of the formation is composed of oolitic dolomite with some anhydrite cement. However, Kelley (1971) describes the upper member of the San Andres Formation, the Four-mile Draw Member, as having increasing amounts of gypsum in separate lenses or beds, and pods or nodules in dolomite north of about T21S, R21E (approximately four miles south and six miles west of Artesia). The deep well lithologic logs from the refinery area (Appendix C;

State Engineer's Office [SEO] numbers) indicate that the San Andres Formation is primarily carbonate (logged by drillers as lime or lime-rock) and probably includes limestone and dolomite. The San Andres Formation in Eddy County is approximately 1,100 ft thick (Hendrickson and Jones 1952).

3.2.2 Structure

The refinery is underlain by a gentle eastward dip of the Permian formations. However, no other major structural features have been reported in the refinery area by workers such as Kelley (1971), Lyford (1973), and Welder (1983).

Kinney (1985) inferred the presence of two faults from subsurface data, the first located at the refinery northwest of Eagle Draw and the second located near the Pecos River. Kinney (1985) postulated the presence of one fault based on the orientation of Eagle Draw; an evaluation of the drill hole logs, in this review, provided no evidence to support a fault in that area.

Kinney (1985) inferred a second fault east of the refinery area near the Pecos River, underlying Sections 11, 12, and 14, and this fault is referenced by Geoscience Consultants, Ltd. (1984, 1987). In both Geoscience reports, the fault has been inferred from subsurface data. However, the subsurface data were not presented in either report and therefore could not be evaluated. Evaluation of the structural contour maps of the Permian units presented by Welder (1983) and the lithologic logs of wells in the refinery area, in this review, provided no evidence of a fault in that location.

3.3 REGIONAL HYDROGEOLOGY

Ground water, in useful volumes, occurs primarily in two hydrologic units within the Permian Basin: an artesian aquifer occurring in the Grayburg and San Andres Formations, and a shallow alluvial water table aquifer occurring in Quaternary deposits (Welder 1983). The intervening units of the Grayburg, Queen, and Seven Rivers Formations make up the primary confining system separating the aquifers. This confining unit ranges in thickness from zero to over 1,000 ft throughout the region.

Extensive use of ground water in this region has caused significant lowering of potentiometric levels in both aquifers. Welder (1983) reports that hydrostatic head levels in the artesian aquifer decreased up to 230 ft between 1905 and 1975. Head levels in the shallow valley fill aquifer declined over 120 ft between 1938 and 1975. Each of the aquifers provides a source of water for domestic and agricultural development in the Artesia area. Of the 377,851 acre-feet of water produced from the two aquifers in 1978, 95 percent was utilized by agriculture, four percent for domestic use, and one percent for industrial activities.

3.3.1 Shallow Valley Fill Aquifer

The shallow valley fill aquifer system is generally composed of gravel, sand, silt, and clay associated with alluvial deposits and is approximately 150 to 250 ft thick in the vicinity of Artesia, New Mexico. At the Pecos River, water occurs in this aquifer at a depth of approximately five to 35 ft below the surface (approximately 3300 ft amsl). Recharge of the shallow valley fill aquifer is generally attributed to irrigation return flow from pumpage in both the shallow valley fill and the artesian aquifers, and from infiltration from the Pecos River. Minor recharge is thought to occur from precipitation and upward leakage through the confining zone from the artesian aquifer (Welder 1983).

The upper surface of the shallow valley fill aquifer is the water table. The lower limit of the aquifer is the top of the confining unit separating the artesian aquifer. The confining unit in the vicinity of Artesia is estimated to be 350 to 400 ft thick (Welder 1983). Ground water flow in the shallow valley fill aquifer is variable around pumping centers and in the vicinity of the Pecos River; however, water generally flows in a south-southeast direction around Artesia (Welder 1983).

Water quality in the shallow valley fill aquifer is generally poorer than in the artesian aquifer with concentrations of total dissolved solids in many wells exceeding 16,000 milligrams per liter (mg/l). East of the refinery in the vicinity of the evaporation ponds and Pecos River, the shallow valley fill aquifer occurs within five feet of the surface. Water quality in the shallow valley fill is highly variable as shown in Figure 3.2. Water quality appears to be related to proximity to the Pecos River with higher dissolved chloride concentrations occurring in wells near the river. Chloride, calcium, and sulfate provide the primary constituents.

3.3.2 Artesian Aquifer

The artesian aquifer occurs approximately 750 ft below the land surface in the vicinity of Artesia, New Mexico, and is approximately 350 to 400 ft thick. Water in this aquifer is generally associated with the San Andres Formation; however, water-bearing strata in the Grayburg Formation also contribute to the system (Welder 1983).

Potentiometric elevations in the artesian aquifer in the vicinity of Artesia occur at approximately 3305 to 3320 ft amsl, or five to 50 ft below the ground surface (Figure 3.3). Historically, flowing artesian wells were common in the aquifer; however, only a few wells currently flow naturally. Recharge of the artesian aquifer is thought to be primarily from infiltration of precipitation and intermittent streambed leakage on outcrop portions of the aquifer (Welder 1983). Ground water flow in the

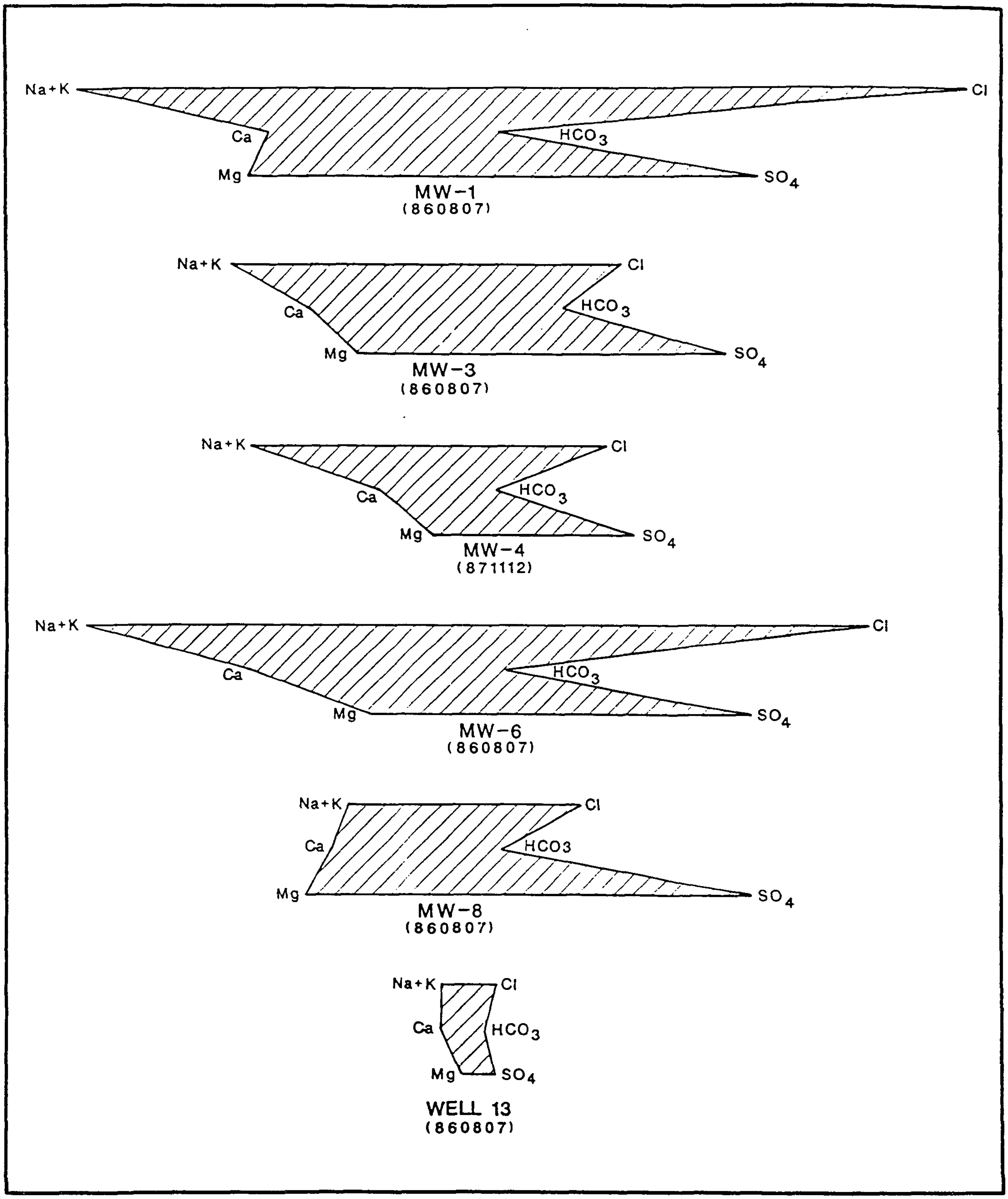


Figure 3.2 Shallow Valley Fill Aquifer Water Quality, Stiff Diagrams.

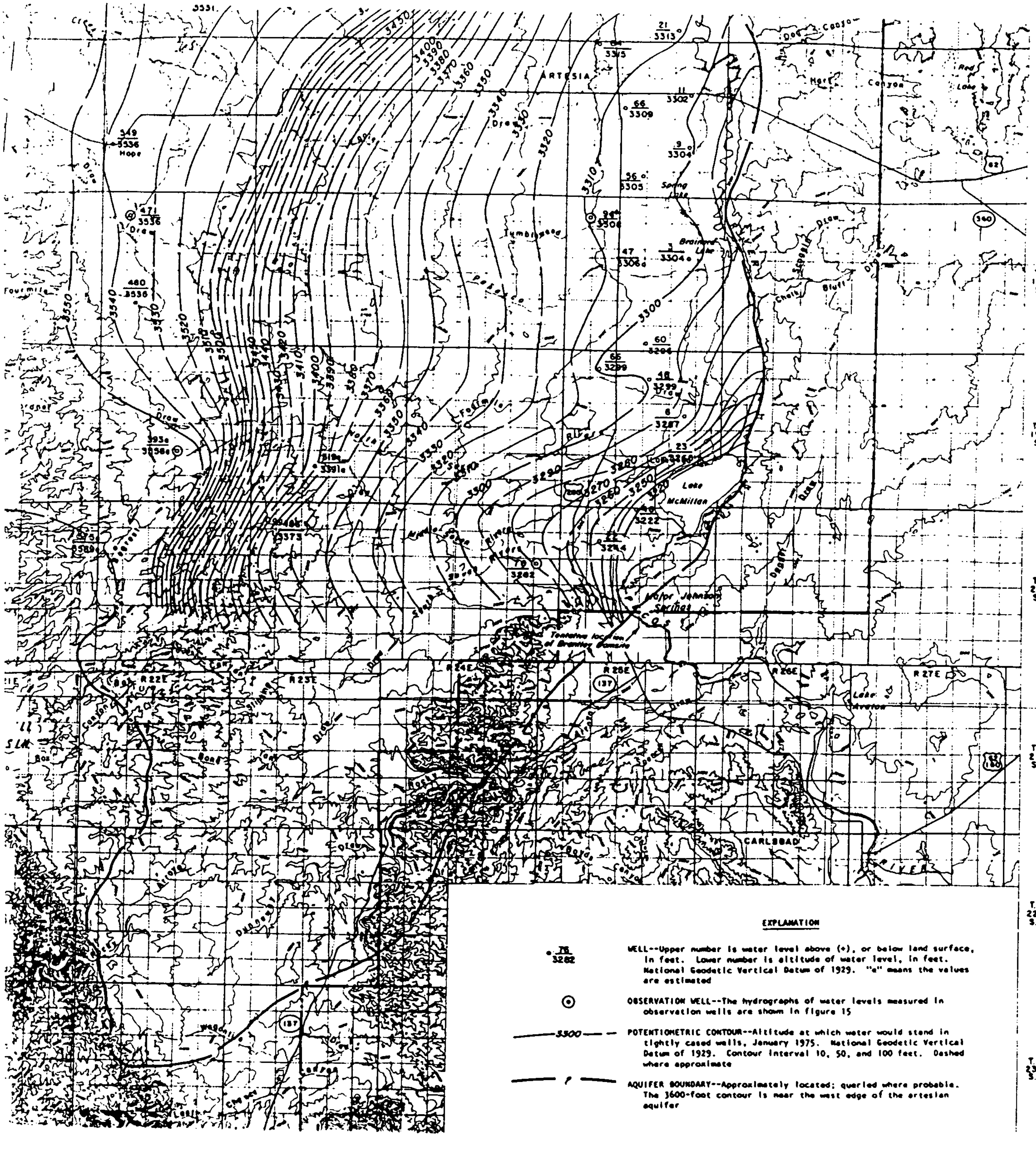


Figure 3.3 Artesian Aquifer, Potentiometric Surface Map.

artesian aquifer is generally eastward with discharge occurring through vertical upward leakage and through water production wells (Welder 1983).

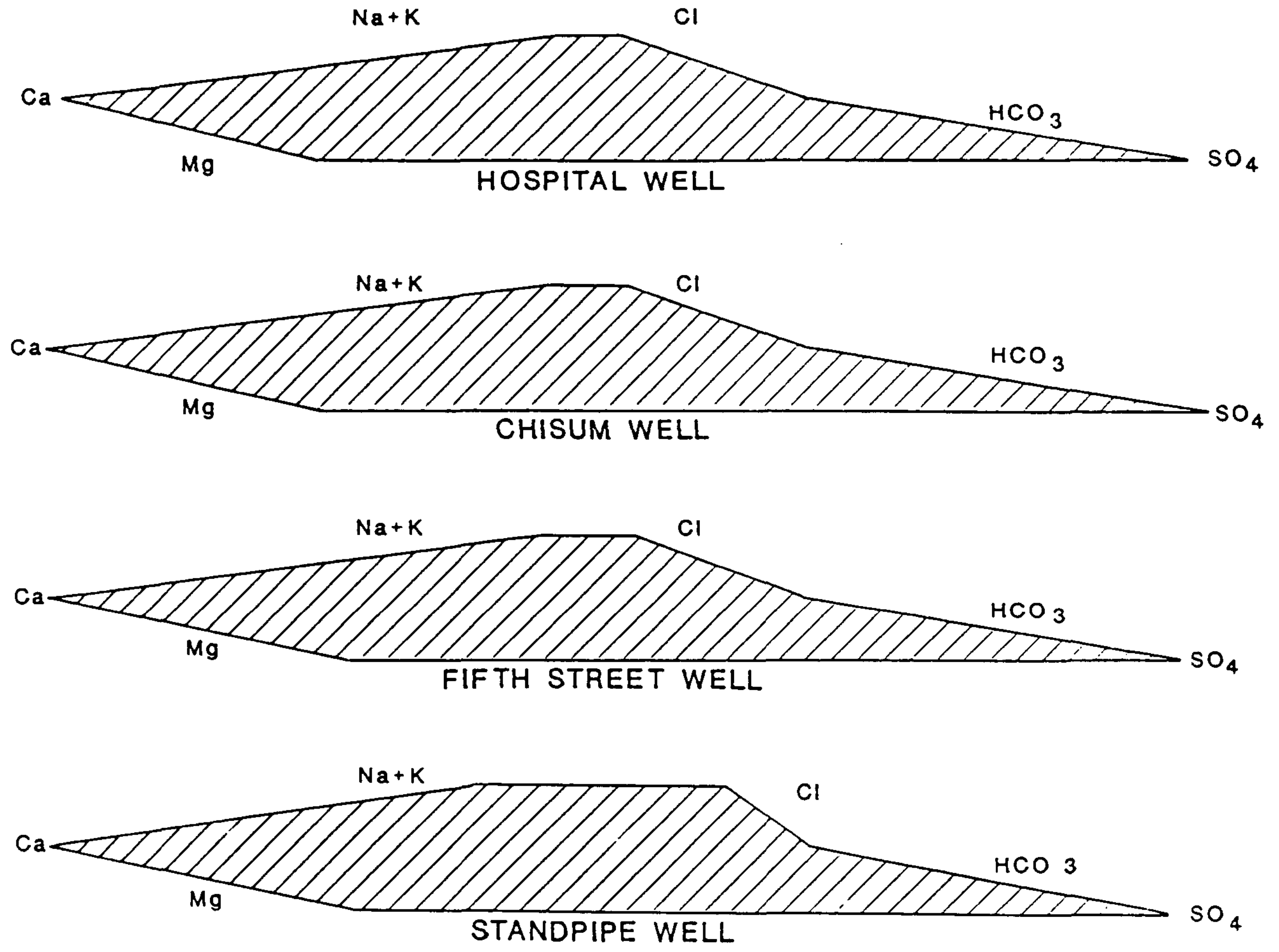
Water quality in the artesian aquifer is generally good to very good with calcium and sulfate being the primary dissolved constituents. Stiff diagrams for selected water samples from the artesian aquifer are presented in Figure 3.4. Dissolved constituents, such as chloride, increase in concentration towards the Pecos River, as would be expected.

3.4 CLIMATE

The Artesia, New Mexico, area has a semiarid continental climate, characterized by hot summers and mild winters (U.S. Soil Conservation Service [SCS] 1971). Average annual precipitation is 10 to 14 inches, with nearly 80 percent falling from May through October. Measurable rainfall occurs approximately 42 days per year. Annual snowfall averages three to eight inches. Minimum temperatures are typically 44.0° to 49.0° F but may fall below 0° F in winter; maximum temperatures may exceed 110° F on summer days. The frost free season is April to October (National Oceanic and Atmospheric Association [NOAA] 1982).

3.5 SUMMARY

Navajo's Artesia refinery is located in the southeastern portion of the Roswell ground water basin on deposits associated with the Orchard Park terrace. In the refinery area, these deposits consist of interbedded clay, gypsum, anhydritic sand, and shale, which overlie a sand and gravel unit. These deposits are generally less than 20 ft thick (Morgan 1983) and overlie the older valley fill described by Lyford (1973), not the Seven Rivers Formation. Detailed work in the area performed by Morgan (1938), Lyford (1973), and Welder (1983), in conjunction with the



NOTE: Water Quality Data from New Mexico Environmental Improvement Division (1980) Compiled Between 1975 and 1979

Figure 3.4 Artesian Aquifer Water Quality, Stiff Diagrams.

information provided from drill logs, supports this conclusion. The older valley fill is divided into three units: carbonate gravel, clay layers, and quartzose gravel (Lyford 1973). The valley fill varies from one foot to 300 ft thick with the deepest sections occurring in closed depressions near Roswell, Hagerman, and Artesia, New Mexico (Lyford 1973).

The valley fill overlies the Permian age Artesia group. The Artesia group is made up of the Tansill, Yates, Seven Rivers, Queen, and Grayburg Formations (Kelley 1971). The last three of these formations are relevant to this report. The Seven Rivers Formation is composed of gypsum mudstone and thick dolomite beds; however, this formation may not be present under the refinery (Welder 1983). At about the middle of the Seven Rivers Formation, there is supposed to be a sand member called the "Bowers Sand" which has been reported as occurring near the ground surface in the Artesia area. However, if the Seven Rivers Formation does not extend under Artesia or is at a depth of 200 ft, it is not possible for the sand to be near the surface. The Queen/Grayburg Formations are not differentiated in the Roswell ground water basin so are considered as one unit primarily composed of gypsum below the refinery. Unconformably below the Queen/Grayburg Formation are 1,100 ft of San Andres Limestone (Hendrickson and Jones 1952).

Two structures are present in the area. One is the K-M fault, which trends northeast about four miles northwest of Artesia. The other is the Artesia-Vacuum Arch, which is a gentle anticline that trends east-northeast about six miles southeast of Artesia (Kelley 1971).

Two other faults are discussed in reports of the Navajo refinery (Geoscience Consultants, Ltd. 1987). However, there is no mention of these structures in the published literature, and there is no evidence presented in any of the unpublished reports to support the existence of these faults.

The uppermost water-bearing unit is the sand and gravel layer which separates the Orchard Park terrace deposits from the underlying older valley fill. The unit is composed of sand and gravel with interlayers of clay and silt and varies in thickness from two and a half inches to five feet. The water in this unit is confined by an upper unit composed of silty clay and gypsum and a lower unit composed of gypsum and clay with sand, gravel, and shale. The potentiometric surface dips to the east.

The middle water-bearing zone is the shallow aquifer. This aquifer occurs in the valley fill at a depth of 100 ft below the refinery. The bottom of this aquifer is at the base of the valley fill at 220 ft (Welder 1983).

The lowest water-bearing unit is the artesian aquifer which occurs in the upper part of the San Andres Limestone and lower part of the Queen/Grayburg Formation under the refinery. The top of the aquifer is about 700 ft below the ground surface which puts it about 200 ft above the San Andres Limestone (Welder 1983). This is the aquifer which provides water for the refinery.

4.0 TRUCK BYPASS LANDFARM

4.1 SITE DESCRIPTION

4.1.1 Location

The Truck Bypass Landfarm is adjacent to East 5th Street, immediately east of the central part of the refinery. The landfarm is trapezoidal in plan and encompasses approximately three acres (Plate 2, Figure 4.1).

The unit is not in the 100-year floodplain and is surrounded by a dike approximately 1.5 ft above grade. The dike is designed to prevent surface water runoff.

4.1.2 Operations History

The landfarm was created by leveling piles of spoiled dirt that had been excavated for the foundation of the FCC unit in 1979. The excavated dirt had been dumped on top of the original soil surface covering the existing vegetation. This accounts for the roots observed in the three- to five-foot deep core intervals. The landfarm began operations in 1980 and is currently in use. Nonhazardous solid wastes generated at the refinery are deposited in the landfarm; these wastes include unleaded tank bottoms, separated wastewater, spilled hydrocarbons, and hydrocarbon-contaminated materials. An average of 40 tons per year of tank bottoms, 80 tons per year of separated liquids, and 40 tons per year of hydrocarbon-contaminated materials are disposed of in the Truck Bypass Landfarm.

4.1.3 Local Hydrogeology

The Truck Bypass Landfarm is underlain by surficial soils of the Pima series (see Section 3.0). Pima soils are silty loams to

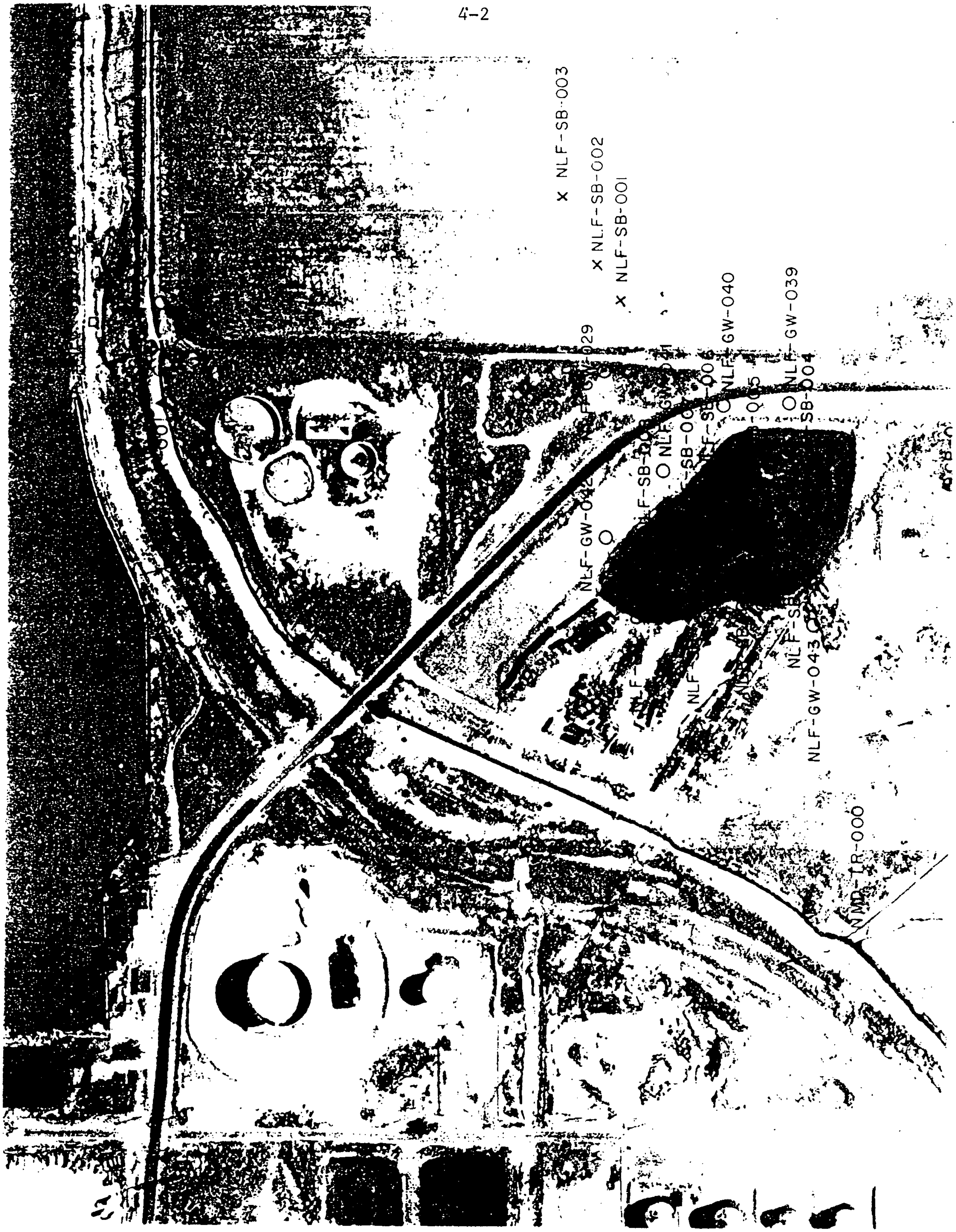


Figure 4.1 Truck Bypass Landfarm Area, Sample Locations, RFI Phase I Report, Navajo Refining Company, October 1990.

silty clay loams with moderately slow permeability (0.2-0.8 inch/hour) (U.S. Department of Agriculture [USDA] 1971).

A complex subsurface lithology is documented down to approximately 30 ft BLS in drillers' logs from monitor wells 39 through 44 which are located immediately adjacent to the landfarm (Appendix 1). Surficial soils range in thickness from four to 16.5 ft. Variously consolidated gypsum with thin layers of anhydrite, clay, shale, and sand underlies soils. Several recorded "dense" or "tight" zones are probable confining layers.

From one to four thin water-bearing zones were encountered in each hole varying in thickness from 0.5 to 4.0 ft. Most saturated intervals are associated with "gravelly" anhydrite or gypsum and gypsum with anhydrite pebbles. Wells 39, 40, and 43 record thin layers with hydrocarbon odor or oil from 0.5 to 5.0 ft thick. All wells bottom in unsaturated clay, silt, or shale-bearing units.

Water levels were measured in February and April 1987 and a potentiometric surface map constructed (Geoscience Consultants, Ltd. 1987). Shallow ground water flow in the vicinity of the landfarm is to the east.

4.2 HISTORICAL WATER QUALITY REVIEW

Historical ground water quality data were obtained from Navajo files for comparison with data generated from this study. Ground water samples were reviewed from monitor wells 39, 40, 41, 42, and 43 from the RCRA compliance monitoring program as mandated under 40 CFR 265.90-92, February 1985 through August 1986. Analytical results are presented in Tables 4.1 through 4.4.

Historical chemical data for waste characterization or soils were not available.

Table 4.1. Truck Bypass Landfarm - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date
COMPOUND /1	UNITS	41 3-86
1,1,1,2-Tetrachloroethane	ug/l	
1,1,1-Trichloroethane	ug/l	< 3.8
1,1,2,2-Tetrachloroethane	ug/l	< 6.9
1,1,2-Trichloroethane	ug/l	< 5.0
1,1-Dichloroethane	ug/l	< 4.7
1,2,3-Trichloropropane	ug/l	
1,2-Dichloroethane	ug/l	< 2.8
1,2-Dichloropropane	ug/l	< 6.0
1,3-Dichloropropylene	ug/l	
1-Chloroethyl vinyl ether	ug/l	
1-Chlorohexane	ug/l	
1-Methylnaphthalene	ug/l	
2,2-Dichloropropane	ug/l	
2-Cloroethyl vinyl ether	ug/l	< 10.0
2-Methylnaphthalene	ug/l	
Benzene	ug/l	< 4.4
Benzyl chloride	ug/l	
Bromobenzene	ug/l	
Bromodichloromethane	ug/l	< 2.2
Bromoform	ug/l	< 4.7
Bromomethane	ug/l	< 10.0
Carbon tetrachloride	ug/l	< 2.8
Chloracetaldehyde	ug/l	
Chlorobenzene	ug/l	< 6.0
Chloroethane	ug/l	< 10
Chloroform	ug/l	< 1.6

		Monitor Well Number Date
COMPOUND	UNITS	Well 41 3-86
Chloromethane	ug/l	< 10
Chloromethyl methyl ether	ug/l	
Chlorotoluene	ug/l	
Cis-1,3-dichloropropene	ug/l	< 5.0
Dibromochloromethane	ug/l	< 3.1
Dibromomethane	ug/l	
Dichlorodifluoromethane	ug/l	
Dichloromethane	ug/l	
Ethylbenzene	ug/l	< 5.0
Freon	ug/l	
Methylene chloride	ug/l	< 2.8
m-Xylene	ug/l	
o-Xylene	ug/l	
p-Xylene	ug/l	
Tetrachloroethene	ug/l	< 1.9
Tetrachlorophenol	ug/l	
Toluene	ug/l	< 6.0
Trans-1,2-dichloroethene	ug/l	< 1.6
Trans-1,3-dichloropropene	ug/l	< 5.0
Trichloroethene	ug/l	< 1.9
Trichlorofluoromethane	ug/l	< 10.0
Trichlorophenol	ug/l	
Vinyl chloride	ug/l	< 10.0
Xylenes	ug/l	

Source: Special Analysis
March 20, 1986

/1 Blanks designate compounds for which no analyses were requested.

Table 4.2. Truck Bypass Landfarm - Historical Groundwater Quality
Semivolatile Organic Compounds

		Monitor Well Number Date							
COMPOUND /1	UNITS	39 2-85	39 7-85	39 11-85	39 3-86	40 2-85	40 7-85	40 11-85	40 2-86
1,2,4-Tricholorobenzene	ug/l				< 1.9				
2,4,5-Trichlorophenol	ug/l								
2,4,6-Trichlorophenol	ug/l	< 0.64	< 2.7	< 0.64	< 0.64	< 0.64	< 2.7	< 0.64	< 0.64
2,4-Dichlorophenol	ug/l	< 0.39	< 2.7	< 0.39	< 0.39	< 0.39	< 2.7	< 0.39	< 0.39
2,4-Dimethylphenol	ug/l	< 0.32	< 2.7	< 0.32	< 0.32	< 0.32	< 2.7	< 0.32	< 0.32
2,4-Dinitrophenol	ug/l	< 13.0	< 42.0	< 13.0	< 13.0	150	< 42.0	< 13.0	< 13.0
2,4-Dinitrotoluene	ug/l				< 5.7				
2,6-Dichlorophenol	ug/l								
2,6-Dinitrotoluene	ug/l				< 1.9				
2-Chloronaphthalene	ug/l				< 1.9				
2-Chlorophenol	ug/l	6.06	< 3.3	< 0.31	< 0.31	< 0.31	< 3.3	< 0.31	< 0.31
2-Cylohexyl-4,6-dinitrophenol	ug/l								
2-Methyl-4,6-dinitrophenol	ug/l	< 16.0	< 24.0	< 16.0	< 16.0	< 16.0	< 24.0	< 16.0	< 16.0
2-Methylnaphthalene	ug/l								
2-Methylphenol	ug/l								
2-Nitroaniline	ug/l								
2-Nitrophenol	ug/l	< 0.45	< 3.6	< 0.45	< 0.45	100	10	< 0.45	< 0.45
3,3'-Dichlorobenzidine	ug/l				< 16.5				
3-Methylcholanthrene	ug/l								
3-Nitroaniline	ug/l								
4,6-Dinitro-2-methylphenol	ug/l								
4-Bromophenyl phenyl ether	ug/l				< 1.9				
4-Chloroaniline	ug/l								
4-Chlorophenyl phenyl ether	ug/l				< 4.2				
4-Chloro-3-methylphenol	ug/l	< 0.36	< 3.0	< 0.36	< 0.36	33	< 3.0	< 0.36	< 0.36
4-Methylphenol	ug/l								
4-Nitroaniline	ug/l								
4-Nitrophenol	ug/l	< 2.8	< 2.4	< 0.28	< 2.8	24	< 2.4	< 2.8	< 2.8
7H-dibenzo(c,g)carbazole	ug/l								
Acenaphthene	ug/l				< 1.9				
Acenaphthylene	ug/l				< 3.5				
Anthracene	ug/l				< 1.9				
Benzoic acid	ug/l								
Benzo(a)anthracene	ug/l				< 7.8				
Benzo(a)pyrene	ug/l				< 2.5				
Benzo(b)fluoranthene	ug/l				< 4.8				
Benzo(g,h,i)perylene	ug/l				< 4.1				
Benzo(j)fluoranthene	ug/l								
Benzo(k)fluoranthene	ug/l				< 2.5				
Benzyl alcohol	ug/l								
Bis(2-chloroethyl)ether	ug/l				< 5.7				
Bis(2-chloroethoxy)methane	ug/l				< 5.3				
Bis(2-chloroisopropyl)ether	ug/l				< 5.7				
Bis(2-Ethylhexyl)phthalate	ug/l				< 2.5				
Butyl benzyl phthalate	ug/l				< 2.5				

Table 4.2 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Semivolatile Organic Compounds

		Monitor Well Number / Date							
COMPOUND	UNITS	39 2-85	39 7-85	39 11-85	39 3-86	40 2-85	40 7-85	40 11-85	40 2-86
Cresols (methyl phenols)	ug/l								
Chrysene	ug/l				< 2.5				
Dibenzofuran	ug/l								
Dibenzo(a,h)anthracene	ug/l				< 2.5				
Dibenzo(a,j)acridine	ug/l								
Dibenzo(a,e)pyrene	ug/l								
Dibenzo(a,h)pyrene	ug/l								
Dibenzo(a,i)pyrene	ug/l								
Diethyl phthalate	ug/l				< 22.0				
Dimethyl phthalate	ug/l				< 1.6				
Di-n-butyl phthalate	ug/l				< 2.5				
Di-n-octyl phthalate	ug/l				< 2.5				
Fluoranthene	ug/l				< 2.2				
Fluorene	ug/l				< 1.9				
Hexachlorobenzene	ug/l				< 1.9				
Hexachlorobutadiene	ug/l				< 0.9				
Hexachloroethane	ug/l				< 1.6				
Hexachlorocyclopentadiene	ug/l				< 10.0				
Indeno(1,2,3-cd)pyrene	ug/l				< 3.7				
Isophorone	ug/l				< 2.2				
Naphthalene	ug/l				< 1.6				
Nitrobenzene	ug/l				< 1.9				
N-nitrosodipropylamine	ug/l								
N-nitrosodiphenylamine	ug/l				< 0.81				
Pentachlorophenol	ug/l	< 7.4	< 3.6	< 7.4	< 7.4	< 7.4	< 3.6	< 7.4	< 7.4
Phenanthrene	ug/l				< 5.4				
Phenol	ug/l				< 0.14				
Pyrene	ug/l				< 1.9				
1,2-Dichlorobenzene	ug/l				< 1.9				
1,3-Dichlorobenzene	ug/l				< 1.9				
1,4-Dichlorobenzene	ug/l				< 4.4				

Source: Truck Bypass Groundwater Quality Monitoring
February 12, 1985; July 08, 1985; November 11, 1985.
Truck Bypass Semiannual Monitoring
February 14 1986; August 06, 1986
Special Analysis
March 20, 1986

/1 Blanks designate compounds for which no analyses were requested.

Table 4.2 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Semivolatile Organic Compounds

		Monitor Well Number Date							
COMPOUND	UNITS	41 2-85	41 7-85	41 11-85	41 3-86	42 2-85	42 7-85	42 11-85	42 3-86
1,2,4-Tricholorobenzene	ug/l				< 1.9				< 1.9
2,4,5-Trichlorophenol	ug/l								
2,4,6-Trichlorophenol	ug/l	< 0.64	< 2.7	< 0.64	< 0.64	< 0.64	< 2.7	< 0.64	< 0.64
2,4-Dichlorophenol	ug/l	< 0.39	< 2.7	< 0.39	< 0.39	< 0.39	< 2.7	< 0.39	< 0.39
2,4-Dimethylphenol	ug/l	< 0.32	< 2.7	< 0.32	< 0.32	< 0.32	< 2.7	< 0.32	< 0.32
2,4-Dinitrophenol	ug/l	< 13.0	< 42.0	< 13.0	< 13.0	< 13.0	< 42.0	< 13.0	< 13.0
2,4-Dinitrotoluene	ug/l				< 5.7				< 5.7
2,6-Dichlorophenol	ug/l								
2,6-Dinitrotoluene	ug/l				< 1.9				< 1.9
2-Chloronaphthalene	ug/l				< 1.9				< 1.9
2-Chlorophenol	ug/l	< 0.31	< 3.3	< 0.31	< 0.31	< 0.31	< 3.3	< 0.31	< 0.31
2-Cylohexyl-4,6-dinitrophenol	ug/l								
2-Methyl-4,6-dinitrophenol	ug/l	< 16.0	< 24.0	< 16.0	< 16.0	< 16.0	< 24.0	< 16.0	< 16.0
2-Methylnaphthalene	ug/l								
2-Methylphenol	ug/l								
2-Nitroaniline	ug/l								
2-Nitrophenol	ug/l	< 0.45	< 3.6	< 0.45	< 0.45	< 0.45	< 3.6	< 0.45	< 0.45
3,3'-Dichlorobenzidine	ug/l				< 16.5				< 16.5
3-Methylcholanthrene	ug/l								
3-Nitroaniline	ug/l								
4,6-Dinitro-2-methylphenol	ug/l								
4-Bromophenyl phenyl ether	ug/l				< 1.9				< 1.9
4-Chloroaniline	ug/l								
4-Chlorophenyl phenyl ether	ug/l				< 4.2				< 4.2
4-Chloro-3-methylphenol	ug/l	< 0.36	< 3.0	< 0.36	< 0.36	2	< 3.0	< 0.36	< 0.36
4-Methylphenol	ug/l								
4-Nitroaniline	ug/l								
4-Nitrophenol	ug/l	< 2.8	< 2.4	< 2.8	< 2.8	100	< 2.4	< 2.8	< 2.8
7-Dibenzo(c,g)carbazole	ug/l								
Acenaphthene	ug/l				< 1.9				< 1.9
Acenaphthylene	ug/l				< 3.5				< 3.5
Anthracene	ug/l				< 1.9				< 1.9
Benzoic acid	ug/l								
Benzo(a)anthracene	ug/l				< 7.8				< 7.8
Benzo(a)pyrene	ug/l				< 2.5				< 2.5
Benzo(b)fluoranthene	ug/l				< 4.8				< 4.8
Benzo(g,h,i)perylene	ug/l				< 4.1				< 4.1
Benzo(j)fluoranthene	ug/l								
Benzo(k)fluoranthene	ug/l				< 2.5				< 2.5
Benzyl alcohol	ug/l								
Bis(2-chloroethyl)ether	ug/l				< 5.7				< 5.7
Bis(2-chloroethoxy)methane	ug/l				< 5.3				< 5.3
Bis(2-chloroisopropyl)ether	ug/l				< 5.7				< 5.7
Bis(2-ethylhexyl)phthalate	ug/l				< 2.5				< 2.5

Table 4.2 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Semivolatile Organic Compounds

		Monitor Well Number Date							
COMPOUND	UNITS	41 2-85	41 7-85	41 11-85	41 3-86	42 2-85	42 7-85	42 11-85	42 3-86
Butyl benzyl phthalate	ug/l				< 2.5				< 2.5
Cresols (methyl phenols)	ug/l								
Chrysene	ug/l				< 2.5				< 2.5
Dibenzofuran	ug/l								
Dibenzo(a,h)anthracene	ug/l				< 2.5				< 2.5
Dibenzo(a,j)acridine	ug/l								
Dibenzo(a,e)pyrene	ug/l								
Dibenzo(a,h)pyrene	ug/l								
Dibenzo(a,i)pyrene	ug/l								
Diethyl phthalate	ug/l				< 22.0				< 22.0
Dimethyl phthalate	ug/l				< 1.6				< 1.6
Di-n-butyl phthalate	ug/l				< 2.5				< 2.5
Di-n-octyl phthalate	ug/l				< 2.5				< 2.5
Fluoranthene	ug/l				< 2.2				< 2.2
Fluorene	ug/l				< 1.9				< 1.9
Hexachlorobenzene	ug/l				< 1.9				< 1.9
Hexachlorobutadiene	ug/l				< 0.9				< 0.9
Hexachloroethane	ug/l				< 1.6				< 1.6
Hexachlorocyclopentadiene	ug/l				< 10.0				< 10.0
Indeno(1,2,3-cd)pyrene	ug/l				< 3.7				< 3.7
Isophorone	ug/l				< 2.2				< 2.2
Naphthalene	ug/l				< 1.6				< 1.6
Nitrobenzene	ug/l				< 1.9				< 1.9
N-nitrosodipropylamine	ug/l								
N-nitrosodiphenylamine	ug/l				< 0.81				< 0.81
Pentachlorophenol	ug/l	< 7.4	< 3.6	< 7.4	< 7.4	< 7.4	< 3.6	< 7.4	< 7.4
Phenanthrene	ug/l				< 5.4				< 5.4
Phenol	ug/l				< 0.14				< 0.14
Pyrene	ug/l				< 1.9				< 1.9
1,2-Dichlorobenzene	ug/l				< 1.9				< 1.9
1,3-Dichlorobenzene	ug/l				< 1.9				< 1.9
1,4-Dichlorobenzene	ug/l				< 4.4				< 4.4
Pyrene									

Table 4.2 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Semivolatile Organic Compounds

		Monitor Well Number Date				
COMPOUND	UNITS	43 2-85	43 7-85	43 11-85	43 2-86	43 3-86
1,2,4-Tricholorobenzene	ug/l					< 1.9
2,4,5-Trichlorophenol	ug/l					
2,4,6-Trichlorophenol	ug/l	< 0.64	< 2.7	< 0.64	< 0.64	< 0.64
2,4-Dichlorophenol	ug/l	< 0.39	< 2.7	< 0.39	< 0.39	< 0.39
2,4-Dimethylphenol	ug/l	< 0.32	< 2.7	4	< 0.32	< 0.32
2,4-Dinitrophenol	ug/l	< 13.0	< 42.0	< 13.0	< 13.0	< 13.0
2,4-Dinitrotoluene	ug/l					< 5.7
2,6-Dichlorophenol	ug/l					
2,6-Dinitrotoluene	ug/l					< 1.9
2-Chloronaphthalene	ug/l					< 1.9
2-Chlorophenol	ug/l	< 0.31	< 3.3	< 0.31	< 0.31	< 0.31
2-Cylohexyl-4,6-dinitrophenol	ug/l					
2-Methyl-4,6-dinitrophenol	ug/l	< 16.0	< 24.0	< 16.0	< 16.0	< 16.0
2-Methylnaphthalene	ug/l					
2-Methylphenol	ug/l					
2-Nitroaniline	ug/l					
2-Nitrophenol	ug/l	< 0.45	< 3.6	< 0.45	< 0.45	< 0.45
3,3'-Dichlorobenzidine	ug/l					< 16.5
3-Methylcholanthrene	ug/l					
3-Nitroaniline	ug/l					
4,6-Dinitro-2-methylphenol	ug/l					
4-Bromophenyl phenyl ether	ug/l					< 1.9
4-Chloroaniline	ug/l					
4-Chlorophenyl phenyl ether	ug/l					< 4.2
4-chloro-3-methylphenol	ug/l	< 0.36	< 3.0	< 0.36	< 0.36	< 0.36
4-Methylphenol	ug/l					
4-Nitroaniline	ug/l					
4-Nitrophenol	ug/l	< 2.8	< 2.4	< 2.8	< 2.8	< 2.8
7H-dibenzo(c,g)carbazole	ug/l					
Acenaphthene	ug/l					< 1.9
Acenaphthylene	ug/l					< 3.5
Anthracene	ug/l					< 1.9
Benzoic acid	ug/l					
Benzo(a)anthracene	ug/l					< 7.8

Table 4.2 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Semivolatile Organic Compounds

COMPOUND	UNITS	43 2-85	43 7-85	43 11-85	43 2-86	43 3-86
Benzo(a)pyrene	ug/l					< 2.5
Benzo(b)fluoranthene	ug/l					< 4.8
Benzo(g,h,i)perylene	ug/l					< 4.1
Benzo(j)fluoranthene	ug/l					
Benzo(k)fluoranthene	ug/l					< 2.5
Benzyl alcohol	ug/l					
Bis(2-chloroethyl)ether	ug/l					< 5.7
Bis(2-chloroethoxy)methane	ug/l					< 5.3
Bis(2-chloroisopropyl)ether	ug/l					< 5.7
Bis(2-ethylhexyl)phthalate	ug/l					< 2.5
Butyl benzyl phthalate	ug/l					< 2.5
Cresols (methyl phenols)	ug/l					
Chrysene	ug/l					< 2.5
Dibenzofuran	ug/l					
Dibenzo(a,h)anthracene	ug/l					< 2.5
Dibenzo(a,j)acridine	ug/l					
Dibenzo(a,e)pyrene	ug/l					
Dibenzo(a,h)pyrene	ug/l					
Dibenzo(a,i)pyrene	ug/l					
Diethyl phthalate	ug/l					< 22.0
Dimethyl phthalate	ug/l					< 1.6
Di-n-butyl phthalate	ug/l					< 2.5
Di-n-octyl phthalate	ug/l					< 2.5
Fluoranthene	ug/l					< 2.2
Fluorene	ug/l					< 1.9
Hexachlorobenzene	ug/l					< 1.9
Hexachlorobutadiene	ug/l					< 0.9
Hexachloroethane	ug/l					< 1.6
Hexachlorocyclopentadiene	ug/l					< 10.0
Indeno(1,2,3-cd)pyrene	ug/l					< 3.7
Isophorone	ug/l					< 2.2
Naphthalene	ug/l					56.8
Nitrobenzene	ug/l					< 1.9
N-nitrosodipropylamine	ug/l					
N-nitrosodiphenylamine	ug/l					< 0.81
Pentachlorophenol	ug/l	< 7.4	< 3.6	< 7.4	< 7.4	< 7.4
Phenanthrene	ug/l					< 5.4
Phenol	ug/l					< 0.14
Pyrene	ug/l					< 1.9
1,2-Dichlorobenzene	ug/l					< 1.9
1,3-Dichlorobenzene	ug/l					< 1.9
1,4-Dichlorobenzene	ug/l					< 4.4

Table 4.3. Truck Bypass Landfarm - Historical Groundwater Quality
Metals

Monitor Well Number
Date

METAL /1	UNITS	39 2-85	39 7-85	39 11-85	39 2-86	39 8-86	40 2-85	40 7-85	40 11-85	40 2-86	40 8-86
Aluminum	mg/l										
Antimony	mg/l										
Arsenic	mg/l	0.02	0.02	< 0.01	0.02	0.09	0.02	< 0.01	< 0.01	0.02	0.07
Barium	mg/l	< 0.1	< 0.1	0.2	< 0.1	0.05	0.14	0.1	0.2	0.2	0.1
Beryllium	mg/l										
Boron	mg/l										
Cadmium	mg/l	< 0.001	< 0.001	0.003	< 0.001	< 0.01	< 0.001	< 0.001	0.002	< 0.001	< 0.01
Chromium	mg/l	0.01	< 0.01	0.03	< 0.01	< 0.05	0.05	< 0.01	< 0.01	< 0.01	< 0.05
Cobalt	mg/l										
Copper	mg/l										
Iron	mg/l	0.6	3.12	8.62	4.8	0.38	1.05	1.09	2.58	3	0.6
Lead	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05
Manganese	mg/l		3.11	2.36	2.63	0.93		6.03	8.11	8.47	4.9
Mercury	mg/l	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.002	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.002
Nickel	mg/l										
Selenium	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silicon	mg/l										
Silver	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05
Strontium	mg/l										
Thallium	mg/l										
Tin	mg/l										
Vanadium	mg/l										
Zinc	mg/l										

Source: Truck Bypass Groundwater Quality Monitoring
February 12, 1985; July 08, 1985; November 11, 1985.
Truck Bypass Semiannual Monitoring
February 14 1986; August 06, 1986
Special Analysis
March 20, 1986

/1 Blanks designate metals for which no analyses were requested.

Table 4.3 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Metals

Monitor Well Number
Date

METAL	UNITS	41 2-85	41 7-85	41 11-85	41 2-86	41 8-86	42 2-85	42 7-85	42 11-85	42 2-86	42 8-86
Aluminum	mg/l										
Antimony	mg/l										
Arsenic	mg/l	0.03	0.02	0.02	0.03	0.042	0.01	0.02	0.02	0.03	0.1
Barium	mg/l	< 0.1	< 0.1	< 0.1	< 0.1	0.14	< 0.1	< 0.1	< 0.1	< 0.1	0.43
Beryllium	mg/l										
Boron	mg/l										
Cadmium	mg/l	< 0.001	< 0.001	0.002	< 0.001	0.03	< 0.001	< 0.001	0.002	< 0.001	0.02
Chromium	mg/l	< 0.01	< 0.01	< 0.01	0.01	0.11	< 0.01	0.03	0.02	< 0.01	0.13
Cobalt	mg/l										
Copper	mg/l										
Iron	mg/l	0.02	0.56	2.76	0.22	0.21	0.31	3.97	0.83	5.15	0.35
Lead	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	0.14	< 0.01	< 0.01	< 0.01	< 0.01	0.21
Manganese	mg/l		1.68	2.72	1.7	2		1.28	0.76	0.87	0.72
Mercury	mg/l	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.002	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.002
Nickel	mg/l										
Selenium	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
Silicon	mg/l										
Silver	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05
Strontium	mg/l										
Thallium	mg/l										
Tin	mg/l										
Vanadium	mg/l										
Zinc	mg/l										

Table 4.3 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Metals

Monitor Well Number
Date

METAL	UNITS	43 2-85	43 7-85	43 11-85	43 2-86	43 8-86
Aluminum	mg/l					
Antimony	mg/l					
Arsenic	mg/l	0.01	0.01	< 0.01	0.01	0.2
Barium	mg/l	1	1.1	0.2	0.4	0.4
Beryllium	mg/l					
Boron	mg/l					
Cadmium	mg/l	< 0.001	< 0.001	0.004	< 0.001	0.03
Chromium	mg/l	0.02	< 0.01	0.01	< 0.01	0.1
Cobalt	mg/l					
Copper	mg/l					
Iron	mg/l	< 0.01	6.67	1.78	4.71	0.74
Lead	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	0.26
Manganese	mg/l		0.4	0.8	0.33	0.27
Mercury	mg/l	< 0.0004	0.0005	< 0.0004	< 0.0004	< 0.002
Nickel	mg/l					
Selenium	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	0.02
Silicon	mg/l					
Silver	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05
Strontium	mg/l					
Thallium	mg/l					
Tin	mg/l					
Vanadium	mg/l					
Zinc	mg/l					

Table 4.4. Truck Bypass Landfarm - Historical Groundwater Quality
Inorganic Components

COMPONENT /1	UNITS	39 2-85	39 7-85	39 11-85	39 2-86	39 8-86	40 2-85	40 7-85	40 11-85	40 2-86	40 8-86
		Monitor Well Number Date									
Ammonia	mg/l										
Bicarbonate	mg/l										
Calcium	mg/l										
Carbonate	mg/l										
Chloride	mg/l	280	393	156	401	54.9	690	805	362	1050	464.8
Cyanide	mg/l										
Fluoride	mg/l	1.3	1.4	1.46	1.19	1	0.94	0.83	0.82	0.78	0.5
Magnesium	mg/l	430					213				
Nitrate (N)	mg/l	0.2	< 0.1	< 0.1		< 0.01	0.1	< 0.1	< 0.1		< 0.01
Nitrite	mg/l										
Total Kjeldahl Nitrogen	mg/l										
Potassium	mg/l										
Sodium	mg/l	351	470	260	413	146	474	430	360	482	318
Sulfate	mg/l	2210	2220	1510	1760	2054	470	290	210	184	700
Sulfide	mg/l										
Total Dissolved Solids	mg/l	4630					2690				
Conductivity	umohs/cm	4690	4900	3640	5355	2590	4040	3960	3840	4820	3050
pH		7.42	7.28	8.02	6.98	7.07	6.82	6.71	7.36	6.82	6.5

Source: Truck Bypass Groundwater Quality Monitoring
February 12, 1985; July 08, 1985; November 11, 1985.
Truck Bypass Semiannual Monitoring
February 14 1986; August 06, 1986
Special Analysis
March 20, 1986

/1 Blanks designate components for which no analyses were requested.

Table 4.4 (cont). Truck Bypass Landfarm - Historical Groundwater Quality
Inorganic Components

		Monitor Well Number Date									
COMPONENT	UNITS	41 2-85	41 7-85	41 11-85	41 2-86	41 8-86	42 2-85	42 7-85	42 11-85	42 2-86	42 8-86
Ammonia	mg/l										
Bicarbonate	mg/l										
Calcium	mg/l										
Carbonate	mg/l										
Chloride	mg/l	690	657	781	669	954.7	800	859	667	724	694.8
Cyanide	mg/l										
Fluoride	mg/l	0.96	0.93	0.93	0.87	0.67	1.2	1.28	1.18	1.32	0.74
Magnesium	mg/l	339					719				
Nitrate (N)	mg/l	0.3	< 0.1	< 0.1		< 0.01	0.2	< 0.1	< 0.1		< 0.01
Nitrite	mg/l										
Total Kjeldahl Nitrogen	mg/l										
Potassium	mg/l										
Sodium	mg/l	526	560	560	529	672	763	770	600	614	668
Sulfate	mg/l	2040	1920	2240	1890	5383	3460	3100	5650	2390	3892
Sulfide	mg/l										
Total Dissolved Solids	mg/l	5150					7590				
Conductivity	umohs/cm	5570	5130	6060	5570	6100	7530	6760	6060	6430	5200
pH		6.98	7.75	7.12	7.02	6.6	7.52	6.91	7.41	7	6.7

Table 4.4 (cont). *Truck Bypass Landfarm - Historical Groundwater Quality Inorganic Components*

COMPONENT	UNITS	43 2-85	43 7-85	43 11-85	43 2-86	43 8-86
		Monitor Well Number Date				
Ammonia	mg/l					
Bicarbonate	mg/l					
Calcium	mg/l					
Carbonate	mg/l					
Chloride	mg/l	1000	1520	3260	2540	1624.5
Cyanide	mg/l					
Fluoride	mg/l	0.94	0.96	1.08	0.98	0.57
Magnesium	mg/l	339				
Nitrate (N)	mg/l	< 0.1	0.1	< 0.1		< 0.01
Nitrite	mg/l					
Total Kjeldahl Nitrogen	mg/l					
Potassium	mg/l					
Sodium	mg/l	530	480	900	582	644
Sulfate	mg/l	70	74	1140	174	541
Sulfide	mg/l					
Total Dissolved Solids	mg/l	3000				
Conductivity	umohs/cm	4670	5240	8730	5670	5800
pH		7.11	6.89	7.32	6.73	6.1

4.2.1 Volatile Organic Compounds

A sample from monitor well 41 collected in March 1986 was analyzed for selected volatile organic compounds. No target compounds were above the detection limits.

4.2.2 Semivolatile Organic Compounds

Analyses for selected semivolatile organic compounds were obtained for samples collected from monitor wells 39, 40, 41, 42, and 43 in February, August, and November 1985 and March 1986 (Table 4.2). Low levels of various phenolic compounds (6.06 to 150 μg/l) were detected in samples from monitor wells 39, 40, 42, and 43 during the February 1985 sampling event. No semivolatile compounds were detected in subsequent sampling.

4.2.3 Metals

Analyses for selected metals were obtained for samples collected from monitor wells 39, 40, 41, 42, and 43 in February and November 1985 and February and August 1986 (Table 4.3). Arsenic, barium, cadmium, chromium, iron, lead, manganese, mercury, and selenium were found above detection limits on at least one occasion.

Unidentified facility operations appear to have affected shallow ground water quality. However, only qualitative assessments can be made due to the lack of background data. Maximum values for arsenic ranged from 0.042 mg/l to 0.10 mg/l in monitor wells 39, 40, 41, and 42. Maximum values for chromium ranged from 0.11 mg/l to 0.13 mg/l in wells 41 and 42. Maximum values for lead ranged from 0.14 mg/l to 0.26 mg/l in monitor wells 41, 42, and 43.

4.3 FIELD INVESTIGATION

Field activities conducted during the hydrogeologic investigation consisted of drilling nine on-site (affected) and three off-site (unaffected) soil borings, collecting 57 subsurface soil samples, measuring water levels in six proximal monitor wells, and collecting ground water samples from five wells.

4.3.1 Soil Borings

Twelve soil borings were completed to characterize the extent of contamination and to compare chemical compositions between the landfarm and background sites.

4.3.1.1 Drilling and Sampling Procedures

Health and safety level C protective equipment was worn by personnel directly involved with landfarm soil borings. Three work zones were delineated during this activity. The exclusion zone consisted of the visibly contaminated portion of the landfarm. The contamination reduction zone was a 10-ft decontamination area used to convey personnel and samples to and from the exclusion zone to the support zone. PID readings varied from 0.4 to 1.0 ppm at the landfarm surface during prework ambient monitoring. Breathing zone PID monitoring during drilling ranged from 0 to 0.2 ppm. Readings from the surface of individual samples and from within the boreholes ranged from 0 to 3 ppm.

All borings were drilled with a truck-mounted Chicago Mining Equipment (CME) 55 drill rig, using an eight-inch outside diameter hollow stem auger. Samples were collected with five-foot long continuous core samplers positioned inside the auger flights.

As each five-foot core was recovered, a geologist first sampled and then logged the lithology and the organic vapor content. Samples were collected in the following sequence: volatiles, semivolatiles, oil and grease, and metals.

All samples were labeled in the field with the following information: sample number, waste management unit, date, time, sample interval, analytes, and name of sampler. Sample containers were then placed in plastic bags and secured in ice chests. Chain-of-custody forms were completed and the samples shipped to the lab on September 19, 1990.

All drilling equipment was steam cleaned before initial use and between boreholes. Sampling equipment was decontaminated by the procedure described in the revised Work Plan.

4.3.1.2 Locations

Nine, 10-foot deep soil cores were drilled within the landfarm boundaries (NLF-SB-004 to NLF-SB-012). Exact locations were randomly selected by Navajo to achieve adequate areal coverage (Plate 2, Figure 4.1). Borings NLF-SB-004 through NLF-SB-009 were sampled at the intervals 0-1', 3-4', 5-5½', 6-7', and 8-9' BLS. Borings NLF-SB-010 through NLF-SB-012 were sampled at the intervals 0-1', 5-5½', 6-7', and 8-9' BLS. Samples are numbered in successive order from shallow interval (-01) to deep interval (-04 or -05) for each boring.

Three, 10-foot deep background soil cores (NLF-SB-001 to NLF-SB-003) were drilled adjacent to the landfarm in a cleared but uncultivated field approximately 300 ft east of the landfarm site (Plate 2). Borings were sampled at the intervals 0-1', 3-4', 5-5½', 6-7', and 8-9'. Samples are numbered in successive order from shallow interval (-01) to deep interval (-05) for each boring.

4.3.1.3 Lithologic Description

Borings encountered material ranging from silt to clay with the majority classified as silty clay. The thickness of sludge varied from 0.8 to 2.0 ft. Lithologic logs appear for each boring in Figures 4.2 through 4.13.

4.3.1.4 Soil Boring Analytical Results

Volatiles

Volatile organic compound analytical results from truck bypass landfarm soil samples are presented in Table 4.5. Only those samples with one or more detectable volatile compounds are included. Five volatile compounds occur in concentrations exceeding their respective CRDLs in four soil samples. No volatile compounds occur above their CRDLs in the background soil boring samples (NLF-SB-001, 002, and 003).

The following volatile organic compounds occur in concentrations that exceed their respective CRDLs: 1,1,2,2-tetrachloroethane, benzene, toluene, ethyl benzene, and total xylene compounds. The compound 1,1,2,2-tetrachloroethane occurs in only one sample, NLF-SB-006-01 (1.2 mg/kg). Benzene occurs in two samples, NLF-SB-004-01 (1.2 mg/kg) and NLF-SB-011-04 (1.7 mg/kg). Toluene is detectable in all four samples listed; NLF-SB-004-01 (1.2 mg/kg), NLF-SB-006-01 (0.73 mg/kg), NLF-SB-006-02 (0.68 mg/kg), and NLF-SB-011-04 (0.63 mg/kg). Ethyl benzene is identified in three samples; NLF-SB-004-01 (1.5 mg/kg), NLF-SB-006-02 (0.95 mg/kg), and NLF-SB-011-04 (0.68 mg/kg). Total combined xylene compounds (xylenes) occur in all four samples; NLF-SB-004-01 (1.4 mg/kg), NLF-SB-006-01 (0.3 mg/kg), NLF-SB-006-02 (2.1 mg/kg), and NLF-SB-011-04 (3.8 mg/kg).

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 001
START DRILLING: Sept. 18, 1990
COMPLETED: Sept. 18, 1990
TOTAL DEPTH (BLS): 9.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER X OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING X
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-0.67 feet BLS	0.0-1.0	Well-sorted silt, very low moisture, no cohesion, no plasticity. 7.5 YR 5/2.	
	0.67-3.0 feet BLS	0.0-1.0	Well-sorted silt, moderate moisture, moderate cohesion and plasticity. 7.5 YR 5/2.	
	3.0-3.67 feet BLS		Well-sorted silt, moderate moisture, moderate cohesion and plasticity, with minor caliche. 7.5 YR 5/2.	
	3.67-5.0 feet BLS	3.0-4.0	Well-sorted silt, moderate moisture, moderate cohesion and plasticity. 7.5 YR 5/2.	
	5.0-5.67 feet BLS	5.0-5.5	Well-sorted silty clay, very low moisture, moderate cohesion, no plasticity, mottled, with caliche. 7.5 YR 7/0 to 7.5 YR 8/3.	
	5.67-9.0 feet BLS		Well-sorted silty clay, cohesive, moderate plasticity, with anhydrite-gypsum pebbles (up to 0.5 inches in diameter). 7.5 YR 5/4.	

Figure 4.2 Soil Boring Log, NLF-SB-001, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 002
START DRILLING: Sept. 18, 1990
COMPLETED: Sept. 18, 1990
TOTAL DEPTH (BLS): 9.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ___ AUGER _X_ OTHER ___
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ___ SPLT SPN ___ SHELBY ___ CORING _X_
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-1.0 feet BLS	0.0-1.0	Well-sorted silt, very low moisture, no cohesion or plasticity. 7.5 YR 6/2.	
	1.0-3.0 feet BLS		Well-sorted silty clay, moderate moisture, moderate cohesion and plasticity. 7.5 YR 5/4.	
	3.0-5.5 feet BLS	3.0-4.0 5.0-5.5	Well-sorted silty clay, moderate moisture, moderate cohesion and plasticity, with 10 percent very fine grained caliche.	
	5.5-6.8 feet BLS		Well-sorted silty clay, moderate moisture, moderate cohesion and plasticity, with 20 to 40 percent crystalline caliche (up to one inch in diameter).	
	6.8-9.0 feet BLS	6.0-7.0 8.0-9.0	Well-sorted clay, cohesive, moderate plasticity, stiff compentent texture, with 10 to 15 percent caliche. 7.5 YR 3/3.	

