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REPORTS

DATE:

4/97

Quantification of Natural Attenuation of Petroleum Hydrocarbons in Groundwater

South For Lakes Unit
Lea County, NM

Phillips Petroleum Company
Permian Profit Center
New Mexico Asset Team
Odessa, Texas

April 1997

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Introduction

SECTION 1

Introduction

1.1 Previous Investigations

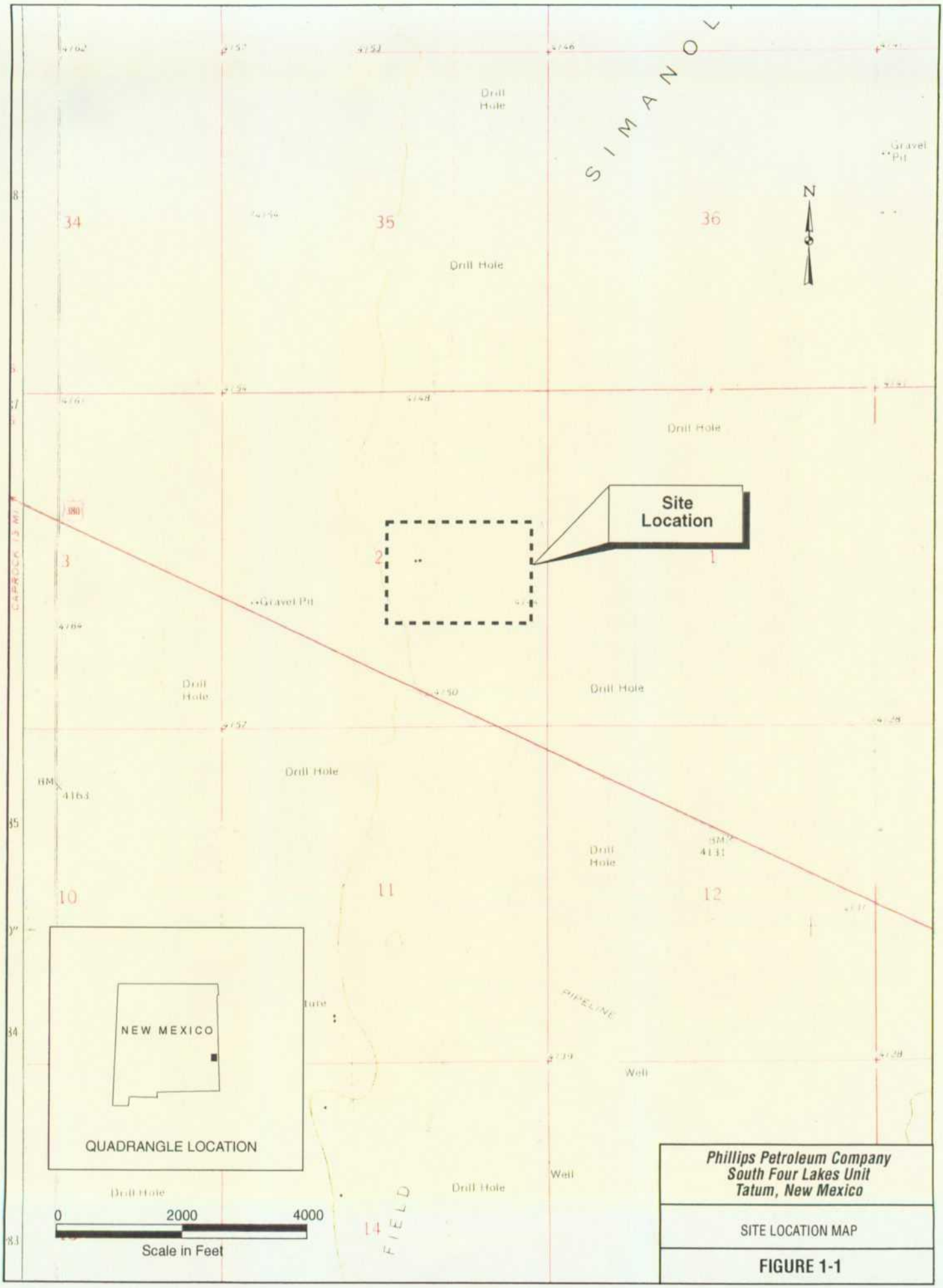
Phillips Petroleum Company (Phillips) owns and operates the South Four Lakes Unit located in Lea County, New Mexico, just north of U.S. Highway 380, approximately 10 miles northwest of the town of Tatum (Figure 1-1). The Unit is an oil and gas lease containing three active producing wells, one saltwater disposal well, and associated production tank battery. Land covered by the tank battery portion of the lease (approximately 5 acres) is owned by the State of New Mexico.

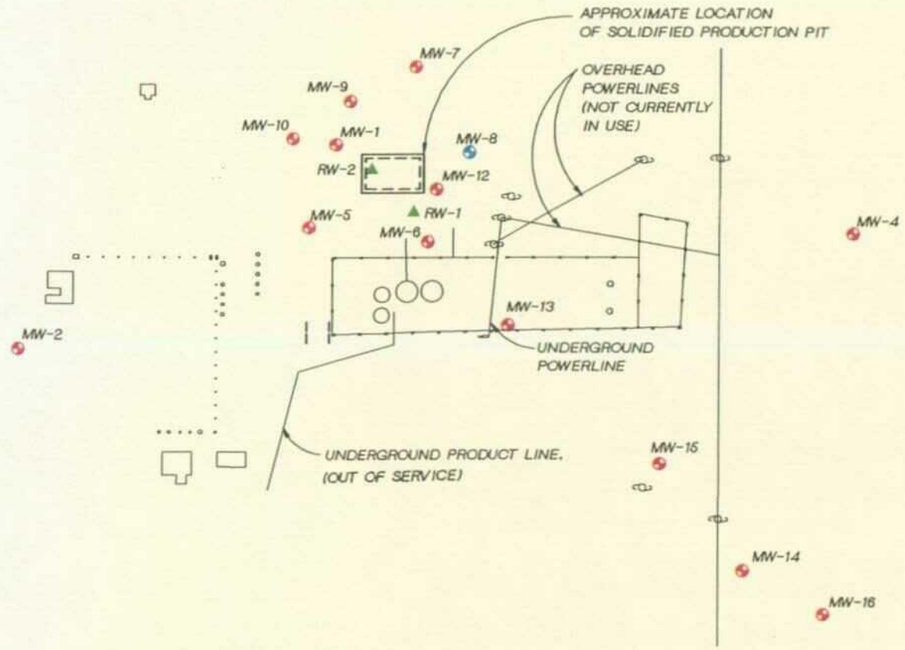
Phillips acquired the Unit from EXXON Company, U.S.A. in November 1990. As part of Phillips' due diligence effort during the acquisition, Phase I and Phase II environmental assessments were completed on the lease and associated facilities. Eight soil borings were drilled for the purposes of soil screening and sampling. Four monitor wells (MW-1 through MW-4) were installed in four of the eight soil borings. The four monitor wells were sampled for benzene, toluene, ethylbenzene, and total xylenes (BTEX) in mid-October 1990. Low levels of dissolved toluene, ethylbenzene, and xylene (0.039, 0.10, and 0.39 mg/L, respectively) were detected in the groundwater sample collected from MW-1, located adjacent to the northwest corner of an abandoned EXXON production pit. No other monitor well contained detectable levels of BTEX or non-aqueous phase liquids (NAPL). Upon acquiring the lease from EXXON, Phillips dismantled the old EXXON tank battery and constructed a new tank battery in its place. Figure 1-2 presents the facility layout, as well as the location of all site monitoring wells

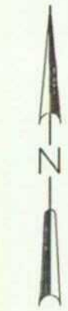
As part of a second environmental due diligence effort for the sale of the Unit, the four monitor wells were sampled again in September 1994. During this sampling event, approximately 2.5 feet of NAPL was present in MW-1. No other monitor well contained detectable levels of dissolved BTEX or measurable NAPL. Upon detection of the NAPL in MW-1, Phillips initiated a source identification effort that included four tasks:

- A production storage tank integrity evaluation
- Excavation of an adjacent Amoco crude oil pipeline
- A comparative analysis (fingerprinting) of crude oil produced from the Unit with the NAPL discovered in MW-1
- A focused soil and groundwater assessment in the area of the abandoned EXXON production pit (Figure 1-2)

Internal inspection of the two crude storage tanks indicated that the tanks had not leaked. Furthermore, excavation of the Amoco crude oil pipeline indicated that the Amoco pipeline had not leaked. The comparative analysis of the crude oil samples produced from the Unit with the NAPL encountered at MW-1 indicated that the oils were essentially the same. One minor but expected difference between the produced crude oils and the NAPL from


Site Location
NEW MEXICO
QUADRANGLE LOCATION
0
2000
4000
Scale in Feet
Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico
SITE LOCATION MAP
FIGURE 1-1





MW-3

LEGEND

- Power Pole
- Monitoring Well
- RW-1 and RW-2 Recovery Well Clusters
- MW-8 Location has been plugged and abandoned.

Note: Underground product line and powerline locations infered based on best available information.

0 150 300 450

SCALE 1"=150'

Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico

Production Lease Tank Battery
Layout and
Monitor Well Locations

Figure 1-2

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MW-1 is that the MW-1 oil has experienced minor evaporation, waterwashing, and/or biodegradation as suggested by the loss of light-end petroleum hydrocarbons (C_4-C_8).

Based on the results of second due diligence effort, it was determined that NAPLs in soils beneath the abandoned EXXON production pit were the source of the dissolved BTEX in groundwater and the NAPL at MW-1.

Soils beneath the abandoned production pit were subsequently excavated and solidified oniste by Ritter Environmental on behalf of Phillips in December 1995.

1.2 Current Investigation Strategy

An extensive review of California Underground Storage Tank (UST) sites by Lawrence Livermore Laboratory showed that *"in general, petroleum hydrocarbon plume lengths tend to stabilize at relatively short distances from the fuel hydrocarbon release site"*(Rice et. al. 1995). The time scale over which this equilibrium condition is reached can vary depending on specific site conditions. When the source area is depleted to the point that the rate of natural attenuation exceeds the source input rate, the result will be a shrinking plume over time.

Based on the results of the due diligence efforts which indicate that the extent of dissolved BTEX in groundwater is quite limited and the fact that BTEX is readily biodegradable, an assessment of the natural biodegradation (bioattenuation) component of natural attenuation was initiated in January, 1996 at the Unit.

The components of this assessment included the following:

- quarterly measurement of groundwater levels and NAPL thickness where present,
- quarterly collection of groundwater samples and subsequent analysis for dissolved BTEX analysis and a suite of natural attenuation parameters,
- quarterly compilation and analysis of results and,
- compilation of this report which documents data collected and conclusions drawn.

Table 1-1 presents the suite of parameters required to demonstrate that natural attenuation processes are active at the Unit. In March 1996, the New Mexico Oil Conservation Division (NMOCD) requested that, in addition to the parameters listed in Table 1-1, Phillips also analyze groundwater samples for arsenic, barium, cadmium, chromium, lead, total mercury, selenium, silver and, naphthalene.

Content and organization of this report are as follows:

- Section 2 presents an overview of the site setting and hydrogeologic characterization
- Section 3 reviews natural attenuation principles
- Section 4 presents an evaluation of natural attenuation processes at the Unit
- Section 5 presents conclusions and insights gained from this evaluation

TABLE 1-1
Parameters and Analytical Methods

Parameter	Objective	Lab or Field	Method	Detection Limit
Organics				
BTEX	Contaminants of concern	Lab	8020 Mod.	1.0 µg/L
TOC	Total organic loading in groundwater	Lab	415.2	1.0 mg/L
Methane	By-product of contaminant degradation	Lab	GC/FID/PID	8.0 µg/L
Electron Acceptors				
Dissolved Oxygen	Preferred electron acceptor	Field	Winkler Titration	0.10 mg/L
Nitrate	Electron acceptor	Lab	300.0	0.05 mg/L
Nitrite	Potential intermediate in reduction of NO_3 to N_2	Lab	354.1	0.50 mg/L
Sulfate	Electron acceptor	Lab	300.0	0.25 mg/L
General Water Chemistry				
Carbonate Species–CO_2, HCO_3, and Alkalinity	Insight into water chemistry (buffering capacity) and microbial activity (CO_2 generation)	Lab	310.1	1.0 mg/L
Major Cations–sodium, calcium, potassium, magnesium, manganese, and phosphorus	For ion balance	Lab	200.7	0.01 to 0.5 mg/L
Chloride	For ion balance	Lab	300.0	2.5 mg/L
Iron	Indicator of low redox conditions	Lab	200.7	0.025 mg/L
Sulfide	Indicator of low redox conditions	Lab	376.1	1.0 mg/L
TDS	General water quality parameter	Lab	160.1	10.0 mg/L
pH	General water quality parameter	Field	Field pH meter	
Eh	Indicator of Redox conditions of groundwater system	Field	Field Eh meter	

SECTION 2

Site Characterization

SECTION 2

Site Characterization

2.1 Site Setting

The South Four Lakes Unit is located in the High Plains portion of the Great Plains physiographic province where flat-laying sedimentary rocks, ranging in age from Permian to Miocene, dominate. Ground elevations at the Unit range from 4,150 feet to 4,148 feet above mean sea level. Regionally, topography slopes to the east-southeast. The area surrounding the Unit is sparsely populated and consists of relatively flat grazing land.

The average rainfall for this area is 9 inches per year. Of that total, approximately 85 percent is lost to evapotranspiration and 10 percent to surface runoff, leaving only 5 percent available for groundwater recharge (approximately 0.45 inches). The majority of the Unit is covered with a shallow soil horizon (Kimbrough-Lea Complex; sandy loams overlying caliche) and is sparsely vegetated with grasses and brush.

Regionally, shallow geologic materials consist of caliche-hardened sediments of the Tertiary Ogallala Formation, caprock of the High Plains aquifer. In general, these shallow materials are made up of interbedded deposits of weathered gravels, sands, silts and, clays that were carried eastward from the southern Rocky Mountains as braided fluvial deposits.

