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STEP Strategies for Today's Environmental Partnership

FIELD STUDIES OF BTEX AND MTBE INTRINSIC BIOREMEDIATION

Health and Environmental Sciences Department
Publication Number 4654
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Field Studies of BTEX and MTBE Intrinsic Bioremediation

Health and Environmental Sciences Department

API PUBLICATION NUMBER 4654

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ABSTRACT

In the last several years, there has been considerable interest in confirming the biodegradation of soluble gasoline constituents in groundwater. Recent acceptance of risk-based approaches to corrective action has accelerated the need to better understand the role biodegradation can play in limiting the transport of and possible exposure to dissolved hydrocarbons in groundwater. This study was initiated to document the *in situ* natural biodegradation (commonly referred to as intrinsic bioremediation) of benzene; ethylbenzene; toluene; o-, m-, and p-xylene; and methyl tert-butyl ether. A rural North Carolina underground storage tank release site was selected for study. The site was instrumented with more than 50 observation wells monitored for several years to allow quantitative characterization of the downgradient mass transport of the dissolved compounds. Companion laboratory and modeling studies were conducted to facilitate interpretation of the field data.

Three dimensional field monitoring of the dissolved gasoline plume showed rapid decay of toluene and ethylbenzene during downgradient transport with slower decay of xylenes, benzene, and MTBE under mixed aerobic-denitrifying conditions. Background dissolved oxygen concentrations range from 7 to 8 mg/L, and nitrate concentrations range from 7 to 17 mg/L as Nitrogen (N) because of extensive fertilization of fields surrounding the spill.

Sampling results indicate that the plume is not growing and has reached a pseudo-steady-state. Field-scale decay rates were determined by estimating the mass flux of contaminants across four plume cross-sections. First-order decay rates for all compounds were highest near the source and lower farther downgradient. Effective first-order decay rates varied from 0 to 0.0010 d^{-1} for MTBE; 0.0006 to 0.0014 d^{-1} for benzene; 0.0005 to 0.0063 d^{-1} for toluene; 0.0008 to 0.0058 d^{-1} for ethylbenzene; 0.0012 to 0.0035 d^{-1} for m-, p-xylene; and 0.0007 to 0.0017 d^{-1} for o-xylene. In a companion study, laboratory microcosm studies confirmed MTBE biodegradation under aerobic conditions; however, the extent of biodegradation was limited.

BIOPLUME II and a 3-D analytical model were evaluated for their ability to simulate the transport and biodegradation of MTBE and BTEX at the site. Neither model could accurately simulate contaminant concentrations throughout the length of the plume.

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EXECUTIVE SUMMARY

Gasoline contains the aromatic hydrocarbons benzene, toluene, ethylbenzene, and xylene isomers (BTEX). Oxygenates such as methyl tert-butyl ether (MTBE) are often used in gasoline for octane enhancement and reducing vehicular emissions. These compounds are water soluble and potentially toxic at high concentrations, and are the indicator compounds targeted for remediation when gasoline releases to groundwater occur. Cleanup requirements for benzene are typically more stringent than for the other compounds, because the federal drinking water Maximum Contaminant Level (MCL) is 5 µg/L. There is no MCL for MTBE, but EPA has prepared several draft Health Advisories since 1993, and the suggested Lifetime Health Advisory in the most current draft is 70 µg/L (Gomez-Taylor, 1997). Because of the high costs associated with long term groundwater remediation at impacted sites, during the last several years there has been growing interest in confirming the biodegradation of soluble gasoline constituents in groundwater. Recent acceptance and increasing application of risk-based approaches to corrective action have accelerated the need to better understand the role biodegradation can play in limiting the transport of and possible exposure to dissolved hydrocarbons and oxygenates in groundwater.

An active, diverse microbial community exists in the subsurface and is capable of degrading a wide variety of hydrocarbons as well as MTBE. Factors that affect the rate and extent of biodegradation are (1) the quantity and metabolic capacity of the microorganisms; (2) the type and amount of electron acceptors present (e.g., oxygen, nitrate, ferric iron, and sulfate); (3) the quantity and quality of nutrients; (4) temperature; (5) pH; and (6) oxidation-reduction potential. If aerobic conditions exist in an aquifer, oxygen will be utilized as an electron acceptor for hydrocarbon biodegradation. Oxygen is a co-substrate for the initiation of hydrocarbon metabolism and is the preferred electron acceptor because microbes gain the most energy from aerobic reactions. Numerous studies have shown the BTEX compounds are readily biodegradable in the presence of excess oxygen (Jamison *et al.*, 1975; Gibson and Subramanian, 1984; Barker *et al.*, 1987; Wilson *et al.*, 1986; Alvarez and Vogel, 1991), and many other studies have documented BTEX biodegradation with other electron acceptors (i.e., anaerobic biodegradation), including nitrate (Hutchins *et al.*, 1991b; Krumholz *et al.*, 1996). There are a few well-documented cases of MTBE biodegradation in the literature, Lee (1986), Jensen and Arvin (1990), Suflita and Mormile (1993), Salanitro *et al.* (1994), Yeh and Novak (1994), Barker *et al.* (1990), Hubbard *et al.* (1994). These studies show that while MTBE can be biodegraded under certain conditions, biodegradation will often be slow and may only occur under specific environmental conditions.

OBJECTIVES

The overall objective of this project was to examine the effectiveness of intrinsic bioremediation in controlling the migration of dissolved benzene; ethylbenzene; toluene; o-, m-, and p-xylene; and methyl tert-butyl ether released from a gasoline spill in Sampson County, N.C. Intrinsic bioremediation is a corrective action technology involving careful characterization and monitoring of the transport of dissolved plume constituents, and documentation of their mass loss due to biodegradation by the naturally occurring bacteria at a site - without attempting to enhance the biodegradation rate (e.g., by adding nutrients or oxygen). This technique may be used alone to contain small releases or in combination with other remediation techniques to complete aquifer restoration.

A gasoline release field site was selected, an extensive monitoring well network installed, and the site was monitored for more than three years to allow calculation of "real world" *in situ* biodegradation rates. Using aquifer materials from this site, laboratory microcosm experiments were performed to further characterize the biodegradation of BTEX and MTBE under ambient, *in situ* conditions. Finally, groundwater modeling studies were conducted to facilitate the interpretation of field data, and to evaluate various approaches for predicting the fate and transport of these gasoline constituents in the subsurface (Borden *et al.*, 1997).

SITE CHARACTERISTICS

A rural underground storage tank (UST) release site in the Coastal Plain of North Carolina was selected for study. The USTs had been removed along with some contaminated soil in the late 1980s. A detailed field characterization of the site was performed to clearly delineate the periphery of the dissolved plume emanating from the remaining residual gasoline present at and below the water table, and to identify hydrologic or geochemical conditions that might influence the rate of biodegradation. The site was instrumented with more than 50 multi-level observation wells, including four monitoring well transects each established perpendicular to the direction of groundwater flow (Figure E-1). Each transect contained up to five or six monitoring well clusters, and each of the clusters contained three wells to allow sampling at the water table, at the bottom of the aquifer, and at a point midway between. One transect was located through the source area, and the three others were established at 36 m, 88 m, and 177 m downgradient from the source. Wells at the site were sampled on a regular basis for more than three years. The mass flux of BTEX and MTBE moving through the plane of each transect could then be determined, which allowed quantitative characterization of the downgradient mass transport of these dissolved compounds (i.e., the rate of intrinsic bioremediation).

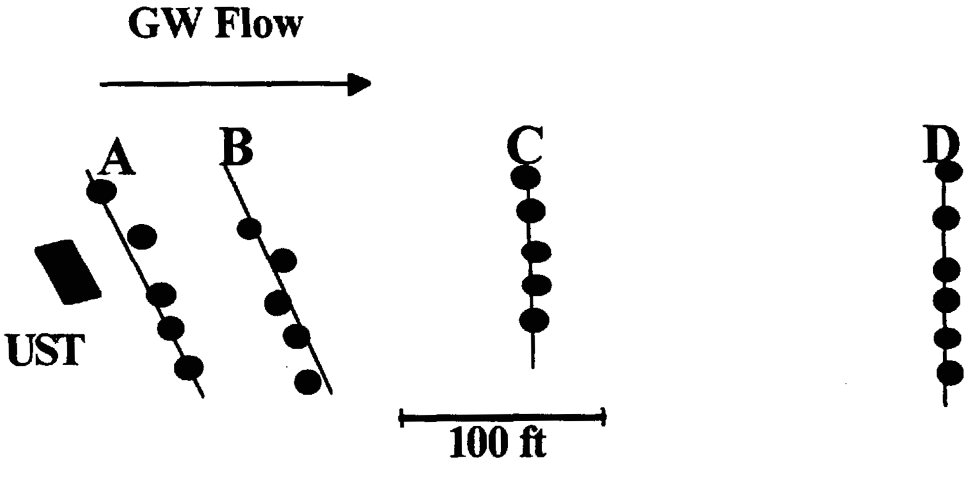


Figure ES-1. Schematic representation of part of the site's monitoring well network showing the four transects established to characterize mass flux of dissolved compounds flowing past each transect. Each circle represents a cluster of three monitoring wells completed to different depths below the water table.

The depth of the water table at the site varied seasonally between 1-3 m below the land surface, the saturated thickness averaged about 7 m. The hydraulic conductivity ranged from 0.3 to 1.1 m/d (average = 0.8 m/d), and the groundwater velocity was estimated at 4-16 m/yr, with an average of 8 m/yr. Soil organic carbon content of the aquifer material was about 0.05%. The pH of the groundwater was 4.3, background dissolved oxygen concentrations ranged from 7 to 8 mg/L, and nitrate concentrations ranged from 7 to 17 mg/L as Nitrogen (N) because of extensive fertilization of the agricultural fields surrounding the spill. Average peak concentrations of dissolved BTEX and MTBE in the source area were around 10-40 mg/L and 10 mg/L, respectively. Measurable concentrations of dissolved BTEX and MTBE present in the aquifer had migrated over 180 m from the source area before discharging to a farm field drainage ditch.

BIODEGRADATION

Significant levels of nitrate were present throughout the dissolved plume, and TEX biodegradation appeared to occur using both oxygen and nitrate as terminal electron acceptors. Dissolved oxygen (DO) concentrations within the dissolved plume were much lower than background levels. They varied from less than 0.5 mg/L in the core of the plume, to about 4-6 mg/L near the fringes. Oxidation-reduction potentials through the plume ranged from +200 to +450 mV, consistent with the dominance of nitrate serving as a redox buffer. Methane was never detected in the groundwater, but some dissolved iron and sulfate were observed in monitoring wells. However, those concentrations were generally low, and there is no evidence of significant biodegradation with subsequent reduction of iron and sulfate. The very rapid removal of toluene, ethylbenzene, and m-, p-xylenes and the much slower removal of o-xylene and benzene at this site are consistent with studies on BTEX biodegradation via denitrification reported in several recent papers (e.g., Hutchins *et al.*, 1991b). For example, over the 88 m distance from Line A to Line D, the mass flux of toluene, ethylbenzene and m-, p-xylenes decreased by 99%. Interpretation of three years of sampling results indicate that the plume is not growing and has reached a pseudo-steady-state.

Results from companion laboratory studies using (1) aerobic, (2) low initial oxygen, and (3) anaerobic-denitrifying microcosms showed no evidence of anaerobic benzene degradation, indicating mass transfer of oxygen into the plume will be the limiting factor influencing benzene biodegradation in the aquifer. Anaerobic biodegradation of TEX in the aquifer is likely enhanced by the presence of high background levels of nitrate leached from fertilizer applied to the overlying and surrounding agricultural fields. This mass loss of TEX under nitrate-reducing conditions contributes to a net decline in the plume's biological oxygen demand further downgradient, which should facilitate the availability of oxygen for aerobic biodegradation of the remaining benzene.

A mass flux calculated from the data obtained from each of the four monitoring well transects was used to estimate field-scale first-order decay rates for MTBE and BTEX. Most groundwater biodegradation models use first-order rate constants as the input data that characterize biodegradation rates. Near the source, first-order decay rate constants are highest for toluene and ethylbenzene and lowest for o-xylene, benzene, and MTBE (Table E-1). The rate constants displayed in Table E-1 are comparable to results summarized previously (Rifai *et al.*, 1995). As the dissolved plume travels downgradient, the rates of mass decay decline for all compounds, indicating that there was a substantially greater amount of biodegradation occurring in the initial 36 m downgradient from the source. The decline in the toluene and ethylbenzene decay rates may be a calculation artifact, since they were almost completely removed from the system (i.e., their concentrations were often close to the analytical detection limit at lines C and D). However, elevated (i.e., easily measurable) concentrations of o-xylene, benzene and MTBE remained at lines C and D, and the decline in their mass decay rates with distance from the source appears to be real.

The field monitoring results provide evidence of MTBE decay near the contaminant source. However, there is no evidence for MTBE decay in the downgradient aquifer. This is supported by aerobic laboratory microcosms (Borden *et al.*, 1997) that showed limited MTBE biodegradation near the source but no evidence for MTBE biodegradation further downgradient. The unusual shape of the MTBE degradation profile in laboratory microcosms suggests that one or more unknown factors are limiting or inhibiting MTBE biodegradation.

Table ES-1. Biodegradation of BTEX and MTBE Expressed as First-Order Decay Rate Constants.

Compound	**Line A to B** (0-36 m)	**Line B to C** (36-88 m)	**Line C to D** (88-177 m)
MTBE	0.0010	0.0008	Not Significant
Benzene	0.0014	0.0009	0.0006
Toluene	0.0063	0.0020	0.0005
Ethylbenzene	0.0058	0.0019	0.0008
m-, p-Xylene	0.0035	0.0022	0.0012
o-Xylene	0.0017	0.0010	0.0007
BTEX	0.0029	0.0010	0.0007

[Note: d^{-1} = "inverse days"; 0.0010 d^{-1} = 0.1% mass loss of that compound per day]

MODELING

BIOPLUME II and a 3-D analytical model (Dominico, 1987) were evaluated for their ability to simulate the transport and biodegradation of MTBE and BTEX in the shallow aquifer. In both models, MTBE biodegradation was represented by a constant first-order decay rate. As a consequence, predicted MTBE distributions using both models were very similar. Both models provided reasonable predictions of MTBE concentrations in the middle of the plume but significantly underestimated concentrations at the most downgradient wells. The poor match between predicted and observed concentrations at the most downgradient wells is primarily due to the decline in contaminant degradation rates with distance observed in the field study. Since these models use a constant decay rate, they overestimated the rate of contaminant loss in the distant portion of the plume at the field site, and therefore predicted lower contaminant concentrations than were actually present.

Chapter 1

INTRODUCTION

1.1. INTRODUCTION

One of the causes of shallow groundwater contamination is the release of gasoline into the subsurface from leaking underground storage tanks (USTs). Gasoline contains the aromatic hydrocarbons benzene, toluene, ethylbenzene, and xylene isomers (BTEX). Oxygenates such as methyl *tert*-butyl ether (MTBE) are often used in gasoline for octane enhancement and air pollution control. These compounds are water soluble and can be toxic at high concentrations. Of the compounds mentioned, benzene causes the greatest concern since it is a known human carcinogen (NIOSH, 1990).

Intrinsic bioremediation is a corrective action approach that allows indigenous microorganisms to biodegrade contaminants without human intervention. This technique may be used alone to contain small releases or in combination with other remediation techniques to complete aquifer restoration. The objective of this study is to examine the effectiveness of intrinsic bioremediation for control of BTEX and MTBE released from a gasoline spill in Sampson County, N.C.

1.2. BTEX BIODEGRADATION

An active, diverse microbial community exists in the subsurface and is capable of degrading a wide variety of hydrocarbons (Zobell, 1946; Webster *et al.*, 1985; Wilson *et al.*, 1986; Ghiorse and Wilson, 1988). Jamison *et al.* (1975) found that a mixed microbial population from a gasoline-contaminated aquifer readily degraded all gasoline components under aerobic conditions. Some hydrocarbons did not support microbial growth when present as the sole carbon source; however, all compounds were degraded when present as a mixture. This finding suggests that a mixed microbial population may be necessary for complete biodegradation of complex hydrocarbon mixtures. Ridgeway *et al.* (1990) studied microbial activity in an aquifer contaminated with unleaded gasoline. They found that most organisms were very specific in their ability to degrade hydrocarbons and were able to degrade only one of several closely related compounds. Toluene, p-xylene, ethylbenzene, and 1,2,4-trimethylbenzene were the most frequently utilized substrates for growth, while cyclic and branched alkanes were the least frequently used. Factors that affect the rate and extent of biodegradation are (1) the quantity and metabolic capacity of the microorganisms, (2) the type and amount of electron acceptors present [O_2, NO_3^-, $SO_4^{=}$, Fe(III), CO_2], (3) the quantity and quality of nutrients, (4) temperature, (5) pH, and (6) oxidation-reduction potential.

If aerobic conditions exist in an aquifer, oxygen will be utilized as an electron acceptor for hydrocarbon biodegradation. Oxygen is a co-substrate for the initiation of hydrocarbon metabolism (Young, 1984) and is the preferred electron acceptor because microbes gain the most energy from aerobic reactions. Numerous studies have shown the BTEX compounds are readily biodegradable in the presence of excess oxygen (Jamison *et al.*, 1975; Gibson and Subramanian, 1984; Barker *et al.*, 1987; Wilson *et al.*, 1986; Alvarez and Vogel, 1991). Some studies suggest that there may be a minimum level of oxygen required for aerobic biodegradation. Chiang *et al.* (1989) found that BTEX biodegradation was rapid (half-life of 5 to 20 days) when oxygen concentrations were greater than 2 mg/L, but little or no biodegradation was observed when initial oxygen concentrations were 0, 0.1, or 0.5 mg/L.

Under anaerobic conditions, toluene; ethylbenzene; and m-, p-xylene can be biodegraded using nitrate as the electron acceptor (Kuhn *et al.*, 1985; Zeyer *et al.*, 1986; Kuhn *et al.*, 1988; Hutchins, 1991a; Hutchins *et al.*, 1991b). o-Xylene has often been found to be recalcitrant under denitrifying conditions when present as a sole substrate but may be slowly biodegraded in the presence of other degradable substrates (Hutchins, 1991a; Kao and Borden, in press). Several investigators have reported that benzene is recalcitrant under denitrifying conditions (Zeyer *et al.*, 1986; Kuhn *et al.*, 1988; Hutchins, 1991a; Hutchins *et al.*, 1991b; Barbaro *et al.*, 1992), but other work indicates that benzene is biodegradable (Major *et al.*, 1988). Even though biodegradation can occur using nitrate as the terminal electron acceptor, the rate of biodegradation is often slower under denitrifying than under aerobic conditions, and there may be a significant lag period before denitrification begins (Hutchins, 1991b).

Recent work has suggested that the presence of nitrate may enhance TEX biodegradation under low oxygen, hypoxic conditions (0.1 to 2 mg/L oxygen). Using an enrichment culture technique, Mikesell *et al.* (1993) isolated a strain of *Pseudomonas fluorescens* in which growth and BTEX degradation under hypoxic conditions (2 mg/L oxygen) were enhanced by the presence of nitrate. Similarly, Hutchins *et al.* (1992) observed an increase in TEX removal from 77% to 97% in oxygen-limited columns when 10 mg/L NO_3-N was added to the column influent. Throughout this experiment, an average of 0.3 mg/L dissolved oxygen (DO) was observed in the nitrate-amended column effluent. These results are somewhat surprising given past research on the effects of oxygen concentration on denitrification. Christiansen and Tiedje (1988) found that low levels of DO (0.1 to 0.4 mg/L) can significantly reduce denitrification rates (0 to 15% of control). Anoxic regions may persist in the center of soil aggregates (Sexstone *et al.*, 1985) even though the mobile pore water contains low levels of DO.

Barker *et al.* (1987) conducted a field study of aerobic BTEX biodegradation at the Canadian Forces' Base Borden, Ontario. When 1800 liters of solution containing 7.6 mg/L of BTEX were injected into the aquifer, all BTEX components were completely degraded in 1.2 years. Chiang *et al.* (1989) studied the intrinsic biodegradation of BTEX at a sandy aquifer in Michigan and showed a spatial relationship between DO and BTEX concentration. Hutchins *et al.* (1991a) stimulated the biodegradation of JP-4 jet fuel at Traverse City, Mich., under denitrifying conditions through the addition of nitrate to the aquifer. Results indicated that toluene; ethylbenzene; and m-, p-xylene were readily degradable while o-xylene was less degradable. Berry-Spark *et al.* (1986) studied the effect of nitrate addition on BTEX biodegradation. Initially, 2500 liters of solution containing 800 μg/L of BTEX were injected into the shallow aquifer at the Canadian Forces' Base Borden. Four days after the BTEX injection, 2400 liters of solution containing 45 mg/L of NO_3^- as N were injected into the aquifer. The results suggested that nitrate may have enhanced the biodegradation of BTEX, although the results were not conclusive since all BTEX components degraded in both the nitrate-treated system and the control system.

1.3. MTBE BIODEGRADATION

There are few well-documented cases of MTBE biodegradation in the literature. Lee (1986) studied BTEX and MTBE biodegradation in soil collected from sites in Traverse City, Mich., and the Texas Gulf Coast. In studies with the Traverse City soil, 84% of MTBE was degraded after 4 weeks of aerobic incubation, but there was no apparent biodegradation of MTBE after 8 weeks of incubation at the Texas site. In studies of aerobic BTEX and MTBE biodegradation, Jensen and Arvin (1990) found no evidence of MTBE degradation after 60 days of incubation. However, BTEX biodegradation was largely unaffected by the presence of MTBE. Only at concentrations greater than 200 mg/L MTBE was there a slight inhibitory effect on BTEX biodegradation.

In an initial study, Suflita and Mormile (1993) found no evidence of MTBE degradation after 182 days of incubation under methanogenic conditions. Results from biodegradation studies using other fuel additives suggest that the chemical structure of these compounds greatly affects their susceptibility to biological decay. Compounds containing a tertiary or quaternary carbon atom, like MTBE, were more resistant to biodegradation than other unbranched or moderately branched chemicals. In more recent work, Mormile *et al.* (1994) found MTBE to be recalcitrant under methanogenic conditions in sediment from a stream, a sanitary landfill, and a gasoline-contaminated aquifer but was biodegraded in one of three replicate microcosms containing Ohio River sediment after 152 days of incubation. MTBE biodegradation in the single Ohio River microcosm was confirmed by the stoichiometric production of *tert*-butanol (TBA).

Salanitro *et al.* (1994) enriched an industrial chemical plant biotreater sludge to develop a mixed bacterial culture that rapidly biodegraded MTBE. In batch experiments, the culture degraded 120 mg/L of MTBE in 4 hours at a rate of 34 mg MTBE/g cells per hour. While none of the individual isolates could use MTBE as a sole carbon source, the culture as a whole was able to convert radiolabeled MTBE to $^{14}CO_2$ and cell mass. TBA was produced as a metabolic product of MTBE biodegradation. TBA was also degraded but at a slightly slower rate (14 mg TBA/g cells per hour) than MTBE.

Yeh and Novak (1994) provided the most substantial evidence for anaerobic degradation of MTBE. Using soils with varying natural organic contents, they evaluated the potential for MTBE biodegradation under denitrifying, sulfate reducing, and methanogenic conditions. While there was no loss of MTBE after 250 days in the organically rich soils, degradation was observed in soil with a low organic carbon content under methanogenic conditions. However, degradation occurred only when nutrient amendments were added. They hypothesized that the first and rate-limiting step in MTBE degradation may be cleavage of the ether bond, resulting in the production of TBA.

In a field experiment at the Canadian Forces' Base in Borden, Ontario, Barker *et al.* (1990) investigated the influence of MTBE on the transport and degradation of monoaromatic hydrocarbons in groundwater. The presence of MTBE had no apparent effect on the rate of migration or decay for the BTEX compounds. While the BTEX compounds were readily degraded, MTBE exhibited no mass loss over the 16-month period of the study. Using sediment from the Borden test site, Hubbard *et al.* (1994) found MTBE to be recalcitrant in both aerobic and oxygen-limited microcosms over incubation periods of 8 to 15 months. As in the field studies, biotransformation of the monoaromatics appeared to be unaffected by the presence of MTBE.

These results indicate that while MTBE can be biodegraded under certain conditions, biodegradation will often be slow and may be limited to specific environmental conditions.

1.4. RESEARCH OBJECTIVES

The overall objective of this project was to examine the effectiveness of intrinsic bioremediation in controlling the migration of dissolved BTEX and MTBE released from a gasoline spill in Sampson County, N.C. A detailed field characterization was performed to determine the rate of BTEX and MTBE biodegradation in the subsurface and to identify hydrologic or geochemical conditions that might influence the rate of biodegradation. Modeling studies were performed to evaluate various approaches for predicting the fate and transport of contaminants in the subsurface. Laboratory microcosm experiments were also performed to document the biodegradation of BTEX and MTBE under ambient, *in situ* conditions (Borden *et al.*, accepted).

Chapter 2

SITE DESCRIPTION

2.1. BACKGROUND

This study was conducted at a gasoline spill located in Sampson County, N.C., approximately 15 miles northwest of the town of Clinton. Two USTs formerly located on the site were used to store gasoline and diesel fuel for farm and personal vehicles. A leak in the gasoline storage tank was discovered sometime in 1986 or 1987. In December 1990, both tanks were removed from the site. One 250-gallon gasoline tank and one 500-gallon diesel fuel tank were located in a single tank bed. Upon removal, the diesel tank appeared to be in good condition; however, the gasoline tank had several rusted holes on the bottom and along the seams of the tank. During tank removal, soil exhibited characteristic gasoline odors, and approximately 15 gallons of gasoline were released into the excavation from the UST. Soil samples collected from the excavation confirmed the presence of petroleum hydrocarbon compounds identified as No. 2 fuel oil and gasoline. Approximately 90 yd^3 of contaminated soil were then excavated from the tank bed for off-site disposal. However, nearby buildings limited excavation, and a substantial amount of residual gasoline remains trapped in the soil below the water table and provides a continuing source of dissolved gasoline constituents to the groundwater.