Figure 4.3 Soil Boring Log, NLF-SB-002, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 003
START DRILLING: Sept. 18, 1990
COMPLETED: Sept. 18, 1990
TOTAL DEPTH (BLS): 8.2 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-1.25 feet BLS	0.0-1.0	Well-sorted silt, very low moisture, no cohesion, no plasticity. 7.5 YR 5/2.	
	1.25-3.0 feet BLS		Well-sorted silt, very low moisture, moderate cohesion, no plasticity.	
	3.0-4.0 feet BLS	3.0-4.0	Well-sorted silt, moderate moisture, moderate cohesion, no plasticity, mottled, with 10 percent caliche.	
	4.0-5.5 feet BLS	5.0-5.5	Well-sorted silt, moderate moisture, moderate cohesion, no plasticity, mottled, with 20 to 30 percent caliche.	
	5.5-7.0 feet BLS	6.0-7.0	Well-sorted silt, moderate moisture, moderate cohesion and plasticity, with aggregates of caliche (up to 1 inch in diameter). 7.5 YR 5/2.	
	7.0-8.2 feet BLS	7.5-8.2	Well-sorted clay, good moisture, good cohesion and plasticity, very stiff texture.	

Figure 4.4 Soil Boring Log, NLF-SB-003, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 004
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ___
AUGER X
OTHER ___
DRILLING FLUID:

METHOD-SPLG: CUTTINGS ___
SPLT SPN ___
SHELBY ___
CORING X
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-1.0 feet BLS	0.0-1.0	Black asphaltic silt, petroliferous, crumbly texture, exuding product.	
	1.0-2.0 feet BLS		Medium brown silty clay. 10 YR 4/3.	
	2.0-5.0 feet BLS	3.0-4.0	Medium brown clay, low moisture, stiff texture, with minor gypsum or caliche, rootlets, no visible contamination. 10 YR 4/3.	
	5.0-7.0 feet BLS	5.0-5.5 6.0-7.0	Medium brown to light brown clayey silt, low moisture, with 10 percent gypsum. 10 YR 4/3 to 10 YR 3/2.	
	8.0-10.0 feet BLS	8.0-9.0	Medium brown to light brown clayey silt, low moisture, with 10 percent gypsum. 10 YR 4/3 to 10 YR 3/2.	

Figure 4.5 Soil Boring Log, NLF-SB-004, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 005
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____
AUGER __X__
OTHER ____
DRILLING FLUID:

METHOD-SPLG: CUTTINGS ____
SPLT SPN ____
SHELBY ____
CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-1.0 feet BLS	0.0-1.0	Black asphaltic clay, crumbly texture, exuding product.	
	1.0-2.0 feet BLS		Eighty percent black clay, low moisture, low plasticity, hard texture. Ten percent medium-brown clay. 10 YR 4/3.	
	2.0-4.0 feet BLS	3.0-4.0	Clayey silt, low moisture, low to moderate plasticity, with minor rootlets, no visible contamination. 10 YR 4/3.	
	4.0-5.0 feet BLS		Medium to light brown clayey silt, with rootlets. 10 YR 4/3 to 10 YR 3/2.	
	5.0-6.0 feet BLS	5.0-5.5	Medium to light brown clayey silt, very low moisture, stiff texture with rootlets. 10 YR 4/3 to 10 YR 3/2.	
	6.0-8.0 feet BLS	6.0-7.0	Light brown clay, low moisture, low plasticity, stiff texture. 10 YR 3/2.	
	8.0-10.0 feet BLS	8.0-9.0	Light brown clay, with 10 to 20 percent white gypsum or caliche, mottled with medium brown clay, with gravel at 9-10 feet BLS (up to one inch in diameter, angular). 10 YR 2/1 to 10 YR 4/3.	

Figure 4.6 Soil Boring Log, NLF-SB-005, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 006
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-0.3 feet BLS	0.0-1.0	Black asphaltic material, very low moisture, crumbly texture.	
	0.3-0.8 feet BLS	0.0-1.0	Oily sludge-day mixture, visibly shiny, with thick-textured fluid.	
	0.8-3.8 feet BLS	3.0-4.0	Fifty percent medium brown clay, low moisture. 10 YR 4/3. Fifty percent black (dissolved) clay, with rootlets.	
	3.8-5.0 feet BLS	3.0-4.0	Medium brown clayey silt, low moisture, low plasticity, with rootlets. 10 YR 4/3.	
	5.0-5.8 feet BLS	5.0-5.5	Medium to light brown clayey silt, with rootlets.	
	5.8-7.5 feet BLS	6.0-7.0	Light brown silty clay, with some white material, with pebbles. 7.5 YR 8/3.	
	7.5-10.0	8.0-9.0	Very light brown to white silty clay, very low moisture, crumbly texture, with well-rounded, blue-gray pebbles (up to two inches in diameter). 7.5 YR 8/2.	

Figure 4.7 Soil Boring Log, NLF-SB-006, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 007
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:

METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-2.0 feet BLS	0.0-1.0	Blue-black silty clay, crumbly texture, asphaltic, compressed during coring.	
	2.0-4.0 feet BLS	3.0-4.0	Medium brown clayey silt, low moisture, with rootlets, no visible contamination. 10 YR 4/3.	
	4.0-7.0 feet BLS	5.0-5.5	Medium brown clayey silt, low moisture, grading to light brown silty clay. 10 YR 4/3 to 7.5 YR 8/3.	
	7.0-9.0 feet BLS	6.0-7.0 8.0-9.0	Light brown silty clay, low moisture, hard texture. 7.5 YR 8/3.	
	9.0-10.0 feet BLS		Light brown silty clay, low moisture, hard texture, with well-rounded gray pebbles (up to one inch in diameter).	

Figure 4.8 Soil Boring Log, NLF-SB-007, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 008
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-2.0 feet BLS	0.0-1.0	Black, asphaltic material, crumbly texture, obviously contaminated.	
	3.0-4.0 feet BLS	3.0-4.0	Medium brown clay silt, with rootlets, no visible contamination. 10 YR 4/3.	
	5.0-6.0 feet BLS	5.0-5.5	Medium brown clay silt, with rootlets, no visible contamination, grading to light gray clay silt. 10 YR 4/3.	
	6.0-8.0 feet BLS	6.0-7.0	Light brown to white clay, mottled, very low moisture, crumbly texture, with gypsum or caliche.	
	9.0-10.0 feet BLS		Light brown to white clay, mottled, very low moisture, crumbly texture, with less gypsum or caliche than in the 6.0-8.0 feet interval.	

Figure 4.9 Soil Boring Log, NLF-SB-008, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 009
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-2.0 feet BLS	0.0-1.0	Bluish-black silty clay, low moisture, crumbly texture, grading to brownish clay, higher moisture.	
	2.0-4.0 feet BLS	3.0-4.0	Medium brown clay, low moisture, moderate plasticity, hard texture, with caliche, rootlets. 10 YR 4.3.	
	5.0-6.0 feet BLS	5.0-5.5	Medium brown silty clay, no visible contamination. 10 YR 4/3.	
	6.0-7.0 feet BLS	6.0-7.0	Medium to light brown clay, some silt, caliche.	
	7.0-8.0 feet BLS		Greenish-gray clay, soft texture, no visible contamination.	
	8.0-9.0 feet BLS	8.0-9.0	Bluish-gray to white clay, hard texture, with caliche.	
	9.0-10.0 feet BLS		Light gray to white caliche, very low moisture, crumbly texture, no visible contamination.	

Figure 4.10 Soil Boring Log, NLF-SB-009, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 010 - 02
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____
AUGER __X__
OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____
SPLT SPN ____
SHELBY ____
CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-2.0 feet BLS	0.0-1.0	Black asphaltic material, very low moisture, crumbly texture.	
	2.0-4.0 feet BLS		Brown-gray clay silt, moderate plasticity, with rootlets. 7.5 YR 5/2.	
	4.0-5.0 feet BLS		Black clayey silt, with gypsum, rootlets.	
	5.0-6.5 feet BLS	5.0-5.5 6.0-7.0	Gray-black clay, very low moisture, with gypsum.	
	6.5-9.0 feet BLS	6.0-7.0 8.0-9.0	Gray clay, chalky, hard texture, with petroleum odor.	
	9.0-10.0 feet BLS		Gray clay, very hard or gravel-like texture. 7.5 YR 7/0.	

Figure 4.11 Soil Boring Log, NLF-SB-010, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 011
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____
AUGER __X__
OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____
SPLT SPN ____
SHELBY ____
CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-1.0 feet BLS	0.0-1.0	Brown-black asphaltic material, very low moisture, crumbly texture.	
	5.0-5.5 feet BLS	5.0-5.5	Dark gray to black clay, very low moisture, with rootlets, discolored from petroleum product.	
	6.0-7.0 feet BLS	6.0-7.0	Light gray to light brown silty clay, hard texture, petroleum odor. 7.5 YR 8/0 to 7.5 YR 7/2.	
	8.0-9.0 feet BLS	8.0-9.0	Light gray clay, chalky, with gypsum, strong petroleum odor. 7.5 YR 8/0.	

Figure 4.12 Soil Boring Log, NLF-SB-011, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Truck Bypass Landfarm
BORING / WELL: NLF - SB - 012
START DRILLING: Sept. 19, 1990
COMPLETED: Sept. 19, 1990
TOTAL DEPTH (BLS): 10.0 feet
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ___ AUGER _X_ OTHER ___
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ___ SPLT SPN ___ SHELBY ___ CORING _X_
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-1.0 feet BLS	0.0-1.0	Black, asphaltic material, very low moisture, crumbly texture.	
	1.0-2.0 feet BLS		Dark brown clay, mottled with gray and black, hard texture, strong odor.	
	2.0-3.0 feet BLS		Medium brown clay, hard, stiff texture, with rootlets, minor visible contamination. 10 YR 4/3.	
	3.0-5.0 feet BLS		Brownish-gray silty clay, hard texture, with rootlets. 10 YR 5/2.	
	5.0-6.0 feet BLS	5.0-5.5	Brownish-gray silty clay, hard texture. 10 YR 5/2.	
	6.0-8.0 feet BLS	6.0-7.0	Gray clay, very hard texture, with gypsum, no odor. 7.5 YR 8/0.	
	8.0-10.0 feet BLS	8.0-9.0	Light brown to light gray clay, mottled, chalky, very hard texture, no odor. 7.5 YR 7/2 to 7.5 YR 8/0.	

Figure 4.13 Soil Boring Log, NLF-SB-012, RFI Phase I Report, Navajo Refining Company, October 1990.

Table 4.5. Truck Bypass Landfarm, Soils Analytical Results - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		---------- Sample Number ---------			
COMPOUND	UNITS	NLF-SB-004-01	NLF-SB-006-01	NLF-SB-006-02	NLF-SB-011-04
1,1,2,2-Tetrachloroethane	mg/kg		1.2		
Benzene	mg/kg	1.2			1.7
Toluene	mg/kg	1.2	0.73	0.68	0.63
Ethylbenzene	mg/kg	1.5		0.95	0.68
Xylenes	mg/kg	1.4	0.3	2.1	3.8

* Blanks and all other analyses were below reported limits.

Semivolatiles

Semivolatile organic compound analytical results from truck bypass landfarm soil samples are listed in Table 4.6. Only those samples with one or more detectable semivolatile organic compounds are included. Nineteen semivolatile compounds occur above their respective CRDLs in 31 soil samples. No semivolatile compounds occur above their CRDLs in the background soil samples (NLF-SB-001, 002, and 003).

The following semivolatile organic compounds occur in concentrations exceeding their respective CRDLs: anthracene, benzo(a)anthracene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, dibenzofuran, chrysene, di-n-butylphthalate, 2,6-dinitrotoluene, fluoranthene, 2-methylnaphthalene, 2-methylphenol, naphthalene, phenanthrene, pyrene, butyl benzyl phthalate, and 2,4-dinithrotoluene.

The identified compounds are discussed below in order of their relative abundance. The sample(s) in which each compound occurs and the respective concentration levels are included. Di-n-butylphthalate is identified in 26 samples; NLF-SB-002-01 (22 mg/kg), NLF-SB-004-03, 04, 05, 06, and 07 (range from 2.5 mg/kg to 3.1 mg/kg), NLF-SB-005-01, 02, 03, and 05 (range from 2.0 mg/kg to 3.2 mg/kg), NLF-SB-006-01 (2.2 mg/kg), and 02 (1.9 mg/kg), NLF-SB-007-02 (1 mg/kg), and 03 (1.3 mg/kg), NLF-SB-007-02, 03, 04, and 05 (range from 1.2 mg/kg to 2.2 mg/kg), NLF-SB-009-02 (1.2 mg/kg), 03 (2.5 mg/kg), and 04 (2.5 mg/kg), NLF-SB-010-02 (2.4 mg/kg), 03 (2.4 mg/kg), and 04 (2.5 mg/kg), and NLF-SB-011-01 (82 mg/kg), and 04 (1.3 mg/kg). Pyrene is detected in 10 samples; NLF-SB-005-01 (59 mg/kg), NLF-SB-006-01 (55 mg/kg), and 02 (29 mg/kg), NLF-SB-007-01 (240 mg/kg), NLF-SB-008-02 (1.1 mg/kg), NLF-SB-009-01 (0.66 mg/kg), NLF-SB-011-01 (69 mg/kg), and NLF-SB-012-01 (27 mg/kg).

Table 4.6. Truck Bypass Landfarm, Soils Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990 *

		---------------- Sample Number ----------------						
		NLF-SB-004-01	NLF-SB-004-03	NLF-SB-004-04	NLF-SB-004-05	NLF-SB-004-06	NLF-SB-004-07	NLF-SB-005-01
Anthracene	mg/kg							23
Benzo(a)anthracene	mg/kg							
Benzo(k)fluoranthene	mg/kg	29						
Benzo(a)pyrene	mg/kg							8
Butyl benzyl phthalate	mg/kg					1.1		
Chrysene	mg/kg	51						62
Di-n-butyl phthalate	mg/kg		3.1	3	2.8	2.5	2.9	2.4
Fluorene	mg/kg							
2-Methylnaphthalene	mg/kg							
2-Methylphenol	mg/kg							
Phenanathrene	mg/kg	30						27
Pyrene	mg/kg	34						59

* Blanks and all other analyses were below reported limits.

Table 4.6 (cont). Truck Bypass Landfarm, Soils Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		-------- Sample Number ---------					
		NLF-SB-005-02	NLF-SB-005-03	NLF-SB-005-05	NLF-SB-006-01	NLF-SB-006-02	NLF-SB-007-01
COMPOUND	UNITS						
Anthracene	mg/kg				3.7		7.9
Benzo(b)fluoranthene	mg/kg						36
Benzo(g,h,i)perylene	mg/kg						17
Benzo(a)pyrene	mg/kg				0.66		75
Dibenzofuran	mg/kg					3.8	
Di-n-butylphthalate	mg/kg	2	2.2	3.2	2.2	1.9	
2,6-Dinitrotoluene	mg/kg					1.3	
Fluoranthene	mg/kg				6.4		21
Fluorene	mg/kg				4.2	6.2	
2-Methylnaphthalene	mg/kg					20.2	
Naphthalene	mg/kg					5.2	
Phenanathrene	mg/kg				55	46	160
Pyrene	mg/kg				55	29	240

Table 4.6 (cont). Truck Bypass Landfarm, Soils Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		----------- Sample Number ------------							
		NLF-SB-007-02	NLF-SB-007-03	NLF-SB-008-01	NLF-SB-008-02	NLF-SB-008-03	NLF-SB-008-04	NLF-SB-008-05	NLF-SB-009-01
COMPOUND	UNITS								
Anthracene	mg/kg					0.72			
Benzo(b)fluoranthene	mg/kg			0.85					0.82
Benzo(k)fluoranthene	mg/kg			1.4					1.4
Chrysene	mg/kg			0.71					
Di-n-butyl phthalate	mg/kg	1	1.3		1.3	1.4	1.2	2.2	
Phenanathrene	mg/kg				0.95				
Pyrene	mg/kg				1.1				0.66

Table 4.6 (cont). Truck Bypass Landfarm, Soils Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		------------- Sample Number --------------							
		NLF-SB-009-02	NLF-SB-009-03	NLF-SB-009-04	NLF-SB-010-01	NLF-SB-010-02	NLF-SB-010-03	NLF-SB-010-04	NLF-SB-011-01
COMPOUND	UNITS				12				
					19				
Benzo(a)anthracene	mg/kg				22				29
Benzo(b)fluoranthene	mg/kg		0.84		22				67
Benzo(k)fluoranthene	mg/kg		1.4		11				
Chrysene	mg/kg				0.89				50
Di-n-butyl phthalate	mg/kg	1.2	2.5	2.5	27	2.4	2.4	2.5	82
Fluorene	mg/kg				20				43
Phenanathrene	mg/kg				33				26
Pyrene	mg/kg								69

Table 4.6 (cont). Truck Bypass Landfarm, Soils Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		-- Sample Number --	
COMPOUND	UNITS	NLF-SB-011-04	NLF-SB-012-01
Anthracene	mg/kg		79
Benzo(a)anthracene	mg/kg		38
Benzo(b)fluoranthene	mg/kg		66
Benzo(a)pyrene	mg/kg		9
Chrysene	mg/kg		29
Di-n-butyl phthalate	mg/kg	1.3	
2,4-Dinitrotoluene	mg/kg	0.76	
Fluoranthene	mg/kg		10
Fluorene	mg/kg	0.69	
Phenanathrene	mg/kg	1.3	45
Pyrene	mg/kg		27

Phenanthrene is also detected in 10 samples; NLF-SB-002-01 (20 mg/kg), NLF-SB-004-01 (30 mg/kg), NLF-SB-005-01 (27 mg/kg), NLF-SB-006-01 (55 mg/kg), and 02 (46 mg/kg), NLF-SB-007-01 (160 mg/kg), NLF-SB-008-02 (0.95 mg/kg), NLF-SB-011-01 (26 mg/kg), NLF-SB-011-04 (1.3 mg/kg), and NLF-SB-012-01 (45 mg/kg). Anthracene occurs in six samples; NLF-SB-002-01 (12 mg/kg), NLF-SB-005-01 (23 mg/kg), NLF-SB-006-01 (3.7 mg/kg), NLF-SB-007-01 (7.9 mg/kg), NLF-SB-008-03 (0.72 mg/kg), and NLF-SB-012-01 (79 mg/kg). Benzo(b)fluoranthene is identified in six samples; NLF-SB-007-01 (36 mg/kg), NLF-SB-008-01 (0.85 mg/kg), NLF-SB-009-01 (0.82 mg/kg), and 03 (0.84 mg/kg), NLF-SB-011-01 (67 mg/kg), and NLF-SB-012-01 (66 mg/kg). Chrysene is also detected in six samples; NLF-SB-002-01 (22 mg/kg), NLF-SB-004-01 (51 mg/kg), NLF-SB-005-01 (62 mg/kg), NLF-SB-008-01 (0.71 mg/kg), NLF-SB-011-01 (50 mg/kg), and NLF-SB-012-01 (29 mg/kg). Fluorene occurs in five samples; NLF-SB-002-01 (11 mg/kg), NLF-SB-006-01 (4.2 mg/kg), and 02 (6.2 mg/kg), NLF-SB-011-01 (43 mg/kg), and NLF-SB-011-04 (0.69 mg/kg). Benzo(a)pyrene is identified in four samples; NLF-SB-005-01 (8 mg/kg), NLF-SB-006-01 (0.66 mg/kg), NLF-SB-007-01 (75 mg/kg), and NLF-SB-012-01 (9 mg/kg). Benzo(k) fluoranthene also occurs in four samples; NLF-SB-004-01 (29 mg/kg), NLF-SB-008-01 (1.4 mg/kg), NLF-SB-009-01 (1.4 mg/kg), and NLF-SB-009-03 (1.4 mg/kg). Benzo(a)anthracene is detected in three samples; NLF-SB-002-01 (19 mg/kg), NLF-SB-011-01 (29 mg/kg), and NLF-SB-012-01 (38 mg/kg). Fluoranthene is also detected in three samples; NLF-SB-006-01 (6.4 mg/kg), NLF-SB-007-01 (21 mg/kg), and NLF-SB-012-01 (10 mg/kg). The compound 2-methylnaphthalene occurs in two samples; NLF-SB-002-01 (0.89 mg/kg), and NLF-SB-006-02 (20.2 mg/kg). The remaining seven compounds occur in only one sample each; benzo(g,h,i) perylene (NLF-SB-007-01, 17 mg/kg), dibenzofuran (NLF-SB-006-02, 3.8 mg/kg), 2,6-dinitrotoluene (NLF-SB-006-02, 1.3 mg/kg), 2-methyphenol (NLF-SB-002-01, 27 mg/kg), naphthalene (NLF-SB-006-02, 5.2 mg/kg), butyl benzylphthalate (NLF-SB-004-06, 1.1 mg/kg), and 2,4-dinitrotoluene (NLF-SB-011-04, 0.76 mg/kg).

Metals

Soil boring metals analytical data for the Truck Bypass Landfarm are listed in Table 4.7.

Background Soil Borings

A comparison of background samples from all depths (15 samples) is undertaken for the purpose of discussion. Antimony, mercury, and selenium are below the CRDL for all samples. The background concentration range and mean for metals above the CRDL are as follows: arsenic (2.75-28.7 mg/kg, 10.0 mg/kg, 10.0 mg/kg), barium (14.5-674 mg/kg, 103.7 mg/kg), beryllium (0-1.03 mg/kg, 0.63 mg/kg), cadmium (0-6.56 mg/kg, 2.76 mg/kg), chromium (0-14.9 mg/kg, 6.05 mg/kg), lead (2.47-15.00 mg/kg, 6.8 mg/kg), nickel (5.16-14.6 mg/kg, 9.8 mg/kg), silver (0-3.75 mg/kg, 1.9 mg/kg), zinc (6.8-36.6 mg/kg, 21.7 mg/kg), and oil and grease (0-0.084%, 0.017%).

Landfarm Soil Borings

At least one sample is above the CRDL for arsenic, barium, beryllium, cadmium, chromium, lead, nickel, silver, zinc, and oil and grease. All samples are below CRDLs for antimony and selenium. Mercury values for all samples are near or below the CRDLs.

Samples that exceed background concentration ranges are exclusively located in the uppermost sample intervals (1-3' BLS). Metals that exhibit this distribution pattern are arsenic, chromium, lead, nickel, and zinc. Silver exhibits the reverse relationship in samples NLF-SB-004, 006, 010, and 011, with concentrations ranging from 2.55 mg/kg to 5.68 mg/kg. The enrichment of arsenic, chromium, lead, nickel, and zinc in the

Table 4.7. Truck Bypass Landfarm, Soils Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number									
METAL	UNITS	NLF-SB-001-01	NLF-SB-001-02	NLF-SB-001-03	NLF-SB-001-04	NLF-SB-001-05	NLF-SB-002-01	NLF-SB-002-02	NLF-SB-002-03	NLF-SB-002-04	NLF-SB-002-05
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	6.64	4.77	3.1	2.75	28.7	13.1	11	4.61	6.58	26.5
Barium	mg/kg	86.5	101	39.5	134	14.5	83.9	674	112	20.3	15.7
Beryllium	mg/kg	1.03	0.954	0.662	0.6	0.815	0.579	0.45	0.298	0.94	0.825
Cadmium	mg/kg	5.04	4.14	3.4	3.4	2.5	2.2	1.6	3.3	4.4	3.3
Chromium	mg/kg	1.49	0.89	< 0.30	< 0.30	14	5.89	8.95	5.35	8.21	14.9
Lead	mg/kg	14.6	8.05	2.47	3	7.03	21.7	5.91	2.71	5.33	8
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	14.6	13.7	9.02	9.5	11	7.65	9	6.24	8.15	12
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	1.93	1.49	1.5	3.75	0.84	2.23	2.53	2.17	2.82	1
Zinc	mg/kg	34.9	28.3	11.4	6.8	36.6	42.1	23.4	12.8	19.7	36.3
Oil and Grease	percent	0.017	0.004	0.01	0.011	0.01	0.004	0.014	0.02	0.014	0.025

Table 4.7 (cont). Truck Bypass Landfarm, Soils Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number								
METAL	UNITS	NLF-SB-003-01	NLF-SB-003-02	NLF-SB-003-03	NLF-SB-003-04	NLF-SB-003-05	NLF-SB-004-01	NLF-SB-004-02	NLF-SB-004-03	NLF-SB-004-04
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	4.67	4.61	3	5.01	24.2	6.44	2.96	6.97	4.11
Barium	mg/kg	103	54.9	66.1	29.9	20.2	38.5	78.6	223	17
Beryllium	mg/kg	0.493	< 0.30	0.367	0.94	0.568	0.399	0.532	0.995	0.601
Cadmium	mg/kg	0.52	< 0.30	0.67	0.31	6.56	1.99	2.51	5.84	3.26
Chromium	mg/kg	6.53	3.07	3.8	8.11	9.62	52.1	< 0.30	4.91	< 0.30
Lead	mg/kg	15	2.71	4.67	2.82	13	148	4.43	6.3	3.13
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	8.55	5.16	7.67	14.1	8.16	9.81	8.28	14.9	9.81
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	< 0.50	2.44	2.67	3.44	< 0.50	< 0.50	< 0.50	2.65	3.16
Zinc	mg/kg	22.6	11.7	18.7	12.8	28.4	41.7	11.8	28.2	10.8
Oil and Grease	percent	0.016	0.005	0.084	< 0.01	0.005	22.3	0.001	0.005	0.007

Table 4.7 (cont). Truck Bypass Landfarm, Soils Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number									
METAL	UNITS	NLF-SB-005-01	NLF-SB-005-02	NLF-SB-005-03	NLF-SB-005-04	NLF-SB-005-05	NLF-SB-006-01	NLF-SB-006-02	NLF-SB-006-03	NLF-SB-006-04	NLF-SB-006-05
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	14		4.56	4.47	2.8	14.2	3.33	4.96	4.62	2.73
Barium	mg/kg	107		99	100	113	100	84.3	255	94.1	53.3
Beryllium	mg/kg	0.762		0.517	0.417	0.535	0.68	0.54	0.49	0.37	< 0.30
Cadmium	mg/kg	6		3.35	2.8	3.46	6.25	3.33	3.89	3.05	2.62
Chromium	mg/kg	68.8	12.2	3.38	2.26	3.76	89.4	9.49	9.38	3.38	4.78
Lead	mg/kg	299	10.4	5.78	2.98	2.55	163	7.7	6.34	2.77	2.46
Mercury	mg/kg	0.06	< 0.05	< 0.05	< 0.05	< 0.05	0.06	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	31.4	14.2	8.83	7.74	8.95	34	10.5	10.8	7.08	7.37
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	1.59	< 0.50	0.913	2.38	2.55	< 0.50	< 0.50	1.38	< 0.50	4.37
Zinc	mg/kg	87.7	44.2	19.8	11.3	15.3	100	31.5	26.7	14.8	8.7
Oil and Grease	percent	17.4	0.013	0.006	0.077	0.008	17.9	4.08	0.014	0.013	0.015

Table 4.7 (cont). Truck Bypass Landfarm, Soils Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number									
METAL	UNITS	NLF-SB-007-01	NLF-SB-007-02	NLF-SB-007-03	NLF-SB-007-04	NLF-SB-007-05	NLF-SB-008-01	NLF-SB-008-02	NLF-SB-008-03	NLF-SB-008-04	NLF-SB-008-05
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	14.3	2.06	4.78	4.37	3.75	25.6	10.8	9.46	3.44	3
Barium	mg/kg	91.3	79	87.2	123	145	105	97.9	119	51.5	28.2
Beryllium	mg/kg	0.54	0.44	0.34	0.51	0.35	0.528	0.528	0.397	< 0.30	< 0.30
Cadmium	mg/kg	5.04	1.85	1.99	4.09	2.75	4.8	1.3	0.61	< 0.30	0.5
Chromium	mg/kg	82.7	4.07	4.03	9.82	5.4	89	8	6.44	1.46	4.08
Lead	mg/kg	191	7.73	6.37	5.91	2.75	252	10.3	7.02	1.26	2.5
Mercury	mg/kg	0.07	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	23.1	6.96	6.63	10.5	6.5	37.3	9.31	8.55	4.01	6.5
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	0.96	1.51	1.22	2.58	2.5
Zinc	mg/kg	92.8	13.1	13.8	27	13.3	101	30.7	25.3	8	11
Oil and Grease	percent	18.4	0.017	< 0.01	0.009	0.008	15.3	0.021	0.064	0.019	0.014

Table 4.7 (cont). Truck Bypass Landfarm, Soils Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		------------------------------------ Sample Number								
METAL	UNITS	NLF-SB-009-01	NLF-SB-009-02	NLF-SB-009-03	NLF-SB-009-04	NLF-SB-009-05	NLF-SB-010-01	NLF-SB-010-02	NLF-SB-010-03	NLF-SB-010-04
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 3.00	< 3.00	< 3.00
Arsenic	mg/kg	27.5	13.9	6.33	2.91	1.85	18.1	1.83	6	1.65
Barium	mg/kg	87.3	128	81.5	80.2	83.4	147	< 3.00	16.7	33
Beryllium	mg/kg	0.571	0.599	0.385	0.402	< 0.30	1.16	0.03	0.2	0.09
Cadmium	mg/kg	3.5	1.9	< 0.30	< 0.30	< 0.30	8.08	< 0.20	< 0.20	< 0.20
Chromium	mg/kg	56.2	11.8	6.71	3.71	1.77	50.4	6.3	16	7.67
Lead	mg/kg	193	10.1	5.23	4.33	1.44	231	0.8	1.77	0.57
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.06	< 0.05	< 0.05	< 0.50
Nickel	mg/kg	21.2	12.3	7.7	6.02	4.81	33.1	2.9	7.7	6.3
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 1.50	< 1.50	< 1.50
Silver	mg/kg	2.18	1.89	2.08	2.17	3.04	1.22	2.03	2.67	5.68
Zinc	mg/kg	69.9	40	22.8	13	4.6	64.3	6.38	11.7	2.27
Oil and Grease	percent	17.5	0.32	0.163	0.008	0.003	11.9	0.212	0.022	0.058

Table 4.7 (cont). Truck Bypass Landfarm, Soils Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

METAL	UNITS	Sample Number							
		NLF-SB-011-01	NLF-SB-011-02	NLF-SB-011-03	NLF-SB-011-04	NLF-SB-012-01	NLF-SB-012-02	NLF-SB-012-03	NLF-SB-012-04
Antimony	mg/kg	< 3.00	< 3.00	< 3.00	< 3.00	< 3.00	< 3.00	< 3.00	< 3.00
Arsenic	mg/kg	41.5	6.19	2.64	0.045	34.3	10.6	1.69	1.25
Barium	mg/kg	95	43.6	63	107	118	591	55	51.8
Beryllium	mg/kg	0.59	0.28	0.05	0.06	0.614	0.37	0.149	0.153
Cadmium	mg/kg	0.31	< 0.20	< 0.20	< 0.20	0.2	< 0.20	< 0.20	< 0.20
Chromium	mg/kg	74.3	12.1	7.36	8.07	77.6	14.9	4.88	1.83
Lead	mg/kg	214	2.8	1.15	0.63	210	6.22	0.51	0.94
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	22.6	3.94	2.5	2.7	19.4	5.6	2.7	3.4
Selenium	mg/kg	< 1.50	< 1.50	< 1.50	< 1.50	< 1.50	< 1.50	< 1.50	< 1.50
Silver	mg/kg	1.86	1.41	4.09	4.48	0.97	1.87	2.97	2.74
Zinc	mg/kg	86.7	12.4	4.09	1.49	77.6	14.9	4.76	9.44
Oil and Grease	percent		0.033		0.126	16.9	0.014	0.012	< 0.01

near-surface of the landfarm occurs in samples NLF-SB-004, 005, 006, 007, 008, 009, 010, 011, and 012. Arsenic ranges from 6.44 mg/kg to 41.5 mg/kg, chromium ranges from 50.4 mg/kg to 89.4 mg/kg, lead ranges from 148 mg/kg to 299 mg/kg, nickel ranges from 9.81 mg/kg to 37.3 mg/kg, and zinc ranges from 41.7 mg/kg to 101.0 mg/kg in the upper intervals of these samples. Oil and grease are also enriched in the upper intervals of this sample set, ranging from 11.9 percent to 22.3 percent. Samples NLF-SB-004, 008, and 010 exhibit particularly pronounced enrichment of some of these elements and oil and grease.

4.3.1.5 Truck Bypass Landfarm, Soils Borings, Statistical Analyses - Metals

Two-way analysis of variance (ANOVA) was performed to test for main effects of sample location and sample depth and interactive effects of location and depth on concentrations of metals in landfarm and background soils. ANOVA is a statistical procedure that tests for effects of independent variables on a dependent variable and, in general, can determine if the means of three or more groups are significantly different. Statistical differences between group means are tested with an F statistic. The probability of making an error of determining that the means of two groups are significantly different when they are not is denoted by a P value. In this report, if $P \leq 0.05$, group means are significantly different.

There were two independent variables used in the ANOVA, sampling location (Truck Bypass Landfarm and background sites) and sampling depth (five depths). The ANOVA was performed using an SPSSX statistical package.

Results of the two-way ANOVA (Table 4.8) show that there are significant statistical differences in concentration of metals in landfarm soils compared with background soils, and that sampling

Table 4.8 Truck Bypass Landfarm, Soils Statistical Results, P Values and Means-Metals, RFI Phase I Report, Navajo Refining Company, October, 1990.

		----- P Value -----		
Element	n	Site	Depth	Interaction
Chromium	52	$\leq$0.0001	$\leq$0.0001	$\leq$0.0001
Lead	56	$\leq$0.0001	$\leq$0.0001	$\leq$0.0001
Arsenic	56	0.264	$\leq$0.0001	$\leq$0.0001
Nickel	56	0.221	$\leq$0.0001	$\leq$0.0001
Zinc	56	0.033	$\leq$0.0001	$\leq$0.0001
Beryllium	51	0.002	0.028	0.170
Barium	55	0.796	0.145	0.158
Cadmium	42	0.704	0.742	0.583
Silver	43	0.829	$\leq$0.0001	$\leq$0.0001
Oil and Grease	51	$\leq$0.0001	$\leq$0.0001	$\leq$0.0001

----- Means -----

	Chromium		Lead		Arsenic		Nickel	
Depth	Backgr.	Landf.	Backgr.	Landf.	Backgr.	Landf.	Backgr.	Landf.
0	4.64	71.17	17.1	211.22	8.14	21.77	10.27	25.77
1	4.3	9.11	5.56	9.25	6.79	6.97	9.29	10.65
2	4.57	7.91	3.28	5	3.57	5.74	7.64	7.03
3	8.16	5.98	3.72	3	4.78	4.12	10.58	7.02
4	12.84	4.67	9.34	1.89	26.47	2.35	10.39	6.26
Mean	6.99	21.55	7.8	49.66	9.95	8.31	9.63	11.41

	Zinc		Beryllium		Barium		Cadmium	
Depth	Backgr.	Landf.	Backgr.	Landf.	Backgr.	Landf.	Backgr.	Landf.
0	33.2	80.19	0.7	0.65	91.13	98.79	2.59	4.02
1	21.13	31.9	0.7	0.59	276.63	106.44	2.87	2.83
2	14.3	17.1	0.44	0.37	72.53	169.36	2.46	2.47
3	13.1	13.65	0.83	0.39	61.4	89.61	2.7	3.94
4	33.77	8.54	0.74	0.3	16.8	70.19	4.12	2.52
Mean	23.1	30.12	0.68	0.46	103.7	105.36	2.95	3.25

Depth	Silver		Oil and Grease	
	Backgr.	Landf.	Backgr.	Landf.
0	2.08	1.46	0.01	17.2
1	2.15	1.7	0.01	0.89
2	2.11	1.56	0.04	0.06
3	3.34	2.79	0.01	0.02
4	0.92	3.57	0.01	0.03
Mean	2.22	2.37	0.02	3.86

depth also can have important effects on metals concentration. Significant interactive effects indicate that metal concentrations related to sampling depth are statistically dependent on sampling location. The following section describes results of the two-way ANOVA for each metal analyzed.

There were a significant main effect of location and depth on chromium concentrations ($P \leq 0.0001$) and a significant interaction of location and depth ($P \leq 0.0001$). Mean chromium concentrations were highest (71.17 mg/kg) in the surface soil samples within the landfarm and decreased with depth to 4.67 mg/kg. Mean chromium concentration in background soils ranged from 4.30 to 12.84 mg/kg and were highest at the bottommost sampling depths.

There were a significant effect of sample location ($P \leq 0.0001$) and depth ($P \leq 0.0001$) and a significant interaction ($P \leq 0.0001$) on lead concentrations. Mean lead concentrations were highest in the landfarm surface soils (211.22 mg/kg) and decreased with depth to 1.89 mg/kg. Background soils had a mean surface amount of 17.10 mg/kg, and the mean was 3.28 to 9.34 mg/kg in subsurface levels.

Arsenic levels were significantly affected by depth of sample ($P \leq 0.0001$ but not significantly affected by sample location ($P = 0.264$). There was a significant interaction between location and depth on arsenic concentrations ($P \leq 0.0001$). In the Truck Bypass Landfarm, arsenic concentrations were highest at the surface (21.77 mg/kg) and decreased with depth to 2.35 mg/kg. Mean concentrations in background soils were highest at the base of the soil profile (26.47 mg/kg) and lowest in the middle sampling position (3.57 mg/kg).

Nickel concentrations were significantly affected by depth of sample ($P \leq 0.0001$) but not by sample location ($P = 0.221$). There was no significant interaction between location and depth ($P = .243$). Mean nickel concentration was highest in surface soils within the landfarm (25.77 mg/kg) and decreased with depth to 6.26 mg/kg. In background soils, mean concentrations were similar throughout the soil profile, ranging from 7.64 to 10.58 mg/kg.

Effects of location, depth, and the interaction between location and depth on percent oil and grease were highly significant ($P \leq 0.0001$). This is due primarily to differences in oil and grease percentages in the surface soil samples which were 17.20 percent in the landfarm and 0.01 percent in the background soils. The majority of subsurface samples ranged from 0.01 to 0.06 percent oil and grease at both locations.

Zinc levels were significantly higher in landfarm soils than in background soils ($P = 0.033$). There was a significant effect of sample depth ($P \leq 0.0001$) due to the sharp decrease with depth in landfarm soils (80.19 mg/kg at the surface; 8.54 mg/kg at the base of the profile). There was a significant interactive effect of location and depth on zinc concentrations, probably also due to the steep gradient in landfarm soils.

There were only two additional significant results in this analysis. Beryllium levels were significantly affected by location and depth ($P = 0.002$ and 0.028, respectively), and there were a significant effect of depth and a significant interaction between location and depth on silver concentrations ($P \leq 0.0001$).

4.3.2 Truck Bypass Landfarm Ground Water Sampling

Ground water samples were collected from six previously installed monitor wells adjacent to the Truck Bypass Landfarm site. Samples were analyzed for volatile organics, semivolatile organics, oil and grease, metals, and inorganics in order to characterize potential areal and vertical impact to ground water from disposal activities.

4.3.2.1 Monitor Well Locations

Monitor wells 39, 40, 41, 42, and 29 are downgradient, east of the landfarm site. Monitor wells 39, 40, 41, and 42 are immediately outside the landfarm boundary. Monitor well 29 is approximately 100 ft to the east. Monitor well 43 is upgradient, on the landfarm western boundary (Plate 2).

4.3.2.2 Monitor Well Description

Monitor well 29 is 22 ft deep and constructed of six-inch PVC pipe with a 10-ft screened interval. Monitor wells 39, 40, 41, 42, and 43 are constructed of two-inch PVC pipe with 10-ft screened intervals and range from approximately 20 to 32 ft in total depth. Construction details appear in Table 4.9.

4.3.2.3 Sampling Procedures

Prior to sampling on September 19, 1990, the water level in each well was measured with a steel tape and water-cut paste. Figure 4.14 shows the potentiometric surface in the Truck Bypass Landfarm area (see also Table 4.10). Monitor well 29 was sampled with a teflon bailer after pH, temperature, and conductivity measurements stabilized during the purging of three to five casing volumes. Monitor wells 39, 40, 41, 42, and 43 were sampled with disposable polyethylene bailers after purging from five to seven volumes. Conductivity, pH, and temperature were not measured due to the presence of thick (2.0-3.5') product layers in wells (Table 4.10).

Table 4.9 Truck Bypass Landfarm, Monitor Well Construction Details, RFI Phase I Report, Navajo Refining Company, October 1990.

Well #	Year Completed	Total Depth (ft)	Casing Diameter (in)	Elevation of Top of Casing (ft)	Screened Interval[1] (ft)
29	1982	22.0	6.0	3364.55	19.0-22.0
39	1984	24.0	2.0	3361.07	14.0-24.0
40	1984	30.0	2.0	3361.06	20.0-25.0
41	1984	21.0	2.0	3361.53	14.0-19.0
42	1984	21.0	2.0	3352.55	14.0-19.0
43	1984	22.5	2.0	3362.80	15.5-20.5

[1] Measured from top of casing.

Table 4.10. Truck Bypass Landfarm, Ground Water Levels
RFI Phase I Report, Navajo Refining Company, October 1990

Monitor Well Number	Date Sampled	Elevation Top of Pipe (ft)	Product Thickness (ft)	Elevation Top of Water (ft)
29	9-21	3364.55	< 0.25	3343.8
30	9-22	3359.69	0	3343.48
39	9-22	3361.07	2.36	3344.426
40	9-21	3361.06	3.04	3344.654
41	9-21	3361.53	3.51	3344.883
42	9-21	3352.55	2.94	3335.079
43	9-21	3362.8		3346.33
45	9-22	3356.92		3342.93
46	9-22	3354.81		3340.602
47	9-22	3349.08		3338.205

Table 4.11 Truck Bypass Landfarm, Ground Water Physical Parameters, RFI Phase I Report, Navajo Refining Company, October 1990 .

Well #	Date	Time	pH	Electrical Conductivity (μmhos/cm)	Temperature (°F)
29	9-22	2010	7.05	4840	67
39	NOT SAMPLED DUE TO PRESENCE OF PRODUCT IN WELL				
40	NOT SAMPLED DUE TO PRESENCE OF PRODUCT IN WELL				
41	NOT SAMPLED DUE TO PRESENCE OF PRODUCT IN WELL				
42	NOT SAMPLED DUE TO PRESENCE OF PRODUCT IN WELL				

Figure 4.14. Groundwater Elevations - September, 1990

Truck Bypass Landfarm Area

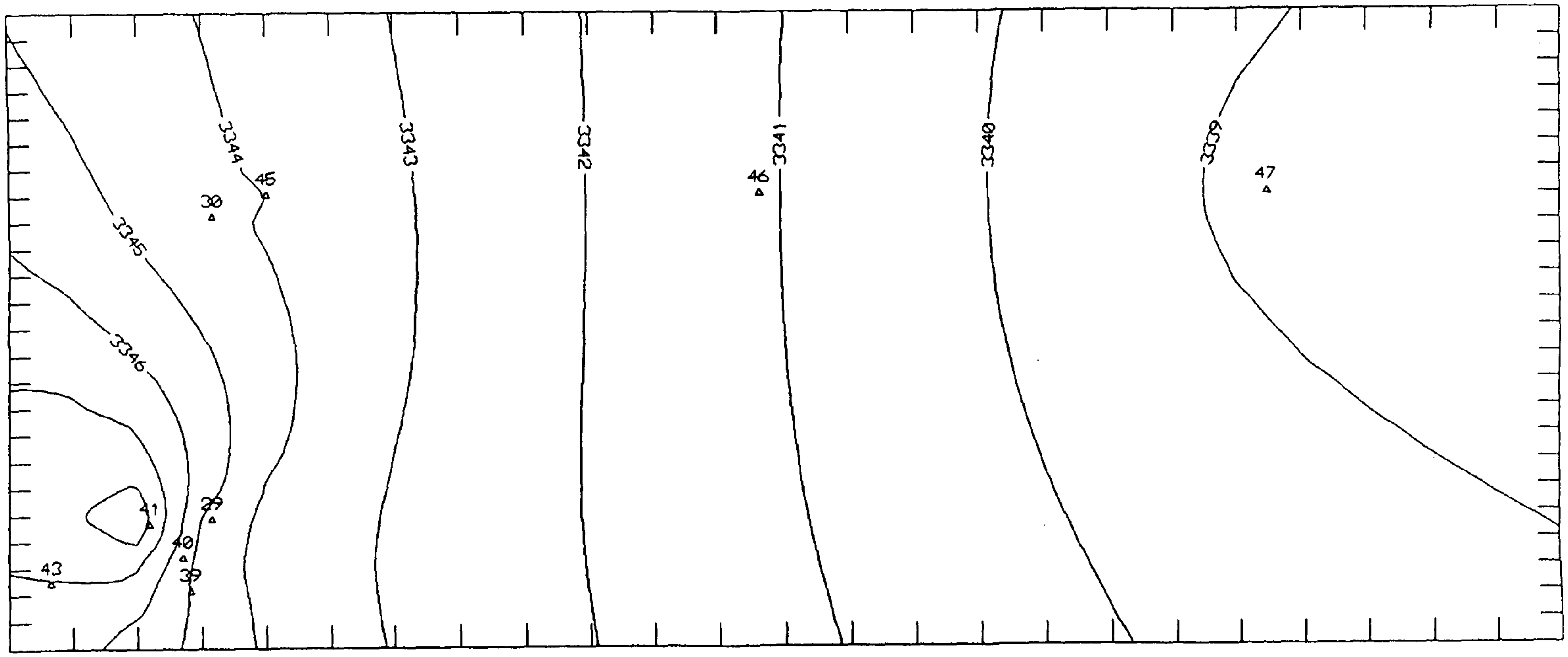


Figure 4.14 Truck Bypass Landfarm Area, Potentiometric Surface Map, RFI Phase I Report, Navajo Refining Company, October 1990.

4.3.2.4 Groundwater Analytical Results

Volatiles

Ground water volatile data from monitor wells at the Truck Bypass Landfarm are listed in Table 4.12. Six volatile organic compounds are detected in the Truck Bypass Landfarm monitor wells. Well 42 contains these six compounds at concentrations exceeding their CRDLs. Three wells (39, 40, and 41) contain detectable levels of four of these compounds. One well (29) is devoid of analytically detectable volatile organic compounds. Concentrations of these six compounds in the background monitor well 49 are all below analytical detection limits. Analytical detection limits for these six compounds are: chloromethane (10 ug/l), 1,2-dichloroethane, benzene, toluene, ethyl benzene, and total xylenes (5 ug/l).

Chloromethane (23 ug/l) and 1,2-dichloroethane (93 ug/l) are detectable only in well 42. Benzene is present in analytically detectable concentrations that range from 2200 ug/l to 11,000 ug/l in wells 39, 40, 41, and 42. Toluene concentrations range from 350 ug/l to 19,600 ug/l in wells 39, 40, 41, and 42. Ethyl benzene is present in detectable concentrations that range from 600 ug/l to 3,000 ug/l in wells 39, 40, 41, and 42. Total xylene compounds occur in concentrations that range from 445 ug/l to 7100 ug/l in wells 39, 40, 41, and 42. Note the variation in the data for all six compounds between well 42 and its duplicate. A histogram representing total volatile concentration vs. sample depth is presented in Figure 4.15. The high volatile concentration recorded in the eight to nine ft interval is due to results from one sample (NLF-SB-011-04).

Table 4.12. Truck Bypass Landfarm, Groundwater Analytical Results - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well				
		NLF-GW-039-01 # 39	NLF-GW-040-01 # 40	NLF-GW-041-01 # 41	NLF-GW-042-01 # 42	NLF-GW-042-02 ~~# 42~~ #43
COMPOUND	UNITS					
Chloromethane	ug/l				23	12
1,2-Dichloroethane	ug/l				93	24
Benzene	ug/l	2200	4400	11000	7200	4300
Toluene	ug/l	350	3900	2000	19600	7400
Ethylbenzene	ug/l	600	3000	1100	3000	990
Xylenes	ug/l	445	7100	1800	6300	1700

* Blanks and all other analyses were below reported limits.

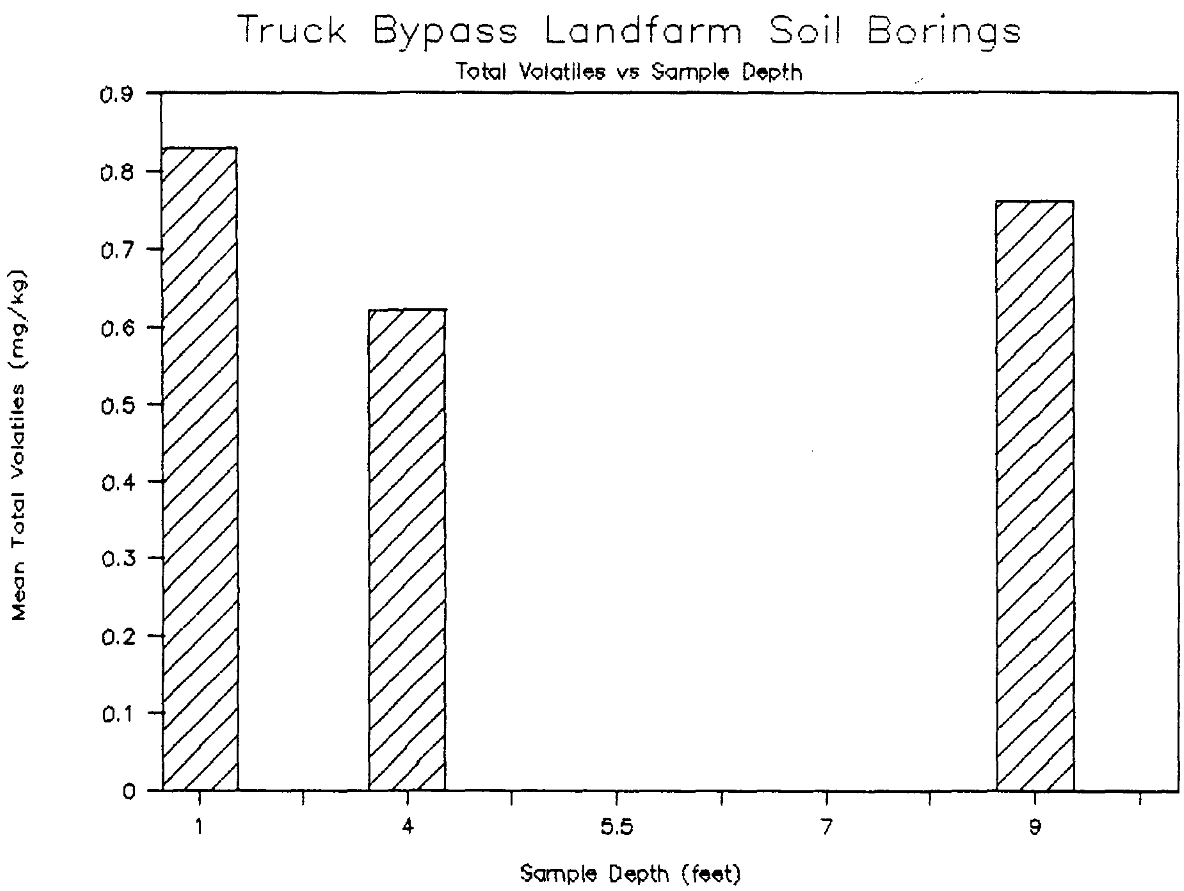


Figure 4.15 Truck Bypass Landfarm Soils, Total Volatiles vs. Sample Depth, RFI Phase I Report, Navajo Refining Company, October 1990.

Semivolatiles

Ground water semivolatile data from monitor wells at the Truck Bypass Landfarm are listed in Table 4.13. Twenty semivolatile organic compounds occur above their respective CRDL concentrations in six monitor wells. Seven of these compounds occur in detectable concentrations in only one well each, and five of the compounds occur in no more than two wells each. The remaining eight compounds occur in four to six wells each. None of these 20 compounds occur above their respective CRDL in background well 49 with the exception of 4-chloro-3-methylphenol (20 ug/l) and 3-nitroanaline (50 ug/l). The analytical detection limit for all compounds is 10 ug/l.

Detected semivolatile compounds, their concentrations, and the wells they occur in are as follows: acenapthene (22 ug/l, well 43); acenaphthalene (49 ug/l, well 40 and 750 ug/l, well 39); anthracene (180 ug/l, well 42 and 240 ug/l, well 40); benzo(a)anthracene (43 ug/l, well 41 and 57 ug/l, well 39); benzo(a)pyrene (47 ug/l well 40); bis (2-ethylhexyl)phthalate (13 ug/l, well 29 and 12 ug/l, well 40); 2-chloronaphthalene (100 ug/l, well 41); 4-chloro-3-methyphenol (20 ug/l, well 39); dibenzofuran ranges from 54 to 1400 ug/l in wells 39, 40, 41, 42, and 43; 2,4-dinitrotoluene ranges from 140 to 160 ug/l in wells 39, 40, 41, and 42; 2,6-dinitrotoluene ranges from 33 to 340 ug/l in wells 39, 40, 41, and 43; fluoranthene ranges from 27 to 55 ug/l in wells 39, 40, 41, and 42; fluorene ranges from 53 to 280 ug/l in wells 39, 40, 41, 42, and 43; 2-methylnaphthalene ranges from 14 to 1100 ug/l in wells 29, 39, 40, 41, 42, and 43; 3-nitroaniline (220 ug/l, well 42); phenanthrene ranges from 11 to 590 ug/l in wells 29, 39, 40, 41, and 42; phenol (25 ug/l, well 42); pyrene (41 ug/l, well 40 and 15 ug/l, well 41).

Table 4.13. Truck Bypass Landfarm Groundwater Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well					
COMPOUND	UNITS	NLF-GW-029-01 # 29	NLF-GW-039-01 # 39	NLF-GW-040-01 # 40	NLF-GW-041-01 # 41	NLF-GW-042-01 # 42	NLF-GW-042-02 # 43
Acenaphthene	ug/l						22
Acenaphthylene	ug/l		750	49			
Anthracene	ug/l			240		180	
Benzo(a)anthracene	ug/l		57		43		
Benzo(a)pyrene	ug/l			47			
Bis(2-ethylhexyl)phthalate	ug/l	13		12			
2-Chloronaphthalene	ug/l				100		
4-Chloro-3-methylphenol	ug/l		20				
Dibenzofuran	ug/l		210	260	1400	55	54
Di-n-butyl phthalate	ug/l	31					
2,4-Dinitrotoluene	ug/l		160	160	150	140	
2,6-Dinitrotoluene	ug/l		200	87	340		33
Fluoranthene	ug/l		51	55	31	27	
Fluorene	ug/l		260	280	220	200	53
2-Methylnaphthalene	ug/l	14	940	1100	430	650	180
Naphthalene	ug/l		940	890	390	450	190
3-Nitroaniline	ug/l					220	
Phenanathrene	ug/l	11	480	590	350	310	
Phenol	ug/l					25	
Pyrene	ug/l			41	15		

* Blanks and all other analyses were below reported limits.

A histogram representing total semivolatiles vs. sample depth is presented in Figure 4.16. Metals are atlenvated in materials near the surface.

Metals

Ground water analytical data from the Truck Bypass Landfarm are listed in Table 4.14. Seven of the 12 elements (metals) analyzed occur above analytical detection limits (exceed the CRDL) in at least one of the Truck Bypass Landfarm monitor wells. Antimony, cadmium, mercury, selenium, and silver are below the CRDL and background monitor well (well 49) concentrations in all monitor well samples. Barium (0.020 mg/l), nickel (0.003 mg/l), selenium (0.004 mg/l), and zinc (0.015 mg/l) exceed CRDL concentration levels in Truck Bypass Landfarm background monitor well number 49. Metals which exceed background concentration levels in monitor wells are discussed below.

Chromium, nickel, lead, arsenic, and barium exceed background concentrations in all five (plus one duplicate) monitor wells. Beryllium exceeds background concentration (<0.001 mg/l) levels in one monitor well (well 42; 0.004 mg/l). Zinc is 0.015 mg/l in the background well and exceeds background concentrations in well 29 (0.08 mg/l). Chromium is below detectable concentrations (0.007 mg/l) in the background monitor well and ranges with little variance from 0.01 mg/l to 0.04 mg/l in all five monitor wells. Nickel concentration in the background well is 0.003 mg/l, and ranges from 0.04 mg/l to 0.09 mg/l in all other monitor wells. Lead concentration in the background well is below the analytical detection limit (0.002 mg/l), and ranges from 0.013 mg/l to 0.28 mg/l, in other monitor wells. The highest lead concentrations are in monitor wells 29 (0.22 mg/l), 40 (0.28 mg/l) and 42 (0.18 mg/l). Wells 39, 41, and 42 duplicate are 0.014 mg/l, 0.053 mg/l, and 0.13 mg/l, respectively. Note that the analyses for well 42 and its

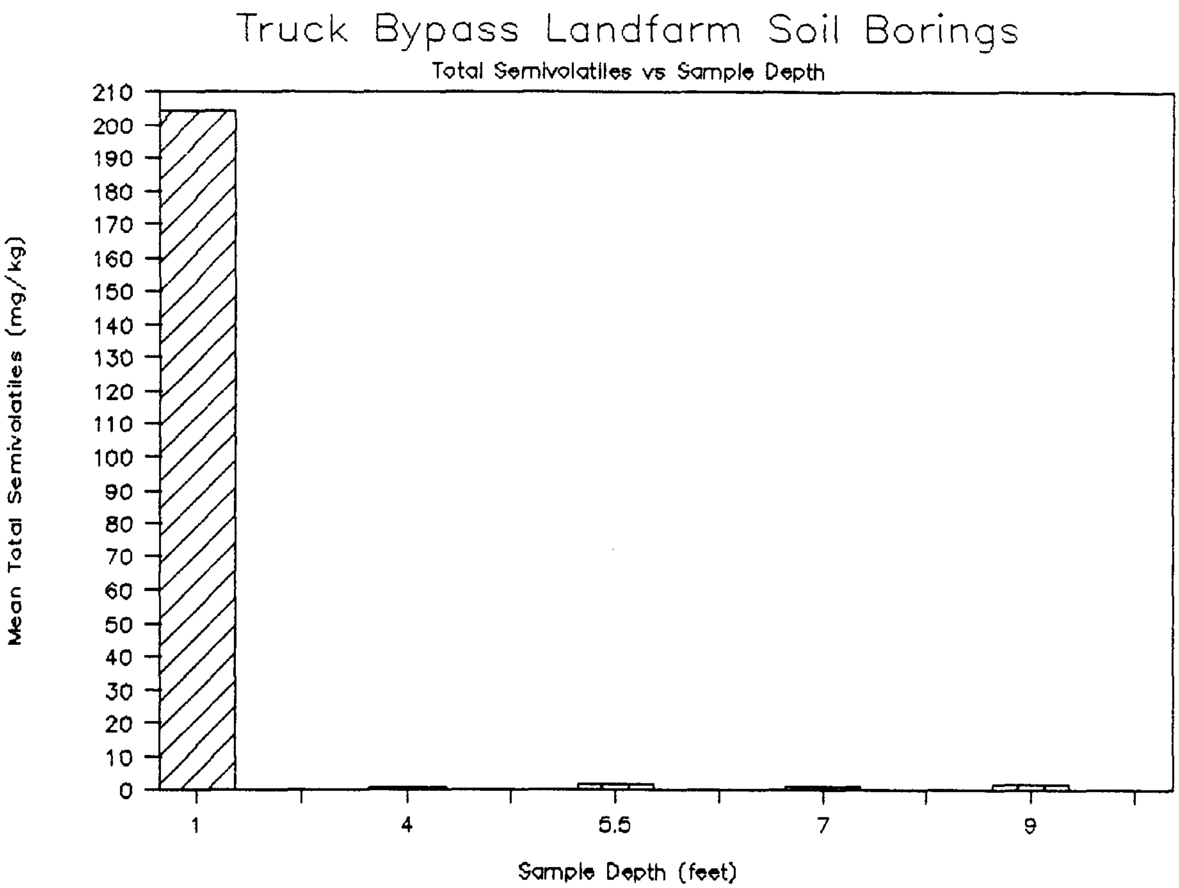


Figure 4.16 Truck Bypass Landfarm Soils, Total Semivolatiles vs. Sample Depth, RFI Phase I Report, Navajo Refining Company, October 1990.

Table 4.14. Truck Bypass Landfarm Groundwater Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well				
		NLF-GW-029-01	NLF-GW-039-01	NLF-GW-040-01	NLF-GW-041-01	NLF-GW-042-01
COMPOUND	UNITS	#29	#39	#40	#41	#42
Antimony	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	mg/l	0.029	0.024	0.029	0.074	0.13
Barium	mg/l	0.17	0.48	0.19	0.05	0.1
Beryllium	mg/l	<0.001	<0.001	<0.001	<0.001	0.004
Cadmium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.04	0.01	0.02	0.02	0.03
Lead	mg/l	0.22	0.014	0.28	0.053	0.18
Mercury	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/l	0.07	0.05	0.04	0.09	0.05
Selenium	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/l	0.08	<0.01	<0.01	<0.01	<0.01

duplicate vary by an order of magnitude. Arsenic concentration in the background well is below analytical detection limit (0.02 mg/l) and ranges from 0.024 mg/l to 0.13 mg/l. Monitor wells 29, 39, and 40 are only slightly above detection limit. Wells 41 and 42 are somewhat higher than the others, 0.074 mg/l and 0.13 mg/l arsenic, respectively. Barium concentration in the background well is 0.02 mg/l and ranges from 0.05 mg/l to 0.48 mg/l in the affected monitor wells. Well 39 contains 0.48 mg/l barium. Wells 29, 40, and 42 are all in the range 0.1 to 0.19 mg/l, and well 41 is 0.05 mg/l barium.

A histogram representing total metals vs. sample depths is presented in Figure 4.17.

Inorganics

Ground water inorganic compound data from the Truck Bypass Landfarm are listed in Table 4.15. The inorganic compounds bicarbonate, chloride, fluoride, sulfate, and total dissolved solids are analyzed in five (plus a duplicate) Truck Bypass Landfarm monitor wells (29, 39, 40, 41, 42, and 42 duplicate). Bicarbonate ranges from 540 mg/l to 984 mg/l. Chloride ranges from 638 mg/l to 4960 mg/l (well 39). Note the significant duplicate variation (638 mg/l and 2,340 mg/l). Fluoride concentrations range with little variation from 1.06 mg/l to 1.75 mg/l. Sulfate concentrations range from 346 mg/l to 2,300 mg/l. The range of total dissolved solids varies only slightly between 3,240 mg/l and 4,750 mg/l.