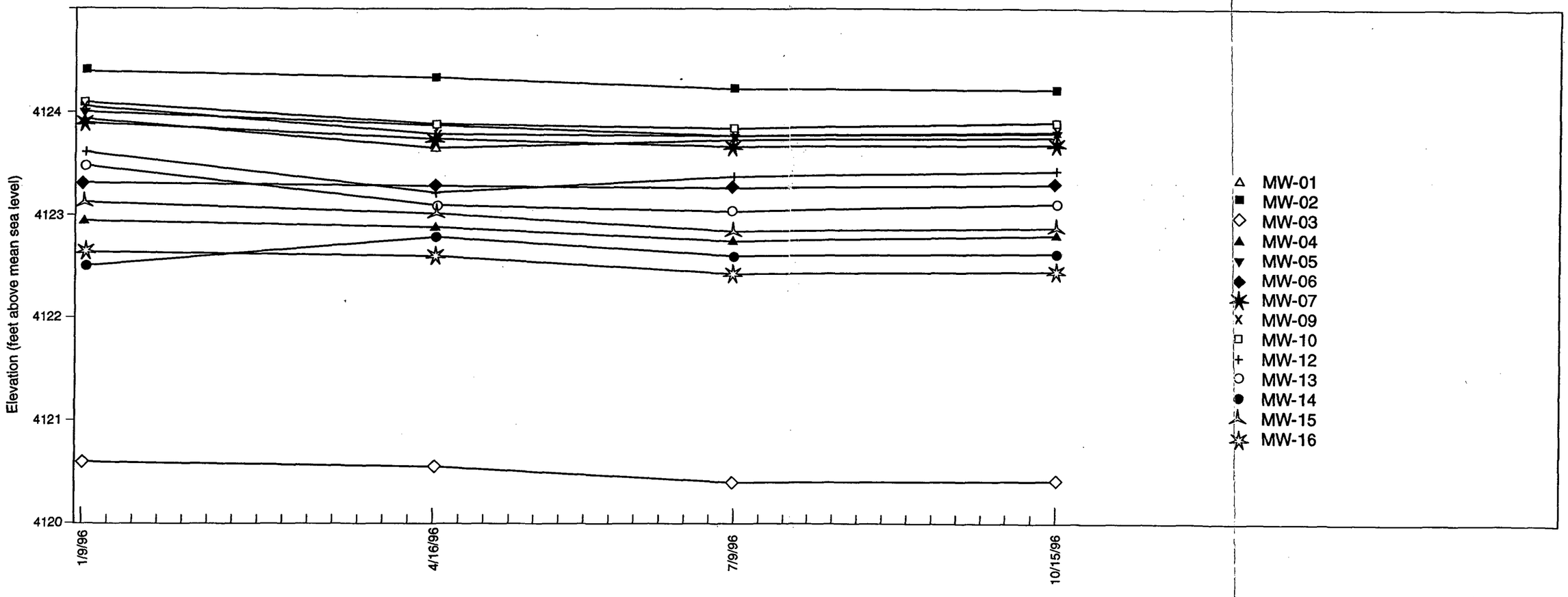
The Ogallala in borings, drilled to a maximum depth of 34 feet at the Unit, is comprised predominantly of fine-grained caliche-hardened materials. From approximately 0 to 20 feet below ground surface (bgs), caliche-hardened fine sands and clays were encountered. Below 20 feet bgs, the sediments are generally comprised of unconsolidated to semiconsolidated fine- to very fine-grained, well-sorted, interbedded sands and silts.

Groundwater beneath the Unit is encountered at approximately 23 to 25 feet bgs.

2.2 Groundwater Flow

Fluctuations in water levels beneath the Unit are illustrated in Figure 2-1 for the period January 1996 through October 1996. With the exception of MW-14, groundwater levels in January 1996 were slightly higher than in the other three quarters. The low value reported for MW-14 in January 1996 is likely an invalid measurement and the remaining quarterly measurements at MW-14 agree favorably with the other wells (Figure 2-1).

During the April 1996 fieldwork, the windmill-driven free-product recovery system (RW-2) was pumping continuously causing a slight depression in water levels at MW-1 and MW-12. Overall, however; groundwater levels beneath the Unit did not fluctuate significantly during 1996 (Figure 2-1).



Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico

Groundwater Hydrographs
January through October 1996

Figure 2-1

DEN/R/132311.NA.ZZ/12-96

Figure 2-2 presents a typical potentiometric surface beneath the Unit under non-pumping conditions. As shown in Figure 2-2, groundwater flow beneath the Unit is to the east-southeast at an average gradient of 0.002 feet per foot (ft/ft).

Figure 2-3 presents the potentiometric surface beneath the Unit in April 1996. As shown in Figure 2-3, pumping at RW-2 caused a slight deflection in the water surface towards the pumping well; however, the overall direction and magnitude of the hydraulic gradient was unchanged.

The velocity of groundwater flow beneath the Unit is a critical factor in evaluating historical and potential future migration of dissolved hydrocarbons. The groundwater flow velocity can be estimated using Darcy's equation:

$$v = Ki/n \quad (1)$$

where:

v	=	groundwater flow velocity (feet/year)
K	=	hydraulic conductivity (feet/day)
i	=	hydraulic gradient (feet/feet)
n	=	porosity (dimensionless)

Based on physical analysis of soil samples collected at depths of 24 to 25.5 feet bgs in wells MW-7, MW-8, and MW-12, the horizontal hydraulic conductivity ranges from 0.53 to 2.8 feet per day (ft/d). Using the average of reported hydraulic conductivities (1.7 ft/d), the observed gradient of 0.002 ft/ft and an assumed porosity of 30 percent, estimated groundwater flow velocities beneath the site average 4 ft/yr.

Actual groundwater flow velocities are likely to be higher than 4 ft/yr, recognizing that the permeability values used in this analysis come from laboratory tests and that laboratory permeability values are typically lower than field scale values obtained from pumping tests. Considering the physical description of the water-bearing sediments and observed migration of biodegradation by-products described in Section 4, it appears that actual field scale permeability could be an order of magnitude higher than the core test values. Thus, actual groundwater velocities may be on the order of 40 ft/year.

2.3 Groundwater Use

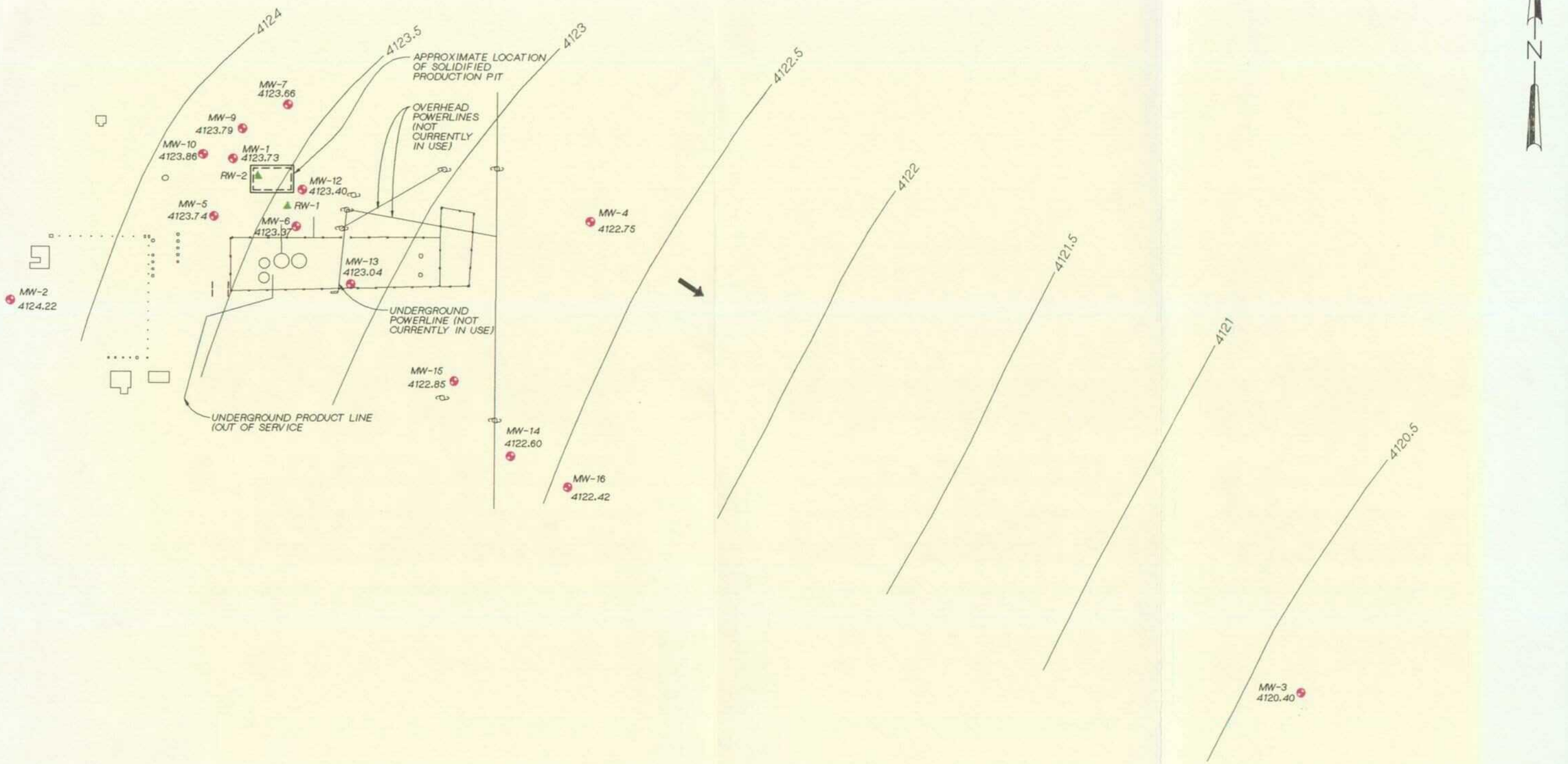
The groundwater bearing unit beneath the site is not used for drinking water in the vicinity of the Unit.

Based on examination of the Simanola Valley Quadrangel map and visual observations in the field, the nearest downgradient well is over two miles away.

A windmill driven pump with livestock watering tank exists over 2,000 feet to the east-northeast of the project area.

2.4 Hydrocarbon Distribution in Groundwater

Hydrocarbons in soils beneath the Unit exist as separate phase liquids (NAPLs) and as dissolved constituents in groundwater. Differentiating the nature of hydrocarbon occurrence is important since 1) NAPL will likely act as a long-term source of dissolved



LEGEND

- Power Pole
- Monitoring Well
- RW-1 and RW-2 Recovery Well Clusters
- Groundwater Flow Direction
- Potentiometric Surface in Feet Above Mean Sea Level

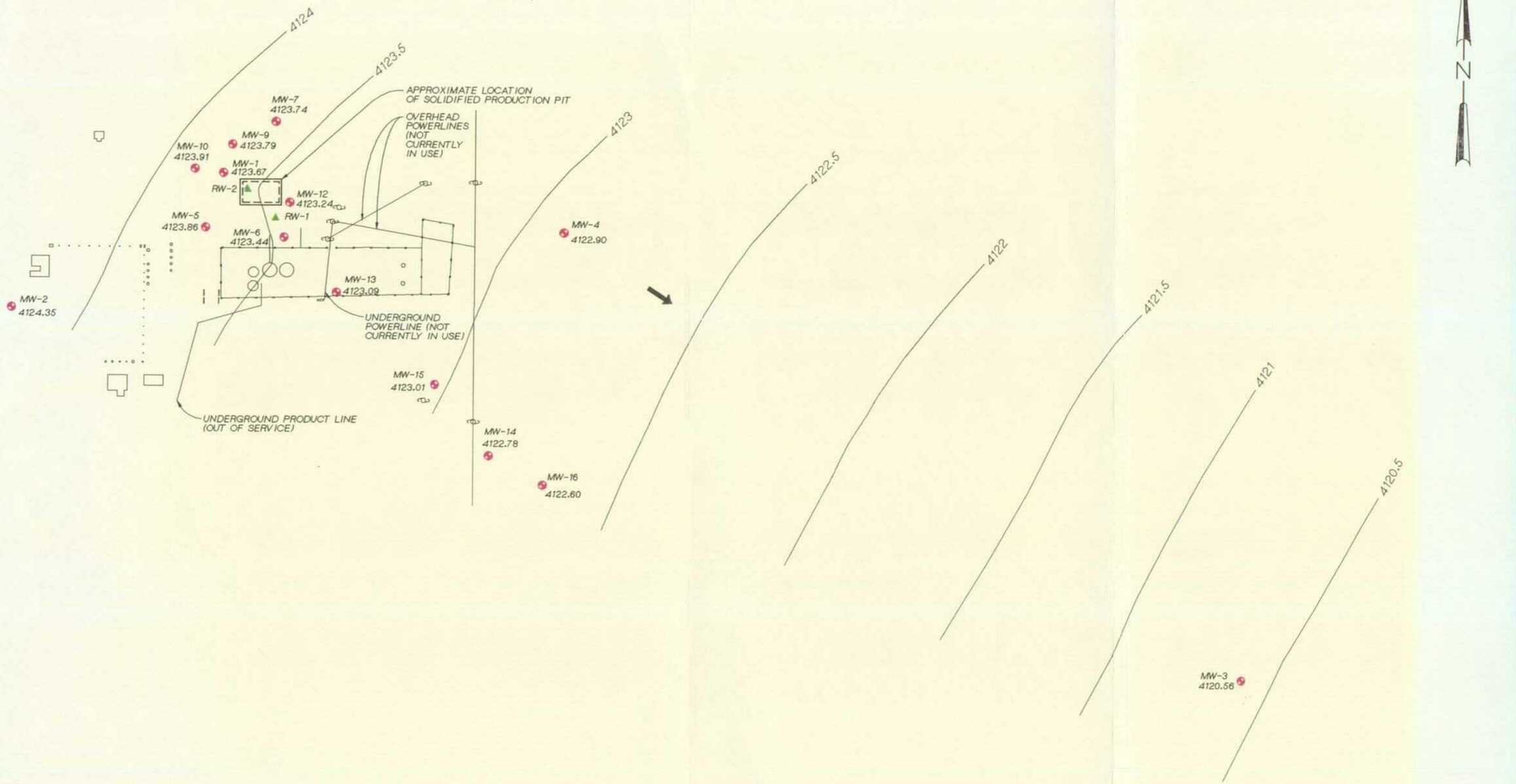
0 150 300 450

SCALE 1"=150'

Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico

Typical Non-Pumping Potentiometric Surface 1996

Figure 2-2



LEGEND

- Power Pole
- Monitoring Well
- RW-1 and RW-2 Recovery Well Clusters
- Groundwater Flow Direction
- Potentiometric Surface In Feet Above Mean Sea Level

Note: RW-2D Actively Pumping During April 1996.

0 150 300 450

SCALE 1"=150'

Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico

Potentiometric Surface
April 1996

Figure 2-3

constituents in groundwater, and 2) the total mass in the dissolved plume is so small that natural attenuation processes often prevent migration, and contain, dissolved constituents.

NAPL thickness measurements are summarized in Table 2-1. With the exception of wells MW-1 and RW-1S, NAPL thicknesses remained fairly constant during 1996. At MW-1 and RW-1S, NAPL thicknesses increased from January to April 1996 and then remained fairly constant during the rest of the year. The increase from January to April 1996 can be attributed to the continuous pumping at RW-2S during April which drew NAPL towards these wells.

TABLE 2-1
Phillips Petroleum Company
South Four Lakes Unit
1996 Non-aqueous Phase Petroleum Hydrocarbon Thickness (feet)

Well ID	January	April	July	October
MW-1	2.67	3.17	3.17	3.21
MW-6	4.46	4.43	4.52	4.56
MW-12	4.00	5.04	4.12	3.99
RW-1S	0.15	3.58	4.72	4.67
RW-1D	Absent	Absent	Absent	Absent
RW-2S	3.50	NA	NA	NA

Note: Product measurements at RW-2S are not available due to the presence of the pump apparatus in the well.

Table 2-2 presents average BTEX values over the four quarters of measurement. With the exception of downgradient monitor well MW-15, BTEX levels in site monitoring wells were stable over the period of measurement (See Appendix A for complete results).

At MW-15, benzene levels decreased from a level of 96 ug/L in January to below detectable levels in October. Ethylbenzene and toluene levels decreased from levels above standards in January (880 ug/L and 870 ug/L, respectively) to levels below standards in October (610 ug/L and 420 ug/L, respectively). Total xylenes concentrations, although above standards in all rounds, also decreased from a level of 2,400 ug/L in January to 1,630 ug/L in October. The observed decrease in the levels of BTEX constituents at MW-15 suggests the dissolved BTEX plume may be shrinking in response to decreased source loading on the system and an accelerated rate of electron-acceptor addition due to pumping at RW-2.