From December 1990 through January 1991, 30 augured borings and 10 monitoring wells were installed to define the extent of soil and groundwater contamination (SGI Environmental Engineering Services, 1992). Results confirmed the presence of dissolved gasoline in the groundwater and its transport in a northeasterly direction. In June 1992, North Carolina State University (NCSU) initiated a study of intrinsic bioremediation processes at this site with support from the American Petroleum Institute. Since that time, a total of 56 monitoring wells were installed to delineate the horizontal and vertical extent of the plume. Soil and groundwater sampling was conducted to monitor hydrocarbon contamination and plume migration. Figure 2-1 shows the location of the former USTs and the monitoring well array that was installed. The approximate horizontal centerline of the contaminant plumes is shown as line A-A' on

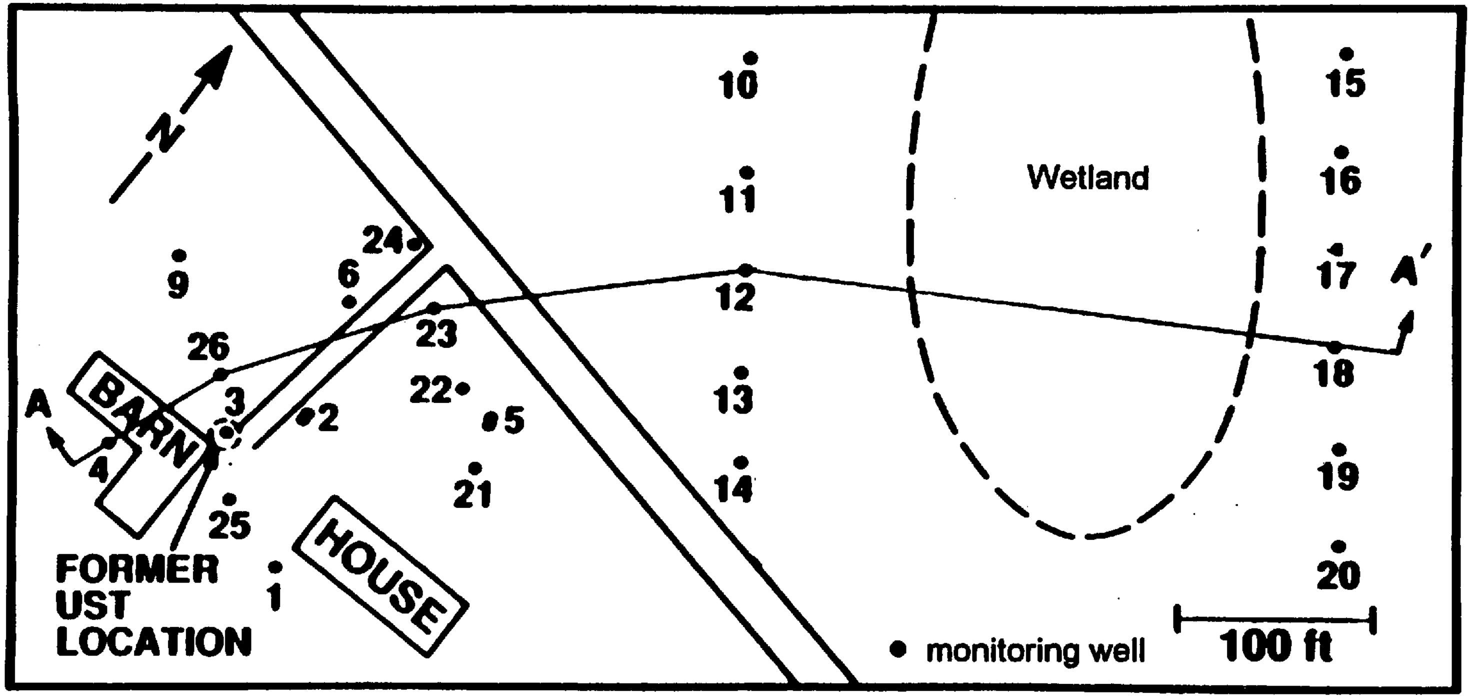


Figure 2-1. Site Map Showing Major Features, Monitoring Well Locations, and Approximate Horizontal Plume Centerline (A-A').

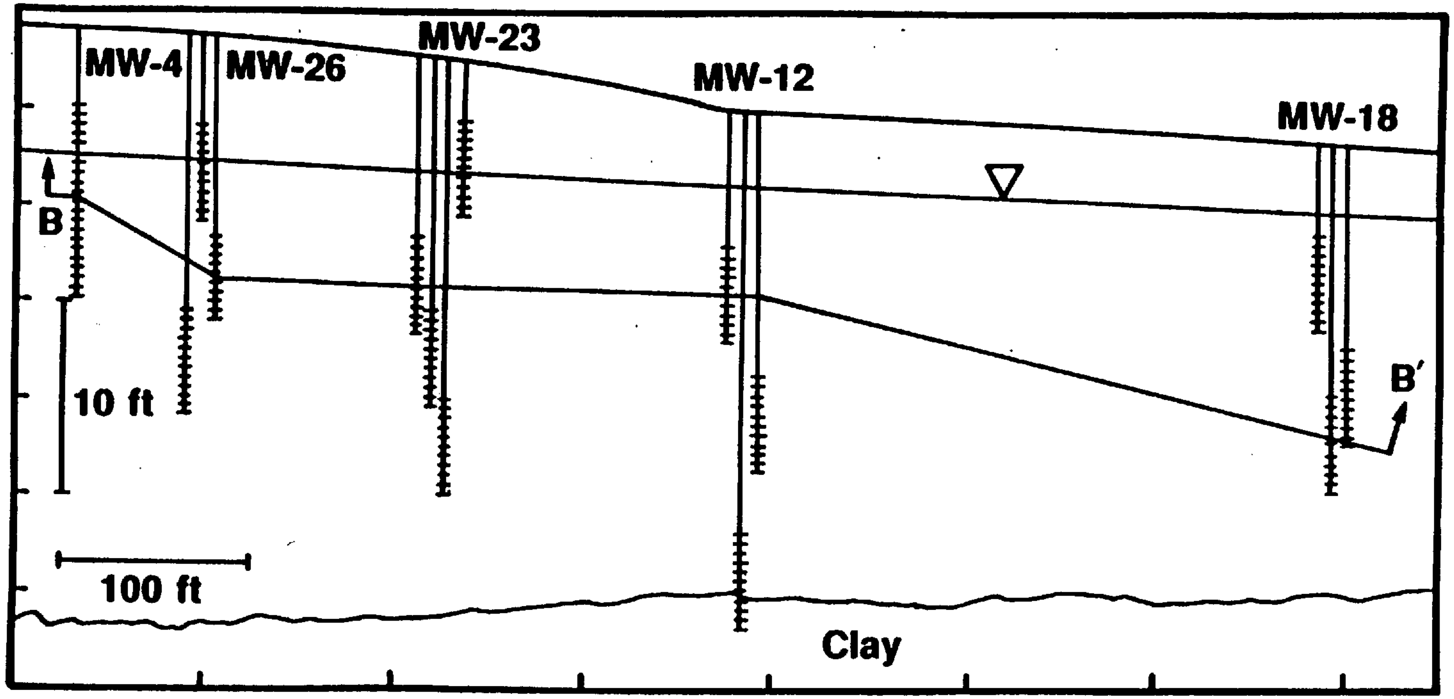


Figure 2-2. Cross Section along Line A-A' from Figure 2-1 Showing Screened Intervals and Approximate Vertical Plume Centerline (B-B').

Figure 2-1. The monitoring wells on this line are shown in the profile view in Figure 2-2. Line B-B' represents the approximate vertical centerline of the contaminant plumes.

2.2. GEOLOGIC SETTING

The Daughtry site is located in the north central portion of Sampson County in the inner Coastal Plain physiographic province. The geology of the Coastal Plain of North Carolina consists mainly of a thin layer of sands and clays beneath which lies much older formations. The topography is characterized by flat terrain dissected by tributaries and man-made drainage canals feeding small ponds and swamps.

The site geology consists mainly of red-to-rose colored clayey sands to a depth of between 1 to 10 ft. Deposits below 10 ft typically consist of layers of moderately coarse quartz sand containing yellow-to-rose colored silty material. Occasional discontinuous lenses of red plastic clay are encountered in the quartz sand. Beneath the sandy layer at a depth of 25 to 30 ft lies a heavy, tight gray-to-black lignitic clay, containing well-rounded broken shell material and medium-to-fine gravel. The overlying clayey and silty sands are believed to correlate with Quaternary surficial deposits, while the underlying organic clays are believed to correlate with the Black Creek Formation (Stephenson, 1923; Swift and Heron, 1969).

2.3. SITE HYDROGEOLOGY

A single unconfined aquifer is present throughout the site. While there are two identifiable zones in this aquifer, their permeabilities are sufficiently similar to consider them a single unit. The vertical extent of contamination will be limited by the underlying lignitic clay layer at 25 to 30 ft below grade.

Water table elevations have been measured periodically from July 1992 to April 1995. Water table contours for each sampling event are shown in Appendix A of the companion appendices document by Borden *et al.* (1997). Groundwater flow is typically to the north-northeast with minor variations. The only significant change in the flow direction occurred in July 1992. At that time, flow was almost due east. This variation could have been caused by measurement error or the low water table position because of an extended dry period. Over a 3-week period in August 1992, approximately 12 inches of rain caused the water table to rise roughly 4 ft. This recharge event shifted the groundwater flow back to a north-northeasterly direction. Subsequent monitoring indicates that the groundwater flow is consistently to the north-northeast.

This site is located immediately adjacent to a wetland on Carolina Bay. Carolina Bay has been described by Stuckey (1965) as depressed circular to elliptical topographical scars that may contain a lake but are usually marshy or swampy (Figure 2-1). The Carolina Bay is believed to act as both a groundwater recharge and discharge area. During the winter, water collects in this area enhancing groundwater recharge. During the summer, the capillary fringe is close to the land surface in this area enhancing evapotranspiration from the water table.

Specific capacity and/or rising head slug tests were conducted on 17 wells located throughout the site. The measured hydraulic conductivity ranged from 0.9 to 3.6 ft/d with an average of 2.6 ft/d. No consistent trends in the horizontal permeability distribution could be identified from the slug and specific capacity test results. The shallow zone appears to be slightly more permeable than the lower zone, although the average permeabilities of these two layers are not statistically different. An effective porosity of 0.1 was estimated from chloride tracer tests conducted on two 18-inch by 1-inch-diameter undisturbed cores (one from shallow and one from deeper zone) and are described in detail by Daniel (1995). The effective porosities from these two tests matched within 10%. The low estimated value of effective porosity is presumably due to the broad range of grain sizes in the soil that cause bypassing of flow around the clay-rich zones.

Soil samples were analyzed for organic carbon content (f_{oc}) to better estimate the extent of sorption occurring at the site. The average soil organic carbon content (average f_{oc}=0.0005) was determined from analysis of three soil samples (8 and 15 ft below grade at an upgradient location and 8 ft below grade at a downgradient location) and analyzed by an independent analytical service laboratory using the high temperature UV oxidation procedure. Retardation factors for the MTBE and the BTEX components were estimated (Section 3.0 of Appendix A in Borden *et al.*, 1997) using the empirical correlation between soil partition coefficient and the octanol-water partition coefficient developed by Schwarzenbach and Westall (1981). The calculated retardation factors were 1.003 for MTBE; 1.03 for benzene; 1.08 for toluene; 1.09 for o-xylene; 1.18 for ethylbenzene; and 1.19 for m-, p-xylene.

The time-averaged water table gradient at the site is 0.0041 ft/ft. Using the measured range of permeability, groundwater velocity was estimated to vary from 13 ft/yr to 54 ft/yr with an average of 39 ft/yr. At these velocities, a non-reactive contaminant should take between 11 and 45 years to reach the most downgradient wells. During the initial site characterization, it became apparent that the actual transport velocity must be slightly higher than the average velocity calculated above. MTBE use was not widespread until 1984. However, in Spring 1993, MTBE was already present in the most downgradient wells indicating that the actual travel time from the source was 9 years or less. To develop a more accurate estimate of the solute transport velocity, a three-dimensional analytical solution to the advection-dispersion-equation (Domenico, 1987) was fit to the MTBE monitoring results from the most downgradient wells using the calculated retardation factor for MTBE and assuming the initial MTBE release occurred in 1984. Observed MTBE concentrations in the most downgradient well are compared to model predictions for several different transport velocities in Figure 2-3. The results from this analysis suggest that the average transport velocity at the site is approximately 57 ft/yr.

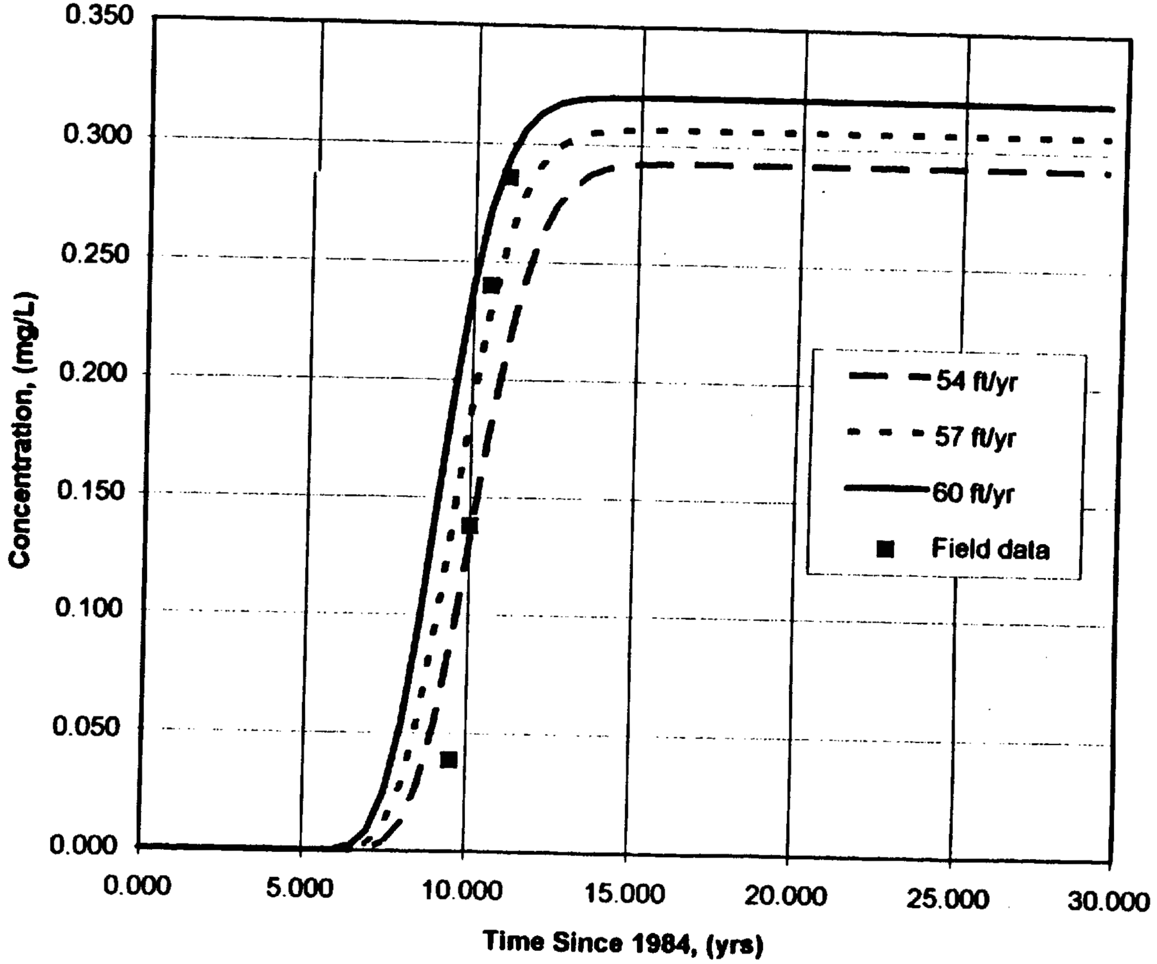


Figure 2-3. MTBE Breakthrough at the Most Downgradient Wells for Various Groundwater Velocities.

Chapter 3

ANALYTICAL AND FIELD METHODS

3.1. MONITORING WELL CONSTRUCTION

The monitoring wells installed at the Sampson County, N.C., site were constructed in accordance with the Well Construction Standards, Subpart 2c, Section .0108, of the N.C. Administrative Code, Title 15 of the Department of Environmental Health and Natural Resources, Division of Environmental Management. NCSU did not install monitoring wells 1, 2, 2D, 3, 4, 5, 6, and 9.

The installation of a monitoring well required the advancement of a 5.25-inch-diam. hole not less than 1.0 ft deeper than the maximum depth of the well. Monitoring wells were constructed of 2.0-inch-diam. PVC well casing with a 5.0-ft-long, 0.01 in. (10 slot) PVC screen and accompanying end plug. A natural sand pack was placed around the screened interval of the well casing and a Bentonite pellet seal was installed above the sand pack to prevent the infiltration of surface water into the aquifer. Natural site material was used to fill the well bore of deeper wells from the Bentonite seal to a depth of about 3 ft below ground surface. The well was completed to ground surface with the installation of a metallic manhole and lid set in concrete. A locking well cap and lock were installed in each monitoring well to prevent unauthorized access and a metal identification tag was affixed in the manhole.

3.2. MONITORING WELL LOCATIONS

Monitoring wells were installed in four cross sections at the Sampson County site to define the vertical and horizontal distribution of contaminants (Figure 3-1): line A, at the source; line B, 137 ft downgradient; line C, 290 ft downgradient; and line D, 580 ft downgradient. The most downgradient line of wells was positioned to represent the "end" of the BTEX plume as of May 1993 and yet was close enough to the source to provide reasonably accurate analytical results. Monitoring well clusters were advanced along each cross section at approximately 50-ft intervals until the section endpoint wells were found to be free of contamination. Because of

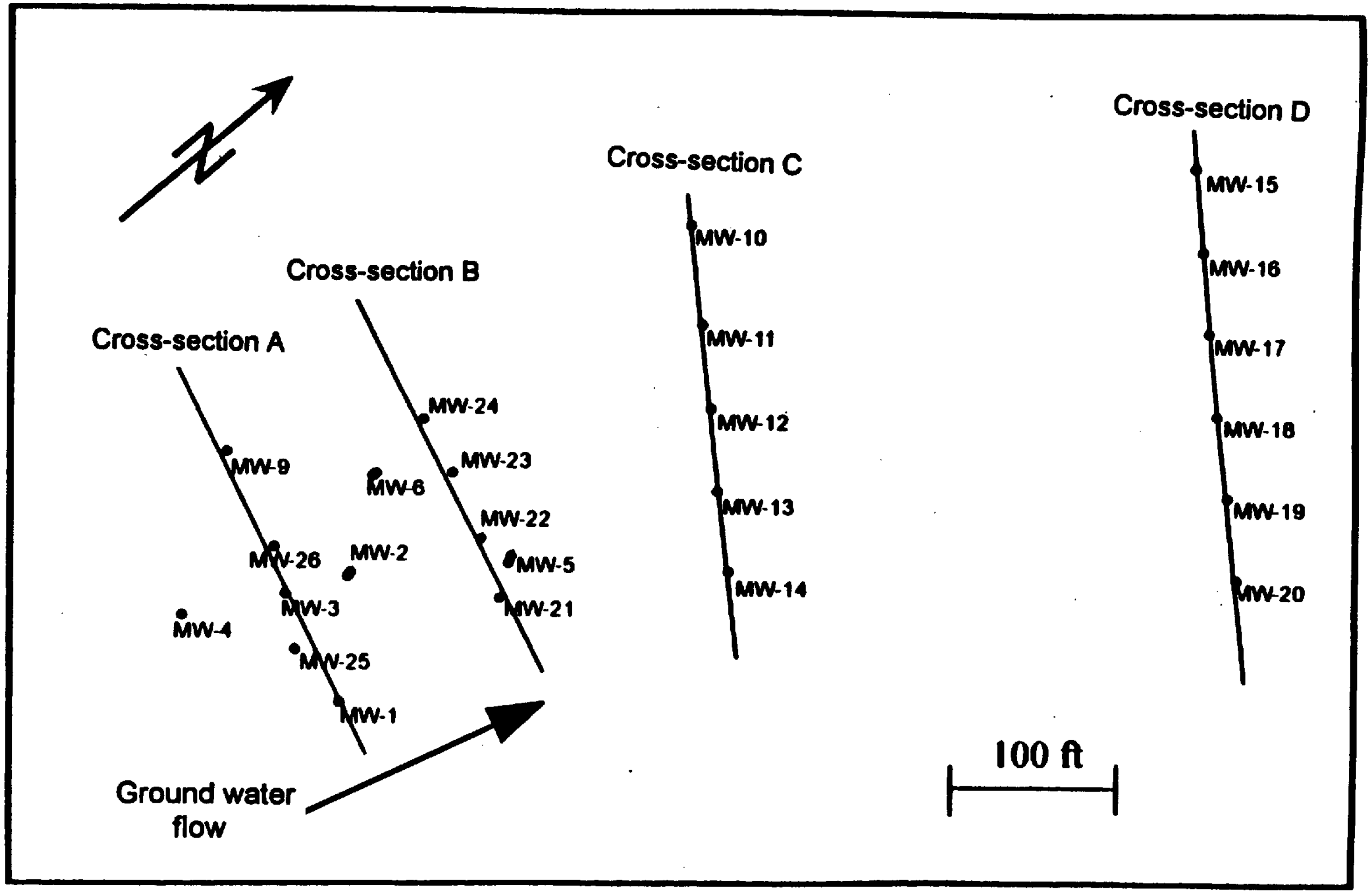


Figure 3-1. Monitoring Well Location Map.

seasonal shifts in the groundwater flow direction, low levels of BTEX and MTBE have occasionally been detected in the outermost wells. At most locations, a well cluster consisting of three 5-foot well screens was installed to define the vertical distribution of contaminants through the full saturated thickness of the aquifer. One monitoring well screen (shallow or "s") was installed across the water table interface, and a second well screen (deep or "d") was installed immediately above the clay-confining layer present at 25 to 30 ft below grade. A third well screen (middle or "m") was installed midway between the upper and lower well screens. A slight overlapping of well screens occurs at some of the well clusters. Monitoring wells were constructed of 2.0-in.-diam. PVC well casing with a 5.0-ft-long, 0.01-in. slotted PVC screen; natural sand pack; Bentonite pellet seal; and flush mount locking cover. A 5-ft screened interval was chosen over discreet sampling points to provide more accurate estimates of vertically averaged concentrations. These vertically averaged concentrations will be used in calculations of the mass flux of contaminants through the aquifer. The wells in line B deviated slightly from the standard cross-sectional arrangement to meet the aesthetic considerations of the property owner. Though some of the original monitoring wells do not lie on plume cross sections, they were sampled for long-term reference. The coordinates and screened intervals for all monitoring wells are provided in Section 4.0 of Appendix A (Borden *et al.*, 1997).

3.3. GROUNDWATER SAMPLING

Groundwater samples were collected from all wells and analyzed for BTEX, MTBE, and indicator parameters 11 times between Spring 1993 and Fall 1995. Several of the upgradient wells were also monitored beginning in June 1992. Groundwater samples were collected and handled according to the protocol described by Barcelona *et al.* (1988) with the following sequence of operations: (1) Well Purging, (2) Sample Collection, (3) Field Blanks, (4) Field Determination, (5) Preservation/Storage, and (6) Transportation.

A dedicated Waterra® model D-25 inertial pump attached to a section of high density polyethylene tubing was installed in each monitoring well. Groundwater samples were obtained by vertically oscillating the tubing, advancing a column of water to the ground surface. During sampling, a short section of new vinyl tubing was attached to the end of the polyethylene tubing to allow for easier sample collection.

Before sampling, the monitoring well head space was purged with purified argon gas to prevent the introduction of oxygen into the samples. At least five well volumes were pumped from the well prior to sample collection. A total of four 40-mL borosilicate vials with Teflon®–lined septa and plastic caps were collected from each well. To prevent volatilization of organics, all samples were collected without head space and with caps affixed tightly.

Samples were collected, filtered, labeled, and preserved according to the information shown in Table 3-1. Field samples were stored in large insulated ice chests full of ice and were transported to the NCSU Environmental Engineering Laboratories. In the laboratory, samples were stored in an ignition-safe refrigerator at 4°C and were analyzed within 48 hours of arrival.

Table 3-1. Sample Collection and Preparation Protocol.

Analysis	Container	Label ID	Filter	Preserved
Volatile Organics	40 mL Vial	MW-X GC-1	No	Yes, 0.5 mL of 2.0 N HCl
Organics Back-up	40 mL Vial	MW-X GC-2	No	Yes, 0.5 mL of 2.0 N HCl
Nutrients	40 mL Vial	MW-X SS-NP	Yes 0.45 µm	NO
Metals	40 mL Vial	MW-X SS-HCl	Yes 0.45 µm	Yes, 0.5 mL of 2.0 N HCl

Groundwater testing was conducted in the field for DO, dissolved CO_2, pH, Eh, and temperature. Groundwater temperature and DO were measured using an Orion® model 840 Dissolved Oxygen Meter. The DO meter probe was introduced into the well in the middle of the screened interval. Keeping the probe stationary in a sample results in DO readings that continuously decrease with time. Therefore, the probe was slowly oscillated up and down over a total distance of about 1 ft until readings stabilized. Sample pH and Eh were measured by identical Orion® model 920 ISE meters using an Orion® pH triode and a Corning® platinum redox electrode model 96-78-00. Field CO_2 measurement was carried out using a Hach® Method 8205 digital titrator.

3.4. LABORATORY ANALYTICAL METHODS

NCSU performed laboratory analysis of organic compounds (BTEX and MTBE) using a Tekmar® Purge-and-Trap Model LSC 2000 with a Perkin-Elmer® Model 9000 Auto System Gas Chromatograph fitted with a 75m DB®-624 Megabore capillary column.

NCSU Soil Science Department Analytical Service Laboratory analyzed samples collected for inorganic nutrients, anions, and metals. Sample analysis for Cl^-, Br^-, and SO_4^{2-} was conducted on a Dionex® Ion Chromatograph. A Perkin-Elmer Plasma II Ion Coupled Argon Emission Spectrometer (ICP-AES) was used for determination of soluble concentrations of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), aluminum (Al), nickel (Ni), copper (Cu), manganese (Mn), zinc (Zn), and silica (Si). Nitrogen compound analysis was performed using a LACHAT® auto analyzer and a spectrophotometric method was used for phosphorus analysis. Starting with the October 1994 sampling event, several of the Soil Science Department analyses were discontinued because their results had shown little variation with time. From this period forward, the Soil Science Department analyzed NO_3^-, NO_2^-, total organic carbon, and Cl^-.

Chapter 4

SPATIAL DISTRIBUTION OF BTEX AND INDICATOR PARAMETERS

4.1. GEOCHEMICAL INDICATOR PARAMETERS

Background DO concentrations at this site ranged from 7 to 8 mg/L. Background nitrate concentrations in the aquifer varied from 7 to 17 mg/L NO_3-N because of extensive fertilization of fields surrounding the site. Dissolved iron was low in most wells (<0.1 to 0.4 mg/L). However, 1 to 2 mg/L of dissolved iron were detected in the more highly contaminated wells (MW-3, MW-23, and MW-26). The presence of dissolved iron in a few contaminated wells at low levels indicates that while some iron reduction may have occurred in this aquifer, it was not a major electron acceptor. Dissolved sulfate concentrations ranged from less than <0.5 to 8 mg/L throughout the aquifer and did not appear to follow any consistent pattern. Methane was never observed above the analytical detection limit of 0.01 mg/L in any well. The oxidation-reduction potential ranged from +200 to +450 mV. While redox potentials were often lower in the most contaminated wells, they were always greater than +200 mV indicating oxidizing conditions in all wells. These results indicate that the presence of oxygen and nitrate buffers the oxidation-reduction potential in this aquifer. While minor amounts of iron reduction may occur, the major electron acceptors available for hydrocarbon biodegradation in this aquifer are oxygen and nitrate.

The temperature of the aquifer ranged from 15 to 21°C. Dissolved ammonia (NH_4 as N) was below the detection limits of 0.5 mg/L in most wells. Low levels of ammonia (0.5 to 2.0 mg/L as N) were often detected in the source area (MW-3), possibly due to use of ammonia-based fertilizers in a nearby shed or assimilatory nitrate reduction. Dissolved phosphate ranged from 13 to 339 µg/L as P across the site. These phosphate concentrations are low; however, they are comparable to background phosphate levels observed by Swindoll *et al.* (1988) and Armstrong *et al.* (1991). In both of these studies, increases in phosphate at some locations resulted in an increase in the rate of biodegradation and/or reduced the lag period, while in other samples from the same or adjoining locations, phosphate addition had little or no effect.