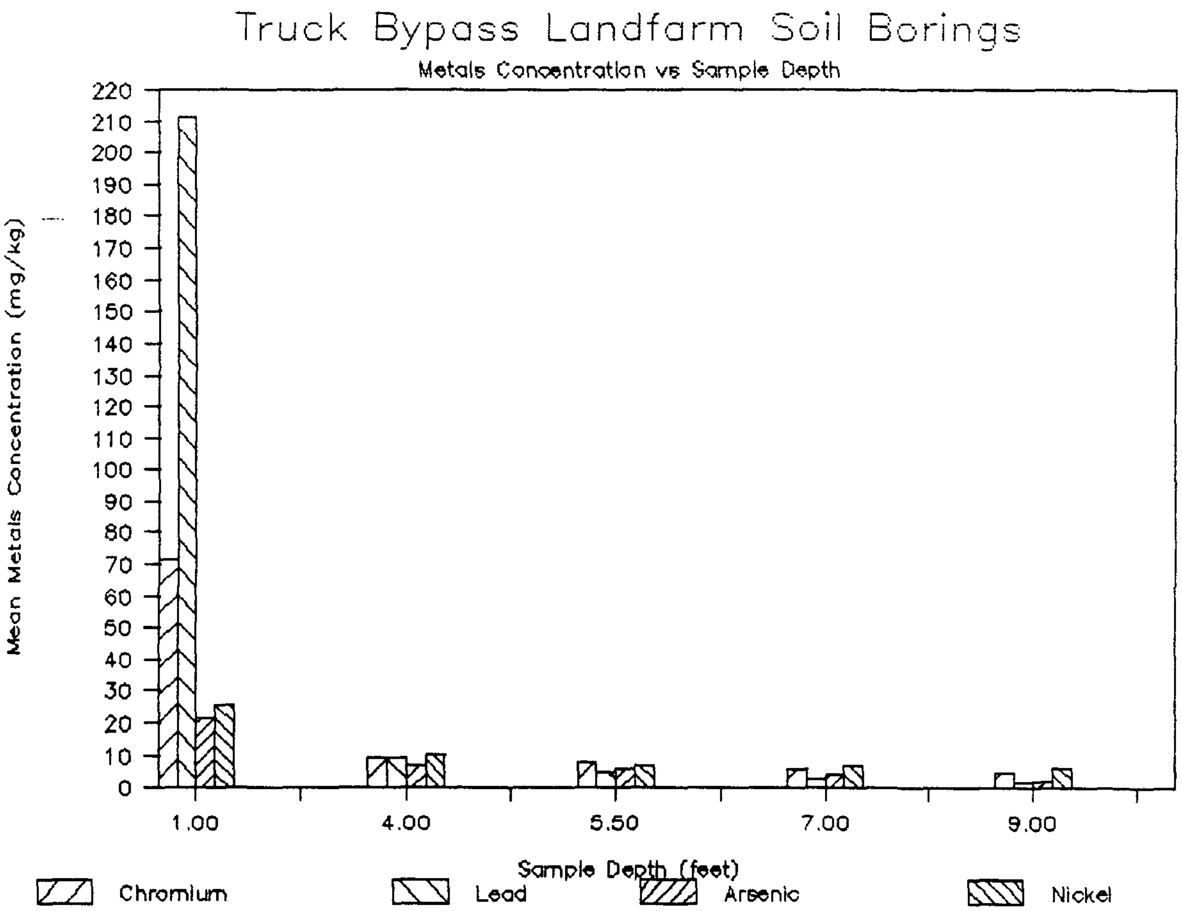


Figure 4.17 **Truck Bypass Landfarm Soils, Metal Concentrations vs. Sample Depth, RFI Phase I Report, Navajo Refining Company, October 1990.**

Table 4.15. Truck Bypass Landfarm Groundwater Analytical Results - Inorganics
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well				
COMPOUND	UNITS	NLF-GW-029-01 #29	NLF-GW-039-01 #39	NLF-GW-040-01 #40	NLF-GW-041-01 #41	NLF-GW-042-01 #42
Bicarbonate	mg/l	540	724	984	664	735
Chloride	mg/l	709	4960	1280	638	638
Fluoride	mg/l	1.35	1.75	1.06	1.54	1.56
Sulfate	mg/l	900	1190	346	943	2060
Total Dissolved Solids	mg/l	3940	3240	3510	4640	3690

5.0 THREE-MILE DITCH/EAGLE CREEK

5.1 SITE DESCRIPTION

5.1.1 Location

Eagle Creek is an ephemeral stream that begins in the low foothills west of Artesia. Its normally dry channel courses through the Navajo refinery, east to the Pecos River. It enters the refinery midway along the western border of the Navajo property. To convey process wastewater to the evaporation ponds three miles to the east, Navajo and its predecessors operated an effluent ditch (Three-Mile Ditch) which parallels the course of Eagle Creek (Plates 2, 3, and 4). As the ditch approaches the Pecos River, its course shifts away from Eagle Creek, turning south toward the evaporation ponds, where Three-Mile Ditch terminates at the western edge of Evaporation Pond #1.

Eagle Creek, an arroyo, has cut a channel that in some places is more than 100 ft across and 10 ft deep. The effluent ditch directly parallels Eagle Creek, being positioned only three to five feet away in some areas. Because of their close proximity, overflow from the effluent ditch into Eagle Creek is possible. The effluent ditch is four to six feet across, with a two- to five-foot depth. It was constructed with small levies (two to five feet high) on each side to prevent the influx of surface runoff. In some areas (e.g., near trench NMD-TR-005), Three-Mile Ditch has widened, creating a channel to the south, away from Eagle Creek, measuring approximately 75 ft or more in width.

The Eagle Creek/Three-Mile Ditch system is constructed in soils of the Pima silt loam (Pe), Pima clay loam (Pv), Karro loam, Arno silty clay loam (An), and Arno-Harkley sandy loam Series (Ak) (USDA 1971). These light to dark, calcareous loams have developed on carbonate bedrock and carbonate-rich alluvial material. They are moderately permeable (0.2-0.8 inch/hour) and have a high water-holding capacity (0.18-0.20 inch/hour).

5.1.2 Operations History

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 and was periodically cleared of surface debris to keep it flowing. In addition, it was necessary to occasionally dredge the ditch with a backhoe, and the removed material was piled onto the ditch berms; thus, the berms became larger over the years. The berms were dozed into the ditch for approximately 4500 ft at the eastern end by local landowners in 1988. No information was available concerning the early history of Three-Mile Ditch although ditch use by predecessors of Navajo has been reported as early as the 1930s. The use of the system was discontinued in late 1987, when Navajo constructed a primary wastewater treatment plant with a three-mile pipeline to convey treated effluent to the evaporation ponds. It is estimated that the ditch was in use for approximately 50 years.

5.1.3 Local Hydrogeology

Very little information regarding site hydrology was available for review. Logs for the two area wells indicate that the upper five to eight feet are a white to gray sandy clay with some pea-sized gravel, followed by approximately five feet of brown, clayey sand with moderate amounts of gravel. Depth to water is approximately 10 ft, with an eastward regional flow. Since the water table elevation is similar to that of Eagle Creek's bed, it is probable that the shallow water table aquifer periodically emerges as springs or seeps in the channel bottom, especially in the area where Bolton Road crosses the draw. It is assumed that the deeper confined aquifer follows the regional gradient, with flow being generally toward the south.

5.2 HISTORICAL WATER QUALITY

Only two monitoring wells provide any significant historical data for the shallow aquifer in the vicinity of Three-Mile Ditch. These wells, MW-8 and MW-9, are located near trench 5 (see Section 5.3.1). According to Geoscience Consultants, Ltd. (1987), these wells indicate no contamination in the valley fill aquifer adjacent to this portion of the ditch (Tables 5.1 through 5.4). Wells 45, 46, and 47, although located near the ditch, are included in the discussion of the Truck Bypass Landfarm because of their proximity to that unit.

5.3 FIELD INVESTIGATION

The purpose of this investigation was to characterize sediment, soils, surface water, and ground water associated with Three-Mile Ditch and Eagle Creek. Field activities consisted of trenching across the ditch and collecting soil samples at 12 locations, collecting soil samples by hand auger at three ditch sites and five background sites, and collecting sediment-surface water samples at five sites along Eagle Creek. The activities (except where noted in this text) followed procedures and protocols as noted in the Health and Safety Plan and the Quality Assurance Project Plan (QAPP).

5.3.1 Three-Mile Ditch Trenching

Backhoe trenches were cut perpendicular to the original ditch at 12 locations to document the volume of sludge remaining and possible impacts to adjacent soils.

Table 5.1. Three Mile Ditch/Eagle Creek - Historical Groundwater Quality
Volatile Organic Compounds

COMPOUND /1	UNITS	Monitor Well Number Date MW-8 9/86	MW-9 9/86
1,1,1,2-Tetrachloroethane	ug/l		
1,1,1-Trichloroethane	ug/l	< 5	< 5
1,1,2,2-Tetrachloroethane	ug/l	< 5	< 5
1,1,2-Trichloroethane	ug/l	< 5	< 5
1,1-Dichloroethane	ug/l	< 5	< 5
1,2,3-Trichloropropane	ug/l		
1,2-Dichloroethane	ug/l	< 5	< 5
1,2-Dichloropropane	ug/l	< 5	< 5
1,3-Dichloropropylene	ug/l	< 5	< 5
1-Chloroethyl vinyl ether	ug/l		
1-Chlorohexane	ug/l		
1-Methylnaphthalene	ug/l		
2,2-Dichloropropane	ug/l		
2-Chloroethyl vinyl ether	ug/l	< 5	< 5
2-Methylnaphthalene	ug/l		
2-Sec-butyl-4,6-dinotrophenol	ug/l		
Benzene	ug/l	< 5	< 5
Benzyl chloride	ug/l		
Bromobenzene	ug/l		
Bromodichloromethane	ug/l		
Bromoform	ug/l		
Bromomethane	ug/l		
Carbon tetrachloride	ug/l	< 5	< 5
Chloracetaldehyde	ug/l		
Chlorobenzene	ug/l	< 5	< 5
Chloroethane	ug/l	< 10	< 10
Chloroform	ug/l	< 5	< 5
Chloromethane	ug/l		
Chloromethyl methyl ether	ug/l		
Chlorotoluene	ug/l		
Cis-1,3-dichloropropene	ug/l		

Table 5.1 (cont). Three Mile Ditch/Eagle Creek - Historical Groundwater Quality
Volatile Organic Compounds

COMPOUND	UNITS	Monitor Well Number Date MW-8 9/86	MW-9 9/86
Dibromochloromethane	ug/l	< 5	< 5
Dibromomethane	ug/l		
Dichlorodifluoromethane	ug/l		
Dichloromethane	ug/l		
Ethyl benzene	ug/l	<5	<5
Freon	ug/l		
Methylene chloride	ug/l	< 10	< 10
m-Xylene	ug/l		
o-Xylene	ug/l		
p-Xylene	ug/l		
Tetrachloroethene	ug/l	< 5	< 5
Tetrachlorophenol	ug/l		
Toluene	ug/l	< 5	< 5
Trans-1,2-dichloroethene	ug/l		
Trans-1,3-dichloropropene	ug/l		
Trichloroethene	ug/l		
Trichlorofluoromethane	ug/l		
Trichlorophenol	ug/l		
Vinyl chloride	ug/l	< 10	< 10
Xylenes	ug/l		

Source: Proposed Site Investigations of Pond #1 and Conveyance Ditch
to Determine Potential Effects to Ground Water Quality.
Navajo Refinery, Artesia, New Mexico
Geoscience Consultants, Ltd. October 29, 1986.

1/ Blanks designate compounds for which no analyses were requested.

Table 5.2. Three Mile Ditch/Eagle Creek - Historical Groundwater Quality
Semi-volatile Compounds

COMPOUND /1	UNITS	MW-8 9/86	MW-9 9/86
		Monitor Well Number Date	
1,2,4-Tricholorobenzene	ug/l	< 5	< 5
2,4,5-Trichlorophenol	ug/l		
2,4,6-Trichlorophenol	ug/l		
2,4-Dichlorophenol	ug/l	< 5	< 5
2,4-Dimethylphenol	ug/l	< 5	< 5
2,4-Dinitrophenol	ug/l	< 10	< 10
2,4-Dinitrotoluene	ug/l	< 5	< 5
2,6-Dichlorophenol	ug/l		
2,6-Dinitrotoluene	ug/l	< 5	< 5
2-Chloronaphthalene	ug/l	< 5	< 5
2-Chlorophenol	ug/l	< 5	< 5
2-Cylohexyl-4,6-dinitrophenol	ug/l		
2-Methyl-4,6-dinitrophenol	ug/l		
2-Methylnaphthalene	ug/l	< 5	< 5
2-Methylphenol	ug/l	< 5	< 5
2-Nitroaniline	ug/l		
2-Nitrophenol	ug/l	< 5	< 5
3,3'-Dichlorobenzidine	ug/l	< 20	< 20
3-Nitroaniline	ug/l		
4,6-Dinitro-2-methylphenol	ug/l		
4-Bromophenyl phenyl ether	ug/l	< 5	< 5
4-Chloroaniline	ug/l		
4-Chlorophenyl phenyl ether	ug/l	< 5	< 5
4-Chloro-3-methylphenol	ug/l		
4-Methylphenol	ug/l	< 5	< 5
4-Nitroaniline	ug/l		
4-Nitrophenol	ug/l	< 10	< 10
7H-dibenzo(c,g)carbazole	ug/l		
Acenaphthene	ug/l	< 5	< 5
Acenaphthylene	ug/l	< 5	< 5
Anthracene	ug/l	< 5	< 5
Benzidine	ug/l	< 20	< 20
Benzoic acid	ug/l		
Benzo(a)anthracene	ug/l	< 5	< 5
Benzo(a)pyrene	ug/l	< 5	< 5
Benzo(b)fluoranthene	ug/l		
Benzo(g,h,i)perylene	ug/l	< 5	< 5
Benzo(j)fluoranthene	ug/l		
Benzo(k)fluoranthene	ug/l	< 5	< 5
Benzyl alcohol	ug/l		
Bis(2-chloroethyl)ether	ug/l	< 5	< 5
Bis(2-chloroethoxy)methane	ug/l	< 5	< 5
Bis(2-chloroisopropyl)ether	ug/l	< 5	< 5
Bis(2-ethylhexyl)phthalate	ug/l	< 5	< 5

Table 5.2 (cont). Three Mile Ditch/Eagle Creek - Historical Groundwater Quality
Semi-volatile Compounds

COMPOUND	UNITS	Monitor Well Number / Date: MW-8 9/86	MW-9 9/86
Butyl benzyl phthalate	ug/l	< 5	< 5
Cresols (methyl phenols)	ug/l		
Chrysene	ug/l	< 5	< 5
Dibenzofuran	ug/l	< 5	< 5
Dibenzo(a,h)anthracene	ug/l		
Dibenzo(a,j)acridine	ug/l		
Dibenzo(a,e)pyrene	ug/l		
Dibenzo(a,h)pyrene	ug/l		
Dibenzo(a,i)pyrene	ug/l		
Diethyl phthalate	ug/l	< 5	< 5
Dimethyl phthalate	ug/l	< 5	< 5
Di-n-butyl phthalate	ug/l	< 5	< 5
Di-n-octyl phthalate	ug/l	< 5	< 5
Fluoranthene	ug/l	< 5	< 5
Fluorene	ug/l	< 5	< 5
Hexachlorobenzene	ug/l	< 5	< 5
Hexachlorobutadiene	ug/l	< 5	< 5
Hexachloroethane	ug/l	< 5	< 5
Hexachlorocyclopentadiene	ug/l	< 5	< 5
Indeno(1,2,3-cd)pyrene	ug/l	< 5	< 5
Isophorone	ug/l	< 5	< 5
Naphthalene	ug/l	< 5	< 5
Nitrobenzene	ug/l	< 5	< 5
N-nitrosodipropylamine	ug/l	< 5	< 5
N-nitrosodiphenylamine	ug/l	< 5	< 5
Pentachlorophenol	ug/l	< 5	< 5
Phenanathrene	ug/l	< 5	< 5
Phenol	ug/l	< 5	< 5
Pyrene	ug/l	< 5	< 5
1,2-Dichlorobenzene	ug/l	< 5	< 5
1,3-Dichlorobenzene	ug/l	< 5	< 5
1,4-Dichlorobenzene	ug/l	< 5	< 5

Source: Proposed Site Investigations of Pond #1 and Conveyance Ditch
to Determine Potential Effects to Ground Water Quality.
Navajo Refinery, Artesia, New Mexico
Geoscience Consultants, Ltd. October 29, 1986.

1/ Blanks designate compounds for which no analyses were requested.

Table 5.3. Three Mile Ditch/Eagle Creek - Historical Groundwater Quality Metals

		Monitor Well Number Date	
METAL /1	UNITS	MW-8 9-86	MW-9 9-86
Aluminum	mg/l		
Antimony	mg/l	0.006	< 0.002
Arsenic	mg/l	0.012	0.02
Barium	mg/l	0.049	0.02
Beryllium	mg/l	< 0.002	< 0.002
Cadmium	mg/l	< 0.008	< 0.008
Chromium	mg/l	< 0.01	< 0.01
Cobalt	mg/l	0.018	0.012
Copper	mg/l	< 0.03	< 0.03
Iron	mg/l	1.7	
Lead	mg/l	< 0.04	< 0.04
Manganese	mg/l		
Mercury	mg/l	< 0.0001	< 0.0001
Nickel	mg/l	0.039	0.048
Selenium	mg/l	< 0.04	< 0.04
Silicon	mg/l		
Silver	mg/l	< 0.006	< 0.006
Strontium	mg/l		
Thallium	mg/l	< 0.04	< 0.04
Tin	mg/l		
Vanadium	mg/l	0.053	0.048
Zinc	mg/l	< 0.02	< 0.02

Source: Proposed Site Investigations of Pond #1 and Conveyance Ditch to Determine Potential Effects to Ground Water Quality, Navajo Refinery, Artesia, New Mexico
Geoscience Consultants, Ltd. October 29, 1986.

1/ Blanks designate metals for which no analyses were requested.

Table 5.4. Three Mile Ditch/Eagle Creek - Historical Groundwater Quality
Inorganics

		Monitor Well Number Date	
COMPONENT /1	UNITS	MW-8 9-86	MW-9 9-86
Ammonia	mg/l		
Bicarbonate	mg/l		
Calcium	mg/l	635	
Carbonate	mg/l		
Chloride	mg/l	904	
Cyanide	mg/l		
Fluoride	mg/l	2	
Magnesium	mg/l	451	
Nitrate (N)	mg/l	1.7	
Total Kjeldahl Nitrogen	mg/l	0.9	
Potassium	mg/l	2.6	
Sodium	mg/l	637	
Sulfate	mg/l	3430	
Sulfide	mg/l	0.05	< 0.05
Total Dissolved Solids	mg/l	7420	
Conductivity			
pH			
Temperature			
Alkalinity 'P' as CaCO3		< 5.0	
Alkalinity 'M'			

Source: Proposed Site Investigations of Pond #1 and Conveyance Ditch to Determine Potential Effects to Ground Water Quality, Navajo Refinery, Artesia, New Mexico Geoscience Consultants, Ltd. October 29, 1986.

1/ Blanks designate components for which no analyses were requested.

5.3.1.1 Trenching Procedure

A John Deere 440 backhoe was used to cut trenches from 15 to 30 ft long and up to 13 ft deep, oriented perpendicular to the original ditch course. The exact dimension of each trench was determined by the visual extent of contamination. Trenching continued laterally until the visual contamination stopped, and vertically until either visual contamination stopped or the water table was encountered. Trenches were cut at approximately 1,500-ft intervals along the length of the ditch and were representative of all five soil types encountered.

Four samples were obtained from each trench, where possible, to represent a vertical profile. Samples were collected from:

1) The original ditch surface
2) Midpoint within the visually contaminated horizon
3) The interface of the visually contaminated soil and the visually clean soil
4) Three feet below the visually contaminated soil

The fourth sample could not be collected either when the water table was reached or when visual contamination extended beyond the backhoe's maximum depth (approximately 13 ft). The sampling schema for Three-Mile Ditch soils is presented in Table 5.5.

Organic vapor concentrations were monitored with a PID (HNU PI-101) throughout the trenching phase. Level C protective gear was worn by the backhoe operator and the sampler. PID readings ranged from 0 to 3.5 ppm in the breathing zone, from 0 to >3 ppm in the trenches upon opening, and from 0 to 800 ppm for individual samples.

Table 5.5 Three-Mile Ditch, Trench Soil Sampling Schema, RFI Phase I Report, Navajo Refining Company, October 1990.

	COLLECTED ABOVE VISIBLE CONTAMINATION (SAMPLE NUMBER)	COLLECTED WITHIN VISIBLE CONTAMINATION (SAMPLE NUMBER)	COLLECTED BELOW VISIBLE CONTAMINATION (SAMPLE NUMBER)
Pe		NMS-51-01,02,03	
		NMD-000-01,02,03	
		NMD-001-01,02,03	
		NMD-002-01,02,03	NMD-002-04
		NMD-003-01	NMD-003-02,03
		NMD-004-01,02,03	NMD-004-04
		NMD-005-01,02,03	
	NMD-006-01	NMD-006-02	NMD-006-03
Ri	NMD-007-02	NMD-007-01	NMD-007-03,04
Pv		NMD-008-01,02,03	
		NMD-009-01,02,03,04	
An		NMD-010-01,02,03	NMD-010-04
		NMD-011-01,02,03	NMD-011-04
		NMD-012-01,02,03	
Ak		NMD-013-01,02,03	

[1] Pe = Pima silt loam
Ri = Reeves loam
Pv = Pima clay loam
An = Arno silty clay loam
Ak = Arno-Harkley complex

Samples were collected with a stainless steel scoop and placed directly in glass sample jars. The first sample was obtained from the exposed ditch surface after 0.5-3.0 ft of overlying soil was removed. The remaining samples were collected from the center of the backhoe bucket to avoid safety risks associated with personnel entering unstable trenches. Samples were labeled in the field, placed in plastic bags, and secured in ice chests. Chain-of-custody forms were completed and samples shipped daily from September 13 through September 20, 1990.

Two geologists were present during operations to collect samples, construct cross sections, log organic vapor levels, and videotape trench walls.

In three locations originally planned for trenching, samples were instead collected using a stainless steel bucket auger. The procedure had to be modified due to the presence of a buried natural gas pipeline. The geologists attempted to sample from horizons equivalent to those of the trenches.

5.3.1.2 Trench Descriptions

The volume of remaining sludge varied from very minor (two inches thick) at trench NMD-TR-006 to extensive at trenches NMD-TR-010, NMD-TR-011, and NMD-TR-012. Cross sections or boring logs for each trench site appear in Figures 5.1 through 5.17.

Localization of significantly large volumes of sludge appears to be controlled by several factors. Trenches NMD-TR-011, NMD-TR-012, and NMD-TR-013 contained sludge to the deepest levels. These trenches are located nearest the ditch terminus and probably result from wastewater backup into the evaporation ponds. Sufficient

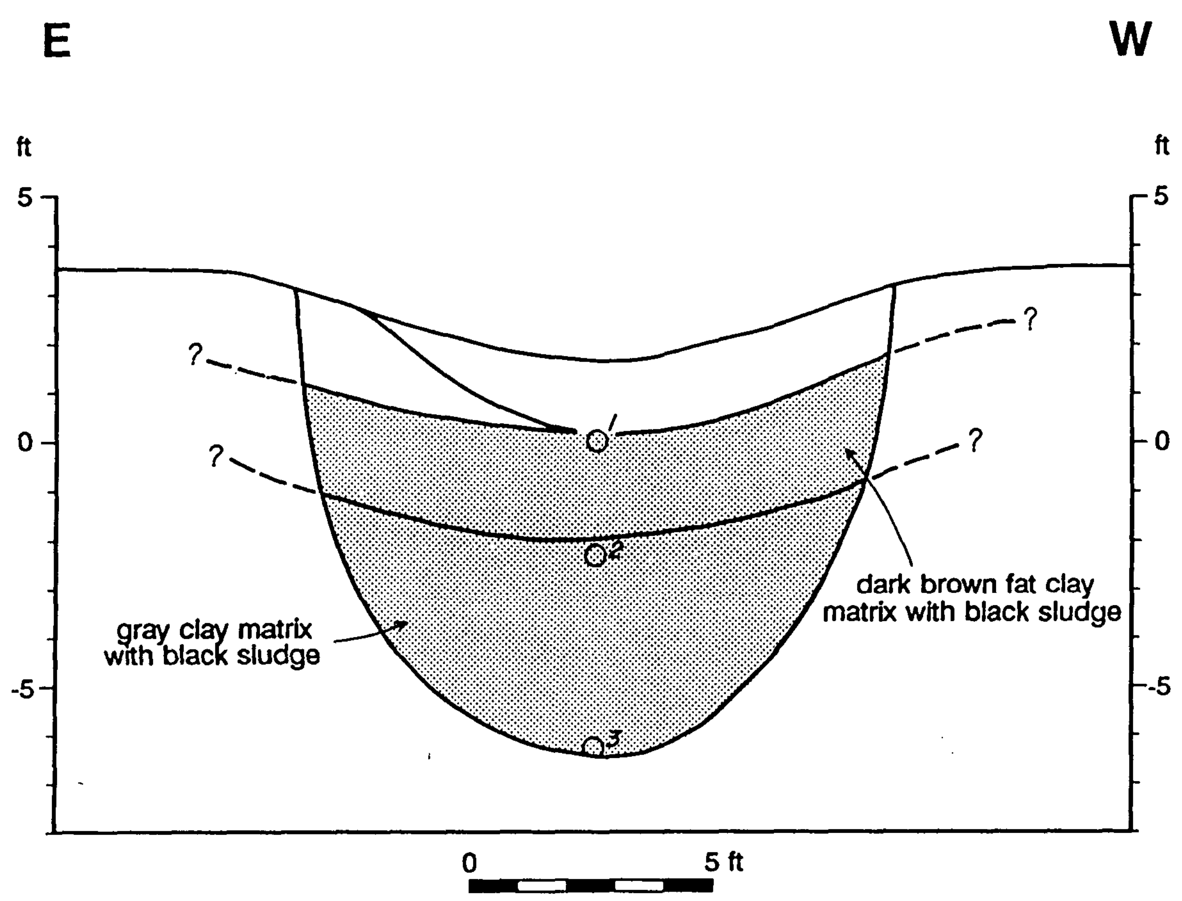


Figure 5.1 Three-Mile Ditch, Trench Cross Section NMD-TR-S1, RFI Phase I Report, Navajo Refining Company, October 1990.

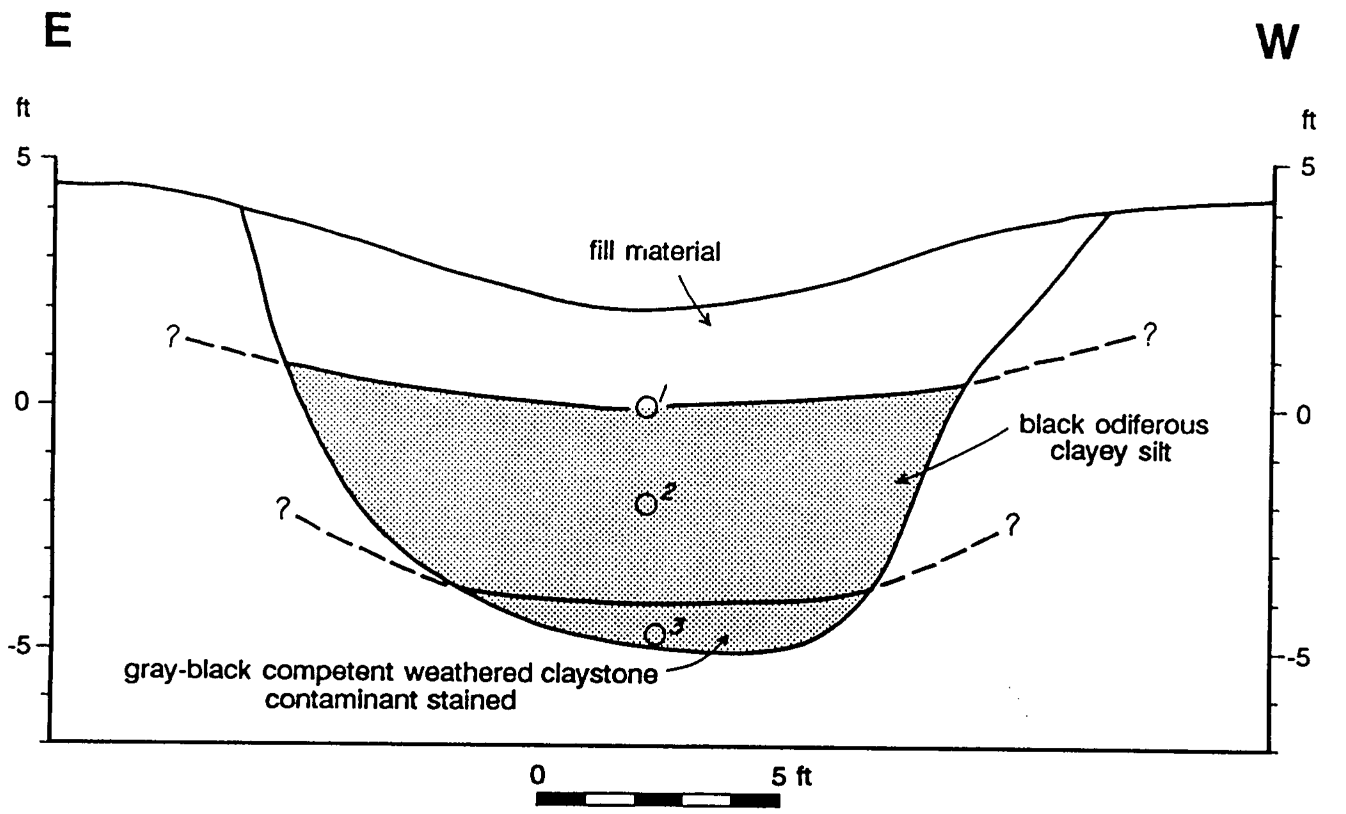


Figure 5.2 Three-Mile Ditch, Trench Cross Section NMD-TR-000, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Site 001
BORING / WELL: NMD-TR-001
START DRILLING: Sept. 15, 1990
COMPLETED: Sept. 15, 1990
TOTAL DEPTH (BLS):
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.3-0.7 feet BLS	0.3-0.7 feet BLS	Dark brown silty clay, mottled, with reddish-brown silt. 5Y 4/1-2.5 YR 4/6.	
	1.7-2.0	1.7-2.0 feet BLS	Black to grey sludge/clay, moderate plasticity, very hard texture, with strong organic odor.	
	3.5-4.0 feet BLS	3.5-4.0 feet BLS	Grey clayey silt, moderate moisture, with petroleum odor.	
	8.5-9.0 feet BLS		Grey-green clay, low plasticity, hard texture, with dark clasts, gypsum. 5GY 5/1.	

Figure 5.3 Three-Mile Ditch, Soil Boring Log, NMD-TR-001, RFI Phase I Report, Navajo Refining Company, October 1990

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Site 002
BORING / WELL: NMD-TR-002
START DRILLING: Sept. 16, 1990
COMPLETED: Sept. 16, 1990
TOTAL DEPTH (BLS): 8.0
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____
AUGER __X__
OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____
SPLT SPN ____
SHELBY ____
CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0-0.25 feet BLS		Well-sorted silty clay, mottled, very low moisture.	
	0.25-0.5 feet BLS	.25-0.5 feet BLS	Well-sorted silty clay, mottled, moderate moisture, moderate plasticity and cohesiveness with slight oil odor. 2.5 YR 4/3.	
	0.5-2.5 feet BLS		Well-sorted silty clay, mottled, moderate moisture, moderate plasticity and cohesiveness with slight oil odor 2.5 YR 4/3.	
	2.5-5.0 feet BLS		Black sludge, good plasticity, amorphous.	
	5.0-6.5 feet BLS	5.0 feet BLS	Well-sorted silty clay, moderate plasticity, good cohesion. 5 YR 7/3.	
	6.5-7.0 feet BLS		Well-sorted silty clay, moderate plasticity, good cohesion, 2.5 YR 7/3.	
	7.0-8.0 feet BLS		Well-sorted silty clay, moderate plasticity, good cohesion, mottled with black sludge.	

Figure 5.4 Three-Mile Ditch, Soil Boring Log, NMD-TR-002, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Site 002
BORING / WELL: NMD-TR-002a
START DRILLING: Sept. 16, 1990
COMPLETED: Sept. 16, 1990
TOTAL DEPTH (BLS): 6.0
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0-1.0 feet BLS		Well-sorted silty clay, very low moisture, no plasticity or cohesion 2.5 YR 4/3.	
	1.0-3.5 feet BLS		Well-sorted silty clay, low moisture, moderate plasticity, moderate cohesion.	
	3.5-4.5 feet BLS		Well-sorted silty clay, low moisture, moderate plasticity and cohesion with stringers of sludge.	
	4.5-5.0 feet BLS		Well-sorted silty clay, low moisture, moderate plasticity and cohesion.	
	5.0-6.0 feet BLS	5.5-6.0 feet BLS	Clay, good moisture, good cohesion and plasticity. 10 YR 7/3.	

Figure 5.5 Three-Mile Ditch, Soil Boring Log, NMD-TR-002a, RFI Phase I Report, Navajo Refining Company, October 1990.

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Site 003
BORING / WELL: NMD-TR-003
START DRILLING: Sept. 18, 1990
COMPLETED: Sept. 18, 1990
TOTAL DEPTH (BLS): 5.0
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE:
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____
AUGER x
OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____
SPLT SPN ____
SHELBY ____
CORING x
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.5-1.0 feet BLS	0.5-1.0 feet BLS	Blue-gray and dark brown clay, low moisture, moderate plasticity, stiff mixture, mottled with black staining from contamination.	
	1.25-1.7 feet BLS	1.25-1.7 feet BLS	Medium brown clay, good plasticity, no visible contamination. 10 YR 4/3.	
	5.0 feet BLS	5.0 feet BLS	Light brown clay, moderate to good plasticity, stiff texture, with pebbles.	

Figure 5.6 Three-Mile Ditch, Soil Boring Log, NMD-TR-003, RFI Phase I Report, Navajo Refining Company, October 1990.

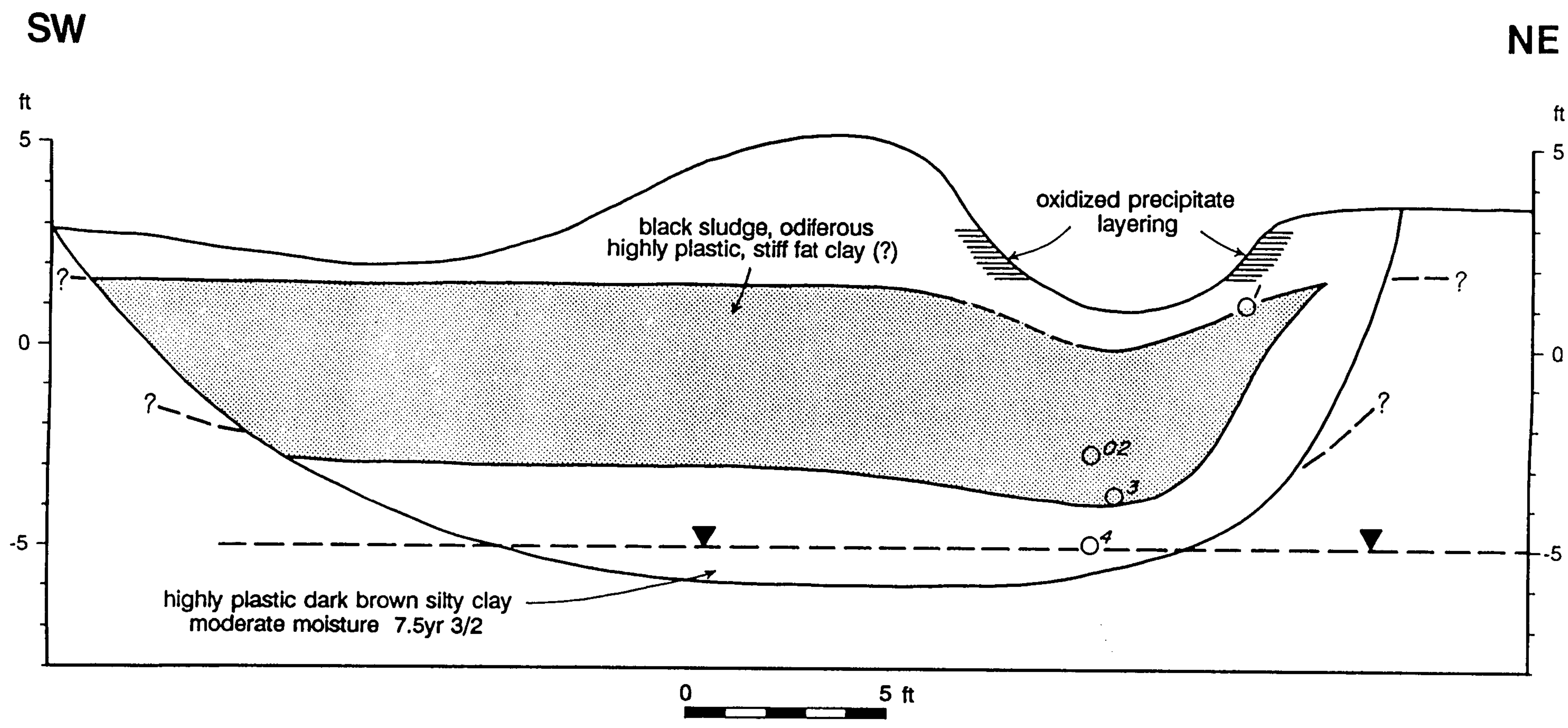


Figure 5.7 Three-Mile Ditch, Trench Cross Section NMD-TR-004, RFI Phase I Report, Navajo Refining Company, October 1990.

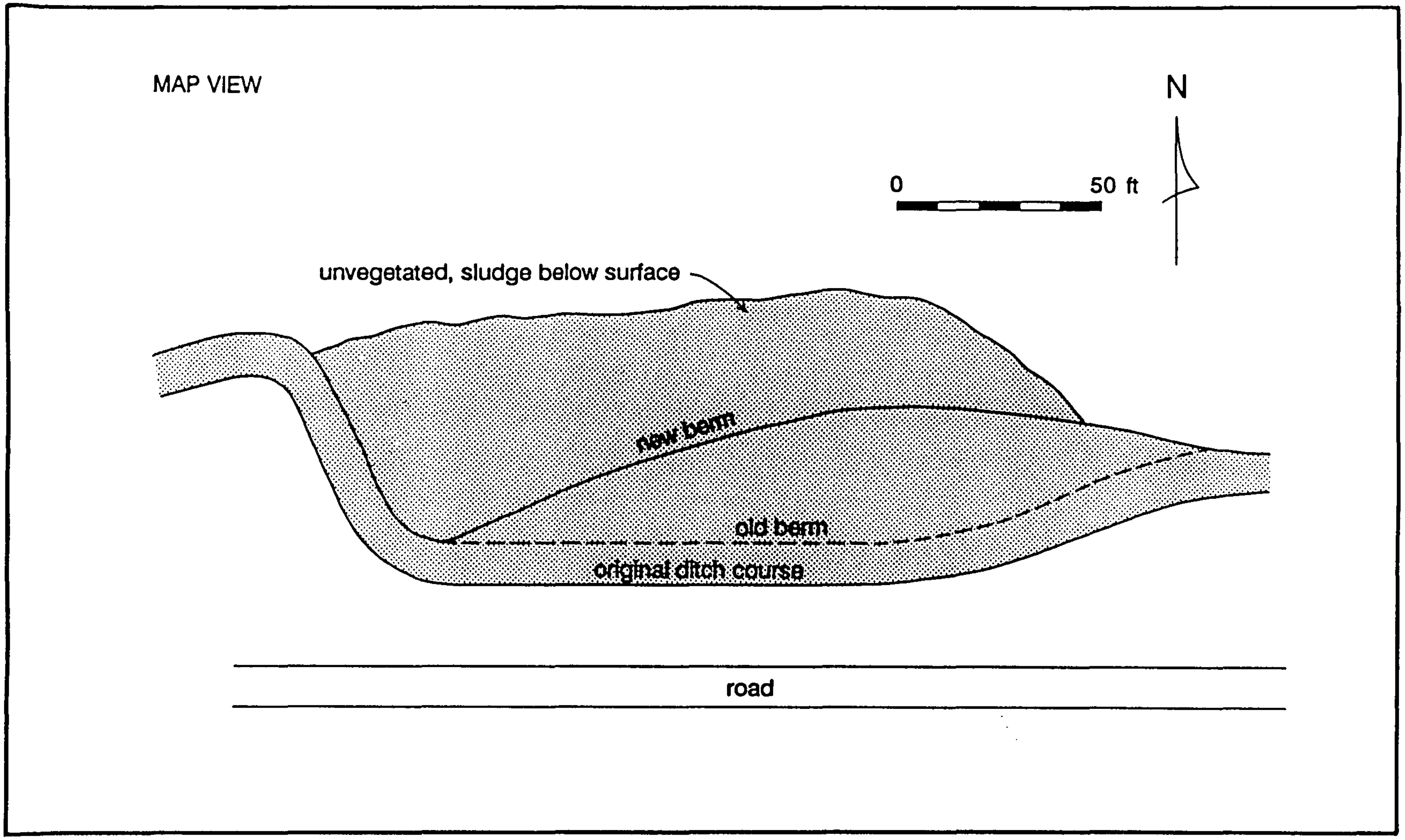


Figure 5.8 Three-Mile Ditch, Trench Map NMD-TR-005, RFI Phase I Report, Navajo Refining Company, October 1990.

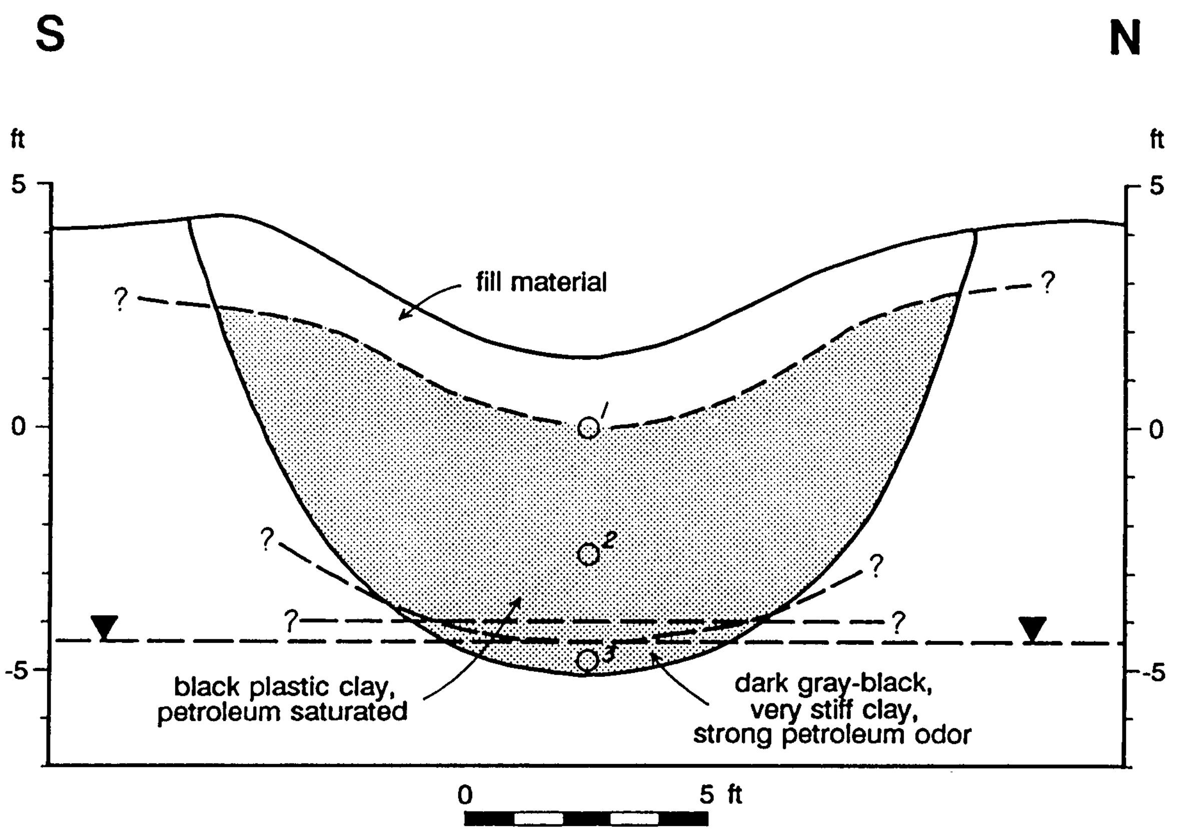


Figure 5.9 Three-Mile Ditch, Trench Cross Section NMD-TR-005, RFI Phase I Report, Navajo Refining Company, October 1990.

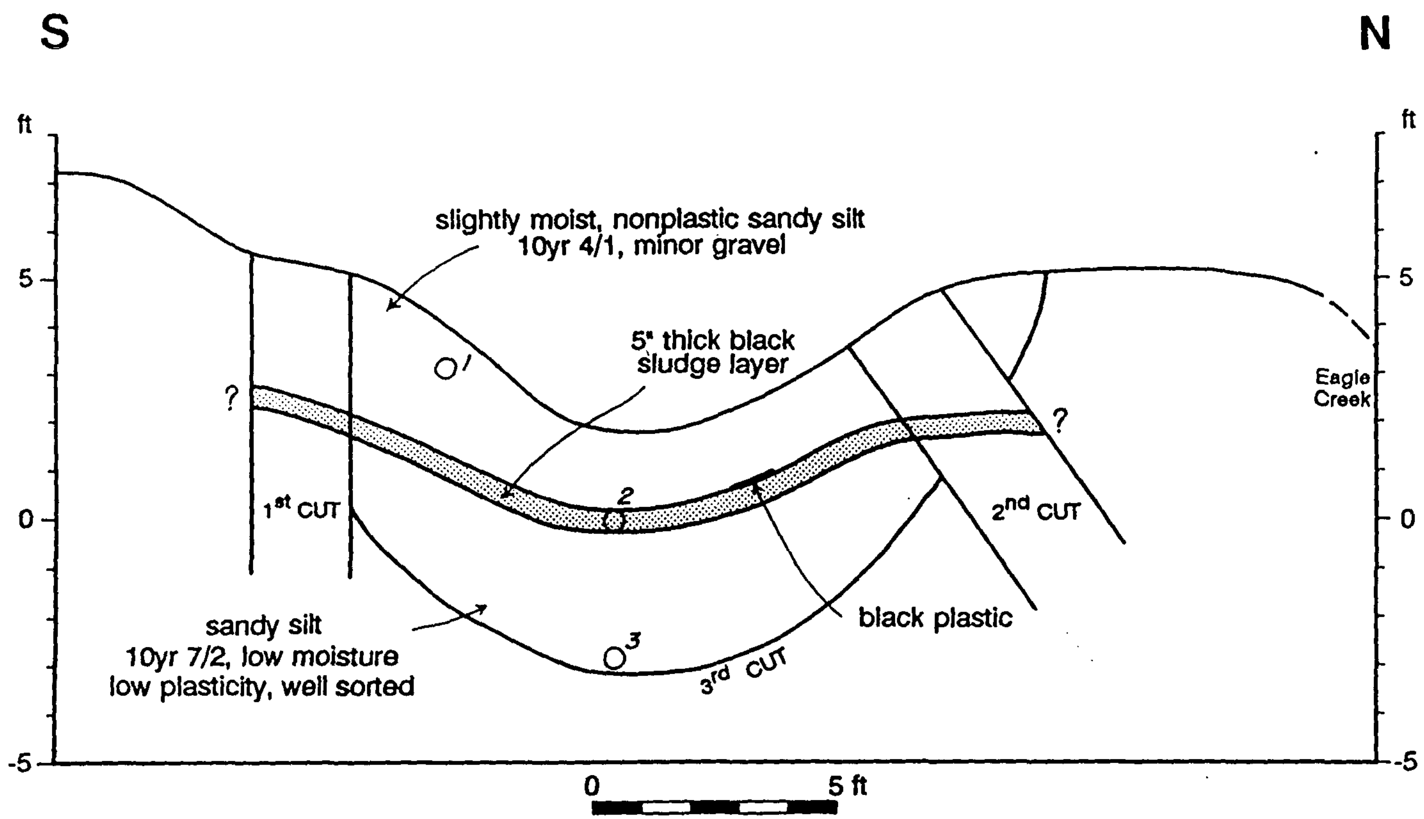


Figure 5.10 Three-Mile Ditch, Trench Cross Section NMD-TR-006, RFI Phase I Report, Navajo Refining Company, October 1990.

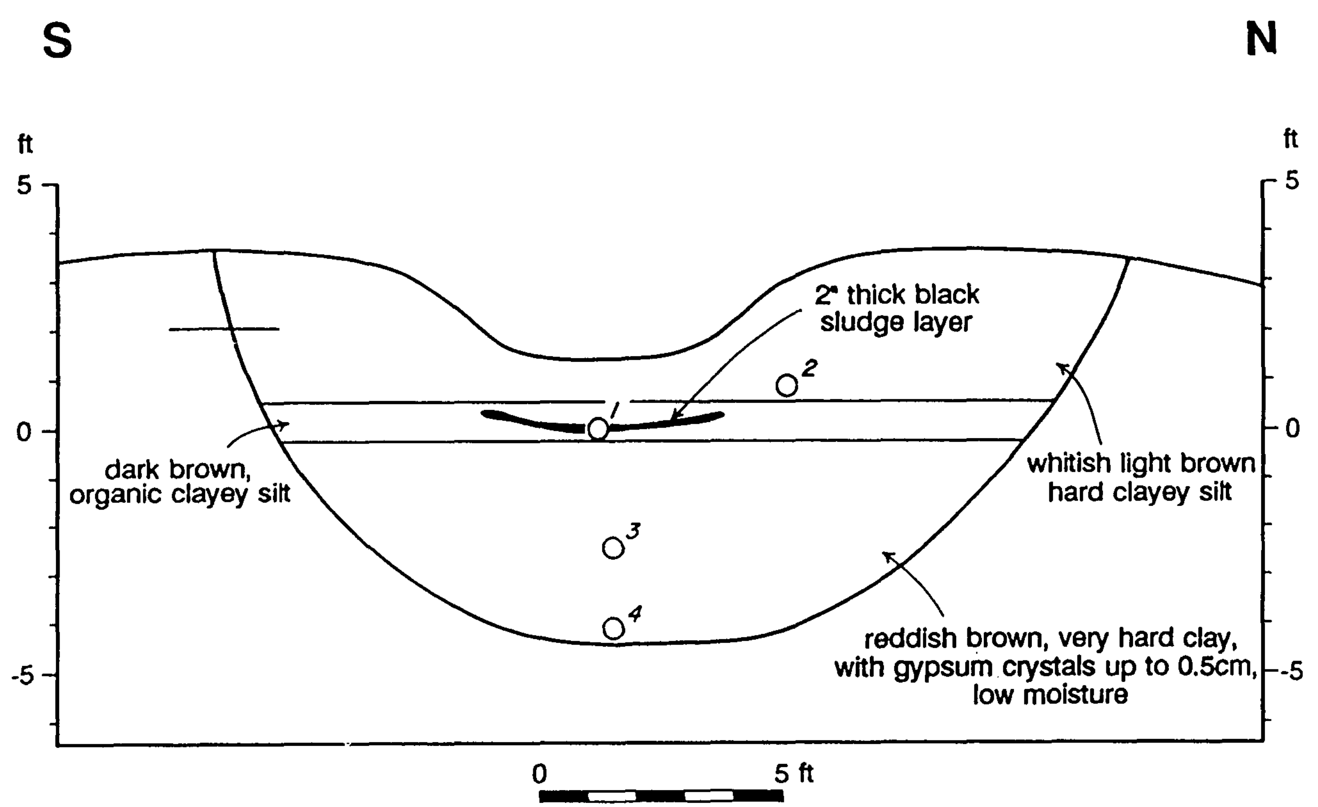


Figure 5.11 Three-Mile Ditch, Trench Cross Section NMD-TR-007, RFI Phase I Report, Navajo Refining Company, October 1990.

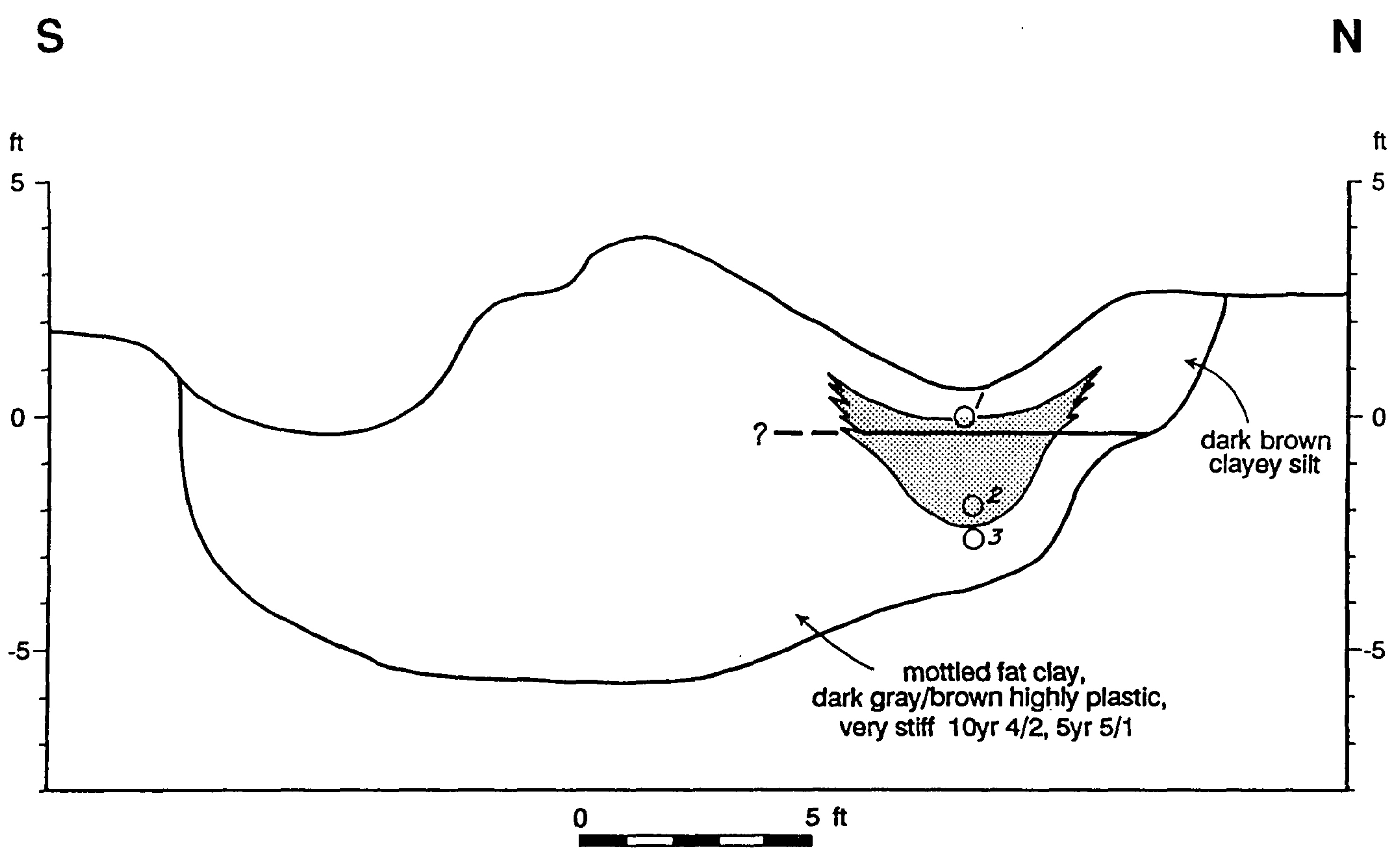


Figure 5.12 Three-Mile Ditch, Trench Cross Section NMD-TR-008, RFI Phase I Report, Navajo Refining Company, October 1990.

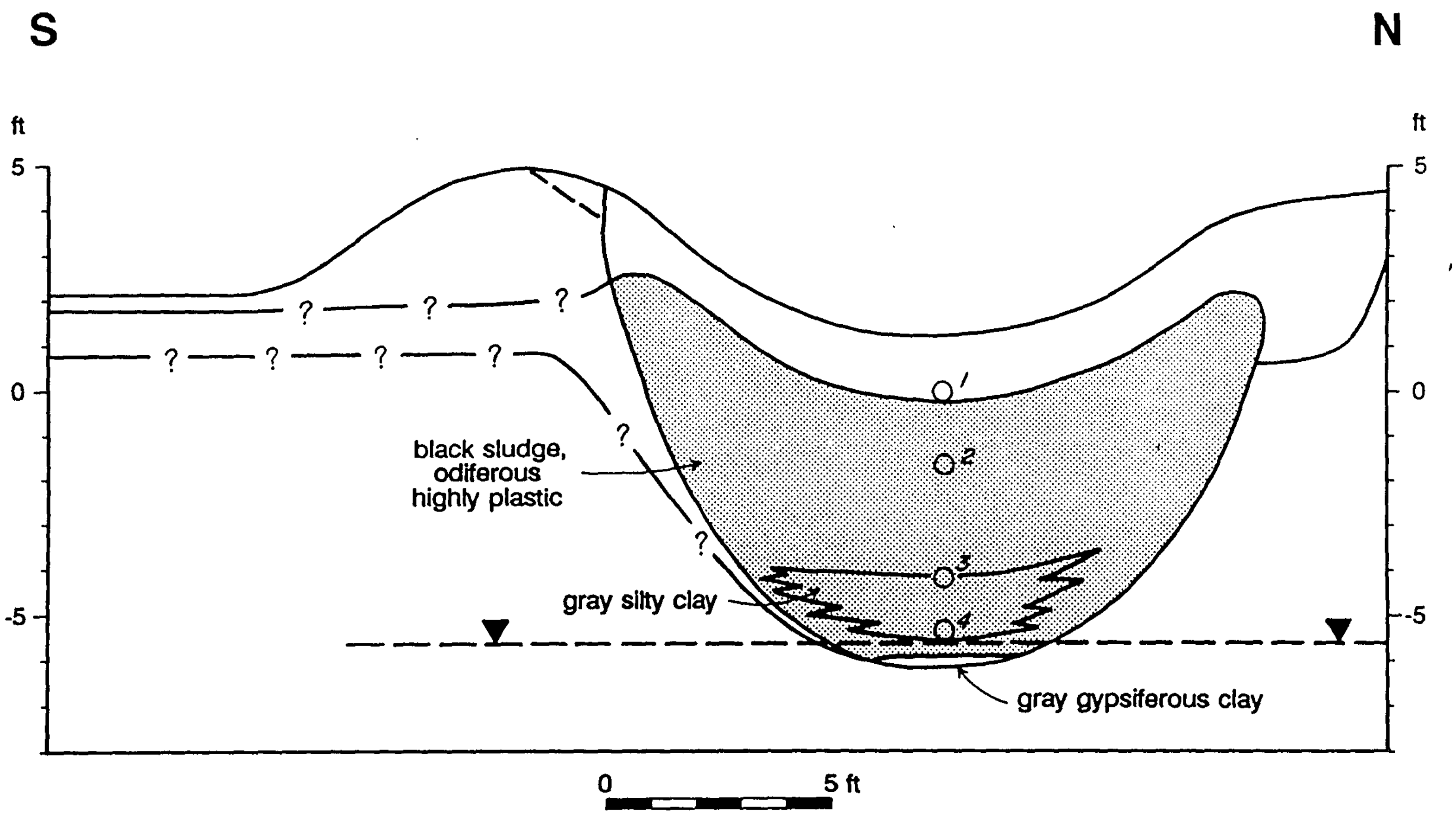


Figure 5.13 Three-Mile Ditch, Trench Cross Section NMD-TR-009, RFI Phase I Report, Navajo Refining Company, October 1990.

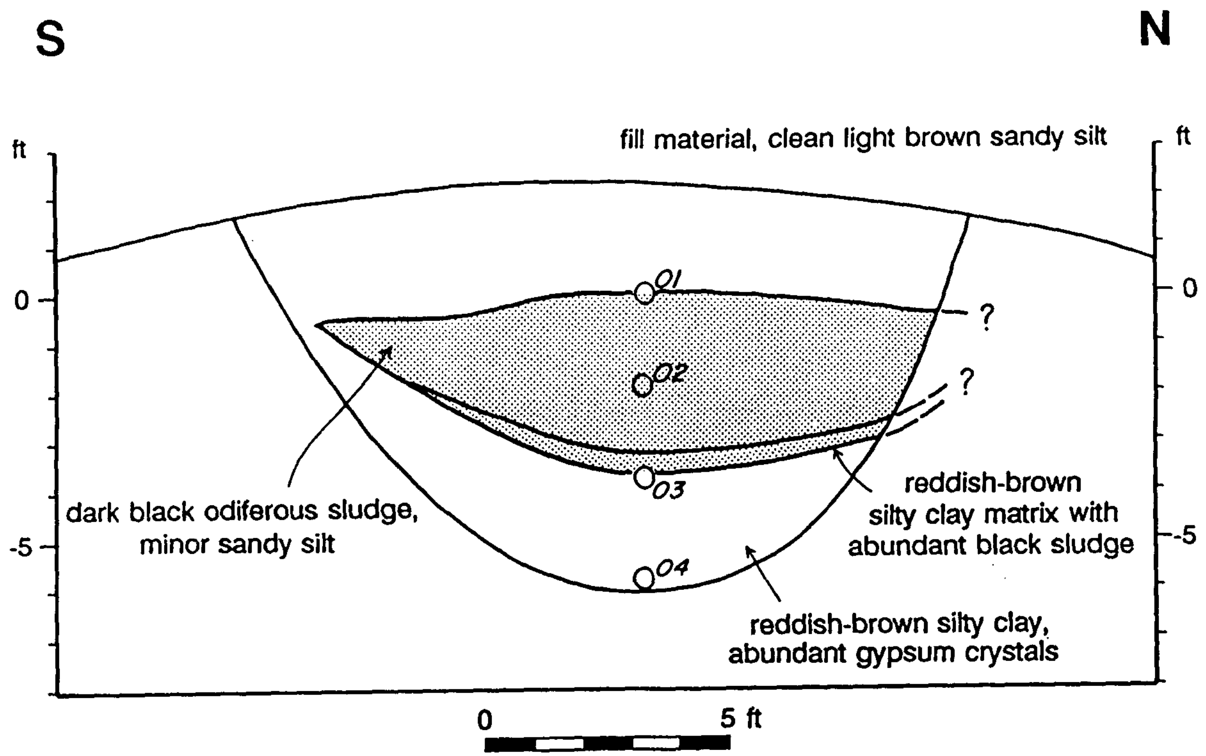


Figure 5.14 Three-Mile Ditch, Trench Cross Section NMD-TR-010, RFI Phase I Report, Navajo Refining Company, October 1990.

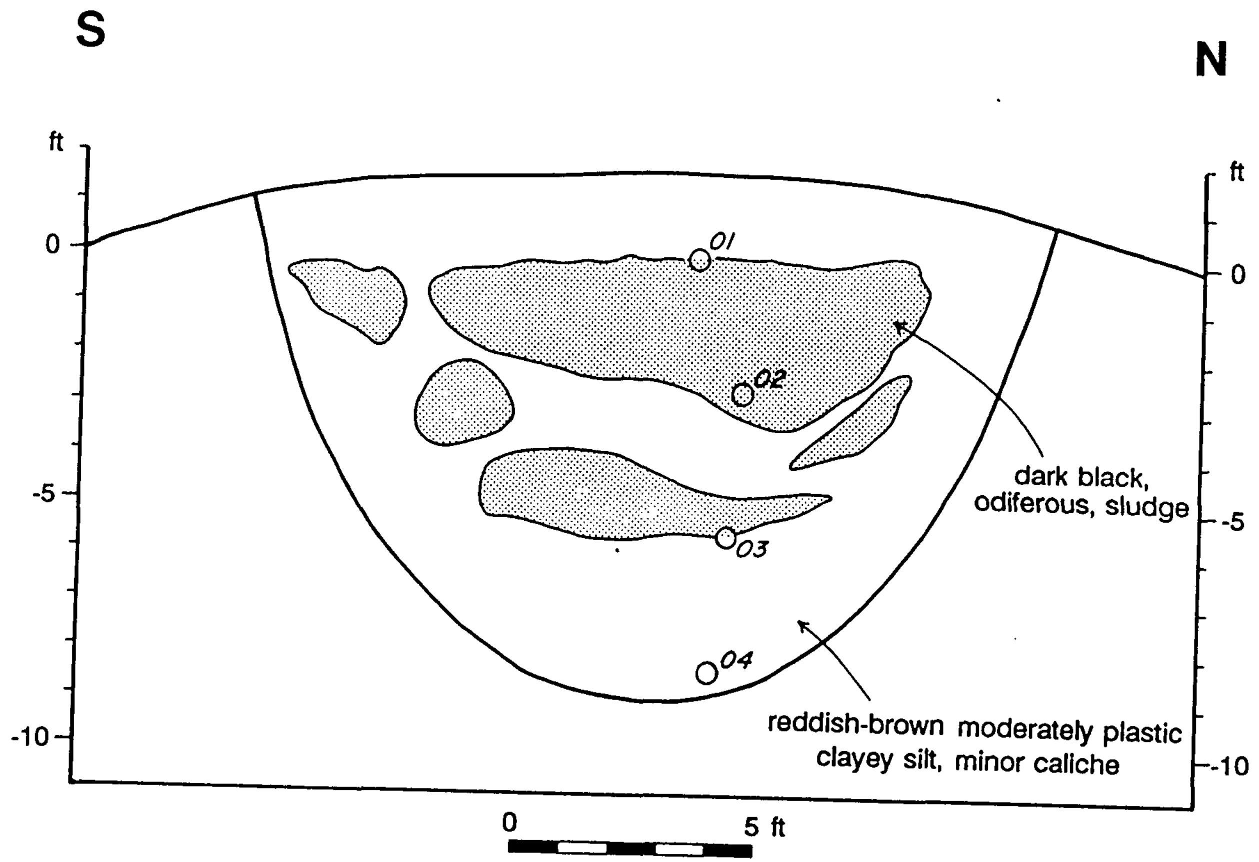


Figure 5.15 Three-Mile Ditch, Trench Cross Section NMD-TR-011, RFI Phase I Report, Navajo Refining Company, October 1990.