TABLE 2-2
Phillips Petroleum Company
South Four Lakes Unit
1996 Average Total BTEX (mg/L)

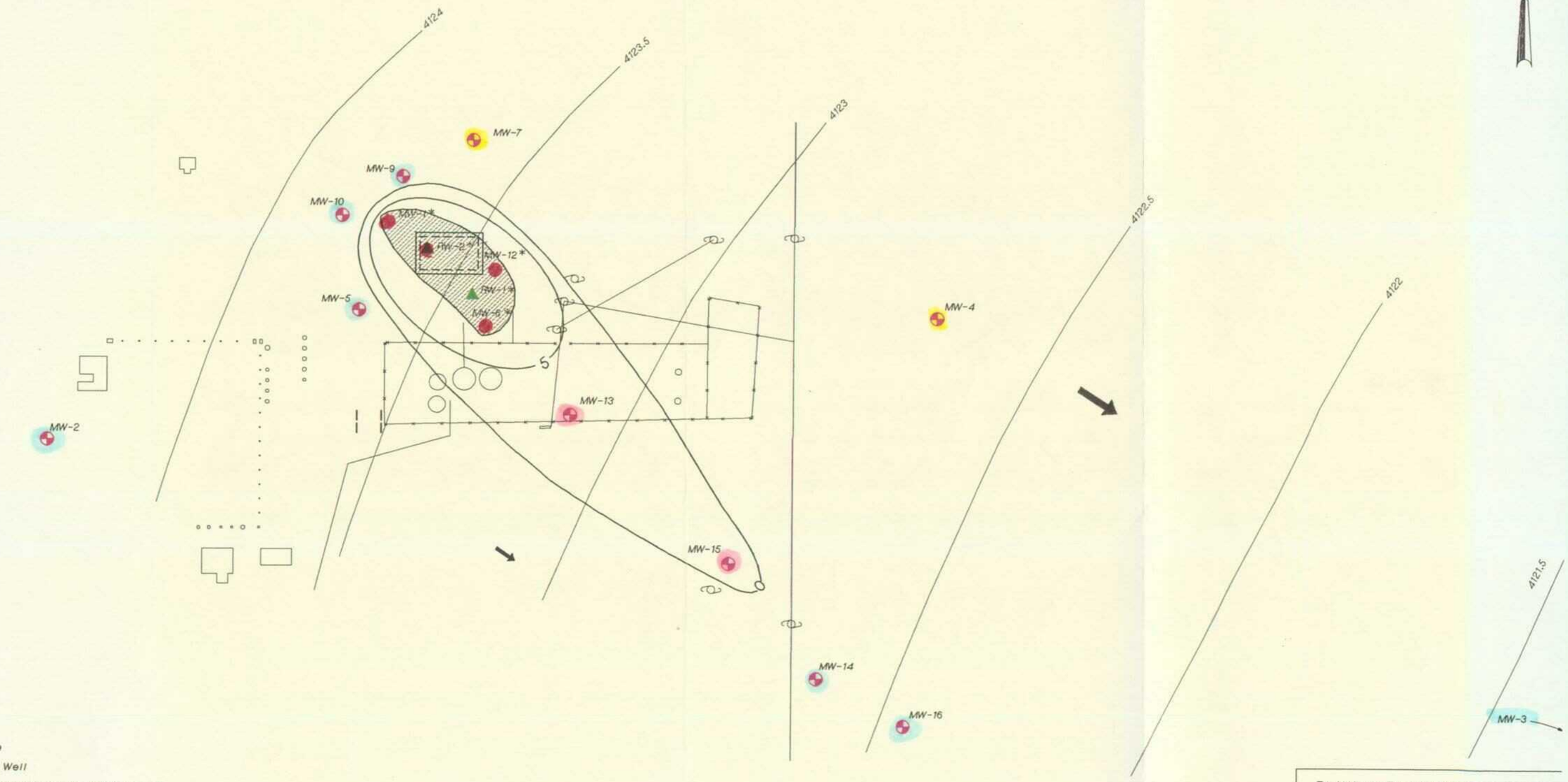
Well ID	BTEX (mg/L)	Comments
MW-1	3.51	NAPL present
MW-2	BDL	
MW-3	BDL	
MW-4	BDL	
MW-5	BDL	
MW-6	BDL	
MW-7	43.9	NAPL present
MW-8	0.017	
MW-9	BDL	
MW-10	BDL	
MW-12	25.9	NAPL present
MW-13	4.39	
MW-14	BDL	
MW-15	3.44	
RW-15	16.9	NAPL present
RW-1D	4.15	
RW-25	11.7	NAPL recovery well
RW-2D	0.045	

Notes: BDL = Below Method Detection Limit
NAPL = Non-aqueous Phase Liquid

Figure 2-4 presents the estimated extent of dissolved BTEX in groundwater based on the quarterly average, the locations where measurable NAPL was observed and, the inferred extent of NAPL based on those observations.

As shown in Figure 2-4, detectable levels of BTEX are generally limited to within the vicinity of the closed EXXON production pit to a distance of approximately 340 feet downgradient of the NAPL zone. The zone of NAPL is limited to the vicinity of the closed EXXON production pit (Figure 2-4).

Further migration of NAPL is unlikely since the source was removed during disposal pit closure (December, 1995), recoverable NAPL is being removed at RW-2 and, the fact that NAPL migration is limited by the high residual saturation left at the trailing edge of a mobile free-phase liquid zone. Additionally, data from MW-15 suggests that the dissolved BTEX plume may be shrinking in response to decreased source loading on the system and an accelerated rate of electron-acceptor addition due to pumping at RW-2. This will be *further detailed in Section 4.*



LEGEND

- Power Pole
- Monitoring Well
- RW-1 and RW-2 Recovery Well Clusters
- Inferred Extent of NAPL
- —5— BTEX Concentrations in mg/L
- * Indicates Measurable Free-phase Product Observed
- Groundwater Flow Direction
- Potentiometric Surface in Feet Above Mean Sea Level

Note: BTEX values posted in Table 2-2 of text

0 100 200 300

SCALE 1"=100

Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico

Extent of BTEX in Groundwater [mg/L]

Figure 2-4

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SECTION 3

Natural Attenuation Principles

SECTION 3

Natural Attenuation Principles

3.1 Fate and Transport Considerations

Natural attenuation is the process in which contaminant concentrations are passively, but continually, reduced by various naturally occurring *in situ* mechanisms, without active remedial actions (McAllister et al., 1994). Contaminant attenuation processes include the following:

- **Nondestructive Processes:**
  - Dilution resulting from diffusion and/or hydrodynamic dispersion
  - Depletion resulting from volatilization
  - Retardation resulting from contaminant adsorption to the aquifer matrix
- **Destructive Processes:**
  - Biodegradation
  - Abiotic contaminant oxidation
  - Hydrolysis

At sites where natural attenuation is well documented, biodegradation of BTEX by indigenous, subsurface microbes appears to be the primary attenuation mechanism (McAllister et al., 1994).

Building on the work of McAllister and Chiang (1994), the following observations can be made regarding the abiotic attenuation mechanisms at the Unit:

- Dilution has the net effect of decreasing concentration but cannot account for either loss in mass or delayed travel times.
- With regard to volatilization, rates of mass transfer from groundwater to the vadose zone are likely to be small due to the depth to water at the site (approximately 25 feet) and the 20-foot-thick caliche-hardened materials overlying the water table.
- Regarding retardation, sorption of hydrocarbons will delay travel times but will not reduce mass.
- Abiotic oxidation and hydrolysis processes are generally not observed for BTEX in groundwater systems.

As stated above, biodegradation of aqueous phase organics by indigenous, subsurface microbes is the primary attenuation mechanism at petroleum hydrocarbon sites. This attenuation mechanism is extremely important in terms of limiting migration of the aqueous phase hyrocarbon (the dissolved groundwater plume emanating from the NAPL zone). In recent years it has become recognized that, because of naturally occurring biodegradation, plumes expand only a finite distance from the source area, at which point

the rate of contaminant biodegradation equals the rate of contaminant loading to groundwater in the NAPL zone. With time, the source area is depleted to the point that the rate of natural attenuation exceeds the rate of contaminant loading in the source area, and the plume then begins to decrease in concentration and eventually shrink in size. This conceptual model of plume migration from petroleum hydrocarbon sites has been validated in a number of studies. For example, an extensive assessment of groundwater plumes at leaking underground fuel tank sites in California demonstrated that *"plume lengths...tend to stabilize at relatively short distances from the (fuel hydrocarbon) release site"* and *"plume lengths rarely exceed about 250 ft."* (Rice et.al., 1995).

3.2 Geochemical Indicators of Intrinsic Bioremediation

Biodegradation of hydrocarbons is the result of the metabolic activity of microorganisms. Metabolism is a term that embraces the diverse reactions by which a microorganism processes food materials to obtain energy and the compounds from which cell components are made. Biodegradation typically relies on heterotrophic microorganisms; that is, microorganisms that require carbon in the form of relatively complex, reduced organic compounds (e.g., petroleum hydrocarbons). These microbes rely on the oxidation of these reduced organics in exothermic degradation reaction sequences that yield energy and the "building blocks" of biosynthesis. Energy is produced through the oxidation of the reduced organic compound in a reaction involving the loss of hydrogen atoms that contain electrons. These electrons are then passed through an electron-transport system to a terminal electron acceptor. The electron-transport system is a series of electron carriers arranged such that the energy liberated in the oxidation of the organic is retained in a usable form by the microorganism.

Because oxygen is an efficient electron acceptor, organic contaminants are most readily biodegraded under aerobic conditions. Therefore, the most common applications of *in-situ* bioremediation involve stimulation of the contaminant biodegradation activity of soil microorganisms under aerobic conditions. In aerobic biodegradation, the organic contaminant exerts a stoichiometric oxygen demand. To biodegrade a given quantity of organic contaminant, a corresponding quantity of oxygen is required. In soils, the presence of sufficient oxygen is often the factor that limits the rate of contaminant biodegradation. However, certain organic contaminants can be biodegraded by bacteria that use other electron acceptors under anaerobic conditions. When oxygen is not present in sufficient amounts, nitrate, sulfate, ferrous iron, and/or carbon dioxide may be used as electron acceptors.

Table 3-1 summarizes both aerobic and anaerobic degradation processes. The stoichiometry of these processes is illustrated in Figure 3-1.

TABLE 3-1
Summary of Aerobic and Anaerobic Biodegradation Processes

Process	Electron Acceptors	By-Products of Degradation
Aerobic Degradation	O_2	CO_2
Anaerobic Degradation		
Denitrification	NO^-_3	CO_2
Sulfate Reduction	SO_4^{2-}	HCO^-_3
Methanogenesis	CO_2	CO_2, CH_4
Iron III Reduction	Fe^{3+}	Fe^{2+}, CO_2

Monitoring groundwater for the geochemical parameters presented in Table 3-1 can provide evidence that biodegradation is occurring, insight into the dominant biodegradation processes and, when used in conjunction with other site data, assess the rate and extent of the biodegradation processes (Weidemeier et. al. 1995)

(1) Aerobic Degradation

$$C_6H_5\text{-}CH_3 + 90_2 \rightarrow 7CO_2 + 4H_2O$$

(2) Denitrification

$$C_6H_5\text{-}CH_3 + 7.2H^+ + 7.2NO_3 \rightarrow 7CO_2 + 7.6H_2O + 3.6N_2$$

(3) Sulfate Reduction

$$C_6H_5\text{-}CH_3 + 4.5\ SO_4^{2-} + 3H20 \rightarrow + 2.25\ H_2S + 2.25HS^- + 7HCO_3^- + 0.25\ H^+$$

(4) Methanogenesis

$$C_6H_5\text{-}CH_3 + 5\ H_2O \rightarrow 2.5\ CO_2 + 4.5\ CH_4$$

(5) Iron III Reduction

$$C_6H_5\text{-}CH_3 + 36Fe\,(OH)_3 + 72H^+ \rightarrow 7CO_2 + 94H_2O + 36Fe^{2+}$$

Phillips Petroleum Company *South Four Lakes Unit* *Tatum, New Mexico*
Oxidation/Reduction Equations
FIGURE 3-1

SECTION 4

Discussion of Site-Specific Natural Attenuation

SECTION 4

Discussion of Site-Specific Natural Attenuation

4.1 Methods

In an effort to understand the long-term impacts of subsurface petroleum hydrocarbons at the Unit, groundwater samples were collected quarterly from the wells shown in Figure 1-2 for subsequent analysis for the parameters listed in Table 1-1. Analytical results from this effort are tabulated in Appendix A and reviewed in the following text. Samples were collected using slow purge sampling techniques as recommended in the American Petroleum Institute's (API's) draft guidance manual **Field Methods for Measuring Indicators of Intrinsic Bioremediation** (Piontek, et al., 1996).

4.2 Historical Dissolved Plume Migration

Site aerial photographs were reviewed in order to determine the duration that NAPLs have been in contact with the groundwater system. Based on this review, it appears that the closed disposal pit area had been active since 1966. Assuming that NAPL reached its current extent by 1970, 26 years have passed in which NAPL had been in contact with the groundwater system. Based on this information and the average estimated flow velocity of 40 ft/yr, a conservative solute tracer (e.g., chloride) would have migrated 1,040 feet over the 26 year period.

To date, BTEX has not been detected in MW-14, MW-16, MW-4, or MW-3. The first two wells are located approximately 440 to 530 feet downgradient of the interval in which NAPL has been identified in soils at the watertable. The third well, MW-4, is located approximately 375 feet due east of the NAPL zone, slightly north of the observed downgradient groundwater flow direction. Monitor well MW-3 is located approximately 1500 feet downgradient of the NAPL interval (Figure 2-4). If the groundwater flow distance over the last 26 years is estimated to be 1,040 feet, detectable levels of BTEX should be present in the downgradient wells (excluding MW-3) if plume migration was not naturally being attenuated.

The fact that BTEX has not been found at detectable levels in MW-4, MW-14 and, MW-16 suggests that natural attenuation processes are limiting BTEX movement. Of the attenuation processes discussed in Section 3, retardation and bioattenuation are considered to be the most significant and are reviewed in the following sections.

4.2.1 Retardation

Due to the presence of organic carbon in soil, estimated to be 0.25 percent by weight in the soils at the Unit, dissolved hydrocarbons will tend to sorb onto the aquifer matrix. This has the net effect of retarding the velocity of the dissolved hydrocarbons relative to the velocity of the groundwater. Using organic carbon partitioning coefficients (Koc) and the fraction of organic carbon in soils, distribution coefficients (Kd) and retardation factors can be

calculated for BTEX. Table 4-1 summarizes the estimates of travel distance for BTEX assuming no bioattenuation (i.e. retardation only).