The average pH was 4.3 (sd = 0.3) and alkalinity ranged from 12 to 30 mg/L as $CaCO_3$. The low pH and acid neutralization capacity indicate that the aquifer has a weak buffering capacity. These pH values are low but should be adequate for aerobic biodegradation. Denitrifiers are more sensitive to pH and may be inhibited by the low pH found in the aquifer. Denitrification rates are usually optimal at a pH between 7 and 9 and may drop off rapidly below pH 6 (Delwiche and Bryan, 1976). Studies have shown that although denitrification can occur at pH values as low as 4, the rate of denitrification is reduced (Parkin *et al.*, 1985; Tiedje, 1988). The low pH levels at this site may be limiting BTEX biodegradation in the presence of excess nitrate.

High concentrations of total dissolved solids, sodium, and chloride were regularly observed in selected wells in the aquifer. These elevated concentrations are due to NaCl released into the aquifer from a salt house that was formerly located adjoining MW-25 (50 to 75 ft from source). A distinct NaCl plume emanates from this area and migrates downgradient following the same general pattern as the MTBE and BTEX plumes. No significant variations were observed in the parameters Al, Br, Ca, Cd, Cu, Mg, Mn, Ni, Si, and Zn.

4.2. VARIATION OF BTEX WITH TIME

Groundwater samples have been collected from the complete well network and analyzed for dissolved BTEX and MTBE 11 times since May 1993. Several of the upgradient wells were also monitored for BTEX starting in June 1992. Concentration versus time plots were evaluated to determine if there were significant trends in contaminant concentration versus time. The time axis on these plots is referenced to January 1, 1992, as day 1; however, monitoring by NCSU did not begin until day 170.

In the area immediately adjoining the former USTs, total BTEX concentrations vary from 10–20 mg/L in MW-3m to 60–80 mg/L in MW-26m (Figure 4-1A). The lower concentrations in MW-3m are likely due to the greater amount of contaminated soil removed in this area. There were no detectable trends in BTEX concentration with time in either well or detectable correlation with water table elevation.

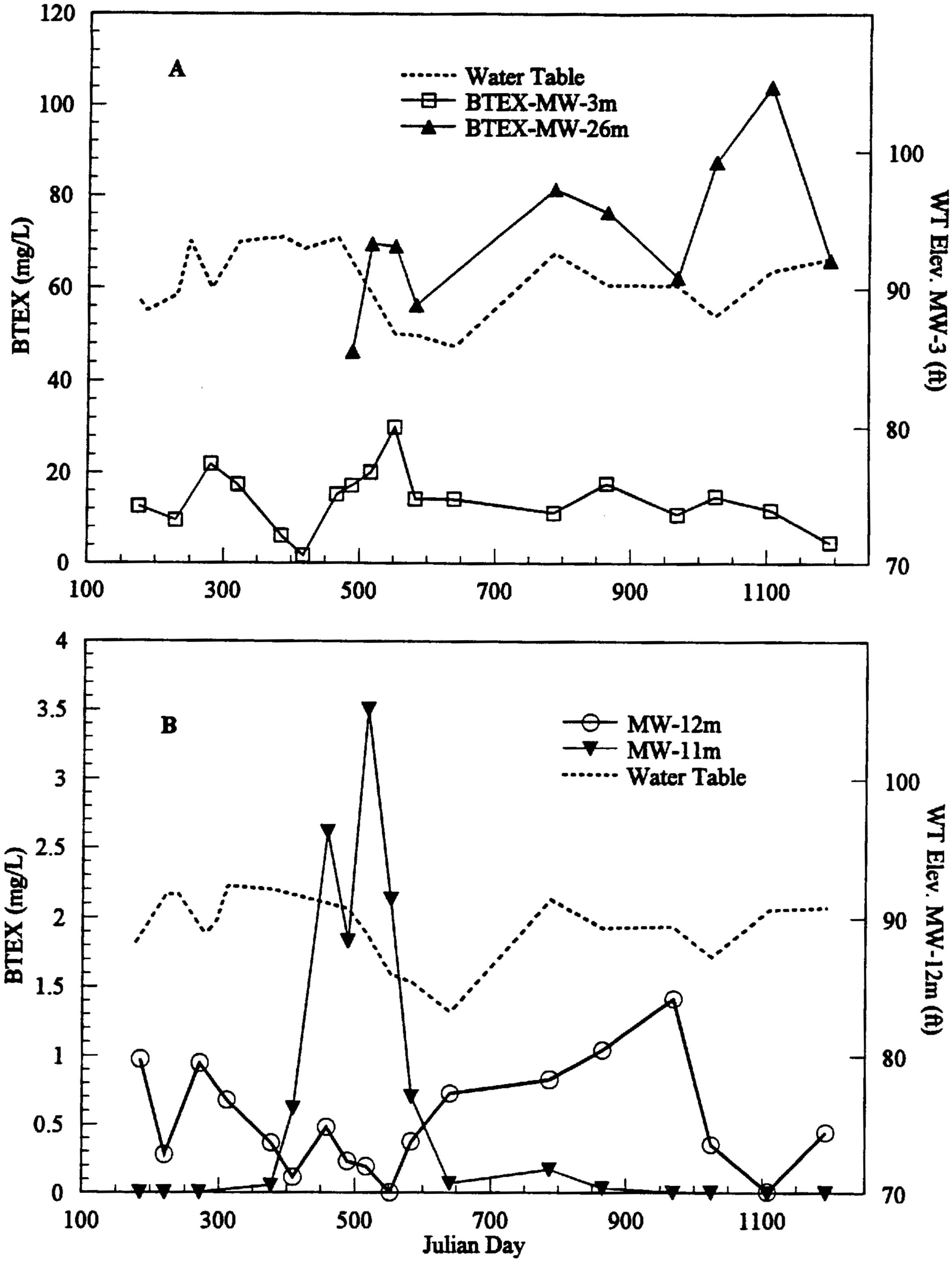


Figure 4-1. Variation in Total BTEX Concentration with Time and Water Table Elevation in (A) MW-3s and in (B) MW-11m and MW-12m (Julian Day 0 = 1/1/92).

At well line C, the center of the plume shifts in response to changes in groundwater flow direction. During the period from day 250 to 500, BTEX concentrations decreased in MW-12m and increased in MW-11m (Figure 4-1B). During this same period, the water table was high and groundwater flow was in a more northerly direction. After day 500, the water table fell and the flow shifted to a more easterly direction that resulted in higher BTEX concentrations in MW-12m and lower concentrations in MW-11m. Here also, we have not observed any long-term trends in contaminant concentrations.

MTBE and BTEX concentrations are plotted versus time in Figure 4-2 for MW-17m, one of the most contaminated wells in line D. When these wells were installed in the Spring of 1993 (500 days), line D was positioned downgradient of the leading edge of the BTEX plume but within the MTBE plume. Shortly after installation of these wells, benzene, o-xylene, and MTBE concentrations began to increase indicating that these compounds were continuing to migrate downgradient. However, by day 700, benzene, o-xylene, and MTBE stabilized at pseudo-steady-state concentrations of ~100, ~ 40, and ~ 250 µg/L, respectively. After day 800, toluene and m-, p-xylene increased slightly and then declined, while ethylbenzene remained at or below the analytical detection limit (< 1 µg/L). The more rapid breakthrough of benzene does not appear to be strictly due to hydrophobic sorption since o-xylene followed a nearly identical pattern. In contrast, ethylbenzene and m-, p-xylene never broke through at significant concentrations. If hydrophobic sorption was the only attenuation mechanism, ethylbenzene; o-xylene; and m-, p-xylene should migrate at similar rates since they have similar aqueous solubilities and octanol-water partition coefficients. The initial increase and subsequent decline in toluene and m-, p-xylene may be due to gradual microbial adaptation to these compounds and subsequent biodegradation.

4.3. HORIZONTAL AND VERTICAL DISTRIBUTION OF CHLORIDE, OXYGEN, NITRATE, AND INORGANIC CARBON

Plan views and vertical cross sections of the chloride, oxygen, nitrate and total carbon dioxide plumes in April 1995 are shown in Figure 4-3 to 4-6. Dots indicate the location of the monitoring well clusters. In the cross sections, crosses indicate the center of the monitoring well screens.

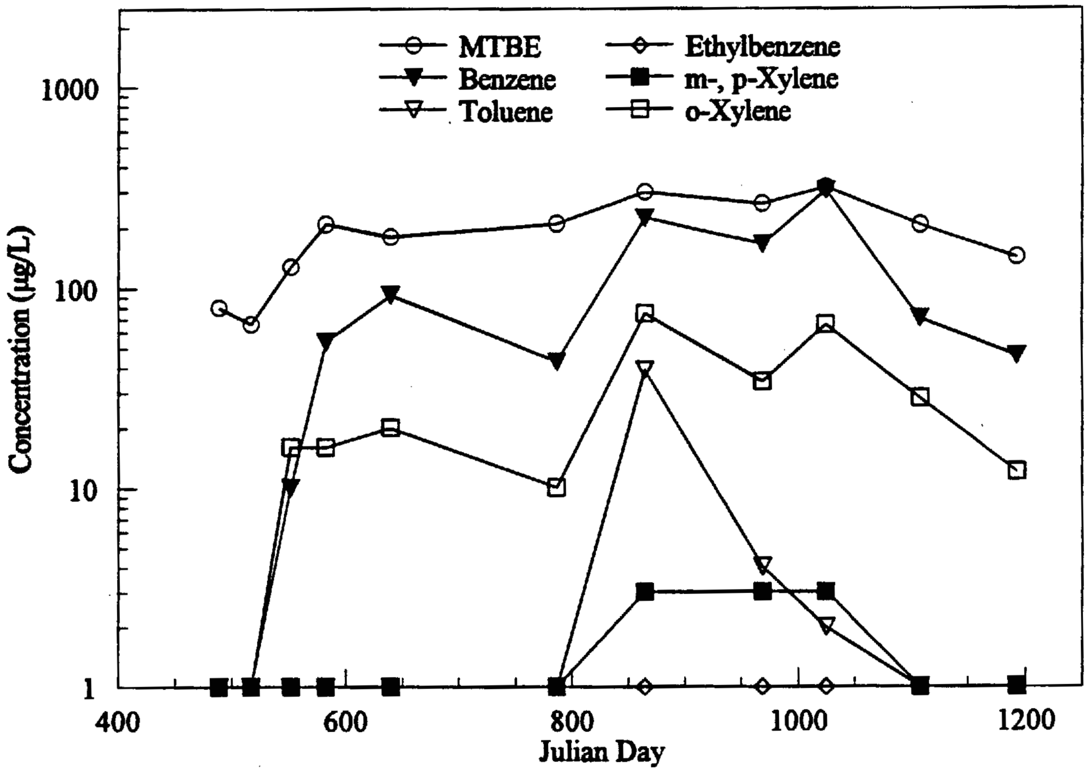


Figure 4-2. Variation in MTBE and BTEX Components with Time in MW-17m (Julian Day 0 = 1/1/92).

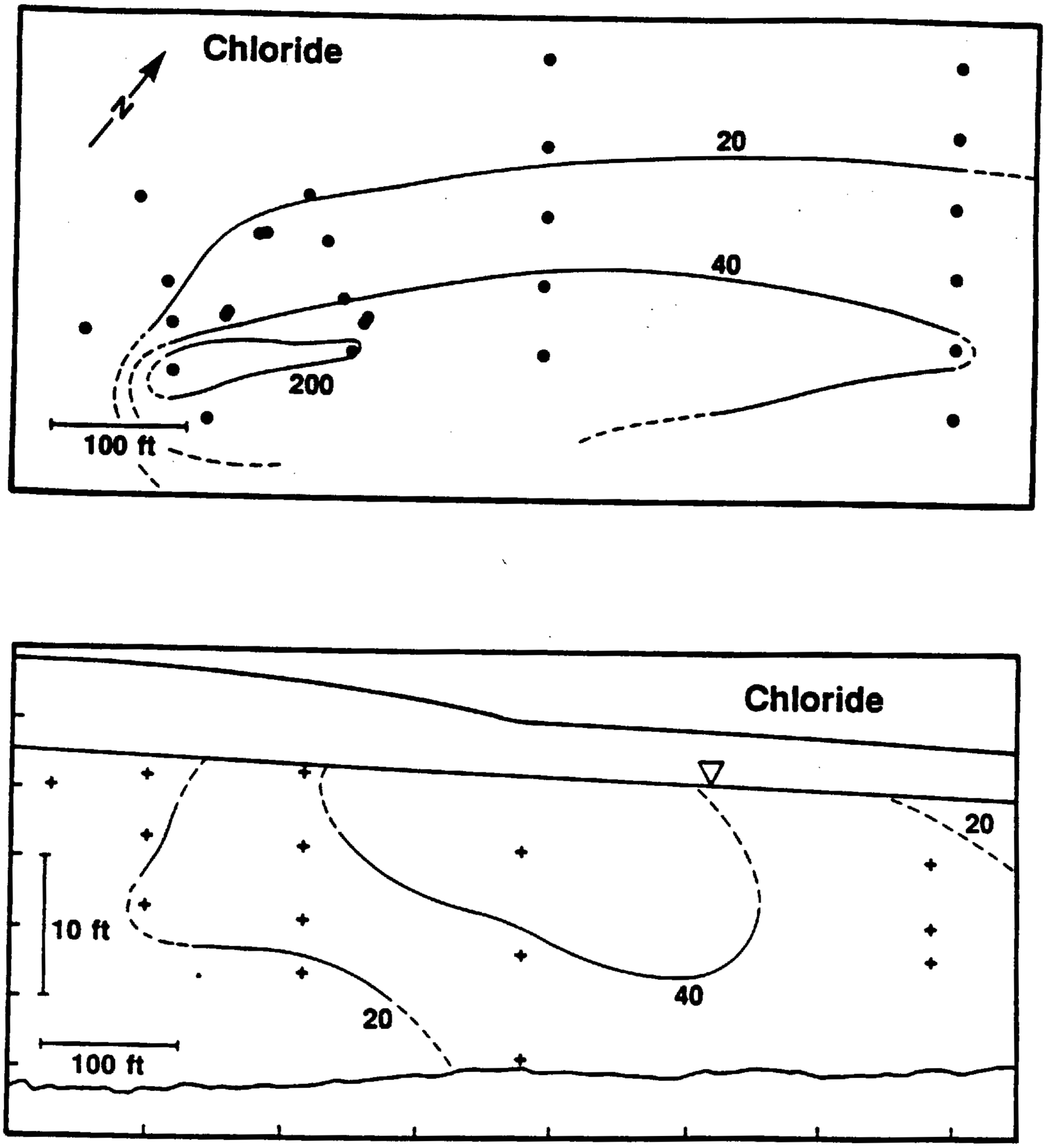


Figure 4-3. April 1, 1995, Chloride Concentration Distribution (mg/L): Plan and Profile Views.

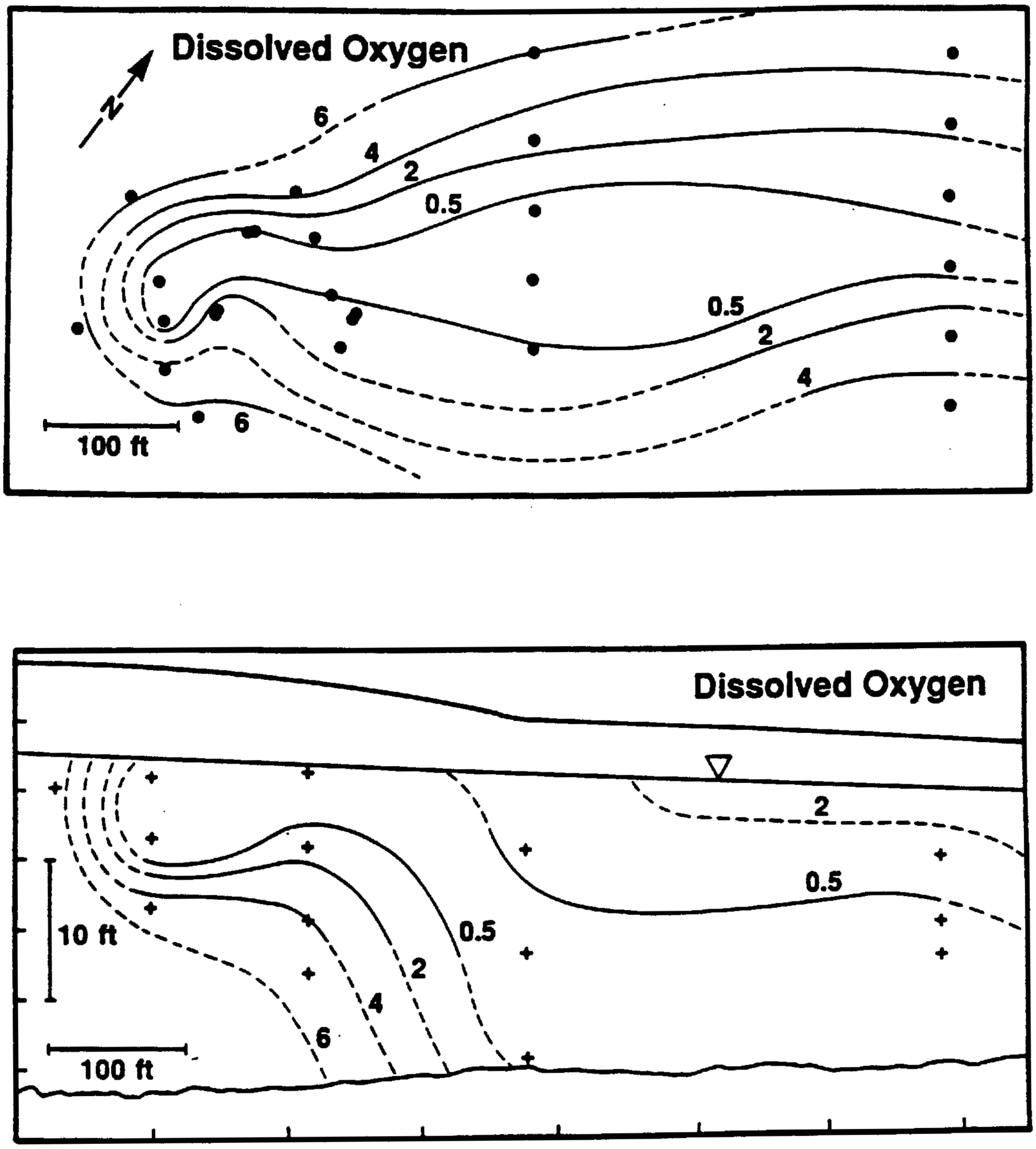


Figure 4-4. April 1, 1995, Dissolved Oxygen Concentration Distribution (mg/L): Plan and Profile Views.

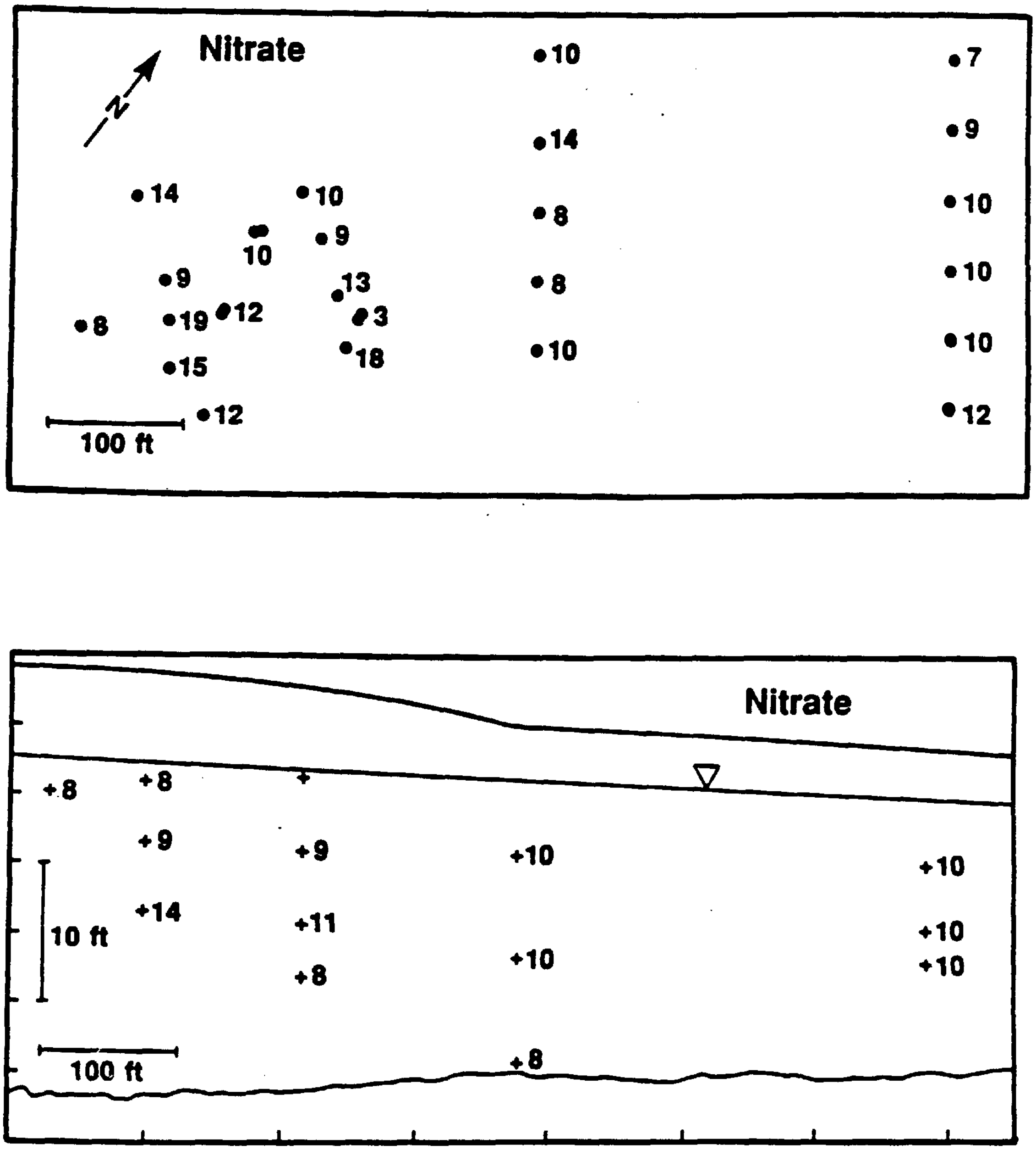


Figure 4-5. April 1, 1995, Nitrate Concentration Distribution (mg/L): Plan and Profile Views.

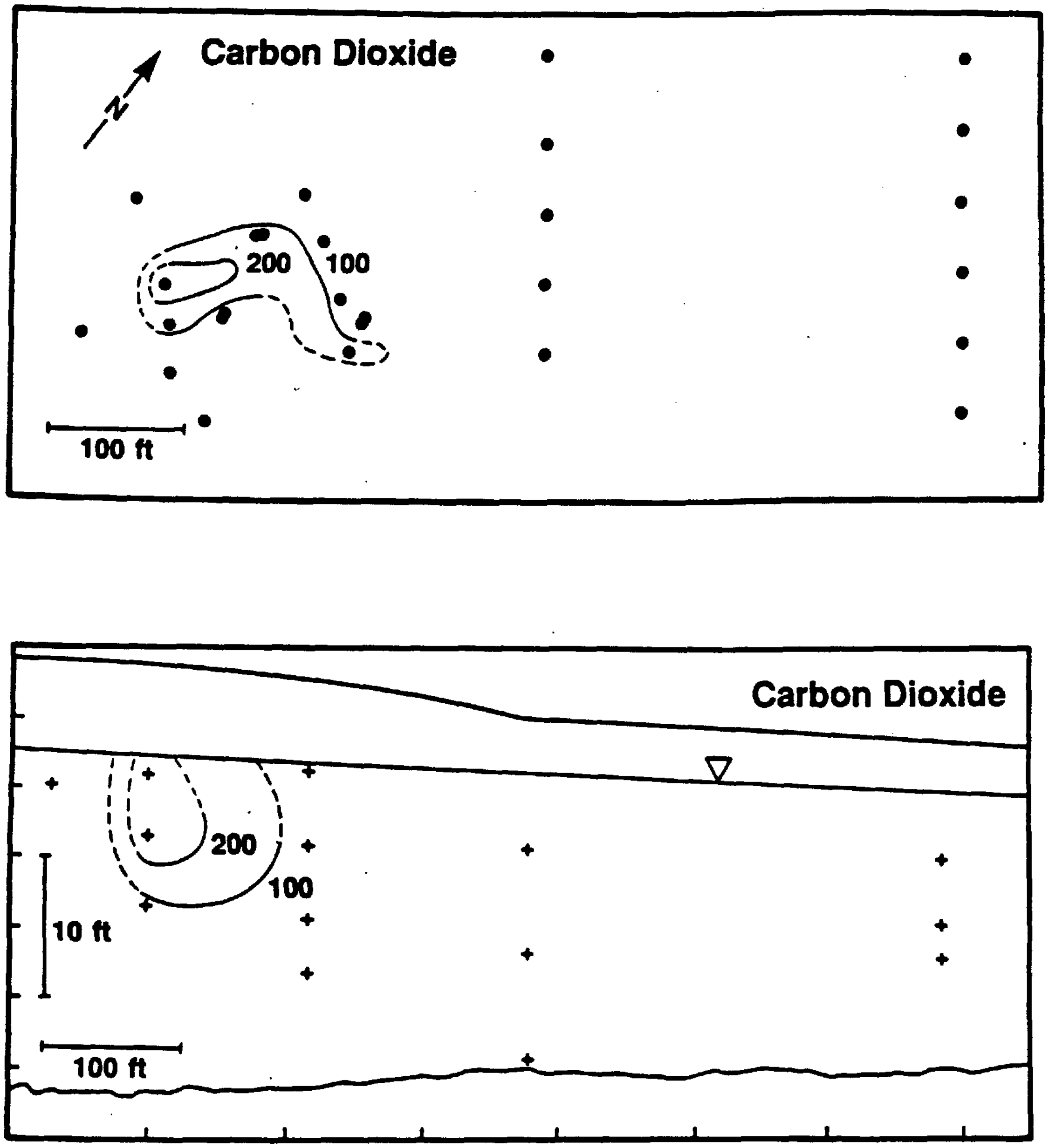


Figure 4-6. April 1, 1995, Carbon Dioxide Concentration Distribution (mg/L): Plan and Profile Views.

The plan views were plotted for the vertical interval of the aquifer with the highest MTBE and BTEX concentrations (line B-B' in Figure 2-2). The cross sections were drawn along the approximate MTBE/BTEX plume centerline as of April 1995 (line A-A' in Figure 2-1). Because of this procedure, the cross section does not follow the chloride plume centerline. The contours were drawn by linearly interpolating between the closest data points.

The chloride plume emanates from a former salt house located near MW-25 and migrates to the northeast following the general groundwater flow direction (Figure 4-3). Because the chloride plume originates to the east of the BTEX plume, it was not entirely intercepted by the network of monitoring wells. The large spread of the chloride plume is believed to result from changes in the groundwater flow direction. At well line C, the plume bends slightly to the east. A shallow (3-ft-deep) drainage tile is located approximately 100 ft northwest of the northern most well in this line (MW-10). When the water table is high, this drain pulls the plume to the northwest. When the water table is below the drain elevation, the plume follows the regional groundwater flow toward a small stream located 1200 ft to the northeast of the 580-ft line of wells.