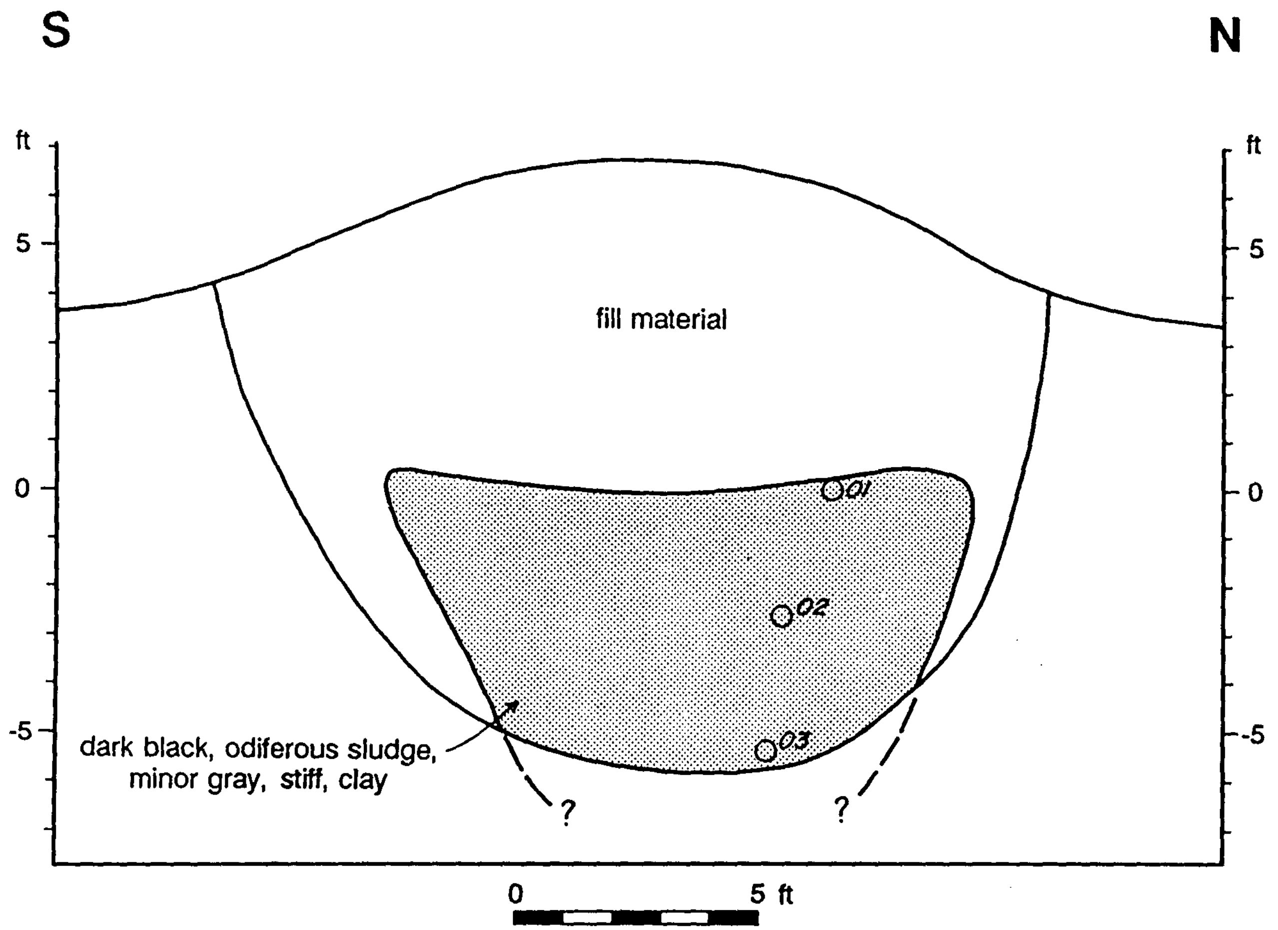


Figure 5.16 Three-Mile Ditch, Trench Cross Section NMD-TR-012, RFI Phase I Report, Navajo Refining Company, October 1990.

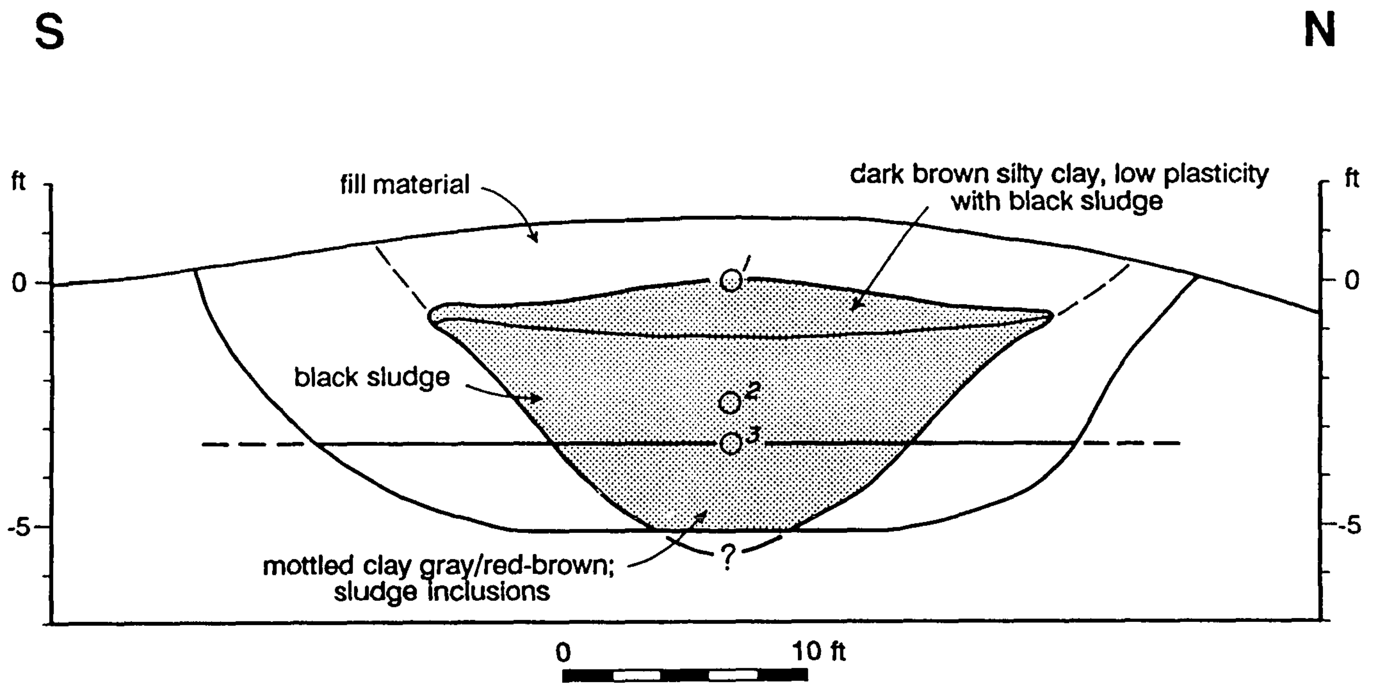


Figure 5.17 Three-Mile Ditch, Trench Cross Section NMD-TR-013, RFI Phase I Report, Navajo Refining Company, October 1990.

gradient for constant flow was probably not maintained in this area due to the relatively rapid rate of sludge accumulation at the ditch surface and to the natural topographic gradient change flattening upon entering the Pecos River floodplain. Conversely, near the refinery where the topographic grade is greater, little sludge accumulated. At specific sites along the ditch course, the berm was apparently breached allowing wastewater to flow laterally (trench NMD-TR-005). The resulting change in gradient and ponding also allowed sludge to accumulate.

5.3.1.3 Soils Analytical Results

Volatiles

Volatile organic compound results from three-mile ditch trench soil samples are listed in Table 5.6. Six volatile compounds occur above their respective detection limits (CRDLs) in 20 trench soil samples. No volatile compounds occur above their CRDLs in the background soil boring soil samples (NMD-SB samples).

The following volatile organic compounds occur in concentrations above their CRDLs: chloromethane, benzene, 1,1,2,2,-tetrachloroethane, toluene, ethyl benzene, and total xylene compounds. Chloromethane occurs in samples NMD-TR-001-03 (0.69 mg/kg), NMD-TR-001-04 (0.31 mg/kg), and NMD-TR-004-02 (0.4 mg/kg). Benzene is detected in samples NMD-TR-000-01, 02, 03 (2 mg/kg, 10 mg/kg, 5.8 mg/kg, respectively), NMD-TR-005-02 (3.2 mg/kg), NMD-TR-012-01,02 (4.5 mg/kg, 0.6 mg/kg, respectively), and NMD-TR-013-02,03 (1.8 mg/kg, 1.4 mg/kg, respectively). 1,1,2,2-tetrachloroethane is identified in samples NMD-TR-004-02 (0.78 mg/kg), and NMD-TR-012-03 (0.8 mg/kg). Toluene occurs in samples NMD-TR-000-01, 02, 03 (5.7 mg/kg, 56 mg/kg, 17 mg/kg, respectively), NMD-TR-004-02 (0.72 mg/kg), NMD-TR-005-02,03,05 (4.2 mg/kg, 0.78 mg/kg, 1.3 mg/kg, respectively), NMD-TR-010-3 (0.33 mg/kg), NMD-TR-011-02 (1.2 mg/kg), NMD-TR-012-01, 02, 03 (14.4

Table 5.6. Three Mile Ditch, Trench and Boring Soils Analytical Results - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990*

		------- Sample Number ----------							
		NMD-TR-000-01	NMD-TR-000-02	NMD-TR-000-03	NMD-TR-001-02	NMD-TR-001-03	NMD-TR-001-04	NMD-TR-001-05	NMD-TR-004-02
COMPOUND	UNITS								
Chloromethane	mg/kg					0.69	0.31		0.4
Benzene	mg/kg	2	10	5.8					
1,1,2,2-Tetrachloroethane	mg/kg				1.2			0.51	0.78
Toluene	mg/kg	5.7	56	17					0.72
Ethylbenzene	mg/kg	24	34	0.5					0.36
Xylenes	mg/kg	120	60	30					1.5

* Blanks and all other analyses were below reported limits.

Table 5.6 (cont). Three Mile Ditch, Trench and Boring Soils Analytical Results - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

COMPOUND	UNITS	----- Sample Number ------ NMD-TR-005-02	NMD-TR-005-03	NMD-TR-005-05	NMD-TR-010-03	NMD-TR-010-05	NMD-TR-011-02
Benzene	mg/kg	3.2					
Toluene	mg/kg	4.2	0.78	1.3	0.33		1.2
Ethyl benzene	mg/kg	4.1	1.4	1.7		0.5	5
Xylenes	mg/kg	15	2.5	3		3.5	9.7

Table 5.6 (cont). Three Mile Ditch, Trench and Boring Soils Analytical Results - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

COMPOUND	UNITS	Sample Number NMD-TR-012-01	NMD-TR-012-02	NMD-TR-012-03	NMD-TR-013-01	NMD-TR-013-02	NMD-TR-013-03
Benzene	mg/kg	4.5		0.6		1.8	1.4
1,1,2,2-Tetrachloroethane	mg/kg			0.8			
Toluene	mg/kg	14.4	3.3	7.9	0.67	7	1.2
Ethyl benzene	mg/kg	13.6	4.2	10		8.5	1.3
Xylenes	mg/kg	21	7.4	16		19	2.8

mg/kg, 3.3 mg/kg, 7.9 mg/kg, respectively), and NMD-TR-013-01, 02, 03 (0.67 mg/kg, 7 mg/kg, 1.2 mg/kg, respectively).

Ethylbenzene is detected in samples NMD-TR-000-01, 02, 03 (24 mg/kg, 34 mg/kg, 0.5 mg/kg, respectively), NMD-TR-004-02 (0.36 mg/kg), NMD-TR-005-02, 03, 05 (4.1 mg/kg, 1.4 mg/kg, 1.7 mg/kg, respectively), NMD-TR-010-05 (0.5 mg/kg, NMD-TR-011-02 (5 mg/kg), NMD-TR-012-01, 02, 03 (13.6 mg/kg, 4.2 mg/kg, 10 mg/kg, respectively), and NMD-TR-013-02, 03 (8.5 mg/kg, 1.3 mg/kg, respectively). Xylene compounds (reported as total xylenes) are identified in samples NMD-TR-000-01, 02 , 03 (120 mg/kg, 60 mg/kg, 30 mg/kg), NMD-TR-004-02 (1.5 mg/kg), NMD-TR-005, 02, 03, 05 (15 mg/kg, 2.5 mg/kg, 3 mg/kg, respectively), NMD-TR-010-05 (3.5 mg/kg), NMD-TR-011-02 (9.7 mg/kg), NMD-TR-012-01, 02, 03 (21 mg/kg, 7.4 mg/kg, 16 mg/kg, respectively), and NMD-TR-013-02, 03 (19 mg/kg, 2.8 mg/kg).

Semivolatiles

Semivolatile organic compound analytical results from Three-Mile Ditch trench soil samples are listed in Table 5.7. Only those samples with one or more detectable semivolatile organic compounds are included. Forty-six separate trench soil samples contain one or more of 24 individual semivolatile organic compounds. No semivolatile organic compounds occur above their CRDLs in the Three-Mile Ditch soil boring background (NMD-SB).

In the following discussion the visually contaminated samples are discussed separately from the visually uncontaminated samples. Trenching and sampling goals, constraints, and procedures are discussed in Section 5.3.1.1 (trenching procedure).

Table 5.7. Three-Mile Ditch, Trench and Soil Borings, Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number									
COMPOUND	UNITS	NMD-TR-000-01	NMD-TR-000-02	NMD-TR-000-03	NMD-TR-001-01	NMD-TR-001-02	NMD-TR-001-03	NMD-TR-001-04	NMD-TR-001-05	NMD-TR-002-02	NMD-TR-002-03
Acenaphthene	mg/kg	31	9.2	4.5							
Anthracene	mg/kg	88	20	23			0.67		1.7		
Benzo(a)anthracene	mg/kg	7.1	2	1.6							
Benzo(b)fluoranthene	mg/kg	4.9	0.8								
Benzo(a)pyrene	mg/kg	2.7									
Bis(2-ethylhexyl)phthalate	mg/kg	0.79			1.1	1.4	2.5	0.89	1.9	1.3	
4-Chloroaniline	mg/kg					0.73					
2-Chloronaphthalene	mg/kg	0.96									
4-Chloro-3-methylphenol	mg/kg										
Chrysene	mg/kg	14	3.4	2.4							
Dibenzofuran	mg/kg	34	9.7	12							
Di-n-butyl phthalate	mg/kg			2.6	2.7	2.2	1.2				
Fluoranthene	mg/kg	120	22	11							
Fluorene	mg/kg		43	25							
2-Methylnaphthalene	mg/kg	260	65	43		2.7	0.95		0.66		
Naphthalene	mg/kg	89	20	9.1							
Phenanthrene	mg/kg	72	18	15		0.98			4.3		5
Pyrene	mg/kg	53	15	14							0.7

Table 5.7 (cont). Three-Mile Ditch. Trench and Soil Borings. Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company. October, 1990

		Sample Number									
COMPOUND	UNITS	NMD-TR-002-04	NMD-TR-003-01	NMD-TR-003-02	NMD-TR-003-03	NMD-TR-004-01	NMD-TR-004-02	NMD-TR-004-03	NMD-TR-004-04	NMD-TR-005-01	NMD-TR-005-02
Acenaphthene	mg/kg										3.2
Anthracene	mg/kg										20.4
Benzo(a)anthracene	mg/kg										6.8
Benzo(g,h,i)perylene	mg/kg									3.6	2
Benzo(a)pyrene	mg/kg									1	1
Bis(2-ethylhexyl)phthalate	mg/kg						1.7	1.7		1	28.2
Chrysene	mg/kg										3.2
Dibenzofuran	mg/kg										5.6
Di-n-butyl phthalate	mg/kg	1.7			2.3			1.1			
Diethylphthalate	mg/kg				4.2						
Fluoranthene	mg/kg										9.8
Fluorene	mg/kg										27.2
2-Methylnaphthalene	mg/kg						0.99				39
2-Nitroaniline	mg/kg										9.4
Phenanthrene	mg/kg					8					71
Pyrene	mg/kg									1.2	11

Table 5.7 (cont). Three-Mile Ditch, Trench and Soil Borings, Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

COMPOUND	UNITS	Sample Number							
		NMD-TR-005-03	NMD-TR-005-05	NMD-TR-006-01	NMD-TR-006-02	NMD-TR-006-03	NMD-TR-007-01	NMD-TR-007-02	NMD-TR-007-03
Anthracene	mg/kg		0.88						
Benzo(b)fluoranthene	mg/kg		0.82						
Bis(2-chloroisopropyl)ether	mg/kg					1.5			
Bis(2-ethylhexyl)phthalate	mg/kg			1.3	1	0.81			1.1
Butyl benzyl phthalate	mg/kg			1		0.75			
2-Chlorophenol	mg/kg	5.3	5.5	6.1	6.2	6.3	7.1	7.2	
Di-n-butyl phthalate	mg/kg		1.4	1.3	1.1	1.5			
Fluoranthene	mg/kg	0.7							
Fluorene	mg/kg	2.5	1.2						
2-Methylnaphthalene	mg/kg	2.3	2.3						
Phenanthrene	mg/kg	6.7	2.6		6.8				
Pyrene	mg/kg	1.3					2.3		

Table 5.7 (cont). Three-Mile Ditch, Trench and Soil Borings, Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		-------------------- Sample Number ----------------------									
COMPOUND	UNITS	NMD-TR-007-04	NMD-TR-008-01	NMD-TR-008-02	NMD-TR-008-03	NMD-TR-009-01	NMD-TR-009-02	NMD-TR-009-03	NMD-TR-009-04	NMD-TR-010-01	NMD-TR-010-02
Acenaphthene	mg/kg										15
Anthracene	mg/kg										21
Benzo(a)anthracene	mg/kg					14					
Benzo(b)fluoranthene	mg/kg					7.5					
Benzo(g,h,i)perylene	mg/kg					5.8					
Benzo(a)pyrene	mg/kg					7.2					11
Bis(2-ethylhexyl)phthalate	mg/kg	1.1				6.5	1.2	1.4			
Butyl benzyl phthalate	mg/kg	1									
Chrysene	mg/kg					15					
Dibenzofuran	mg/kg										29
Di-n-butyl phthalate	mg/kg					0.67					2
2,6-Dinitrotoluene	mg/kg										17
Di-n-octyl phthalate	mg/kg										2
Fluoranthene	mg/kg					6.6					15
Fluorene	mg/kg										56
2-Methylnaphthalene	mg/kg										230
Naphthalene	mg/kg										46
Phenanthrene	mg/kg					5.1				8.5	270
Pyrene	mg/kg					25				7.5	60

Table 5.7 (cont). Three-Mile Ditch, Trench and Soil Borings, Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

COMPOUND	UNITS	Sample Number NMD-TR-010-03	NMD-TR-010-04	NMD-TR-010-05	NMD-TR-011-01	NMD-TR-011-02	NMD-TR-011-03	NMD-TR-012-01	NMD-TR-012-02	NMD-TR-012-03	NMD-TR-013-01
Acenaphthene	mg/kg	0.77				6.1		15	12.4	7.8	
Anthracene	mg/kg								14.1	7.4	
Benzo(a)anthracene	mg/kg	2.8				14.7		19.8	27	20	
Benzo(g,h,i)perylene	mg/kg								6.1		
Benzo(a)pyrene	mg/kg								9.9	6.8	
Bis(2-ethylhexyl)phthalate	mg/kg	2.8	1.2								
Chrysene	mg/kg	2.2				15		20	29	19.8	
Dibenzofuran	mg/kg	1.8				14.7		27	18.4	12.3	
Di-n-butyl phthalate	mg/kg		0.69	0.8	1.6	1.2		1.8	5.3	1.5	
2,4-Dinitrotoluene	mg/kg			2.9	7.9	10.2		3.1			
2,6-Dinitrotoluene	mg/kg				1.2	12.8		12.6	13.5	7.6	
Fluoranthene	mg/kg	1.2				6.1	0.75	5.4	13.8	6.3	
Fluorene	mg/kg	4.1				29.9		37	52	29	
2-Methylnaphthalene	mg/kg	12									
Naphthalene	mg/kg	2				22.3		55	33	23	
4-Nitrophenol	mg/kg									7	
Phenanthrene	mg/kg	18		10.2	15.4	101	2.6		220	96	3.3
Pyrene	mg/kg	4.1		8.9	14.9	31	3	33	43		1.5

Table 5.7 (cont). Three-Mile Ditch, Trench and Soil Borings, Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

COMPOUND	UNITS	Sample Number NMD-TR-013-02	NMD-TR-013-03	NMD-TR-S1-01	NMD-TR-S1-02	NMD-TR-S1-03
Acenaphthene	mg/kg		0.71			
Anthracene	mg/kg		5.9			
Benzo(a)anthracene	mg/kg		1.8			
Butyl benzyl phthalate	mg/kg				0.92	1.3
Dibenzofuran	mg/kg	3.8	1.2			
Di-n-butyl phthalate	mg/kg		10	1.4	2	
2,4-Dinitrotoluene	mg/kg	2.4				
2,6-Dinitrotoluene	mg/kg	5.1				
Fluoranthene	mg/kg		0.9			
Fluorene	mg/kg	7.2	6.1			
2-Methylnaphthalene	mg/kg	2.5	5			
Naphthalene	mg/kg	5				
Phenanthrene	mg/kg		10			
Pyrene	mg/kg		0.82			

Visually Contaminated Samples

The list of visually contaminated samples includes: NMD-TR-SI-01, 02, 03, NMD-TR-000-01, 02, 03, NMD-TR-001-01, 02, 03, NMD-TR-002-01, 02, 03, NMD-TR-003-01, NMD-TR-004-01, 02, 03, NMD-TR-005-01, 02, 03, NMD-TR-006-02, NMD-TR-007-01, NMD-TR-008-01, 02, 03, NMD-TR-009-01, 02, 03, 04, NMD-TR-010-01, 01, 03, NMD-TR-011,01, 02, 03, NMD-TR-012-01, 02, 03, and NMD-TR-013-01, 02, 03.

Every trench is visually contaminated from top to bottom except NMD-TR-002, 003, 004, 006, 007, 010, and 011. Most visually uncontaminated intervals are at the bottom of the trench (NMD-TR-002-04, NMD-TR-003-02, 03, NMD-TR-004-04, NMD-TR-006-03, NMD-TR-007-03, 04, NMD-TR-010-04, and NMD-TR-011-04). However, trenches NMD-TR-006 and -007 (intervals 01 and 02, respectively) are also visually uncontaminated at the top (Table 5.5).

Acenaphthene is detected in trenches NMD-TR-000, 005, 012, and 013 at concentration levels that range from 0.71 mg/kg to 31 mg/kg. NMD-TR-012-01, 010-02, and 000-01 contain the highest levels of acenaphthene; 15 mg/kg, 15 mg/kg, and 31 mg/kg, respectively.

Anthracene is identified in trenches NMD-TR-000, 001, 005, 010, 012, and 013 at concentration levels that range from 0.67 mg/kg to 88 mg/kg. Samples NMD-TR-000-01, 02, 03 (88 mg/kg, 20 mg/kg, 23 mg/kg, respectively), 005-02 (20.4 mg/kg), and 010-02 (21 mg/kg) contain the highest levels of anthracene.

Benzo(a)anthracene occurs in trenches NMD-TR-000, 005, 009, 010, 011, 012, and 013 at concentration levels that range from 1.6 mg/kg to 27 mg/kg. The highest levels of benzo(a)anthracene are in samples NMD-TR-009-01 (14 mg/kg), 011-02 (14.7 mg/kg) and 012-01, 02, 03 (19.8 mg/kg, 27 mg/kg, 20 mg/kg, respectively).

Benzo(b)fluoranthene is detected in trenches NMD-TR-000, 005, and 009 at concentrations that range from 0.08 mg/kg to 4.9 mg/kg (NMD-TR-000-01).

Benzo(g,h,i)perylene is identified in trenches NMD-TR-005, 009, and 012 at concentration levels that vary from 2 mg/kg to 6.1 mg/kg. Samples NMD-TR-009-01 (5.8 mg/kg) and 012-02 (6.1 mg/kg) have the highest concentrations of the compound.

Benzo(a)pyrene occurs in trenches NMD-TR-000, 005, 009, 010, and 012, and ranges in concentration from 1 mg/kg to 11 mg/kg. Samples NMD-TR-012-02, 03 (9.9 mg/kg, 6.8 mg/kg), 009-01 (7.2 mg/kg), and 010-02 (11 mg/kg) contain the highest concentrations.

Bis(2-ethylhexyl) phthalate is detected in trenches NMD-TR-000, 001, 002, 004, 005, and 009 at concentration levels that vary from 0.79 mg/kg to 28.2 mg/kg (NMD-TR-005-02). NMD-TR-005-02 and 009-01 (6.5 mg/kg) are the only samples that exceed 2.6 mg/kg.

The compounds 4-chloroaniline and 2-chloroaniline occur in one trench sample each. NMD-TR-001-02 contains 0.73 mg/kg 4-chloraniline, and NMD-TR-000-01 contains 0.96 mg/kg 2-chloraniline.

Butyl benzyl phthalate is identified in trenches NMD-TR-S1, 006, and 007 at concentrations ranging from 0.75 mg/kg to 1.3 mg/kg.

Chrysene occurs in trenches NMD-TR-000, 005, 009, 010, 011, and 012, at concentration levels that vary from 2.2 mg/kg to 29 mg/kg. Samples NMD-TR-000-01 (14 mg/kg), 009-01 (15 mg/kg), 011-02 (15 mg/kg), and 012-01, 02, 03 (20 mg/kg, 29 mg/kg, 19.8 mg/kg) contain the highest levels of chyrsene.

Dibenzofuran is detected in trenches NMD-TR-000, 005, 010, 011, 012, and 013 at concentration levels that range from 1.2 mg/kg to 34 mg/kg. Samples NMD-TR-000-01 (34 mg/kg), 010-02 (29 mg/kg), and 012-01 (27 mg/kg) contain the highest concentrations.

Di-n-butylphthalate occurs in trenches NMD-TR-000, 001, 004, 005, 006, 009, 010, 011, 012, 013, and S1 at low level concentrations that range from 0.67 mg/kg to 10 mg/kg. Samples NMD-TR-03 (10 mg/kg) and 012-02 (5.3 mg/kg) are the only samples to exceed 2.3 mg/kg.

The compound 2,4-dinitrotoluene is identified in trenches NMD-TR-010, 011, 012, and 013 at concentrations ranging from 2.4 mg/kg to 10.2 mg/kg. 2,6-dinitrotoluene occurs in trenches NMD-TR-010, 011, 012, and 013 at concentrations that range from 1.2 mg/kg to 17 mg/kg. Samples NMD-TR-010-02 (17 mg/kg), 011-02 (12.8 mg/kg), and 012-01, 02 (12.6 mg/kg, 13.5 mg/kg, respectively) contain the highest concentrations of 2,6-dinitrotoluene.

Di-n-octyl phthalate is detected only in trench sample NMD-TR-010-02 (2 mg/kg).

Fluoranthene occurs in trenches NMD-TR-000, 005, 009, 010, 012, and 013 at concentrations that range from 0.7 mg/kg to 120 mg/kg. Sample NMD-TR-000-01 (120 mg/kg) is the only one that exceeds 22 mg/kg.

Fluorene is detected in trenches NMD-TR-000, 005, 010, 011, 012, and 013 at concentrations ranging from 1.2 mg/kg to 56 mg/kg. Samples NMD-TR-000-02, 03 (43 mg/kg, 25 mg/kg, respectively), 005-02 (39 mg/kg), 010-02 (56 mg/kg), 011-02 (29.9 mg/kg), and 012-01, 02, 03 (37 mg/kg (52 mg/kg, 29 mg/kg) contain the highest concentrations of fluorene.

The compound 2-methylnaphthalene is identified in trenches NMD-TR-000, 001, 004, 005, 010, and 013 at concentrations that range from 0.99 mg/kg to 260 mg/kg. The highest concentrations occur in samples NMD-TR-000-01 (260 mg/kg), and 010-02 (230 mg/kg).

The compound 2-nitroaniline is detected only in trench sample NMD-TR-005-02 (9.4 mg/kg).

Naphthalene occurs in trenches NMD-TR-000, 010, 011, 012, and 013 at concentrations that range from 2 mg/kg to 89 mg/kg. Samples NMD-TR-000-01 (89 mg/kg), 010-02 (46 mg/kg), and 012-01 (55 mg/kg) contain the highest concentrations of naphthalene.

Phenanthrene is identified in trenches NMD-TR-000, 001, 002, 004, 005, 006, 009, 010, 011, 012, and 013 at concentrations that range from 0.98 mg/kg to 270 mg/kg. The highest concentrations occur in samples NMD-TR-000-01 (72 mg/kg), 010-02 (270 mg/kg), 011-02 (101 mg/kg), and 012-02, 03 (220 mg/kg, 96 mg/kg, respectively).

Pyrene occurs in trenches NMD-TR-000, 002, 005, 007, 009, 010, 011, 012, and 013 at concentrations that range from 0.7 mg/kg to 60 mg/kg. Samples NMD-TR-000-01 (53 mg/kg), 009-01 (25 mg/kg), 010-02 (60 mg/kg), 011-02 (31 mg/kg), and 012-01, 02 (33 mg/kg, 43 mg/kg, respectively) contain the highest concentrations of pyrene.

Note that samples NMD-TR-000-01 and 010-02 are significantly more contaminated than the others. Samples NMD-TR-000-02, 03, 012-01, 03 also contain high-level volatile concentrations.

Visually Uncontaminated Samples

Only two of the 10 visually uncontaminated trench samples contain more than two detectable semivolatile organic compounds. NMD-TR-006-01 contains four, and 006-03 contains five. All semivolatile compounds contained in these samples occur at low concentration levels (range from 0.68 mg/kg di-n-butylphthalate to 7.2 mg/kg 2-chlorophenol).

Metals

Analytical data from Three-Mile Ditch trench and boring soil samples are listed in Table 5.8. All metals (and oil and grease) analyzed occur above their respective CRDLs in at least one of the 51 ditch samples and five soil types. Metal (and oil and grease) values from visually contaminated and visually uncontaminated samples of each soil type are compared to their corresponding background values (Table 5.9). Only those samples that exceed their respective soil type background value are discussed

Antimony occurs above its CRDL and background value in only one soil type (Pima series, or Pe) and two visually contaminated samples (NMD-TR-004-01 and 005-01, 0.67 mg/kg and 0.62 mg/kg, respectively).

Arsenic occurs above Pe soil background (5.5 mg/kg) in 12 visually contaminated Pe soil samples, ranging from 6.01 mg/kg to 46.1 mg/kg and averaging 17.2 mg/kg. Arsenic is above background in two visually uncontaminated Pe soil samples, NMD-TR-003-02 (14.6 mg/kg) and 006-03 (11.0 mg/kg). Only one affected Reeves loam (Ri) soil sample is visually contaminated, and it contains above background arsenic (NMD-TR-007-01, 19.6 mg/kg). Two visually uncontaminated Ri soil samples contain above background arsenic, NMD-TR-007-03 (18.5 mg/kg) and 007-04 (9.49 mg/kg). There are no background values for Pima clay loam series (Pv) soils. Seven visually contaminated Pv soil samples range from 3.27 mg/kg to 48.3 mg/kg and average 14.18 mg/kg. There are no visually uncontaminated Pv soil samples. Seven of nine visually contaminated Arno silty clay loam (An) soil samples contain above background arsenic values, ranging from 57.4 mg/kg to 130 mg/kg and averaging 101 mg/kg. One visually uncontaminated An soil sample

Table 5.8. Three Mile Ditch, Trench and Soil Borings Analytical Results - Metals and Oil and Grease
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		Sample Number								
METAL	UNITS	NMD-TR-S1-01	NMD-TR-S1-02	NMD-TR-S1-03	NMD-TR-000-01	NMD-TR-000-02	NMD-TR-000-03	NMD-TR-001-01	NMD-TR-001-02	NMD-TR-001-03
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	15.2	5.29	6.11	12.9	3.03	13.9	3.16	6.92	2.89
Barium	mg/kg	70.8	124	96.1	73.5	75.9	366	75.8	85	99.3
Beryllium	mg/kg	0.621	0.809	0.611	< 0.30	< 0.30	< 0.30	0.85	0.58	< 0.30
Cadmium	mg/kg	5.59	3.95	3.2	3.03	0.94	0.74	6.2	4.98	2.64
Chromium	mg/kg	433	< 0.30	< 0.30	3390	5.9	10.5	19.5	13.7	10.2
Lead	mg/kg	22.3	6.22	< 0.50	2175	0.974	1.01	13.3	10.2	17
Mercury	mg/kg	0.17	< 0.05	< 0.05	1	0.17	0.07	0.09	0.07	0.06
Nickel	mg/kg	14.3	11.5	8.61	12	4.84	0.29	16.1	12.7	6.43
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	1.39	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	2.79	< 0.50	4.72	1.2	3.03	3.25	< 0.50	< 0.50	2.25
Zinc	mg/kg	35.4	22.4	6.4	57.2	4	2.16	47.3	31.2	11.8
Oil and Grease	percent	16.7	0.014	0.034	5.15	2.21	2.19	0.076	0.144	0.026

Table 5.8 (cont). Three Mile Ditch, Trench and Soil Borings Analytical Results - Metals and Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number									
METAL	UNITS	NMD-TR-001-04	NMD-TR-002-01	NMD-TR-002-03	NMD-TR-002-04	NMD-TR-003-01	NMD-TR-003-02	NMD-TR-003-03	NMD-TR-004-01	NMD-TR-004-02	NMD-TR-004-03
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	0.668	< 0.50	< 0.50
Arsenic	mg/kg	2.79	2.89	3.5	3.81	32.7	14.6	2.34	22.9	6.01	4.08
Barium	mg/kg	21	124	78.6	82.2	80.7	135	69.5	210	95.9	79.5
Beryllium	mg/kg	0.46	0.78	0.32	0.41	0.76	0.62	0.3	0.63	0.72	0.58
Cadmium	mg/kg	3.1	5.4	2.5	2.8	5.07	4.05	2.31	6.4	6	3
Chromium	mg/kg	19.2	31.6	10.2	13.5	56.3	18.8	9.53	373	20.1	11
Lead	mg/kg	3.98	11.6	3.63	4.05	67.7	14.7	2.79	480	682	48.1
Mercury	mg/kg	0.05	< 0.05	< 0.05	< 0.05	*	< 0.05	< 0.05	1	0.067	0.19
Nickel	mg/kg	7	13.3	7	7.5	14.7	11.5	5.26	14.4	13.5	10.2
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	< 0.50	1.45	1.28	1.45	1.09	1.41	1.17	2.2	< 0.50	< 0.50
Zinc	mg/kg	16.9	44.5	17.3	21.3	46.8	33.7	16.5	200	43.4	27.8
Oil and Grease	percent	0.016	0.206	0.297	0.036	0.379	1.5	0.049	1.35	0.136	0.065

*insufficient sample

Table 5.8 (cont). Three Mile Ditch, Trench and Soil Borings Analytical Results - Metals and Oil and Grease
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		Sample Number							
METAL	UNITS	NMD-TR-004-04	NMD-TR-005-01	NMD-TR-005-02	NMD-TR-005-03	NMD-TR-006-01	NMD-TR-006-02	NMD-TR-006-03	NMD-TR-007-01
Antimony	mg/kg	< 0.50	0.616	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	5.17	46.1	17.3	11	3.53	15.2	11	19.6
Barium	mg/kg	195	122	185	110	80.2	140	54	148
Beryllium	mg/kg	0.81	0.29	0.62	0.59	0.48	0.71	< 0.30	< 0.30
Cadmium	mg/kg	7.3	4.7	5.9	2.9	5.3	7.7	7.2	3.57
Chromium	mg/kg	19.4	16.8	305	22.6	17.7	76.7	6.05	800
Lead	mg/kg	123	18.03	830	35.2	340	223	3.3	275
Mercury	mg/kg	< 0.05	1	0.67	< 0.05	0.08	0.7	0.03	1
Nickel	mg/kg	15.2	25.8	15.3	10.1	11.9	17.5	8.24	13
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	< 0.50	2.64	1.47	1.31	0.962	2.26	2.44	3.16
Zinc	mg/kg	45.6	352	264	28	35.6	171	15.7	262
Oil and Grease	percent	< 0.01	3.98	6.5	0.584	< 0.01	2.95	0.023	4.43

Table 5.8 (cont). Three Mile Ditch, Trench and Soil Borings Analytical Results - Metals and Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number										
METAL	UNITS	NMD-TR-007-02	NMD-TR-007-03	NMD-TR-007-04	NMD-TR-008-01	NMD-TR-008-02	NMD-TR-008-03	NMD-TR-009-01	NMD-TR-009-02	NMD-TR-009-03	NMD-TR-009-04	NMD-TR-010-01
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	2.65	18.5	9.49	48.3	4.96	3.91	32.9	2.53	3.42	3.27	91.4
Barium	mg/kg	35	116	82	75.2	90.1	113	171	75.7	46.1	47.8	71.5
Beryllium	mg/kg	< 0.30	< 0.30	0.6	0.39	0.69	0.62	< 0.30	< 0.30	< 0.30	< 0.30	< 0.30
Cadmium	mg/kg	1.53	5.7	4.1	3.7	4.4	4.5	4.06	3.44	1.89	1.75	3.62
Chromium	mg/kg	8.4	171	11.6	61.9	28.3	18.5	594	12.8	9	6.6	1220
Lead	mg/kg	467	863	10.1	2196	15.5	6.63	305	7.7	8.93	2.92	206
Mercury	mg/kg	0.07	0.27	0.03	0.67	< 0.05	< 0.05	0.533	< 0.05	< 0.05	< 0.05	0.153
Nickel	mg/kg	4.36	13.2	12.7	12.2	12.1	10.1	19.4	7.7	5.52	4.08	9.46
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	1.57	2.96	< 0.50	1.93	0.83	0.98	2.15	1.38	< 0.50	< 0.50	8.11
Zinc	mg/kg	11.6	336	29.5	84.7	41	35.6	683	29.6	19.1	15	250
Oil and Grease	percent	< 0.01	0.056	< 0.01	4.47	1.66	1.54	12.2	0.208	0.021	< 0.01	5.61

Table 5.8 (cont). Three Mile Ditch, Trench and Soil Borings Analytical Results - Metals and Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

METAL	UNITS	Sample Number NMD-TR-010-02	NMD-TR-010-03	NMD-TR-010-04	NMD-TR-011-01	NMD-TR-011-02	NMD-TR-011-03	NMD-TR-011-04	NMD-TR-012-01	NMD-TR-012-02	NMD-TR-012-03
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	29.9	39	8.43	108	98	110	69.6	57.4	130	112
Barium	mg/kg	102	224	87	82	75	140	64.3	32.8	184	136
Beryllium	mg/kg	< 0.30	0.33	0.33	< 0.30	< 0.30	0.71	0.55	< 0.30	0.61	0.78
Cadmium	mg/kg	3.41	5.14	4.16	3.13	3.38	5.29	3.41	1.75	5.3	5.4
Chromium	mg/kg	1173	500	33	1950	2080	28.7	31.2	2550	1070	174
Lead	mg/kg	252	378	24.9	239	362	671	10.9	110	47.1	25.1
Mercury	mg/kg	0.3	< 0.05	< 0.05	0.067	< 0.05	0.1	< 0.05	0.133	0.133	< 0.05
Nickel	mg/kg	13	14.4	11.1	10.6	11.1	14.9	11.4	10.1	18.4	15.3
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	2.22	2.52	1.51	5.71	7.67	3.25	5.27	1.62	5.33	2.79
Zinc	mg/kg	480	267	41.2	210	571	68.1	30.1	510	400	98.5
Oil and Grease	percent	10.8	5.28	0.046	15.3	8.09	2.91	0.01	18.3	11.4	5.82

Table 5.8 (cont). Three Mile Ditch, Trench and Soil Borings Analytical Results - Metals and Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number		
METAL	UNITS	NMD-TR-013-01	NMD-TR-013-02	NMD-TR-013-02
Antimony	mg/kg	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	4.48	12.6	4.05
Barium	mg/kg	222	41.7	240
Beryllium	mg/kg	0.47	< 0.30	0.41
Cadmium	mg/kg	2.93	1.33	2.5
Chromium	mg/kg	47.4	547	11.1
Lead	mg/kg	22.8	14.5	3.08
Mercury	mg/kg	0.1	0.07	< 0.05
Nickel	mg/kg	11.1	4.1	9
Selenium	mg/kg	< 0.50	< 0.50	< 0.50
Silver	mg/kg	0.53	1.26	0.58
Zinc	mg/kg	40.9	50.5	20.8
Oil and Grease	percent	*	4.92	0.562

*insufficient sample

Table 5.9. Three Mile Ditch, Background Soil Borings Analytical Results - Metals and Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number					
METAL	UNITS	NMD-SB-002-01	NMD-SB-002-02	NMD-SB-007-01	NMD-SB-007-02	NMD-SB-010-01	NMD-SB-010-02
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	6.42	4.58	3.58	3.81	7.12	9.09
Barium	mg/kg	106	109	77.4	89.2	87.3	76
Beryllium	mg/kg	< 0.30	< 0.30	< 0.30	< 0.30	0.3	0.47
Cadmium	mg/kg	4.08	2.21	3.28	3.91	3.01	5.25
Chromium	mg/kg	17.5	10	12.6	13.2	11.3	15.3
Lead	mg/kg	19.7	8.01	9.54	19.7	8.79	10.3
Mercury	mg/kg	0.05	0.05	< 0.05	0.03	< 0.05	< 0.05
Nickel	mg/kg	12.4	5.45	9.24	10.8	9.31	13.5
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	2.02	3.53	1.79	2.22	< 0.50	1.47
Zinc	mg/kg	41.6	17.4	29.2	34.1	30.5	40.1
Oil and Grease	percent	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

Table 5.9 (cont). Three Mile Ditch, Background Soil Borings Analytical Results - Metals and Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number			
METAL	UNITS	NMD-SB-012-01N	NMD-SB-012-02N	NMD-SB-012-01S	NMD-SB-012-02S
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	4.41	1.03	83	70
Barium	mg/kg	270	132	241	59.8
Beryllium	mg/kg	0.83	< 0.30	0.68	0.44
Cadmium	mg/kg	4.4	1.4	3.81	3.42
Chromium	mg/kg	13.8	5.4	26.8	25
Lead	mg/kg	14.6	5.16	9.51	4.91
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	16.5	5.7	15.2	10.4
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	< 0.50	< 0.50	3.1	1.58
Zinc	mg/kg	35.7	15.9	34.4	26.5
Oil and Grease	percent	< 0.01	0.032	0.002	0.002

contains above background arsenic (NMD-TR-011-04, 69.6 mg/kg). All three visually contaminated Arno-Harkey complex (Ak) soil samples exceed background arsenic concentrations, ranging from 4.05 mg/kg to 12.6 mg/kg and averaging 7.04 mg/kg. There are no visually uncontaminated Ak soil samples.

Barium occurs above background in eight of 20 visually contaminated Pe soil samples, ranging from 110 mg/kg to 366 mg/kg and averaging 183 mg/kg. One visually uncontaminated Pe soil sample contains above background barium (NMD-TR-003-02, 135 mg/kg). The only visually uncontaminated Ri soil sample contains above background barium (NMD-TR-007-01, 148 mg/kg). One of the three visually uncontaminated Ri soil samples contains above background barium (NMD-TR-007-03, 116 mg/kg). Barium ranges from 46.1 mg/kg to 171 mg/kg and averages 88.4 mg/kg in the seven visually contaminated Pv soil samples. There are no visually uncontaminated Pv soil samples. Four of the nine visually contaminated An soil samples exceed background barium levels, ranging from 136 mg/kg to 224 mg/kg and averaging 171 mg/kg. Neither of the two visually uncontaminated soil samples exceeds background. Two of the three visually contaminated Ak soil samples exceed Ak soils barium background, NMD-TR-013-01, 03 (222 mg/kg, 240 mg/kg, respectively). There are no visually uncontaminated Ak soil samples.

Beryllium exceeds Pe soil background in 16 of 20 visually contaminated samples, ranging from 0.29 mg/kg to 0.81 mg/kg and averaging 0.66 mg/kg. Five of the six visually uncontaminated Pe soil samples exceed beryllium background, ranging from 0.03 mg/kg to 0.81 mg/kg and averaging 0.52 mg/kg. Three of the seven visually contaminated Pv soil samples exceed beryllium's CRDL, ranging from 0.39 mg/kg to 0.69 mg/kg and averaging 0.57 mg/kg. There are no visually uncontaminated PV soil samples. No background data are available for Pv soils. Beryllium in the only visually contaminated Ri soil sample is below its CRDL. One of the three visually uncontaminated Ri soil samples slightly exceeds background (NMD-TR-007-04, 0.6 mg/kg). Three of the nine visually contaminated An soil samples exceed beryllium background levels, ranging from 0.61 mg/kg to 0.78 mg/kg and averaging 0.70 mg/kg. One of the two visually uncontaminated An samples exceeds background (NMD-TR-011-04, 0.55 mg/kg). One of the visually contaminated Ak soil samples slightly exceeds background (NMD-TR-013-01, 0.47 mg/kg). There are no visually uncontaminated Ak soils.

Cadmium exceeds Pe soil background levels in 12 of the 20 visually contaminated Pe soil samples, ranging from 3.2 mg/kg to 7.7 mg/kg and averaging 5.4 mg/kg. Four of the six visually uncontaminated Pe soil samples exceed background, ranging from 4.1 mg/kg to 7.3 mg/kg and averaging 6.0 mg/kg. The single visually contaminated Ri soil sample does not exceed Ri soil cadmium background levels. One of the three visually uncontaminated Ri soil samples does exceed background (NMD-TR-007-03, 5.7 mg/kg). The seven visually contaminated Pv soil samples range from 1.75 mg/kg to 4.5 mg/kg and average 3.4 mg/kg. There are no background data for the Pv soils, nor are there visually uncontaminated samples. Four of the nine visually contaminated An soil samples exceed cadmium background levels, ranging from 5.14 mg/kg to 5.4 mg/kg and averaging 5.28 mg/kg. One of the two visually uncontaminated soil sample exceeds background (NMD-TR-010-04, 4.16 mg/kg). No Ak soil samples exceed background cadmium levels.

Chromium background levels are exceeded by 12 of the 20 visually contaminated Pe soil samples, with values ranging from 16.8 mg/kg to 3390 mg/kg and averaging 397 mg/kg. Three of the six visually uncontaminated samples slightly exceed background, ranging from 17.7 mg/kg to 19.4 mg/kg and averaging 18.6 mg/kg. The one visually contaminated Ri soil sample exceeds the chromium background level (NMD-TR-007-01, 800 mg/kg). One of the three visually uncontaminated Ri soil samples exceeds background (NMD-TR-007-03, 171 mg/kg). Chromium in seven visually contaminated Pv soil samples ranges from 6.6 mg/kg to 594 mg/kg and averages 61.59 mg/kg. All nine visually contaminated and the two visually uncontaminated An soil samples exceed chromium background levels. Visually contaminated samples range from 28.7 mg/kg to 2,550 mg/kg and average 1,194 mg/kg. The two visually uncontaminated samples have chromium values of 33 mg/kg (NMD-TR-010-04) and 31.2 mg/kg (011-04). All three of the visually contaminated Ak soil samples contain chromium in excess of background, NMD-TR-013-01 (47.4 mg/kg), 013-02 (547 mg/kg), and 013-03 (11.1 mg/kg). There are no visually uncontaminated Ak soil samples.

Eleven of the 20 visually contaminated Pe soil samples exceed lead background levels, ranging from 17 mg/kg to 2,175 mg/kg and averaging 418 mg/kg. Three of the six visually uncontaminated Pe soil samples exceed background, NMD-TR-003-02 (14.7 mg/kg), 004-04 (123 mg/kg), and 006-01 (340 mg/kg). The single visually contaminated Ri soil sample exceeds the Ri soil type lead background value (NMD-TR-007-01, 275 mg/kg). Two of the three visually uncontaminated Ri soils also exceed background, NMD-TR-007-02 (467 mg/kg) and 007-03 (863 mg/kg). The seven visually contaminated Pv soil samples range from 2.92 mg/kg to 2,196 mg/kg and average 363.2 mg/kg. All 11 An soil samples exceed the lead background level. Nine visually contaminated An soils range from 25.1 mg/kg to 671 mg/kg and average 254.5 mg/kg. Both of the visually uncontaminated samples exceed lead background, NMD-TR-010-04 (24.9 mg/kg) and 011-04 (10.9 mg/kg). Two of the three visually contaminated Ak soil samples exceed background, NMD-TR-013-01 (22.8 mg/kg) and 013-02 (14.5 mg/kg).

Mercury values in 14 of the 20 visually contaminated Pe soil samples exceed background, ranging from 0.05 mg/kg to 1.0 mg/kg and averaging 0.4 mg/kg. One of the six visually uncontaminated samples exceeds background, NMD-TR-006-01 (0.08 mg/kg). The one visually contaminated Ri soil sample exceeds background, NMD-TR-007-01 (1.0 mg/kg). Two of the three visually uncontaminated Ri soils are also above mercury background levels, NMD-TR-007-02 (0.07 mg/kg) and 007-03 (0.27 mg/kg). Mercury occurs above CRDL in two of the seven Pv soil samples, NMD-TR-008-01 (0.67 mg/kg) and 009-01 (0.53 mg/kg). Six of the nine visually contaminated An soil samples contain mercury above background concentrations, ranging from 0.07 mg/kg to 0.3 mg/kg and averaging 0.15 mg/kg. There is no detectable mercury in the two visually uncontaminated An soil samples. Two of the three visually contaminated Ak soil samples contain mercury above background, NMD-TR-013-01 (0.1 mg/kg) and 013-02 (0.07 mg/kg).

Nickel occurs above background in 14 of 20 Pe soil samples, ranging from 10.1 mg/kg to 25.8 mg/kg and averaging 14.39 mg/kg. Three of the six visually uncontaminated Pe soil samples contain nickel slightly above background, ranging from 11.5 mg/kg to 15.2 mg/kg and averaging 12.8 mg/kg. The nickel concentration of the one visually contaminated Ri soil sample only slightly exceeds background (NMD-TR-007-01, 13 mg/kg). Two of the three visually uncontaminated Ri soils slightly exceed background, NMD-TR-007-03 (13.2 mg/kg) and 007-04 (12.7 mg/kg). Visually contaminated Pv soil samples range from 4.08 mg/kg to 19.4 mg/kg and average 10.2 mg/kg. Five of nine visually contaminated An soil samples exceed the nickel background concentration level, ranging from 13 mg/kg to 18.4 mg/kg and averaging 15.2 mg/kg. The two visually uncontaminated soil samples do not exceed the background level. None of the three visually contaminated Ak soil samples exceed background.

Only one sample of the entire Three-Mile Ditch soil sample set exceeds the selenium CRDL. The Pe soil sample NMD-TR-000-01 contains 1.39 mg/kg selenium.

Silver occurs above background in only four of the 20 visually contaminated Pe soil samples, ranging from 2.79 mg/kg to 4.72 mg/kg and averaging 3.45 mg/kg. None of the visually uncontaminated Pe soil samples contain silver above background levels. The only visually contaminated Ri soil sample contains silver in excess of background, NMD-TR-007-01 (3.16 mg/kg). One of the three visually uncontaminated samples exceeds background, NMD-TR-007-03 (2.96 mg/kg). Silver ranges from 0.83 mg/kg to 2.15 mg/kg in five visually contaminated Pv soil samples and averages 1.45 mg/kg. Eight of the nine An soil samples exceed silver background, ranging from 2.22 mg/kg to 8.11 mg/kg and averaging 5.36 mg/kg. One of the two visually uncontaminated An soils exceeds background, NMD-TR-011-04 (5.27 mg/kg). All three of the Ak soil samples exceed the silver background level, ranging from 0.53 mg/kg to 1.26 mg/kg and averaging 0.79 mg/kg.

Zinc exceeds the Pe soil background level in 11 of the 20 visually contaminated soil samples, ranging from 31.2 mg/kg to 352 mg/kg and averaging 117.5 mg/kg. Three of the six visually uncontaminated Pe soil samples exceed zinc background, ranging from 33.7 mg/kg to 45.6 mg/kg and averaging 38.3 mg/kg. The only visually uncontaminated Ri soil sample greatly exceeds zinc background, NMD-TR-007-1 (262 mg/kg). One of the three visually uncontaminated Ri soil samples also greatly exceeds background, NMD-TR-007-03 (336 mg/kg). Seven Pv soil samples range from 15 mg/kg to 683 mg/kg and average 129.7 mg/kg zinc. All nine visually contaminated An soil samples exceed the An zinc background ranging from 68.1 mg/kg to 571 mg/kg and averaging 317.2 mg/kg. One of the two visually uncontaminated An soil samples slightly exceeds background, NMD-TR-010-04 (41.2 mg/kg). Two of the three visually contaminated Ak soil samples slightly exceed background NMD-TR-013-01 (40.9 mg/kg) and 013-02 (50.5 mg/kg).

Oil and grease occur above background in all 20 visually contaminated Pe soil samples, ranging from 0.014 % to 16.7% and averaging 2.15%. Four of the six visually uncontaminated Pe soil samples contain oil and grease in excess of background, ranging from 0.023% to 1.5% and averaging 0.4%. The one visually contaminated Ri soil sample (NMD-TR-007-01, 4.43%) exceeds the background oil and grease level. One of the visually uncontaminated Ri soils, NMD-TR-007-03, exceeds background and contains 0.056% oil and grease. Six of the seven visually contaminated Pv soil samples contain detectable oil and grease, ranging from 0.02% to 12.2% and averaging 5.1%. All of the nine visually contaminated An soil samples contain oil and grease in excess of background, ranging from 2.91% to 18.3% and averaging 9.28 mg/kg. Both of the visually uncontaminated An soil samples contain low levels of oil and grease, NMD-TR-010-04 (.046%) and 011-04 (0.01%). Two of the three visually contaminated Ak soil samples contain detectable oil and grease in excess of background levels, NMD-TR-013-02 (4.92%) and 013-03 (0.56%).

5.3.1.4 Soils Analytical Results - Statistical Analyses

A two-way ANOVA was performed to test for main effects of sampling location and soil type on concentration of metals in soils. Effects of depth could not be tested quantitatively because background sampling depths were not paired with trench sampling depths, and therefore, they could not be compared. The independent variables were sampling location (trench sites vs. background sites) and soil type (Pe, Ri, Pv, An, Ak). The dependent variable was average concentration of a given metal in each trench and background soil boring.

Average metal concentration across all depths (each trench site was sampled at three or four depths, and each background soil boring was sampled at two depths) was computed for each trench and background site, and entered into an SPSSX statistical package for ANOVA. Values that were below reported limit were included as zeros when averages were computed in order to get a reasonable approximation of the average of all depths sampled.

Results of the ANOVA show that there was a significant main effect of sampling location on concentrations of zinc ($P = 0.030$) and oil and grease ($P = 0.036$), and a significant main effect of soil type on silver ($P = 0.011$), arsenic ($P = 0.001$), and zinc ($P = 0.026$) (Table 5.10). There were no significant interactions between sampling location and soil type on metals concentrations.

Because field observations indicate that trench soils are notably contaminated with product and background soils are not (see sample descriptions), the ANOVA results are misleading. The ANOVA did not produce significant differences in metals concentrations between trench and background soil samples because of three factors. First, the data are highly variable within trenches because samples were selectively taken in visibly contaminated material and in visibly uncontaminated material. Second, because some trenches are more contaminated than others, the data are highly variable between trenches, even within a single soil type. Third, in the ANOVA, the magnitude of local contamination was diluted because data from visibly contaminated samples were lumped with data from visibly uncontaminated samples.

To statistically evaluate differences in metals concentrations between contaminated soils and uncontaminated soils, the data were separated into three groups based on field notes describing whether the sample was visibly contaminated (VC), or beneath the visibly contaminated zone (BVC) sample in the trench, or a background (BKGR) soil boring. T-tests were performed to detect for significant differences in metals concentrations between VC and BVC trench samples, between VC and BKGR soil samples, and between BVC and BKGR samples.

Statistics were computed for samples in soil types Pe and An only because these were the only two types with enough replication to allow statistical analysis. Within each soil type (Pe and An), average concentrations of each metal in each trench were calculated for VC and BVC, and average BKGR concentrations were computed for each soil boring (Table 5.11). The variance of these averages was

Table 5.10 Three-Mile Ditch Soils Analytical Results - Metals - Statistical Results - Analysis of Variance.

P-VALUES FOR TWO-WAY ANOVA, METALS CONCENTRATIONS VS. SAMPLING LOCATION AND SOIL TYPE. VALUES LESS THAN 0.05 INDICATE SIGNIFICANT DIFFERENCES BETWEEN GROUPS.

Metal	Hg	Br	Ag	Cd	Ni	As	Pb	Zn	Ba	Cr	OAG
Effects of:											
Site	0.200	0.417	0.402	0.693	0.744	0.155	0.265	0.030	0.835	0.072	0.036
Soil Type	0.774	0.572	0.011	0.706	0.746	0.001	0.794	0.026	0.058	0.086	0.062
Site x Soil Type	0.858	0.342	0.090	0.882	0.769	0.567	0.908	0.242	0.869	0.453	0.311

Table 5.11 Three-Mile Ditch, Soils Analytical Results, Metals, Statistical Results, t-test.

	Hg	Be	Ag	Cd	Ni	As	OAG	Pb	Zn	Ba	Cr
					VC X BVC						
SOIL TYPE Pe											
Mean VC	.401	.641	1.803	4.597	12.63	13.753	2.079	247.893	78.298	118.117	221.905
n VC	4	6	5	8	8	8	8	7	8	8	7
S VC	.065	.01	.346	2.836	14.837	104.214	4.214	66726.87	5629.282	1003.021	16429.0
Mean BVC	.04	.535	1.727	4.716	9.264	6.248	.212	28.615	24.92	90.89	14.463
N BVC	2	4	3	5	5	5	4	5	5	5	5
S BVC	.0002	.034	.388	5.372	11.326	11.646	.141	2788.629	147.532	4322.235	29.652
t	.536	1.048	.150	-.098	1.479	1.462	1.647	1.708	1.452	.920	3.302
df	4	8	6	11	11	11	10	10	11	11	10
					VC X BVC						
SOIL TYPE An											
Mean VC			4.358	4.047	13.029	86.189	9.279	254.467	317.178	116.367	1193.966
n VC			3	3	3	3	3	3	3	3	3
S VC			1.323	.012	1.853	812.349	5.510	33429.89	878.056	281.703	41494.88
Mean BVC			3.39	3.785	11.25	39.015	.028	17.9	35.65	75.65	32.1
N BVC			2	2	2	2	2	2	2	2	2
S BVC			7.069	.281	.045	1870.884	.001	98.0	61.605	257.645	1.62
t			.432	.642	1.421	1.388	4.317	1.416	10.174	2.095	6.248
df			3	3	3	3	3	3	3	3	3
					VC X BKGR						
SOIL TYPE An											
Mean VC				4.047	13.029	86.189		254.467	317.178	116.367	1193.966
n VC				3	3	3		3	3	3	3
S VC				.012	1.853	812.349		33429.89	878.056	281.703	41494.88
Mean BKGR				3.873	12.103	42.303		8.378	32.875	116.025	19.6
N BKGR				2	2	2		2	2	2	2
S BKGR				.133	.973	2338.94		2.726	11.761	2363.281	79.38
t				.767	.642	.987		1.474	10.464	.009	6.311
df				3	3	3		3	3	3	3

Table 5.11 Continued.

	BVC X BKGR										
	Hg	Be	Ag	Cd	Ni	As	OAG	Pb	Zn	Ba	Cr
<u>SOIL TYPE An</u>											
Mean BVC		.44		3.785	11.25	39.015		17.9	35.65	75.65	32.1
n BVC		2		2	2	2		2	2	2	2
S BVC		.024		.281	.045	1870.884		98.0	61.605	257.645	1.62
Mean BKGR		.473		3.873	12.103	42.303		8.378	32.875	116.025	19.6
N BKGR		2		2	2	2		2	2	2	2
S BKGR		.015		.133	.973	2338.938		2.726	11.761	2363.281	79.38
t		-.164		-.136	-.845	-.057		.949	.324	-.789	1.389
df		2		2	2	2		2	2	2	2

n = Number of sample averages used in t-test.

s = Variance of sample averages.

calculated, and these means and variances were used to compute t statistics (Table 5.12). Alpha was 0.05 for all analyses.

Results of the t-test give a much better indication of the level of contamination in trench soils (Table 5.12). In the Pe soil type, chromium levels are significantly higher in VC trench soils (221.905 mg/kg) than in BVC trench soils (14.463 mg/kg) (Figure 5.12a). Because there was insufficient replication in BKGR sampling, comparisons between VC and BKGR, and BVC and BKGR could not be made.

In the An soil type, chromium levels were significantly higher in VC samples (1,193.966 mg/kg) than in BVC samples (32.1 mg/kg), and significantly higher in VC samples than in BKGR samples (79.38 mg/kg) (Figure 5.12d). There were no significant differences between chromium or other metals values in BVC and BKGR samples.

Because some trenches are more contaminated than others, there is a high degree of variability in the data, which prevents quantitative description of conditions in the Three-Mile ditch. Following is a qualitative comparison between VC, BVC, and BKGR metals data for selected metals within each soil type. Average VC, BVC, and BKGR were computed for each trench and soil boring and are shown in Figures 5.23 through 5.27.

Chromium values were notably higher in VC trench samples than in BVC or BKGR samples for all soils (Figure 5.23). Differences between VC and BVC in soils Pe (trenches 000, 001, 002, 003, 004, 005, 006, S1 combined) and An (trenches 010, 011, 012, background 010) were shown to be statistically significant, as were differences in VC and BKGR in the An soil type (see above). Visually contaminated chromium concentrations were lowest in trench 008 (soil type Pv). Chromium concentrations were highest in trench 011 (soil type An). Background values were similar across all soil types sampled.