TABLE 4-1
Predicted BTEX Migration with No Biodegradation

Parameter	Koc (ml/g)[a]	Kd (ml/g)[b]	Retardation Factor[b]	Travel Distance (feet)
Conservative Tracer	-	-	1.0	1,040
Benzene	83	0.21	2.3	455
Toluene	300	0.75	5.7	184
Ethylbenzene	1,100	2.8	18.1	58
Xylenes	240	0.60	4.7	220

[a]*Superfund Public Health Evaluation Manual*, EPA 540/1-86/060.(4)
[b]Fetter, C. W. *Contaminant Hydrogeology*. MacMillan Publishing, 1993.(5)

Assumptions
- NAPL zone reached approximate current extent by 1970
- Average groundwater flow velocity = 40 feet/year
- Organic carbon content of sand unit = 0.25 percent (typical for silty sand deposits)
- Sand bulk density = 116 lbs/ft^3 = 1.86 kg/l
- Sand total porosity = 0.3

These calculations indicate that benzene, in the absence of biodegradation, should have migrated approximately 455 feet in the last 26 years. With monitoring wells at a distances of 375 to 440 feet downgradient of the estimated extent of NAPL, retardation alone is not sufficient to explain the absence of BTEX in downgradient wells.

4.2.2 Bioattenuation

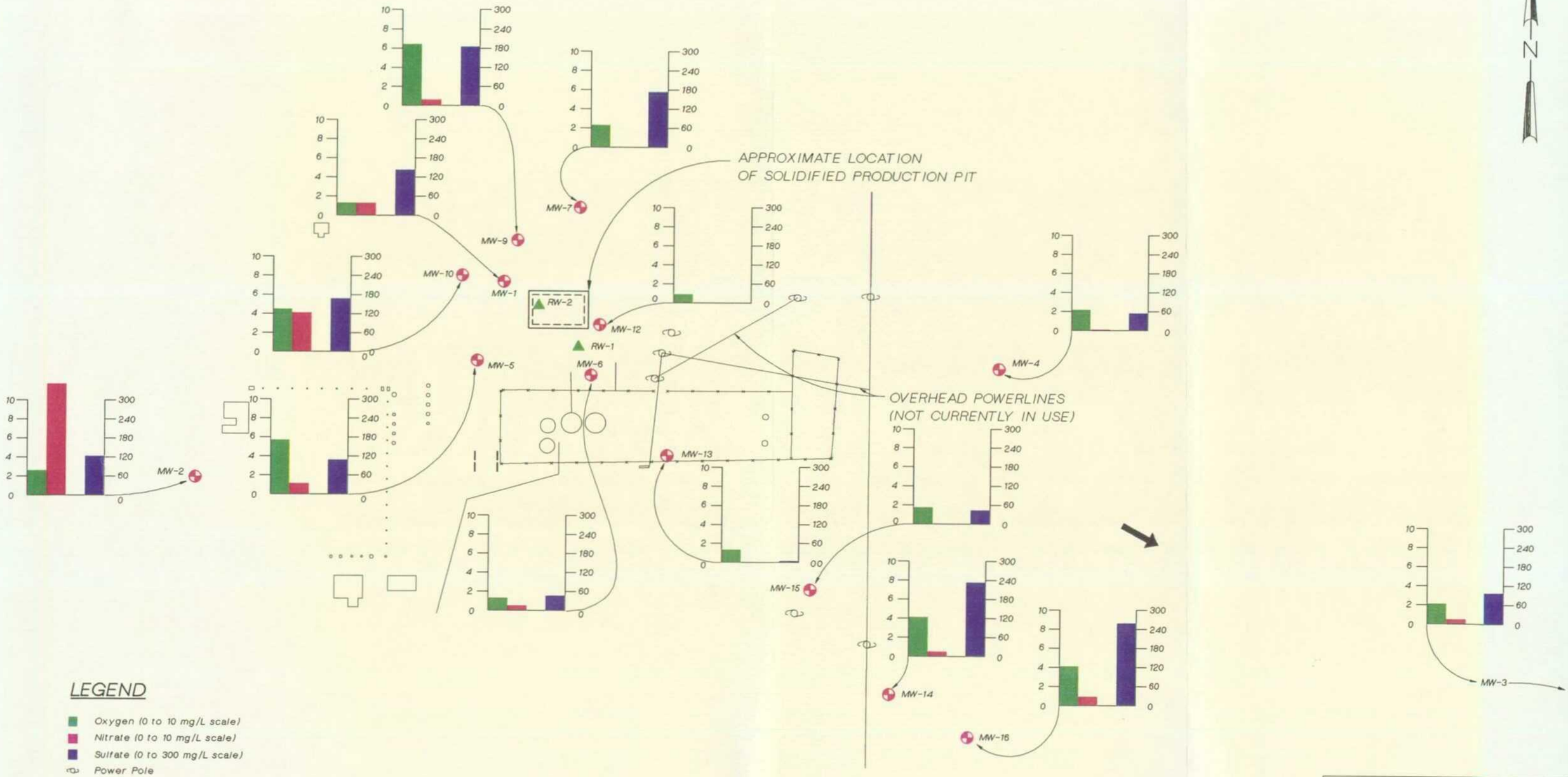
Four quarters of geochemical data were collected at the site in 1996. Overall, no significant variability in the geochemical data was observed. Therefore, evaluation of the site geochemical data is based on the average value from the four quarters of data.

The geochemical data collected from the site clearly indicates that biological processes are actively attenuating and degrading subsurface dissolved petroleum hydrocarbons. Figures 4-1 and 4-2 present graphically the uptake of electron acceptors and the generation of reaction by-products, respectively across the site as a result of subsurface biological activity. Figures 4-1 and 4-2 depict the invese relationship between electron acceptors and reaction by-products.

Key observations regarding this data include the following:

Uptake of Electron Acceptors–Figure 4-1 presents average dissolved concentrations of primary electron acceptors over four quarters of sampling along with the direction of groundwater flow. Monitoring wells MW-2, MW-5, MW-7, MW-9, and MW-10 reflect either upgradient or background conditions at the site. Average concentrations of oxygen, nitrate, and sulfate in these wells are 4.3, 4.6, and 151 mg/L, respectively.

Monitoring wells MW-1, MW-6, MW-12, MW-13, RW-1, and RW-2 are all located in the immediate vicinity of NAPL. Average concentrations of oxygen, nitrate, and sulfate in these wells are 0.83, 0.41, and 57 mg/L, respectively. These concentrations reflect a reduction of



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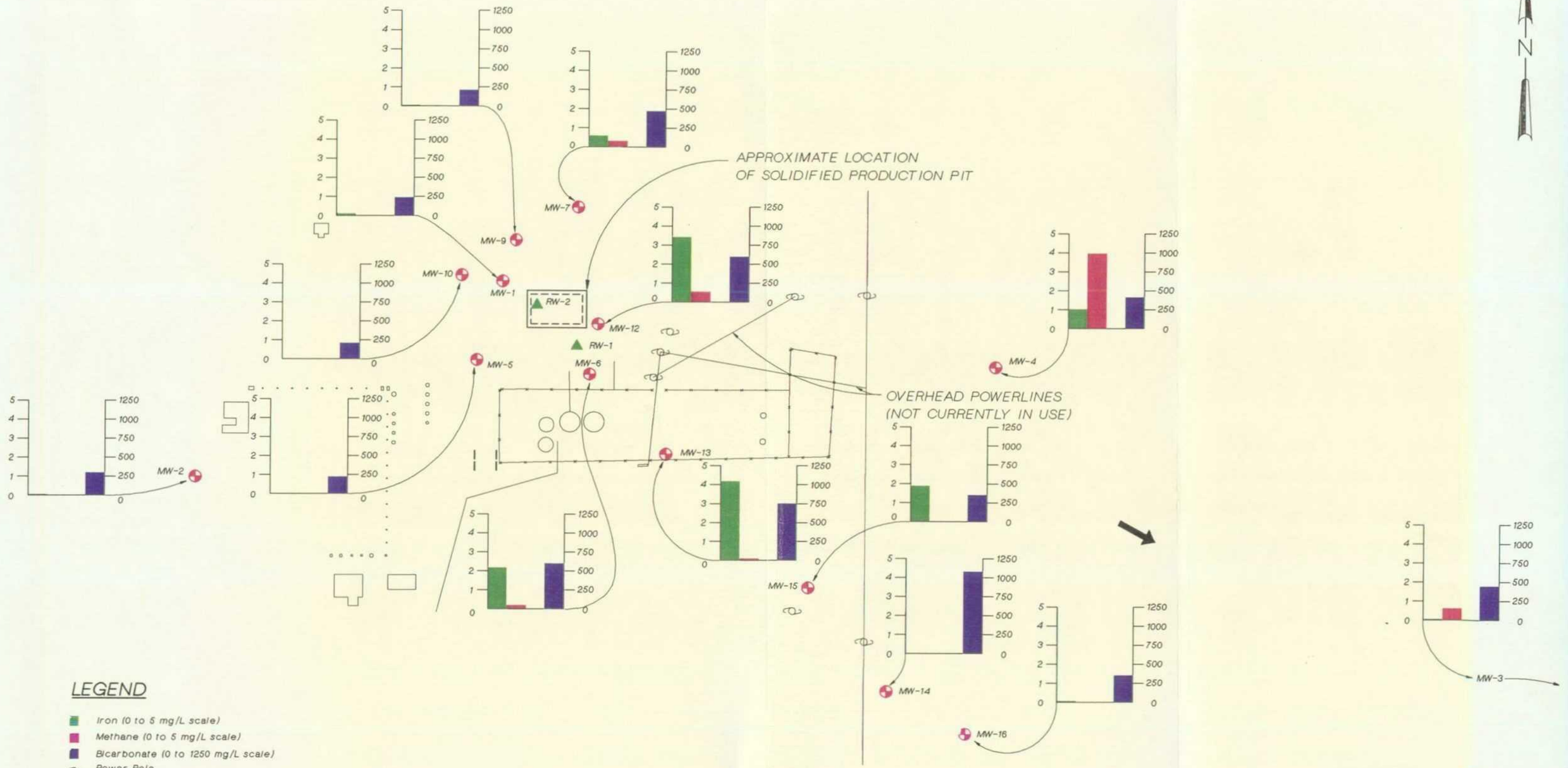
Tatum, New Mexico

Electron Acceptors
in Groundwater (mg/L))

Figure 4-1

2311F011.DLV 26-NOV-19



LEGEND

- Iron (0 to 5 mg/L scale)
- Methane (0 to 5 mg/L scale)
- Bicarbonate (0 to 1250 mg/L scale)
- Power Pole
- Monitoring Well
- RW-1 and RW-2 Recovery Well Clusters
- Groundwater Flow Direction

Notes:
Underground product line and powerline locations infered based on best available information.

0 100 200 300

SCALE 1"=100

Phillips Petroleum Company
South Four Lakes Unit
Tatum, New Mexico

Biodegradation Byproducts in Groundwater (mg/L))

Figure 4-2

2311F012.DLV 26-NOV-9

electron acceptors (oxygen, nitrate, and sulfate) ranging from 62 to 92 percent and indicate that biological processes are actively reducing dissolved hydrocarbons in groundwater at the site.

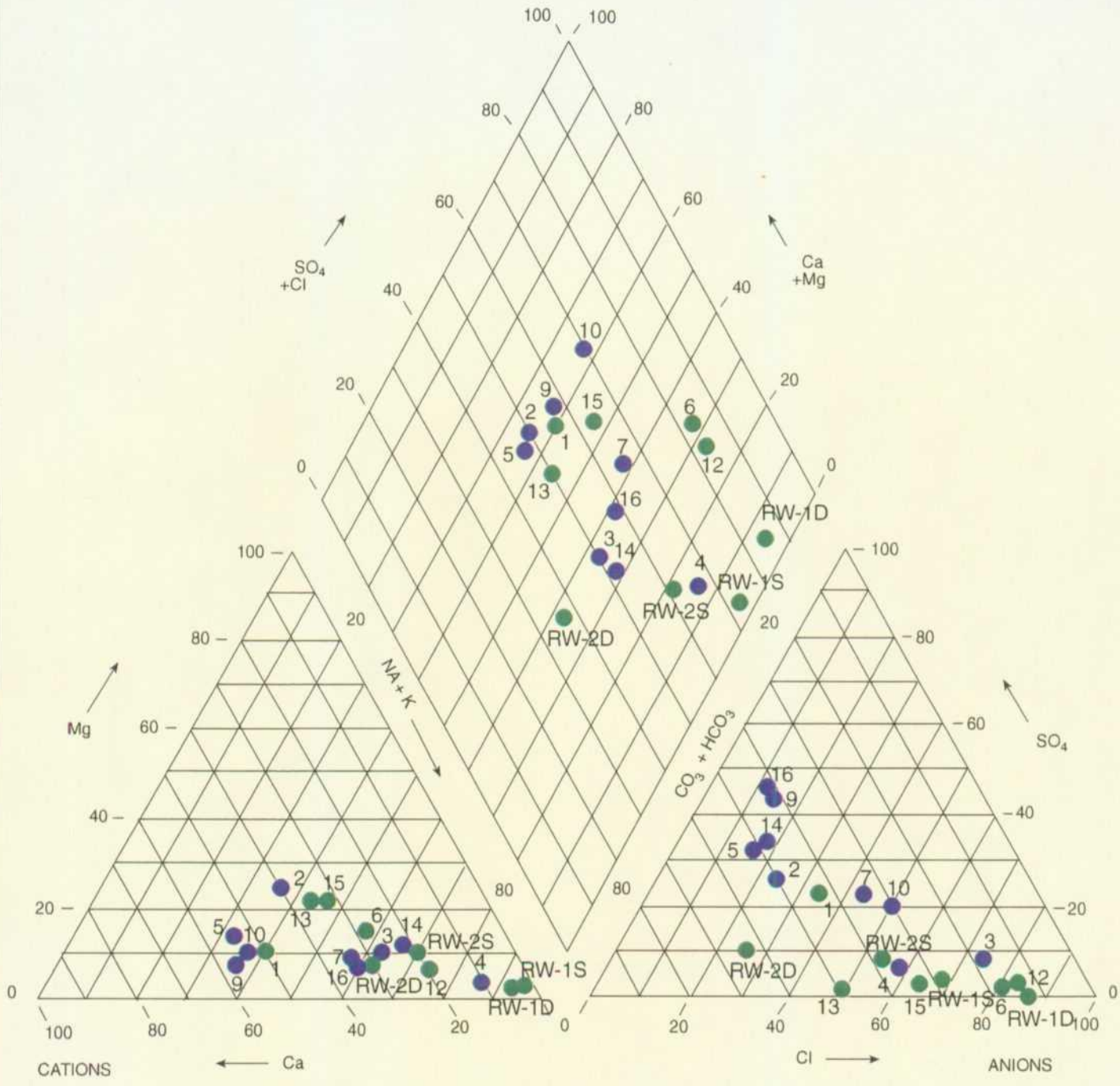
Moving downgradient of the NAPL zone, MW-15 reflects transitional conditions in the dissolved plume. Concentrations of electron acceptors remain depressed at this location at levels similar to those present in the NAPL zone. Finally, moving downgradient to wells MW-3, MW-4, MW-14, and MW-16, levels of electron acceptor rebound to levels similar to those present at background locations. This is consistent with the absence of BTEX in these wells and suggests that a significant capacity for biological attenuation of dissolved hydrocarbons exists downgradient of the site.

Reaction By-products–Another piece of evidence indicating active bioattenuation at the site is the production of the reaction by-products. These by-products include bicarbonate, iron, and methane. Naturally occurring biodegradation of petroleum hydrocarbons tends to increase the alkalinity of groundwater through the uptake of hydronium ions associated with specific biodegradation processes, (eg. sulfate reduction) and/or the dissolution of soil minerals resulting from reaction with acids generated in hydrocarbon degradation (see reactions 1 through 5 in Figure 3-1). Methane is produced as hydrocarbons are oxidized, as illustrated in reaction 4 in Figure 3-1. Iron concentrations increase as insoluble ferric iron (Fe^{3+}) is used as an electron acceptor (see reaction 5, Figure 3-1), forming soluble ferrous iron (Fe^{2+}).