DO concentrations outside the BTEX plume range from 7 to 8 mg/L, while in the center of the plume, DO concentrations are below the field detection limit of 0.5 mg/L (Figure 4-4). As in previous work, when DO concentrations exceeded 1.0 mg/L, dissolved hydrocarbon concentrations were close to the analytical detection limit (Chiang *et al.*, 1989; Borden *et al.*, 1986, 1995). However, at this site, low concentrations of dissolved hydrocarbons were sometimes present (< 100 µg/L benzene) when DO concentrations were low (0.5 to 1.0 mg/L).

Nitrate concentrations varied (7 to 19 mg/L NO_3-N) throughout the site, and there was no evidence of a zone of depressed nitrate concentrations similar to the DO distribution (Figure 4-5). While low nitrate concentrations did occasionally coincide with high BTEX levels, this pattern was not consistent throughout the site or over time. The high background nitrate concentrations are due to extensive fertilization of the farmland surrounding the site. The absence of a detectable depression in NO_3-N associated with the dissolved BTEX plume is believed to be due to spatial variability in groundwater recharge and fertilizer application rates. Given the high NO_3-N concentrations in the aquifer, nitrate availability should not limit BTEX biodegradation via denitrification.

A plume of elevated total carbon dioxide (CO_2) was present in the aquifer (Figure 4-6) and coincides with the BTEX plume. CO_2 is produced as a result of organic carbon biodegradation, demonstrating that hydrocarbon biodegradation is occurring. Background inorganic carbon concentrations ranged from 25 to 50 mg/L as CO_2. CO_2 concentrations were highest at MW-26 (300 mg/L) and decreased gradually from the source. At the downgradient line of wells, CO_2 concentrations were highest in wells with the highest MTBE and BTEX concentrations.

4.4. HORIZONTAL AND VERTICAL DISTRIBUTION OF MTBE AND BTEX

The horizontal and vertical distributions of MTBE and BTEX components are shown in Figures 4-7 to 4-12. Average contaminant concentrations in the most contaminated wells in each line are listed in Table 4-1 for the 1994–95 monitoring period. Data from 1993 were not included in these averages to eliminate the effects of the gradual breakthrough of contaminants in line D. Concentrations of all contaminants are highest in MW-26m and decrease steadily with distance from the source. MW-26m is located immediately to the northwest of the former USTs, and a sheen of gasoline has occasionally been observed on water samples collected from this well. Toluene and ethylbenzene decline most rapidly with distance from the source followed by m-, p-xylene and then o-xylene, benzene, and MTBE. During transport from line A to C, the average peak concentration of toluene; ethylbenzene; and m-, p-xylene decreased by more than 99%; o-xylene, benzene, and MTBE decreased by 97 to 98%.

The o-xylene, benzene, and MTBE plumes all have the same general shape and they flow to the northeast. The width of the MTBE plume is similar to the chloride plume, but the o-xylene and benzene plumes are somewhat narrower than the chloride plume. The narrower plume width is believed to be due to aerobic biodegradation at the plume fringes. The vertical cross sections for o-xylene, benzene, and MTBE all have the same general appearance. The center of each plume sinks gradually with distance. This sinking is believed to be due to recharge of clean oxygenated water on top of the contaminant plumes. While the general appearance of the MTBE and benzene

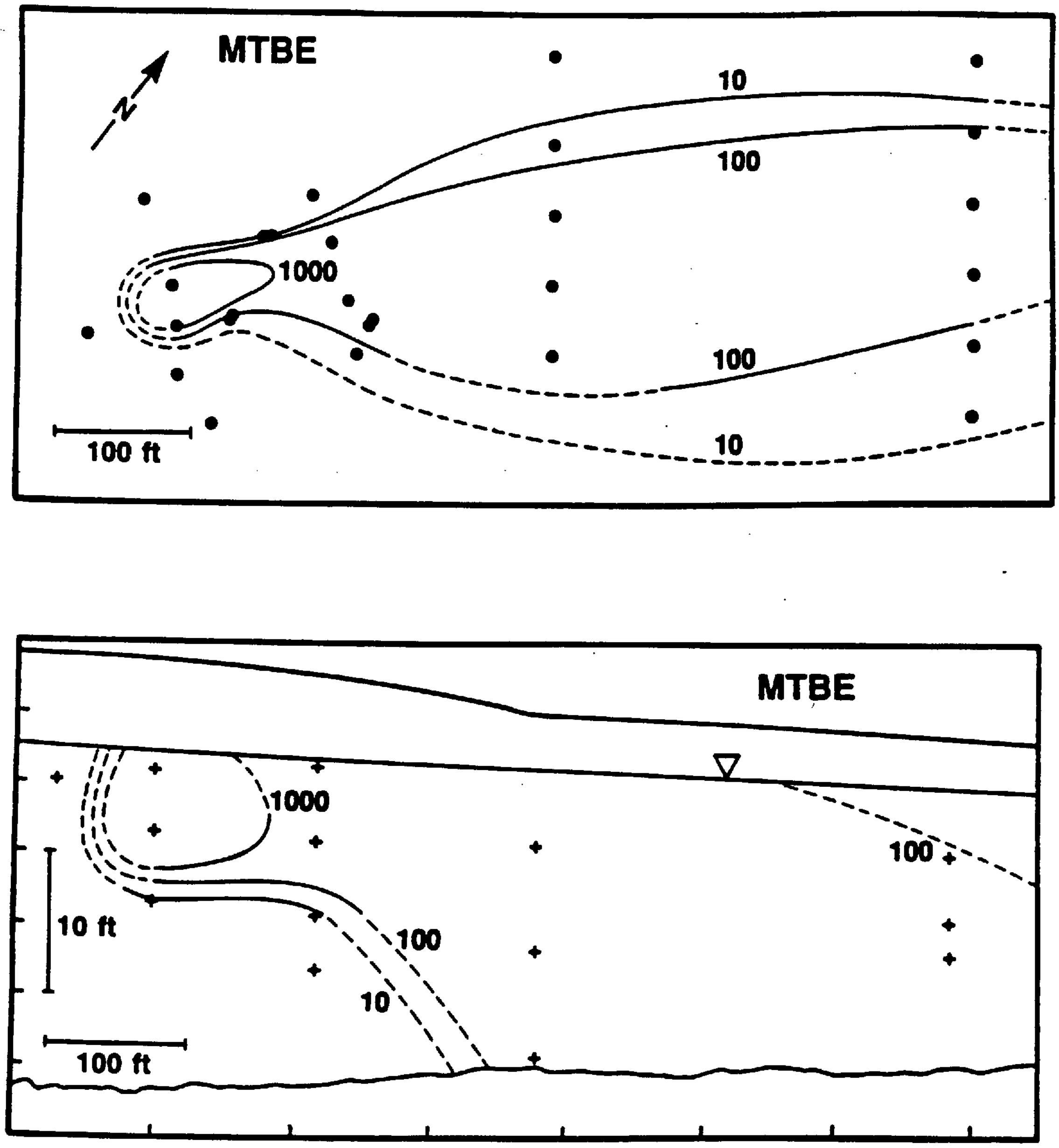
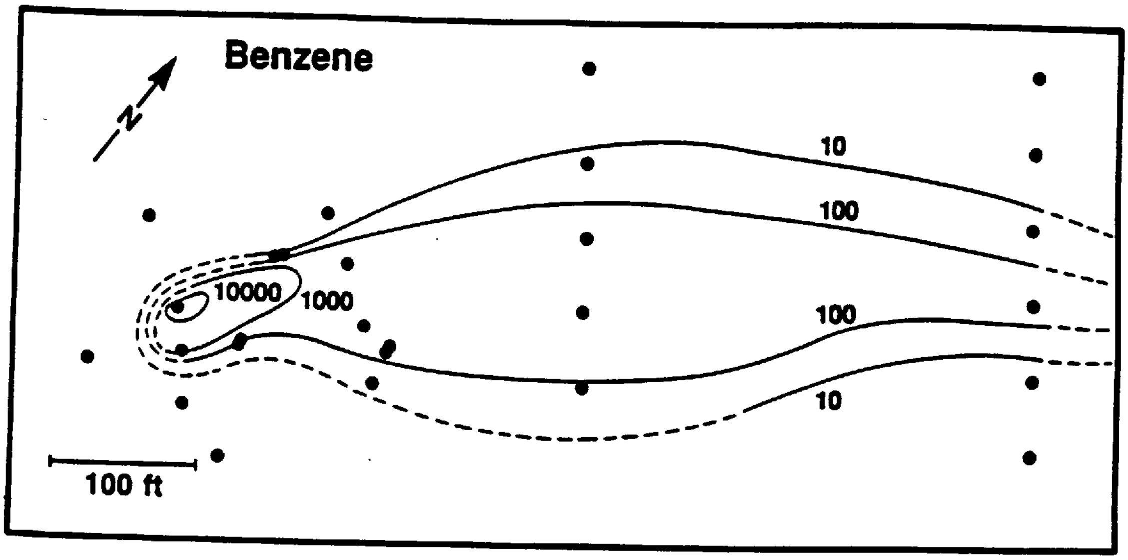


Figure 4-7. April 1, 1995, MTBE Concentration Distribution (µg/L): Plan and Profile Views.



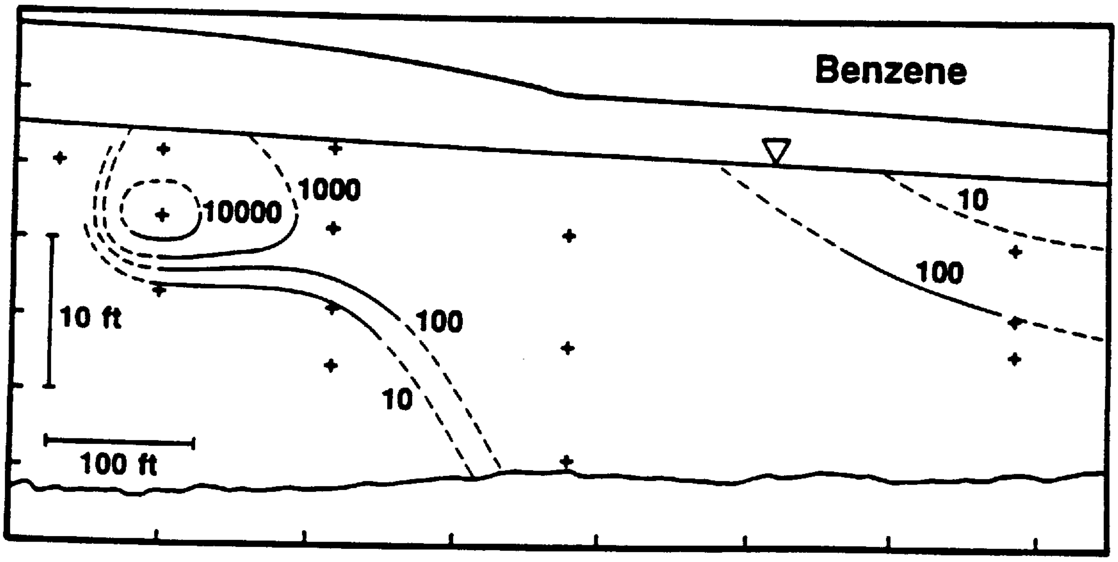


Figure 4-8. April 1, 1995, Benzene Concentration Distribution (µg/L): Plan and Profile Views.

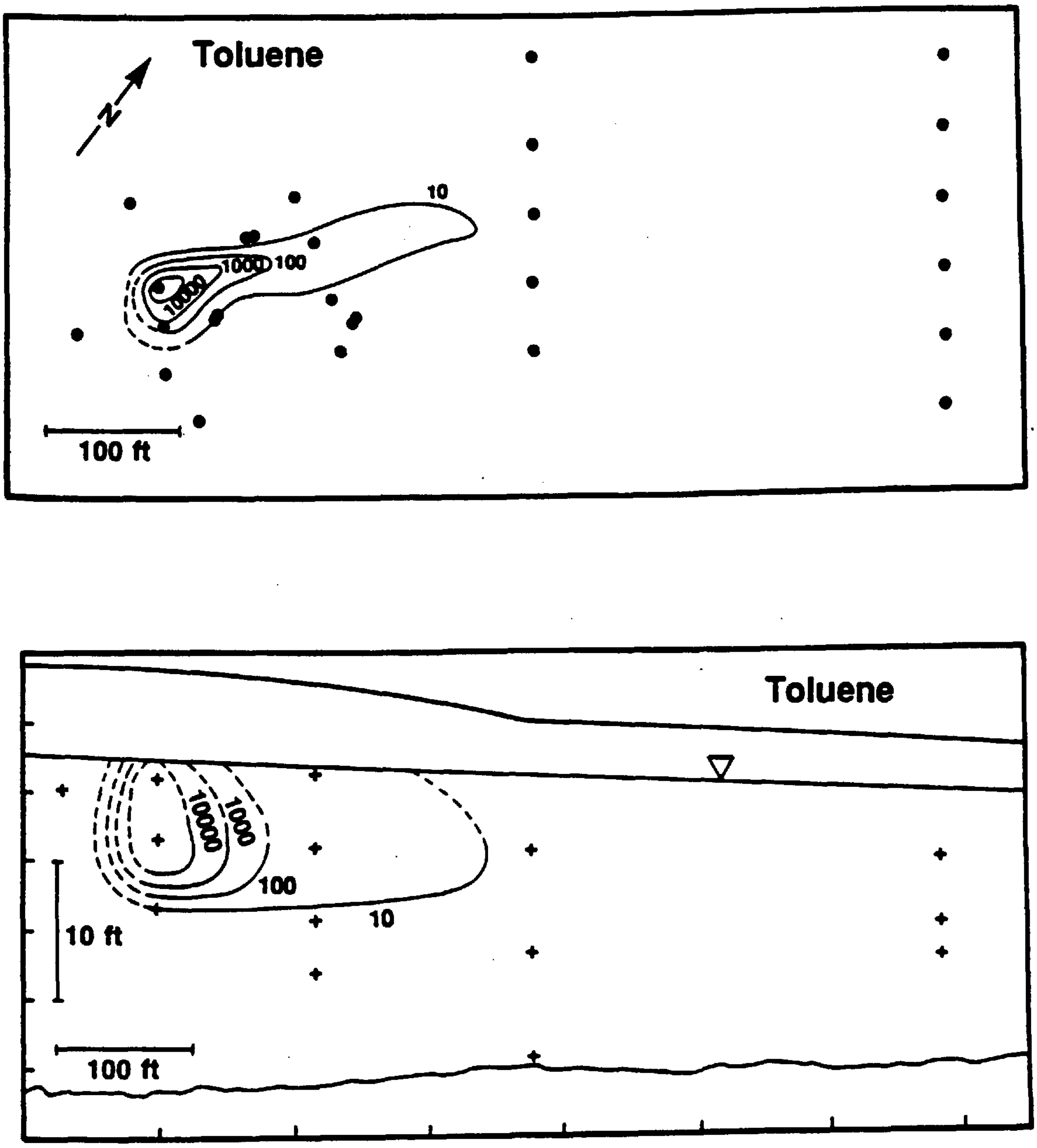


Figure 4-9. April 1, 1995, Toluene Concentration Distribution (µg/L): Plan and Profile Views.

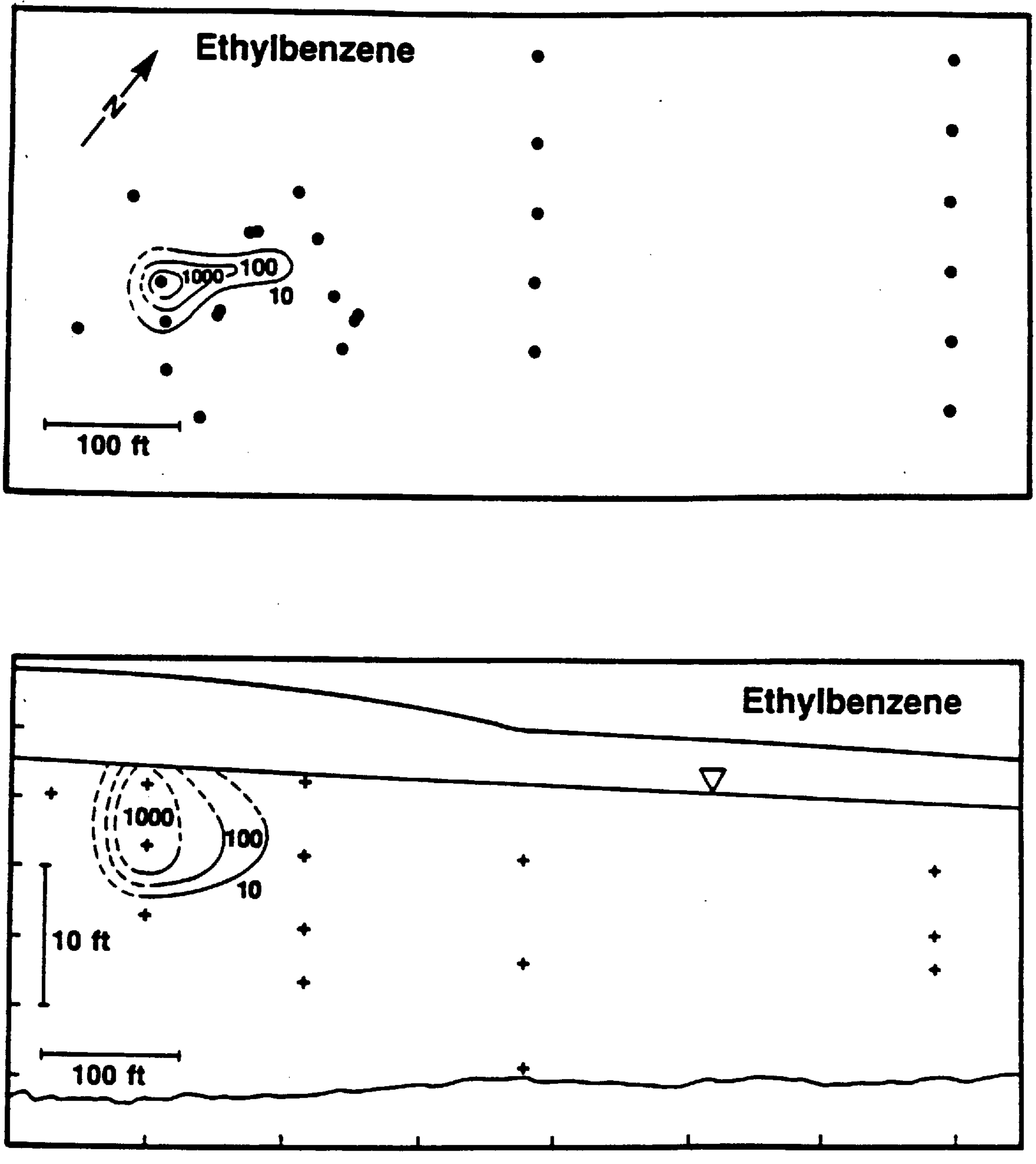
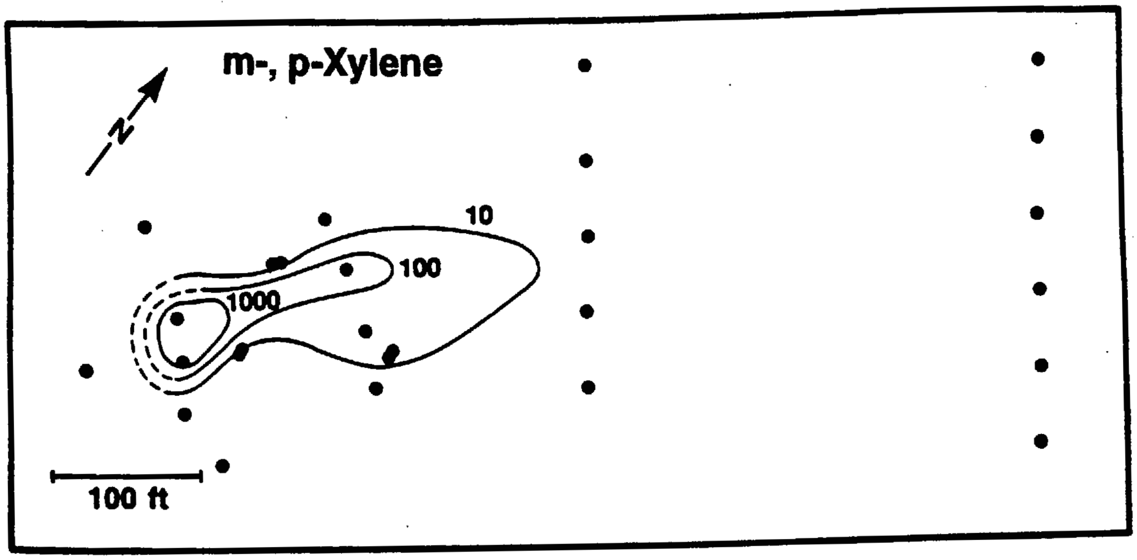


Figure 4-10. April 1, 1995, Ethylbenzene Concentration Distribution (µg/L): Plan and Profile Views.



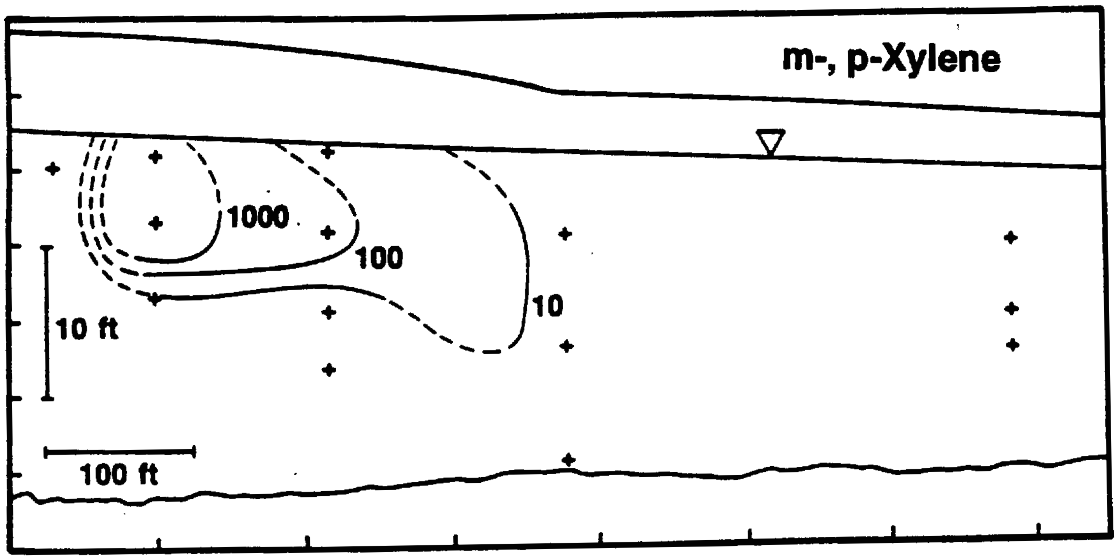


Figure 4-11. April 1, 1995, m-, p-Xylene Concentration Distribution (µg/L): Plan and Profile Views.

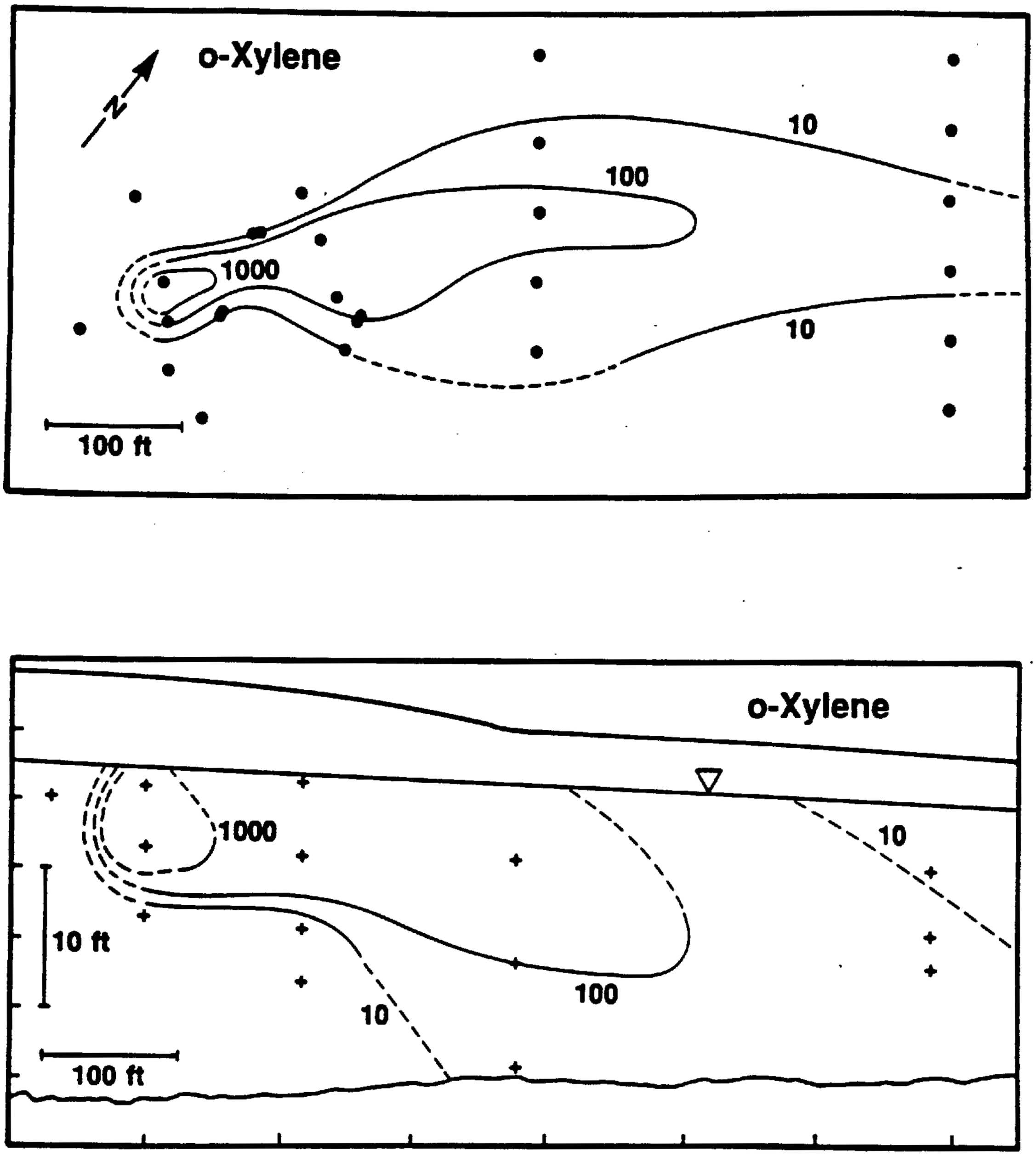


Figure 4-12. April 1, 1995, o-Xylene Concentration Distribution (µg/L): Plan and Profile Views.

Table 4-1. Average Peak Concentrations Observed in Well Lines A, B, C, and D for the 1994–95 Monitoring Period.