Table 5.12. Three-Mile Ditch Soils Analytical Results - Statistical Results
Average Metals Concentrations in Visibly Contaminated (VC),
Below Visibly Contaminated (BVC), and Background (BKGR) Soil Samples

Trench/
Soil Boring ID

Soil Type Pe:

	Location	Hg mg/kg	Be mg/kg	Ag mg/kg	Cd mg/kg	Ni mg/kg	As mg/kg	O & G percent	Pb mg/kg	Zn mg/kg	Ba mg/kg	Cr mg/kg
000	VC	0.413		2.433	1.570	5.710	9.943	3.183	725.661	21.120	171.800	1135.467
001	VC	0.073			4.607	11.743	4.323	0.082	13.500	30.100	86.700	14.467
002	VC		0.550	1.365	3.950	10.150	3.195	0.252	7.615	30.900	101.300	20.900
003	VC		0.760	1.090	5.070	14.700	32.700	0.379	67.700	46.800	80.700	56.300
004	VC	0.419	0.643		5.133	12.700	10.997	0.517	403.367	90.400	128.467	134.700
005	VC		0.500	1.807	4.500	17.067	24.800	3.688	294.410	214.667	139.000	114.800
006	VC	0.700	0.710	2.260	7.700	17.500	15.200	2.950	223.000	171.000	140.000	76.700
S1	VC		0.680		4.247	11.470	8.867	5.583		21.400	96.967	
001	BVC	0.050	0.460		3.100	7.000	2.790	0.016	3.980	16.900	21.000	19.200
002	BVC		0.410	1.450	2.800	7.500	3.810	0.036	4.050	21.300	82.200	13.500
003	BVC		0.460	1.290	3.180	8.380	8.470	0.775	8.745	25.100	102.250	14.165
004	BVC		0.810		7.300	15.200	5.170		123.000	45.600	195.000	19.400
006	BVC	0.030		2.440	7.200	8.240	11.000	0.023	3.300	15.700	54.000	6.050
002	BKGR	0.050		2.775	3.145	8.925	5.500		13.855	29.500	107.500	13.750

Soil Type Ri:

	Location	Hg mg/kg	Be mg/kg	Ag mg/kg	Cd mg/kg	Ni mg/kg	As mg/kg	O & G percent	Pb mg/kg	Zn mg/kg	Ba mg/kg	Cr mg/kg
007	VC	1.000	< 0.30	3.160	3.570	13.000	19.600	4.430	275.000	262.000	148.000	800.000
007	BVC	0.150			4.900	12.950	13.995		436.550	182.750	99.000	91.300
007	BKGR			2.005	3.595	10.020	3.695		14.620	31.650	83.300	12.900

Soil Type Pv:

	Location	Hg mg/kg	Be mg/kg	Ag mg/kg	Cd mg/kg	Ni mg/kg	As mg/kg	O & G percent	Pb mg/kg	Zn mg/kg	Ba mg/kg	Cr mg/kg
008	VC		0.567	1.247	4.200	11.467	19.057	2.557	739.377	53.767	92.767	36.233
009	VC				2.785	9.175	10.530		81.138	186.675	85.150	155.600

Soil Type An:

	Location	Hg mg/kg	Be mg/kg	Ag mg/kg	Cd mg/kg	Ni mg/kg	As mg/kg	O & G percent	Pb mg/kg	Zn mg/kg	Ba mg/kg	Cr mg/kg
010	VC			4.283	4.057	12.287	53.433	7.230	278.667	332.333	132.500	964.333
011	VC			5.543	3.933	12.200	105.333	8.767	424.000	283.033	99.000	1352.900
012	VC			3.247	4.150	14.600	99.800	11.840	60.733	336.167	117.600	1264.667
010	BVC		0.330	1.510	4.160	11.100	8.430	0.046	24.900	41.200	87.000	33.000
011	BVC		0.550	5.270	3.410	11.400	69.600	0.010	10.900	30.100	64.300	31.200
010	BKGR		0.385		4.130	11.405	8.105		9.545	35.300	81.650	13.300
012 S	BKGR		0.560	2.340	3.615	12.800	76.500	0.002	7.210	30.450	150.400	25.900

Soil Type Ak:

	Location	Hg mg/kg	Be mg/kg	Ag mg/kg	Cd mg/kg	Ni mg/kg	As mg/kg	O & G percent	Pb mg/kg	Zn mg/kg	Ba mg/kg	Cr mg/kg
013	VC			0.790	2.253	8.067	7.043	1.827	13.460	37.400	167.900	201.833
013	BKGR				2.900	11.100	2.720	0.016	9.880	25.800	201.000	9.600

Figure 5.23. Three-Mile Ditch Soils Analytical Results - Metals
Comparison of Visibly Contaminated (VC), Below Visibly Contaminated (BVC), and
Background (BKGR) Metals Concentrations - Chromium
RFI Phase I Report, Navajo Refining Company, October, 1990

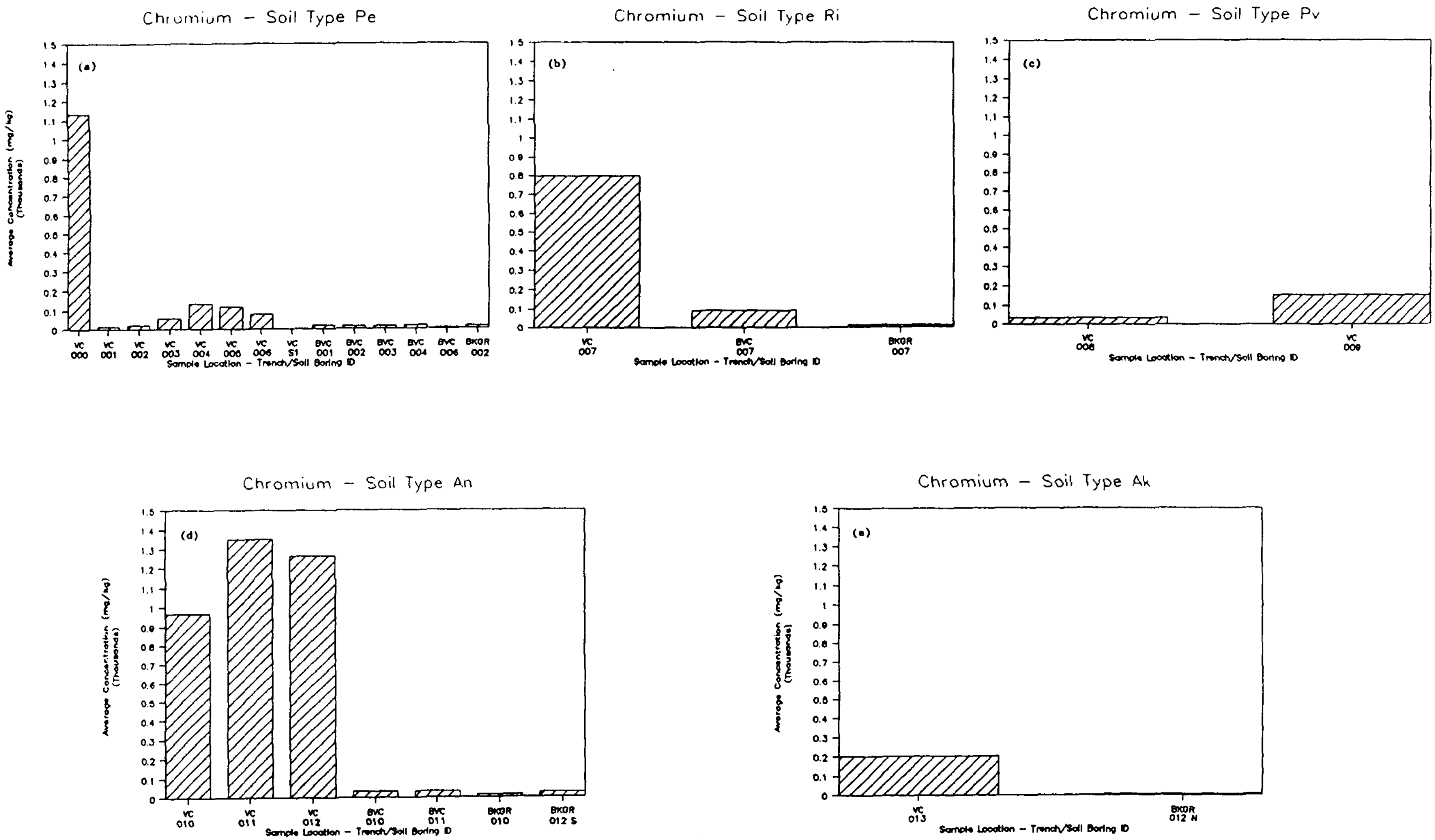


Figure 5.24. Three-Mile Ditch Soils Analytical Results - Metals
Comparison of Visibly Contaminated (VC), Below Visibly Contaminated (BVC), and
Background (BKGR) Metals Concentrations - Lead
RFI Phase I Report, Navajo Refining Company, October, 1990

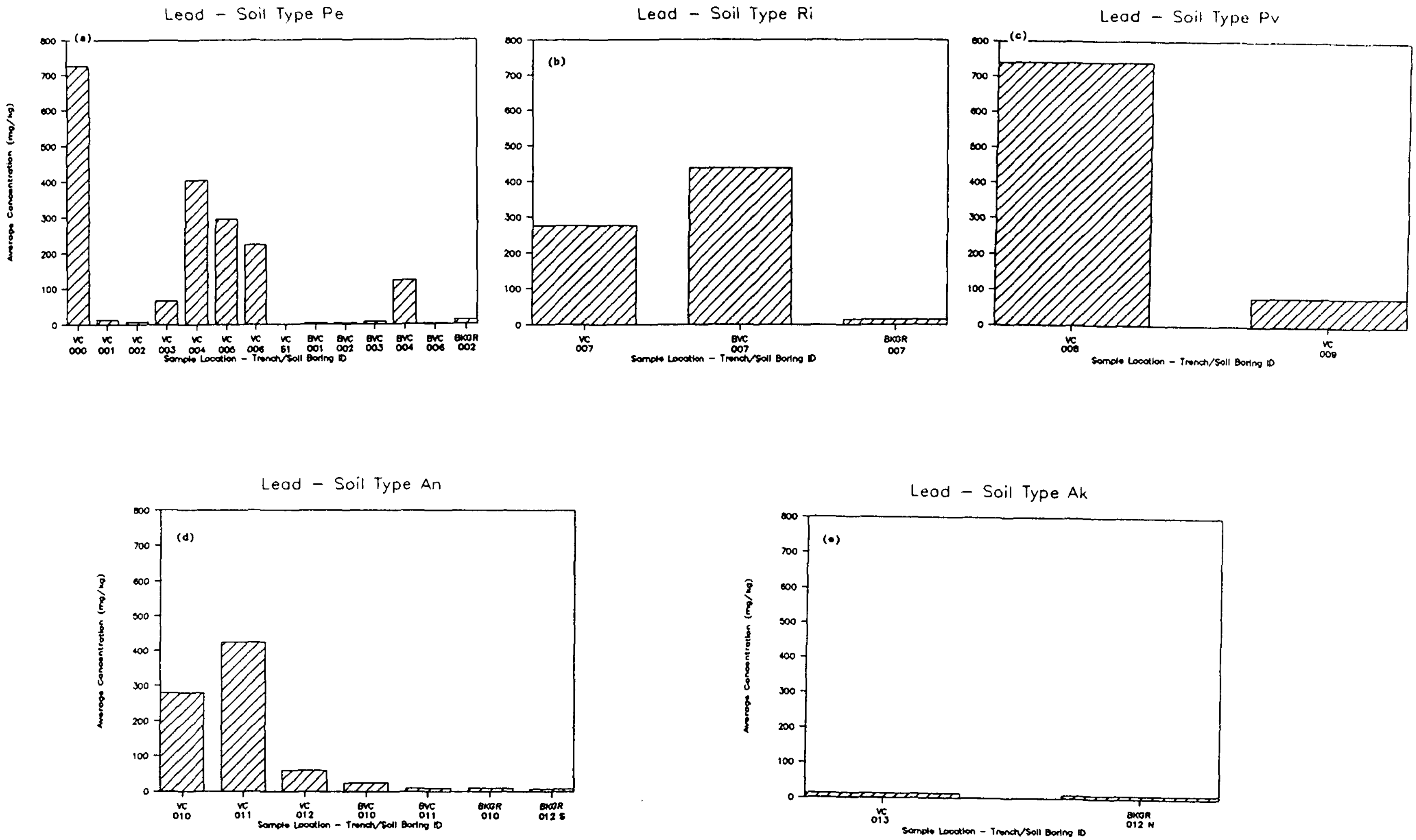


Figure 5.25. Three-Mile Ditch Soils Analytical Results - Metals
Comparison of Visibly Contaminated (VC), Below Visibly Contaminated (BVC), and
Background (BKGR) Metals Concentrations - Arsenic
RFI Phase I Report, Navajo Refining Company, October, 1990

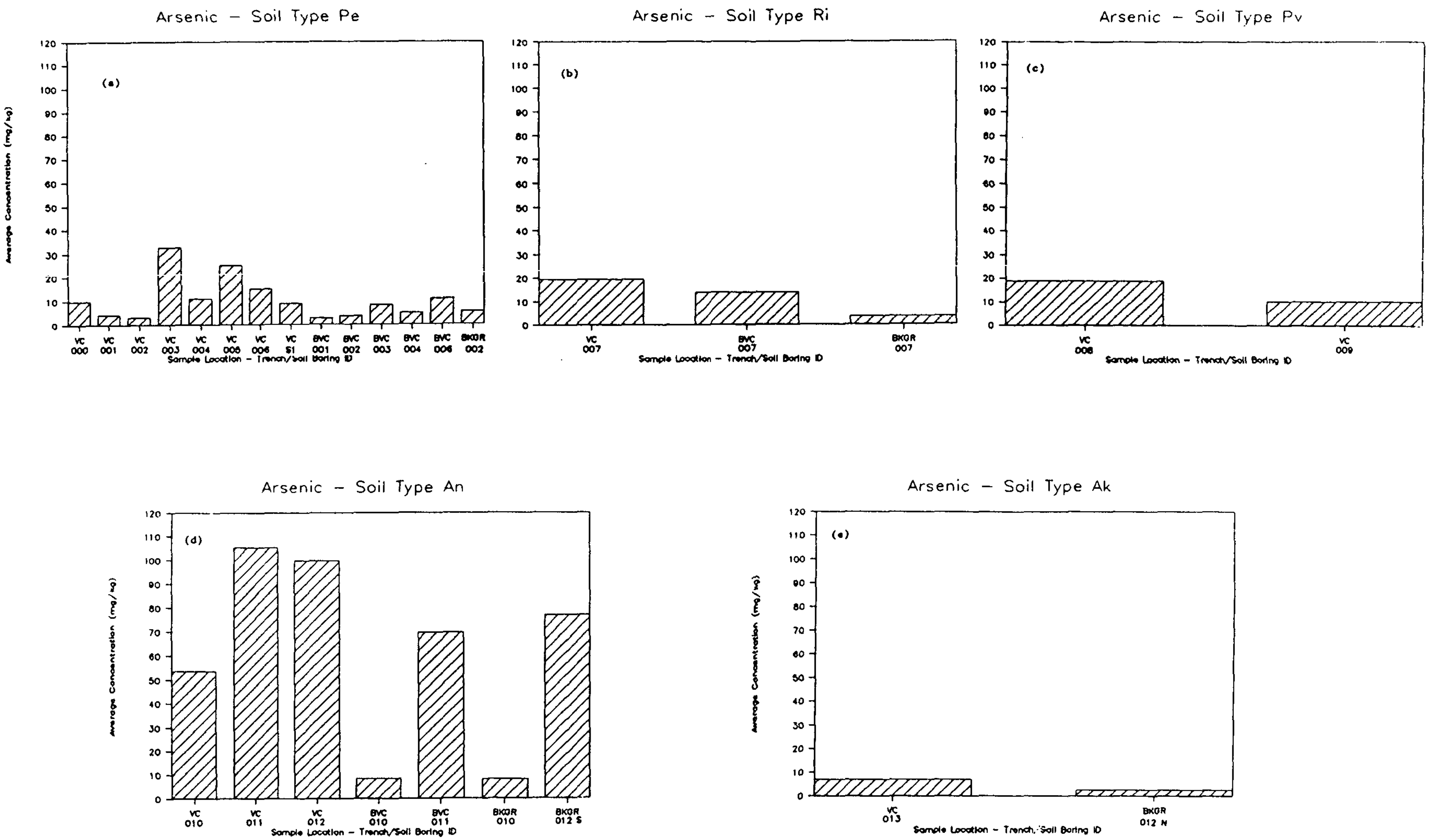


Figure 5.26. Three-Mile Ditch Soils Analytical Results - Metals
Comparison of Visibly Contaminated (VC), Below Visibly Contaminated (BVC), and
Background (BKGR) Metals Concentrations - Zinc
RFI Phase I Report, Navajo Refining Company, October, 1990

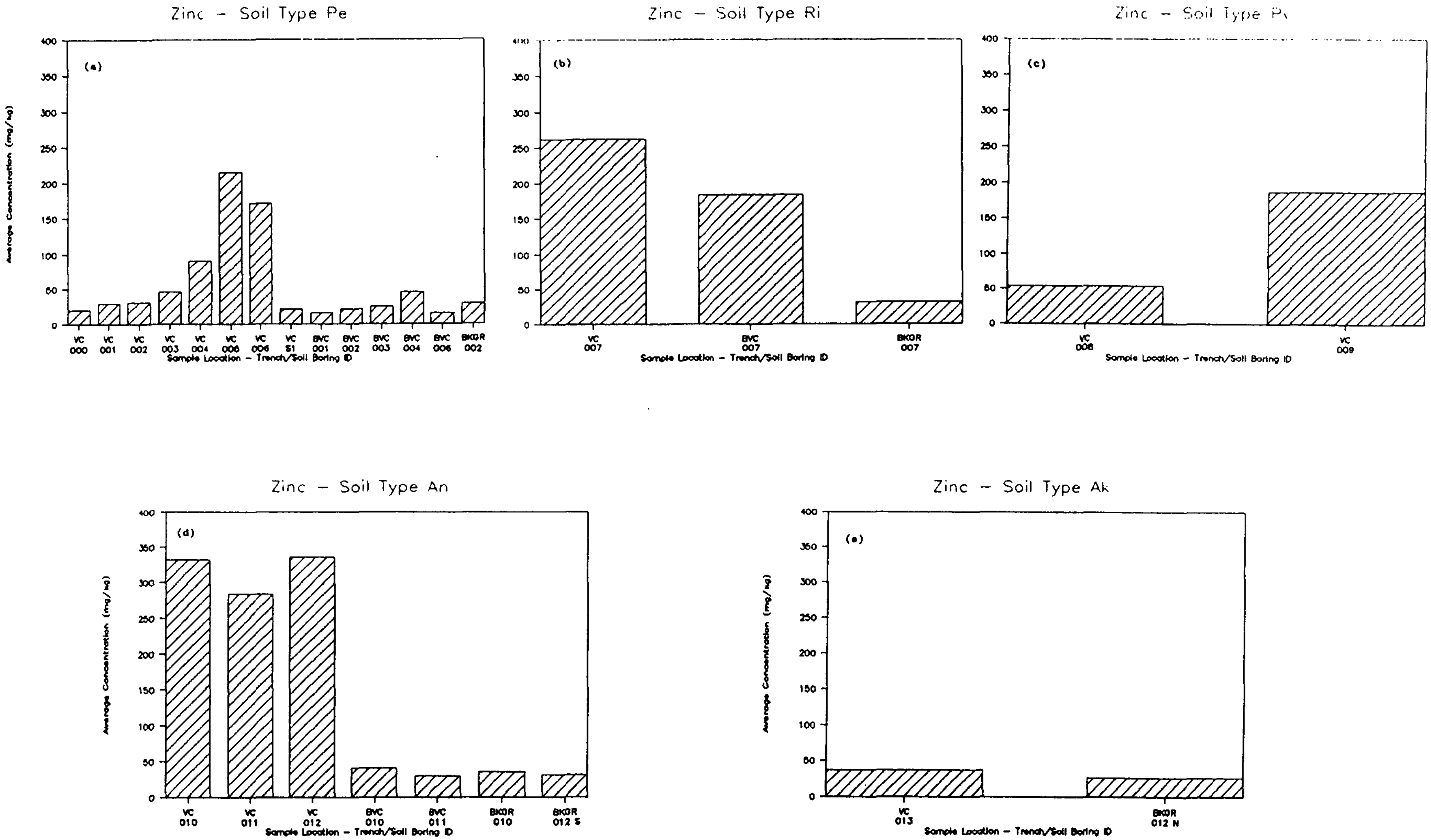
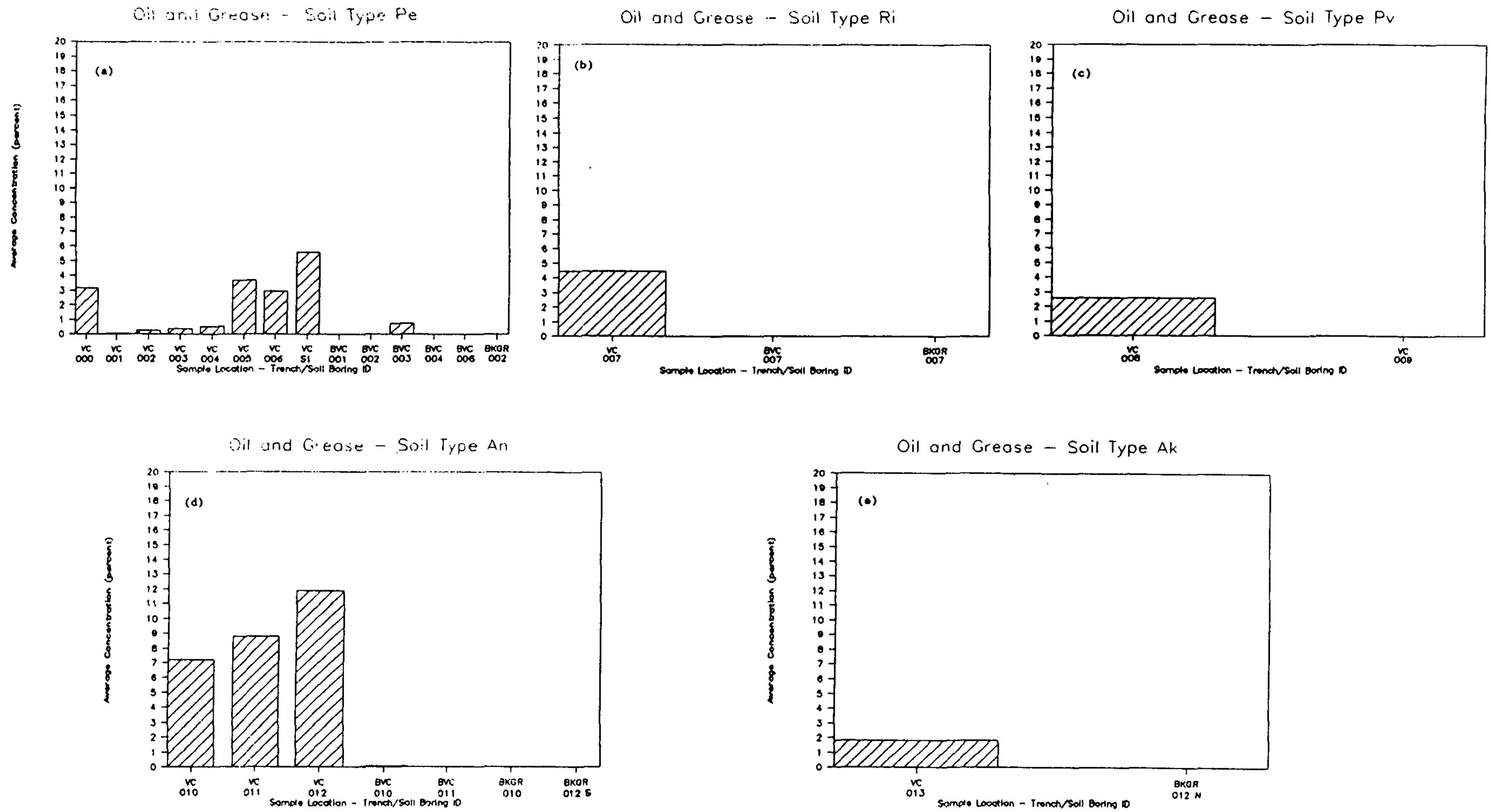


Figure 5.27. Three-Mile Ditch Soils Analytical Results - Metals
Comparison of Visibly Contaminated (VC), Below Visibly Contaminated (BVC), and
Background (BKGR) Metals Concentrations - Oil and Grease
RFI Phase I Report, Navajo Refining Company, October, 1990



Note: Zeros denote analyses that were below reported limit or for which there was insufficient sample to analyze

Lead levels were higher in VC than BVC or BKGR samples in soils Pe, Pv, and An (Figure 5.24). Trenches 000, 004, and 008 had the highest VC lead concentrations. VC lead concentrations were lowest in trenches 001, 002, and 013 and were similar to BKGR levels. In trench 007 (soil Ri) lead values were higher in BVC samples than in VC samples. Background values were similar across all soils sampled.

Arsenic concentrations were generally higher in VC samples, but not markedly so (Figure 5.25). Trenches 010, 011, 012 (soil type An) had the highest levels of arsenic in the VC portion of the trench, but also had high BVC and BKGR arsenic levels. There were high levels of arsenic in the BVC portion of trench 011 and in BKGR boring 010. Trenches 000, 001, 002, and 013 had low levels of arsenic in VC zones. Except for boring 010, all background analyses are comparable.

Zinc is included in this discussion because there were statistically significant differences in zinc concentrations in VC and BVC samples in soils Pe and An, and between VC and BKGR samples in soil type An (Figures 5.26a, 5.26d). Samples from the VC portion of trenches 010, 011, and 012 had the highest zinc concentrations. Trenches 004, 005, and 006 in soil Pe, 007 in soil Ri, and 008 in Pv also had relatively high zinc concentrations. Background levels were similar across all sites.

Oil and grease are generally confined to VC portions of trenches, are present in BVC zones in two cases, and are absent from background soils (Figure 5.27). There was a significant difference in oil and grease concentrations in VC and BVC samples from soil An (Figure 5.27d). Oil and grease levels were highest in trenches S1, 010, 011, and 012, and lowest in trenches 001, 002, 003, and 004.

These results show that, in general, potential for further soil contamination due to product migration is limited. In soil Pe only lead and oil and grease are notably higher in BVC than in BKGR samples. Soil type Ri (trench 007) had markedly high BVC chromium, lead, arsenic, and zinc levels compared with BKGR levels and may have a greater potential for product migration than other soil types.

There may be a high potential for arsenic migration in soil type An because BVC arsenic levels in trench 011 were high. However, arsenic levels in BKGR boring 010 were even higher. Results of this study cannot determine whether high levels in the BVC zone of trench 011 were due to migration or to natural variability in arsenic levels in this soil type. No other elements show potential for migration in soil type An.

5.3.2 Background Soil Borings

To statistically evaluate the metals results, it was necessary to obtain background samples from each of the five soil types traversed by the ditch (Plates 2, 3, 4). These background locations were chosen to offset five of the trench locations, one for each of the soil types. In most cases, locations were staked 100-200 ft from the trench, on a line perpendicular to the trend of Three-Mile Ditch. The background soil boring was omitted for Reeves loam due to a plotting error. Lithologic logs for the background borings are included in Figures 5.18-5.22.

5.3.2.1 Sampling Procedures

The background soil borings were made using a stainless steel bucket auger. Samples were taken from the 1-1.5 ft interval and the 5-5.5 ft interval to statistically compare with the trench samples. Samples were analyzed for metals, and oil and grease.

WELL LOGGING FORM

LOCATION: Three-Mile Ditch - Soil Background
BORING / WELL: NMD-SB-002
START DRILLING: Sept. 14, 1990
COMPLETED: Sept. 14, 1990
TOTAL DEPTH (BLS):
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE: 4"
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING __X__
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	1.0-1.5 feet BLS	1.0-1.5 feet BLS	Well-sorted clayey silt, low plasticity, moderate cohesiveness. 7.5 YR 5/3.	
	4.0 feet BLS		Well-sorted silty clay, moderate plasticity, cohesive. 7.5 YR 4/4.	
	5.0-5.5 feet BLS	5.0-5.5 feet BLS	Silty clay, moderate plastic, cohesive, mottled. 5 YR 8/1: 5 YR 7/2.	

Figure 5.18 Three-Mile Ditch/Eagle Creek, Background Soil Boring Log NMD-SB-002 , RFI Phase I Report, Navajo Refining Company, October 1990

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Trench 007 - Soil Background
BORING / WELL: NMD-SB-007
START DRILLING: Sept. 14, 1990
COMPLETED: Sept. 14, 1990
TOTAL DEPTH (BLS):
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE: 4"
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER X OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS X SPLT SPN ____ SHELBY ____ CORING ____
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	1.5-2.0 feet BLS	1.5-2.0 feet BLS	Well-sorted sandy silt, no plasticity or cohesion with minor caliche. 7.5 YR 4/4.	
	4.5-5.5 feet BLS	5.0-5.5 feet BLS	Silty clay, moderate plasticity, cohesive with moderate caliche on vertical fracture. 7.5 YR 4/3.	

Figure 5.19 Three-Mile Ditch/Eagle Creek, Background Soil Boring Log NMD-SB-007, RFI Phase I Report, Navajo Refining Company, October 1990

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Trench 010 - Soil Background

BORING / WELL:	NMD-SB-010	SCREEN SIZE-AMOUNT:	
START DRILLING:	Sept. 13, 1990	METHOD-DRLG: ROTARY	
COMPLETED:	Sept. 13, 1990	AUGER	X
TOTAL DEPTH (BLS):		OTHER	
CASING DEPTH (BLS):		DRILLING FLUID:	
CASING SIZE:			
HOLE SIZE:	4"	METHOD-SPLG: CUTTINGS	X
DRILLED BY:		SPLT SPN	
DRILLER'S LICENSE:		SHELBY	
DISTRICT:		CORING	
PERMIT #:		CORED INTERVAL:	
ELEVATION (TOC):			

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	1.0-1.5 feet BLS	1.5 feet BLS	Reddish-brown sandy silt, low moisture with gypsum.	
	5.0-5.5 feet BLS	5.0-5.5 feet BLS	Reddish-brown sandy silt with clay.	

Figure 5.20 Three-Mile Ditch/Eagle Creek, Background Soil Boring Log NMD-SB-010, RFI Phase I Report, Navajo Refining Company, October 1990

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Trench 012 - Soil Background
BORING / WELL: NMD-SB-012N
START DRILLING: Sept. 15, 1990
COMPLETED: Sept. 15, 1990
TOTAL DEPTH (BLS):
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE: 4"
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS __X__ SPLT SPN ____ SHELBY ____ CORING ____
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0.25 feet BLS		Silty clay, very low moisture, no cohesiveness.	
	0.25-4.0 feet BLS	1.0-1.5 feet BLS	Silty clay, moderate plasticity, cohesive with minor caliche. 7.5 YR 3/3.	
	4.0-4.5 feet BLS		Very fine grained silty sand, well-sorted, moderate moisture, no plasticity, moderate cohesion. 5 YR 4/4.	
	4.5-6.0 feet BLS	5.5-6.0 feet BLS	Very fine grained silty sand, well-sorted, saturated, no plasticity, moderate cohesion. 5 YR 4/4.	

Figure 5.21 Three-Mile Ditch/Eagle Creek, Background Soil Boring Log NMD-SB-012N, RFI Phase I Report, Navajo Refining Company, October 1990

WELL LOGGING FORM

LOCATION: Three-Mile Ditch Trench 012 - Soil Background
BORING / WELL: NMD-SB-012S
START DRILLING: Sept. 13, 1990
COMPLETED: Sept. 13, 1990
TOTAL DEPTH (BLS):
CASING DEPTH (BLS):
CASING SIZE:
HOLE SIZE: 4"
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER X OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS X SPLT SPN ____ SHELBY ____ CORING ____
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	1.5-2.0 feet BLS	1.5-2.0 feet BLS	Well-sorted medium to light brown clay silty, very low moisture, no plasticity with minor roots.	
	5.0-5.5 feet BLS	5.0-5.5 feet BLS	Well-sorted medium to light brown sandy silt, very low moisture, no plasticity with minor caliche, roots.	

Figure 5.22 Three-Mile Ditch/Eagle Creek, Background Soil Boring Log NMD-SB-012S, RFI Phase I Report, Navajo Refining Company, October 1990

5.3.2.2 Soils Analytical Results

Metals

Metals analytical data for soil samples from Three-Mile Ditch background soil borings are listed in Table 5.9. All metals (plus oil and grease) except antimony and selenium occur above their respective CRDLs in at least one of the 10 listed background soil boring samples. The 10 background soil boring samples represent four soil types. The range and mean of each detected metal is reported below for each sample and soil type.

Arsenic is detected in all background samples and soil types (Table 5.11). The Pima silt loam series (Pe soil type) ranges from 4.58 mg/kg to 6.42 mg/kg and averages 5.5 mg/kg (samples NMD-SB-002-01, 02); Reeves loam series (Ri soil type) ranges from 3.58 mg/kg to 3.81 mg/kg and averages 3.70 mg/kg (samples NMD-SB-007-01,02); Arno silty clay loam series (An soil type) ranges from 7.12 mg/kg and 9.09 mg/kg (NMD-SB-010-01, 02) to 70 mg/kg and 83 mg/kg (NMD-SB-012-015, 025) and averages 42.3 mg/kg; Arno Harkey soil complex (Ak soil type) ranges from 1.02 mg/kg to 4.4.2 mg/kg and averages 2.72 mg/kg (samples NMD-SB-012-01N, 02N).

Barium is identified in all background samples and soil types. The Pe soil type ranges from 106 mg/kg to 109 mg/kg and averages 107.5 mg/kg; Ri soil type ranges from 77.4 mg/kg to 89.2 mg/kg and averages 83.3 mg/kg; An soil type ranges from 59.8 mg/kg to 241 mg/kg and averages 116 mg/kg; Ak soil type ranges from 132 mg/kg to 270 mg/kg and averages 201 mg/kg.

Beryllium is detected in five samples and two soil types. The An soil type ranges from 0.3 mg/kg to 0.68 mg/kg (samples NMD-SB-010-01, 02 and NMD-SB-012-015, 025) and averages 0.47 mg/kg; Ak soil type has one sample with detectable beryllium (NMD-SB-012-01N, 0.83 mg/kg).

Cadmium occurs above CRDL in all samples and soil types. Ranges and means of cadmium analyses are: Pe soil type ranges from 2.21 mg/kg to 4.08 mg/kg and averages 3.15 mg/kg; Ri soil type ranges from 3.28 mg/kg to 3.91 mg/kg and averages 3.60 mg/kg; An soil type ranges from 3.01 mg/kg to 5.25 mg/kg and averages 3.87 mg/kg; Ak soil type ranges from 1.4 mg/kg to 4.4. mg/kg and averages 2.9 mg/kg.

Chromium is identified in all samples and soil types. Pe soil type ranges from 10 mg/kg to 17.5 mg/kg and averages 13.75 mg/kg; Ri soil type ranges from 12.6 mg/kg to 13.2 mg/kg and averages 12.9 mg/kg; An soil type ranges from 11.3 mg/kg to 26.8 mg/kg and averages 19.6 mg/kg.

Lead is detected in all samples and soil types. Pe soil type ranges from 8.01 mg/kg to 19.7 mg/kg and averages 13.86 mg/kg; Ri soil type ranges from 9.54 mg/kg to 19.7 mg/kg and averages 14.6 mg/kg; An soil type ranges from 4.91 mg/kg to 10.3 mg/kg and averages 8.38 mg/kg; Ak soil type ranges from 5.16 mg/kg to 14.6 mg/kg and averages 9.88 mg/kg.

Mercury occurs above or at its CRDL in two samples and one soil type. Both Pe soil type samples contain 0.05 mg/kg mercury.

Nickel is in all samples and soil types. Pe soil type ranges from 5.45 mg/kg to 12.4 mg/kg and averages 8.93 mg/kg; Ri soil type ranges from 9.24 mg/kg to 10.8 mg/kg and averages 10.02 mg/kg; An soil type ranges from 9.31 mg/kg to 15.2 mg/kg and averages 12.10 mg/kg; Ak soil type ranges from 5.7 mg/kg to 16.5 mg/kg and averages 11.1 mg/kg.

Silver occurs above its CRDL is seven samples and three soil types. Pe soil type ranges from 2.02 mg/kg to 3.53 mg/kg and averages 2.78 mg/kg; Ri soil type ranges from 1.79 mg/kg to 2.22 mg/kg and averages 2.01 mg/kg; An soil type ranges from 1.47 mg/kg to 3.1 mg/kg and averages 2.05 mg/kg (samples NMD-SB-010-02 and NMD-SB-012-01S, 02S). Silver is not detected in soil type Ak.

Zinc is identified in all samples and soil types. Ranges and means of zinc analyses are: Pe soil type ranges from 17.4mg/kg to 41.6 mg/kg and averages 29.5 mg/kg; Ri soil type ranges from 29.2 mg/kg to 34.1 mg/kg and averages 31.7 mg/kg; An soil type ranges from 26.5 mg/kg to 40.1 mg/kg and averages 32.9 mg/kg; Ak soil type ranges from 15.9 mg/kg to 35.7 mg/kg and averages 25.8 mg/kg. Oil and grease is detected in only one sample of Ak soil type (NMD-SB-012-012N, 0.032%).

5.3.3 Surface Water - Sediment Sampling

Eagle Creek is an ephemeral stream whose course parallels the Three-Mile Ditch. Since the ditch is approximately five to 10 feet above the creek bed, past overflows may have impacted stream sediments and surface water. Samples were collected to document possible occurrences.

5.3.3.1 Sampling Procedure

At each site a geologist was present to select sample locations; record pertinent descriptive information; measure temperature, pH, dissolved oxygen, and specific conductance; and collect samples. Table 5.13 lists the surface water physical parameters recorded during sampling. Surface water was collected by submersing appropriate sample containers halfway between the stream-bed and the water surface. Samples for metals analysis were preserved beneath each water sample by adding 5-10 ml of concentrated nitric acid. An aliquot was then checked with pH paper to insure a pH of approximately 2. Corresponding sediments were obtained by transferring samples to a container with a stainless steel scoop. Samples were labeled, placed in plastic bags, and secured in ice chests at 4° C. Chain-of-custody forms

Table 5.13 Eagle Creek Surface Water Physical Parameters, RFI Phase I Report, Navajo Refining Company, October 1990.

Site	Date	Time	pH	Electrical Conductivity (μmhos/cm)	Temperature (° C)	Dissolved Oxygen (mg/l)
EC-001	9-20	1730	8.36	1890	26.4	5.6
EC-002	9-20	1810	9.40	375	27.9	10.4
EC-003	9-20	1842	7.90	670	25.7	7.6
EC-004	9-23	1415	8.52	776	23.0	6.2
EC-005	9-23	1530	9.44	1480	23.5	9.2

were completed and samples shipped to the contract lab on September 24, 1990.

Surface waters were analyzed for volatile organics, semivolatile organics, total metals, total dissolved solids, and oil and grease. Sediments were analyzed for volatile organics, semivolatile organics, inorganics, and total metals.

5.3.3.2 Surface Water Analytical Results

Volatiles

Analyses of all compounds in all Eagle Creek surface water samples are below their respective reported detection limits (CRDLS).

Semivolatiles

Semivolatile analytic data from Eagle Creek surface water samples are listed in Table 5.14. Only those compounds that occur above their respective detection limits (CRDLs) are listed.

Four semivolatile organic compounds are detected in four Eagle Creek surface water samples. Bis(2-ethylhexyl)phthalate occurs in three of the fours samples; NEC-SW-001-01 (26 mg/l), 002-01 (14 mg/l), and 004-01 (10 mg/l). Di-n-butylphthalate (10 mg/l), isophorone (170 mg/l), and naphthalene (21 mg/l) all occur in only one of the listed samples, NEC-SW-003-01.

Metals

Metals analytical data from Eagle Creek surface water samples are listed in Table 5.15. Four affected samples contain at least one of four metals at concentrations that exceed their respective

Table 5.14. Eagle Creek, Surface Water Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October 1990*

		---------- Sample Number ---------			
		NEC-SW-001-01	NEC-SW 002-01	NEC-SW-003-01	NEC-SW-004-01
COMPOUND	UNITS				
Bis(2-ethylhexyl)phthalate	mg/l	26	14		10
Di-n-butyl phthalate	mg/l			10	
Isophorone	mg/l			170	
Naphthalene	mg/l			21	

* Blanks and all other analyses were below reported limits.

Table 5.15. Eagle Creek Surface Water Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		---------------- Sample Number -------------				
		NEC-SW-001-01	NEC-SW-002-01	NEC-SW-003-01	NEC-SW-004-01	NEC-SW-005-01
Antimony	mg/l	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Arsenic	mg/l	0.011	0.008	0.014	0.013	<0.005
Barium	mg/l	< 0.10	< 0.10	< 0.10	0.05	0.08
Beryllium	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cadmium	mg/l	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Chromium	mg/l	< 0.01	< 0.01	0.02	0.01	0.01
Lead	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Mercury	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nickel	mg/l	< 0.01	< 0.01	0.02	0.02	0.01
Selenium	mg/l	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Silver	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

reported detection limits (CRDLs). One background sample (NEC-SW-001-01) contains arsenic at a level above its CRDL (0.011 mg/l; arsenic CRDL is 0.005 mg/l). All other analyzed elements are below CRDL in the background sample.

Arsenic, barium, chromium, and nickel occur above their respective CRDLs in the affected samples. Besides the background sample, arsenic is detected in NEC-SW-002-01 (0.008 mg/l), 003-01 (0.014 mg/l), and 004-01 (0.013 mg/l).

Barium occurs above its CRDL (0.01 mg/l) in NEC-SW-004-01 (0.05 mg/l), and 005-01 (0.08 mg/l). Chromium is above its CRDL (0.01 mg/l) in NEC-SW-003-01 (0.02 mg/l), 004-01 (0.01 mg/l), and 005-01 (0.01 mg/l). Nickel occurs above its CRDL (0.01 mg/l) in NEC-SW-003-01 (0.02 mg/l), 004-01 (0.02 mg/l), and 005-01 (0.01 mg/l).

5.3.3.3 Sediment Analytical Results

Volatiles

All volatile organic compounds are below their respective reported detection limits (CRDLs) in the background sediment sample. All volatile compounds are also below their respective CRDLs in the Eagle Creek sediment samples.

Semivolatiles

Semivolatile compound analyses from Eagle Creek sediment samples are listed in Table 5.16. Only two semivolatile compounds occur above CRDL concentration levels in one sample. Sample NEC-SD-001-01 contains detectable levels of bis (2-ethylhexyl) phthalate (0.81 ug/l), and di-n-butylphthalate (1.7 ug/l).

Table 5.16. Eagle Creek, Sediments Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October 1990

		Sample Number
COMPOUND	UNITS	NEC-SD-001-01
Bis(2-ethylhexyl)phthalate	mg/kg	0.81
Di-n-butyl phthalate	mg/kg	1.7

* Blanks and all other analyses were below reported limits.

Metals

Metals analytical data from Eagle Creek sediment samples are listed in Table 5.17. All analyzed metals except mercury and selenium occur above their respective reported detection limits (CRDLs) in at least one of the five samples. All analyzed metals except mercury, selenium, and silver exceed their respective CRDLs in the listed background sample NEC-SD-001-01. Background metal values above CRDL (from NEC-SD-001-01) are: antimony (3.16 mg/kg), arsenic (2.47 mg/kg), barium (85.6 mg/kg), beryllium (0.03 mg/kg), cadmium (2.4 mg/kg), chromium (8.29 mg/kg), lead (15.4 mg/kg), nickel (6.45 mg/kg), and zinc (46.5 mg/kg).

Metal analyses above respective CRDLs for affected samples are presented below. Antimony is detected (CRDL is 3.0 mg/kg) in only one sample, NEC-SD-001-01 (3.16 mg/kg). Arsenic occurs above CRDL (0.02 mg/kg) in five samples, ranging in concentration from 2.74 mg/kg to 4.87 mg/kg (mean = 3.96 mg/kg). Barium is identified in all five affected samples, ranging from 5.9 mg/kg to 143 mg/kg (mean = 84.6 mg/kg). Beryllium occurs above CRDL in four of the affected samples, ranging from 0.189 mg/kg to 0.254 mg/kg (mean = 0.22 mg/kg). Cadmium does not occur above its CRDL (0.20 mg/kg) in any of the affected samples, although it is detected in the background sample (2.4 mg/kg). Chromium is above CRDL in all five affected samples, and ranges from 4.7 mg/kg to 17.0 mg/kg (mean = 9.45 mg/kg). Lead is also detected in all five samples, ranging from 4.06 mg/kg to 69.3 mg/kg (mean = 27.3 mg/kg). Nickel is identified in the five samples, ranging from 4.5 mg/kg to 8.81 mg/kg (mean = 6.26 mg/kg). Silver occurs above its CRDL in the five samples, ranging from 0.85 mg/kg to 2.72 mg/kg (mean = 1.96 mg/kg). Zinc is detected in the five samples, and ranges from 0.31 mg/kg to 48.3 mg/kg (mean = 17.52 mg/kg).

Table 5.17. Eagle Creek Sediments Analytical Results - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number					
		NEC-SD-001-01	NEC-SD-002-01	NEC-SD-003-01	NEC-SD-003-02	NEC-SS-004-01	NEC-SS-005-01
Antimony	mg/kg	3.16	< 3.00	< 3.00	< 3.00	< 3.00	< 3.00
Arsenic	mg/kg	2.47	4.13	3.62	3.03	<0.2	4.87
Barium	mg/kg	85.6	5.9	65.5	100	143	109
Beryllium	mg/kg	0.3	0.254	0.23	0.212	<0.03	0.189
Cadmium	mg/kg	2.4	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Chromium	mg/kg	8.29	5.08	12.3	8.17	17	4.7
Lead	mg/kg	15.4	12.7	37.7	13	69.3	4.06
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/kg	6.45	5.4	5.3	4.5	8.81	7.3
Selenium	mg/kg	< 0.50	< 1.50	< 1.50	< 1.50	< 1.50	< 1.50
Silver	mg/kg	< 0.50	1.9	1.65	2.72	0.85	2.7
Zinc	mg/kg	46.5	11.1	16.1	11.8	48.3	0.31

5.3.4 Ground Water Sampling

Five monitor wells were sampled to identify possible impacts to shallow ground water from sludge remaining in Three-Mile Ditch.

5.3.4.1 Monitor Well Locations

Monitor wells 30, 45, 46, and 47 are located near the facility at the western end of Three-Mile Ditch (Plate 2). Monitor wells MW-8 and MW-9 are located along the central reach of Three-Mile Ditch near trench location NMD-TR-005 (Plate 3).

5.3.4.2 Monitor Well Construction Details

Monitor wells 45, 46, and 47 are approximately 25 ft deep, constructed of two-inch PVC pipe, with 10-ft screen sections. Monitor well 30 is approximately 20 ft deep, constructed of six-inch PVC pipe, with a 10-ft screened section. Drillers' logs and construction diagrams appear in Appendices 1 and 2. Table 5.18 provides a synopsis of well construction details.

Monitor wells MW-8 and MW-9 are 20 ft deep, constructed of two-inch PVC, with 10-ft screened sections. Construction details and lithologic logs appear in Appendices 1 and 2. Table 5.18 provides a synopsis of well construction details.

5.3.4.3 Sampling Procedure

Prior to sampling, the water level was measured with an electric or steel tape. Each well was then purged by bailing until pH, conductivity, and temperature measurements stabilized (Table 5.19). Measurements were taken at one well volume intervals and equilibrated within three to five total volumes. Samples were then obtained with a teflon bailer and dispensed directly into the

Table 5.18 Eagle Creek/Three-Mile Ditch, Monitor Well Construction Details, RFI Phase I Report, Navajo Refining Company, October 1990.

Well #	Year Completed	Total Depth (ft)	Casing Diameter (in)	Elevation of Top of Casing (ft)	Screened Interval[1] (ft)
MW - 8	1986	20.0	2.0	3334.96	7.0-17.0
MW - 9	1986	20.0	2.0	3334.82	8.0-18.0
30	1982	22.0	6.0	3359.69	17.0-22.0
45	1984	16.0	2.0	3356.92	10.5-15.5
46	1984	17.0	2.0	3354.81	12.0-17.0
47	1984	14.0	2.0	3349.08	9.0-14.0

[1] Measured from top of casing.

Table 5.19 Eagle Creek/Three-Mile Ditch, Ground Water Physical Parameters, RFI Phase I Report, Navajo Refining Company, October 1990.

Well #	Date	Time	pH	Electrical Conductivity (μmhos/cm)	Temperature (° C)
MW - 8	9-20	1018	6.60	5370	21.00
MW - 9	9-20	1202	6.60	5100	22.00
30	9-22	1645	7.22	3520	20.85
45	9-22	1330	7.15	3440	21.91
46	9-22	1624	7.04	5450	20.53
47	9-22	1700	7.05	4840	18.46

appropriate sample containers. Samples for metals analysis were preserved with 5-10 ml of concentrated nitric acid; pH was confirmed with pH paper to be approximately 2.

5.3.4.4 Ground Water Analytical Results

Volatiles

All compounds are below respective reported detection limits (CRDLs) in background ground water samples (well 49).

No volatile organic compounds occur above their respective CRDLs in any of the listed wells and respective ground water samples.

Semivolatiles

Semivolatile organic compounds data from Eagle Creek-Three-Mile Ditch ground water samples are listed in Table 5.20. Only those compounds that occur above their reported detection limits (CRDL), and the affected samples are listed.

Bis(2-ethyhexyl) phthalate is the only semivolatile compound that occurs above its CRDL in the Eagle Creek/Three-Mile Ditch ground water samples. It is detected in four monitor wells; well MW-8 (sample NMD-GW-006-01, 24 ug/l), well MW-9 (sample NMD-GW-007-01, 31 ug/l), well 45 (sample NMD-GW-045-01, 23 ug/l), and well 46 (sample NMD-GW-046-01, 21 ug/l).

Metals

Metals data for ground water samples from Three-Mile Ditch/Eagle Creek monitor wells are listed in Table 5.21. At least one of five monitor well samples are above the respective

Table 5.20. Eagle Creek/Three-Mile Ditch Groundwater Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990*

		-------- Sample Number ----------			
COMPOUND	UNITS	NMD-GW-006-01 MW-8	NMD-GW-007-01 MW-9	NMD-GW-045-01 # 45	NMD-GW-046-01 # 46
Bis(2-ethylhexyl)phthalate	ug/l	24	31	23	21

* Blanks and all other analyses were below reported limits.

Table 5.21. Three-Mile Ditch/Eagle Creek Groundwater Analytical Results - Metals
RFI Phase I Report, Navajo Mining Company, October, 1990

		Sample Number				
		Monitor Well				
		NMD-GW-030-01	NMD-GW-045-01	NMD-GW-046-01	NMD-GW 006-01	NMD-GW 007-01
COMPOUND	UNITS	#30	#45	#46	MW-8	MW-9
Antimony	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	mg/l	0.058	0.055	0.037	0.014	0.35
Barium	mg/l	1.56	0.62	0.33	<0.10	<0.10
Beryllium	mg/l	0.008	0.004	0.001	<0.001	<0.001
Cadmium	mg/l	0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	0.05	0.1	0.05	2.27	3.99
Lead	mg/l	0.09	1.83	0.028	<0.01	<0.01
Mercury	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/l	0.09	0.09	0.08	0.28	1.2
Selenium	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	mg/l	<0.01	0.02	<0.01	<0.01	<0.01
Zinc	mg/l	0.11	0.13	<0.01	<0.01	<0.01

CRDL for all metals analyzed except antimony, cadmium, mercury, and selenium. Only barium (0.02 mg/l), nickel (0.003 mg/l), selenium (0.004 mg/l), and zinc (0.015 mg/l) are above their respective detection limits in the background monitor well 49.

Arsenic exceeds background concentrations in wells 30 (0.06 mg/l), 45 (0.06 mg/l), 46 (0.04 mg/l), MW-8 (0.01 mg/l), and MW-9 (0.35 mg/l). Barium is detectable and exceeds background concentration in wells 30 (1.56 mg/l), 45 (0.62 mg/l), and 46 (0.33 mg/l). Beryllium is detectable and exceeds background in wells 30 (0.008 mg/l), 45 (0.004 mg/l), and 46 (0.001 mg/l). Chromium is detectable and above background in all five wells (well 30, 0.05 mg/l; well 45, 0.01 mg/l; well 46, 0.05 mg/l; well MW-8, 2.27 mg/l; and well MW-9, 3.99 mg/l). Lead is detectable and above background in well 30 (0.09 mg/l), well 45 (1.83 mg/l), and well 46 (0.03 mg/l). Nickel is above background and detectable in well 30 (0.09 mg/l) 45 (0.09 mg/l), 46 (0.08 mg/l), MW-8 (0.28 mg/l), and MW-9 (1.2 mg/l). Silver is detectable only in well 45 (0.02 mg/l). Zinc is detectable in well 30 (0.11 mg/l), and well 45 (0.13 mg/l). Note that wells MW-8 and MW-9 contain significant concentrations of chromium and nickel. Lead concentration is high in well 45.

Inorganics

Inorganic compound data for ground water samples from Three-Mile Ditch/Eagle Creek monitor wells are listed in Table 5.22. Four inorganic compounds and total dissolved solids are all present in concentrations exceeding their respective CRDLs in three monitor wells. Two other monitor wells contain only total dissolved solids at detectable levels.

Bicarbonate occurs in analytically detectable concentrations in wells 30 (460 mg/l), 45 (338 mg/l), and 46 (358 mg/l). Chloride is present at detectable levels in wells 30 (354 mg/l), 45 (283

Table 5.22. Three-Mile Ditch/Eagle Creek Groundwater Analytical Results - Inorganics
RFI Phase I Report, Navajo Refining Company, October 1990

		------------- Sample Number -------------- Monitor Well				
		NMD-GW-030-01	NMD-GW-045-01	NMD-GW-046-01	NMD-GW 006-01	NMD-GW 007-01
		#30	#45	#46	MW-8	MW-9
COMPOUND	UNITS					
Bicarbonate	mg/l	460	338	358		
Chloride	mg/l	354	283	638		
Fluoride	mg/l	1.67	2.59	3.17		
Sulfate	mg/l	964	1310	1250		
Total Dissolved Solids	mg/l	2820	3160	364	5640	5440

mg/l), and 46 (638 mg/l). Fluoride is detectable in wells 30 (1.67 mg/l), 45 (2.59 mg/l), and 46 (3.17 mg/l). Sulfate is detectable in wells 30 (964 mg/l), 45 (1,310 mg/l), and 46 (1,250 mg/l). Total dissolved solids occur at detectable levels in wells 30, 45, 46, MW-8 and MW-9, and range from 364 mg/l to 5,640 mg/l.

6.0 EVAPORATION PONDS

6.1 SITE DESCRIPTION

6.1.1 Location

Historically, process wastewater was conveyed through Three-Mile Ditch to a series of four evaporation ponds located approximately three miles east of the refinery complex (Plate 4). The evaporation ponds are situated directly adjacent to the Pecos River, with the northeast pond area almost completely surrounded by a Pecos meander. The base of the ponds are reported to be approximately 10 ft above the surface of the Pecos. Pond #1 has a surface area of approximately 16 acres. Total pond acreage is approximately 85 acres (Geoscience Consultants, Ltd. 1984). All ponds are contained by earthen dikes that are five to 10 feet high and approximately 25 to 50 ft wide at their base. These dikes serve to keep wastewater in and surface runoff out. The original dike between Ponds #2 and #3 has been breached, and these are effectively one pond.

6.1.2 Operations History

The ponds have been utilized by Navajo and past operators of the refinery to evaporate process wastewater. The wastewater was conveyed through the ditch system up until September 1987, at which time Navajo completed the installation of a primary wastewater treatment plant and effluent pipeline. The treated wastewater is now discharged directly into Pond #2 via the pipeline, as Pond #1 is no longer in use.

6.1.3 Local Hydrogeology

The ponds are built on the Pecos River floodplain, in soils of the Arno and Harkey series which are described as developing on fine, silty alluvium in the Pecos River Valley (USDA 1971). These soils have low to moderate permeabilities (0.25-0.20 inch/hour) and high water-holding capacity (0.18-0.20 inch/hour). According to the boring logs for monitoring wells installed in the pond area, the first 25 ft of sediments consist mainly of poorly sorted, fine-grained silty sands with minor clay to the north of the ponds, with 2-5 ft thick clay lenses appearing to the east of the ponds at approximately 5-10 ft below ground surface. There are no data available on the deeper lithologies in the immediate pond area, but there is no reason to suspect that it is substantially different than that of the known regional geology. Figure 6.1 provides geologic cross sections through the pond area.

The local direction of flow for the valley fill aquifer is to the south. A pump test conducted adjacent to Pond #1 in 1986 yielded the following information: transmissivity 6,240 gpd/ft, specific yield 0.20, and hydraulic conductivity 250 gpd/ft2. It has been reported that the Pecos is a gaining stream during a normal flow regime, but is a losing stream when the river rises more than six feet above normal (Geoscience Consultants, Ltd. 1987).

6.2 HISTORICAL WATER QUALITY

Samples taken from monitoring wells surrounding the evaporation ponds have detected an organic contaminant plume consisting primarily of toluene, ethylbenzene, and xylenes. This plume is located downgradient (south) of the ponds. The contamination was first detected in 1986 at which time it extended approximately 2000 feet to the south (Geoscience Consultants, Ltd.

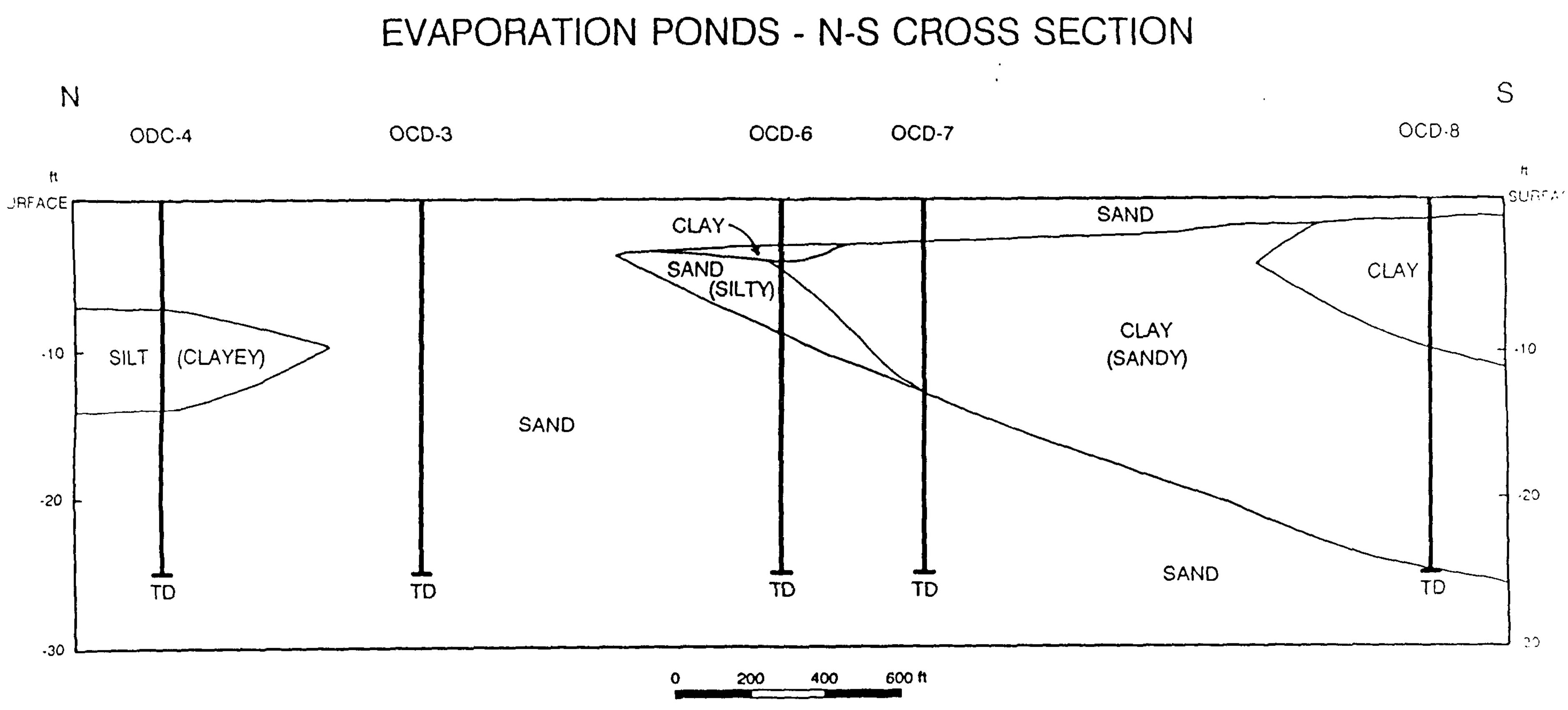
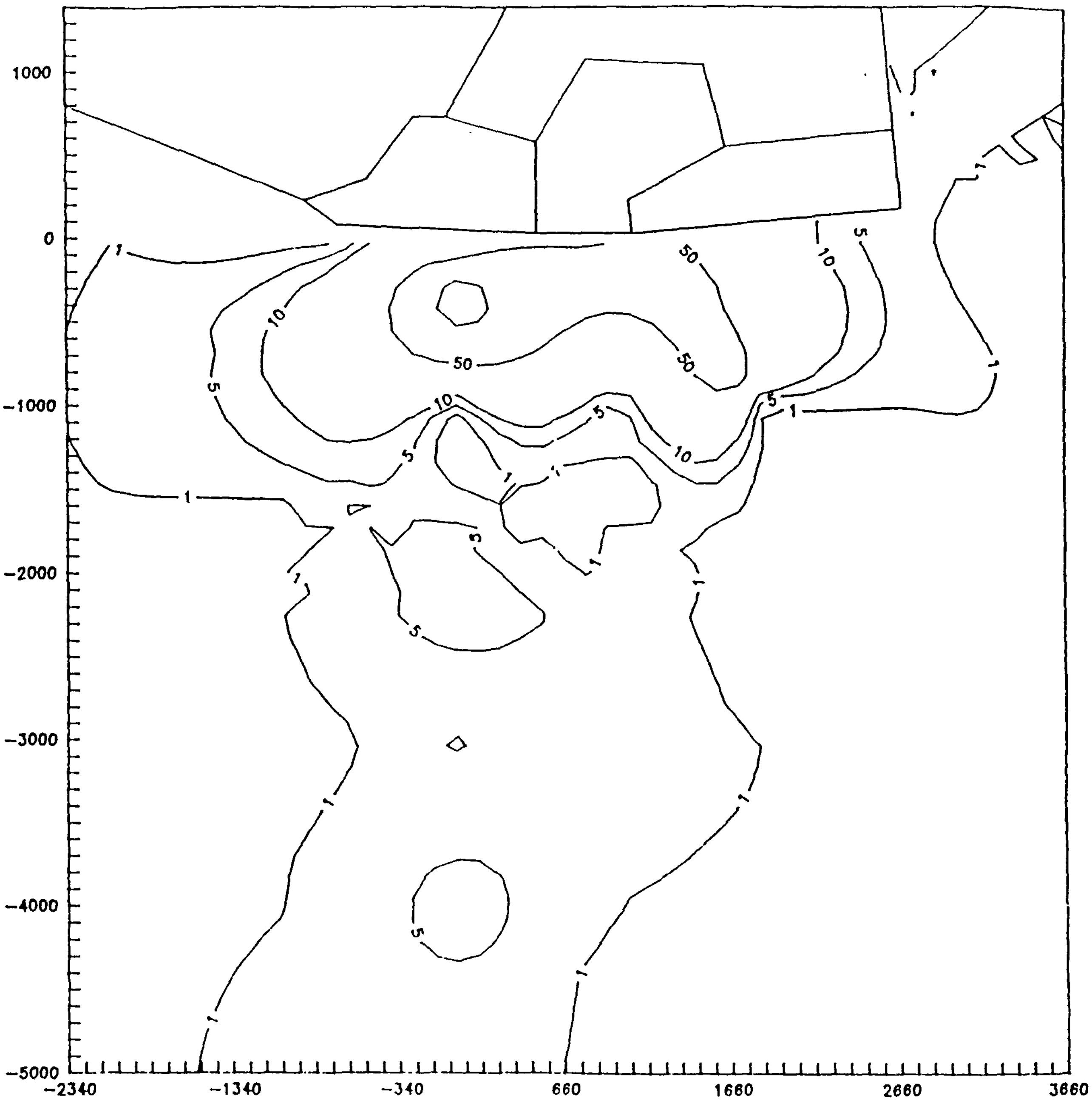


Figure 6.1 Evaporation Ponds, North-South Cross Section, RFI Phase I Report, Navajo Refining Company, October 1990.