Figure 4-2 presents average aqueous concentrations of biological reaction by-products over four quarters of sampling. Comparing background wells to wells within the NAPL zone, levels of iron, methane and, bicarbonate increase by 110, 73 and, 62 percent, respectively. Moving downgradient of the NAPL zone, elevated levels of by-products are seen in the dissolved plume at MW-15 and near background conditions are observed at MW-3, MW-4, MW-14, and MW-16.

General Geochemistry–Figure 4-3 presents a trilinear diagram illustrating major anion/cations chemistry in background and NAPL/dissolved plume wells. In general, background water quality at the Unit is a calcium-magnesium-sulfate type water quality. When this water comes in contact with site hydrocarbons:

- Sulfate is reduced to sulfide that, in all probability, precipitates out with ferrous iron to form pyrite (FeS_2).
- The dominant anion in the vicinity of the NAPL and dissolved hydrocarbons becomes chloride, probably reflecting precipitation of sulfide and minor releases of produced-water in the vicinity of the NAPL.
- Concentration of calcium is reduced, probably reflecting precipitation of the Ca^{2+} with carbonate to form calcite.
- The dominant cation becomes sodium once again reflecting the possible release of produced-water in the vicinity of the NAPL.



PERCENTAGE REACTING VALUES

Background Wells

MW-2
MW-3
MW-4
MW-5
MW-7
MW-9
MW-10
MW-14
MW-16

Wells Within NAPL and Dissolved Plume Areas

MW-1
MW-6
MW-12
MW-13
MW-15
RW-2-S/D
RW-1-S/D

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South Four Lakes Unit
Tatum, New Mexico

Trilinear Diagram of Major Anion/Cation Chemistry

FIGURE 4-3

SECTION 5

Conclusion

SECTION 5

Conclusion

This report presents the findings of four rounds of natural attenuation monitoring, focusing on bioattenuation, at Phillips' South Four Lakes Production Unit.

Based on the findings of this monitoring program, natural attenuation is a protective remedy for the dissolved plume at Phillips' South Four Lakes Unit. This finding is based on the following line of reasoning:

1. Given the time elapsed since the presumed date of the initial historical release at the unit, the length of the aqueous phase plume is limited. It does not extend to MW-14 or MW-16, located approximately 440 to 530 feet down-gradient of the area in which NAPL has been identified in soils at the water table.

2. The current extent of the plume is less than would be the case if no biodegradation was occurring.

3. The geochemical data for the site provides clear evidence of uptake of electron acceptors and production of biological reaction by-products. This is clear evidence that dissolved petroleum hydrocarbon biodegradation is occurring.

4. The premise that naturally occurring biodegradation is limiting plume migration at the South Four Lakes Unit to a relatively short distance down-gradient from the source area is consistent with the current technical understanding of plume migration at petroleum hydrocarbon sites (Rice et. al., 1995).

5. Given local and regional groundwater use, the groundwater plume in its current extent poses no risk to human health or the environment.

6. Source control has been implemented with the removal of contaminated soils beneath the closed EXXON production pit (December 1995) and the ongoing NAPL recovery operations at RW-2. Given these source control measures, contaminant loading to groundwater will decrease through time, and the groundwater plume will decrease in concentration and areal extent over time.

SECTION 6

References

SECTION 6

References

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APPENDIX A

Groundwater Data

Phillips Petroleum Company, South Four Lakes Unit
1996 Analytical Data

Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-01	IN	Alkalinity	260.00	210.00	230.00	250.00	237.50	22.17		1.000	MG/L
MW-01	IN	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.1	0.005	MG/L
MW-01	IN	Barium	NA	0.13	0.24	0.75	0.37	0.33	1.0	0.010	MG/L
MW-01	IN	Benzene	260.00	51.00	NA	NA	155.50	147.79	10.00	1.000	UG/L
MW-01	IN	Bicarbonate	260.00	210.00	230.00	250.00	237.50	22.17		1.000	MG/L
MW-01	IN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-01	IN	Calcium	100.00	130.00	140.00	100.00	117.50	20.62		0.200	MG/L
MW-01	IN	Carbonate	BDL	BDL	BDL	BDL	BDL	0.00		1.000	MG/L
MW-01	IN	Chloride	120.00	150.00	160.00	170.00	150.00	21.60		2.500	MG/L
MW-01	IN	Chromium	NA	0.06	0.05	BDL	0.05	0.01	0.05	0.010	MG/L
MW-01	IN	Ethyl Benzene	450.00	340.00	NA	NA	395.00	77.78	750.0	1.000	UG/L
MW-01	IN	Iron	0.14	0.08	0.07	0.06	0.09	0.04		0.025	MG/L
MW-01	IN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-01	IN	Magnesium	13.00	16.00	18.00	12.00	14.75	2.75		0.200	MG/L
MW-01	IN	Manganese	0.40	0.32	0.36	0.35	0.36	0.03		0.010	MG/L
MW-01	IN	Mercury	NA	BDL	BDL	BDL	BDL	BDL	0.002	0.0002	MG/L
MW-01	IN	Methane	20.00	BDL	8.60	NA	14.30	8.06		8.000	UG/L
MW-01	IN	Naphthalene	NA	140.00	NA	NA	140.00		30.0	1.000	UG/L
MW-01	IN	Nitrogen, Nitrate	1.00	1.60	1.60	1.00	1.30	0.35		0.050	MG/L
MW-01	IN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-01	IN	Oxygen	1.50	2.50	1.19	BDL	1.73	0.68		0.100	MG/L
MW-01	IN	Phosphorus	0.06	0.08	0.07	0.07	0.07	0.01		0.030	MG/L
MW-01	IN	Potassium	1.40	1.20	1.30	1.00	1.23	0.17		0.200	MG/L
MW-01	IN	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-01	IN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-01	IN	Sodium	91.00	73.00	85.00	80.00	82.25	7.63		0.200	MG/L
MW-01	IN	Solids	680.00	750.00	800.00	1300.00	882.50	282.65		10.000	MG/L
MW-01	IN	Sulfate	120.00	160.00	160.00	130.00	142.50	20.62		0.250	MG/L
MW-01	IN	Sulfide	BDL	BDL	3.00	2.00	2.50	0.71		1.000	MG/L
MW-01	IN	Toluene	730.00	270.00	NA	NA	500.00	325.27	750.0	1.000	UG/L
MW-01	IN	Total Organic Carbon	80.00	3.60	5.90	13.00	25.63	36.47		1.000	MG/L
MW-01	IN	Total Xylenes	2720.00	2190.00	NA	NA	2455.00	374.77	620.0	1.000	UG/L

BDL = Below Method Detection Limit
DWN = Down Gradient Well
IN = Well Within NAPL Zone
NA = Not Analyzed
UP = Upgradient Well
WQCC = Water Quality Control Commission

Phillips Petroleum Company, South Four Lakes Unit
1996 Analytical Data

Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-02	UP	Alkalinity	290.00	270.00	340.00	300.00	300.00	29.44		1.000	MG/L
MW-02	UP	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-02	UP	Barium	NA	0.06	0.06	0.05	0.06	0.01	1.0	0.010	MG/L
MW-02	UP	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-02	UP	Bicarbonate	290.00	270.00	340.00	300.00	300.00	29.44		1.000	MG/L
MW-02	UP	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-02	UP	Calcium	85.00	100.00	100.00	87.00	93.00	8.12		0.200	MG/L
MW-02	UP	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-02	UP	Chloride	80.00	80.00	84.00	79.00	80.75	2.22		2.500	MG/L
MW-02	UP	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-02	UP	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-02	UP	Iron	BDL	0.04	0.03	BDL	0.03	0.01		0.025	MG/L
MW-02	UP	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-02	UP	Magnesium	31.00	33.00	33.00	28.00	31.25	2.36		0.200	MG/L
MW-02	UP	Manganese	0.29	0.32	0.32	0.28	0.30	0.02		0.010	MG/L
MW-02	UP	Mercury	NA	BDL	0.001	BDL	0.001		0.002	0.0002	MG/L
MW-02	UP	Methane	BDL	BDL	BDL	BDL	BDL	BDL		8.000	UG/L
MW-02	UP	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-02	UP	Nitrogen, Nitrate	16.00	17.00	17.00	16.00	16.50	0.58		0.050	MG/L
MW-02	UP	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-02	UP	Oxygen	1.60	3.44	3.44	1.83	2.58	1.00		0.100	MG/L
MW-02	UP	Phosphorus	0.08	0.05	0.19	0.06	0.10	0.06		0.030	MG/L
MW-02	UP	Potassium	2.40	2.60	2.40	2.10	2.38	0.21		0.200	MG/L
MW-02	UP	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-02	UP	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-02	UP	Sodium	82.00	82.00	79.00	65.00	77.00	8.12		0.200	MG/L
MW-02	UP	Solids	680.00	700.00	680.00	680.00	685.00	10.00		10.000	MG/L
MW-02	UP	Sulfate	120.00	120.00	120.00	130.00	122.50	5.00		0.250	MG/L
MW-02	UP	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-02	UP	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-02	UP	Total Organic Carbon	BDL	BDL	3.80	2.00	2.90	1.27		1.000	MG/L
MW-02	UP	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

BDL = Below Method Detection Limit
DWN = Down Gradient Well
IN = Well Within NAPL Zone
NA = Not Analyzed
UP = Upgradient Well
WQCC = Water Quality Control Commission

Phillips Petroleum Company, South Four Lakes Unit
1996 Analytical Data

Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-03	DWN	Alkalinity	440.00	440.00	440.00	440.00	440.00	0.00		1.000	MG/L
MW-03	DWN	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-03	DWN	Barium	NA	0.10	0.10	0.09	0.10	0.01	1.0	0.010	MG/L
MW-03	DWN	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-03	DWN	Bicarbonate	440.00	440.00	440.00	440.00	440.00	0.00		1.000	MG/L
MW-03	DWN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-03	DWN	Calcium	200.00	220.00	210.00	190.00	BDL	BDL		0.200	MG/L
MW-03	DWN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-03	DWN	Chloride	1000.00	990.00	1100.00	1200.00	1072.50	98.45		2.500	MG/L
MW-03	DWN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-03	DWN	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-03	DWN	Iron	BDL	0.03	0.03	BDL	0.03	0.003		0.025	MG/L
MW-03	DWN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-03	DWN	Magnesium	43.00	46.00	44.00	40.00	43.25	2.50		0.200	MG/L
MW-03	DWN	Manganese	BDL	BDL	BDL	BDL	BDL	BDL		0.010	MG/L
MW-03	DWN	Mercury	NA	BDL	0.0013	0.0003	0.001	0.001	0.002	0.0002	MG/L
MW-03	DWN	Methane	240.00	1200.00	490.00	480.00	602.50	414.76		8.000	UG/L
MW-03	DWN	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-03	DWN	Nitrogen, Nitrate	0.46	0.48	0.40	0.44	0.45	0.03		0.050	MG/L
MW-03	DWN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	0.00	0.00		0.500	MG/L
MW-03	DWN	Oxygen	3.26	2.15	1.88	1.14	2.11	0.88		0.100	MG/L
MW-03	DWN	Phosphorus	0.04	BDL	0.05	0.04	0.04	0.01		0.030	MG/L
MW-03	DWN	Potassium	14.00	15.00	14.00	13.00	14.00	0.82		0.200	MG/L
MW-03	DWN	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-03	DWN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-03	DWN	Sodium	490.00	570.00	560.00	490.00	527.50	43.49		0.200	MG/L
MW-03	DWN	Solids	2300.00	2300.00	2400.00	2400.00	2350.00	57.74		10.000	MG/L
MW-03	DWN	Sulfate	99.00	90.00	97.00	96.00	95.50	3.87		0.250	MG/L
MW-03	DWN	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-03	DWN	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-03	DWN	Total Organic Carbon	5.20	BDL	11.00	1.30	6.15	6.86		1.000	MG/L
MW-03	DWN	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

BDL = Below Method Detection Limit
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IN = Well Within NAPL Zone
NA = Not Analyzed
UP = Upgradient Well
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Phillips Petroleum Company, South Four Lakes Unit
1996 Analytical Data

Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-04	DWN	Alkalinity	480.00	390.00	400.00	380.00	412.50	45.73		1.000	MG/L
MW-04	DWN	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-04	DWN	Barium	NA	0.17	0.31	0.42	0.30	0.13	1.0	0.010	MG/L
MW-04	DWN	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-04	DWN	Bicarbonate	480.00	390.00	400.00	380.00	412.50	45.73		1.000	MG/L
MW-04	DWN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-04	DWN	Calcium	45.00	76.00	100.00	110.00	82.75	28.93		0.200	MG/L
MW-04	DWN	Carbonate	BDL	BDL	BDL	BDL	0.00	0.00		1.000	MG/L
MW-04	DWN	Chloride	460.00	450.00	460.00	460.00	457.50	5.00		2.500	MG/L
MW-04	DWN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-04	DWN	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-04	DWN	Iron	0.52	1.00	1.60	0.97	1.02	0.44		0.025	MG/L
MW-04	DWN	Lead	NA	BDL	BDL	BDL	BDL	BDL		0.005	MG/L
MW-04	DWN	Magnesium	8.20	14.00	20.00	22.00	16.05	6.24		0.200	MG/L
MW-04	DWN	Manganese	0.07	0.12	0.16	0.17	0.13	0.05		0.010	MG/L
MW-04	DWN	Mercury	NA	BDL	0.0004	BDL	0.0004		0.002	0.0002	MG/L
MW-04	DWN	Methane	720.00	6600.00	5000.00	3500.00	3955.00	2500.69		8.000	UG/L
MW-04	DWN	Naphthalene	NA	12.00	19.00	15.00	15.33	3.51	30.0	1.000	UG/L
MW-04	DWN	Nitrogen, Nitrate	BDL	BDL	BDL	0.06	0.06			0.050	MG/L
MW-04	DWN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-04	DWN	Oxygen	2.65	2.00	1.90	NA	2.18	0.41		0.100	MG/L
MW-04	DWN	Phosphorus	0.14	0.05	0.11	0.04	0.09	0.05		0.030	MG/L
MW-04	DWN	Potassium	17.00	20.00	23.00	22.00	20.50	2.65		0.200	MG/L
MW-04	DWN	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-04	DWN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-04	DWN	Sodium	410.00	400.00	280.00	210.00	325.00	96.78		0.200	MG/L
MW-04	DWN	Solids	1300.00	1300.00	1200.00	1200.00	1250.00	57.74		10.000	MG/L
MW-04	DWN	Sulfate	78.00	60.00	43.00	36.00	54.25	18.77		0.250	MG/L
MW-04	DWN	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-04	DWN	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-04	DWN	Total Organic Carbon	4.00	BDL	11.00	BDL	7.50	4.95		1.000	MG/L
MW-04	DWN	Total Xylenes	BDL	1.20	BDL	BDL	1.20		620.0	1.000	UG/L