Line		A	B	C	D
Well		MW-26m	MW-23o	MW-12m	MW-17d[a]
Distance from Source		0 ft	137 ft	290 ft	580 ft
MTBE	mean	9,955	703	332	245
	std. dev.	4,588	660	430	69
	% source	100	7.1	3.3	2.5
Benzene	mean	17,218	1,164	494	168
	std. dev.	3,606	984	359	94
	% source	100	6.8	2.9	1.0
Toluene	mean	40,137	114	12	4
	std. dev.	6,245	115	11	7
	% source	100	0.3	0.03	0.01
Ethylbenzene	mean	4,305	12	2	0
	std. dev.	1,403	14	1	–
	% source	100	0.3	0.05	0
m-, p-Xylene	mean	12,190	365	46	2
	std. dev.	2,797	351	48	1
	% source	100	3.0	0.4	0.02
o-Xylene	mean	5,859	462	136	39
	std. dev.	1,587	372	100	21
	% source	100	7.8	2.3	0.7

[a] On average, MW-17d was the most contaminated well in line D. However, in April 1995 when the plume cross sections were drawn, BTEX/MTBE concentrations were slightly higher in MW-18d.

plumes are similar, the vertical concentration gradients for benzene are steeper. At the downgradient end, MTBE decreases from 179 to 104 µg/L from the middle to upper screen, but benzene decreases from 101 to 27 µg/L. The steeper concentration gradient for benzene is believed to be due to enhanced biodegradation caused by the higher oxygen concentration in the recharge water.

The plan views and cross sections show toluene and ethylbenzene declining rapidly with distance from the source, but m-, p-xylene appears to degrade somewhat more slowly. However, at line C, the maximum toluene; ethylbenzene; and m-, p-xylene concentrations were similar (8, 1, and 8 µg/L, respectively, in April 1995). The toluene; ethylbenzene; and m-, p-xylene plumes also appear to sink with distance, although the effect is less apparent because the concentrations of these compounds are close to the analytical detection limit at lines C and D.

The total BTEX composition changes with distance from the source because of the more rapid biodegradation of toluene; ethylbenzene; and m-, p-xylene. The pie charts in Figure 4-13 show that the proportions of benzene and o-xylene increase at locations further downgradient, while proportions of other compounds decrease further from the source. Benzene and o-xylene comprise only 28% of total BTEX at the source, but the two compounds account for 98% of BTEX at MW-18d. On the other hand, toluene decreases from 52% of BTEX at the source to only 1% at MW-18d.

4.5. DISCUSSION OF FIELD MONITORING RESULTS

The field monitoring results indicate that, although microbial activity is reducing the hydrocarbon transport, low levels of MTBE, benzene, and o-xylene have migrated more than 580 ft from the source. The MTBE plume is somewhat wider than the benzene plume, suggesting that benzene is more rapidly degraded at the edges of the plume where oxygen concentrations are higher.

The relative order of removal for the BTEX components at this site is consistent with BTEX biodegradation under denitrifying conditions. At this site, toluene and ethylbenzene degrade most rapidly followed by m-, p-xylene, then o-xylene and benzene. This is the same order of

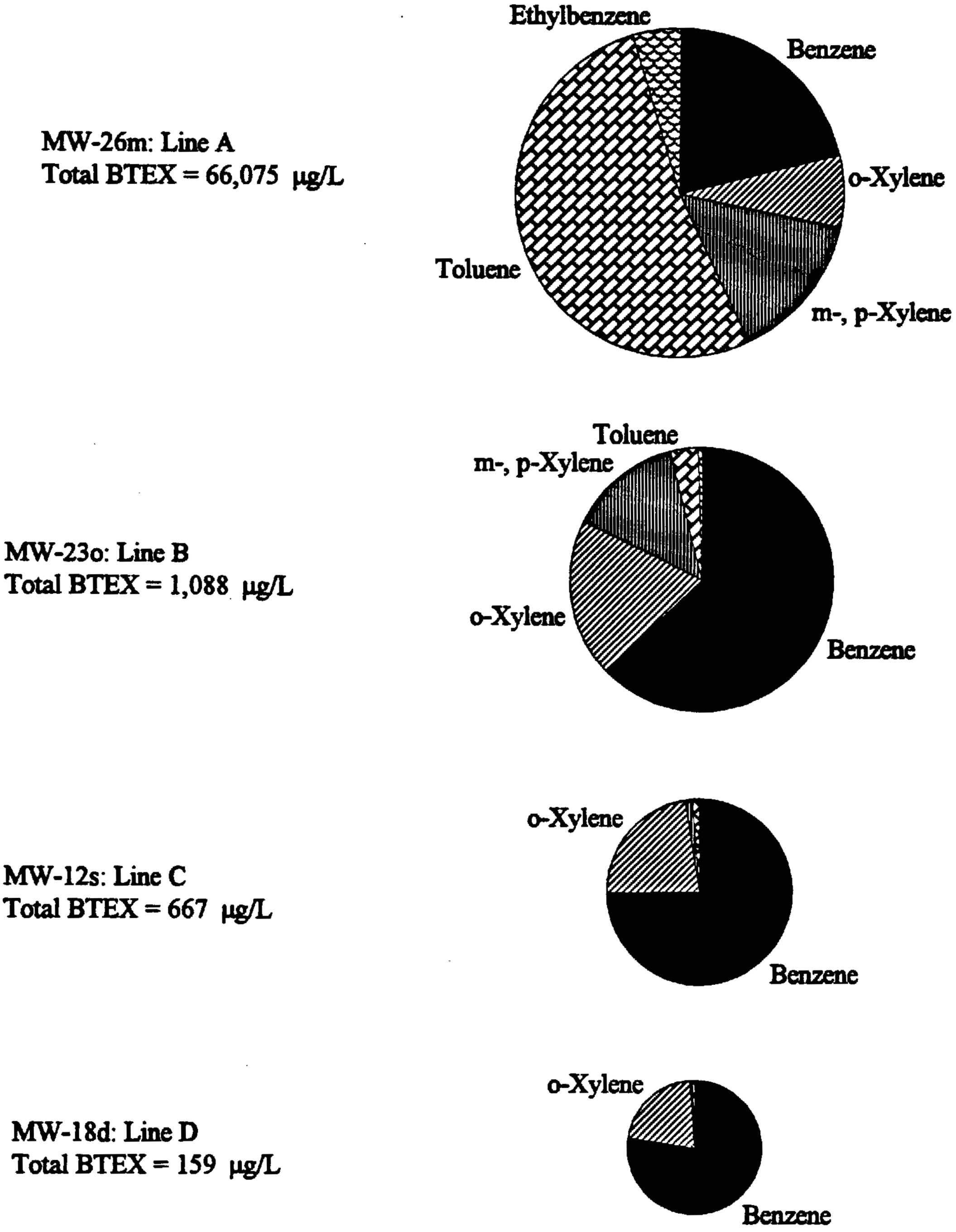


Figure 4-13. Proportion of BTEX Compounds in Each Cross Section of the Most Contaminated Well for the April 1995 Sampling Event.

disappearance as reported by Hutchins (1991a), Hutchins *et al.* (1991b), and Kao and Borden (in press). Kuhn *et al.* (1988), Hutchins (1991a), and Hutchins *et al.* (1991b) reported that toluene was rapidly degraded in the presence of nitrate. With the high nitrate concentrations found at this site, it is surprising that the hydrocarbon source is not more rapidly remediated. The low pH of the aquifer (4 to 5) may be limiting hydrocarbon biodegradation via denitrification.

Approximately 40 µg/L of o-xylene has migrated almost 580 ft downgradient from the source, whereas toluene; ethylbenzene; and m-, p-xylene concentrations are 1 µg/L or less at line D. Since ethylbenzene; m-, p-xylene; and o-xylene have similar sorption characteristics, the disappearance of ethylbenzene and m-, p-xylene with respect to o-xylene is a strong indication of biodegradation. Hutchins (1991a) and Hutchins *et al.* (1991b) have shown that o-xylene biodegradation is often slow under denitrifying conditions and may stop once other TEX compounds are removed. This finding is supported at this site by the persistence of o-xylene when toluene; ethylbenzene; and m-, p-xylene are at the detection limit.

The dissolved benzene plume has traveled more than 580 ft from the source. Over this distance, benzene concentrations decline from 17,200 to 170 µg/L (~ 99% reduction). Benzene concentrations at the downgradient wells have been consistent or have declined slightly over the past two years, indicating that the decline in benzene with distance is not due to sorption to the sediment. The benzene plume also narrows with distance from the source, indicating the decline in concentration is not due to dilution.

Based on the qualitative interpretation of the field data presented in this chapter, it is not clear whether MTBE is totally recalcitrant or just less biodegradable than BTEX. Laboratory studies on MTBE are mixed. While most studies report negligible MTBE biodegradation, recent work by Salanitro *et al.* (1994) and Mormile *et al.* (1994) indicates that MTBE is potentially biodegradable under certain conditions.

Dissolved oxygen concentrations are less than the field detection limit (0.5 mg/L) in all wells with significant benzene concentrations (> 100 µg/L). However, nitrate concentrations are high throughout the aquifer (9 to 19 mg/L as N). Anaerobic biodegradation using nitrate as the terminal electron acceptor is the likely cause of the rapid biodegradation of toluene; ethylbenzene; and m-, p-xylene. The high background nitrate concentrations do not appear to have enhanced benzene removal, suggesting that benzene only biodegrades aerobically. This is consistent with previous work in which benzene was recalcitrant under denitrifying conditions (Zeyer *et al.*, 1986; Kuhn *et al.*, 1988; Hutchins, 1991a; Hutchins *et al.*, 1991b; Barbaro *et al.*, 1992).

The production of CO_2 in the plume indicates that native organisms are degrading BTEX. The spreading of the CO_2 plume is due to dilution and dispersion. Background concentrations range from 25 to 50 mg/L. Dissolved CO_2 concentrations are high at the source (300 mg/L as CO_2) and decrease with distance from the source. The production of approximately greater than 250 mg/L CO_2 above background indicates that in excess of 68 mg/L of hydrocarbon have been mineralized.

In other petroleum-contaminated aquifers, BTEX biodegradation has been associated with large increases in dissolved Fe(II), depletion of sulfate, and CH_4 production (Baedecker *et al.*, 1993; Borden *et al.*, 1995). In this aquifer, the high background DO and nitrate concentrations strongly buffer the oxidation-reduction potential. As a consequence, the minimum redox potential observed in any well was more than +200 mV, and the dissolved BTEX plume minimally influenced the aqueous geochemistry. There was no evidence of sulfate reduction or CH_4 production. Small amounts of dissolved iron were observed in a few of the most contaminated wells. However, the impact of iron reduction on BTEX biodegradation is believed to be minimal.

Chapter 5

MASS FLUX ESTIMATION OF CONTAMINANT DEGRADATION RATES

When modeling contaminant transport and biodegradation, it is first necessary to determine the *in situ* biodegradation rate. Various investigators have estimated effective first-order decay rates (λ) for petroleum hydrocarbon plumes from field data. The most common approach has been to assume λ is equal to the slope of a plot of the natural logarithm of contaminant concentration versus travel time from the source (Kemblowski *et al.*, 1987; Buscheck *et al.*, 1993; McAllister and Chiang, 1994). The effects of transverse dispersion and non-ideal well placement can be accounted for by normalizing contaminant concentrations to an internal standard (Wilson *et al.*, 1993). Ideally, the internal standard should be a component of the original release, should have the same sorption characteristics as the problem contaminants, and should be recalcitrant to biodegradation. A second approach for estimating the decay rate is to monitor changes in the total mass of a dissolved pollutant over time (Chiang *et al.*, 1989; Barker *et al.*, 1987; MacIntyre *et al.*, 1993). However, in many cases, dissolved gasoline plumes will reach a pseudo-steady-state condition when contaminant concentrations in monitoring wells stabilize (with minor fluctuations) because of the combined effects of contaminant dissolution at the source, downgradient transport of the dissolved constituents, and subsequent biodegradation. In this situation, the mass balance approach cannot be used to estimate biodegradation rates since the mass of dissolved contaminant in the aquifer will be constant.

In this work, a modification of the mass balance approach was used to estimate intrinsic bioremediation rates after the plume has reached a pseudo-steady-state condition. Four lines of monitoring wells were installed perpendicular to the groundwater flow direction and sampled to estimate the mass flux of contaminant crossing each line. Changes in mass flux versus distance were used to estimate effective first-order decay rates for MTBE and BTEX in the field.

5.1. MASS FLUX ESTIMATION

The mass flux approach was used to overcome limitations associated with previous methods. By using mass fluxes instead of point concentrations, the effects of vertical and transverse dispersion and non-ideal well placement were eliminated. Also, the mass flux approach does not require the use of an internal standard. The major limitations of this approach are: (1) contaminant concentrations in monitoring wells must stabilize before decay rates can be calculated; and (2) incorporation of the dispersive mass flux is difficult.

The advective mass flux (f_i) associated with an individual monitoring well screen on sampling date i was calculated as $f_i = C_i q_i A_i$, where C_i is the concentration at the screen, q_i is the specific discharge perpendicular to the line of wells, and A_i is the area associated with that screen. Specific discharge was calculated using the water table gradient from each sampling event (Section 2.0 of Appendix A in Borden *et al.*, 1997). The specific discharge was not corrected for sorption to the aquifer material. Once the plume reaches a steady-state condition, contaminants migrate only in the aqueous phase and there is no net exchange of contaminants between the solid and aqueous phases. Values of C_i, q_i, and A_i were determined for each sampling date i. The total advective mass flux through a line of wells is the sum of the fluxes associated with each screen. A Theissen polygon centered at the midpoint of the monitoring well screen defines the area associated with each screen. Figure 5-1 shows the location of each monitoring well screen and the Theissen polygons for line B. Perpendicular bisectors of all surrounding sampling points define the edges of the polygons. The shallowest and deepest polygons in each well cluster are limited by the groundwater table above and by the underlying confining layer below. Polygons at the horizontal extremes of the well lines are assumed to have an area of influence that extends 30 m beyond the last well in a cross section to provide a very conservative estimate of the maximum extent of the plume. Since the wells in the outermost polygons were usually close to the analytical detection limit, they do not contribute significantly to the total mass flux and their exact dimensions are not important. When water levels in a well were too low to allow sample collection, the next lower polygon was extended up to the water table surface.

In a related study, Semprini *et al.* (1995) used the mass flux approach to study the anaerobic transformation of chlorinated solvents in groundwater. These authors used a nonlinear estimation procedure to construct contour lines of equal concentration and estimate mass fluxes perpendicular to each sampling transect. Use of the nonlinear estimation procedure could result

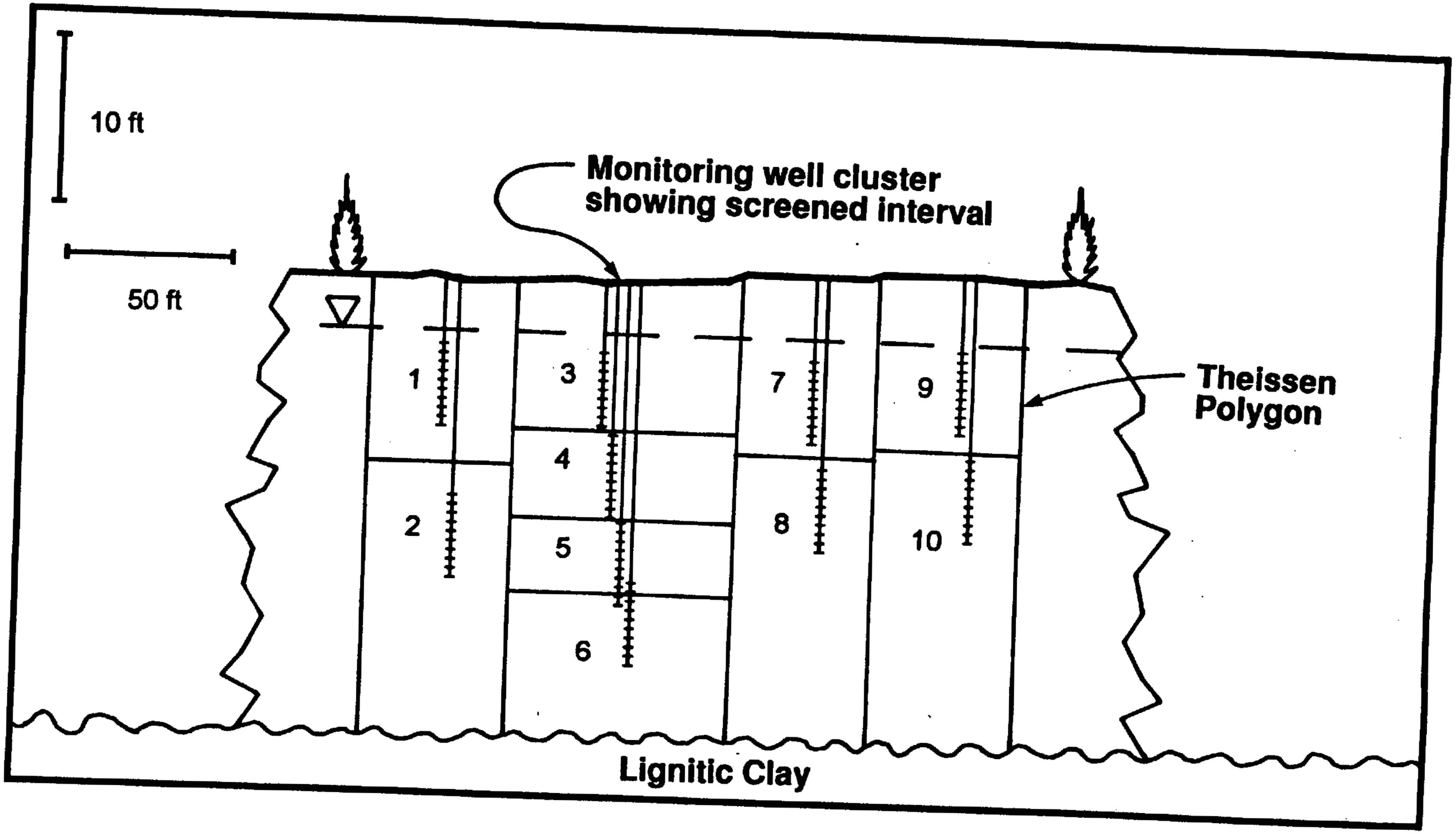


Figure 5-1. Theissen Polygon Plot for Cross-Section B Showing Ten Polygons Used to Calculate Contaminant Mass Flux.

in more accurate estimates of mass flux than the Theissen polygon approach. One disadvantage of the nonlinear estimation procedure is the difficulty a reader may have in evaluating the effect of the fitting parameters on calculated mass fluxes. In contrast, the Theissen polygon procedure is much more transparent to the reader and results in mass fluxes equivalent to a linear interpolation of point concentrations.

Dispersive mass fluxes were not calculated in this study because of the difficulty in accurately estimating longitudinal dispersivities and longitudinal concentration gradients. Instead, it was assumed that most of the mass flux is due to advection and the dispersive flux can be neglected when calculating decays rates. To evaluate this assumption, the three-dimensional continuous source model of Domenico (1987) was used to generate steady-state solute distributions for different values of λ. The longitudinal dispersivity (α_L) was assumed to be 1 m based on field studies by Freyberg (1986) and Garabedian *et al.* (1991). λ was then estimated using the advective mass flux procedure and compared to the original value of λ used to generate the solute distribution. For values of λ between 0.001 and 0.01 d^{-1}, the advective flux procedure underestimated the actual value λ by 2 to 16%; larger errors were associated with higher values of λ. These results indicate that the advective mass flux procedure can be used to develop reasonably accurate estimates of λ. In most cases, the error introduced by ignoring the dispersive mass flux will be much less than the uncertainty in λ associated spatial variations in permeability.

During the initial stages of this project, it appeared that the chloride plume could be used as an internal standard to validate the mass flux approach. However, the source of the chloride plume (former salt house) was located 50 to 75 ft east of the gasoline spill. Because of this, the monitoring well network designed to capture the BTEX plume did not fully capture the chloride plume, and the calculated chloride mass fluxes would not be accurate.

5.2. VARIATION IN MTBE AND BTEX MASS FLUX WITH TIME

In many cases, dissolved gasoline plumes will reach a pseudo-steady-state condition when contaminant concentrations in monitoring wells stabilize (with minor fluctuations) because of the combined effects of contaminant dissolution at the source, downgradient transport of the dissolved constituents, and subsequent biodegradation. Once the plume stabilizes, the mass flux approach can then be used to estimate contaminant degradation rates.

One approach for determining if the plume has stabilized is to examine contaminant concentrations in individual monitoring wells. However, minor shifts in the groundwater flow direction can cause significant changes in concentrations in individual wells (Figure 4-1B). A more appropriate method for determining if the plume has stabilized is to examine changes in mass flux across each line of wells over time. This approach eliminates the effects of plume shifts on concentrations in individual wells.

Figures 5-2 and 5-3 show the mass flux of MTBE and BTEX components versus time across lines A, B, C, and D. Over the 2-year monitoring period, contaminant concentrations in the source area (line A) monitoring wells were reasonably consistent. However, fluctuations in the water table position (~ 6 ft) altered the size of the Theissen polygons and the calculated mass fluxes. This effect was most notable when the water table fell below the bottom of the shallowest, most contaminated well screens and resulted in a relatively strong correlation between total BTEX mass flux and water table elevation ($r^2 = 0.76$). While the absolute magnitude of the mass fluxes varied from one sampling event to the next, the general trends in mass flux versus distance were very consistent.

In line B, the mass fluxes were initially very low, gradually increasing until they appeared to stabilize around day 400. The low initial mass fluxes were primarily due to the low concentrations measured in all of the monitoring wells in line B. Total BTEX mass flux was not correlated with water table elevation ($r^2 = 0.001$). The reason for the low initial concentrations in line B is not known. In line C, changes in total BTEX mass flux were weakly correlated with water table elevation ($r^2 = 0.26$). This correlation was primarily due to transverse shifts in the plume centerline that caused changes in contaminant concentrations in MW-11 and MW-12.

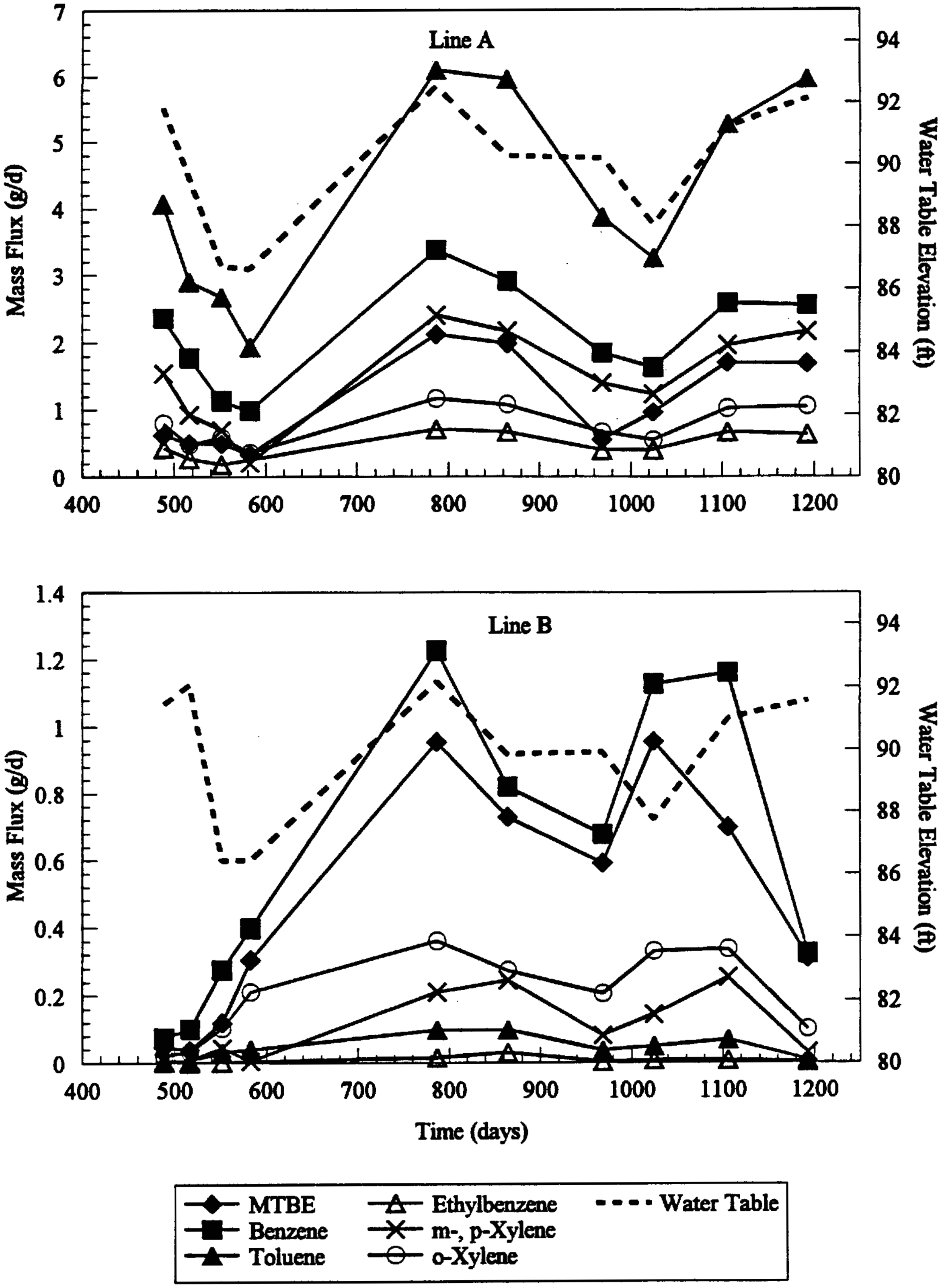


Figure 5-2. MTBE, Benzene, Toluene, Ethylbenzene, m-, p-Xylene, and o-Xylene Mass Flux Versus Time at Lines A and B (Julian day 0 = 1/1/92).