1987). Toluene levels have ranged from below detection level (BDL) to 280 ppb (MW-4), ethylbenzene from BDL to 656 ppb (MW-5), and total xylenes from BDL to 992 ppb (MW-4). Low levels of volatile organic compounds were also recorded sporadically in MW-2 and OCD-8. The majority of specific documentation for BTEX plumes is from a one-time sampling event of a piezometer array installed south of the ponds in 1986. Figures 6.2 through 6.7 show the mapped contaminant plumes for the three major contaminants (Geoscience Consultants, Ltd. 1987). Historical volatile groundwater data is compiled in Table 6.1.

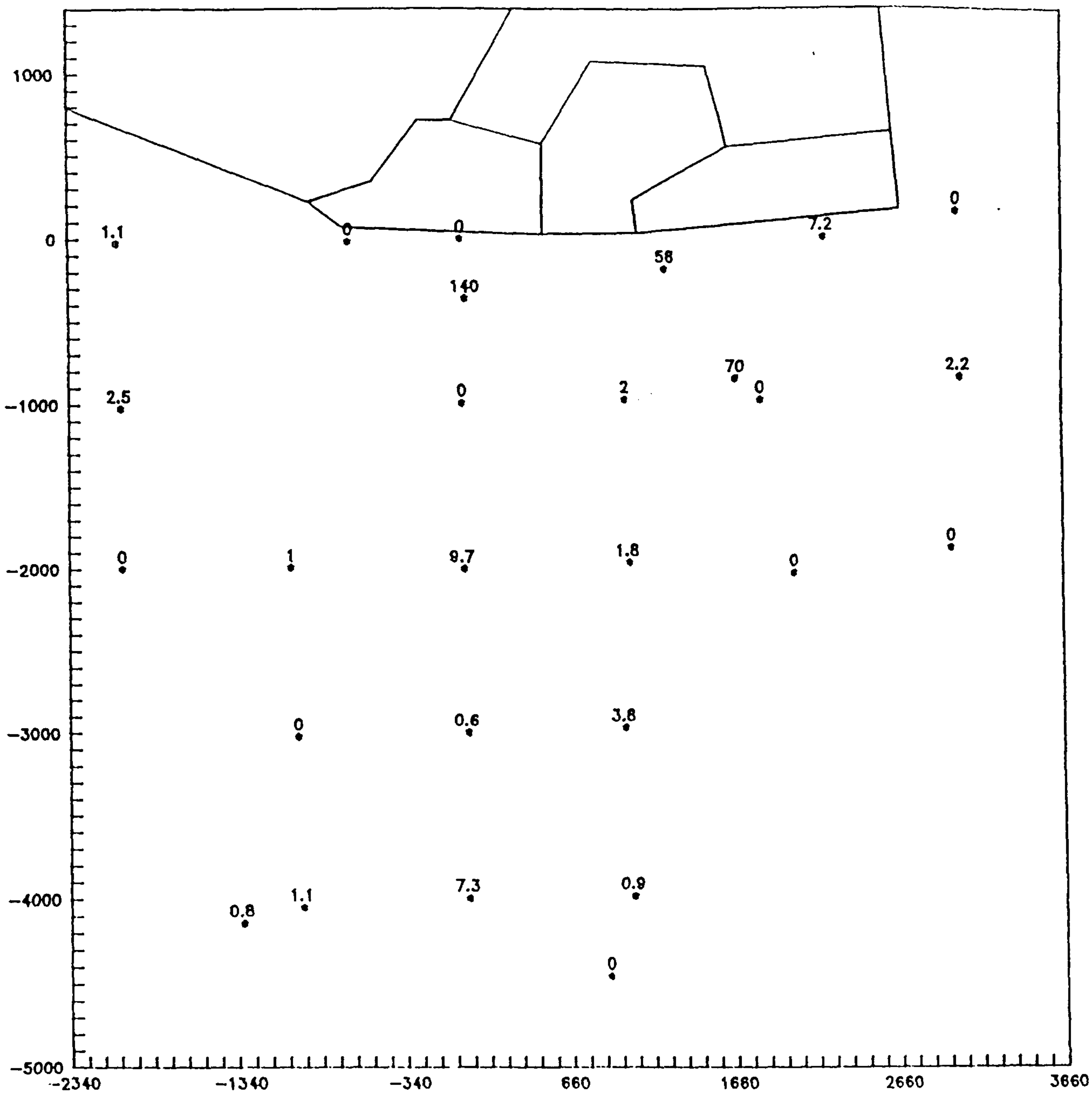
Low level concentrations of the semivolatile compounds acenaphthalene, benzo(a)anthracene, flourene, pyrene, phenanthrene, and various phenols have been sporadically detected in MW-3, MW-4, MW-5, MW-6, and MW-7. Results from samples sent to two labs during July 89 are inconsistent. Compounds detected at one laboratory were below detection at the other. No semivolatile analyses were available for OCD series wells. Historical semivolatile ground water data are compiled in Table 6.2.

Metals results from several wells indicate minor chromium and arsenic contamination. Arsenic concentrations ranged from 0.07 mg/lg to 0.27 mg/l in MW-2, MW-3, MW-4, MW-5, MW-6, OCD-1, OCD-2, and OCD-3 during 1986 and 1988 sampling events. A selected group of those wells containing the highest levels were resampled in 1989. Arsenic concentrations were considerably lower ranging from below detection limit to 0.087 mg/l. OCD-1 and OCD-2 contained 0.061 mg/l and 0.076 mg/l chromium when sampled in 1989. Chromium results from the 1988 sampling event were below the detection limit. Metals ground water data are compiled in Table 6.3.



Contoured Toluene Concentrations in Valley-Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

Figure 6.2 **Evaporation Ponds, Toluene Concentration Map 1987, Phase I Report, Navajo Refining Company, October 1990 (Geoscience Consultants Ltd. 1987).**

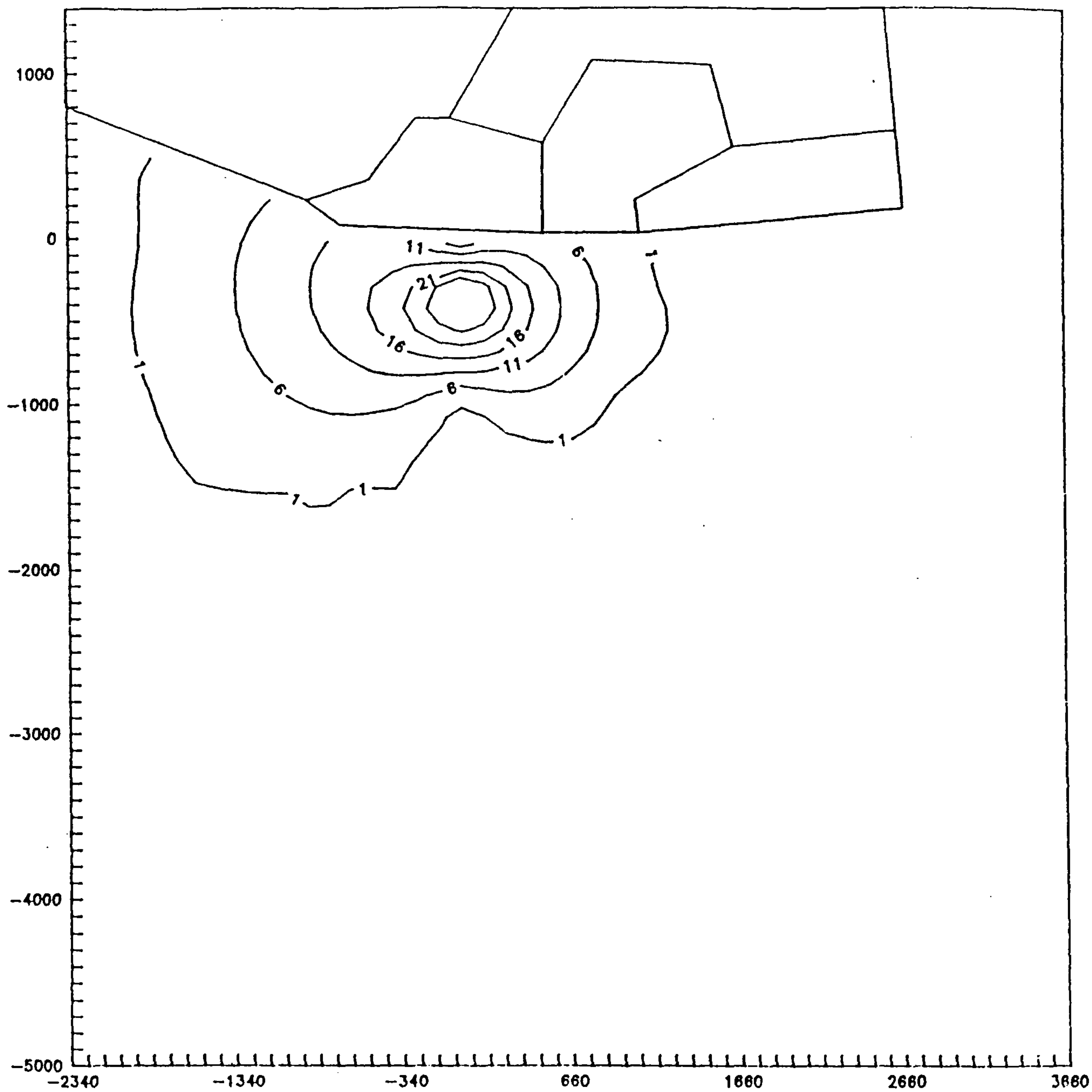


Mapped Toluene Concentrations

Scales in Feet, Grid Origin is well MW-3

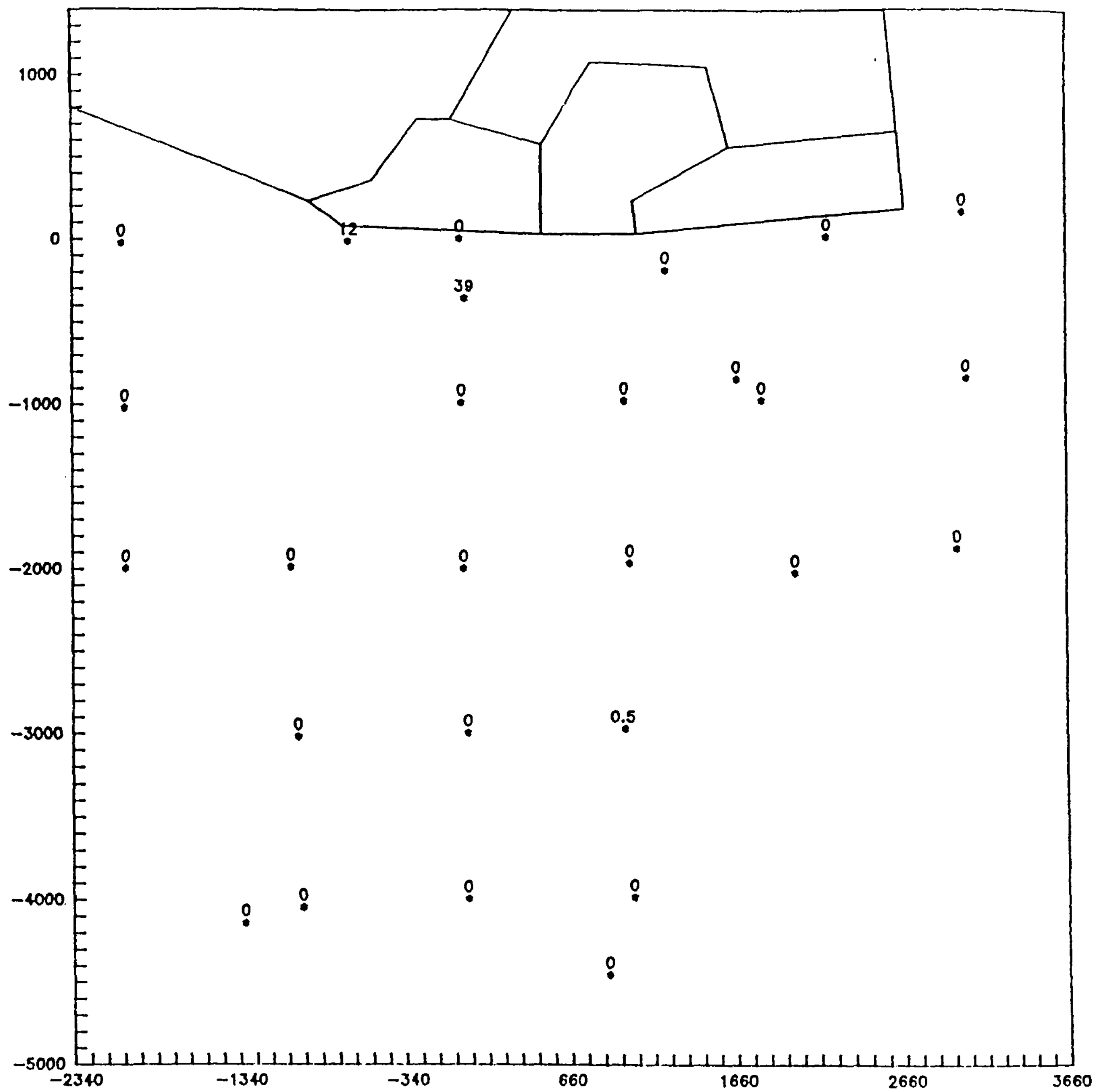
All Concentrations in ug/l

Figure 6.3 **Evaporation Ponds, Toluene Concentration Contour Map 1987, Phase I Report, Navajo Refining Company, October 1990 (Geoscience Consultants Ltd. 1987).**



Contoured Ethylbenzene Concentrations in Valley-Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

Figure 6.4 **Evaporation Ponds, Ethyl Benzene Concentration Map 1987, Phase I Report, Navajo Refining Company, October 1990 (Geoscience Consultants Ltd. 1987).**

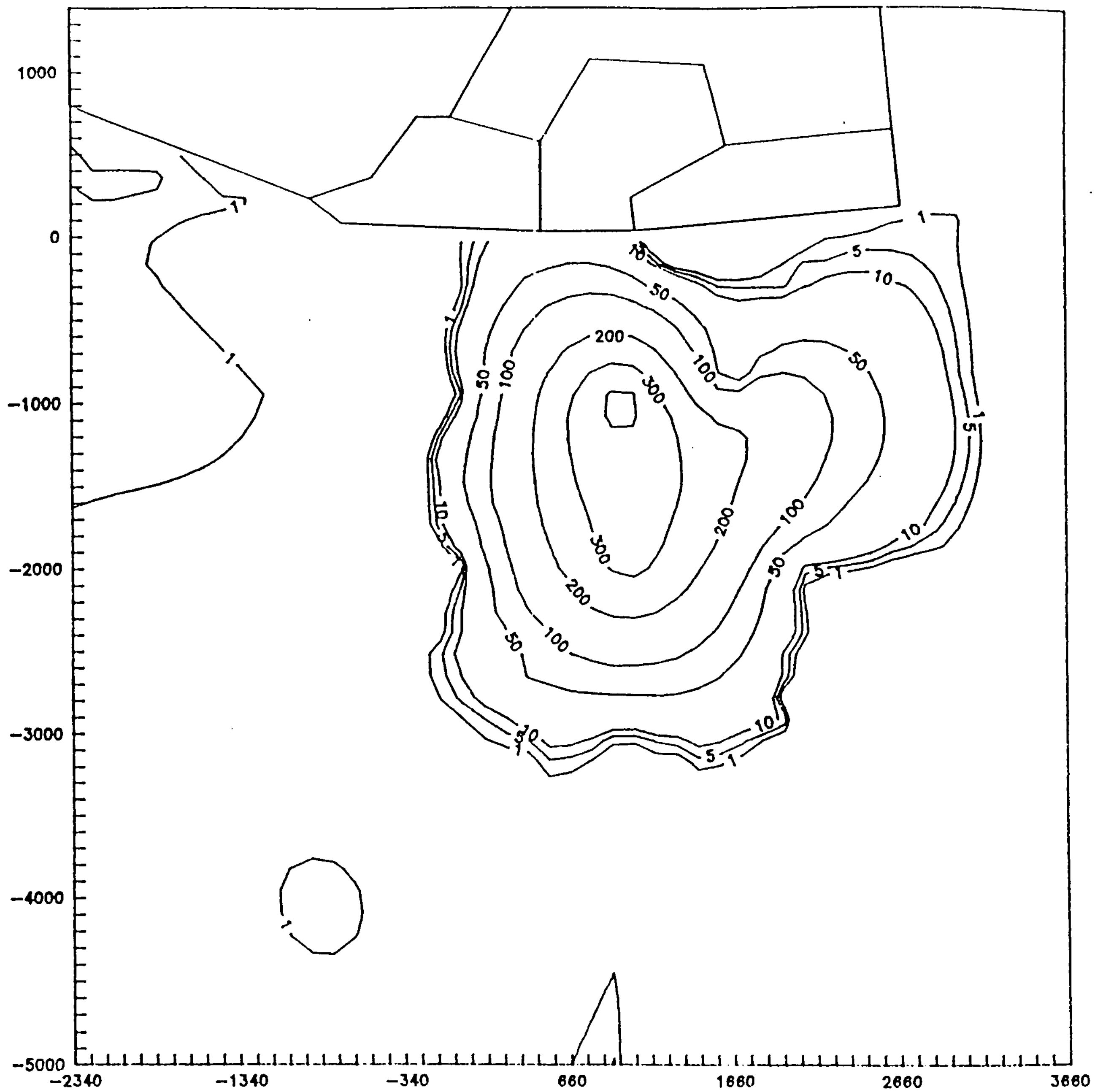


Mapped Ethylbenzene Concentrations

Scales in Feet, Grid Origin is well MW-3

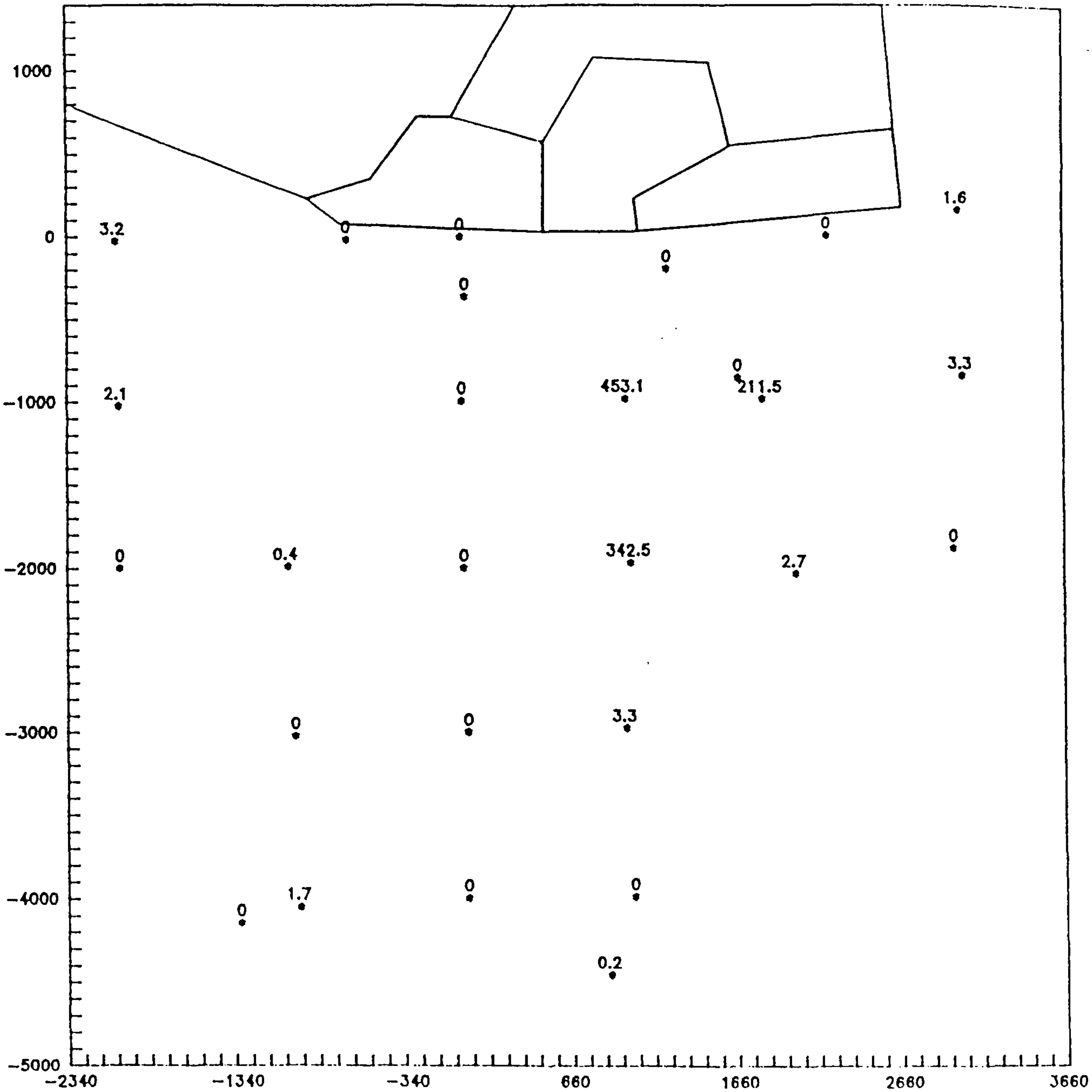
All Concentrations in ug/l

Figure 6.5 Evaporation Ponds, Ethyl Benzene Concentration Contour Map 1987, Phase I Report, Navajo Refining Company, October 1990 (Geoscience Consultants Ltd. 1987).



Contoured Xylene Concentrations in Valley-Fill Aquifer
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

Figure 6.6 **Evaporation Ponds, Xylene Concentration Map 1987, Phase I Report, Navajo Refining Company, October 1990 (Geoscience Consultants Ltd. 1987).**



Mapped Xylene Concentrations
Scales in Feet, Grid Origin is well MW-3
All Concentrations in ug/l

Figure 6.7 **Evaporation Ponds, Xylene Concentration Contour Map 1987, Phase I Report, Navajo Refining Company, October 1990 (Geoscience Consultants Ltd. 1987).**

Table 6.1. Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

Monitor Well Number
Date

COMPOUND /1	UNITS	OCD-1 7/89b	OCD-2 7/89b	OCD-3 7/89b	OCD-4 7/89b	ODC-5 7/89b	OCD-6 7/89b	OCD-7 7/89b	OCD-8 7/89a	OCD-8 7/89b	OCD-8 6/89
1,1,1,2-Tetrachloroethane	ug/l								< 1		
1,1,1-Trichloroethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
1,1,2,2-Tetrachloroethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
1,1,2-Trichloroethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
1,1-Dichloroethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
1,2,3-Trichloropropane	ug/l								< 1		
1,2-Dichloroethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
1,2-Dichloropropane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
1,3-Dichloropropylene	ug/l								< 1		
1-Chloroethyl vinyl ether	ug/l								< 1		
1-Chlorohexane	ug/l								< 1		
1-Methylnaphthalene	ug/l										
2,2-Dichloropropane	ug/l								< 1		
2-Chloroethyl vinyl ether	ug/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10		< 10	
2-Methylnaphthalene	ug/l										
2-Sec-butyl-4,6-dinitrophenol	ug/l										
Benzene	ug/l	< 5	< 5	< 5	< 5	6.0	< 5	< 5	<0.2	< 5	4.4
Benzyl chloride	ug/l								< 1		
Bromobenzene	ug/l								< 1		
Bromodichloromethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Bromoform	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Bromomethane	ug/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 1	< 10	
Carbon tetrachloride	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Chloracetaldehyde	ug/l								< 1		
Chlorobenzene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	<0.2	< 5	
Chloroethane	ug/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 1	< 10	
Chloroform	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Chloromethane	ug/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 1	< 10	
Chloromethyl methyl ether	ug/l								< 1		
Chlorotoluene	ug/l								< 1		
Cis-1,3-dichloropropene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5		< 5	

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date									
COMPOUND /1	UNITS	OCD-1 7/89b	OCD-2 7/89b	OCD-3 7/89b	OCD-4 7/89b	ODC-5 7/89b	OCD-6 7/89b	OCD-7 7/89b	OCD-8 7/89a	OCD-8 7/89b	OCD-8 6/89
Dibromochloromethane	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Dibromomethane	ug/l								< 1		
Dichlorodifluoromethane	ug/l								< 1		
Dichloromethane	ug/l								< 1		
Ethylbenzene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	<0.2	< 5	14
Freon	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5		< 5	
Methylene chloride	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5		< 5	
m-Xylene	ug/l								<0.2		
o-Xylene	ug/l								<0.2		
p-Xylene	ug/l								<0.2		
Tetrachloroethene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Tetrachlorophenol	ug/l										
Toluene	ug/l	< 5	< 5	< 5	< 5	6.0	< 5	< 5	18.38	< 5	
Trans-1,2-dichloroethene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Trans-1,3-dichloropropene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5		< 5	
Trichloroethene	ug/l	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 1	< 5	
Trichlorofluoromethane	ug/l								< 1		
Trichlorophenol	ug/l										
Vinyl chloride	ug/l	< 1	< 1	< 1	< 1	< 1	< 1	< 1		< 1	
Xylenes	ug/l	< 10	< 10	< 10	< 10	< 10	< 10	< 10		< 10	35

Source: Evaporation Ponds Special Analysis. Scientific Laboratory.
June 01, 1988; April 27, 1987; August 12, 1987; November 12, 1987
Evaporation Ponds Special Analysis. Rocky Mountain Laboratories.
March 16, 1988; June 22, 1988
Evaporation Ponds Special Analysis. Inter-mountain Laboratories
July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. Ana-Lab
July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. ENESCO
June 22, 1989

/1 Blanks designate components for which no analyses were requested.

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date									
COMPOUND	UNITS	MW-1 9/86	MW-1 7/89a	MW-2 9/86	MW-2 7/89a	MW-3 9/86	MW-3 7/89a	MW-3 7/89b	MW-4 9/86	MW-4 8/87	MW-4 11/87
1,1,1,2-Tetrachloroethane	ug/l	< 5				< 5		< 1			
1,1,1-Trichloroethane	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
1,1,2,2-Tetrachloroethane	ug/l		< 5		< 5		< 5	< 1			
1,1,2-Trichloroethane	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
1,1-Dichloroethane	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
1,2,3-Trichloropropane	ug/l							< 1			
1,2-Dichloroethane	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
1,2-Dichloropropane	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
1,3-Dichloropropylene	ug/l	< 5				< 5		< 1			
1-Chloroethyl vinyl ether	ug/l							< 1			
1-Chlorohexane	ug/l							< 1			
1-Methylnaphthalene	ug/l									98	
2,2-Dichloropropane	ug/l							< 1			
2-Chloroethyl vinyl ether	ug/l	< 5	< 10		< 10	< 5	< 10				
2-Methylnaphthalene	ug/l									< 10	
2-Sec-butyl-4,6-dinotrophenol	ug/l							< 1			
Benzene	ug/l	< 5	< 5	< 0.5	< 5	< 5	< 5	<0.2	< 5	45	51
Benzyl chloride	ug/l							< 1			
Bromobenzene	ug/l							< 1			
Bromodichloromethane	ug/l		< 5		< 5		< 5				
Bromoform	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
Bromomethane	ug/l		< 10		< 10		< 10	< 1			
Carbon tetrachloride	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
Chloracetaldehyde	ug/l							< 1			
Chlorobenzene	ug/l	< 5	< 5	< 1	< 5	< 5	< 5	<0.2	< 10		
Chloroethane	ug/l	< 10	< 10		< 10	< 10	< 10	< 1			
Chloroform	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
Chloromethane	ug/l		< 10		< 10		< 10	< 1			
Chloromethyl methyl ether	ug/l							< 1			
Chlorotoluene	ug/l							< 1			
Cis-1,3-dichloropropene	ug/l		< 5		< 5		< 5				

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date									
COMPOUND	UNITS	MW-1 9/86	MW-1 7/89a	MW-2 9/86	MW-2 7/89a	MW-3 9/86	MW-3 7/89a	MW-3 7/89b	MW-4 9/86	MW-4 8/87	MW-4 11/87
Dibromochloromethane	ug/l		< 5		< 5		< 5	< 1			
Dibromomethane	ug/l							< 1			
Dichlorodifluoromethane	ug/l							< 1			
Dichloromethane	ug/l							< 1			
Ethylbenzene	ug/l	< 5	< 5	< 1	< 5	< 5	< 5	<0.2	< 10	130	156
Freon	ug/l		< 5		< 5		< 5				
Methylene chloride	ug/l	< 10	< 5		< 5	< 10	< 5				
m-Xylene	ug/l							<0.2		942	12
o-Xylene	ug/l							<0.2		40	32
p-Xylene	ug/l							<0.2		10	15
Tetrachloroethene	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
Tetrachlorophenol	ug/l										
Toluene	ug/l	< 5	< 5	6.4	< 5	< 5	< 5	21.9	< 10	280	25
Trans-1,2-dichloroethene	ug/l		< 5		< 5		< 5	< 1			
Trans-1,3-dichloropropene	ug/l		< 5		< 5		< 5				
Trichloroethene	ug/l	< 5	< 5		< 5	< 5	< 5	< 1			
Trichlorofluoromethane	ug/l							< 1			
Trichlorophenol	ug/l										
Vinyl chloride	ug/l	< 10	< 1		< 1	< 10	< 1				
Xylenes	ug/l		< 10		< 10		< 10				

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date									
COMPOUND	UNITS	MW-4 3/88	MW-4 6/89	MW-4 7/89a	MN-4 7/89b	MW-5 9/86	MW-5 8/87	MW-5 11/87	MW-5 7/89a	MW-5 7/89b	MW-6 9/86
1,1,1,2-Tetrachloroethane	ug/l				< 1					< 1	
1,1,1-Trichloroethane	ug/l			< 5	< 1				< 5	< 1	< 5
1,1,2,2-Tetrachloroethane	ug/l			< 5	< 1				< 5	< 1	< 5
1,1,2-Trichloroethane	ug/l			< 5	< 1				< 5	< 1	< 5
1,1-Dichloroethane	ug/l			< 5	< 1				< 5	< 1	< 5
1,2,3-Trichloropropane	ug/l				< 1					< 1	
1,2-Dichloroethane	ug/l			< 5	< 1				< 5	< 1	< 5
1,2-Dichloropropane	ug/l			< 5	< 1				< 5	< 1	< 5
1,3-Dichloropropylene	ug/l				< 1					< 1	< 5
1-Chloroethyl vinyl ether	ug/l				< 1					< 1	
1-Chlorohexane	ug/l				< 1					< 1	
1-Methylnaphthalene	ug/l										
2,2-Dichloropropane	ug/l				< 1					< 1	
2-Chloroethyl vinyl ether	ug/l			< 10					< 10		< 5
2-Methylnaphthalene	ug/l										
2-Sec-Butyl-4,6-dinotrophenol	ug/l				< 1					< 1	
Benzene	ug/l	30	14	< 5	<0.2	< 5	TR		< 5	<0.2	< 5
Benzyl chloride	ug/l				< 1					< 1	
Bromobenzene	ug/l				< 1					< 1	
Bromodichloromethane	ug/l			< 5	< 1				< 5	< 1	
Bromoform	ug/l			< 5	< 1				< 5	< 1	< 5
Bromomethane	ug/l			< 10	< 1				< 10	< 1	
Carbon tetrachloride	ug/l			< 5	< 1				< 5	< 1	< 5
Chloracetaldehyde	ug/l				< 1					< 1	
Chlorobenzene	ug/l			< 5	< 1	< 10			< 5	< 1	< 5
Chloroethane	ug/l			< 10	< 1				< 10	< 1	< 10
Chloroform	ug/l			< 5	< 1				< 5	< 1	< 5
Chloromethane	ug/l			< 10	< 1				< 10	< 1	
Chloromethyl methyl ether	ug/l				< 1					< 1	
Chlorotoluene	ug/l				< 1					< 1	
Cis-1,3-dichloropropene	ug/l			< 5					< 5		

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date									
COMPOUND	UNITS	MW-4 3/88	MW-4 6/89	MW-4 7/89a	MN-4 7/89b	MW-5 9/86	MW-5 8/87	MW-5 11/87	MW-5 7/89a	MW-5 7/89b	MW-6 9/86
Dibromochloromethane	ug/l			< 5	< 1				< 5	< 1	
Dibromomethane	ug/l				< 1					< 1	
Dichlorodifluoromethane	ug/l				< 1					< 1	
Dichloromethane	ug/l				< 1					< 1	
Ethylbenzene	ug/l	78	65	< 5	<0.2	< 10	656	52	< 5	<0.2	< 5
Freon	ug/l			< 5					< 5		
Methylene chloride	ug/l			< 5					< 5		< 10
m-Xylene	ug/l	53			<0.2		830	755		<0.2	
o-Xylene	ug/l				<0.2					<0.2	
p-Xylene	ug/l				<0.2			TR		<0.2	
Tetrachloroethene	ug/l			< 5	< 1				< 5	< 1	
Tetrachlorophenol	ug/l				< 1						
Toluene	ug/l	220	160	< 5	35.72	< 10	TR		< 5	27.58	< 5
Trans-1,2-dichloroethene	ug/l			< 5	< 1				< 5	< 1	
Trans-1,3-dichloropropene	ug/l			< 5					< 5		
Trichloroethene	ug/l			< 5	< 1				< 5	< 1	< 5
Trichlorofluoromethane	ug/l				< 1				< 1		
Trichlorophenol	ug/l				< 1						
Vinyl chloride	ug/l			< 1					< 1		< 10
Xylenes	ug/l	203	93	< 10					< 10		

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

		Monitor Well Number Date				
COMPOUND	UNITS	MW-6 7/89a	MW-6 7/89b	MW-7 9/86	MW-7 7/89a	MW-7 7/89b
1,1,1,2-Tetrachloroethane	ug/l		< 1			
1,1,1-Trichloroethane	ug/l	< 5	< 1		< 5	
1,1,2,2-Tetrachloroethane	ug/l	< 5	< 1		< 5	
1,1,2-Trichloroethane	ug/l	< 5	< 1		< 5	
1,1-Dichloroethane	ug/l	< 5	< 1		< 5	
1,2,3-Trichloropropane	ug/l		< 1			
1,2-Dichloroethane	ug/l	< 5	< 1		< 5	
1,2-Dichloropropane	ug/l	< 5	< 1		< 5	
1,3-Dichloropropylene	ug/l		< 1			
1-Chloroethyl vinyl ether	ug/l		< 1			
1-Chlorohexane	ug/l		< 1			
1-Methylnaphthalene	ug/l					
2,2-Dichloropropane	ug/l		< 1			
2-Chloroethyl vinyl ehter	ug/l	< 10			< 10	
2-Methylnaphthalene	ug/l					
2-Sec-butyl-4,6-dinotrophenol	ug/l		< 1			< 1
Benzene	ug/l	26	<0.2	< 0.5	< 5	
Benzyl chloride	ug/l		< 1			
Bromobenzene	ug/l		< 1			
Bromodichloromethane	ug/l	< 5	< 1		< 5	
Bromoform	ug/l	< 5	< 1		< 5	
Bromomethane	ug/l	< 10	< 1		< 10	
Carbon tetrachloride	ug/l	< 5	< 1		< 5	
Chloracetaldehyde	ug/l		< 1			
Chlorobenzene	ug/l	< 5	<0.2	< 1	< 5	
Chloroethane	ug/l	< 10	< 1		< 10	
Chloroform	ug/l	< 5	< 1		< 5	
Chloromethane	ug/l	< 10	< 1		< 10	
Chloromethyl methyl ether	ug/l		< 1			
Chlorotoluene	ug/l		< 1			
Cis-1,3-dichloropropene	ug/l	< 5			< 5	

Table 6.1 (cont). Evaporation Ponds - Historical Groundwater Quality
Volatile Organic Compounds

					Monitor Well Number Date	
COMPOUND	UNITS	MW-6 7/89a	MW-6 7/89b	MW-7 9/86	MW-7 7/89a	MW-7 7/89b
Dibromochloromethane	ug/l	< 5	< 1		< 5	
Dibromomethane	ug/l		< 1			
Dichlorodifluoromethane	ug/l		< 1			
Dichloromethane	ug/l		< 1			
Ethylbenzene	ug/l	< 5	<0.2	< 1	< 5	
Freon	ug/l	< 5			< 5	
Methylene chloride	ug/l	< 5			< 5	
m-Xylene	ug/l		<0.2			
o-Xylene	ug/l		<0.2			
p-Xylene	ug/l		<0.2			
Tetrachloroethene	ug/l	< 5	< 1		< 5	
Tetrachlorophenol	ug/l					
Toluene	ug/l	20	27.01	7.2	< 5	
Trans-1,2-dichloroethene	ug/l	< 5	< 1		< 5	
Trans-1,3-dichloropropene	ug/l	< 5			< 5	
Trichloroethene	ug/l	< 5	< 1		< 5	
Trichlorofluoromethane	ug/l		< 1			
Trichlorophenol	ug/l					
Vinyl chloride	ug/l	< 1			< 1	
Xylenes	ug/l	20			< 10	

Table 6.2 Evaporation Ponds - Historical Groundwater Quality
Semi-volatile Organic Compounds

		Monitor Well Number Date									
COMPOUND /1	UNITS	MW-1 9-86	MW-1 7-89	MW-2 9-86	MW-2 7-89	MW-3 9-86	MW-3 7-89	MW-3 9-86	MW-4 9-86	MW-4 8-87	MW-4 11-87
1,2,4-Tricholorobenzene	ug/l										
2,4,5-Trichlorophenol	ug/l										
2,4,6-Trichlorophenol	ug/l	< 5		< 5		< 5	< 10		< 5		
2,4-Dichlorophenol	ug/l	< 5		< 5		< 5	< 10		< 5		
2,4-Dimethylphenol	ug/l	< 5		< 5		< 5	< 10		< 5		
2,4-Dinitrophenol	ug/l	< 10		< 10		< 10	< 50		< 10		
2,4-Dinitrotoluene	ug/l	< 5				< 5					
2,6-Dichlorophenol	ug/l										
2,6-Dinitrotoluene	ug/l	< 5				< 5					
2-Chloronaphthalene	ug/l	< 5				< 5					
2-Chlorophenol	ug/l	< 5		< 5		< 5	< 10		< 5		
2-Cylohexyl-4,6-dinitrophenol	ug/l										
2-Methyl-4,6-dinitrophenol	ug/l						< 50				
2-Methylnaphthalene	ug/l	< 5				< 5				< 10	
2-Methylphenol	ug/l	< 5		< 5		< 5					
2-Nitroaniline	ug/l										
2-Nitrophenol	ug/l	< 5		< 5		< 5	< 10		< 5		
3,3'-Dichlorobenzidine	ug/l	< 5				< 5					
3-Methylcholanthrene	ug/l						< 1				
3-Nitroaniline	ug/l										
4,6-Dinitro-2-methylphenol	ug/l										
4-Bromophenyl phenyl ether	ug/l	< 5				< 5					
4-Chloroaniline	ug/l										
4-Chlorophenyl phenyl ether	ug/l	< 5				< 5					
4-Chloro-3-methylphenol	ug/l						< 20				
4-Methylphenol	ug/l			< 5							
4-Nitroaniline	ug/l										
4-Nitrophenol	ug/l	< 10		< 10		< 10	< 50		< 10		
7H-Dibenzo(c,g)carbazole	ug/l							< 1			
Acenaphthene	ug/l	< 5				< 5		<1.8		< 10	
Acenaphthylene	ug/l	< 5				< 5		<2.3		31	
Anthracene	ug/l	< 5				< 5		< 1			
Benzoic acid	ug/l										
Benzo(a)anthracene	ug/l	< 5				< 5		33.4			
Benzo(a)pyrene	ug/l	< 5				< 5		< 1			
Benzo(b)fluoranthene	ug/l							< 1			
Benzo(g,h,i)perylene	ug/l	< 5				< 5		< 1			
Benzo(j)fluoranthene	ug/l							< 1			
Benzo(k)fluoranthene	ug/l	< 5				< 5		< 1			
Benzyl alcohol	ug/l										
Bis(2-chloroethyl)ether	ug/l	< 5				< 5					
Bis(2-chloroethoxy)methane	ug/l	< 5				< 5		< 1			
Bis(2-chloroisopropyl)ether	ug/l	< 5				< 5		< 1			
Bis(2-ethylhexyl)phthalate	ug/l	< 5				< 5					

Table 6.2 (cont). Evaporation Ponds - Historical Groundwater Quality
Semi-volatile Organic Compounds

COMPOUND	UNITS	Monitor Well Number / Date									
		MW-1 9-86	MW-1 7-89	MW-2 9-86	MW-2 7-89	MW-3 9-86	MW-3 7-99	MW-3 7-89	MW-4 9-86	MW-4 8-87	MW-4 11-87
Butyl benzyl phthalate	ug/l	< 5				< 5					
Cresols (methyl phenols)	ug/l										
Chrysene	ug/l	< 5				< 5		< 1			
Dibenzofuran	ug/l	< 5				< 5					
Dibenzo(a,h)anthracene	ug/l							< 1			
Dibenzo(a,j)acridine	ug/l							< 1			
Dibenzo(a,e)pyrene	ug/l							< 1			
Dibenzo(a,h)pyrene	ug/l							< 1			
Dibenzo(a,i)pyrene	ug/l							< 1			
Diethyl phthalate	ug/l										
Dimethyl phthalate	ug/l	< 5				< 5					
Di-n-butyl phthalate	ug/l	< 5				< 5					
Di-n-octyl phthalate	ug/l	< 5				< 5					
Fluoranthene	ug/l	< 5				< 5		< 1			
Fluorene	ug/l	< 5				< 5		< 1		< 10	
Hexachlorobenzene	ug/l	< 5				< 5					
Hexachlorobutadiene	ug/l	< 5				< 5					
Hexachloroethane	ug/l	< 5				< 5					
Hexachlorocyclopentadiene	ug/l	< 5				< 5					
Indeno(1,2,3-cd)pyrene	ug/l	< 5				< 5		< 1			
Isophorone	ug/l	< 5				< 5					
Naphthalene	ug/l	< 5				< 5		< 1.8		< 10	
Nitrobenzene	ug/l	< 5				< 5					
N-nitrosodipropylamine	ug/l	< 5				< 5					
N-nitrosodiphenylamine	ug/l	< 5				< 5					
Pentachlorophenol	ug/l	< 5		< 5		< 5	< 50		< 5		
Phenanathrene	ug/l	< 5				< 5		< 1			
Phenol	ug/l	< 5		< 5		< 5	< 10		< 5		
Pyrene	ug/l	< 5				< 5		25.4			
1,2-Dichlorobenzene	ug/l	< 5		< 2		< 5			< 20		
1,3-Dichlorobenzene	ug/l	< 5		< 2		< 5			< 20		
1,4-Dichlorobenzene	ug/l	< 5		< 2		< 5			< 20		

Source: Evaporation Ponds Special Analysis. Scientific Laboratory. June 01, 1988; April 27, 1987; August 12, 1987; November 12, 1987
Evaporation Ponds Special Analysis. Rocky Mountain Laboratories, March 16, 1988; June 22, 1988
Evaporation Ponds Special Analysis. Inter-mountain Laboratories, July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. Ana-Lab, July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. ENESCO, June 22, 1989

/1 Blanks designate components for which no analyses were requested.

Table 6.2 (cont). Evaporation Ponds - Historical Groundwater Quality
Semi-volatile Organic Compounds

Monitor Well Number
Date

COMPOUND	UNITS	MW-4 3-88	MW-4 6-89	MW-4 7-89	MW-4 7-89	MW-5 9-86	MW-5 8-87	MW-5 11-87	MW-5 7-89	MW-5 7-89	MW-6 9-86
1,2,4-Tricholorobenzene	ug/l										< 5
2,4,5-Trichlorophenol	ug/l										
2,4,6-Trichlorophenol	ug/l			< 10	< 1	< 5			< 10		
2,4-Dichlorophenol	ug/l			< 10	< 1	< 5			< 10		
2,4-Dimethylphenol	ug/l			< 10	59	< 5			< 10		
2,4-Dinitrophenol	ug/l			< 50	< 15	< 10			< 50		
2,4-Dinitrotoluene	ug/l										< 5
2,6-Dichlorophenol	ug/l				< 1						
2,6-Dinitrotoluene	ug/l										< 5
2-Chloronaphthalene	ug/l			< 10							< 5
2-Chlorophenol	ug/l			< 10	3.1	< 5			< 10		
2-Cylohexyl-4,6-dinitrophenol	ug/l				< 1						
2-Methyl-4,6-dinitrophenol	ug/l			< 50	< 15				80		
2-Methylnaphthalene	ug/l										< 5
2-Methylphenol	ug/l					< 5					
2-Nitroaniline	ug/l										
2-Nitrophenol	ug/l			< 10	< 1	< 5			< 10		
3,3'-Dichlorobenzidine	ug/l										< 20
3-Methylcholanthrene	ug/l				< 1					< 1	
3-Nitroaniline	ug/l										
4,6-Dinitro-2-methylphenol	ug/l										
4-Bromophenyl phenyl ether	ug/l										
4-Chloroaniline	ug/l										
4-Chlorophenyl phenyl ether	ug/l										< 5
4-Chloro-3-methylphenol	ug/l			< 20	< 1				< 20		
4-Methylphenol	ug/l					< 5					
4-Nitroaniline	ug/l										
4-Nitrophenol	ug/l			< 50	30	< 10			< 50		
7H-Dibenzo(c,g)carbazole	ug/l				< 1					< 1	
Acenaphthene	ug/l	< 10		< 10	<1.8					<1.8	< 5
Acenaphthylene	ug/l	< 10		< 10	<2.3					<2.3	< 5
Anthracene	ug/l	< 10			< 1					< 1	< 5
Benzoic acid	ug/l										
Benzo(a)anthracene	ug/l	< 10		< 10	< 1					< 1	< 5
Benzo(a)pyrene	ug/l	< 10		< 10	< 1					< 1	< 5
Benzo(b)fluoranthene	ug/l	< 10		< 10	< 1					< 1	
Benzo(g,h,i)perylene	ug/l	< 10		< 10	< 1					< 1	< 5
Benzo(j)fluoranthene	ug/l				< 1					< 1	
Benzo(k)fluoranthene	ug/l	< 10		< 10	< 1					< 1	< 5
Benzyl alcohol	ug/l										
Bis(2-chloroethyl)ether	ug/l										< 5
Bis(2-chloroethoxy)methane	ug/l				< 1					< 1	< 5
Bis(2-cloroisopropyl)ether	ug/l				< 1					< 1	< 5
Bis(2-ethylhexyl)phthalate	ug/l										< 5

Table 6.2 (cont). Evaporation Ponds - Historical Groundwater Quality
Semi-volatile Organic Compounds

COMPOUND	UNITS	MW-4 3-88	MW-4 6-89	MW-4 7-89	MN-4 7-89	MW-5 9-86	MW-5 8-87	MW-5 11-87	MW-5 7-89	MW-5 7-89	MW-6 9-86
					Monitor Well Number Date						
Butyl benzyl phthalate	ug/l										< 5
Cresols (methyl phenols)	ug/l				< 1						
Chrysene	ug/l	< 10		< 10	< 1					< 1	< 5
Dibenzofuran	ug/l										< 5
Dibenzo(a,h)anthracene	ug/l	< 10		< 10	< 1					< 1	< 5
Dibenzo(a,j)acridine	ug/l				< 1					< 1	
Dibenzo(a,e)pyrene	ug/l				< 1					< 1	
Dibenzo(a,h)pyrene	ug/l				< 1					< 1	
Dibenzo(a,i)pyrene	ug/l				< 1					< 1	
Diethyl phthalate	ug/l										< 5
Dimethyl phthalate	ug/l										< 5
Di-n-butyl phthalate	ug/l										< 5
Di-n-octyl phthalate	ug/l										< 5
Fluoranthene	ug/l	< 10		< 10	< 1					< 1	< 5
Fluorene	ug/l	< 10		< 10	< 1					< 1	< 5
Hexachlorobenzene	ug/l										< 5
Hexachlorobutadiene	ug/l										< 5
Hexachloroethane	ug/l										< 5
Hexachlorocyclopentadiene	ug/l										< 5
Indeno(1,2,3-cd)pyrene	ug/l	< 10		< 10	< 1					< 1	< 5
Isophorone	ug/l										< 5
Naphthalene	ug/l	< 10		< 10	< 1.8					< 1.8	< 5
Nitrobenzene	ug/l										< 5
N-nitrosodipropylamine	ug/l										< 5
N-nitrosodiphenylamine	ug/l										< 5
Pentachlorophenol	ug/l			< 50	< 8	< 5			< 50		
Phenanathrene	ug/l	< 10		< 10	< 1					< 1	< 5
Phenol	ug/l			< 10	30	< 5			< 10		
Pyrene	ug/l	< 10		< 10	< 1					< 1	< 5
1,2-Dichlorobenzene	ug/l					< 20					< 5
1,3-Dichlorobenzene	ug/l					< 20					< 5
1,4-Dichlorobenzene	ug/l					< 20					< 5

Table 6.2 (cont). Evaporation Ponds - Historical Groundwater Quality
Semi-volatile Organic Compounds

					Monitor Well Number Date	
COMPOUND	UNITS	MW-6 7-89	MW-6 7-89	MW-7 9-86	MW-7 7-89	MW-7 7-89
1,2,4-Tricholorobenzene	ug/l					
2,4,5-Trichlorophenol	ug/l					
2,4,6-Trichlorophenol	ug/l	< 10		< 5	< 10	
2,4-Dichlorophenol	ug/l	< 10		< 5	< 10	
2,4-Dimethylphenol	ug/l	< 10		< 5	< 10	
2,4-Dinitrophenol	ug/l	< 50		< 10	< 50	
2,4-Dinitrotoluene	ug/l					
2,6-Dichlorophenol	ug/l					
2,6-Dinitrotoluene	ug/l					
2-Chloronaphthalene	ug/l					
2-Chlorophenol	ug/l	< 10		< 5	< 10	
2-Cylohexyl-4,6-dinitrophenol	ug/l					
2-Methyl-4,6-dinitrophenol	ug/l	< 50			< 50	
2-Methylnaphthalene	ug/l					
2-Methylphenol	ug/l			< 5		
2-Nitroaniline	ug/l					
2-Nitrophenol	ug/l	< 10		< 5	< 10	
3,3'-Dichlorobenzidine	ug/l					
3-Methylcholanthrene	ug/l		< 1			< 1
3-Nitroaniline	ug/l					
4,6-Dinitro-2-methylphenol	ug/l					
4-Bromophenyl phenyl ether	ug/l					
4-Chloroaniline	ug/l					
4-Chlorophenyl phenyl ether	ug/l					
4-Chloro-3-methylphenol	ug/l	< 20			< 20	
4-Methylphenol	ug/l			< 5		
4-Nitroaniline	ug/l					
4-Nitrophenol	ug/l	< 50		< 10	< 50	
7H-Dibenzo(c,g)carbazole	ug/l		< 1			< 1
Acenaphthene	ug/l		14.3			<1.8
Acenaphthylene	ug/l		12.9			<2.3
Anthracene	ug/l		< 1			< 1
Benzoic acid	ug/l					
Benzo(a)anthracene	ug/l		< 1			< 1
Benzo(a)pyrene	ug/l		< 1			< 1
Benzo(b)fluoranthene	ug/l		< 1			< 1
Benzo(g,h,i)perylene	ug/l		< 1			< 1
Benzo(j)fluoranthene	ug/l		< 1			< 1
Benzo(k)fluoranthene	ug/l		< 1			< 1
Benzyl alcohol	ug/l					
Bis(2-chloroethyl)ether	ug/l					
Bis(2-chloroethoxy)methane	ug/l		< 1			
Bis(2-chloroisopropyl)ether	ug/l		< 1			
Bis(2-ethylhexyl)phthalate	ug/l					

Table 6.2 (cont). Evaporation Ponds - Historical Groundwater Quality
Semi-volatile Organic Compounds

		Monitor Well Number Date				
COMPOUND	UNITS	MW-6 7-89	MW-6 7-89	MW-7 9-86	MW-7 7-89	MW-7 7-89
Butyl benzyl phthalate	ug/l					
Cresols (methyl phenols)	ug/l					
Chrysene	ug/l		< 1			< 1
Dibenzofuran	ug/l					
Dibenzo(a,h)anthracene	ug/l		< 1			< 1
Dibenzo(a,j)acridine	ug/l		< 1			< 1
Dibenzo(a,e)pyrene	ug/l		< 1			< 1
Dibenzo(a,h)pyrene	ug/l		< 1			< 1
Dibenzo(a,i)pyrene	ug/l		< 1			< 1
Diethyl phthalate	ug/l					
Dimethyl phthalate	ug/l					
Di-n-butyl phthalate	ug/l					
Di-n-octyl phthalate	ug/l					
Fluoranthene	ug/l		94.1			< 1
Fluorene	ug/l		< 1			< 1
Hexachlorobenzene	ug/l					
Hexachlorobutadiene	ug/l					
Hexachloroethane	ug/l					
Hexachlorocyclopentadiene	ug/l					
Indeno(1,2,3-cd)pyrene	ug/l		< 1			< 1
Isophorone	ug/l					
Naphthalene	ug/l		114			<1.8
Nitrobenzene	ug/l					
N-nitrosodipropylamine	ug/l					
N-nitrosodiphenylamine	ug/l					
Pentachlorophenol	ug/l			< 5		
Phenanathrene	ug/l		206			< 1
Phenol	ug/l			< 5		
Pyrene	ug/l		< 1			12.5
1,2-Dichlorobenzene	ug/l			2		
1,3-Dichlorobenzene	ug/l			2		
1,4-Dichlorobenzene	ug/l			2		

Table 6.3. Evaporation Ponds - Historical Water Quality
Metals

Monitor Well Number
Date

METAL /1	UNITS	OCD-1 6/88	OCD-1 7/89a	OCD-2 6/88	OCD-2 7/89a	OCD-3 6/88	OCD-4 6/88	OCD-4 7/89a	OCD-5 6/88	OCD-6 6/88	OCD-7 6/88	OCD-8 6/88
Aluminum	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Antimony	mg/l											
Arsenic	mg/l	0.27	0.027	0.083	0.007	0.012	0.02	<0.005	0.025	0.01	0.11	0.11
Barium	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Beryllium	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Boron	mg/l	0.7		0.7		0.8	1.4		1.1	0.7	0.6	0.9
Cadmium	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Chromium	mg/l	<0.005	0.076	<0.005	0.061	<0.005	<0.005	0.043	<0.005	<0.005	<0.005	<0.005
Cobalt	mg/l	<0.05		<0.05		<0.05	<0.05		<0.05	<0.05	<0.05	<0.05
Copper	mg/l	<0.1		0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Iron	mg/l	1.7		6.2		0.8	0.7		2.1	2.5	0.3	0.6
Lead	mg/l	<0.01	<0.02	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01
Manganese	mg/l	2.1		2.2		0.72	0.67		0.81	1.7	3.7	2.9
Mercury	mg/l											
Molybdenum	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Nickel	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Selenium	mg/l											
Silicon	mg/l	11		12		4.5	9.2		10	9.4	7.1	9.2
Silver	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Strontium	mg/l											
Thallium	mg/l											
Tin	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Vanadium	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Zinc	mg/l	<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1

Source: Evaporation Ponds Special Analysis. Scientific Laboratory.
June 01, 1988; April 27, 1987; August 12, 1987; November 12, 1987
Evaporation Ponds Special Analysis. Rocky Mountain Laboratories.
March 16, 1988; June 22, 1988
Evaporation Ponds Special Analysis. Inter-mountain Laboratories
July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. Ana-Lab
July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. ENESCO
June 22, 1989

/1 Blanks designate components for which no analyses were requested.

Table 6.3 (cont). Evaporation Ponds - Historical Water Quality
Metals

METAL	UNITS	MW-1 8/86	MW-1 4/87	MW-2 8/86	MW-3 7/89	MW-3 8/86	MW-4 4/87	MW-4 6/88	MN-4 7/89	MW-5 4/87	MW-5 6/88	MW-5 7/89
						Monitor Well Number Date						
Aluminum	mg/l				0.1		<0.1	<0.1			<0.1	
Antimony	mg/l	0.004		0.007								
Arsenic	mg/l	< 0.002		0.092	0.079	0.084		0.21	0.087		0.13	<0.005
Barium	mg/l	0.03		0.04	<0.5	0.22	<0.1	<0.1			<0.1	
Beryllium	mg/l	< 0.002		<0.002			0.1	<0.1			<0.1	
Boron	mg/l				1.16		0.7	0.7			1.5	
Cadmium	mg/l	< 0.008		<0.008	<0.002		<0.1	<0.1			< 0.1	
Chromium	mg/l	< 0.01	<0.005	0.019	0.02	0.02	<0.005	<0.005	0.038	<0.005	0.007	<0.02
Cobalt	mg/l	< 0.06		<0.06	<0.01		<0.05	<0.05			<0.05	
Copper	mg/l	< 0.03		<0.03	0.03		<0.1	<0.1			<0.1	
Iron	mg/l	1.3		19	1.7	7.5	<0.1	1.5			3	
Lead	mg/l	< 0.04	<0.01	<0.04	<0.02		<0.01	<0.01	<0.02	<0.01	<0.01	<0.02
Manganese	mg/l				4.07		2.3	2.4			1.6	
Mercury	mg/l	< 0.0001		<0.0001								
Molybdenum	mg/l				0.05		<0.1	<0.1			<0.1	
Nickel	mg/l	0.1		<0.02	<0.01	0.02	<0.1	<0.1			<0.1	
Selenium	mg/l	< 0.04		<0.04	<0.005							
Silicon	mg/l				7.7		25	17			13	
Silver	mg/l	< 0.006		<0.006	<0.01		<0.1	<0.1			<0.1	
Strontium	mg/l											
Thallium	mg/l	< 0.04		<0.04								
Tin	mg/l						0.1	<0.1			<0.1	
Vanadium	mg/l	< 0.004		0.005		0.014	<0.1	<0.1			<0.1	
Zinc	mg/l	< 0.02		<0.02	<0.01		<0.1	<0.1			<0.1	

Table 6.3 (cont). Evaporation Ponds - Historical Water Quality
Metals

Monitor Well Number
Date

METAL	UNITS	MW-6 6/88	MW-6 7/89	MW-7 8/86	MW-7 6/88	MW-7 7/89
Aluminum	mg/l	<0.1			<0.1	
Antimony	mg/l			0.004		
Arsenic	mg/l	0.07	0.012	<0.002	0.051	0.009
Barium	mg/l	<0.1		0.03	<0.1	
Beryllium	mg/l	<0.1		<0.005	<0.1	
Boron	mg/l	0.5			0.5	
Cadmium	mg/l	< 0.1		<0.02	< 0.1	
Chromium	mg/l	0.005	0.03	<0.025	<0.005	0.026
Cobalt	mg/l	<0.05		<0.015	<0.05	
Copper	mg/l	<0.1		<0.03	<0.1	
Iron	mg/l	0.4		1.3	3.1	
Lead	mg/l	<0.01	<0.02	<0.1	<0.01	<0.02
Manganese	mg/l	0.65			1.3	
Mercury	mg/l			<0.0001		
Molybdenum	mg/l	<0.1			<0.1	
Nickel	mg/l	<0.1		0.1	<0.1	
Selenium	mg/l			<0.04		
Silicon	mg/l	24			5.3	
Silver	mg/l	<0.1		<0.015	<0.1	
Strontium	mg/l					
Thallium	mg/l			<0.04		
Tin	mg/l	<0.1			<0.1	
Vanadium	mg/l	<0.1		<0.01	<0.1	
Zinc	mg/l	<0.1		<0.02	<0.1	

Table 6.4. Evaporation Ponds - Historical Groundwater Quality
Inorganic Components

COMPONENT /1	UNITS	OCD-1 6/88	OCD-1 7/89	OCD-2 6/88	OCD-2 7/89	OCD-3 6/88	OCD-3 7/89	OCD-4 6/88	OCD-4 7/89	OCD-5 6/88	OCD-5 7/89
		Monitor Well Number Date									
Ammonia	mg/l										
Bicarbonate	mg/l	448	611.72	471	686.02	225	282.33	194	317	209	242.71
Calcium	mg/l	616	63.05	716	688.57	992	1020.41	912	920.86	880	887.67
Carbonate	mg/l		0		0		0		0		0
Chloride	mg/l	2865	281.45	4375	3637.17	4175	4562.42	4675	5636.55	4475	4254
Cyanide	mg/l										
Fluoride	mg/l	1.38	3	0.73	1.16	0.82	0.98	0.81	0.86	0.68	0.79
Magnesium	mg/l	285.5	591.04	565	521.72	337	285.05	300.1	295.01	290.4	253.35
Nitrate (N)	mg/l										
Nitrite	mg/l										
Total Kjeldahl Nitrogen	mg/l										
Potassium	mg/l	10	5	10	7	30	20.3	10	55.6	35	37.8
Sodium	mg/l	2605	2638.5	3245	3220.5	2370	2523	3035	3240	2910	2649
Sulfate	mg/l	4150	4032.7	4575	4829.36	2445	2726.6	2850	3059.91	2800	2994.07
Sulfide	mg/l										
Total Dissolved Solids	mg/l	11514	10900	14510	14108	11754	11724	13088	13856	12688	11724
Conductivity	umohms/cm	14715	13368	17965	16485	15558	14952	17607	17517	17073	14150
pH		7.98	8.19	7.8	7.45	7.98	8.02	8	8.06	7.85	8.34
Temperature	deg. C										
Total Alk as CaCO3			501.41		562.31		231.42		259.84		198.94
Total Acidity as CaCO3			0		0		0		0		0

Source: Evaporation Ponds Special Analysis. Scientific Laboratory.
June 01, 1988; April 27, 1987; August 12, 1987; November 12, 1987
Evaporation Ponds Special Analysis. Rocky Mountain Laboratories.
March 16, 1988; June 22, 1988
Evaporation Ponds Special Analysis. Inter-mountain Laboratories
July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. Ana-Lab
July 25, 1989; July 26, 1989
Evaporation Ponds Special Analysis. ENESCO
June 22, 1989

/1 Blanks designate components for which no analyses were requested.