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Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-05	UP	Alkalinity	220.00	230.00	220.00	220.00	222.50	5.00		1.000	MG/L
MW-05	UP	Arsenic	NA	BDL	BDL	0.01	0.01		0.10	0.005	MG/L
MW-05	UP	Barium	NA	0.06	0.05	0.05	0.05	0.01	1.0	0.010	MG/L
MW-05	UP	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-05	UP	Bicarbonate	220.00	230.00	220.00	220.00	222.50	5.00		1.000	MG/L
MW-05	UP	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-05	UP	Calcium	85.00	92.00	84.00	78.00	84.75	5.74		0.200	MG/L
MW-05	UP	Carbonate	BDL	BDL	BDL	BDL	0.00	0.00		1.000	MG/L
MW-05	UP	Chloride	41.00	40.00	38.00	36.00	38.75	2.22		2.500	MG/L
MW-05	UP	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-05	UP	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-05	UP	Iron	BDL	BDL	BDL	BDL	BDL	BDL		0.025	MG/L
MW-05	UP	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-05	UP	Magnesium	13.00	14.00	13.00	12.00	13.00	0.82		0.200	MG/L
MW-05	UP	Manganese	BDL	BDL	BDL	BDL	BDL	BDL		0.010	MG/L
MW-05	UP	Mercury	NA	BDL	BDL	BDL	BDL	BDL	0.002	0.0002	MG/L
MW-05	UP	Methane	BDL	21.00	BDL	BDL	21.00			8.000	UG/L
MW-05	UP	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-05	UP	Nitrogen, Nitrate	1.30	1.20	0.91	1.10	1.13	0.17		0.050	MG/L
MW-05	UP	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-05	UP	Oxygen	5.27	5.38	NA	6.51	5.72	0.69		0.100	MG/L
MW-05	UP	Phosphorus	BDL	BDL	0.05	0.04	0.05	0.01		0.030	MG/L
MW-05	UP	Potassium	1.30	1.30	1.30	1.20	1.28	0.05		0.200	MG/L
MW-05	UP	Selenium	NA	BDL	BDL	0.01	0.01		0.05	0.005	MG/L
MW-05	UP	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-05	UP	Sodium	54.00	56.00	50.00	46.00	51.50	4.43		0.200	MG/L
MW-05	UP	Solids	500.00	490.00	470.00	500.00	490.00	14.14		10.000	MG/L
MW-05	UP	Sulfate	110.00	110.00	100.00	110.00	107.50	5.00		0.250	MG/L
MW-05	UP	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-05	UP	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-05	UP	Total Organic Carbon	BDL	BDL	1.90	2.00	1.95	0.07		1.000	MG/L
MW-05	UP	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

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MW-06	IN	Alkalinity	550.00	340.00	530.00	970.00	597.50	265.75		1.000	MG/L
MW-06	IN	Arsenic	NA	0.02	0.02	0.02	0.02	0.00	0.10	0.005	MG/L
MW-06	IN	Barium	NA	4.40	3.00	2.20	3.20	1.11	1.0	0.010	MG/L
MW-06	IN	Benzene	9100.00	13000.00	NA	NA	11050.00	2757.72	10.0	1.000	UG/L
MW-06	IN	Bicarbonate	550.00	340.00	530.00	970.00	597.50	265.75		1.000	MG/L
MW-06	IN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-06	IN	Calcium	260.00	230.00	210.00	180.00	220.00	33.67		0.200	MG/L
MW-06	IN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-06	IN	Chloride	1400.00	1200.00	1100.00	890.00	1147.50	212.19		2.500	MG/L
MW-06	IN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-06	IN	Ethyl Benzene	930.00	5000.00	NA	NA	2965.00	2877.92	750.0	1.000	UG/L
MW-06	IN	Iron	3.20	2.20	1.90	1.40	2.18	0.76		0.025	MG/L
MW-06	IN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-06	IN	Magnesium	66.00	57.00	53.00	41.00	54.25	10.37		0.200	MG/L
MW-06	IN	Manganese	1.10	1.00	0.85	0.72	0.92	0.17		0.010	MG/L
MW-06	IN	Mercury	NA	BDL	0.0008	BDL	0.0008		0.002	0.0002	MG/L
MW-06	IN	Methane	120.00	380.00	39.00	NA	179.67	178.16		8.000	UG/L
MW-06	IN	Naphthalene	NA	1900.00	NA	NA	1900.00		30.0	1.000	UG/L
MW-06	IN	Nitrogen, Nitrate	BDL	0.73	0.48	0.29	0.50	0.22		0.050	MG/L
MW-06	IN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-06	IN	Oxygen	1.98	BDL	1.67	BDL	1.83	0.22		0.100	MG/L
MW-06	IN	Phosphorus	0.23	0.28	0.11	0.14	0.19	0.08		0.030	MG/L
MW-06	IN	Potassium	2.10	1.80	1.50	1.40	1.70	0.32		0.200	MG/L
MW-06	IN	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-06	IN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-06	IN	Sodium	620.00	500.00	570.00	540.00	557.50	50.58		0.200	MG/L
MW-06	IN	Solids	3700.00	2600.00	2500.00	2500.00	2825.00	585.23		10.000	MG/L
MW-06	IN	Sulfate	46.00	56.00	40.00	43.00	46.25	6.95		0.250	MG/L
MW-06	IN	Sulfide	7.80	3.00	BDL	2.00	4.27	3.10		1.000	MG/L
MW-06	IN	Toluene	11000.00	19000.00	NA	NA	15000.00	5656.85	750.0	1.000	UG/L
MW-06	IN	Total Organic Carbon	750.00	11.00	13.00	13.00	196.75	368.83		1.000	MG/L
MW-06	IN	Total Xylenes	5300.00	24500.00	NA	NA	14900.00	13576.45	620.0	1.000	UG/L

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MW-07	UP	Alkalinity	300.00	430.00	430.00	730.00	472.50	182.28		1.000	MG/L
MW-07	UP	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-07	UP	Barium	NA	0.08	0.05	0.07	0.07	0.01	1.0	0.010	MG/L
MW-07	UP	Benzene	5.90	4.20	3.20	4.70	4.50	1.12	10.0	1.000	UG/L
MW-07	UP	Bicarbonate	300.00	430.00	430.00	730.00	472.50	182.28		1.000	MG/L
MW-07	UP	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-07	UP	Calcium	91.00	94.00	62.00	69.00	79.00	15.90		0.200	MG/L
MW-07	UP	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-07	UP	Chloride	210.00	180.00	110.00	120.00	155.00	47.96		2.500	MG/L
MW-07	UP	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-07	UP	Ethyl Benzene	13.00	11.00	10.00	15.00	12.25	2.22	750.0	1.000	UG/L
MW-07	UP	Iron	0.67	0.77	0.46	0.40	0.58	0.17		0.025	MG/L
MW-07	UP	Lead	NA	BDL	BDL	BDL	0.00	0.00	0.05	0.005	MG/L
MW-07	UP	Magnesium	17.00	17.00	11.00	12.00	14.25	3.20		0.200	MG/L
MW-07	UP	Manganese	0.10	0.11	0.08	0.07	0.09	0.02		0.010	MG/L
MW-07	UP	Mercury	NA	BDL	0.0012	BDL	0.0012		0.002	0.0002	MG/L
MW-07	UP	Methane	170.00	490.00	190.00	440.00	322.50	166.01		8.000	UG/L
MW-07	UP	Naphthalene	NA	5.40	3.50	7.30	4.05	3.11	30.0	1.000	UG/L
MW-07	UP	Nitrogen, Nitrate	BDL	BDL	BDL	BDL	BDL	BDL		0.050	MG/L
MW-07	UP	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-07	UP	Oxygen	2.06	2.82	3.37	0.76	2.25	1.13		0.100	MG/L
MW-07	UP	Phosphorus	0.11	0.15	0.14	0.17	0.14	0.02		0.030	MG/L
MW-07	UP	Potassium	38.00	36.00	30.00	32.00	34.00	3.65		0.200	MG/L
MW-07	UP	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-07	UP	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-07	UP	Sodium	180.00	160.00	120.00	130.00	147.50	27.54		0.200	MG/L
MW-07	UP	Solids	900.00	920.00	730.00	720.00	817.50	107.20		10.000	MG/L
MW-07	UP	Sulfate	170.00	170.00	170.00	180.00	172.50	5.00		0.250	MG/L
MW-07	UP	Sulfide	BDL	2.00	BDL	3.00	2.50	0.71		1.000	MG/L
MW-07	UP	Toluene	BDL	BDL	BDL	BDL	0.00	0.00	750.0	1.000	UG/L
MW-07	UP	Total Organic Carbon	BDL	BDL	1.40	BDL	1.40			1.000	MG/L
MW-07	UP	Total Xylenes	BDL	BDL	BDL	BDL	0.00	0.00	620.0	1.000	UG/L

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MW-09	UP	Alkalinity	230.00	200.00	200.00	210.00	210.00	14.14		1.000	MG/L
MW-09	UP	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-09	UP	Barium	NA	0.06	0.07	0.05	0.06	0.01	1.0	0.010	MG/L
MW-09	UP	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-09	UP	Bicarbonate	230.00	200.00	200.00	210.00	210.00	14.14		1.000	MG/L
MW-09	UP	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-09	UP	Calcium	100.00	100.00	100.00	86.00	96.50	7.00		0.200	MG/L
MW-09	UP	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-09	UP	Chloride	54.00	58.00	57.00	58.00	56.75	1.89		2.500	MG/L
MW-09	UP	Chromium	NA	0.01	BDL	BDL	0.01		0.05	0.010	MG/L
MW-09	UP	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-09	UP	Iron	BDL	0.04	BDL	BDL	0.04			0.025	MG/L
MW-09	UP	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-09	UP	Magnesium	11.00	11.00	11.00	9.30	10.58	0.85		0.200	MG/L
MW-09	UP	Manganese	BDL	BDL	BDL	BDL	BDL	BDL		0.010	MG/L
MW-09	UP	Mercury	NA	BDL	0.0004	BDL	0.0004		0.002	0.0002	MG/L
MW-09	UP	Methane	BDL	BDL	BDL	BDL	BDL	BDL		8.000	UG/L
MW-09	UP	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-09	UP	Nitrogen, Nitrate	0.59	0.56	0.65	0.70	0.63	0.06		0.050	MG/L
MW-09	UP	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-09	UP	Oxygen	5.98	7.03	6.30	6.30	6.40	0.44		0.100	MG/L
MW-09	UP	Phosphorus	0.10	0.06	0.10	0.08	0.09	0.02		0.030	MG/L
MW-09	UP	Potassium	2.00	2.40	1.80	1.60	1.95	0.34		0.200	MG/L
MW-09	UP	Selenium	NA	0.01	BDL	BDL	0.01		0.05	0.005	MG/L
MW-09	UP	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-09	UP	Sodium	74.00	71.00	78.00	65.00	72.00	5.48		0.200	MG/L
MW-09	UP	Solids	620.00	630.00	640.00	620.00	627.50	9.57		10.000	MG/L
MW-09	UP	Sulfate	180.00	190.00	180.00	190.00	185.00	5.77		0.250	MG/L
MW-09	UP	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-09	UP	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-09	UP	Total Organic Carbon	BDL	BDL	6.90	BDL	6.90			1.000	MG/L
MW-09	UP	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

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MW-10	UP	Alkalinity	300.00	200.00	220.00	240.00	240.00	43.20		1.000	MG/L
MW-10	UP	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-10	UP	Barium	NA	0.06	0.07	0.05	0.06	0.01	1.0	0.010	MG/L
MW-10	UP	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-10	UP	Bicarbonate	300.00	200.00	220.00	240.00	240.00	43.20		1.000	MG/L
MW-10	UP	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-10	UP	Calcium	170.00	160.00	160.00	140.00	157.50	12.58		0.200	MG/L
MW-10	UP	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-10	UP	Chloride	290.00	260.00	260.00	260.00	267.50	15.00		2.500	MG/L
MW-10	UP	Chromium	NA	0.62	0.56	0.46	0.55	0.08	0.05	0.010	MG/L
MW-10	UP	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-10	UP	Iron	BDL	BDL	BDL	BDL	BDL	BDL		0.025	MG/L
MW-10	UP	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-10	UP	Magnesium	20.00	19.00	19.00	16.00	18.50	1.73		0.200	MG/L
MW-10	UP	Manganese	BDL	BDL	BDL	0.02	0.02			0.010	MG/L
MW-10	UP	Mercury	NA	BDL	0.0008	BDL	0.0008		0.002	0.0002	MG/L
MW-10	UP	Methane	BDL	BDL	BDL	BDL	BDL	BDL		8.000	UG/L
MW-10	UP	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-10	UP	Nitrogen, Nitrate	4.80	4.10	3.70	3.90	4.13	0.48		0.050	MG/L
MW-10	UP	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-10	UP	Oxygen	4.80	4.57	4.58	4.10	4.51	0.29		0.100	MG/L
MW-10	UP	Phosphorus	0.06	0.05	0.11	0.08	0.08	0.03		0.030	MG/L
MW-10	UP	Potassium	3.40	4.00	3.40	3.00	3.45	0.41		0.200	MG/L
MW-10	UP	Selenium	NA	0.01	BDL	BDL	0.01		0.05	0.005	MG/L
MW-10	UP	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-10	UP	Sodium	130.00	110.00	120.00	120.00	120.00	8.16		0.200	MG/L
MW-10	UP	Solids	1100.00	970.00	1000.00	1000.00	1017.50	56.79		10.000	MG/L
MW-10	UP	Sulfate	160.00	160.00	170.00	180.00	167.50	9.57		0.250	MG/L
MW-10	UP	Sulfide	1.40	5.00	BDL	BDL	3.20	2.55		1.000	MG/L
MW-10	UP	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-10	UP	Total Organic Carbon	BDL	BDL	2.00	2.60	2.30	0.42		1.000	MG/L
MW-10	UP	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

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MW-12	IN	Alkalinity	630.00	550.00	540.00	670.00	597.50	62.92		1.000	MG/L
MW-12	IN	Arsenic	NA	0.02	0.02	0.01	0.02	0.005	0.10	0.005	MG/L
MW-12	IN	Barium	NA	20.00	15.00	15.00	16.67	2.89	1.0	0.010	MG/L
MW-12	IN	Benzene	7200.00	11000.00	NA	NA	9100.00	2687.01	10.0	1.000	UG/L
MW-12	IN	Bicarbonate	630.00	550.00	540.00	670.00	597.50	62.92		1.000	MG/L
MW-12	IN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-12	IN	Calcium	200.00	370.00	320.00	290.00	295.00	71.41		0.200	MG/L
MW-12	IN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-12	IN	Chloride	1700.00	2100.00	1900.00	2000.00	1925.00	170.78		2.500	MG/L
MW-12	IN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-12	IN	Ethyl Benzene	1500.00	1100.00	NA	NA	1300.00	282.84	750.0	1.000	UG/L
MW-12	IN	Iron	2.80	5.60	5.20	0.04	3.41	2.56		0.025	MG/L
MW-12	IN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-12	IN	Magnesium	45.00	90.00	66.00	76.00	69.25	18.93		0.200	MG/L
MW-12	IN	Manganese	0.85	1.60	1.30	1.30	1.26	0.31		0.010	MG/L
MW-12	IN	Mercury	NA	BDL	BDL	0.0015	0.001		0.002	0.0002	MG/L
MW-12	IN	Methane	310.00	430.00	920.00	NA	553.33	323.16		8.000	UG/L
MW-12	IN	Naphthalene	NA	320.00	NA	NA	320.00		30.0	1.000	UG/L
MW-12	IN	Nitrogen, Nitrate	BDL	BDL	BDL	BDL	BDL	BDL		0.050	MG/L
MW-12	IN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-12	IN	Oxygen	0.81	1.32	1.35	BDL	1.16	0.30		0.100	MG/L
MW-12	IN	Phosphorus	0.13	0.26	0.15	0.19	0.18	0.06		0.030	MG/L
MW-12	IN	Potassium	18.00	29.00	23.00	21.00	22.75	4.65		0.200	MG/L
MW-12	IN	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-12	IN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-12	IN	Sodium	800.00	900.00	890.00	590.00	795.00	143.87		0.200	MG/L
MW-12	IN	Solids	3600.00	4300.00	4200.00	4300.00	4100.00	336.65		10.000	MG/L
MW-12	IN	Sulfate	0.86	BDL	BDL	0.37	0.62	0.35		0.250	MG/L
MW-12	IN	Sulfide	BDL	9.00	BDL	3.00	6.00	4.24		1.000	MG/L
MW-12	IN	Toluene	6100.00	11000.00	NA	NA	8550.00	3464.82	750.0	1.000	UG/L
MW-12	IN	Total Organic Carbon	46.00	19.00	14.00	22.00	25.25	14.22		1.000	MG/L
MW-12	IN	Total Xylenes	7400.00	6500.00	NA	NA	6950.00	636.40	620.0	1.000	UG/L