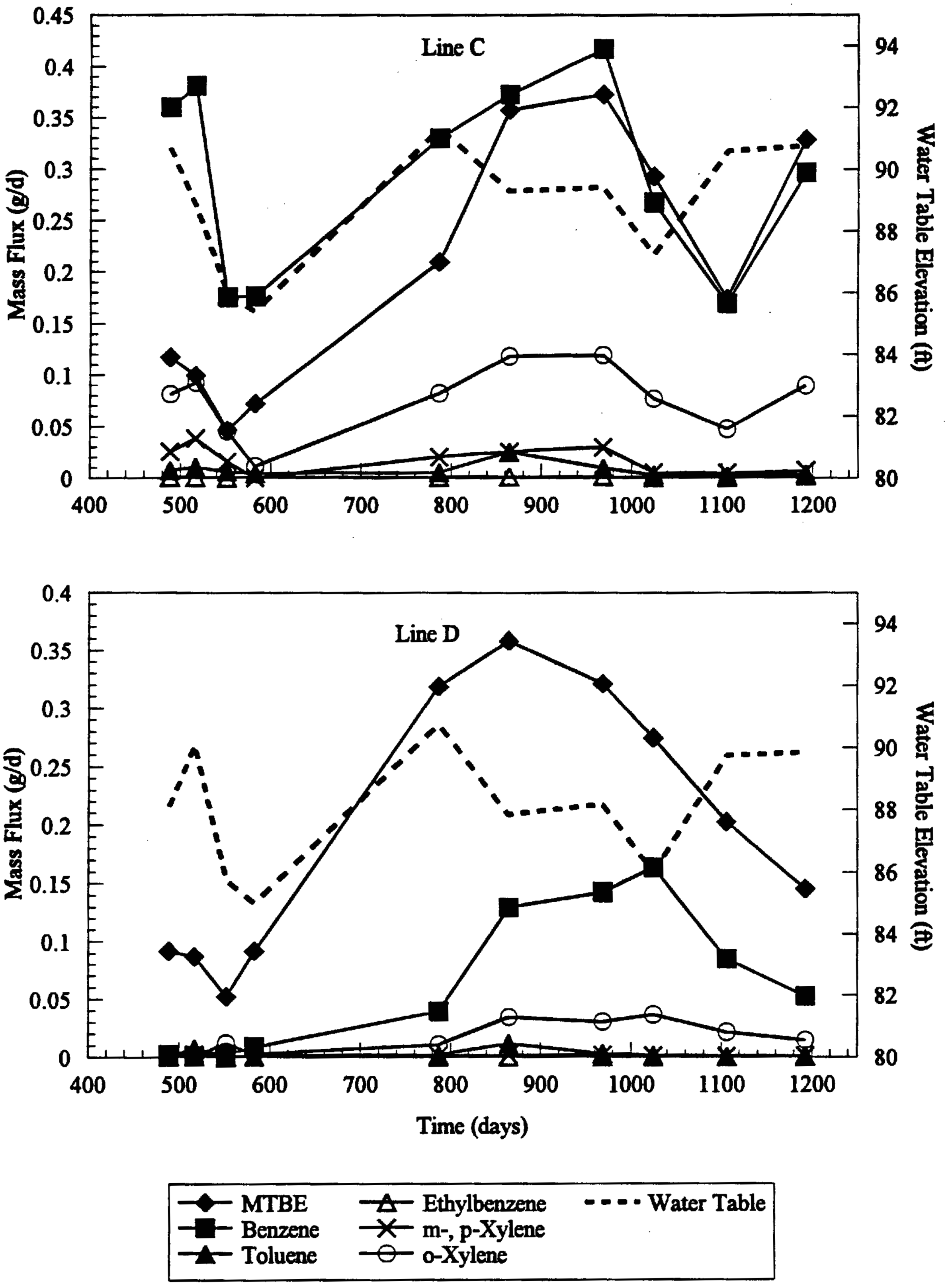


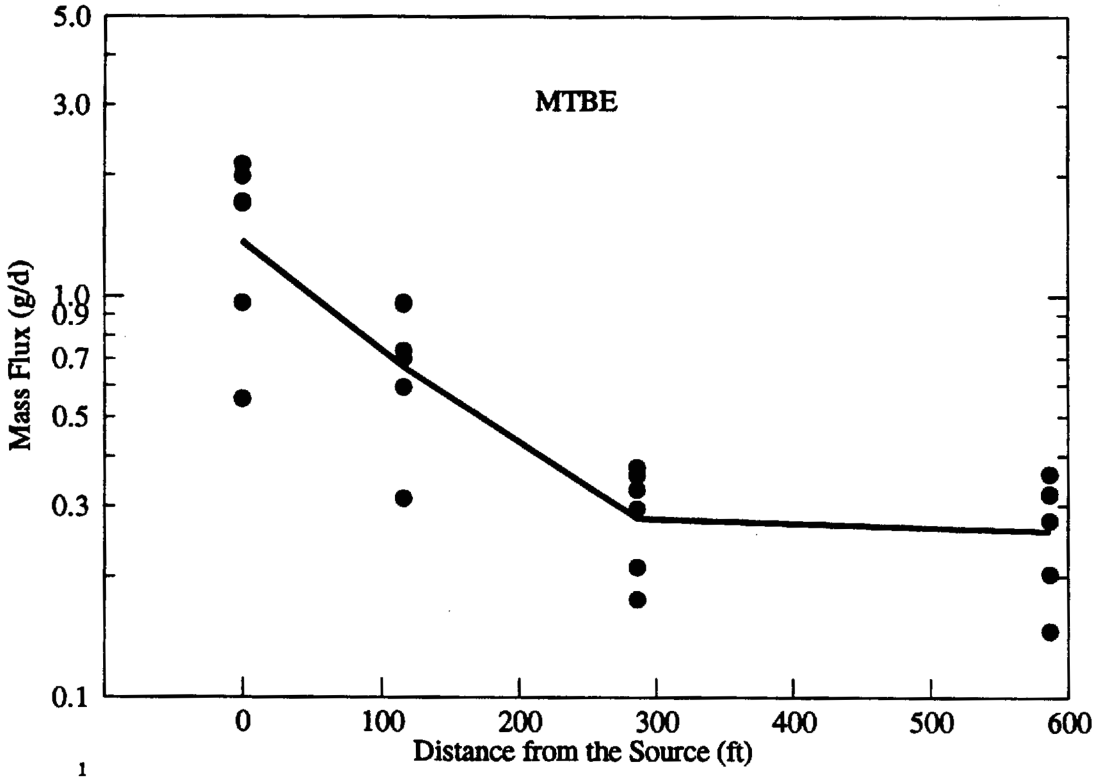
Figure 5-3. MTBE, Benzene, Toluene, Ethylbenzene, m-, p-Xylene, and o-Xylene Mass Flux Versus Time at Lines C and D (Julian day 0 = 1/1/92).

At the downgradient line of wells (D), changes in water table position did not significantly influence the calculated mass flux because the water table fluctuations were smaller and because the most contaminated zone is several meters below the water table surface. Consequently, the total BTEX mass flux did not correlate with changes in water table elevation ($r^2 = 0.004$). However, at this location, we did see an initial increase in contaminant concentrations and associated mass fluxes over time. When these wells were installed in the Spring of 1993 (~ day 450), line D was positioned downgradient of the leading edge of the BTEX plume but within the MTBE plume. Shortly after the start of monitoring, MTBE and BTEX mass fluxes at line D began to rise. After day 780, the benzene, o-xylene, and MTBE mass fluxes stabilized or declined somewhat. Toluene and m-, p-xylene temporarily broke through in line D and then declined back to the detection limit (1 µg/L). This temporary breakthrough may have been due to a slow increase in the number of bacteria capable of toluene and m-, p-xylene biodegradation under denitrifying conditions. In microcosm studies at a nearby petroleum-contaminated aquifer, Kao and Borden (in press) found no evidence of TEX biodegradation under denitrifying conditions, suggesting that the number of denitrifiers that can degrade TEX may be low in some aquifers.

Calculation of field-scale first-order decay rates (λ) using mass fluxes requires that the contaminant plume stabilize at a pseudo-steady-state condition. In the following analysis of contaminant decay rates, only results after day 780 were used in the calculations because of the gradual breakthrough of contaminants in line D. The monitoring results show that mass fluxes at line D stabilized or began to decline somewhat by day 780.

5.3. VARIATION IN MTBE AND BTEX MASS FLUX WITH DISTANCE

Figures 5-4 to 5-7 show plots of total mass flux versus distance from the source (line A) for the 1994-95 monitoring period (days 787 to 1193). The ratio of the mass flux at lines B, C, and D to the mass flux at line A (fractional breakthrough) was calculated for each sampling event to correct for the variability due to water table fluctuations. Average values of the fractional breakthrough are shown in Table 5-1. Toluene and ethylbenzene decline rapidly with distance from the source (Figure 5-5) followed by m-, p-xylene; o-xylene (Figure 5-6); benzene; and MTBE (Figure 5-4). Over the 88-m travel distance from line A to C, the average toluene; ethylbenzene; and



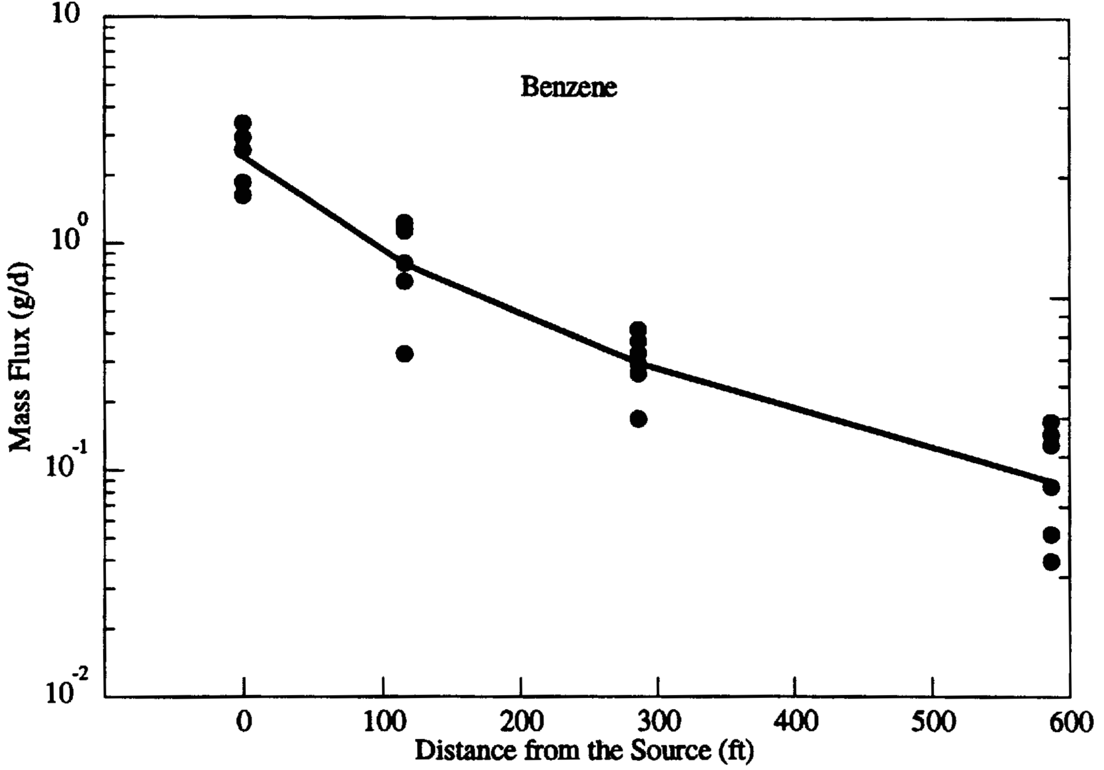


Figure 5-4. MTBE and Benzene Mass Flux Versus Distance from the Source (Line A) for 1994–95.

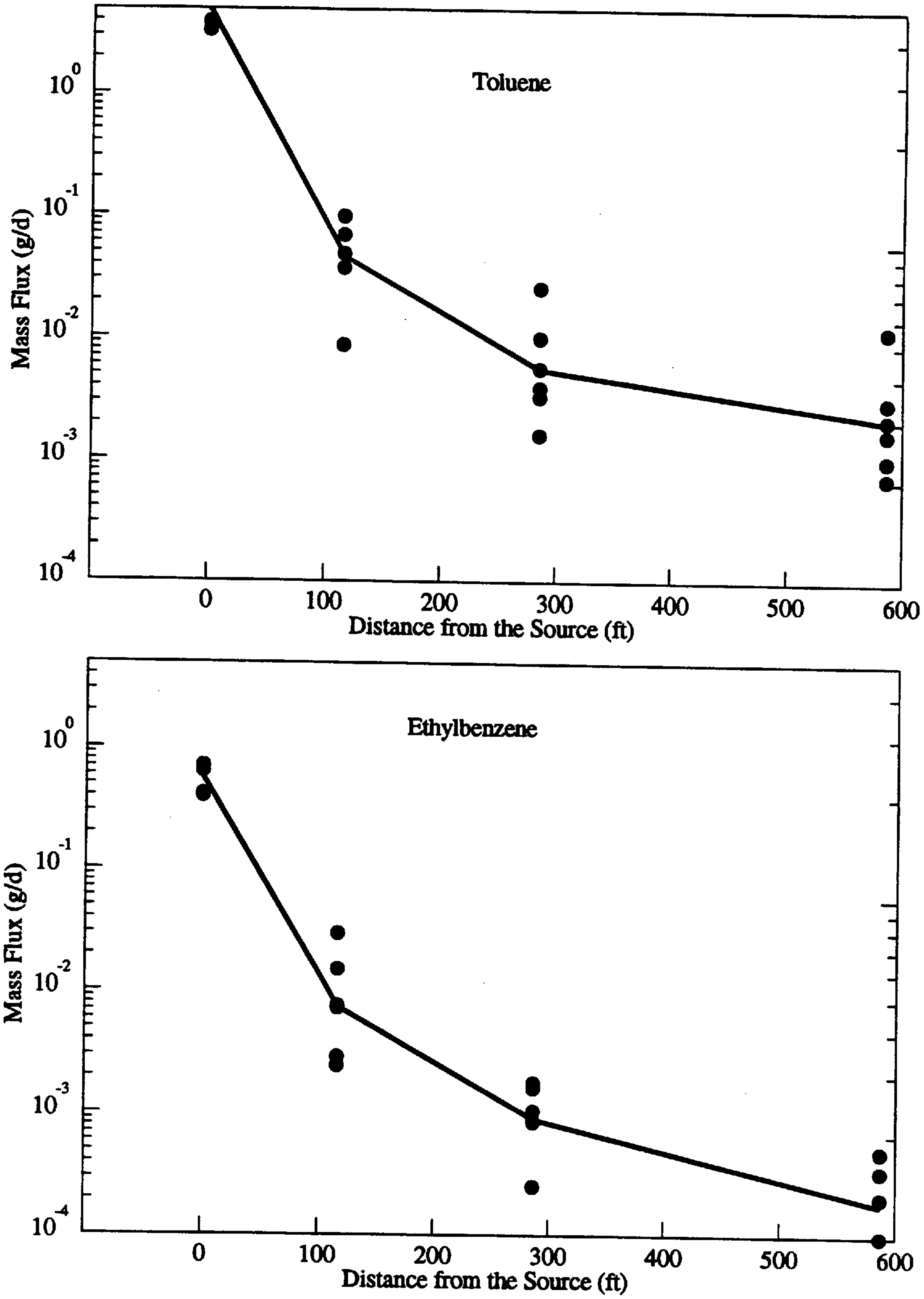


Figure 5-5. Toluene and Ethylbenzene Mass Flux Versus Distance from the Source (Line A) for 1994–95.

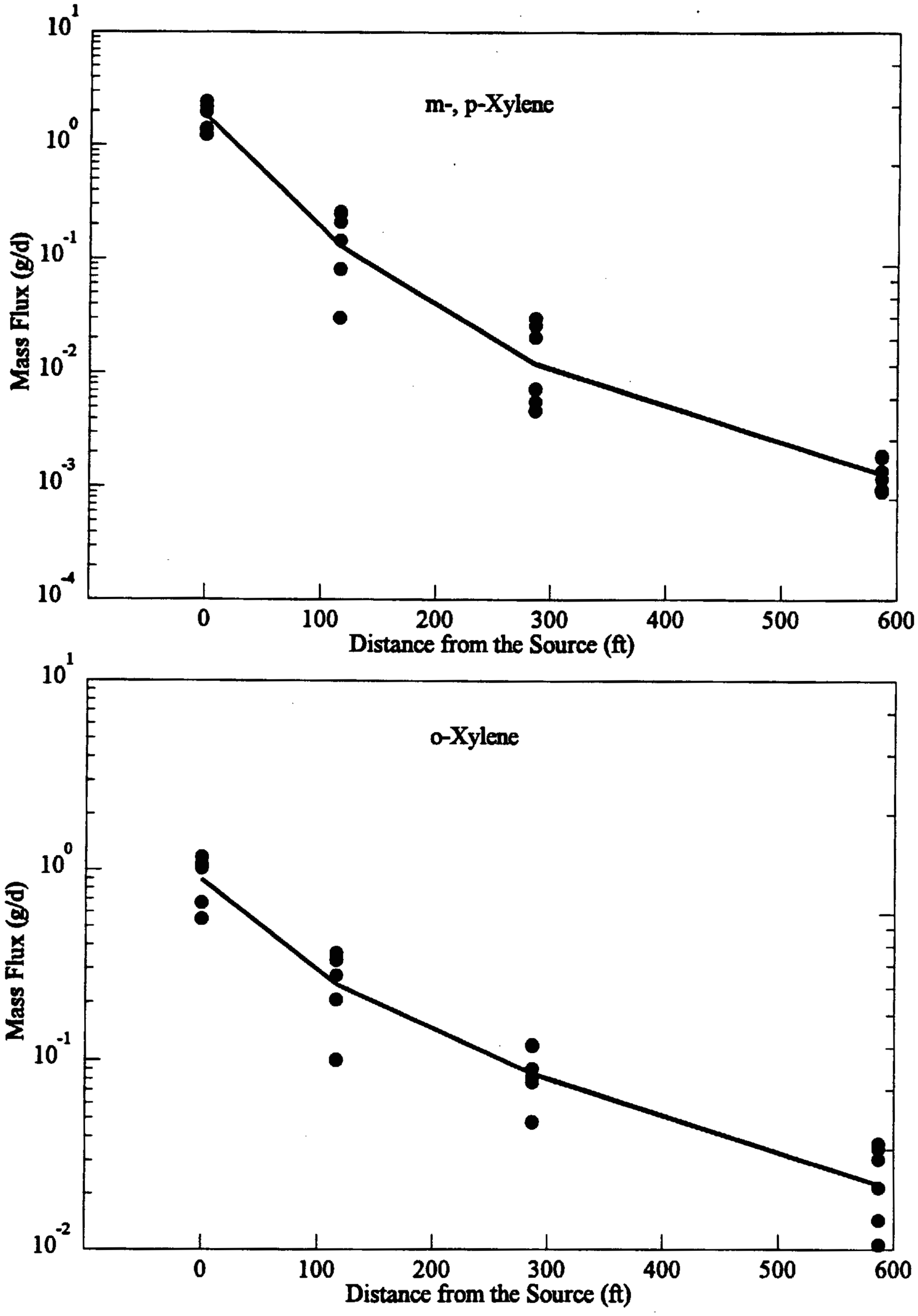


Figure 5-6. m-, p-Xylene and o-Xylene Mass Flux Versus Distance from the Source (Line A) for 1994–95.

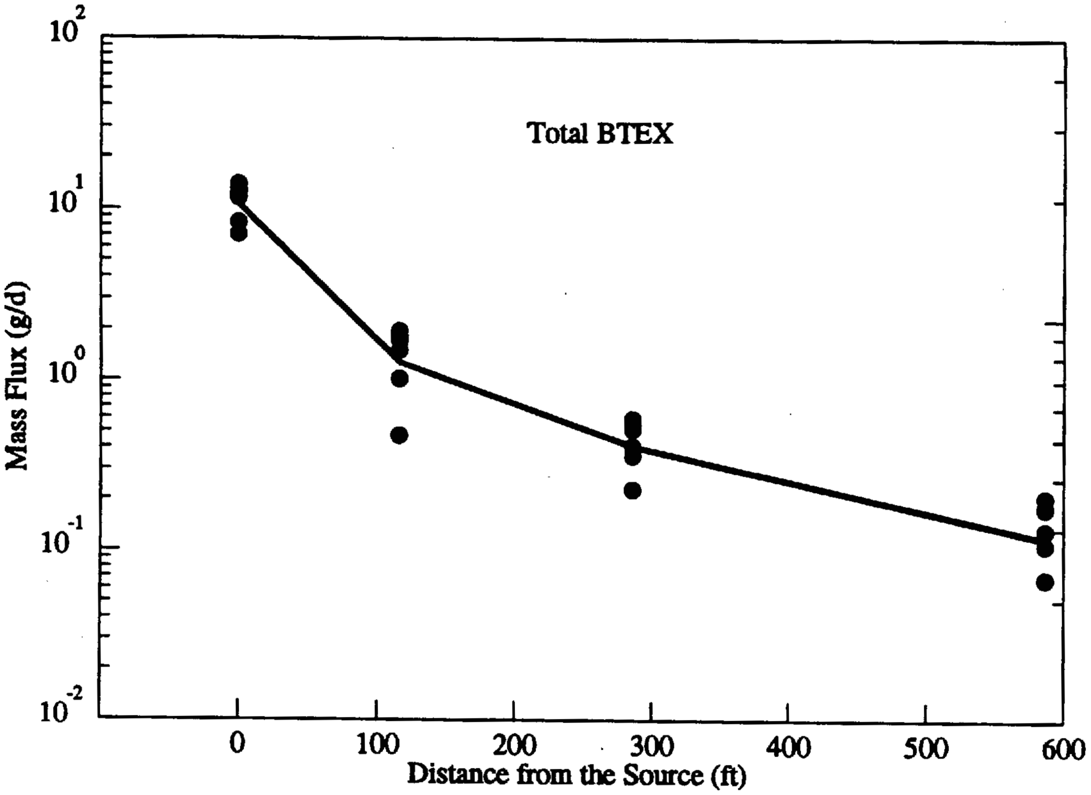


Figure 5-7. Total BTEX Mass Flux Versus Distance from the Source (Line A) for 1994–95.

Table 5-1. Fraction of Mass Flux at Line A.

Compound	----------	Line B	----------	----------	Line C	----------	----------	Line D	---------
	Mean	CV[a]	Alpha[b]	Mean	CV	Alpha	Mean	CV	Alpha
MTBE	0.580	0.62	0.2	0.259	0.83	0.02	0.183	0.78	0.01
Benzene	0.381	0.50	0.03	0.133	0.42	0.0009	0.035	0.72	0.0002
Toluene	0.012	0.48	0.00001	0.002	0.94	$<10^{-5}$	0.001	1.04	$<10^{-5}$
Ethylbenzene	0.017	0.83	0.00004	0.002	0.64	$<10^{-5}$	0.000	0.61	$<10^{-5}$
m-, p-Xylene	0.087	0.51	0.0004	0.009	0.83	0.00001	0.001	0.44	$<10^{-5}$
o-Xylene	0.317	0.52	0.01	0.105	0.46	0.0006	0.031	0.69	0.00009
BTEX	0.135	0.48	0.001	0.042	0.42	0.00006	0.014	0.70	0.00002

[a] CV = coefficient of variation.

[b] Alpha = probability that the mean is equal to 1.0.

m-, p-xylene mass fluxes decline by over 99%, while the average o-xylene, benzene, and MTBE mass fluxes decrease by 89%, 87%, and 74%, respectively. The declines in all BTEX components from line A to C were significant at the 99% level (alpha $\leq$ 0.01), while the MTBE decline was significant at the 95% level (alpha $\leq$ 0.05).

The effective first-order decay rate for each sampling event was obtained from the slope of the natural logarithm of total mass flux on the sampling date versus the average travel time from the source. Travel time was calculated using the non-reactive transport velocity, since under steady-state conditions there should be no exchange with the solid phase. The average decay rate and 95% confidence limits are reported for each compound in Table 5-2. Effective first-order decay rates between lines A and B differed from zero for all compounds (alpha < 0.05). Near the source, decay rates are highest for toluene and ethylbenzene and lowest for o-xylene, benzene, and MTBE. Downgradient, the mass decay rates for all compounds declined. The decline in the toluene and ethylbenzene decay rates is at least partially due to the complete removal of these compounds; toluene and ethylbenzene were often close to the analytical detection limit at lines C and D. However, significant concentrations of o-xylene, benzene, and MTBE remain (peak conc. > 100 µg/L for each compound), and the decline in the mass decay rate is not a calculation artifact.

Table 5-2. Effective First-Order Decay Rates from Mass Flux Analysis.[a,b,c]

	----- A to B -----		----- B to C -----		----- C to D -----	
MTBE	0.0010*	±0.0007	0.0008*	±0.0004	Not Significant	
Benzene	0.0014**	±0.0006	0.0009*	±0.0005	0.0006**	±0.0003
Toluene	0.0063**	±0.0010	0.0020**	±0.0009	0.0005**	±0.0001
Ethylbenzene	0.0058**	±0.0009	0.0019*	±0.0010	0.0008**	±0.0003
m-, p-Xylene	0.0035**	±0.0009	0.0022**	±0.0008	0.0012**	±0.0002
o-Xylene	0.0017**	±0.0006	0.0010*	±0.0005	0.0007**	±0.0002
BTEX	0.0029**	±0.0007	0.0010*	0.0005	0.0007**	±0.0003

[a] Davidian and Gupta, 1991; Gumpertz and Pantula, 1989.

[b] Values are average rate ± 95% confidence limits.

[c] One asterisk (*) indicates the value significantly differs from zero at the 95% level; two asterisks (**) indicate the value significantly differs from zero at the 99% level.

5.4. DISCUSSION OF MASS FLUX RESULTS

A mass flux approach was used to calculate field-scale first-order decay rates. Use of this approach eliminates the effects of non-ideal well placement and transverse dispersion on calculated decay rates. The field monitoring data indicate that the plume upgradient of line D has stabilized. Contaminant concentrations in monitoring wells appear to have reached their maximum values and have stabilized or begun to decline somewhat.

The mass flux analysis indicated that MTBE was being degraded between lines A and C. This result was somewhat surprising since previous laboratory studies have shown MTBE to be recalcitrant under aerobic (Barker *et al.*, 1990) and denitrifying conditions (Mormile *et al.*, 1994; Yeh and Novak, 1994). However, the aerobic laboratory microcosms conducted in a companion project (Borden *et al.*, accepted) showed a similar pattern of biodegradation as compared to the field data. In microcosms constructed with aquifer material from near the source (Core X), MTBE biodegraded from an initial concentration of 2.1 mg/L to between 1.0 and 1.5 mg/L and then remained constant. In the field, the peak MTBE concentration declined from 10 ± 4.6 mg/L (± 1 std. dev.) at line A to 0.3 ± 0.4 mg/L at line C. Downgradient of line C, there was little or no decline in the MTBE mass flux. In microcosms constructed with aquifer material from further downgradient (Core Z), there was no evidence of MTBE biodegradation. In shallow wells at the Core Z location (between lines B and C), the MTBE concentration was consistently less than 1.0 mg/L. At this time, the factors controlling MTBE biodegradation in the laboratory and field are unknown.

The mass flux results show that all BTEX components are degraded during downgradient transport through the aquifer under ambient conditions. Toluene and ethylbenzene were removed most rapidly in the aquifer followed by m-, p-xylene; o-xylene; and benzene. *In situ* decay rates were highest near the source and declined with distance downgradient. The higher decay rates near the source for o-xylene and benzene are not a calculation artifact, but may be due to greater microbial biomass, oxygen, and/or substrate supply near the source. The observed spatial variability in decay rates has significant practical consequences. If a solute transport and first-order decay model were calibrated to the source area data, the model would overestimate the extent of contaminant biodegradation and underestimate the risk to downgradient receptors.

Decay rates calculated using the mass flux approach at this site are comparable to previous reports. Reported field decay rates for benzene vary from 0 to 0.06 d^{-1} with an average of 0.006 d^{-1} (s.d. = 0.015) (Rifai *et al.*, 1995). At this site, the benzene decay rates varied from 0.0014 d^{-1} between lines A and B to 0.0006 d^{-1} between lines C and D, which is well within the reported range.

The laboratory microcosms (Borden *et al.*, accepted) also showed very rapid biodegradation of all BTEX components under aerobic conditions. The complete absence of benzene biodegradation in the denitrifying microcosms is consistent with previous work (Zeyer *et al.*, 1986; Kuhn *et al.*, 1988; Hutchins, 1991b; Hutchins *et al.*, 1991b; Barbaro *et al.*, 1992; Kao and Borden, in press) and suggests that the observed loss of benzene in the aquifer is due to aerobic biodegradation only. In the contaminated portion of the aquifer, DO concentrations are below the field detection limit (0.5 mg/L), and mass transfer of oxygen into the contaminant plume limits aerobic biodegradation. The lower decay rate for benzene in the downgradient aquifer is likely due to the flatter concentration gradients and slower oxygen transfer rate into the contaminated interval.