Table 6.4 (cont). Evaporation Ponds - Historical Groundwater Quality
Inorganic Components

		Monitor Well Number Date								
COMPONENT	UNITS	OCD-6 6/88	OCD-6 7/89	OCD-7 6/88	OCD-7 7/89	OCD-8 6/88	OCD-8 7/89	MW-1 8/86	MW-1 4/87	MW-1 7/89
Ammonia	mg/l									
Bicarbonate	mg/l	252	366.54	388	614.2	412	559.71		482	584.48
Calcium	mg/l	864	929.15	624	638.79	500	696.86	900	912	920.86
Carbonate	mg/l		0		0		0			0
Chloride	mg/l	3850	4604.96	1665	1999.38	2180	2467.32	4250	4753	4679.4
Cyanide	mg/l									
Fluoride	mg/l	0.84	0.76	2.52	5.04	<0.05	2.22	1	0.88	1.11
Magnesium	mg/l	300.1	349.25	231.8	245.47	436.8	366.61	601	549	694.78
Nitrate (N)	mg/l							<0.01		
Nitrite	mg/l									
Total Kjeldahl Nitrogen	mg/l							2.6		
Potassium	mg/l	15	11.1	10	3.6	10	6.4	9.1	6.24	4.5
Sodium	mg/l	1640	2433	1785	2089	1700	1930	2020	1925	2417.8
Sulfate	mg/l	2485	2346.37	3475	3738.07	3475	3520.79	3080	3146	3392.41
Sulfide	mg/l							0.07		
Total Dissolved Solids	mg/l	10536	11414	8422	9198	9010	9618	14900	11450	13148
Conductivity	umohms/cm	14033	13228	10489	10111	11343	10542		13658	14521
pH		7.81	8.12	7.74	8.21	7.81	8.07		7.75	8.1
Temperature	deg. C									
Total Alk as CaCO3			300.44		503.44		458.78	<5		479.08
Total Acidity as CaCO3			0		0		0			0

Table 6.4 (cont). Evaporation Ponds - Historical Groundwater Quality
Inorganic Components

COMPONENT	UNITS	Monitor Well Number Date					
		MW-2 8/86	MW-2 4/87	MW-2 7/89	MW-3 8/86	MW-3 4/87	MW-3 7/89
Ammonia	mg/l						
Bicarbonate	mg/l		537	430.93	768	358	386.35
Calcium	mg/l		600	763.23	703	560	605.61
Carbonate	mg/l			0			0
Chloride	mg/l		2842	2329.07	1210	1316	1265.57
Cyanide	mg/l						
Fluoride	mg/l		5.48	4.24	2.9	2.15	2.75
Magnesium	mg/l		278	91.77	296	317	289.57
Nitrate (N)	mg/l				<0.1		
Nitrite	mg/l						
Total Kjeldahl Nitrogen	mg/l				0.3		
Potassium	mg/l		6.24	2.7	7.2	5.07	3.7
Sodium	mg/l		2279	1983	1220	1148	1203
Sulfate	mg/l		34457	3035.22	2760	2654	3218.75
Sulfide	mg/l				<0.05		
Total Dissolved Solids	mg/l	21600	10064	8518	8080	6844	7082
Conductivity	umohms/cm		12607	10272		8372	7877
pH			7.84	8.18		7.49	8.05
Temperature	deg. C						
Total Alk as CaCO3				353.22	<5		316.68
Total Acidity as CaCO3				0			0

Table 6.4 (cont). Evaporation Ponds - Historical Groundwater Quality
Inorganic Components

		Monitor Well Number Date									
COMPONENT	UNITS	MW-4 8/86	MW-4 4/87	MW-4 11/87	MW-4 6/88	MW-4 7/89	MW-5 8/86	MW-5 4/87	MW-5 11/87	MW-5 6/88	MW-5 7/89
Ammonia	mg/l										
Bicarbonate	mg/l		294	361	271	312.05		444	455	415	465.6
Calcium	mg/l		352	392	340	547.54		600	560	536	663.68
Carbonate	mg/l					0					< 0.1
Chloride	mg/l		1225	1100	1085	1744.14		6939	5300	5350	4679.4
Cyanide	mg/l										
Fluoride	mg/l		1.63	1.94	1.55	1.57		2.62	3.48	3.08	2.75
Magnesium	mg/l		93	95	109.8	179.77		1488	1256	1084	939.11
Nitrate (N)	mg/l										
Nitrite	mg/l										
Total Kjeldahl Nitrogen	mg/l										
Potassium	mg/l		0.78	1.56	2	1		7.8	10.1	10	5.4
Sodium	mg/l		1097	1116	1166	1400.7		5796	5635	4675	4560
Sulfate	mg/l		1520	1770	1540	2612.2		10610	9150	8850	2386.7
Sulfide	mg/l										
Total Dissolved Solids	mg/l	13000	4730	4756	4732	6830	27300	27428	24104	21390	20238
Conductivity	umohms/cm		6514	6213	6406	8288		28255	23017	24009	19030
pH			7.79	7.85	7.95	8.08		7.62	7.75	8.1	8.11
Temperature	deg. C										
Total Alk as CaCO3						255.78					381.64
Total Acidity as CaCO3						0					< 0.1

Table 6.4 (cont). Evaporation Ponds - Historical Groundwater Quality
Inorganic Components

COMPONENT	UNITS	MW-6 8/86	MW-6 4/87	MW-6 6/88	MW-6 7/89	MW-7 8/86	MW-7 4/87	MW-7 6/88	MW-7 7/89
Ammonia	mg/l								
Bicarbonate	mg/l		206	149	208.03		384	387	416.07
Calcium	mg/l	986	356	320	721.75	900	520	572	754.94
Carbonate	mg/l				0				0
Chloride	mg/l	3080	1044	836	978.42		2294	3730	3179.87
Cyanide	mg/l								
Fluoride	mg/l	5.5	4.04	3.1	3.14		1.15	1.51	1.16
Magnesium	mg/l	248	93	112.2	87.94	601	327	622.2	526.84
Nitrate (N)	mg/l	2.1							
Nitrite	mg/l								
Total Kjeldahl Nitrogen	mg/l	5.2							
Potassium	mg/l	9	1.95	2	1.4	9.1	4.68	5	4.2
Sodium	mg/l	1990	950	724	840	2020	1567	2265	2464.5
Sulfate	mg/l	3000	1466	1460	2393.28		2366	4120	4094.43
Sulfide	mg/l	brl							
Total Dissolved Solids	mg/l	10100	4324	3614	5240	10500	8220	11928	11326
Conductivity	umohms/cm		5988	4706	5953		10300	14715	12196
pH			7.82	7.33	8.09		7.71	7.95	8.08
Temperature	deg. C								
Total Alk as CaCO3		brl			170.52				341.04
Total Acidity as CaCO3					0				0

The high variability of metals results over time may be attributed to changes in ground water Eh-pH conditions, turbidity, or to laboratory inaccuracies.

Historical inorganic ground water data are compiled in Table 6.4. High total dissolved solids concentrations are notable, ranging from 3614 to 27,300 mg/l.

6.3 FIELD INVESTIGATION

Field activities conducted during the hydrogeologic investigation included measuring water levels and collecting ground water samples from existing monitor wells, collecting surface soil grab samples, installing and sampling one background monitor well, and determining aquifer parameters through slug tests on five monitor wells.

6.3.1 Soils Sampling

The work plan specified that, since there had been reports of the evaporation ponds overflowing from some undisclosed source, up to 20 surface samples would be obtained from areas impacted by the pond (i.e., stained areas and runoff areas). Upon inspection, no stained areas were discovered along the perimeter, however six surface soil grab samples were collected from unvegetated areas.

6.3.1.1 Sampling Procedure

Health and safety level D protective equipment was worn by personnel engaged in soil sampling. No work zone delineation was made.

Samples were obtained with stainless steel scoops and placed directly in sample containers. Soils were labeled in the field, placed in plastic bags, and secured in ice chests. Chain-of-custody forms were completed, and samples were shipped to the contract lab on September 16, 1990.

Soils were analyzed for volatiles (8270), semivolatiles (8240), selected metals, and oil and grease (Tables 6.5 and 6.6).

6.3.1.2 Locations

Soil samples were collected from six locations surrounding the evaporation pond complex. Samples NEP-SS-001 through NEP-SS-006 were collected from areas of light, grey-blue evaporitic crust on several unvegetated areas near the pond berms (Plate 5).

6.3.1.3 Sample Descriptions

Soil sample descriptions appear in Appendix 1.

6.3.1.4 Soils Analytical Results

Volatiles

All background soil samples (NMD-SB samples) are below reported detection limits (CRDLs). No volatile organic compounds occur above their respective CRDLs in the evaporation pond soil samples.

Semivolatiles

Semivolatile organic compounds analytic data from evaporation pond soil samples are listed in Table 6.5. Bis (2-ethylhexyl)

Table 6.5. Evaporation Ponds. Soils Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		-- Sample Number --	
COMPOUND	UNITS	NEP-SS-001-01	NEP-SS-002-01
Bis(2-ethylhexyl)phthalate	mg/kg	0.95	0.66

* Blanks and all other analyses were below reported limits.

phthalate occurs above it's reported detection limit (CRDL) in only two samples, one of which is a background sample. Background sample NEP-SS-002-01 contains 0.66 mg/kg. These two analyses represent very low levels of bis (2-ethylhexyl) phthalate (CRDL is 0.66 mg/kg).

Metals

Metals data from evaporation pond soil samples are listed in Table 6.6. At least one of the five samples contains analytically detectable concentrations of all elements analyzed except antimony, selenium, and silver.

Arsenic is detectable in samples NEP-SS-001-01 (3.32 mg/kg), 002-01 (2.74 mg/kg), 003-01 (1.02 mg/kg), 004-01 (2.13 mg/kg), and 005-01 (14.1 mg/kg). Barium occurs in detectable concentrations in samples NEP-SS-001-01 (165 mg/kg), 002-01 (210 mg/kg), 003-01 (140 mg/kg), 004-01 (133 mg/kg), and 005-01 (241 mg/kg). Beryllium is detectable in samples NEP-SS-001-01 (0.41 mg/kg), 002-01 (0.47 mg/kg), and 005-01 (0.59 mg/kg). Cadmium is detectable in samples NEP-SS-001-01 (27 mg/kg), 002-01 (2.6 mg/kg), 003-01 (1.6 mg/kg), 004-01 (0.94 mg/kg), and 005-01 (4.4 mg/kg). Chromium is detectable in significant concentrations in samples NEP-SS-001-01 (23.6 mg/kg) and 005-01 (259 mg/kg), and in lesser concentrations in 002-01 (10 mg/kg), 003-01 (5.6 mg/kg), and 004-01 (4 mg/kg). Lead occurs in significant concentrations in samples NEP-SS-001-01 mg/kg), and 005-01 (90.6 mg/kg), and in lesser concentrations in samples 002-01 (7.93 mg/kg), 003-01 (5.72 mg/kg), and 004-01 (4.14 mg/kg). Mercury occurs in detectable concentrations only in NEP-SS-005-01 (0.23 mg/kg). Nickel is detectable in samples NEP-SS-001-01 (8.6 mg/kg), 002-01 (10.7 mg/kg), 003-01 (5.7 mg/kg), 004-01 (3.2 mg/kg), and 005-01 (11.9 mg/kg). Zinc occurs in significant concentrations in SEP-SS-005-01 (109 mg/kg), and in lesser concentrations in 001-01 (27.9 mg/kg), 002-01 (24.7 mg/kg), 003-01 (16.1 mg/kg), and 004-01 (11.8 mg/kg). Oil and grease occur at

Table 6.6. Evaporation Ponds Soils Analytical Results - Metals and Oil & Grease
RFI Phase I Report, Navajo Refining Company, October, 1990

METAL	UNITS	Sample Number NEP-SS-001-01	NEP-SS-002-01	NEP-SS-003-01	NEP-SS-004-01	NEP-SS-005-01
Antimony	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Arsenic	mg/kg	3.32	2.74	1.02	2.13	14.1
Barium	mg/kg	165	210	140	133	241
Beryllium	mg/kg	0.41	0.47	< 0.30	< 0.30	0.59
Cadmium	mg/kg	2.7	2.6	1.6	0.94	4.4
Chromium	mg/kg	23.6	10	5.6	4	259
Lead	mg/kg	20.6	7.93	5.72	4.14	90.6
Mercury	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05	0.23
Nickel	mg/kg	8.6	10.7	5.7	3.2	11.9
Selenium	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Silver	mg/kg	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Zinc	mg/kg	27.9	24.7	16.1	11.8	109
Oil and Grease	percent	0.062	0.712	0.01	0.013	0.412

detectable levels in NEP-SS-001-01 (0.06%), 002-01 (0.71%), 003-01 (0.01%), 004-01 (0.01%), 005-01 (0.4%).

Note that sample NEP-SS-005-01 contains significant concentrations of arsenic, chromium, lead, nickel, and zinc.

6.3.2 Monitor Well Installation

One monitor well (EPA-1) was installed to serve as a shallow background well.

6.3.2.1 Procedure

EPA-1 was installed via eight-inch hollow stem auger method using a CME 55 truck-mounted drill rig. A geologist was present to record procedures, collect samples, and prepare a well log and construction diagram. The well was developed for approximately two hours by pumping (air lift). Temperature, pH, and conductivity stabilized upon the second measurement.

6.3.2.2 Location

EPA-1 was drilled to 25 ft BLS and is located approximately 500 ft south of MW-1 (Plate 5).

6.3.2.3 Description

The well was constructed with a two-foot sump below 10 ft of 0.010-inch slotted screen below five feet of riser pipe and finished with a five-foot section of stainless steel pipe. All other casing material was schedule 40, flush thread PVC. Figure 6.8 depicts well construction details.

EPA-1 encountered primarily silty clays and silty sands to a depth of 19 ft. The top of the saturated soil zone is

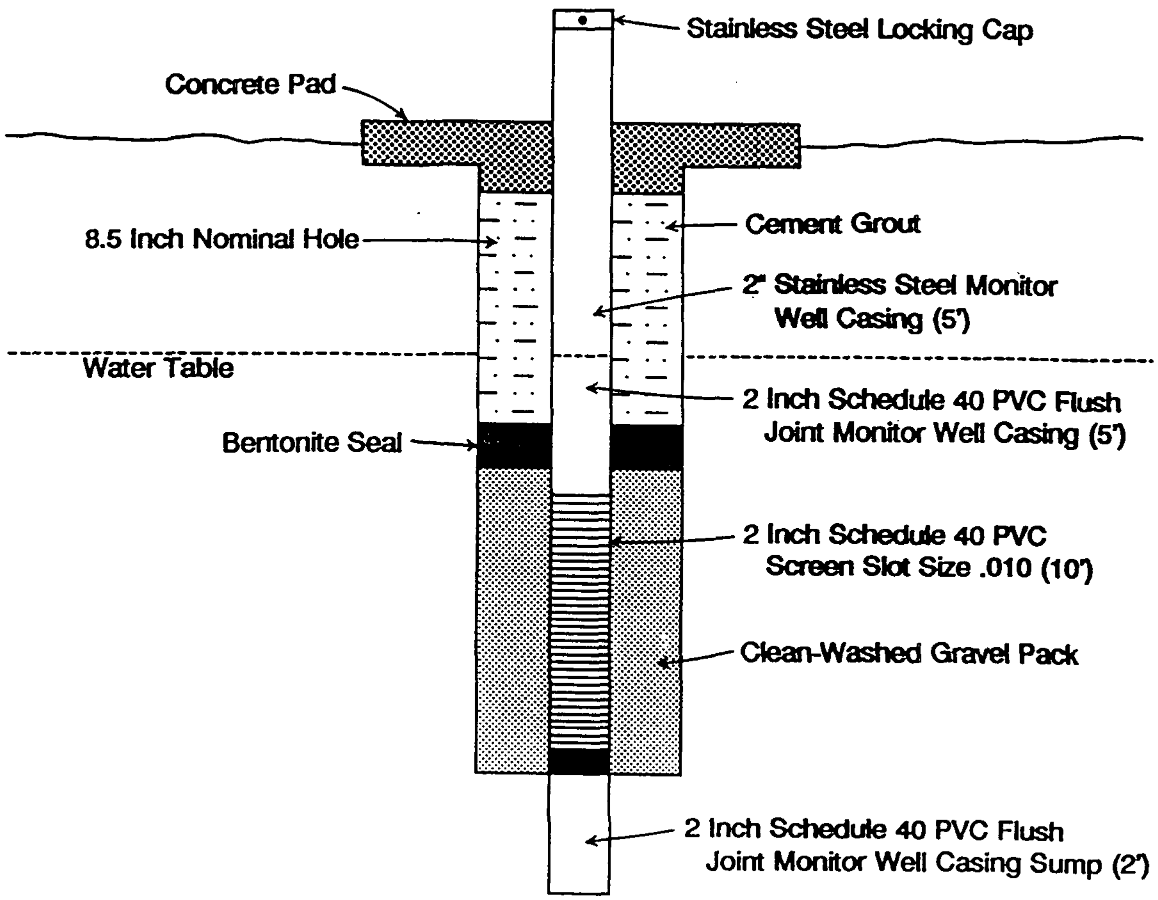


Figure 6.8 Evaporation Ponds, EPA-1 Construction Details Phase I Report, Navajo Refining Company, October 1990.

approximately six feet BLS. A lithologic log appears in Figure 6.9. Individual sample descriptions are included in Appendix 1.

6.3.3 Ground Water Sampling

Sixteen monitor wells were sampled to characterize shallow ground water quality and to provide flow direction and gradient.

6.3.3.1 Procedure

Prior to sampling, the water level was measured with an electric tape. Each well was purged by bailing until pH, conductivity, and temperature measurements stabilized. Measurements were obtained at one well volume intervals and stabilized within three to six total volumes. Samples were collected with a teflon bailer and dispensed directly into the sample containers. The sampling sequence was volatiles, semivolatiles, metals, and inorganics. Bottles were labeled, placed in plastic bags (VOCs), and secured in ice chests. Chain-of-custody forms were completed and samples shipped to the contract lab on September 20 and 23, 1990.

Monitor wells OCD-1 through OCD-8 were air lifted for approximately 30 minutes each because initial sampling attempts encountered extremely turbid water. Samples from these wells were obtained from 24 to 48 hours after development to avoid possible introduction of volatiles into the aquifer. Little turbidity improvement was noted.

6.3.3.2 Location

Locations of monitor wells sampled are shown in Plate 5.

WELL LOGGING FORM

LOCATION: Evaporation Ponds
BORING / WELL: EPA-1
START DRILLING: Sept. 22, 1990
COMPLETED: 18.0 feet
TOTAL DEPTH (BLS):
CASING DEPTH (BLS):
CASING SIZE: 2.0 inches
HOLE SIZE: 8.5 feet
DRILLED BY:
DRILLER'S LICENSE:
DISTRICT:
PERMIT #:
ELEVATION (TOC):

SCREEN SIZE-AMOUNT:
METHOD-DRLG: ROTARY ____ AUGER __X__ OTHER ____
DRILLING FLUID:
METHOD-SPLG: CUTTINGS ____ SPLT SPN ____ SHELBY ____ CORING ____
CORED INTERVAL:

LITH	DEPTH	SPL	SAMPLE DESCRIPTION	COMMENTS
	0.0-0.5		Medium brown silt, very low moisture, crumbly texture, with organic matter, rootlets. 7.5 YR 4/3.	
	0.5-0.75		Light brown silt, very low moisture, with rootlets. 7.5 YR 7/3.	
	0.75-1.67		Medium to dark brown clayey silt, stiff texture with 10 percent gypsum.	
	1.67-3.0		Light brown silt with minor gypsum, rootlets. 7.5 YR 5/4.	
	3.0-4.0		Light brown silt, very low moisture, no rootlets.	
	4.0-5.0		Coarse silt to find sand, low moisture, mottled with light gray silt with gypsum. 7.5 YR 4/4.	
	5.0-6.0		Coarse silt to fine sand, low moisture, mottled with light gray silt with gypsum. 7.5 YR 4/4.	
	6.0-9.2		Light colored silty clay, good moisture, with gypsum. 7.5 YR 6/4.	
	9.2-10.0		Light colored silty clay, good moisture, with gypsum, minor gravel. 7.5 YR 6/4.	
	10.0-13.0		No sample.	
	13.0-15.0		Fine sand, saturated. 10 YR 4/3.	
	15.0-19.0		Fine to coarse mottled sand.	

Figure 6.9 Evaporation Ponds, EPA-1 Lithologic Log, Phase I Report, Navajo Refining Company, October 1990

6.3.3.3 Description

The OCD series wells are two-inch, schedule 40 PVC wells ranging from 16 to 25 ft deep and were installed in 1988. The MW series wells are two-inch, schedule 40 PVC and stainless steel, approximately 20 feet deep, and were installed in accordance with accepted EPA standard operating procedures. Lithologic logs are included in Appendix 2 and well completion diagrams in Appendix 3. Table 6.7 provides a summary of monitoring well construction details.

6.3.3.4 Groundwater Flow Direction

Ground water flow in the shallow zone is generally to the south. Figures 6.10 and 6.11 show the changing water table surface between July and September 1990. Table 6.8 contains measured water levels. Computer contoured water levels were redrawn by hand to account for probable mounding effects caused by recharge from the evaporation ponds (Figures 6.12 and 6.13). Ground water physical parameters are presented in Table 6.9.

6.3.3.5 Ground Water Analytical Results

Volatiles

The following volatile organic compounds are analytically detectable at concentrations exceeding their respective CRDL's in ground water samples from five evaporation pond monitor wells (Table 6.10): benzene, toluene, ethyl benzene, xylenes (total), and 2-hexanone.

Benzene is detectable in one monitor well (MW-3; sample NEP-GW-005-01) at a concentration of 41 ug/l. Toluene also occurs at detectable concentrations in only one monitor well (MW-6; sample NEP-GW-008-01) at 13 ug/l.

Table 6.7 Evaporation Ponds, Monitor Well Construction Details, RFI Phase I Report, Navajo Refining Company, October 1990.

Well #	Coordinate North	Coordinate East	Year Completed	Total Depth (ft)	Casing Diameter (in)	Elevation of Top of Pipe (ft)	Screened Interval (ft)
OCD - 1	11,151.77	8,123.67	1988	25.0	2.0	3312.68	7.0-25.0
OCD - 2	11,446.35	8,713.04	1988	25.0	2.0	3312.68	8.5-25.0
OCD - 3	11,926.99	9,580.72	1988	25.0	2.0	3312.50	6.5-25.0
OCD - 4	12,510.53	10,450.08	1988	25.0	2.0	3312.23	6.5-25.0
OCD - 5	11,492.04	10,851.61	1988	25.0	2.0	3310.08	
OCD - 6	10,949.30	10,096.57	1988	25.0	2.0	3309.93	8.0-25.0
OCD - 7	10,584.02	9,617.71	1988	25.0	2.0	3309.25	3.0-25.0
OCD - 8	9,386.15	9,933.91	1988	25.0	2.0	3308.05	3.0-25.0
MW - 1	9,549.28	5,190.28	1986	20.0	2.0	3311.93	10.0-20.0
MW - 2	10,388.88	7,361.11	1986	18.0	2.0	3311.36	8.0-18.0
MW - 3	8,853.34	7,059.28	1986	17.0	2.0	3308.42	8.0-18.0
MW - 4	8,492.40	7,086.25	1986	18.0	2.0	3310.81	7.0-17.0
MW - 5	8,662.74	8,302.43	1986	19.0	2.0	3307.27	9.0-19.0
MW - 6	8,836.92	6,389.77	1986	15.0	2.0	3311.85	4.0-14.0
MW - 7	8,865.34	9,272.82	1986	20.0	2.0	3306.15	10.0-20.0
EPA - 1			1990	18.0	2.0		6.0-16.0
P87 - 1	7,860.98	7,066.33	1987	6.0-10.0	2.0	3308.17	
P87 - 2	7,877.45	8,050.46	1987	6.0-10.0	2.0	3308.22	
P87 - 3	6,860.52	6,039.77	1987	6.0-10.0	2.0	3308.74	
P87 - 4	6,906.30	7,069.94	1987	6.0-10.0	2.0	3307.14	
P87 - 13	9,017.22	10,083.78	1987	6.0-10.0	2.0	3306.47	
P87 - 14	8,013.55	10,105.91	1987	6.0-10.0	2.0	3306.60	
P87 - 15	7,874.05	8,882.25	1987	6.0-10.0	2.0	3306.52	
P87 - 16	9,081.67	9,081.67	1987	6.0-10.0	2.0	3304.78	
P87 - 17	6,980.05	10,043.43	1987	6.0-10.0	2.0	3306.91	
P87 - 19	6,891.51	8,077.86	1987	6.0-10.0	2.0	3306.99	

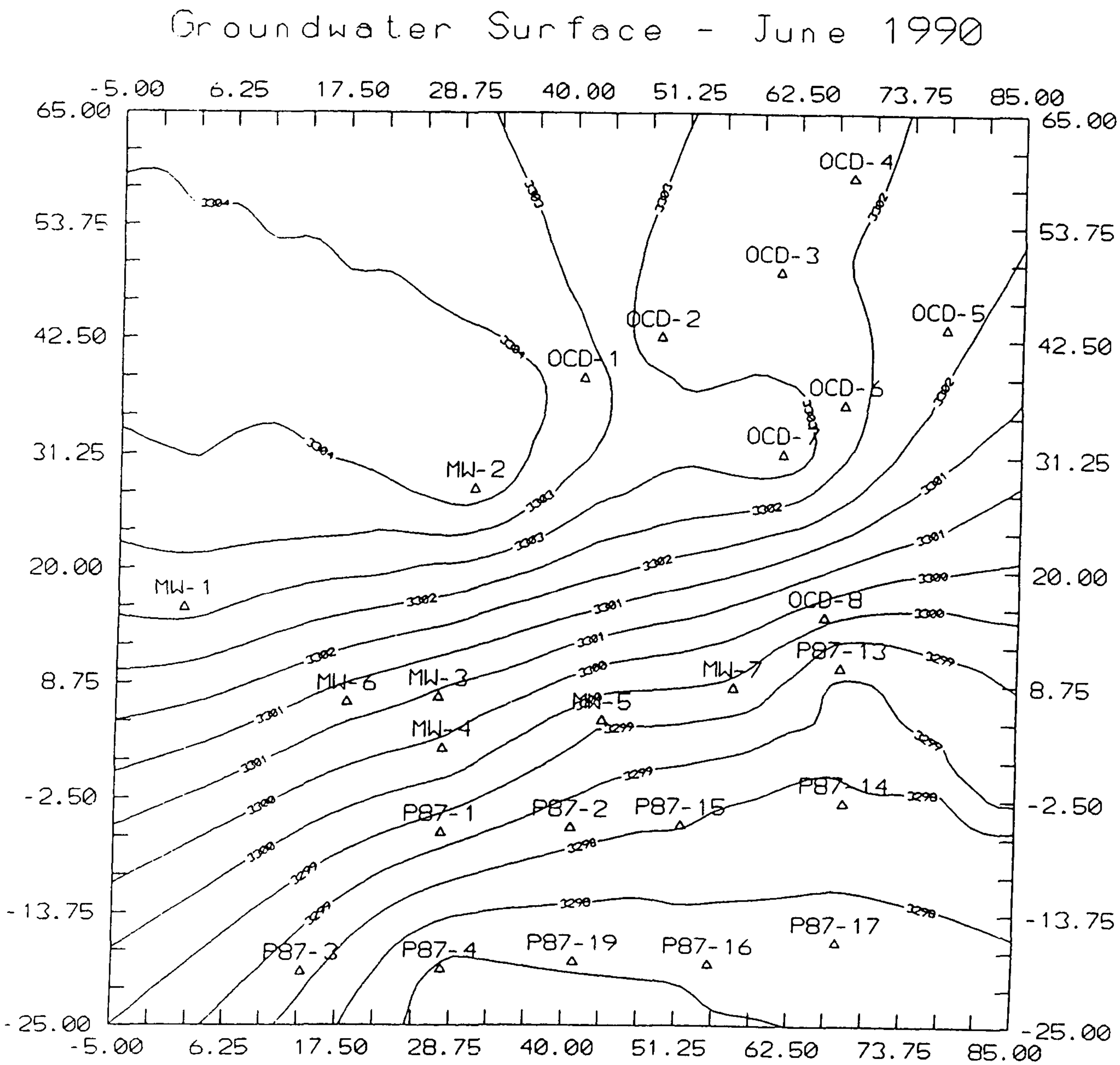


Figure 6.10 Evaporation Ponds, Water Table Surface, July 1990, Phase I Report, Navajo Refining Company, October 1990.

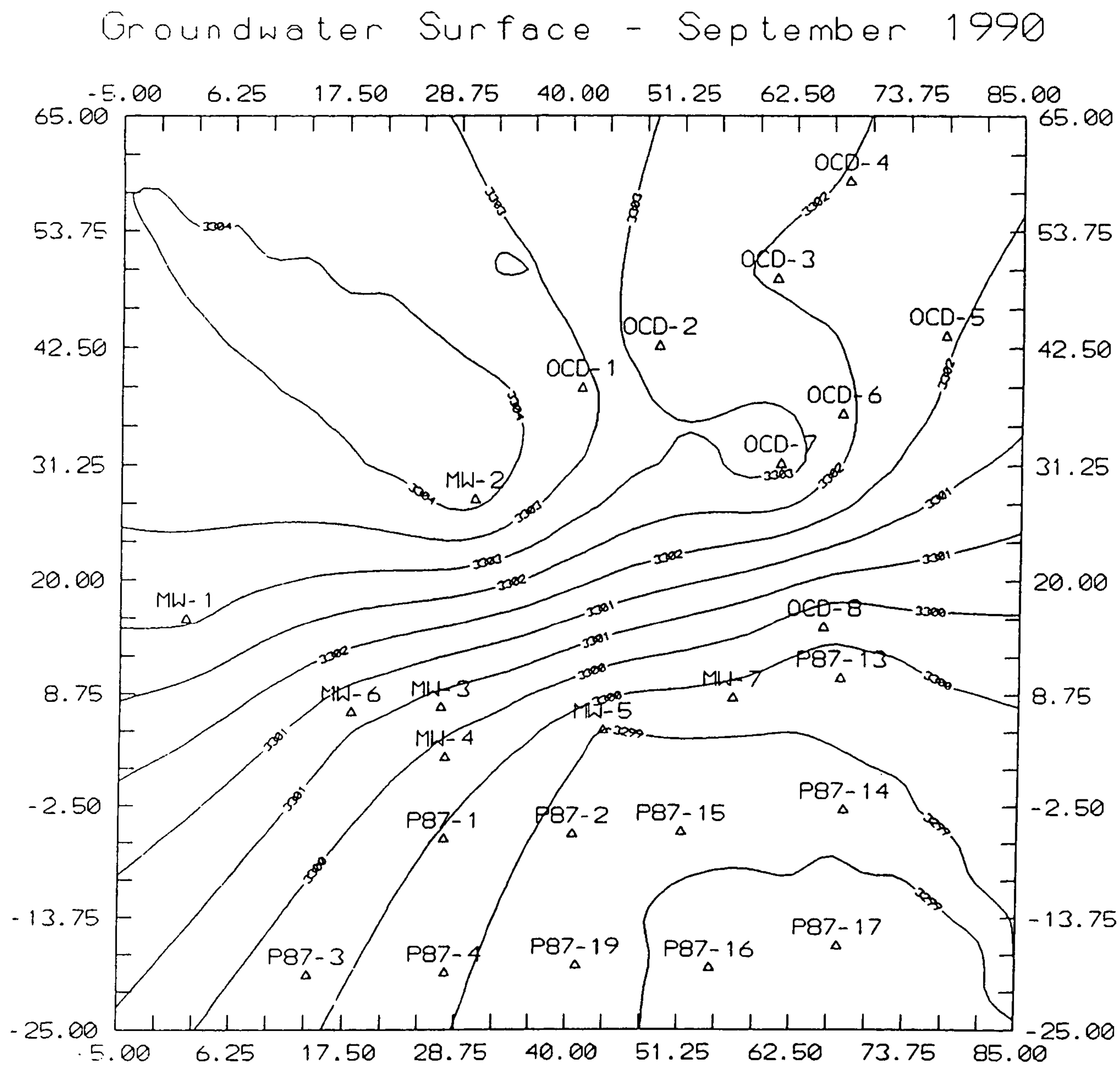


Figure 6.11 Evaporation Ponds, Water Table Surface, September 1990, Phase I Report, Navajo Refining Company, October 1990.

Table 6.8. Evaporation Ponds, Groundwater Levels
RFI Phase I Report, Navajo Refining Company, October 1990

Monitor Well Number	June 1990	September 1990
OCD-1	3303.53	3303.03
OCD-2	3302.33	3301.44
OCD-3	3302.23	3300.11
OCD-4	3302.29	3300.33
OCD-5	3301.85	3300.32
OCD-6	3302.39	3299.3
OCD-7	3303.17	3300.95
OCD-8	3299.88	3306.67
MW-1	3302.89	3300.62
MW-2	3304.07	3301.69
MW-3	3300.55	3299.13
MW-4	3300.19	3298.91
MW-5	3299.27	3998.7
MW-6	3300.93	3299.39
MW-7	3299.61	3299.37
P87-1		
P87-2		
P87-3	3298.37	
P87-4	3297.03	
P87-13	3298.64	
P87-14		
P87-15		
P87-16		
P87-17		
P87-19		

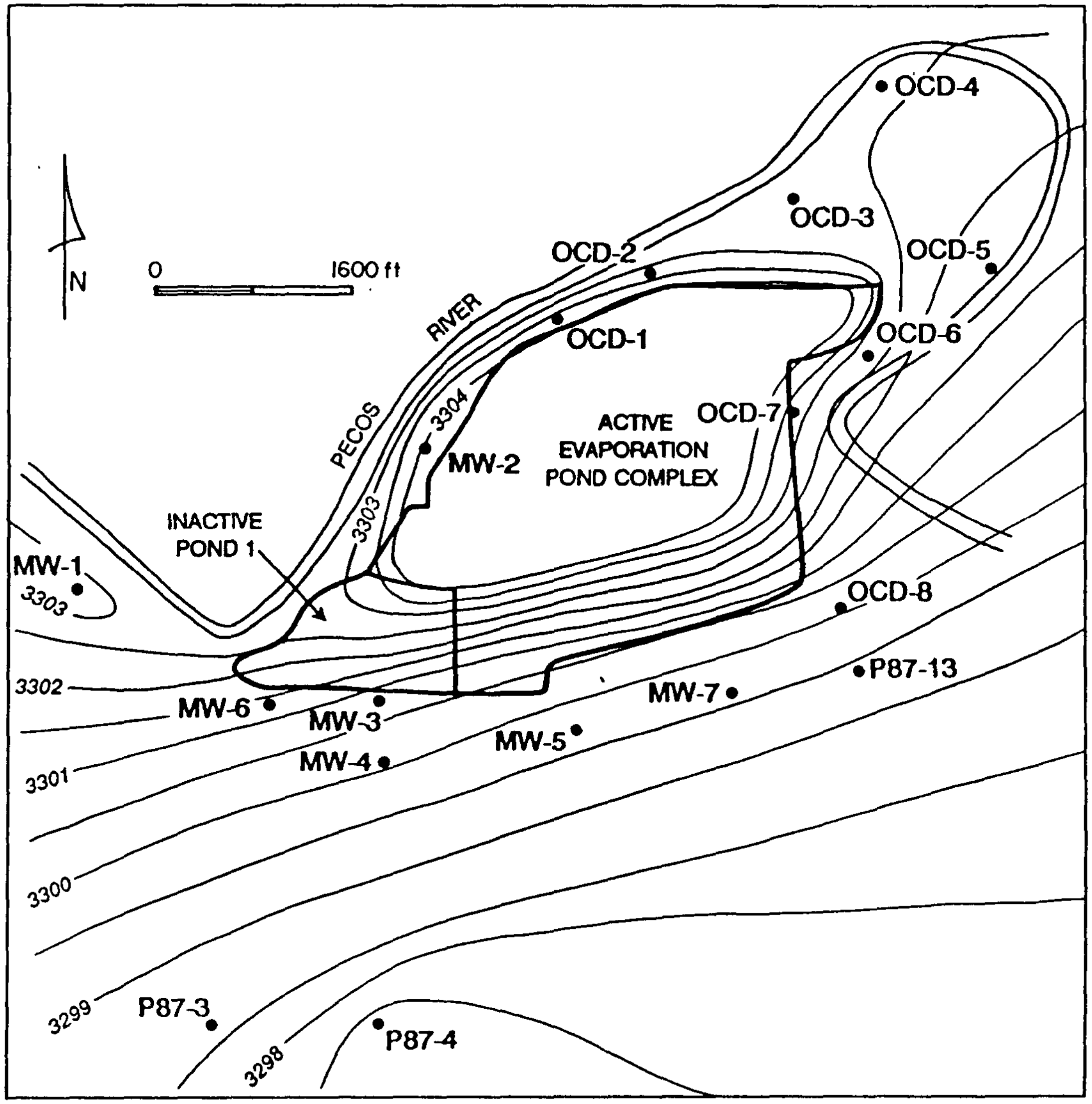


Figure 6.12 Evaporation Ponds, Water Table Surface Interpretation Map, July 1990, RFI Phase I Report, Navajo Refining Company, October 1990.

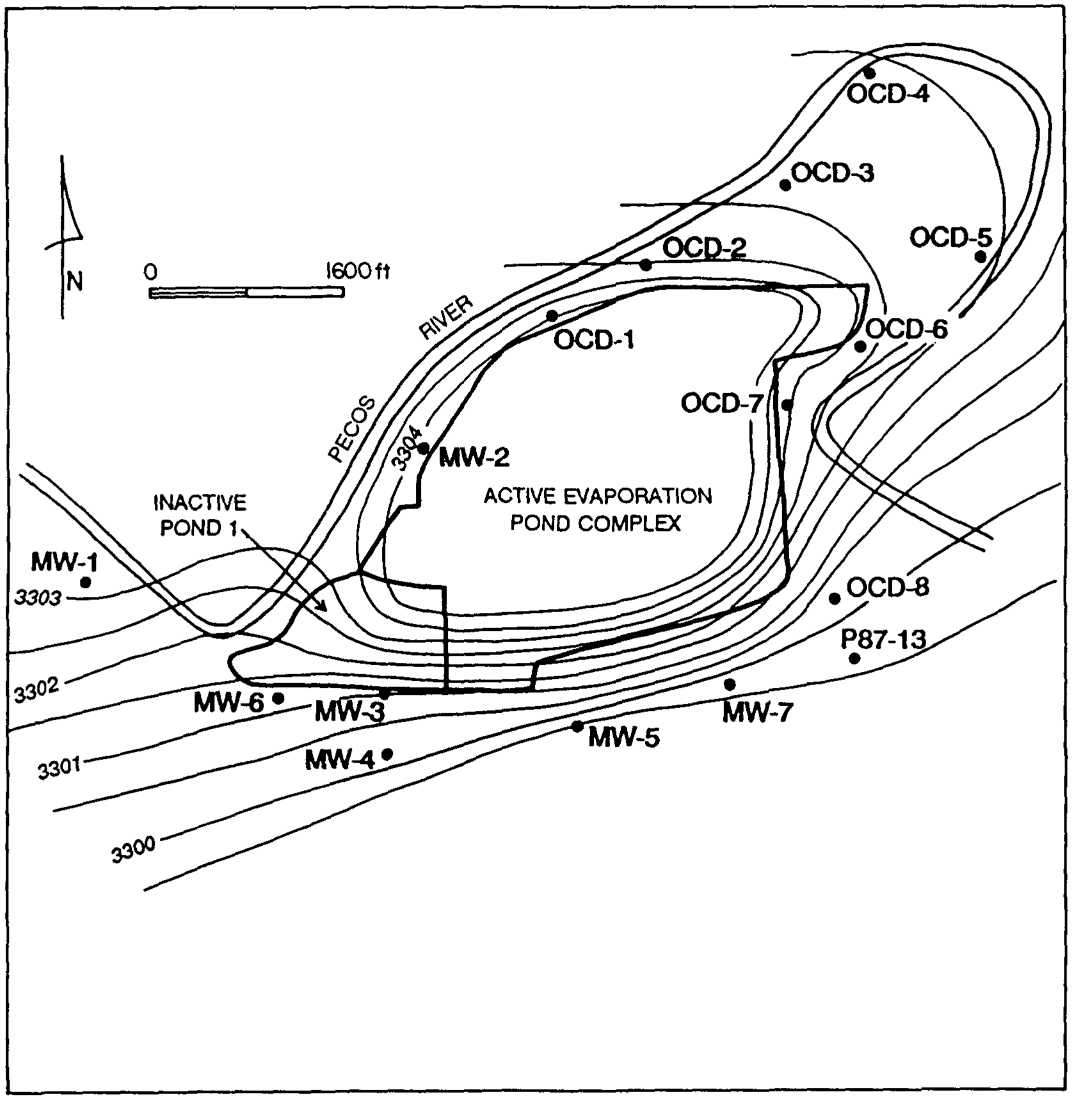


Figure 6.13 Evaporation Ponds, Water Table Surface Interpretation Map, September 1990, RFI Phase I Report, Navajo Refining Company, October 1990.

Table 6.9 Evaporation Ponds, Ground Water Physical Parameters, RFI Phase I Report, Navajo Refining Company, October 1990.

Well #	Date	Time	pH	Conductivity µmhos/cm	Temperature °C
OCD - 1	9-23	1029	7.0	11670	-
OCD - 2	9-23	1102	6.8	15300	-
OCD - 3	9-17	1850	6.8	12590	22
OCD - 4	9-23	1220	7.6	15810	-
OCD - 5	9-23	1313	7.0	11940	-
OCD - 6	9-23	1736	8.7	14750	-
OCD - 7	9-18	1010	6.6	9300	20
OCD - 8	9-23	1421	6.6	9280	-
MW - 1	9-22	1155	6.8	12800	21
MW - 2	9-22	1825	6.8	10600	22
MW - 3	9-19	1307	6.8	6300	24
MW - 4	9-22	935	7.0	6800	21
MW - 5	9-22	1037	6.8	16920	22
MW - 6	9-20	1732	7.0	4200	26
MW - 7	9-20	1839	6.7	10140	23
EPA - 1	9-23	1625	7.0	4290	-

Table 6.19. Evaporation Ponds, Groundwater Analytical Results - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		-------------- Sample Number -------------- Well Number				
		NEP-GW-000-01	NEP-GW-005-01	NEP-GW-008-01	NEP-GW-010-01	NEP-GW-021-01
COMPOUND	UNITS	OCD-3	MW-3	MW-6	MW-4	OCD-8
Benzene	ug/l		41			
Toluene	ug/l			13		
Bthylbenzene	ug/l	32		11	32	
Xylenes	ug/l	23		19	23	
2-Hexanone	ug/l		14	23		12

* Blanks and all other analyses were below reported limits.

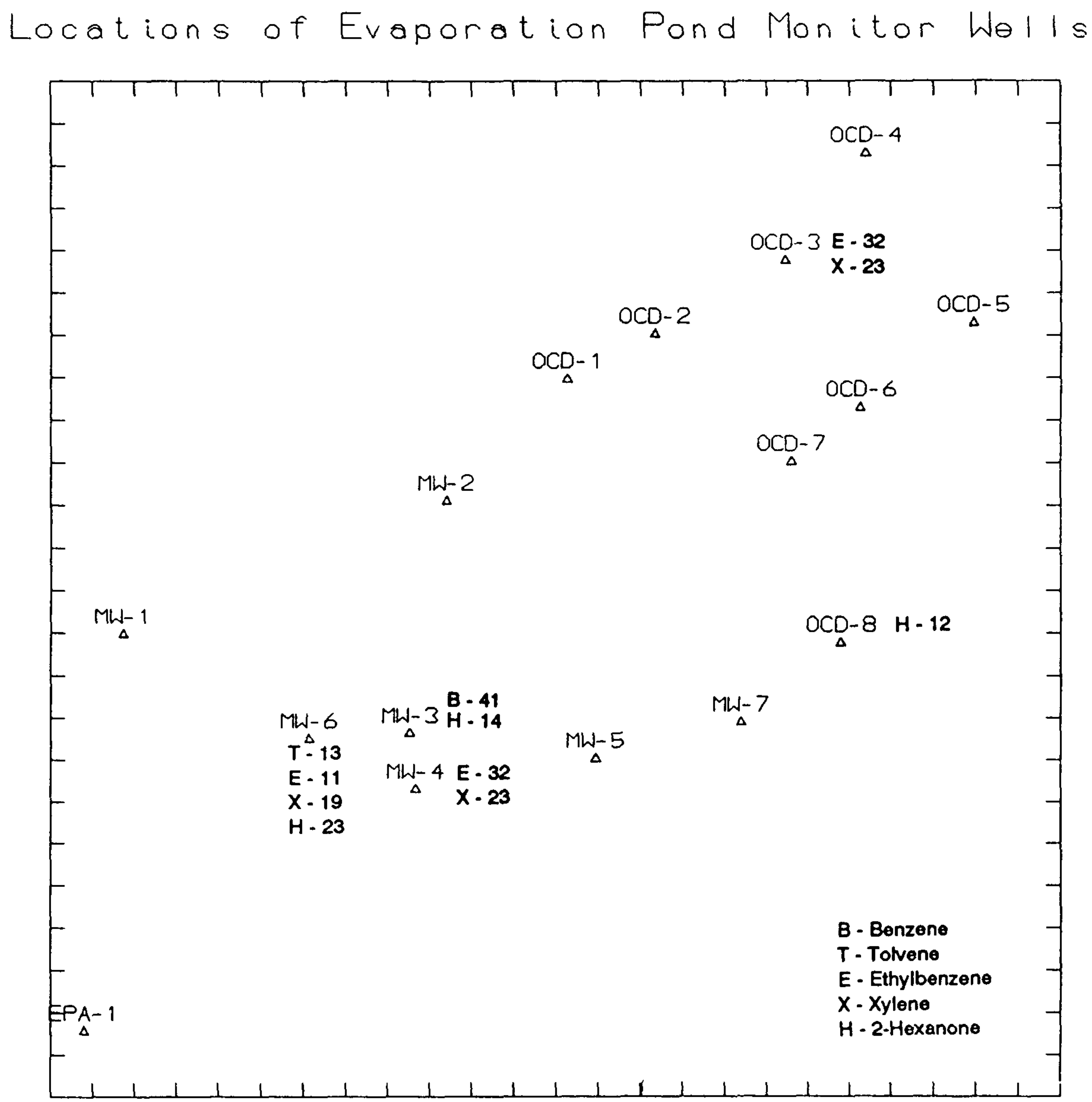


Figure 6.14 **Evaporation Ponds, Ground Water Volatiles Concentration Map, September 1990, RFI Phase I Report, Navajo Refining Company, October 1990.**

Table 6.11. Evaporation Ponds. Groundwater Analytical Results - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well									
		NEP-GW-002-01	NEP-GW-005-01	NEP-GW-008-01	NEP-GW-009-01	NEP-GW-010-01	NEP-GW-011-01	NEP-GW-019-01	NEP-GW-020-01	NEP-GW-021-01	NEP-GW-022-01
COMPOUND	UNITS	OCD-7	MW-3	MW-6	MW-7	MW-4	MW-5	OCD-5	EPA-1	OCD-8	OCD-6
Bis(2-chloroisopropyl)ether	ug/l			22							
Bis(2-ethylhexyl)phthalate	ug/l	44	22	20	17	11	16	16	14	26	20
Di-n-butyl phthalate								31			

* Blanks and all other analyses were below reported limits.

Metals

Ground water analytical summaries for metals are included as Table 6.12. At least one sample was above the CRDL for all elements except mercury and selenium. Background monitor well EPA-1 exceeded the CRDL for arsenic (0.012 mg/l), barium (0.25 mg/l), and nickel (0.02 (mg/l). Metal concentrations from monitor wells which exceed the background levels are discussed in the following section.

Arsenic ranged from 0.02 mg/l to 0.23 mg/l in monitor wells OCD-7, OCD-4, OCD-1, OCD-5, OCD-8, OCD-6, MW-3, MW-6, MW-7, MW-4, and MW-1. Barium background levels were exceeded in OCD-6 (0.56 mg/l). Beryllium was above the CRDL in OCD-6 (0.002 mg/l). Cadmium was above the CRDL in OCD-3 (0.025 mg/l). Chromium was above the CRDL in 13 wells ranging from 0.01 mg/l to 0.18 mg/l. The primary drinking water standard for chromium (0.05 mg/l) was exceeded in MW-1, MW-2, and OCD-1, at 1.0 mg/l, 0.18 mg/l, and 0.07 mg/l, respectively. Lead was above the CRDL in monitor wells OCD-7, OCD-6, MW-2, and MW-7 at 0.01 mg/l, 0.048 mg/l, 0.027 mg/l, and 0.117 mg/l, respectively. Nickel exceeded background concentration in 11 wells, ranging from 0.04 mg/l to 0.13 mg/l. Silver exceeded the CRDL in OCD-3 (0.02 mg/l), OCD-6 (0.02 mg/l) and MW-5 (0.03 mg/l). Zinc exceeded the CRDL in seven wells ranging from 0.02 mg/l to 0.15 mg/l.

A metals concentration map appears in Figure 6.15.

Inorganics

Ground water inorganic data from evaporation pond monitor wells are listed in Table 6.13. At least one of four inorganic compounds plus total dissolved solids occur in concentrations exceeding their respective analytical detection limits in 14 evaporation pond monitor wells. These same four inorganic

Table 6.12 Evaportation Ponds, Groundwater Analytical Results - Metals
RFI Phase I Report, Navajo Refing Company, October 1990

		Sample Number Monitor Well							
		NEP-GW-001-01	NEP-GW-002-01	NEP-GW-004-01	NEP-GW-005-01	NEP-GW-008-01	NEP-GW-009-01	NEP-GW-010-01	NEP-GW-011-01
METAL	UNITS	OCD-3	OCD-7	WIND MILL	MW-3	MW-6	MW-7	MW-4	MW-5
Antimony	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	<.1	0.01	<.1	<.1
Arsenic	mg/l	< 0.01	0.05	< 0.01	0.11	0.056	0.09	0.22	0.14
Barium	mg/l	< 0.10	< 0.10	< 0.10	< 0.10	< 0.01	< 0.10	0.14	0.07
Beryllium	mg/l	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cadmium	mg/l	0.025	< 0.001	< 0.001	<0.005	< 0.005	< 0.005	< 0.005	< 0.005
Chromium	mg/l		< 0.01	< 0.01	0.01	0.01	0.02	0.02	0.04
Lead	mg/l	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.117	< 0.01	< 0.01
Mercury	mg/l	< 0.001	< 0.001	< 0.001	<0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nickel	mg/l	0.01	0.02	< 0.01	0.01	< 0.01	0.01	0.07	0.07
Selenium	mg/l	< 0.01	< 0.01	< 0.01	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	mg/l	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03
Zinc	mg/l	0.073	0.037	0.038	<0.01	<0.01	<0.01	<0.01	0.03

Table 6.12 (cont.) Analytical Results. Ground Water Samples from Evaporation Ponds
Metals

		Sample Number Monitor Well									
		NEP-GW-012-01	NEP-GW-013-01	NEP-GW-014-01	NEP-GW-015-01	NEP-GW-017-01	NEP-GW-018-01	NEP-GW-019-01	NEP-GW-020-01	NEP-GW-021-01	NEP-GW-022-01
METAL	UNITS	MW-1	MW-2	OCD-4	OCD-1	OCD-2	OCD-4	OCD-5	EPA-1	OCD-8	OCD-6
Antimony	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	mg/l	0.02	0.19	0.21	0.21	<0.005	0.005	0.23	0.012	0.11	0.12
Barium	mg/l	0.06	0.05	0.08	0.1	0.02	0.06	0.07	0.25	0.15	0.56
Beryllium	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Cadmium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	mg/l	1	0.18	0.03	0.07	0.02	0.02	0.02	<0.01	0.02	0.04
Lead	mg/l	<0.01	0.027	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.048
Mercury	mg/l	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/l	0.13	0.07	0.05	0.07	0.08	0.11	0.06	0.02	0.04	0.07
Selenium	mg/l	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Zinc	mg/l	<0.01	<0.01	<0.01	<0.01	0.045	<0.01	<0.01	<0.01	0.02	0.15

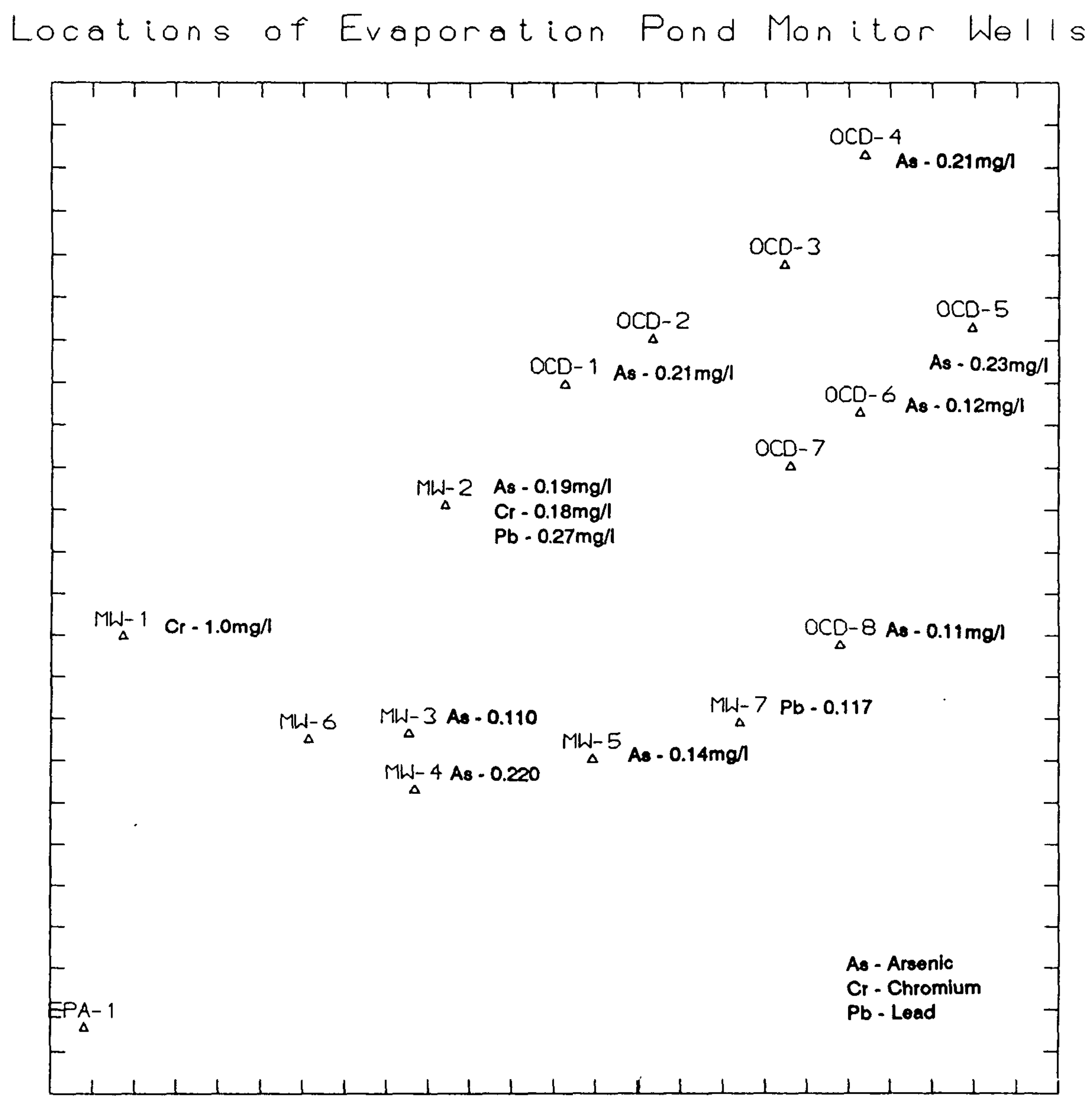


Figure 6.15 Evaporation Ponds, Ground Water Metals Concentration Map, September 1990, RFI Phase I Report, Navajo Refining Company, October 1990.

Table 6.13. Evaporation Ponds, Groundwater Analytical Results - Inorganics
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well							
		NEP-GW-005-01	NEP-GW-008-01	NEP-GW-009-01	NEP-GW-010-01	NEP-GW-011-01	NEP-GW-012-01	NEP-GW-013-01	NEP-GW-014-01
COMPONENT	UNITS	MW-3	MW-6	MW-7	MW-4	MW-5	MW-1	MW-2	OCD-4
Bicarbonate	mg/l				245	413	421	478	504
Chloride	mg/l				2130	5110	4180	2410	2130
Fluoride	mg/l				1.75	6.15	1.7	6.77	5.56
Sulfate	mg/l				2020	3530	2390	2710	2760
Total Dissolved Solids	mg/l	601	4540	1120	4060	15800	11400	6240	8760

* Blanks designate components for which no analyses were requested.

Table 6.13 (cont). Evaporation Ponds, Groundwater Analytical Results - Inorganics
RFI Phase I Report, Navajo Refining Company, October, 1990

		Sample Number Monitor Well						
		NEP-GW-015-01	NEP-GW-017-01	NEP-GW-018-01	NEP-GW-019-01	NEP-GW-020-01	NEP-GW-021-01	NEP-GW-022-01
COMPONENT	UNITS	OCD-1	OCD-2	OCD-4 Duplicate	OCD-5	EPA-1	OCD-8	OCD-6
Bicarbonate	mg/l	472	511	255	181	181	490.0	424
Chloride	mg/l	2570	4890	5600	4960	950	2550	3760
Fluoride	mg/l	4.12	1.82	1.58	1.58	1.1	1.12	1.66
Sulfate	mg/l	2130	3870	2870	2770	1220	2240	2610
Total Dissolved Solids	mg/l	8410	10100	9930	8780	3570	8640	426

compounds plus total dissolved solids occur in detectable concentrations in the background monitor well EPA-1.

Bicarbonate exceeds background concentration (181 ug/l) in nine monitor wells, and ranges from 245 ug/l to 504 ug/l (OCD-4). Chloride exceeds background concentration (950 ug/l) in 10 wells, and ranges from 2110 ug/l to 5600 ug/l (OCD-4). Fluoride exceeds background concentration (1.1 ug/l) in 10 wells, and ranges from 1.12 ug/l to 6.77 ug/l (well MW-2). Fluoride is also anomalously high in wells OCD-1 (4.12 ug/l) and OCD-4 (5.56 ug/l). Sulfate exceeds background concentrations (1220 ug/l) in 10 wells and ranges from 2020 ug/l to 3870 ug/l (well OCD-2). Total dissolved solids exceed backround concentrations (3570 ug/l) in 10 wells, and ranges from 4540 ug/l to 15,800 ug/l (well MW-5).

6.3.4 Aquifer Tests

A series of withdrawal tests was performed between September 22 and 23, 1990, to determine the hydraulic conductivity (k) of the surficial aquifer in the screened intervals of monitor wells MW-4, MW-6, MW-7, OCD-3, and EPA-1. All wells tested were two inches in diameter.

6.3.4.1 Aquifer Test Procedure

A slug was constructed of one-inch diameter PVC pipe six feet in length and filled with sand to allow it to sink in the water. The slug was capped, and nylon cord was attached at one end for use in lowering and raising. The slug displaced approximately 0.0224 cubic foot (approximately one foot of water in a two-inch well) of water when fully submerged.

A Hermit SE1000B environmental logger and a 10 PSIG pressure transducer were used to record the head difference versus elapsed time during the test. The head difference was recorded to an accuracy of one-hundredth of a foot. Elapsed time was counted using a logarithmic scale:

Elapsed Time	Sample Interval
0-2 seconds	0.2 second
2-20 seconds	1 second
20-120 seconds	5 seconds
2-10 minutes	30 seconds
10-100 minutes	2 minutes

The pressure transducer was suspended at least eight to 10 ft beneath the water level to prevent interference by the slug when it was submerged. Because only withdrawal tests (rising head) were performed, the slug was lowered into the water, secured to await aquifer equilibrium, and rapidly withdrawn immediately after starting the data logger. The test was allowed to run until near equilibrium (0.01 or 0.02 ft less than static conditions) was achieved.

Two tests were performed upon each well. A printed copy of the time versus drawdown data was retrieved from the logger via a portable printer (see Appendix 4).

The time increments measured during the tests were normalized to account for the initial period where drawdown values fluctuated due to turbulence created when the slug was withdrawn. The test data were plotted on semilogarithmic graph paper (water level change versus time), and a "best fit" line was constructed through the points (Figures 6.16-6.22).

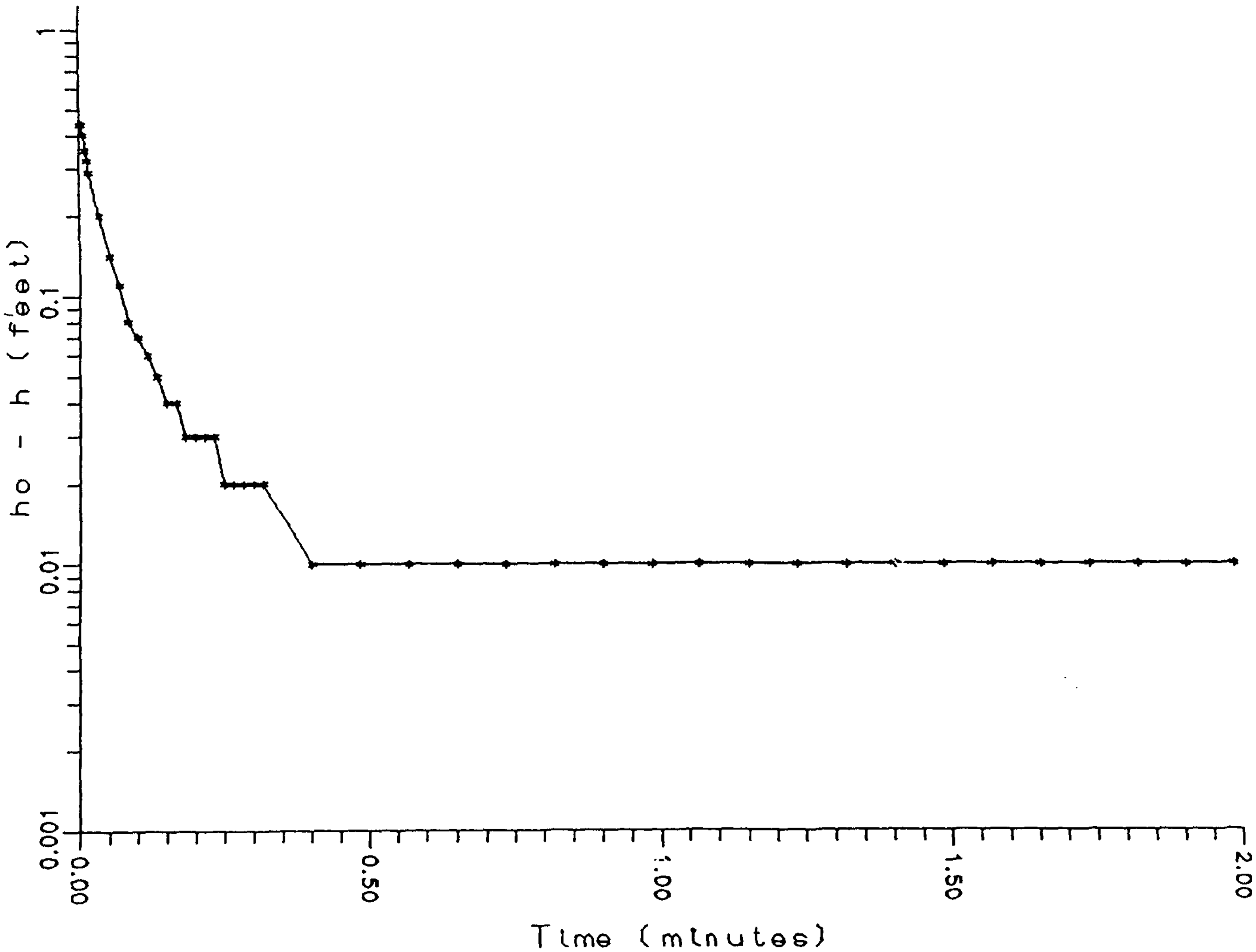


Figure 6.16 Evaporation Ponds, Aquifer Response Curve, MW-4, Test-1, Phase I Report, Navajo Refining Company, October 1990.