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Phillips Petroleum Company, South Four Lakes Unit
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Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-13	DWN	Alkalinity	1000.00	680.00	630.00	690.00	750.00	168.72		1.000	MG/L
MW-13	DWN	Arsenic	NA	0.02	0.02	0.02	0.02	0.001	0.10	0.005	MG/L
MW-13	DWN	Barium	NA	1.70	1.60	1.80	1.70	0.100	1.0	0.010	MG/L
MW-13	DWN	Benzene	2400.00	2400.00	2200.00	2100.00	2275.00	150.00	10.0	1.000	UG/L
MW-13	DWN	Bicarbonate	1000.00	680.00	630.00	690.00	750.00	168.72		1.000	MG/L
MW-13	DWN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-13	DWN	Calcium	190.00	180.00	170.00	190.00	182.50	9.57		0.200	MG/L
MW-13	DWN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-13	DWN	Chloride	560.00	540.00	560.00	530.00	547.50	15.00		2.500	MG/L
MW-13	DWN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-13	DWN	Ethyl Benzene	330.00	370.00	430.00	350.00	370.00	43.20	750.0	1.000	UG/L
MW-13	DWN	Iron	4.30	4.00	4.00	4.40	4.18	0.21		0.025	MG/L
MW-13	DWN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-13	DWN	Magnesium	69.00	62.00	62.00	63.00	64.00	3.37		0.200	MG/L
MW-13	DWN	Manganese	1.90	1.90	1.90	2.10	1.95	0.10		0.010	MG/L
MW-13	DWN	Mercury	NA	BDL	0.0004	BDL	0.0004		0.002	0.0002	MG/L
MW-13	DWN	Methane	60.00	130.00	70.00	120.00	95.00	35.12		8.000	UG/L
MW-13	DWN	Naphthalene	NA	67.00	73.00	75.00	53.75	35.99	30.0	1.000	UG/L
MW-13	DWN	Nitrogen, Nitrate	0.07	BDL	BDL	BDL	0.07			0.050	MG/L
MW-13	DWN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-13	DWN	Oxygen	1.66	1.19	1.49	0.85	1.30	0.36		0.100	MG/L
MW-13	DWN	Phosphorus	0.12	0.08	0.11	0.09	0.10	0.02		0.030	MG/L
MW-13	DWN	Potassium	1.20	1.20	1.00	1.10	1.13	0.10		0.200	MG/L
MW-13	DWN	Selenium	NA	BDL	BDL	0.01	0.01		0.05	0.005	MG/L
MW-13	DWN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-13	DWN	Sodium	260.00	210.00	220.00	220.00	227.50	22.17		0.200	MG/L
MW-13	DWN	Solids	1500.00	1500.00	1500.00	1400.00	1475.00	50.00		10.000	MG/L
MW-13	DWN	Sulfate	4.50	2.30	2.70	2.80	3.08	0.97		0.250	MG/L
MW-13	DWN	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-13	DWN	Toluene	22.00	14.00	34.00	97.00	41.75	37.74	750.0	1.000	UG/L
MW-13	DWN	Total Organic Carbon	21.00	11.00	8.80	13.00	13.45	5.32		1.000	MG/L
MW-13	DWN	Total Xylenes	1590.00	1700.00	1820.00	1710.00	1705.00	93.99	620.0	1.000	UG/L

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Phillips Petroleum Company, South Four Lakes Unit
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MW-14	DWN	Alkalinity	450.00	650.00	1200.00	2000.00	1075.00	693.42		1.000	MG/L
MW-14	DWN	Arsenic	NA	BDL	BDL	0.01	BDL	BDL	0.10	0.005	MG/L
MW-14	DWN	Barium	NA	0.03	0.03	0.03	0.03	0.002	1.0	0.010	MG/L
MW-14	DWN	Benzene	BDL	BDL	BDL	BDL	BDL	BDL	10.0	1.000	UG/L
MW-14	DWN	Bicarbonate	450.00	650.00	1200.00	2000.00	1075.00	693.42		1.000	MG/L
MW-14	DWN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-14	DWN	Calcium	62.00	75.00	79.00	82.00	74.50	8.81		0.200	MG/L
MW-14	DWN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-14	DWN	Chloride	87.00	100.00	110.00	120.00	104.25	14.10		2.500	MG/L
MW-14	DWN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-14	DWN	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-14	DWN	Iron	0.03	0.05	0.03	BDL	0.03	0.01		0.025	MG/L
MW-14	DWN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-14	DWN	Magnesium	18.00	19.00	20.00	18.00	18.75	0.96		0.200	MG/L
MW-14	DWN	Manganese	0.01	0.01	0.01	BDL	0.01	0.001		0.010	MG/L
MW-14	DWN	Mercury	NA	BDL	0.0003	BDL	0.0003		0.002	0.0002	MG/L
MW-14	DWN	Methane	BDL	BDL	BDL	BDL	BDL	BDL		8.000	UG/L
MW-14	DWN	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-14	DWN	Nitrogen, Nitrate	0.38	0.47	0.37	0.60	0.46	0.11		0.050	MG/L
MW-14	DWN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-14	DWN	Oxygen	5.70	NA	3.68	2.96	2.89	2.85		0.100	MG/L
MW-14	DWN	Phosphorus	0.07	0.08	0.11	0.08	0.09	0.02		0.030	MG/L
MW-14	DWN	Potassium	2.60	1.90	1.70	1.20	1.85	0.58		0.200	MG/L
MW-14	DWN	Selenium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-14	DWN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-14	DWN	Sodium	210.00	200.00	180.00	180.00	192.50	15.00		0.200	MG/L
MW-14	DWN	Solids	900.00	920.00	1000.00	930.00	937.50	43.49		10.000	MG/L
MW-14	DWN	Sulfate	230.00	230.00	220.00	250.00	232.50	12.58		0.250	MG/L
MW-14	DWN	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-14	DWN	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-14	DWN	Total Organic Carbon	4.70	BDL	1.90	BDL	3.30	1.98		1.000	MG/L
MW-14	DWN	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

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Phillips Petroleum Company, South Four Lakes Unit
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Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
MW-15	DWN	Alkalinity	400.00	300.00	260.00	430.00	347.50	80.57		1.000	MG/L
MW-15	DWN	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-15	DWN	Barium	NA	1.70	1.80	2.40	1.97	0.38	1.0	0.010	MG/L
MW-15	DWN	Benzene	96.00	52.00	35.00	BDL	45.75	39.89	10.0	1.000	UG/L
MW-15	DWN	Bicarbonate	400.00	300.00	260.00	430.00	347.50	80.57		1.000	MG/L
MW-15	DWN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-15	DWN	Calcium	130.00	130.00	140.00	180.00	145.00	23.80		0.200	MG/L
MW-15	DWN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-15	DWN	Chloride	430.00	410.00	510.00	580.00	482.50	78.05		2.500	MG/L
MW-15	DWN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-15	DWN	Ethyl Benzene	880.00	690.00	850.00	610.00	757.50	128.94	750.0	1.000	UG/L
MW-15	DWN	Iron	1.70	1.60	1.80	2.40	1.88	0.36		0.025	MG/L
MW-15	DWN	Lead	NA	BDL	0.04	BDL	0.04		0.05	0.005	MG/L
MW-15	DWN	Magnesium	52.00	51.00	57.00	70.00	57.50	8.74		0.200	MG/L
MW-15	DWN	Manganese	0.66	0.66	0.75	0.98	0.76	0.15		0.010	MG/L
MW-15	DWN	Mercury	NA	BDL	0.0002	BDL	0.0002		0.002	0.0002	MG/L
MW-15	DWN	Methane	BDL	8.50	BDL	BDL	8.50			8.000	UG/L
MW-15	DWN	Naphthalene	NA	160.00	150.00	130.00	146.67	15.28	30.0	1.000	UG/L
MW-15	DWN	Nitrogen, Nitrate	BDL	BDL	BDL	BDL	BDL	BDL		0.050	MG/L
MW-15	DWN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-15	DWN	Oxygen	1.30	2.17	2.08	1.05	1.65	0.56		0.100	MG/L
MW-15	DWN	Phosphorus	0.05	0.06	0.06	0.05	0.06	0.01		0.030	MG/L
MW-15	DWN	Potassium	1.90	2.20	2.20	2.50	2.20	0.24		0.200	MG/L
MW-15	DWN	Selenium	NA	0.01	0.01	BDL	0.01	0.00	0.05	0.005	MG/L
MW-15	DWN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-15	DWN	Sodium	190.00	170.00	160.00	180.00	175.00	12.91		0.200	MG/L
MW-15	DWN	Solids	1200.00	1200.00	1400.00	1400.00	1300.00	115.47		10.000	MG/L
MW-15	DWN	Sulfate	27.00	42.00	55.00	46.00	42.50	11.68		0.250	MG/L
MW-15	DWN	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-15	DWN	Toluene	870.00	550.00	610.00	420.00	612.50	189.10	750.0	1.000	UG/L
MW-15	DWN	Total Organic Carbon	9.70	BDL	3.90	4.80	6.13	3.12		1.000	MG/L
MW-15	DWN	Total Xylenes	2400.00	1920.00	2150.00	1630.00	2025.00	328.28	620.0	1.000	UG/L

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MW-16	DWN	Alkalinity	330.00	330.00	340.00	390.00	347.50	28.72		1.000	MG/L
MW-16	DWN	Arsenic	NA	BDL	BDL	BDL	BDL	BDL	0.10	0.005	MG/L
MW-16	DWN	Barium	NA	0.03	0.03	0.03	0.03	0.001	1.0	0.010	MG/L
MW-16	DWN	Benzene	BDL	BDL	BDL	BDL	0.00	0.00	10.0	1.000	UG/L
MW-16	DWN	Bicarbonate	330.00	330.00	340.00	390.00	347.50	28.72		1.000	MG/L
MW-16	DWN	Cadmium	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.005	MG/L
MW-16	DWN	Calcium	91.00	92.00	88.00	79.00	87.50	5.92		0.200	MG/L
MW-16	DWN	Carbonate	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-16	DWN	Chloride	66.00	68.00	93.00	73.00	75.00	12.36		2.500	MG/L
MW-16	DWN	Chromium	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-16	DWN	Ethyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-16	DWN	Iron	BDL	0.03	0.04	BDL	0.04	0.003		0.025	MG/L
MW-16	DWN	Lead	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.005	MG/L
MW-16	DWN	Magnesium	15.00	15.00	14.00	13.00	14.25	0.96		0.200	MG/L
MW-16	DWN	Manganese	BDL	BDL	BDL	BDL	BDL	BDL		0.010	MG/L
MW-16	DWN	Mercury	NA	BDL	0.0004	BDL	0.0004		0.002	0.0002	MG/L
MW-16	DWN	Methane	BDL	BDL	BDL	BDL	BDL	BDL		8.000	UG/L
MW-16	DWN	Naphthalene	NA	BDL	BDL	BDL	BDL	BDL	30.0	1.000	UG/L
MW-16	DWN	Nitrogen, Nitrate	1.00	0.92	0.86	0.81	0.90	0.08		0.050	MG/L
MW-16	DWN	Nitrogen, Nitrite	BDL	BDL	BDL	BDL	BDL	BDL		0.500	MG/L
MW-16	DWN	Oxygen	4.90	4.75	3.03	3.56	4.06	0.91		0.100	MG/L
MW-16	DWN	Phosphorus	0.05	0.05	0.06	0.04	0.05	0.01		0.030	MG/L
MW-16	DWN	Potassium	1.50	0.96	1.20	0.89	1.14	0.28		0.200	MG/L
MW-16	DWN	Selenium	NA	0.01	BDL	BDL	0.01		0.05	0.005	MG/L
MW-16	DWN	Silver	NA	BDL	BDL	BDL	BDL	BDL	0.05	0.010	MG/L
MW-16	DWN	Sodium	190.00	170.00	180.00	160.00	175.00	12.91		0.200	MG/L
MW-16	DWN	Solids	900.00	910.00	910.00	870.00	897.50	18.93		10.000	MG/L
MW-16	DWN	Sulfate	280.00	260.00	230.00	260.00	257.50	20.62		0.250	MG/L
MW-16	DWN	Sulfide	BDL	BDL	BDL	BDL	BDL	BDL		1.000	MG/L
MW-16	DWN	Toluene	BDL	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
MW-16	DWN	Total Organic Carbon	BDL	BDL	2.90	BDL	2.90			1.000	MG/L
MW-16	DWN	Total Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	620.0	1.000	UG/L

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RW-1D	IN	Alkalinity	500.00	NA	NA	NA	500.00			1.000	MG/L
RW-1D	IN	Benzene	NA	6000.00	3000.00	3700.00	4233.33	1569.50	10.0	1.000	UG/L
RW-1D	IN	Bicarbonate	500.00	NA	NA	NA	500.00			1.000	MG/L
RW-1D	IN	Calcium	50.00	NA	NA	NA	50.00			0.200	MG/L
RW-1D	IN	Carbonate	BDL	NA	NA	NA	BDL	BDL		1.000	MG/L
RW-1D	IN	Cholride	1600.00	NA	NA	NA	1600.00			2.500	MG/L
RW-1D	IN	Ethyl Benzene	NA	510.00	210.00	220.00	313.33	170.39	750.0	1.000	UG/L
RW-1D	IN	Iron	0.11	NA	NA	NA	0.11			0.025	MG/L
RW-1D	IN	Magnesium	16.00	NA	NA	NA	16.00			0.200	MG/L
RW-1D	IN	Manganese	0.11	NA	NA	NA	0.11			0.010	MG/L
RW-1D	IN	Methane	73.00	NA	NA	NA	73.00			8.000	UG/L
RW-1D	IN	Naphthalene	NA	190.00	BDL	BDL	190.00		30.0	1.000	UG/L
RW-1D	IN	Nitrogen, Nitrite	BDL	NA	NA	NA	BDL	BDL		0.500	MG/L
RW-1D	IN	Nitrogren, Nitrate	BDL	NA	NA	NA	BDL	BDL		0.050	MG/L
RW-1D	IN	Oxygen	1.15	BDL	BDL	BDL	1.15			0.100	MG/L
RW-1D	IN	Phosphorous	0.08	NA	NA	NA	0.08			0.030	MG/L
RW-1D	IN	Potassium	7.00	NA	NA	NA	7.00			0.200	MG/L
RW-1D	IN	Sodium	1100.00	NA	NA	NA	1100.00			0.200	MG/L
RW-1D	IN	Solids	3300.00	NA	NA	NA	3300.00			10.000	MG/L
RW-1D	IN	Sufide	BDL	NA	NA	NA	BDL	BDL		1.000	MG/L
RW-1D	IN	Sulfate	7.90	NA	NA	NA	7.90			0.250	MG/L
RW-1D	IN	Toluene	NA	BDL	BDL	BDL	BDL	BDL	750.0	1.000	UG/L
RW-1D	IN	Total Organic Carbon	35.00	NA	NA	NA	35.00			1.000	MG/L
RW-1D	IN	Total Xylenes	NA	1960.00	350.00	230.00	846.67	966.04	620.0	1.000	UG/L