In the denitrifying laboratory microcosms (Borden *et al.*, accepted), TEX biodegradation was much slower and more limited than in previous reports. Toluene, m-xylene, and o-xylene biodegraded in the Core X denitrifying microcosms; while only toluene degraded in the Core Z denitrifying microcosms. First-order biodegradation rates in the Core X microcosms were 0.042 d^{-1} for toluene, 0.030 d^{-1} for m-xylene, and 0.006 d^{-1} for o-xylene. The low biodegradation rates under denitrifying conditions may have been due to the low pH (mean = 4.3) in this aquifer. Denitrification rates are usually optimal at a pH between 7 and 9 and may drop off rapidly below pH 6 (Delwiche and Bryan, 1976). The limited biodegradation in the Core Z microcosms may have been due to lack of prior exposure to the contaminants. The cores were collected from 0.3 to 1.0 m below the water table. At the Core Z location, the BTEX plume had already dropped below this interval because of surface recharge of oxygenated water.

The absence of ethylbenzene biodegradation in the denitrifying microcosms was surprising. Previous researchers have found ethylbenzene to be readily biodegradable under denitrifying conditions (Zeyer *et al.*, 1986; Kuhn *et al.*, 1988; Hutchins 1991b; Hutchins *et al.*, 1991b; Barbaro *et al.*, 1992). In a previous study at this site, both toluene and ethylbenzene were biodegraded after a 60-day lag period in aquifer material from a core hole 12 m west of Core X (Kao, unpublished data, 1993). The absence of ethylbenzene biodegradation in the Core X microcosms could also be due to the absence of prior exposure to this compound. In the field, ethylbenzene biodegrades very rapidly and is close to the detection limit before the plume reaches line B. Ethylbenzene may have been completely degraded before it reached the Core X location.

The relative order of compound decay was identical in the laboratory microcosms (Borden *et al.*, accepted) and field. However the field decay rates were often much lower than the laboratory biodegradation rates under denitrifying conditions, even though excess nitrate was present throughout the aquifer. This variability may be due to differences in the calculation procedure. In the laboratory, monitoring data are collected weekly or monthly and rapid biodegradation rates can be measured. In the field, the travel time from line A to B is 2.4 years. If most of a compound decays in less than 2 years, there is no way to estimate the actual rate of decay.

Chapter 6

MODELING STUDIES

Several different modeling approaches were evaluated to determine their suitability for simulating the intrinsic bioremediation of MTBE and BTEX at the Sampson County site. Intrinsic bioremediation of MTBE was simulated using two approaches.

1. BIOPLUME II was used to simulate MTBE transport and biodegradation with a constant first-order decay rate. Oxygen-limited instantaneous biodegradation was not included because of the slow rate of MTBE biodegradation.
2. The three dimensional (3-D) analytical solution of Dominico (1987) was used to simulate MTBE transport and biodegradation with a constant first-order decay rate.

Intrinsic bioremediation of BTEX was simulated using three different approaches.

1. BIOPLUME II was used to simulate total BTEX transport and biodegradation with instantaneous oxygen-limited biodegradation and a constant first-order decay rate to simulate anaerobic biodegradation and reaeration.
2. The 3-D analytical solution of Dominico (1987) was used to simulate total BTEX transport and biodegradation with a constant first-order decay rate.
3. The 3-D analytical solution of Dominico (1987) was used to simulate the transport and biodegradation of individual BTEX components. Each component was allowed to have a different decay rate. Total BTEX degradation was calculated as the sum of all components.

6.1. MODEL DESCRIPTIONS

BIOPLUME II (Rifai *et al.*, 1987) was developed based on the Method of Characteristics Solute Transport model (Konikow and Bredehoeft, 1978) and was modified to simulate the biodegradation of a single contaminant by two mechanisms: (1) an instantaneous reaction between oxygen and the contaminant according to a constant stochiometric ratio; and (2) first-order decay of the contaminant due to reaeration, anaerobic degradation, and/or slow aerobic biodegradation. In the current version of BIOPLUME II, there is a computational error that causes the computed decay rate to be equal to one half of the value entered in BIOPLUME II input. Decay rates listed in this report have been corrected for this error. In BIOPLUME II, a uniform two-dimensional grid represents the aquifer. In most cases, the model is run in a plan view and variations in contaminant concentrations in the vertical direction are not considered.

The 3-D analytical solution of Domenico (1987) simulates solute transport due to advection and dispersion. Biodegradation is simulated using a constant first-order decay rate. Advective transport is in the x direction only. Diffusive transport occurs in the x, y, and z directions. For any longitudinal, transverse, and vertical distance (x, y, and z location) from the source, the model predicts a concentration for any time, t, after the release using Equation 6-1.

$$
\begin{aligned}
C(x,y,z,t) = {} & \left(\frac{Co}{8}\right)\exp\left\{\left(\frac{x}{2\alpha_x}\right)\left[1-\left(1+\frac{4\lambda\alpha_x}{v}\right)^{1/2}\right]\right\} \\
& erfc\left[\frac{x-vt\left(1+4\lambda\alpha_x/v\right)^{1/2}}{2\left(\alpha_x vt\right)^{1/2}}\right] \\
& \left\{erf\left[\frac{(y+Y/2)}{2\left(\alpha_y x\right)^{1/2}}\right]-erf\left[\frac{(y-Y/2)}{2\left(\alpha_y x\right)^{1/2}}\right]\right\} \\
& \left\{erf\left[\frac{(z+Z)}{2\left(\alpha_z x\right)^{1/2}}\right]-erf\left[\frac{(z-Z)}{2\left(\alpha_z x\right)^{1/2}}\right]\right\}
\end{aligned}
$$

(Equation 6-1)

The source has a uniform concentration Co and a finite planar area defined by the transverse distance Y and the vertical distance Z oriented perpendicular to groundwater flow. The longitudinal, transverse, and vertical dispersivities are α_x, α_y, and α_z, respectively. The parameter v is the velocity of a non-reactive contaminant. Linear-instantaneous sorption can be included by dividing v by the retardation factor R. Decay is represented by the first-order decay rate constant λ that has dimensions of the inverse of time. While any unit can be specified for the parameter Co, the remaining parameters must use a consistent set of units.

6.2. SIMULATION OF MTBE TRANSPORT AND BIODEGRADATION

6.2.1. BIOPLUME II Results

BIOPLUME II was run in a plan view mode with a constant contaminant source strength and steady-state hydraulics (storativity = 0). A 20-by-30 array of 25-ft by 30-ft cells (Figure 6-1) with uniform hydraulic conductivity and saturated thickness represented the aquifer. Aquifer parameters were developed from the site characterization results and are described in Section 1.0 of Appendix C (Borden *et al.*, 1997). Because BIOPLUME II was run in plan mode with steady-state hydraulics, some manipulation of the field data was required for comparison. Water table elevations and contaminant concentrations for the period from February 1994 to April 1995 were used to generate time-average values. The values from each well cluster were then averaged with depth to generate values for comparison with the BIOPLUME II results. The accuracy of the calibration was evaluated based on the average absolute error between simulated and observed values for all wells and visual inspection of the results.

The observed hydraulic gradient and plume curvature were simulated using constant head cells located along the top and bottom of the grid. Simulated and observed water table elevations are compared in Section 3.0 of Appendix C (Borden *et al.*, 1997). The longitudinal dispersivity (α_L) and transverse dispersivity (α_T) were obtained by calibrating the model to the observed chloride plume assuming no sorption or decay. For chloride, the best fit values of transverse and longitudinal dispersivities were 10 ft and 40 ft, respectively ($\alpha_T = 10$ ft and $\alpha_L = 40$ ft). The observed and simulated chloride concentration distributions are compared in Section 3.0 of Appendix C (Borden *et al.*, 1997). The high value of α_T is likely due to two factors: (1) seasonal shifts in the groundwater flow direction cause the plume to spread out more in the transverse direction, and (2) the background chloride concentration used in the model may have been too low. Chloride concentrations in wells that did not appear to be influenced by the NaCl plume varied from 3 to 16 mg/L. However, it was not always obvious which wells were being influenced by the NaCl plume. To be conservative, the model was calibrated using a background chloride concentration of 5 mg/L.

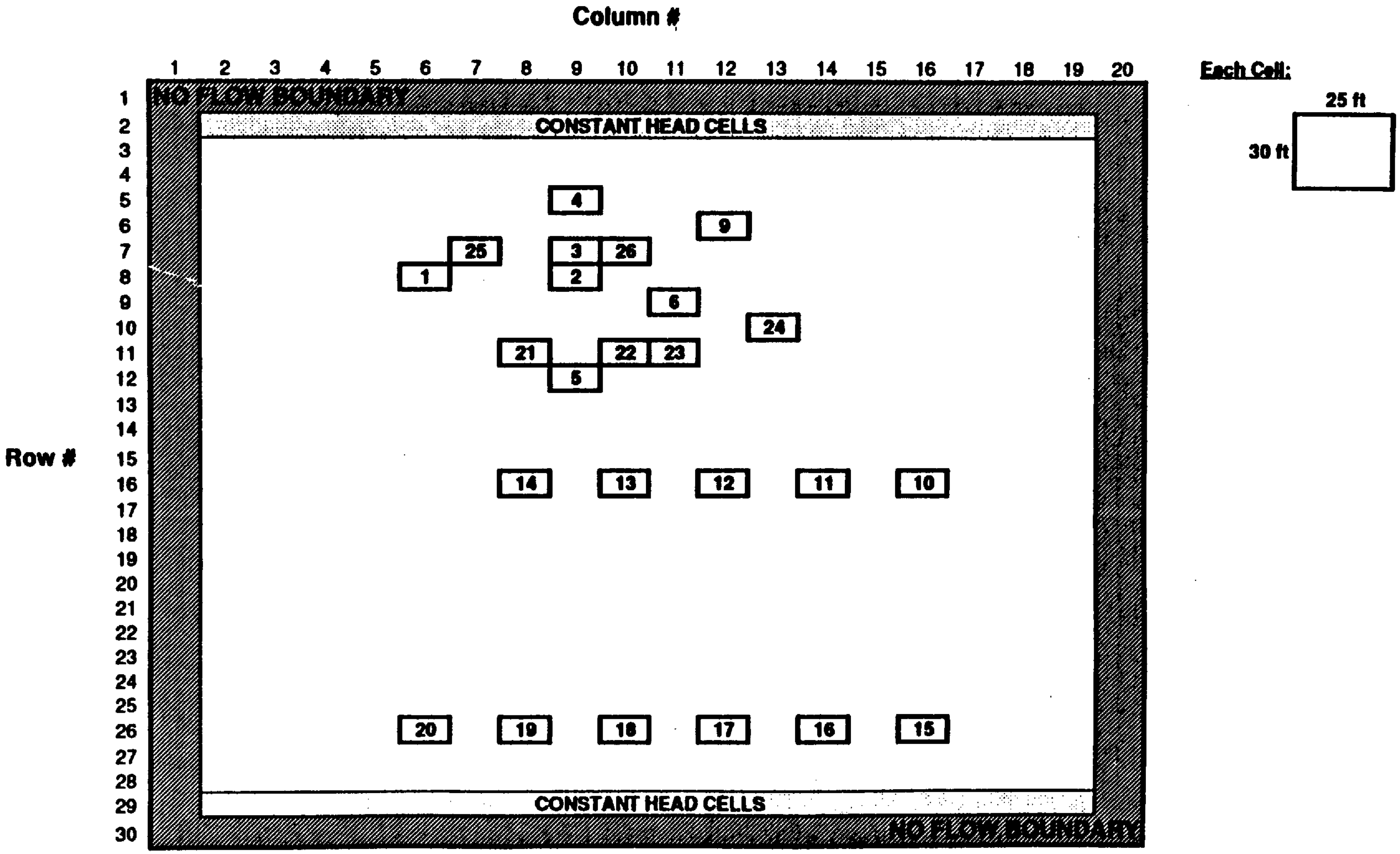


Figure 6-1. Location of Monitoring Wells in the BIOPLUME II Grid.

During the initial calibration of the MTBE plume, it became apparent that the α_T obtained from the chloride plume could not be used to simulate the MTBE. Simulated and observed chloride and MTBE concentrations are compared in Figures 6-2 to 6-5 for α_T values of 5 and 10 ft. The MTBE match could have been somewhat improved using an α_T less than 5 ft. However, α_T was assumed to be equal to 5 ft because of the high transverse dispersivity observed for chloride and the large uncertainty in the MTBE biodegradation rate. The poor match between simulated and observed MTBE concentrations at line D (Figure 6-5) is because of problems with the decay rate calculation, not because of an incorrect value of α_T.

BIOPLUME II was calibrated to the MTBE plume by adjusting the first-order decay rate to produce the best match between simulated and observed concentrations. As previously discussed, MTBE can be expected to biodegrade very slowly or not at all. Consequently, the assumption of an instantaneous reaction between MTBE and oxygen would not be appropriate. Instantaneous biodegradation of MTBE was eliminated by setting the initial and background oxygen concentrations to zero. MTBE degradation was modeled using a constant first-order decay rate.

BIOPLUME II was calibrated to the MTBE plume by adjusting the first-order decay rate to minimize the average absolute error between simulated and observed concentrations (Section 3.0 of Appendix C in Borden *et al.*, 1997). Using BIOPLUME II, the best fit first-order decay for MTBE was 0.0008 d^{-1}. The simulated and observed centerline concentrations of MTBE are shown on Figure 6-6. These results indicate MTBE transport and biodegradation cannot be accurately simulated using a constant first-order decay rate for the whole site. While BIOPLUME II was able to reasonably match the MTBE concentration at line C, the model overestimated concentrations at line B and underestimated concentrations at line D.

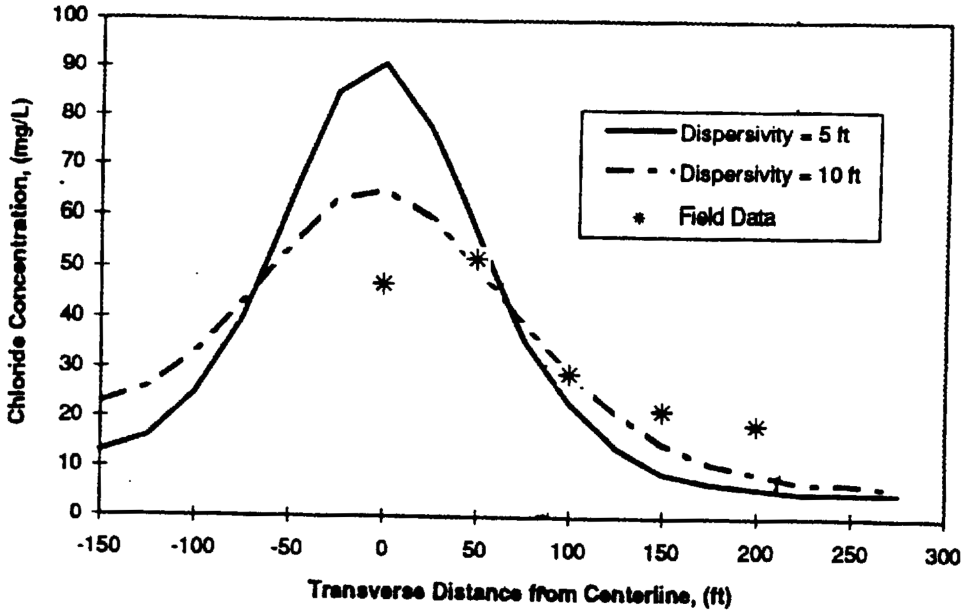


Figure 6-2. Calibration of Transverse Dispersivity with Chloride in BIOPLUME II for Well Line C.

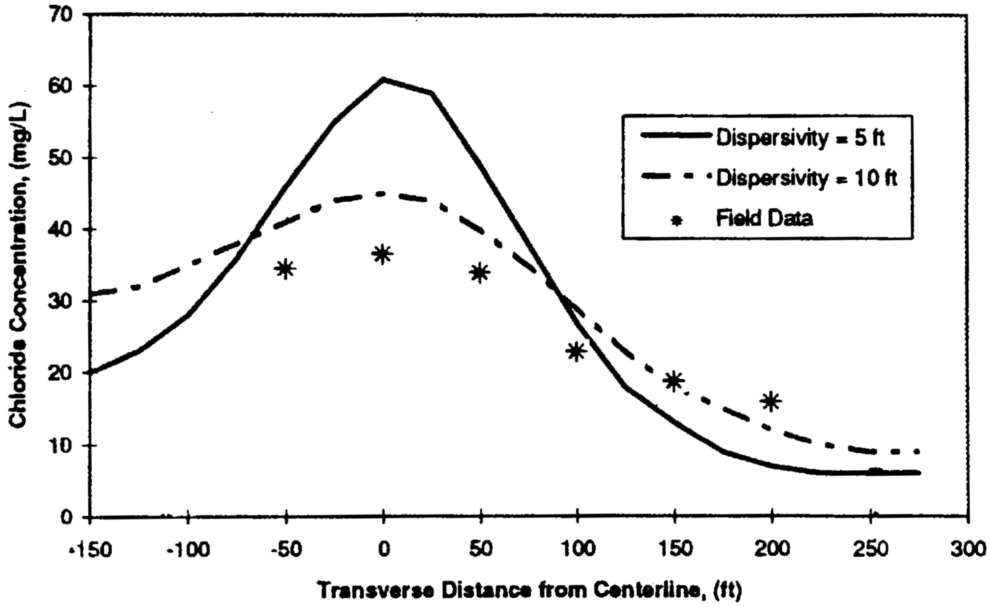


Figure 6-3. Calibration of Transverse Dispersivity with Chloride in BIOPLUME II for Well Line D.

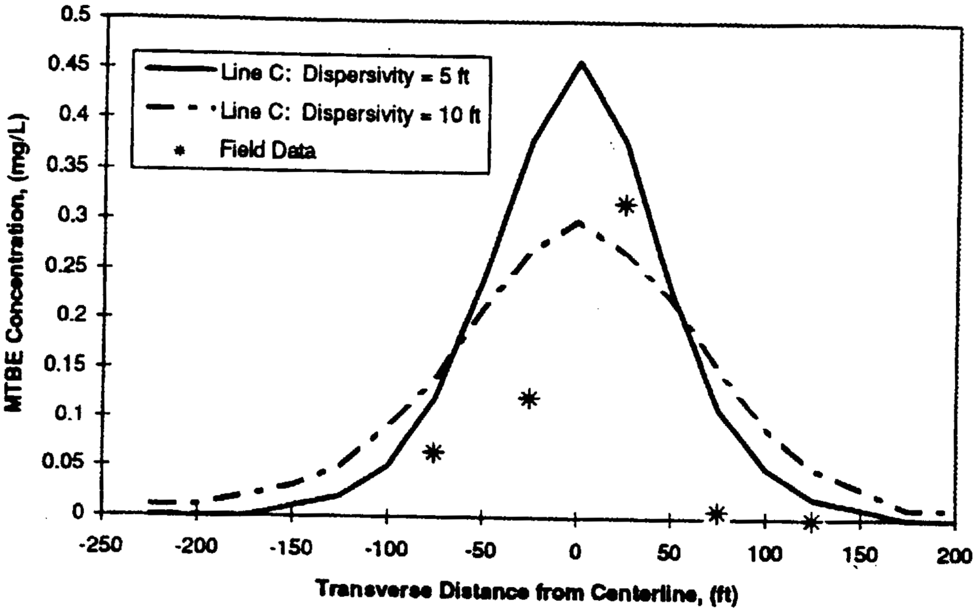


Figure 6-4. Calibration of Transverse Dispersivity with MTBE in BIOPLUME II for Well Line C.

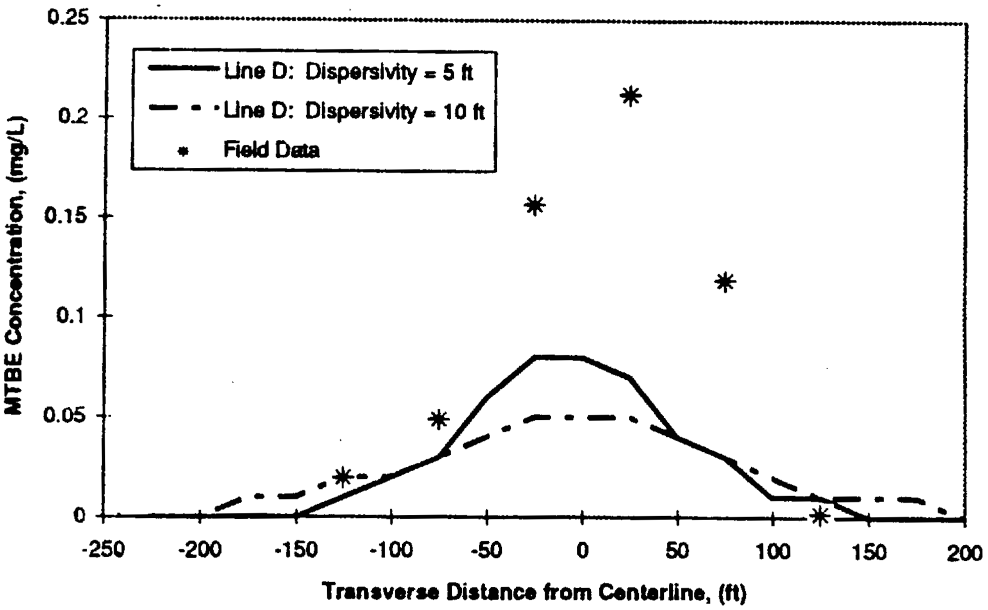


Figure 6-5. Calibration of Transverse Dispersivity with MTBE in BIOPLUME II for Well Line D.

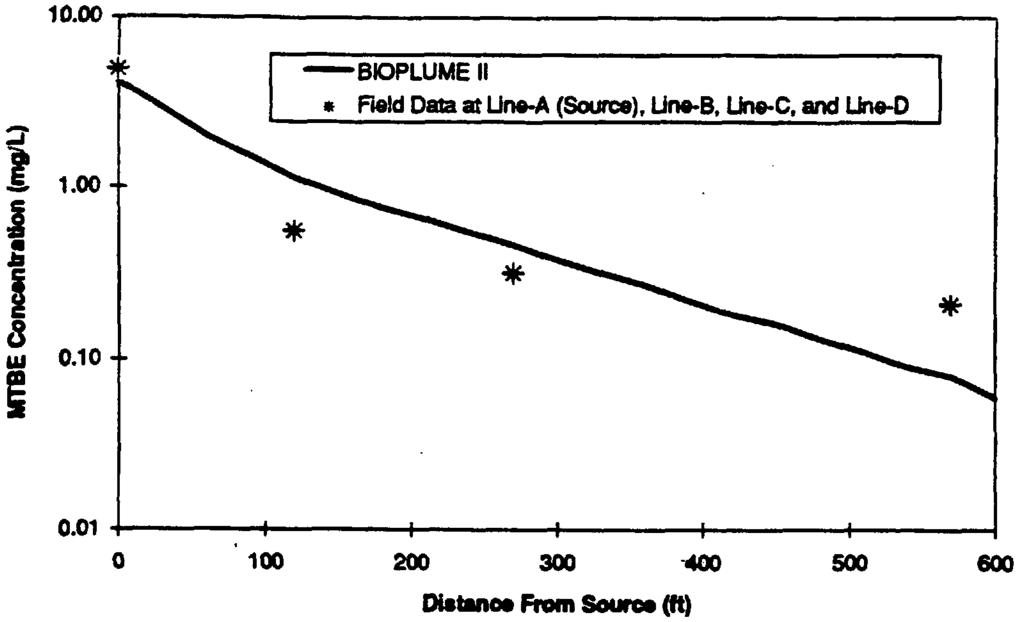


Figure 6-6. Centerline Concentrations of MTBE as Predicted by BIOPLUME II.

6.2.2. 3-D Analytical Solution Results

The 3-D analytical solution (Domenico, 1987) was calibrated using parameters similar to those used in the previous BIOPLUME II simulations. Analytical solution calibration parameters are described in Section 1.0 of Appendix D (Borden *et al*, 1997). Because of curvature of the plume, the longitudinal coordinates used in the analytical solution were calculated as the distance along the plume centerline. Transverse coordinates were taken as the distance from the centerline to each monitoring well. The monitoring well coordinates used in the analytical solution are presented in Section 2 of Appendix D (Borden *et al*, 1997). The model was calibrated by programming Equation 6-1 into a spreadsheet for monitoring wells in lines B, C, and D. Maximum observed concentrations at each monitoring well were compared to maximum concentrations predicted by the model (at $z = 0$). The model was calibrated by using a solver function to minimize the sum of absolute error of modeled values at each line of wells.

As previously discussed, the chloride plume provided a convenient means to estimate the dispersivities. For the chloride plume, the best fit values of the transverse, longitudinal, and vertical dispersivities were 4 ft, 60 ft, and 0.15 ft, respectively ($\alpha_T = 4$ ft, $\alpha_L = 60$ ft, and $\alpha_V = 0.15$ ft). The observed and simulated chloride concentration distributions using the 3-D analytical solution are compared in Section 3.0 of Appendix D (Borden *et al.*, 1997). As was previously observed with BIOPLUME II, no single first-order decay rate produced a reasonable match between simulated and observed MTBE concentrations for the entire site. Therefore, effective first-order decay rates were estimated for each line of wells (line B, line C, and line D) by minimizing the sum of absolute error between the modeled and observed concentrations for that line of wells. These rates represent the average decay rate required to match observed concentrations at a line of wells; they do not represent actual degradation rates at any specific point.

Observed maximum centerline MTBE concentrations are compared to model simulations in Figure 6-7 for the three different first-order decay rates. The average decay rate varied from 0.0017 d^{-1} between the source and line B to 0.0002 d^{-1} between the source and line D (Table 6-1). Using this procedure, the model exactly matches concentrations at one line of wells and either significantly over- or underestimates the concentrations at the other two well lines. Results for each calibration are shown in Section 3.0 of Appendix D (Borden *et al.*, 1997).

Table 6-1. First-Order Decay Rates for MTBE Using the 3-D Analytical Solution by Domenico (1987).