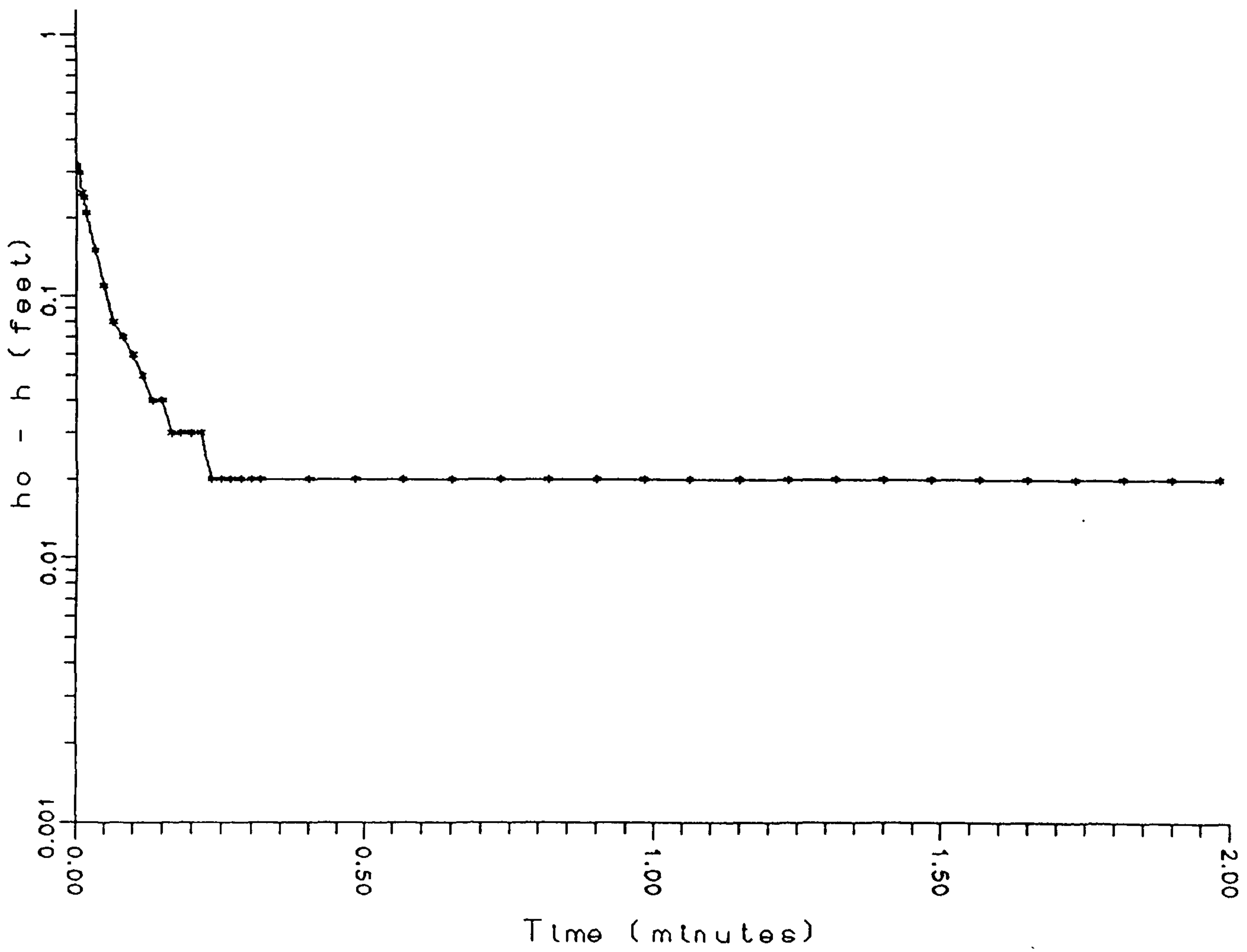


Figure 6.17 Evaporation Ponds, Aquifer Response Curve, MW-4, Test-2, Phase I Report, Navajo Refining Company, October 1990.

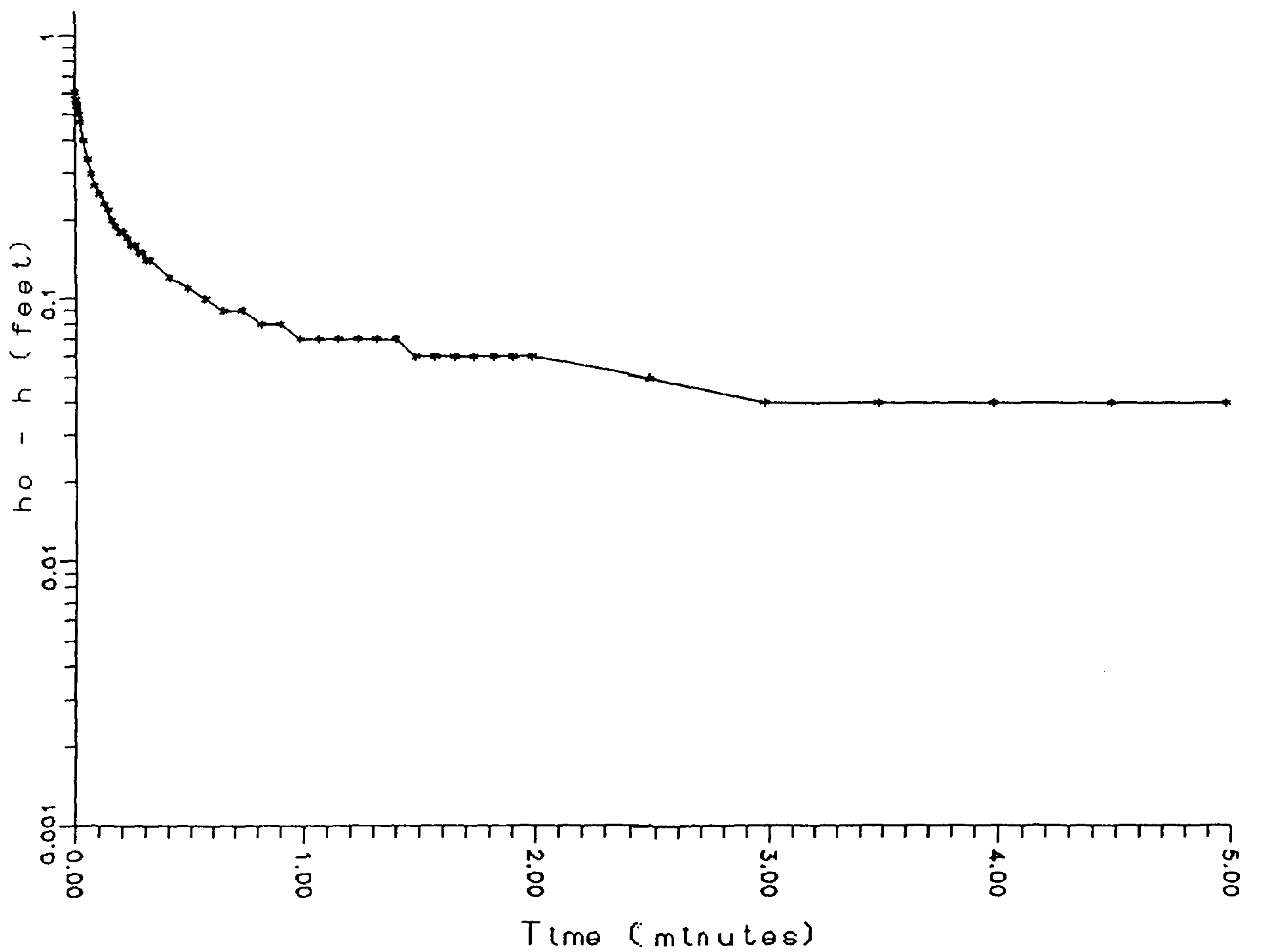


Figure 6.18 Evaporation Ponds, Aquifer Response Curve, MW-6, Test-1, Phase I Report, Navajo Refining Company, October 1990.

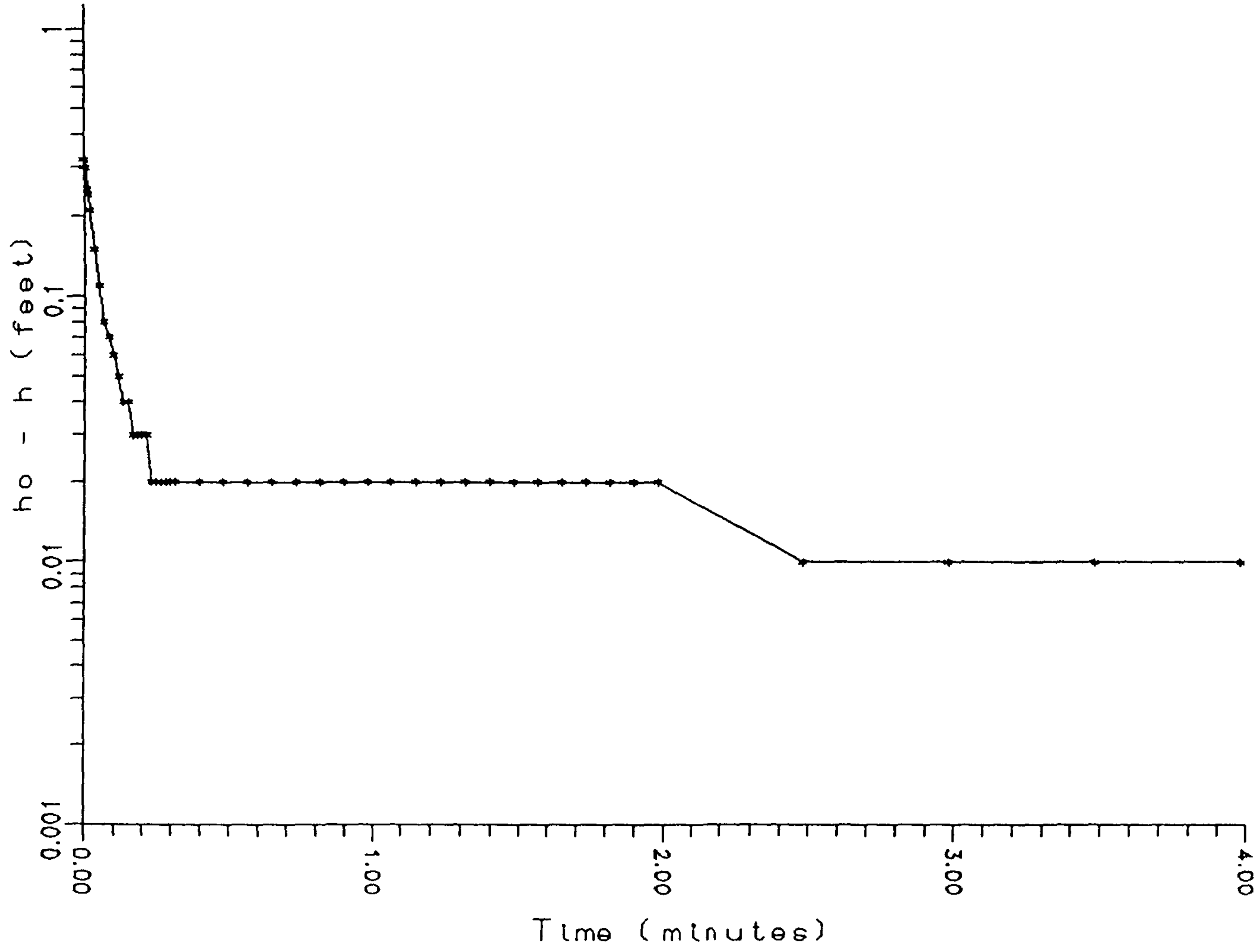


Figure 6.19 Evaporation Ponds, Aquifer Response Curve, MW-6, Test-2, Phase I Report, Navajo Refining Company, October 1990.

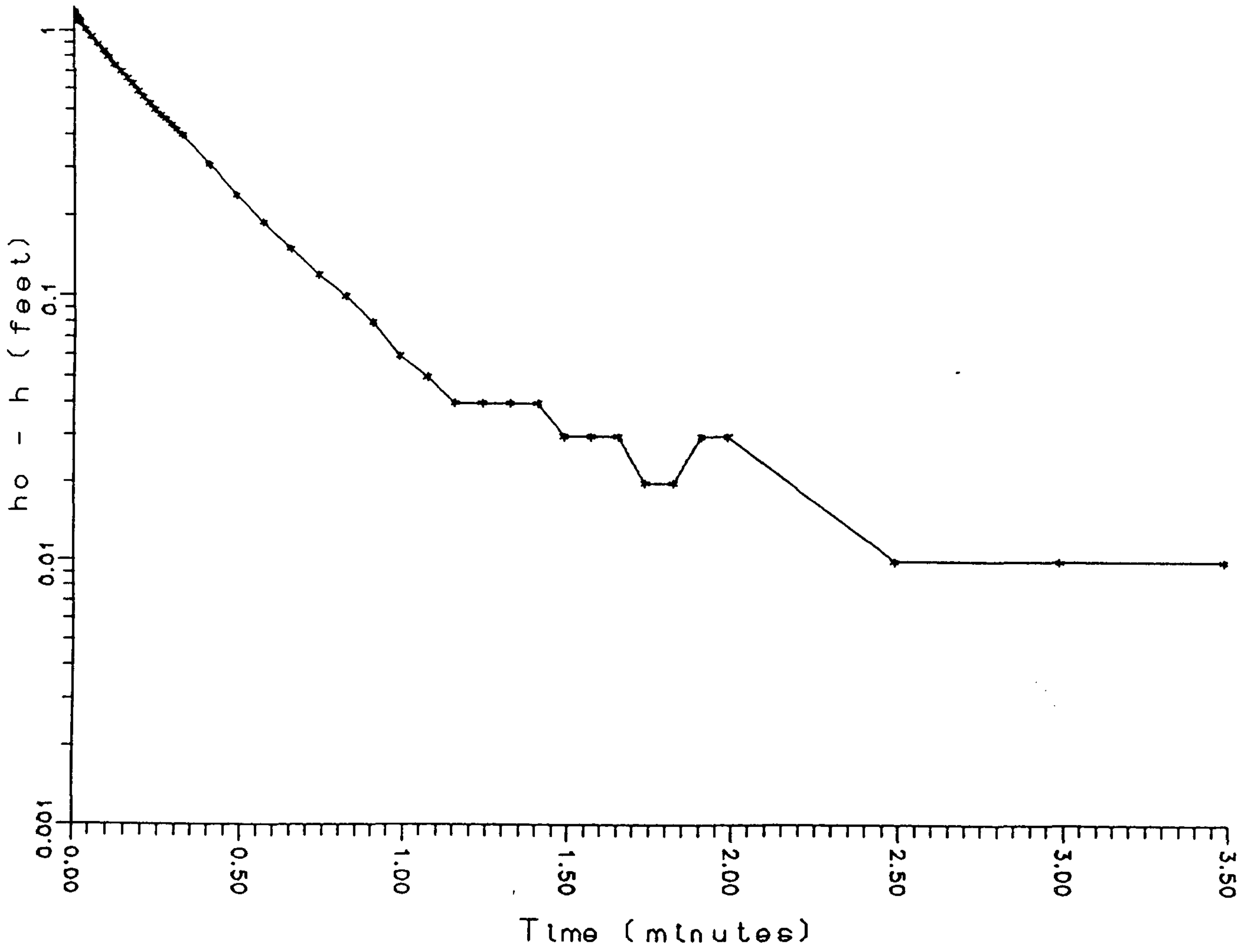


Figure 6.20 Evaporation Ponds, Aquifer Response Curve, OCD-3, Test-1, Phase I Report, Navajo Refining Company, October 1990.

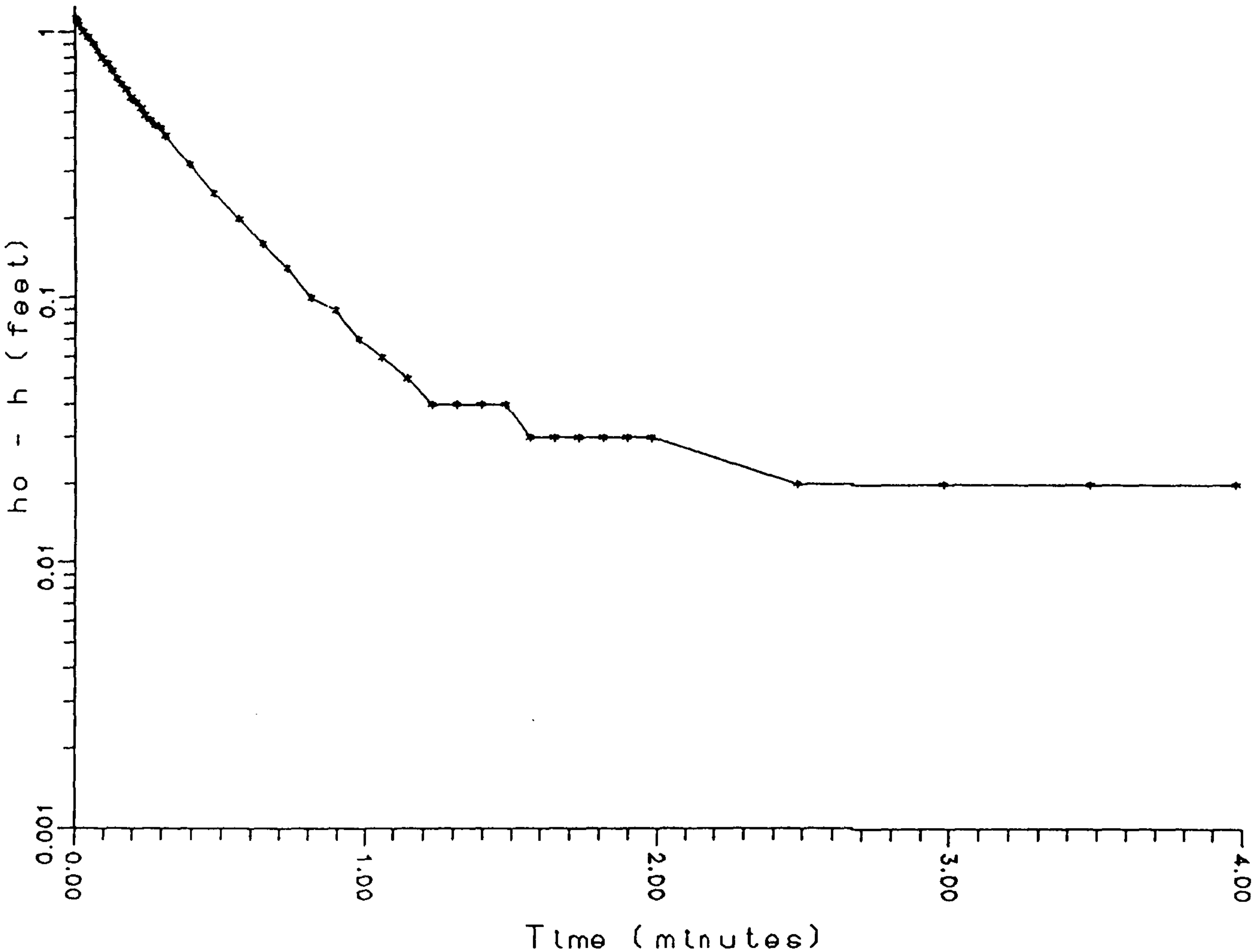


Figure 6.21 Evaporation Ponds, Aquifer Response Curve, OCD-3, Test-2, Phase I Report, Navajo Refining Company, October 1990.

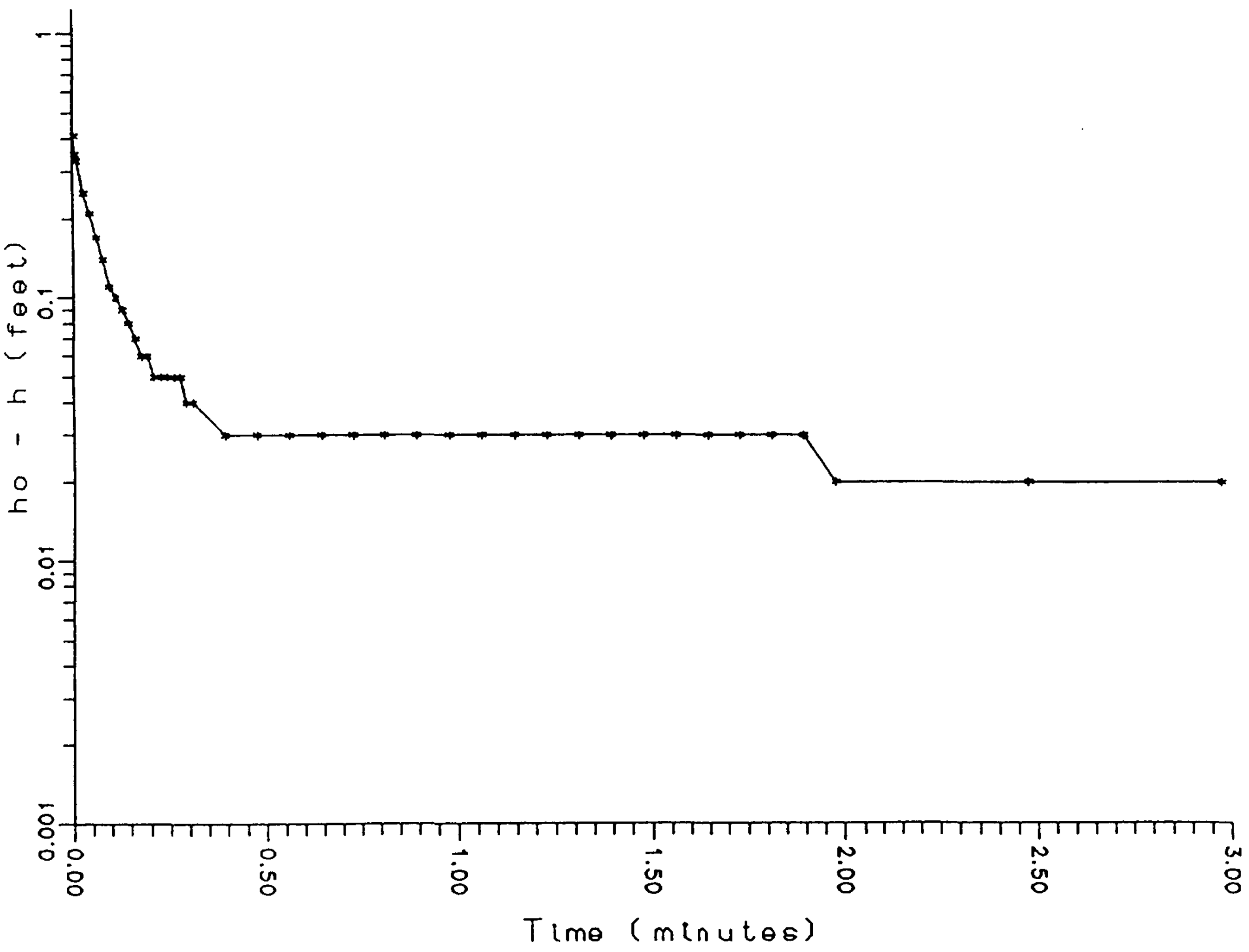


Figure 6.22 Evaporation Ponds, Aquifer Response Curve, EPA-1, Test-1, Phase I Report, Navajo Refining Company, October 1990.

As cited in Bouwer (1989) several of the tested wells exhibited a "double straight line" phenomenon. This represents the initial dewatering of the more permeable gravel pack around the screen (greater slope) and the lesser slope indicating the aquifer response with time. This second line was used to determine Y axis intercepts from the graphs.

Calculations to determine the values of ln Re/rw and hydraulic conductivity (K) were made by substituting the above mentioned graphical intercepts and well parameters into equations one and two of Bouwer and Rice (1976).

$$\ln Re/rw = \frac{1}{\dfrac{1.1}{\ln(Lw/rw)} + \dfrac{A+B\ \ln[(H-Lw)/rw]}{(Le/rw)}} \quad (1)$$

$$K = \frac{re^2 \ln(Re/rw)}{2Le} \quad \frac{1}{t} \quad \ln \frac{Yo}{Y+} \quad (2)$$

where:

A and B = Functions of flow inside the area occupied by the screen and annulus; numerical values are taken from graphs

r_c = Radius of the screen

r_w = Radius of the borehole

Le = Length of the screen

Le/rw = Ratio of screen to annulus

H = Thickness of zone of interest

Lw = Distance from the bottom of screen to top of water table

Re = Affective radial distance over which the head difference is dissipated

t = Time

Yo/Y+ = Head difference

6.3.4.2 Aquifer Test Results

Calculated aquifer parameters appear in Table 6.14. Hydraulic conductivity (k) ranged from 1.26×10^{-5} to 3.12×10^{-4} ft/sec in the 10 foot-thick zones represented by the screened intervals of MW-4, MW-6, MW-7, OCD-3, and EPA-1. Since thickness of the saturated zone is unknown k was calculated for assumed dimensions of 100 and 200 ft. A Darcy velocity was then calculated from the hydraulic gradient measured in September 1990 and an assumed porosity of 30%:

$$v = -\frac{k\,dh/dl}{\theta}$$

where: v = average velocity
k = hydraulic conductivity
dh/dl = hydraulic gradient
θ = effective porosity

Average velocities ranged from 3.63 ft/yr in EPA-1 to 49.19 ft/yr in MW-6.

Table 6.14 Evaporation Ponds - Aquifer Parameters.

Well Number	Assumed Aquifer Thickness	Hydraulic Conductivity (k) (ft/sec)	Average Groundwater Velocity (v) (ft/yr)
MW-4	200	1.15×10^{-4}	
MW-4	100	1.17×10^{-4}	18.45
MW-4	200	8.27×10^{-5}	13.04
MW-4	100	8.41×10^{-5}	13.26
MW-6	200	3.07×10^{-4}	48.41
MW-6	100	3.12×10^{-4}	49.19
MW-6	200	4.56×10^{-5}	7.19
MW-6	100	4.61×10^{-5}	7.27
MW-7	200	3.06×10^{-5}	4.83
MW-7	100	3.10×10^{-5}	4.89
MW-7	200	1.26×10^{-5}	1.99
MW-7	100	1.27×10^{-5}	2.00
OCD-3	200	2.27×10^{-5}	3.58
OCD-3	100	2.30×10^{-5}	3.63
OCD-3	200	2.62×10^{-5}	4.13
OCD-3	100	2.66×10^{-5}	4.19
EPA-1	200	2.90×10^{-5}	4.57
EPA-1	100	3.06×10^{-5}	4.83
EPA-1	200	2.18×10^{-5}	3.47
EPA-1	100	2.30×10^{-5}	3.63

7.0 ENVIRONMENTAL IMPACTS DISCUSSION

7.1 GROUND WATER

7.1.1 Truck Bypass Landfarm

Ground water analytical results from the Truck Bypass Landfarm reflect volatile, semivolatile, and metal impact. From 0.5' to almost 4.0' of product was present on the water table in four of five wells sampled. Navajo Refining Company reports that product plumes have been documented upgradient of the landfarm (personal communication, Zeke Sherman). The likely source of impacts documented in ground water samples is not the Truck Bypass Landfarm site.

7.1.2 Three-Mile Ditch/Eagle Creek

Ground water samples collected from the vicinity of Three-Mile Ditch/Eagle Creek record significant metal impact. Monitor Wells MW-8 and MW-9, near the breached ditch berm at NMD-TR-005, contain 2.27 and 3.99 mg/l chromium respectively. Monitor well 45 near the western ditch extent contains 0.1 mg/l chromium and 1.83 mg/l lead. The source of these metal concentrations appears to be ditch sludges based on the close proximity.

The semivolatile organic compound bis(2-ethylhexyl)phthalate was present in four wells ranging from 21 to 31 mg/l. The source of this compound is unclear at this time, however phthalates are common lab or sampling procedure contaminants. Adequate review of lab QA results has not yet been accomplished.

No volatile organic compounds were above detection limits.

Several trenches record visibly contaminated soils at or below the water table; however, no ground water sampling was possible in these areas.

7.1.3 Evaporation Ponds

Metals concentrations in shallow groundwater appear to be significantly impacted by the ponds for arsenic, lead, and chromium in selected wells. Four monitor wells record arsenic concentrations from 0.21 to 0.23 mg/l; an additional five monitor wells record arsenic concentrations in the 0.100 mg/l to 0.200 mg/l range. These samples are from wells surrounding the pond complex. The mobility (solubility) of arsenic is generally greater than for other characteristic sludge metals explaining the widespread distribution. One well (MW-7) records a significant lead impact, (0.117 mg/l). One well (MW-1) documents a significant nickel impact (0.13 mg/l). Two wells show a significant chromium impact: MW-1 and MW-2, 1.0 mg/l and 0.18 mg/l, respectively.

All metals sample results were biased by the submittal of moderate to highly turbid samples. Metals problems are mostly concentrated in the downgradient southern wells; however, water table mounding effects and seasonal flow direction reversals may explain metals presence in wells to the northwest, north, and east. MW-1 may be impacted primarily by sludges in the ditch.

The pond complex impacts the shallow groundwater volatile concentrations. Low-level volatile organic compounds (benzene, toluene, ethylbenzene, xylenes, or 2-hexanone) were present in monitor wells OCD-3, MW-3, MW-6, MW-4, and OCD-8. All affected wells are located near the ponds' southern perimeter (downgradient) except OCD-3 to the north and OCD-8 to the southeast. Concentrations of individual compounds are low ranging from 11 to 41 μg/l.

The historic data review section discusses BTEX plumes documented up to approximately 2,000 ft south of the ponds. The highest previously documented xylene and toluene concentrations were up to an order of magnitude greater than those obtained in this study. Samples collected during this earlier study include results obtained from a piezometer array to the south of wells sampled for the Navajo RFI study (Plate 5).

7.2 SURFACE WATER AND STREAM SEDIMENTS

Eagle Creek water samples record no significant impact for metal analysis. All values are near or below background levels.

Eagle Creek sediment samples were near background or below detection limits for metals of interest except for one sample (NEC-SS-004-01, 69.3 mg/kg, lead). Semivolatile and volatile organic data tables were unavailable at the time of this report submittal.

7.3 SOILS

7.3.1 Truck Bypass Landfarm

Truck Bypass Landfarm activities do not significantly impact soils underneath the landfarm for any of the metals analyzed. Background metal concentrations are exceeded only in the uppermost sampling interval, reflecting incorporation of landfarm deposit material.

Semivolatile organic compounds are detected mostly from the uppermost two samples within the landfarm (down to 4' BLS). Typical oil sludge components were found due to incorporation of landfarm deposit material, except in NLF-SB-011-04 (2,4-dinitrotoluene, 0.76 mg/kg; fluorene, 0.69 mg/kg; and phenanthrene, 1.3 mg/kg) and NLF-SB-008-03 (anthracene, 0.72 mg/kg). Di-n-butylphthalate was found throughout several borings but may be attributable to laboratory contamination. Low-level volatile organic compounds were detected in only one soil boring (NLF-SB-011-04) below the four-foot level.

The landfarm appears to be functioning properly with only minimal organic impact to underlying soils.

7.3.2 Three-Mile Ditch

Metals impact to soils from the ditch appears insignificant. Where samples could be collected below the sludge layers metals are near background levels within the sludge zones chromium and lead range from moderately anomalous (100 mg/k) to very high >5,000 mg/kg.

Significant semivolatile organics impact to soils also is limited to those zones containing visible sludge. Where samples could be obtained underneath sludge zones organics are below reported limits except in one case where low levels were recorded.

Volatile organic concentrations were below reported limits in samples collected below sludge zones (except for NMD-TR-010-05 a duplicate of NMD-TR-010-04, which was clean). Samples from zones containing sludge range up to 120 mg/kg xylene but most compounds are less than 10 mg/kg or are below reported limits. The age of ditch sludge appears to control the low levels of volatile organic compounds reported.

7.3.3 Evaporation Ponds

The few samples (5) collected from surficial soils do not record significant levels of metals, oil or grease. Recent grease breaches of pond berms were not recognized and surficial soils appear unaffected.

8.0 FINAL QUALITY ASSURANCE/QUALITY CONTROL REPORT

8.1 SUMMARY OF QUALITY ASSURANCE PROJECT PLAN (QAPP)

8.1.1 Introduction

The purpose of the QAPP was to document the quality assurance requirements applicable to the consulting services provided by Mariah and its subcontractors to Navajo for the Navajo refinery RFI Phase I. The plan described the requirements of the QAPP for organizing, planning, performing, reviewing, and documenting activities which affected the quality of work conducted during the project by personnel, consultants, and subcontractors of Mariah. It was intended that this plan incorporate the requirements of the EPA. The scope of the plan included field sampling, analytical testing, equipment maintenance, data reduction, and reporting.

The QAPP applied to all work performed by Mariah and subcontractors as authorized by Navajo, whether performed at the site or in any office or laboratory.

8.1.2 Objectives

The samples, the data generated from the samples, and the site-generated data must provide the information necessary to complete the site summary. Since all data are subject to some error such as sampling analysis errors, faulty selection of sampling sites, or inappropriate data reduction, control or recognition of these errors is important in analyzing the data and in preparing the final summary.

Quality assurance objectives for measurement data generally are expressed in terms of accuracy, precision, completeness, representativeness, and comparability. Definitions and descriptions of these characteristics are provided below.

Accuracy and Precision

Accuracy is a measure of the system bias. Bias is defined as the difference between the mean (average) of the true sample values and the mean (average) of the laboratory analyses. The exact system bias never will be known since the true sample values are not accessible; however, inferences can be drawn from an examination of field blank and trip blank analyses and of laboratory matrix spiked sample analyses. Field blanks measure the bias introduced by contaminated equipment, sample handling, shipping, and laboratory procedures. Trip blanks measure the bias introduced by field, shipping, and laboratory procedures. Spike samples measure biases in laboratory analyses.

Acceptable accuracy measures are dependent upon the sample matrix. Accuracy measures are not meaningful for the screening tests conducted in the field based on the semiqualitative/semiquantitative data acquired from the PID and based on the nature of the pH, temperature, and conductivity meters. Accuracy of the meters was checked by calibrating prior to daily use.

Precision is a measure of the variability of individual sample measurements. Precision can be inferred through the use of matrix spike duplicate samples. If duplicate samples contain identical contaminant concentrations, any variability in the laboratory analyses must be due to variability induced by sampling, handling, or laboratory procedures.

Acceptable precision values are dependent on the sample matrix. Precision values for field screening are not meaningful based upon the lack of reproducibility of the samples. Field screening was performed in real time mode, thus making duplication difficult for the PID and other field instruments. The pH, temperature, and conductivity meters are continuous readout instruments; duplicate readings of the sample would not yield precision values.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected under normal conditions. Completeness usually is expressed as a percentage.

Mariah's goal for this project was 100 percent completeness. However, sampling problems, analytical problems, and the data validation process all contributed to missing data.

Comparability

Comparability expresses the confidence with which one set of data can be compared with another. Comparability can be related to precision and accuracy as these quantities are measures of data reliability. No attempt was made to quantify the relative reliability of data obtained during historical studies. Comparability was evaluated by reviewing duplicate samples for a given medium and a given sampling series. Duplicates that correlated well with their respective samples were considered to possess higher comparability than those duplicates that did not correlate well with their respective samples. Qualitatively, data subjected to strict QA/QC procedures were deemed more reliable than other data.

Representativeness

Representativeness is the degree to which a set of data accurately reproduces the characteristics of the population. Data usually are considered representative if the sample distribution is within statistically defined bounds of the population mean and variance.

8.1.3 Summary of Final QA/QC Report

Included in this section is a review of the following programs performed during the remedial investigation of the Navajo site: sampling procedures, lab procedures, and audits. Also included is an evaluation of each of these programs.

8.2 SAMPLING PROGRAM

8.2.1 Introduction

There were several sampling events (qualitative/quantitative) during the RFI including:

- Monitor wells
- Soil borings
- Trench soils
- Surface water
- Stream sediments

8.2.2 Sampling Procedures

Preliminary sample locations were predetermined for some tasks based upon available data and/or project data objectives. For other tasks, sample locations were determined in the field. For each task, locations of all samples were referenced to marked grid stakes and/or permanent ground features and landmarks. These measurements were included in the sample log books.

Sampling protocol generally followed Standard Operating Procedures (SOPs) as described in the Work Plan. Exceptions to the

SOPs were documented to the Navajo and EPA through written correspondence. The activities during each sampling event, along with any field measurements (pH, temperature, specific conductance), were noted in a field log book. Proper decontamination practices were carefully followed.

After the samples were collected, they were tagged with identification labels, placed in plastic bags, and sealed for shipment. The samples then were placed in ice chests; packing material was added to the ice chests to prevent breakage and leakage. Chain-of-custody forms were completed and added to the ice chests to further ensure the integrity of the samples until they arrived at the laboratory. The samples were shipped via overnight delivery to Professional Service Industries, Inc., Deer, Park, Texas.

8.3 ANALYTICAL PROGRAM

8.3.1 Summary of Analytical Program

Chemical analyses were performed by Professional Service Industries, Inc., Deer Park, Texas. Samples were sent to the laboratory within two days of collection. Once the samples arrived at the laboratory, the analysis coordinator verified that the incoming samples corresponded to the chain-of-custody form accompanying the samples. Additionally, he inspected the samples and annotated the condition of each sample; he also noted the analyses required for each sample.

Analyses were performed at the laboratory according to specifications detailed in the Work Plan. After analyses were complete, the data was reviewed. The data review included three tasks: 1) an evaluation of the method blanks, surrogate spikes, quality control samples, and holding times; 2) an examination of the results, including an inspection of the chromatograms, the spectra, and the adsorption traces; 3) a certification of the results; which required the analytical coordinator to selectively recalculate results to ensure that the calculation was performed properly (approximately one calculation was verified for every 20 samples analyzed).

Upon completion of the review of the analytical program, the verified data were transferred from analytical data sheets to reporting forms. These reports were delivered to Navajo for review. The data packages included summaries of the analyses of the samples and of all blanks. Backup data also were included as were summaries of the precision and accuracy results.

8.3.2 Review of Analytical Program

Review of the data indicates that overall results of the analytical program generally were within limits specified in the Work Plan. Compliance with respect to duplicates, matrix surrogate spikes, and quality control samples was adhered to. All samples were analyzed according to the Work Plan.

8.4 AUDITS

Audits were performed to review and evaluate the adequacy of the QAPP and to ascertain whether it was being completely and uniformly implemented. The objectives of performance and system audit were to ensure that the quality assurance program developed for this project was being implemented according to the specified requirements, to assess the effectiveness of the quality assurance program, to identify nonconformances, and to verify that identified deficiencies were corrected.

8.4.1 Performance Audits

A performance audit can be defined as a review of the existing sample and quality assurance data to determine the accuracy of the total measurement system(s) or a component part of the system. The analysis of project-specific performance evaluation samples may be included in the performance audit.

8.4.1.1 Laboratory Performance Audit

The quality assurance manager (QAM) was responsible for monitoring and auditing the performance of the QA procedures and ensuring that the project was performed in accordance with the data quality objectives. The LLP procedures are subject to audits by the EPA. Navajo contractor, Earth Technology Corp., Houston, Texas performed the laboratory audit. Results of that audit and are included in Appendix 5.

8.4.1.2 Field Performance Audit

During the RFI, a field performance audit was conducted by the Mariah QA/QC officer. During this audit, the QA/QC officer observed and reviewed the procedures being used for surface water and sediment sampling. The audit was conducted June 22, 1987.

8.4.2 Systems Audits

Systems audits consisted of an evaluation to determine if the components of the measurement system(s) were properly selected and were being used correctly. The systems audits included a careful evaluation of field and laboratory quality control procedures.

8.4.2.1 Laboratory Systems Audits

Laboratory systems audits were conducted on a regular basis by the Professional Service Industries analysis coordinator. The analysis coordinator conducted an initial systems audit to ensure that all instruments proposed for use were properly selected for the given methods and were performed properly. This included a review of the analytical methods proposed for use and the laboratory procedures prepared for the methods. Once the initial systems audit was complete, the analysis coordinator performed the following tasks to maintain initial conditions:

- Implemented the analytical plan and ensured that all quality control measures were executed as written
- Conducted performance tests on analysts and technicians assigned to the program
- Verified that all instruments were operating properly
- Verified that proper chain-of-custody procedures were used for all incoming samples
- Ensured use of proper decontamination and cleanup procedures
- Ensured maintenance of all records

8.4.2.2 Field Systems Audit

A field systems audit was conducted by the QA/QC officer. During this audit, field equipment selection was reviewed. A report was generated which included a summary of the audit as well as the findings.

8.5 CORRECTIVE ACTION

Overall compliance with the Work Plan with respect to sampling and analysis programs was maintained throughout the RFI. No corrective actions were needed.

8.6 OVERALL RESULTS OF QAPP

Overall, compliance with the Work Plan and QAPP was maintained. The following section describes deviations from the Work Plan.

Conductivity, pH, and temperature were not measured in Monitor Wells 39, 40, 41, and 42. Samples were obtained through decanting small volumes of water from the base of disposable polyethylene bailers after purging 4 - 7 well volumes. Aquifer tests were not performed. Monitor Wells 39, 40, 41, and 42 contained from 1-4 feet of heavy product. Due to difficulty in obtaining sufficient equipment decontamination and potential damage to probes and pressure transducer, Navajo requested the variance described above (personal communication, September 22, 1990, with Zeke Sherman, Navajo Refinery).

Monitor Well 43 was not sampled due to insufficient water (i.e., contained product only) (approved, personal communication, September 22, 1990, with Zeke Sherman, Navajo Refinery).

The prescribed upgradient monitor well was not installed because an existing monitor well was of appropriate construction and location. Samples were collected as part of Navajo's quarterly monitoring program (personal communication, September 19, 1990, with Zeke Sherman, Navajo Refinery).

Static water levels were not obtained from piezometers. Water level measurements from June 11, 1990 were used to construct water table maps for the final RFI report (approved, telephone communication, October 2, 1990 with Zeke Sherman, Navajo Refinery).

Sediment samples were not collected at 1000-foot intervals from the bottom of the ditch. EPA revision of the original work plan (Section 3.1.3.2.2 Ditch Subsurface Sampling) includes sampling from the ditch surface at 1500 foot intervals (personal communication, September 11, 1990, with Zeke Sherman, Navajo Refinery).

Samples from specified intervals 2, 3, and 4 were collected from the center of the backhoe bucket to minimize safety concerns associated with personnel entering trenches with unstable walls. Trenching was not performed in a "cross-ditch" (T configuration). Trenching perpendicular to the ditch course (i.e., cross-section) provided better sampling and a statistically relevant estimate of the volume of contaminated material (personal communication, September 13, 1990, with Zeke Sherman, Navajo Refinery).

Soil borings were completed by stainless steel hand auger at three trench sites directly east of the refinery. Trenching was not feasible due to the coincident location of a buried natural gas pipeline (personal communication, September 13, 1990, with Zeke Sherman, Navajo Refinery).

Monitor Well 48 does not exist.

Monitor Well 47 was not sampled. Damage to the riser pipe below ground surface rendered the well unsuitable for sampling via bailer (personal communication, September 22, 1990, with Zeke Sherman, Navajo Refinery).

Rising-head slug tests were performed on five wells near the evaporation ponds. A Hermit data logger and pressure transducer were used instead of electric tape, providing significantly increased accuracy for rapid recovery wells (approved, telephone communication, September 7, 1990, with Rich Meyer, EPA).

Monitor Well EPA-1 was installed upgradient of the evaporation ponds. The uppermost section of riser pipe is 2" stainless steel with a locking cap. Steel protective casing and guard posts were not used because the well is located in a remote area, unimpacted by vehicular traffic (approved, personal communication, September 20, 1990, by Zeke Sherman, Navajo Refinery).

Monitor Well EPA-1 was developed by removing approximately 100 gallons over a two-hour period via air lifting. Conductivity, pH, and temperature were recorded at 20 gallon intervals. Values stabilized on the second measurement. The specified surge block-bailer method was not set because the equipment was not available (approved, personal communication, September 21, 1990, by Zeke Sherman, Navajo Refinery).

Water-level recovery measurements were not recorded during development because slug-tests were subsequently performed (approved, personal communication, September 22, 1990, by Zeke Sherman, Navajo Refinery).

The specified equipment decontamination procedure was enhanced for better insurance against cross contamination potential. Sampling equipment was washed with Seat and drinking quality water, followed by rinses in the sequence: DI water, 10% $STUD_3$ solution, DI water, and isopropenol (approved, telephone communication, September 5, 1990, with Rich Meyer, EPA).

Soil cores from the Truck Bypass Landfarm site were collected with a five-foot continuous core sampler positioned inside an eight-inch auger flight. Samples were collected directly from the interior of the core barrel in a manner intended to minimize volatile loss. The specified hammer-driven split-spoon procedure was not followed due to the unavailability of required equipment (approved, telephone communication, September 7, 1990, by Rich Meyer, EPA).

Surface water samples collected from Eagle Creek were not filtered for dissolved metals (approved, telephone communication, September 7, 1990, by Rich Meyer, EPA).

8.6.2.1 QA/QC Sample Numbering/Chain of Custody Discrepancies

Samples NMD-TR-003-01, -02, and -03 appeared twice on chain-of-custody forms and laboratory analysis sheets, and samples NMD-TR-013-01, -02, and -03 were omitted. Through the use of field log books, it was verified that samples NMD-TR-003-01, -02, and -03 were collected on September 17, 1990, at 1530, 1542, and 1605 hours, respectively, and that NMD-TR-013-01, -02, and -03 were collected on September 18, 1990, at 0850, 0935, and 1007 hours, respectively. Samples were renumbered.

Sample NLF-SB-002-01 appeared twice on laboratory analysis sheets, and sample NLF-SB-010-01 was omitted. Field logs were used to determine that NLF-SB-002-01 was collected on September 18, 1990 at 1600 hours, and NLF-SB-010-01 was collected on September 19, 1990 at 1530 hours. Samples were renumbered.

Sample NMD-SS-001-01 was mislabeled NMD-D-SS-001-01 on the laboratory sheets. Sample NMD-TRB-005-02 was mislabeled NM-TRB-005-02. Samples NLF-SB-010-02 was mislabeled NLF-010-02 on the laboratory sheets for metals analyses. Field logs were used to confirm that the time and date of collection corresponded to NLF-SB-010-02.

Samples NEC-SW-005-05, NEC-SS-005-01, NEC-SW-004-01, and NEC-SS-004-01 were mislabeled EC-SW-005-01, EC-SS-005-01, EC-SW-004-01, and EC-SS-004-01.

Two background soil borings were inadvertently labeled with the same sample numbers (NMD-SB-012). Since the samples were collected on two separate days, adequately labeled with collection date, and documented in a notebook, analytical results were identifiable per unique sample. Samples were renumbered.

Data quality objectives generally were maintained. The internal laboratory audit (Appendix 6) confirms that most matrix spike recovery limits, matrix spike duplicate recovery limits, and relative percent difference values were within specified ranges indicating acceptable precision and accuracy.

While the EPA and the Work Plan do not have specific guidances for quality of field-generated QA/QC samples, examination of duplicates, equipment blanks, and trip blanks may give an indication of the overall quality of the data. In general, data quality objectives were attained.

During field sampling activities, eight sets of duplicate soil samples and one set of duplicate groundwater samples were taken (Table 8.1). Relative percent difference (RPD) was calculated as (a-b)/[(a+b)/2] of reach pair of samples.

Relative differences between amounts of volatiles in soils duplicate samples ranges from 0.0 to 80.7 percent (Table 8.2), 0.0 to 174.68 percent for semi-volatiles (Table 8.3), 0.0 to 150.0 for metals (Table 8.4), and 50.43 to 117.95 percent for inorganics (Table 8.5).

Table 8.1 List of Duplicate Soils and Groundwater Samples RFI Phase I Report, Navajo Refining Company, October, 1990.

Soils Duplicates:	
NLF-SB-004-02	NLF-SB-004-05
NLF-SB-004-03	NLF-SB-004-06
NLF-SB-004-04	NLF-SB-004-07
NEC-SD-003-01	NEC-SD-003-02
NMD-TR-001-02	NMD-TR-001-05
NMD-TR-005-03	NMD-TR-005-01
NMD-TR-010-01	NMD-TR-010-05
NMD-TR-013-02	NMD-TR-013-05
Groundwater Duplicates:	
NLF-GW-042-01	NLF-GW-042-02

Table 8.2. QA/QC Soils Analytical Results - Duplicates - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		---------- Sample Number ------------					
		NMD-TR-010-01	NMD-TR-010-05	RPD	NMD-TR-001-02	NMD-TR-001-05	RPD
COMPOUND	UNITS						
1,1,2,2-Tetrachloroethane	mg/kg				1.2	0.51	80.70
Ethylbenzene	mg/kg	0.4	0.5	22.22			
Xylenes	mg/kg	0.4	0.3	28.57			

* Blanks and all other analyses were below reported limits.

Table 8.3. QA/QC Soils Analytical Results - Duplicates - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990
RPD is Relative Percent Difference

		----------------- Sample Number -------------------								
COMPOUND	UNITS	NLF-SB-004-02	NLF-SB-004-05	RPD	NLF-SB-004-03	NLF-SB-004-06	RPD	NLF-SB-004-04	NLF-SB-004-07	RPD
4-Bromophenyl phenyl ether	mg/kg					1.1				
Di-n-butyl phthalate	mg/kg		2.8		3.1	2.5	21.43	3	2.9	3.39

* RPD was not computed if one or both duplicates were below reported limits.

Table 8.4. QA/QC Soils Analytical Results - Duplicates - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990
RPD is Relative Percent Difference

		-------------- Sample Number ----------------					
		NLF-SB-004-02	NLF-SB-004-05	RPD	NLF-SB-004-03	NLF-SB-004-06	RPD
METAL	UNITS						
Antimony	mg/kg	< 0.50	< 0.50		< 0.50	< 0.50	
Arsenic	mg/kg	2.96	3.99	29.64	6.97	5.32	26.85
Barium	mg/kg	78.6	172	74.54	223	141	45.05
Beryllium	mg/kg	0.532	0.697	26.85	0.995	0.735	30.06
Cadmium	mg/kg	2.51	3.65	37.01	5.84	4.74	20.79
Chromium	mg/kg	< 0.30	< 0.30		4.91	3.29	39.51
Lead	mg/kg	4.43	8.3	60.80	6.3	4.82	26.62
Mercury	mg/kg	< 0.05	< 0.05		< 0.05	< 0.05	
Nickel	mg/kg	8.28	12	36.69	14.9	11.9	22.39
Selenium	mg/kg	< 0.50	< 0.50		< 0.50	< 0.50	
Silver	mg/kg	< 0.50	1.99		2.65	2.03	26.50
Zinc	mg/kg	11.8	19.9	51.10	28.2	21.5	26.96
Oil and Grease	mg/kg	0.001	0.007	150.00	0.005	0.005	0.00

* RPD was not computed if one or both duplicates were below reported limits.

Table 8.5. QA/QC Groundwater Analytical Results - Duplicates - Volatiles
RFI Phase I Report. Navajo Refining Company, October, 1990
RPD is Relative Percent Difference

		----- Sample Number -----		
COMPOUND	UNITS	NLF-GW-042-01	NLF-GW-042-02	RPD
Chloromethane	ug/l	23	12	62.86
1.2-Dichloroethane	ug/l	33	24	117.95
Benzene	ug/l	7200	4300	50.43
Toluene	ug/l	19600	7400	90.37
Ethylbenzene	ug/l	3000	990	100.75
Xylenes	ug/l	6300	1700	115.00

Because only a few samples had detectable amounts of volatile and semivolatile compounds, the QA/QC analysis of duplicates is limited to discussion of a few duplicate pairs.

Within Truck Bypass Landfarm, RPD for volatiles could not be computed for any sample pairs because levels were below reported limits. Relative differences for semivolatiles were 3.0, 3.1, and 3.39 percent for di-n-butylphthalate (Table 8.3).

Relative percent differences between Three-Mile Ditch trench duplicates for volatiles ranged from 0.0 (benzene) to 80.70 (1,1,2,2-Tetrachlorethane, Table 8.2). The range in RPD for semivolatiles was 0 (2-Methylnaphthalene and Naphthalene) to 174.68 (2-Methylnaphthalene, Table 8.3). Differences in amount of volatiles was greater than fifty percent about one quarter of the time. For semivolatiles the differences were greater than fifty percent about 41 percent of the time, and greater than thirty percent about 59 percent of the time.

Amounts of metals in duplicate samples also varied widely, from pairs having the same amount of a specific metal to RPDs up to 150.0.

In Truck Bypass Landfarm, the RPD in lead duplicates ranged from 14.02 to 60.80 (Table 8.4). The RPD in chromium could be computed in only one instance (39.51); for arsenic it ranged from 12.97 to 26.85. Differences between amount of nickel in duplicates was 13.23 to 36.69 percent. The highest RPD between duplicates in Landfarm soils was 150.0, for oil and grease.

In the Three-Mile Ditch, trench soils, RPD for lead was moderate to high, ranging from 27.45 to 100.73 (Table 8.4). Amounts of chromium differed by 26.95 to 92.76 percent, and arsenic differed by 15.38 to 55.98 percent. Paired nickel values had 2.33

to 31.52 RPD. RPD for oil and grease in Trench samples ranged from 1.4 to 74.82.

One set of duplicates was taken from sediments in Eagle Creek. RPD for lead was 97.44; for chromium, 40.35; 17.74 for arsenic; 16.33 for nickel. Analyses of oil and grease were not requested.

Relative differences in amounts of metals were above fifty percent about 27 percent of the time and above thirty percent about one half of the time. The magnitude of these differences apparently was not affected by sampling location.

In summary, differences in amounts of volatiles, semivolatiles, and metals in duplicate soils samples ranged from no difference to large discrepancies between pairs. Large differences can probably be attributed to two main factors. First, because the sites sampled are highly contaminated and soils contained a large percentage of sludge, samples were notably heterogeneous, even over a short distance. Second, because the product at these sites was relatively old, matrix interference from non-target compounds during laboratory analyses may have contributed to heterogeneity in the results. Target compounds may have been altered by chemical processes to the point were their presence was masked by existence of alteration products.

Two sets of duplicate ground water samples were collected (Table 8.1). RPDs in volatiles for the duplicate set NLF-GW-042-01 and 042-02 are high, ranging from 50.43% (benzene) to 117.95% (1,2-dichloroethane). All volatile analyses for the other duplicate set (NEP-GW-014-01 and 022-01) are BRL (Table 8.5). Differences in amounts of semivolatiles in the duplicate set NLF-GW-042-01 and 042-02 range from o.o (2,4-dinitrophenol) to 70.5 (2-methylnaphthalene). Only one semivolatile compound is detected in one of the two samples from the other duplicate set (NEP-GW-022-01, 21 ug/l), and BRL in 014-01 (Table 8.6). The only nonzero RPDs for metal analyses of the duplicate set NLF-GW-042-01 and 042-02 are lead (173.06) and nickel (46.15). There are four nonzero RPDs for the duplicate set NEP-GW-014-01 and 022-01; arsenic (54.5), barium (150.0), chromium (28.6), and nickel (33.3) (Table 8.7). RPD values for inorganic analyses of the duplicate set NLF-GW-042-01, 042-02 range from 0.55 (bicarbonate) to 114.3 (chloride). Inorganic data RPD values for the duplicate set NEP-GW-014-01, 022-01 range from 5.6 (sulfate) to 181.5 (total dissolved solids) (Table 8.8).

During RFI field activities, 10 equipment blanks and 12 trip blanks were taken in order to provide QA/QC checks on equipment decontamination SOPs and sample handling, storage, transportation, and laboratory SOPs (Table 8.9). Equipment blanks consisted of deionized water that had been poured over equipment immediately after standard decontamination procedures. Trip blanks consisted of containers of deionized water that were carried through all field activities on a given day, sample storage, transport, and laboratory procedures.

Sample NMD-TR-001-01 was a highly contaminated equipment blank (Table 8.10). It contains large amounts of 1,1-dichloroethane, benzene, toluene, ethyl benzene, and total xylenes. Volatiles were not detected in any other equipment blanks.

Bis(2-ethyl hexyl)phthalate occurred in five equipment blanks, ranging from 10.0 to 27.0 ug/l (Table 8.11). No notable amounts of metals were detected in equipment blanks, but one blank from a Three-Mile Ditch trench site contained 4.0 percent oil and grease (Table 8.12). Two equipment blanks were analyzed for inorganics (Table 8.13). One contained 1 mg/l bicarbonate and 105.00 mg/l TDS, and the other contained 79.0 mg/l TDS.

Table 8.6. QA/QC Groundwater Analytical Results - Duplicates - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990
RPD is Relative Percent Difference

COMPOUND	UNITS	----- Sample Number ----- NLF-GW-042-01	NLF-GW-042-02	RPD -----
Acenaphthene	ug/l		10	
Anthracene	ug/l	180	210	15.38
Benzo(a)anthracene	ug/l		45	
Dibenzofuran	ug/l	55	93	51.35
2,4-Dinitrophenol	ug/l	140	140	0.00
Fluoranthene	ug/l	27	40	38.81
Fluorene	ug/l	200	220	9.52
2-Methylnaphthalene	ug/l	650	640	1.55
Naphthalene	ug/l	450	940	70.50
3-Nitroaniline	ug/l	220		
Phenanthrene	ug/l	310	440	34.67
Phenol	ug/l	25	39	43.75

* Blanks and all other analyses were below reported limits.
RPD was not computed of one or both duplicates were below reported limits.

Table 8.7. QA/QC Groundwater Analytical Results - Duplicates - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990
RPD is Relative Percent Difference

		----- Sample Number -----					
COMPOUND	UNITS	NLF-GW-042-01	NLF-GW-042-02	RPD	NEP-GW-014-01	NEP-GW-022-01	RPD
Antimony	mg/l	< 0.1	< 0.1				
Arsenic	mg/l	0.13	0.13	0	0.21	0.12	54.55
Barium	mg/l	0.1	0.1	0	0.08	0.56	150.00
Beryllium	mg/l	0.004	0.004	0	< 0.001	0.002	
Cadmium	mg/l	< 0.005	< 0.005		< 0.005	< 0.005	
Chromium	mg/l	0.03	0.03	0	0.03	0.04	28.57
Lead	mg/l	0.18	0.013	173.06	< 0.01	0.048	
Mercury	mg/l	< 0.001	< 0.001		< 0.01	< 0.001	
Nickel	mg/l	0.05	0.08	46.15	0.05	0.07	33.33
Selenium	mg/l	< 0.05	< 0.05		< 0.05	< 0.05	
Silver	mg/l	< 0.01	< 0.01		< 0.01	0.02	
Zinc	mg/l	< 0.01	< 0.01		< 0.01	0.15	

* RPD was not computed if one or both duplicates were below reported limits.

Table 8.8. QA/QC Groundwater Analytical Results - Duplicates - Inorganics
RFI Phase I Report, Navajo Refining Company, October, 1990
RPD is Relative Percent Difference

----- Sample Number -----

	UNITS	NLF-GW-042-01	NLF-GW-042-02	RPD	NEP-GW-014-01	NEP-GW-022-01	RPD
Bicarbonate	mg/l	735	731	0.55	504	424	17.24
Chloride	mg/l	638	2340	114.30	2130	3760	55.35
Fluoride	mg/l	1.56	1.52	2.60	5.56	1.66	108.03
Sulfate	mg/l	2060	2300	11.01	2760	2610	5.59
Total Dissolved Solids	mg/l	3690	4750	25.12	8760	426	181.45

Table 8.9 List of Equipment Blanks and Trip Blanks RFI Phase I Report, Navajo Refining Company, October, 1990.

Equipment Blanks - Date and Time of Collection		
NMD-TRB-010-01	9-13	1545
NMD-TRB-007-01	9-14	1600
NMD-TRB-001-01	9-16	0800
NMD-TRB-005-02	9-16	1602
NLF-SBB-004-01	9-19	1450
NLF-SBB-004-07	9-19	1520
NLF-SBB-012-04	9-20	1501
NLF-GWB-042-01	9-24	0945
NEP-GWB-007-01	9-20	1505
NEP-GWB-016-01	9-22	1020
Trip Blanks - Date and Time of Collection		
NMD-TRB-002-01	9-16	1615
NMD-TRB-005-01	9-16	1551
NMD-GWB-045-01	9-22	0810
NLF-SBB-004-08	9-19	1535
NLF-SBB-004-05	9-19	1540
NEP-GWB-001-01	9-17	0845
NEP-GWB-002-01	9-19	0913
NEP-GWB-003-01	9-20	0855
NEP-GWB-004-01	9-20	1500
NEP-GWB-010-01	9-22	0830
NEP-GWB-020-01	9-22	1600
NEP-GWB-014-01	9-23	0930
NLF-GWB-040-01	9-23	0930

Table 8.10. QA/QC Analytical Results - Equipment Blanks - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

COMPOUND	UNITS	Sample Number Date Time NMD-TRB- 001-01 9-16 0800
1,2-Dichloroethane	ug/l	11
Benzene	ug/l	320
Toluene	ug/l	800
Ethylbenzene	ug/l	250
Xylenes	ug/l	1400

* All other analyses were below reported limit.

Table 8.11. QA/QC Analytical Results - Equipment Blanks - Semivolatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		---------------- Sample Number ------------- Date Time				
COMPOUND	UNITS	NEP-GWB-007-01 9-20 1505	NMD-TRB-005-02 9-16 1602	NMD-TRB-007-01 9-14 1600	NLF-SBB-004-07 9-19 1520	NLF-SBB-012-04 9-20 1501
Bis(2-ethylhexyl)phthalate	ug/l	10	12	13	27	25

* All other analyses were below reported limit.

Table 8.12. QA/QC Analytical Results - Equipment Blanks - Metals
RFI Phase I Report, Navajo Refining Company, October, 1990

		----- Sample Number / Date / Time -----									
METAL	UNITS	NMD-TRB-010-01 9-13 1545	NMD-TRB-007-01 9-14 1600	NMD-TRB-001-01 9-16 0800	NMD-TRB-005-02 9-16 1602	NLF-SBB-004-01 9-19 1450	NLF-SBB-004-07 9-19 1520	NLF-SBB-012-04 9-20 1501	NEP-GWB-007-01 9-20 1505	NEP-GWB-016-01 9-22 1020	NLF-GWB-042-01 9-24 0945
Antimony	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.10	< 0.10	< 0.10	< 0.10
Arsenic	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.005	< 0.005	< 0.01	< 0.005
Barium	mg/l	< 0.10	< 0.10	< 0.10	< 0.10	< 0.01	< 0.10	< 0.10	< 0.10	0.01	0.1
Beryllium	mg/l	< 0.005	< 0.001	< 0.001	< 0.001	< 0.01	0.01	< 0.001	< 0.001	< 0.001	< 0.001
Cadmium	mg/l	< 0.001	< 0.001	< 0.001	< 0.001	0.019	0.023	< 0.005	< 0.005	< 0.001	< 0.005
Chromium	mg/l	*	< 0.01	< 0.01	< 0.01	< 0.01	0.05	< 0.01	< 0.01	0.02	0.05
Lead	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Mercury	mg/l	*	*	< 0.001	*	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Nickel	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.03	< 0.01	< 0.01	0.05	< 0.01
Selenium	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05	< 0.01	< 0.05
Silver	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	mg/l	< 0.01	< 0.01	< 0.01	< 0.01	0.08	0.05	< 0.01	< 0.01	< 0.01	< 0.01
Oil and Grease	percent	*	< 1.0	< 1.0	4.00	*	*				

* Insufficient Sample
Blanks designate analyses that were not performed

Table 8.13. QA/QC Analytical Results - Equipment Blanks - Inorganics
RFI Phase I Report, Navajo Refining Company, October, 1990

		- Sample Number - Date Time	
COMPONENT	UNITS	NEP-GWB-016-01 9-22 1020	NLF-GWB-042-01 9-24 0945
Bicarbonate	mg/l	1.00	< 1.0
Chloride	mg/l	< 1.0	< 1.0
Fluoride	mg/l	< 0.02	< 0.02
Sulfate	mg/l	< 1.0	< 1.0
Total Dissolved Solids	mg/l	105.00	79.00

The presence of contaminants in equipment blanks may be due to several factors or combinations of factors. Of primary concern is the possibility that equipment was not properly decontaminated prior to sampling a new site, thereby contaminating subsequent samples. There also may have been impurities in the deionized water used. Finally, blanks may have been contaminated during storage or transportation, or within the laboratory during analysis.

Trip blanks were analyzed for volatiles only to insure quality control in sample handling through field and laboratory activities. Only two of the 12 trip blanks collected contained detectable volatiles (Table 8.14). NMD-TRB-005-01 contained notable amounts of toluene, ethyl benzene, and total xylenes. NMD-GWB-020-01 contained 10.0 ug/l each of benzene and toluene. Contamination may have occurred due to impure deionized water, during sample storage or transportation, or in the laboratory during analysis.

Mariah believes that all samples are representative of each medium. Locations of samples were adequately chosen. SOPs were followed, indicating representative sampling.

Compliance with the Work Plan and the QAPP was maintained except as previously outlined. Quality assurance objectives specified in the Work Plan were adhered to in terms of accuracy, precision, completeness, comparability, and representativeness.

Table 8.14. QA/QC Analytical Results - Trip Blanks - Volatiles
RFI Phase I Report, Navajo Refining Company, October, 1990

		- Sample Number - Date Time	
COMPOUND	UNITS	NMD-TRB-005-01 9-16 1551	NEP-GWB-020-01 9-23 1600
Benzene	ug/l		10
Toluene	ug/l	63	10
Ethylbenzene	ug/l	20	
Xylenes	ug/l	130	

* Blanks and all other analyses were below reported limits.

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RFI PHASE I REPORT
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