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RW-2D	IN	Alkalinity	1000.00	NA	NA	NA	1000.00			1.000	MG/L
RW-2D	IN	Benzene	NA	190.00	32.00	10.00	77.33	98.19	10.0	1.000	UG/L
RW-2D	IN	Bicarbonate	1000.00	NA	NA	NA	1000.00			1.000	MG/L
RW-2D	IN	Calcium	76.00	NA	NA	NA	76.00			0.200	MG/L
RW-2D	IN	Carbonate	BDL	NA	NA	NA	BDL	BDL		1.000	MG/L
RW-2D	IN	Chloride	250.00	NA	NA	NA	250.00			2.500	MG/L
RW-2D	IN	Ethyl Benzene	NA	64.00	BDL	4.10	34.05	42.36	750.0	1.000	UG/L
RW-2D	IN	Iron	0.08	NA	NA	NA	0.08			0.025	MG/L
RW-2D	IN	Magnesium	15.00	NA	NA	NA	15.00			0.200	MG/L
RW-2D	IN	Manganese	0.06	NA	NA	NA	0.06			0.010	MG/L
RW-2D	IN	Methane	BDL	NA	NA	NA	BDL	BDL		8.000	UG/L
RW-2D	IN	Naphthalene	NA	33.00	4.60	4.60	14.07	16.40	30.0	1.000	UG/L
RW-2D	IN	Nitrogen, Nitrate	0.07	NA	NA	NA	0.07			0.050	MG/L
RW-2D	IN	Nitrogen, Nitrite	BDL	NA	NA	NA	BDL	BDL		0.500	MG/L
RW-2D	IN	Oxygen	NA	NA	NA	NA	NA	NA		0.100	MG/L
RW-2D	IN	Phosphorus	0.34	NA	NA	NA	0.34			0.030	MG/L
RW-2D	IN	Potassium	4.30	NA	NA	NA	4.30			0.200	MG/L
RW-2D	IN	Sodium	180.00	NA	NA	NA	180.00			0.200	MG/L
RW-2D	IN	Solids	900.00	NA	NA	NA	900.00			10.000	MG/L
RW-2D	IN	Sulfate	130.00	NA	NA	NA	130.00			0.250	MG/L
RW-2D	IN	Sulfide	BDL	NA	NA	NA	BDL	BDL		1.000	MG/L
RW-2D	IN	Toluene	NA	110.00	3.60	7.10	40.23	60.45	750.0	1.000	UG/L
RW-2D	IN	Total Organic Carbon	23.00	NA	NA	NA	23.00			1.000	MG/L
RW-2D	IN	Total Xylenes	NA	260.00	80.00	24.00	121.33	123.31	620.0	1.000	UG/L

BDL = Below Method Detection Limit
DWN = Down Gradient Well
IN = Well Within NAPL Zone
NA = Not Analyzed
UP = Upgradient Well
WQCC = Water Quality Control Commission

Phillips Petroleum Company, South Four Lakes Unit
1996 Analytical Data

Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
RW-1S	IN	Alkalinity	790.00	NA	NA	NA				1.000	MG/L
RW-1S	IN	Benzene	5800.00	NA	NA	NA			10.0	1.000	UG/L
RW-1S	IN	Bicarbonate	790.00	NA	NA	NA				1.000	MG/L
RW-1S	IN	Calcium	39.00	NA	NA	NA				0.200	MG/L
RW-1S	IN	Carbonate	BDL	NA	NA	NA				1.000	MG/L
RW-1S	IN	Chloride	1100.00	NA	NA	NA				2.500	MG/L
RW-1S	IN	Ethyl Benzene	900.00	NA	NA	NA			750.0	1.000	UG/L
RW-1S	IN	Iron	0.06	NA	NA	NA				0.025	MG/L
RW-1S	IN	Magnesium	11.00	NA	NA	NA				0.200	MG/L
RW-1S	IN	Manganese	0.10	NA	NA	NA				0.010	MG/L
RW-1S	IN	Methane	130.00	NA	NA	NA				8.000	UG/L
RW-1S	IN	Naphthalene	NA	NA	NA	NA			30.0	1.000	UG/L
RW-1S	IN	Nitrogen, Nitrate	BDL	NA	NA	NA				0.050	MG/L
RW-1S	IN	Nitrogen, Nitrite	BDL	NA	NA	NA				0.500	MG/L
RW-1S	IN	Oxygen	2.25	NA	NA	NA				0.100	MG/L
RW-1S	IN	Phosphorus	0.32	NA	NA	NA				0.030	MG/L
RW-1S	IN	Potassium	5.70	NA	NA	NA				0.200	MG/L
RW-1S	IN	Sodium	920.00	NA	NA	NA				0.200	MG/L
RW-1S	IN	Solids	2600.00	NA	NA	NA				10.000	MG/L
RW-1S	IN	Sulfate	82.00	NA	NA	NA				0.250	MG/L
RW-1S	IN	Sulfide	BDL	NA	NA	NA				1.000	MG/L
RW-1S	IN	Toluene	5100.00	NA	NA	NA			750.0	1.000	UG/L
RW-1S	IN	Total Organic Carbon	47.00	NA	NA	NA				1.000	MG/L
RW-1S	IN	Total Xylenes	5100.00	NA	NA	NA			620.0	1.000	UG/L

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Phillips Petroleum Company, South Four Lakes Unit
1996 Analytical Data

Well ID	Group	Parameter	January	April	July	October	Average	Deviation	WQCC Standard	Method Limit	Units
RW-2S	IN	Alkalinity	500.00	NA	NA	NA				1.000	MG/L
RW-2S	IN	Benzene	2800.00	NA	NA	NA			10.0	1.000	UG/L
RW-2S	IN	Bicarbonate	500.00	NA	NA	NA				1.000	MG/L
RW-2S	IN	Calcium	65.00	NA	NA	NA				0.200	MG/L
RW-2S	IN	Carbonate	BDL	NA	NA	NA				1.000	MG/L
RW-2S	IN	Chloride	410.00	NA	NA	NA				2.500	MG/L
RW-2S	IN	Ethyl Benzene	630.00	NA	NA	NA			750.0	1.000	UG/L
RW-2S	IN	Iron	0.08	NA	NA	NA				0.025	MG/L
RW-2S	IN	Magnesium	17.00	NA	NA	NA				0.200	MG/L
RW-2S	IN	Manganese	0.03	NA	NA	NA				0.010	MG/L
RW-2S	IN	Methane	22.00	NA	NA	NA				8.000	UG/L
RW-2S	IN	Naphthalene	NA	NA	NA	NA			30.0	1.000	UG/L
RW-2S	IN	Nitrogen, Nitrate	BDL	NA	NA	NA				0.050	MG/L
RW-2S	IN	Nitrogen, Nitrite	BDL	NA	NA	NA				0.500	MG/L
RW-2S	IN	Oxygen	0.79	NA	NA	NA				0.100	MG/L
RW-2S	IN	Phosphorus	0.14	NA	NA	NA				0.030	MG/L
RW-2S	IN	Potassium	5.10	NA	NA	NA				0.200	MG/L
RW-2S	IN	Sodium	250.00	NA	NA	NA				0.200	MG/L
RW-2S	IN	Solids	990.00	NA	NA	NA				10.000	MG/L
RW-2S	IN	Sulfate	92.00	NA	NA	NA				0.250	MG/L
RW-2S	IN	Sulfide	BDL	NA	NA	NA				1.000	MG/L
RW-2S	IN	Toluene	4300.00	NA	NA	NA			750.0	1.000	UG/L
RW-2S	IN	Total Organic Carbon	32.00	NA	NA	NA				1.000	MG/L
RW-2S	IN	Total Xylenes	4000.00	NA	NA	NA			620.0	1.000	UG/L

BDL = Below Method Detection Limit
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APPENDIX B

Field Parameter Values

Phillips Petroleum Company, South Four Lakes Unit
1996 Field Parameter Data

Well ID	Parameter	January	April	July	October	Units
MW-01	Conductance	1250	753	1330	1310	µmohs
MW-01	Eh	-205	-160	-158	-180	millivolts
MW-01	Oxygen	1.51	2.5	1.19	0.1	MG/L
MW-01	Temperature	66.7	74.5	67.5	67.1	F°
MW-01	pH	7.54	8	7.89	8.01	UNITS
MW-02	Conductance	1332	9200	1145	1160	µmohs
MW-02	Eh	153.5	4.99	210	234	millivolts
MW-02	Oxygen	1.6	3.44	3.44	1.83	MG/L
MW-02	Temperature	66.5	61.7	67.7	67.6	F°
MW-02	pH	7.34	6.76	8.47	7.37	UNITS
MW-03	Conductance	5190	4120	4210	4360	µmohs
MW-03	Eh	117.5	5.46	28.4	108	millivolts
MW-03	Oxygen	3.26	2.15	1.88	1.14	MG/L
MW-03	Temperature	68.9	67.3	68.8	68.7	F°
MW-03	pH	6.8	6.51	7.64	7.06	UNITS
MW-04	Conductance	3050	2400	2220	2360	µmohs
MW-04	Eh	14	NA	-170	-196	millivolts
MW-04	Oxygen	2.65	2	1.9	NA	MG/L
MW-04	Temperature	67.9	70.2	67.8	67.7	F°
MW-04	pH	7.29	6.72	7.87	7.15	UNITS
MW-05	Conductance	951	608	745	778	µmohs
MW-05	Eh	266	247	195	161	millivolts
MW-05	Oxygen	5.27	5.38	NA	6.51	MG/L
MW-05	Temperature	63.7	60.7	67.3	66.3	F°
MW-05	pH	7.51	7.1	7.45	7.42	UNITS
MW-06	Conductance	5370	1850	4550	4090	µmohs
MW-06	Eh	-205	-156	-130	-205	millivolts
MW-06	Oxygen	1.98	NA	1.67	0.1	MG/L
MW-06	Temperature	64.2	78.9	67.7	65.8	F°
MW-06	pH	7.16	NA	7.28	7.83	UNITS
MW-07	Conductance	1860	1280	1315	1200	µmohs
MW-07	Eh	-283	10.6	-220	-274	millivolts
MW-07	Oxygen	2.06	2.82	3.37	0.76	MG/L
MW-07	Temperature	67.3	66.4	67.8	66.9	F°

Phillips Petroleum Company, South Four Lakes Unit
1996 Field Parameter Data

Well ID	Parameter	January	April	July	October	Units
MW-07	pH	7.4	7.3	7.75	7.69	UNITS
MW-09	Conductance	1171	780	928	935	µmohs
MW-09	Eh	241	3.45	235	283	millivolts
MW-09	Oxygen	5.98	7.03	6.3	6.3	MG/L
MW-09	Temperature	66.7	64.7	67.2	68.3	F°
MW-09	pH	7.31	6.7	8.33	7.59	UNITS
MW-10	Conductance	2000	1215	1538	1598	µmohs
MW-10	Eh	241	182	235	241	millivolts
MW-10	Oxygen	4.8	4.57	4.58	4.1	MG/L
MW-10	Temperature	65.5	60.8	66.7	67	F°
MW-10	pH	7.33	6.76	8.08	7.45	UNITS
MW-12	Conductance	6580	2700	5890	6950	µmohs
MW-12	Eh	-206	-165	-80	-24	millivolts
MW-12	Oxygen	0.81	1.32	1.35	0.1	MG/L
MW-12	Temperature	68	64.1	67.3	71	F°
MW-12	pH	7.58	7.12	7.11	7.09	UNITS
MW-13	Conductance	3300	1705	2810	2610	µmohs
MW-13	Eh	-227	-175	-160	-205	millivolts
MW-13	Oxygen	1.66	1.19	1.49	0.85	MG/L
MW-13	Temperature	66.8	70.8	67.3	66	F°
MW-13	pH	6.38	6.76	7.03	7.04	UNITS
MW-14	Conductance	1660	1097	1790	1450	µmohs
MW-14	Eh	114.7	5.11	109	142	millivolts
MW-14	Oxygen	5.7	NA	3.68	2.96	MG/L
MW-14	Temperature	67.3	65.3	75.7	65.2	F°
MW-14	pH	7.8	7.87	9.06	7.62	UNITS
MW-15	Conductance	2480	1508	2340	2540	µmohs
MW-15	Eh	-258	10.76	-118	-223	millivolts
MW-15	Oxygen	1.3	2.17	2.08	1.05	MG/L
MW-15	Temperature	65.3	71.1	66.7	64.7	F°
MW-15	pH	7.21	7.04	7.35	7.24	UNITS
MW-16	Conductance	1684	1208	1355	1370	µmohs
MW-16	Eh	258	4.51	99	146	millivolts
MW-16	Oxygen	4.9	4.75	3	3.56	MG/L
MW-16	Temperature	66.7	61.4	69.1	64.1	F°

Phillips Petroleum Company, South Four Lakes Unit
1996 Field Parameter Data

Well ID	Parameter	January	April	July	October	Units
MW-16	pH	7.45	7.2	7.75	7.55	UNITS
RW-1D	Conductance	6540	3550	5850	5370	µmohs
RW-1D	Eh	-130	-238	-243	-310	millivolts
RW-1D	Oxygen	1.15	NA	0.1	0.1	MG/L
RW-1D	Temperature	64.9	69.8	67.4	67.7	F°
RW-1D	pH	7.72	7.59	7.81	7.81	UNITS
RW-1S	Conductance	4350	NA	NA	NA	µmohs
RW-1S	Eh	30	NA	NA	NA	millivolts
RW-1S	Oxygen	2.25	NA	NA	NA	MG/L
RW-1S	Temperature	64.7	NA	NA	NA	F°
RW-1S	pH	7.68	NA	NA	NA	UNITS
RW-2D	Conductance	1690	NA	NA	NA	µmohs
RW-2D	Eh	-226	NA	NA	NA	millivolts
RW-2D	Temperature	66	NA	NA	NA	F°
RW-2D	pH	7.57	NA	NA	NA	UNITS
RW-2S	Conductance	2430	NA	NA	NA	µmohs
RW-2S	Eh	-205	NA	NA	NA	millivolts
RW-2S	Oxygen	0.79	NA	NA	NA	MG/L
RW-2S	Temperature	69.6	NA	NA	NA	F°
RW-2S	pH	7.66	NA	NA	NA	UNITS

NA=Not Measured