Transport Distance	Effective First-Order Decay Rate for MTBE (d^{-1})
Line A to line B	0.0017
Line A to line C	0.0011
Line A to line D	0.0002
Entire Site	0.0007
Entire Site - BIOPLUME II	0.0008

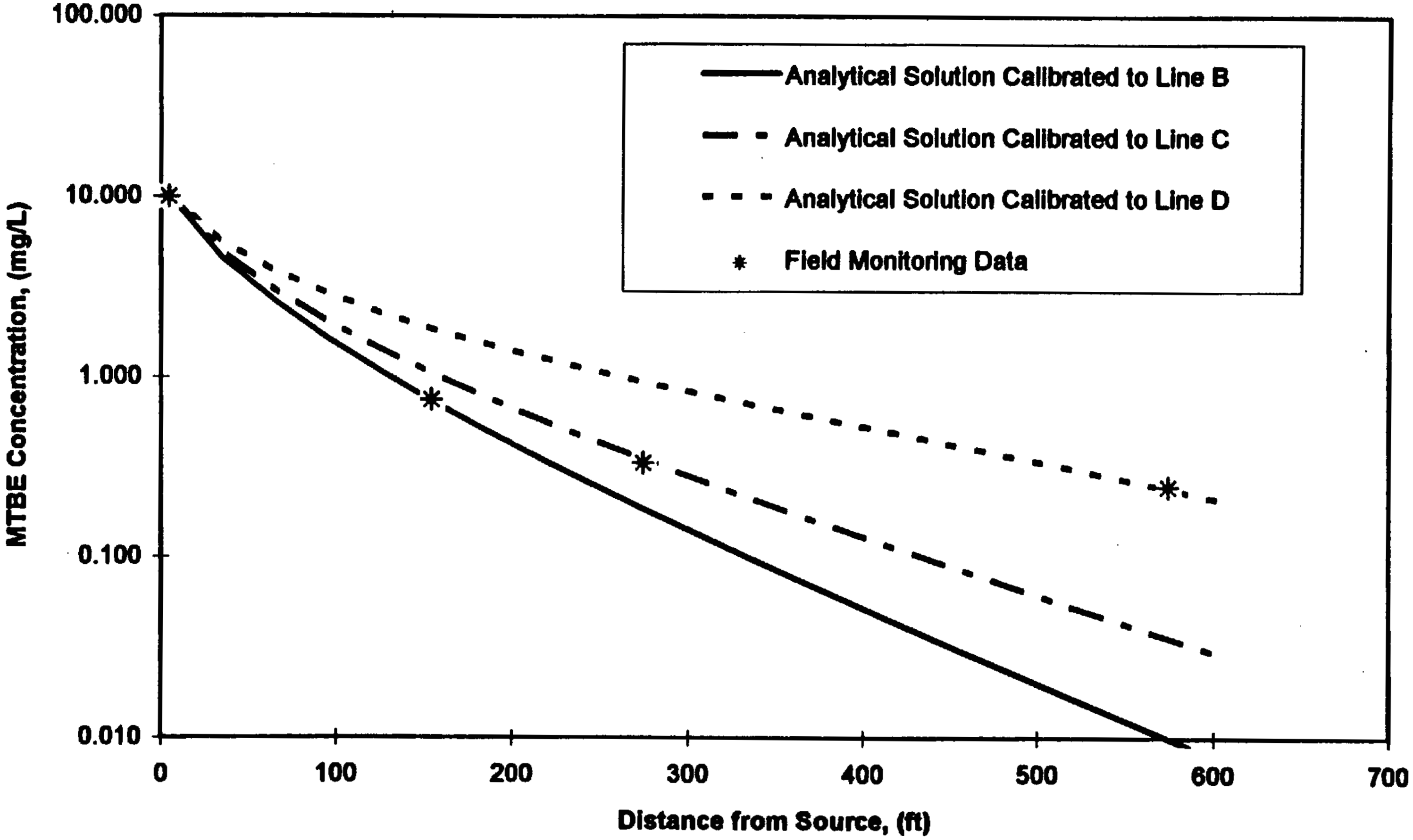


Figure 6-7. Decay Rate Calibration to Each Line of Wells: Centerline Concentrations of MTBE.

6.2.3. Comparison of MTBE Simulation Results Using BIOPLUME II and the 3-D Analytical Solution

Direct comparison of the BIOPLUME II and the 3-D analytical solution results is complicated by differences in the assumed geometry of the plume. BIOPLUME II is a two-dimensional model that does not consider vertical variations with depth. In contrast, the 3-D analytical solution simulates vertical variations in concentration with depth. To allow a direct comparison between the two models, the analytical model with the overall site decay rate was used to predict contaminant concentrations in 1-ft vertical intervals. These concentrations were then averaged over the 15-ft saturated thickness for direct comparison with BIOPLUME.

Results from BIOPLUME II and the depth-averaged analytical solution results are compared with field monitoring results in Figure 6-8. Both models generated very similar results. This is to be expected since the best fit value of the first-order decay rate was very similar for the two models (0.0008 d^{-1} for BIOPLUME II, 0.0007 d^{-1} for the analytical solution). Since both models use a constant first-order decay rate, they both overestimated the MTBE concentration at line B and underestimated the concentration at line D. Results from both BIOPLUME II and the analytical solution demonstrate that decay of MTBE can not accurately simulated using a constant first-order rate for the entire site. Neither model showed a superior ability to predict MTBE concentrations at the site.

6.3. SIMULATION OF BTEX TRANSPORT AND BIODEGRADATION

6.3.1. BIOPLUME II Results for Total BTEX

In this project, we have chosen not to use BIOPLUME II to simulate the degradation of individual BTEX components. In an aquifer, the presence of one contaminant (e.g., benzene) will influence the degradation rate of other contaminants (e.g., toluene, ethylbenzene, xylenes, and other biodegradable organics) by reducing the amount of oxygen available for aerobic biodegradation. If BIOPLUME II is used to simulate total BTEX, the model should be able to crudely represent this interaction. However, if BIOPLUME II is used to model a single component, the amount of oxygen available for biodegradation will be greater than what actually

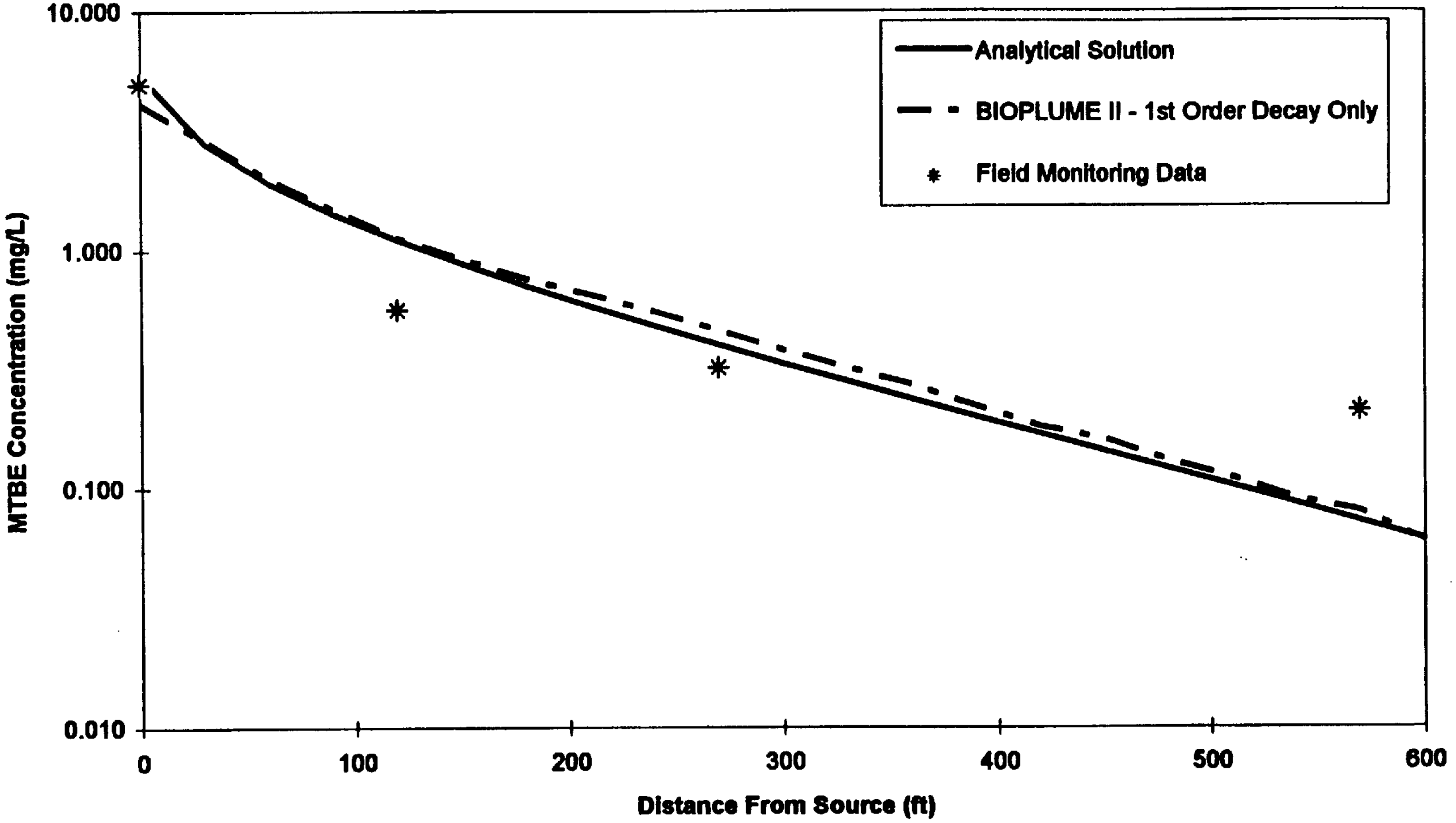


Figure 6-8. Model Comparison with Depth-Averaged Centerline Concentrations of MTBE.

occurs in the aquifer, and the predicted biodegradation rate should be too high. This problem can be eliminated by setting the background DO concentration to zero and modeling degradation using the first-order decay function only. However, this approach should generate results that are very similar to the analytical solution, since the mathematical representation of biodegradation in BIOPLUME II and the analytical solution would be the same. In the previous section, it was demonstrated that predicted MTBE concentrations were very similar using BIOPLUME II and the 3-D analytical solution when similar first-order decay rates were used.

BIOPLUME II was calibrated to simulate total BTEX following the same procedures used for MTBE. All calibration parameters were the same except the background DO concentration (7 mg/L) and first-order decay rate for total BTEX (0.0025 d^{-1}). Observed total BTEX concentrations are compared to BIOPLUME II simulation results in Figure 6-9. BIOPLUME II provided a reasonable match to the measured concentrations in lines B and C but could not accurately simulate the total BTEX concentrations in line D. Several different factors combined to cause the poor match between the observed concentrations and the BIOPLUME II simulation.

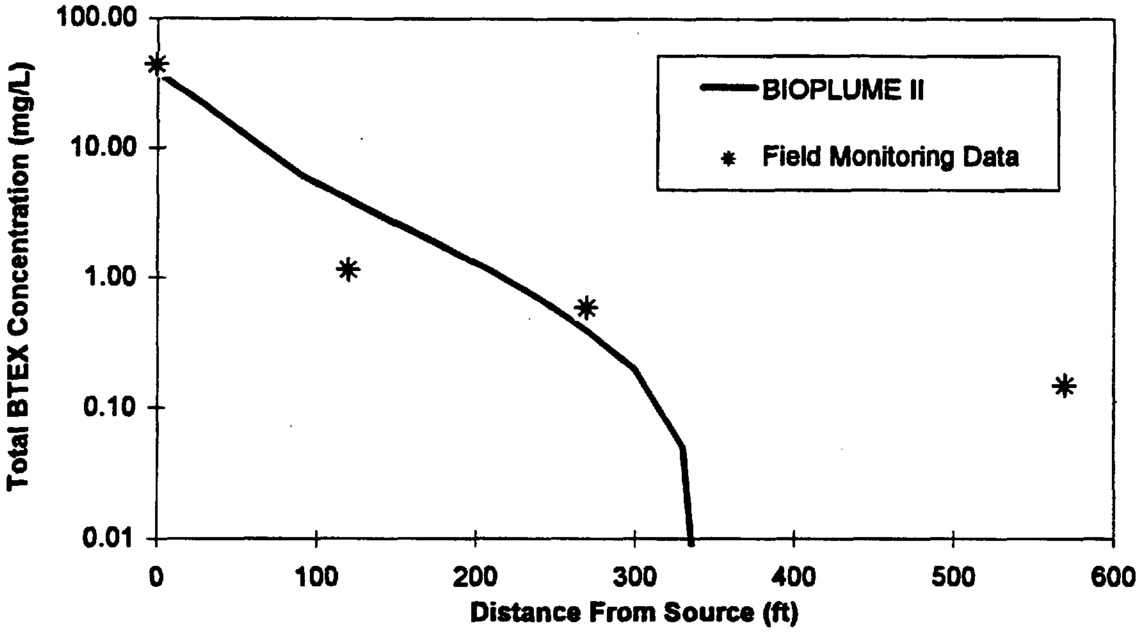


Figure 6-9. Centerline Concentrations of Total BTEX as Predicted by BIOPLUME II.

BIOPLUME II cannot simulate vertical variations in DO or contaminant concentration. However, the field data from the Sampson County site showed a distinct vertical stratification in total BTEX and oxygen (Figures 4-4 and 4-8 to 4-12). Oxygen concentrations were largest where the BTEX concentrations were smallest. Since BIOPLUME II can not account for the vertical separation of aerobic and anaerobic zones, oxygen and BTEX are mixed within a cell, resulting in complete biodegradation of the BTEX.

One approach to overcoming the vertical mixing problem would be to calibrate BIOPLUME II to simulate the highest contaminant concentrations at a location (not vertical averages). This approach could reduce the errors generated by BIOPLUME II but not totally eliminate them, since the first-order decay rate would have to be increased somewhat to account for the decline in BTEX concentration associated with vertical mixing.

BIOPLUME II assumes an instantaneous reaction between the contaminant and oxygen that is independent of concentration. Once total BTEX concentrations decline to less than 0.1 mg/L by either aerobic or anaerobic decay, introduction of even a very small amount of oxygen results in complete biodegradation in BIOPLUME II. However, in the field, total BTEX concentrations were less than 1 mg/L at line C; yet, low but measurable levels of BTEX persist 300 ft further downgradient (at line D). The persistence of BTEX at line D is likely due to very limited vertical mixing and a much slower rate of contaminant biodegradation when oxygen and contaminant concentrations are low. Chiang *et al.* (1989) found that BTX degraded at much slower rates when oxygen levels went below 1 mg/L. When oxygen is present in the downgradient portion of the plume, the concentrations are very low and can be expected to significantly reduce the rate of aerobic biodegradation.

6.3.2. 3-D Analytical Solution Results for Total BTEX and Individual Compounds

The 3-D analytical solution was calibrated to simulate each of the individual compounds and total BTEX following the same procedures used for MTBE. All calibration parameters were the same except the source concentrations, retardation factors, and first-order decay rates. As previously observed with MTBE, no single value of the first-order decay rate adequately matched the field data at lines B, C, and D. Therefore, decay rates were calibrated to a particular line of monitoring wells (B, C, or D) by minimizing the sum of absolute error between the modeled and observed concentrations for that line of wells. Using this procedure, the model exactly matches concentrations at one line of wells and either significantly over- or underestimates the concentrations at the other two well lines. Results for each calibration are shown in Section 3.0 of Appendix D (Borden *et al.*, 1997). Calculated decay rates at each line of wells are reported in Table 6-2.

Table 6-2. First-Order Decay Rates for BTEX Using the 3-D Analytical Solution by Domenico (1987).

Transport Distance	Benzene (d^{-1})	Toluene (d^{-1})	Ethylbenzene (d^{-1})	m-, p-Xylene (d^{-1})	o-Xylene (d^{-1})	Total BTEX (d^{-1})
Line A to line B	0.0026	0.0202	0.0153	0.0080	0.0028	0.0056
Line A to line C	0.0015	0.0088	0.0069	0.0041	0.0016	0.0026
Line A to line D	0.0006	0.0029	BDL[a]	0.0026	0.0007	0.0011
Anaerobic Decay rate for BIOPLUME II	NC[b]	NC	NC	NC	NC	0.0025

[a] Ethylbenzene was below detection at line D.

[b] NC: decay rates for individual compounds were not calculated using BIOPLUME II.

Comparison of the field and analytical modeling results generated two major findings.

1. The different BTEX components are degrading at different rates. Degradation rates of benzene and o-xylene are much lower than that of toluene and ethylbenzene.
2. The degradation rate of all of the BTEX components declined with distance from the source. Typically, decay rates calibrated to line D were at least three times smaller than the rate calibrated to the line B. This indicates that use of a single first-order decay rate for all compounds is an oversimplification and does not represent the actual degradation process at this site.

Two different approaches were used to simulate total BTEX concentrations for comparison with the BIOPLUME II results.

1. The concentration of each BTEX component was predicted using a compound specific decay rate. Total BTEX was then calculated as the sum of all components.
2. Total BTEX degradation was calculated using a single decay rate.

To allow a direct comparison between these approaches, first-order decay rates estimated from lines B and C were averaged and used to predict depth averaged total BTEX concentrations. Both approaches are compared with the BIOPLUME II results and field monitoring data in Figure 6-10. As previously discussed, BIOPLUME II could not accurately simulate contaminant concentrations at the downgradient location. Use of different first-order decay rates for each BTEX compound slightly improved the total BTEX simulation at each of the monitoring well line locations. However, large errors at line D continued to occur because the model was calibrated using the average of the decay rates from lines B and C.

6.4. MODEL COMPARISON

One of the objectives of this study was to evaluate the usefulness of BIOPLUME II and the analytical solution for simulating intrinsic bioremediation processes at the Sampson County site. Each approach was evaluated based on its: (1) ease of implementation, (2) predictive accuracy, and (3) theoretical representation of groundwater transport and biodegradation processes.

Both BIOPLUME II and the three-dimensional analytical solution required a significant amount of time to calibrate. However, the analytical solution was somewhat easier to understand and manipulate. Calibration of the analytical model was completed very quickly using simple functions and 'solver' scenarios with spreadsheet software. On the other hand, BIOPLUME II required more parameters, took much longer to run, and was harder to calibrate. In addition, parameter adjustments required more effort, and the modeling results were more difficult to manipulate from output files.

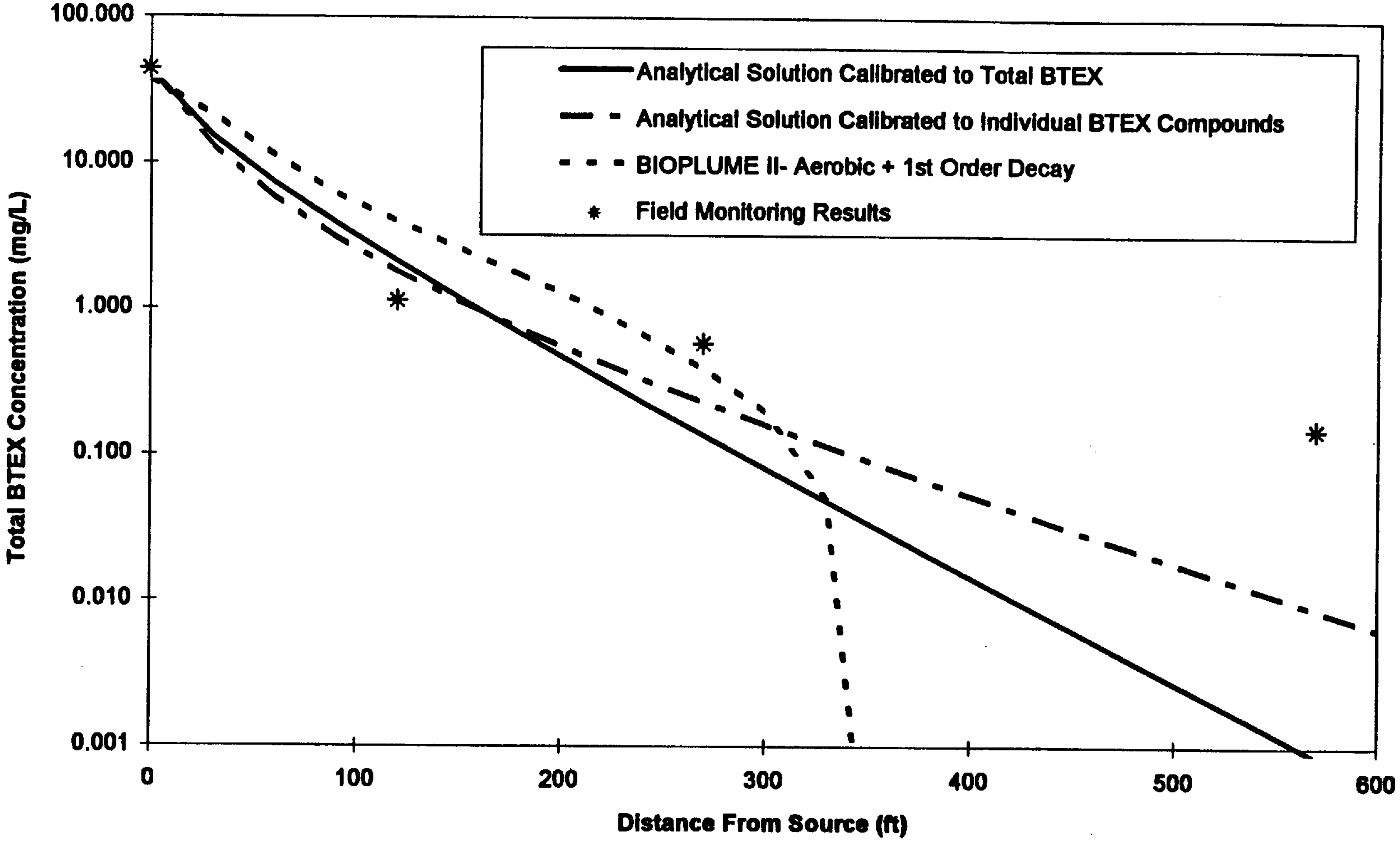


Figure 6-10. Model Comparison with Depth-Averaged Centerline Concentrations of Total BTEX.

Neither BIOPLUME II nor the analytical solution was able to accurately simulate the change in contaminant concentration with distance. Both approaches significantly underestimated contaminant concentrations at the most downgradient location. In a typical field investigation, more data are available near the source, and models are used to predict the maximum extent of contaminant migration at some future time. If this occurred at the Sampson County site, both BIOPLUME II and the analytical solution would have underestimated the extent of contaminant migration and risk to downgradient receptors.

Each model had certain advantages and disadvantages in the representation of groundwater transport and biodegradation processes. When using the analytical solution, the monitoring well coordinates had to be corrected for the curvature of the contaminant plumes. In contrast, it was easy to simulate the site hydrogeology and plume curvature using BIOPLUME II. One major limitation of BIOPLUME II was the two-dimensional representation of the aquifer which did not allow for an accurate simulation of the observed contaminant and oxygen distributions. Neither model was able to accurately describe the spatial variations in decay rate. This suggests that one or more fundamental microbiological processes are not accurately represented by these models.

Chapter 7

SUMMARY AND CONCLUSIONS

An extensive field study was conducted at an UST release in Sampson County, N.C., to improve our understanding of those factors limiting intrinsic bioremediation of dissolved gasoline components in groundwater. Plumes of dissolved BTEX and MTBE are present in the aquifer and have migrated over 580 ft from the source area. Fluctuations in water table elevation and groundwater flow direction have a significant impact on contaminant concentrations during individual sampling events and cause transverse spreading of the plume. Surface recharge of uncontaminated oxygenated water causes the center of the contaminant plumes to sink with distance from the source. Toluene; ethylbenzene; and m-, p-xylene are rapidly biodegraded, whereas o-xylene, benzene, and MTBE are more slowly biodegraded.

Significant levels of nitrate are present throughout the plume, and TEX biodegradation appears to occur using both oxygen and nitrate as terminal electron acceptors. The very rapid removal of toluene; ethylbenzene; and m-, p-xylenes and the much slower removal of o-xylene and benzene are consistent with studies on BTEX biodegradation via denitrification by Hutchins (1991a), Hutchins *et al.* (1991b), and Kao and Borden (in press). There is no evidence of significant iron and sulfate reduction or methanogenesis.

Results from companion aerobic, low initial oxygen, and anaerobic-denitrifying microcosms (Borden *et al.*, accepted) showed no evidence of anaerobic benzene degradation, indicating mass transfer of oxygen into the plume will be the limiting factor influencing benzene biodegradation in the aquifer. TEX biodegradation in the aquifer is likely enhanced by the presence of high levels of nitrate due to fertilization of surrounding farmland. This is believed to reduce the overall oxygen demand on the aquifer and increase the net amount of oxygen available for benzene biodegradation.

A mass flux approach was used to estimate field-scale first-order decay rates for MTBE and BTEX. Use of this approach does not require fitting a solute transport model to concentrations at individual wells. However, the approach does suffer from the following limitations: (1) contaminant concentrations in monitoring wells must stabilize before decay rates can be calculated, and (2) incorporation of the dispersive mass flux is difficult because of uncertainties in the longitudinal concentration gradients and longitudinal dispersivity. In this work, only the advective mass flux was used in the decay rate calculations.

Near the source, first-order decay rates are highest for toluene and ethylbenzene and lowest for o-xylene, benzene, and MTBE (Table 7-1). Downgradient, the mass decay rates for all compounds decline. The decline in the toluene and ethylbenzene decay rates is at least partially due to the complete removal of these compounds; toluene and ethylbenzene were often close to the analytical detection limit at lines C and D. However, significant concentrations of o-xylene, benzene and MTBE remain, and the decline in the mass decay rate is not a calculation artifact.

Table 7-1. Summary of First-Order Decay Rates from the Mass Flux Approach.

Compound	Line A to B (d^{-1})	Line B to C (d^{-1})	Line C to D (d^{-1})
MTBE	0.0010	0.0008	Not Significant
Benzene	0.0014	0.0009	0.0006
Toluene	0.0063	0.0020	0.0005
Ethylbenzene	0.0058	0.0019	0.0008
m-, p-Xylene	0.0035	0.0022	0.0012
o-Xylene	0.0017	0.0010	0.0007
BTEX	0.0029	0.0010	0.0007

The field monitoring results also show evidence of MTBE decay near the contaminant source. However, there is no evidence for MTBE decay in the downgradient aquifer. This is supported by aerobic laboratory microcosms (Borden *et al.*, accepted) that showed limited MTBE biodegradation near the source but no evidence for MTBE biodegradation further downgradient. The unusual shape of the MTBE degradation profile in laboratory microcosms suggests that one or more unknown factors are limiting or inhibiting MTBE biodegradation.

BIOPLUME II and a 3-D analytical model (Dominico, 1987) were evaluated for their ability to simulate the transport and biodegradation of MTBE and BTEX in the shallow aquifer. In both models, MTBE biodegradation was represented by a constant first-order decay rate. As a consequence, predicted MTBE distributions using both models were very similar. Both models provided reasonable predictions of MTBE concentrations in the middle of the plume but significantly underestimated concentrations at the most downgradient wells.

When BIOPLUME II was calibrated to simulate the transport and biodegradation of total BTEX, the model provided a reasonable match to the measured total BTEX concentrations in the middle of the plume. However, at the most downgradient wells, BIOPLUME II predicted complete biodegradation of BTEX, while significant levels of total BTEX persisted at this location. The large simulation errors generated by BIOPLUME II at the downgradient wells are believed to be due to two factors.

1. BIOPLUME II cannot simulate vertical variations in DO or contaminant concentration that occur in many hydrocarbon plumes.
2. BIOPLUME II assumes an instantaneous reaction between the contaminant and oxygen that is independent of concentration. However, field and laboratory results suggest that biodegradation rates are much lower when oxygen and contaminant concentrations are low.

The 3-D analytical solution was used to simulate the transport and biodegradation of each BTEX component and total BTEX. Biodegradation of each contaminant was represented by a constant first-order decay rate. Using this approach, the analytical model could be calibrated to reasonably simulate the concentration of each BTEX component in the middle of the plume. However, the analytical model significantly underestimated contaminant concentrations at the most downgradient wells. The poor match between predicted and observed concentrations at the most downgradient wells is primarily due to the observed decline in contaminant degradation rates with distance.

Neither BIOPLUME II nor the 3-D analytical solution were able to accurately simulate contaminant concentrations over the length of the plume. Both approaches significantly underestimated contaminant concentrations at the most downgradient location. This suggests that one or more fundamental microbiological processes are not accurately represented in both models.

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FIELD STUDIES OF BTEX AND MTBE INTRINSIC BIOREMEDIATION

APPENDICES

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Appendix A

HYDROGEOLOGIC DATA

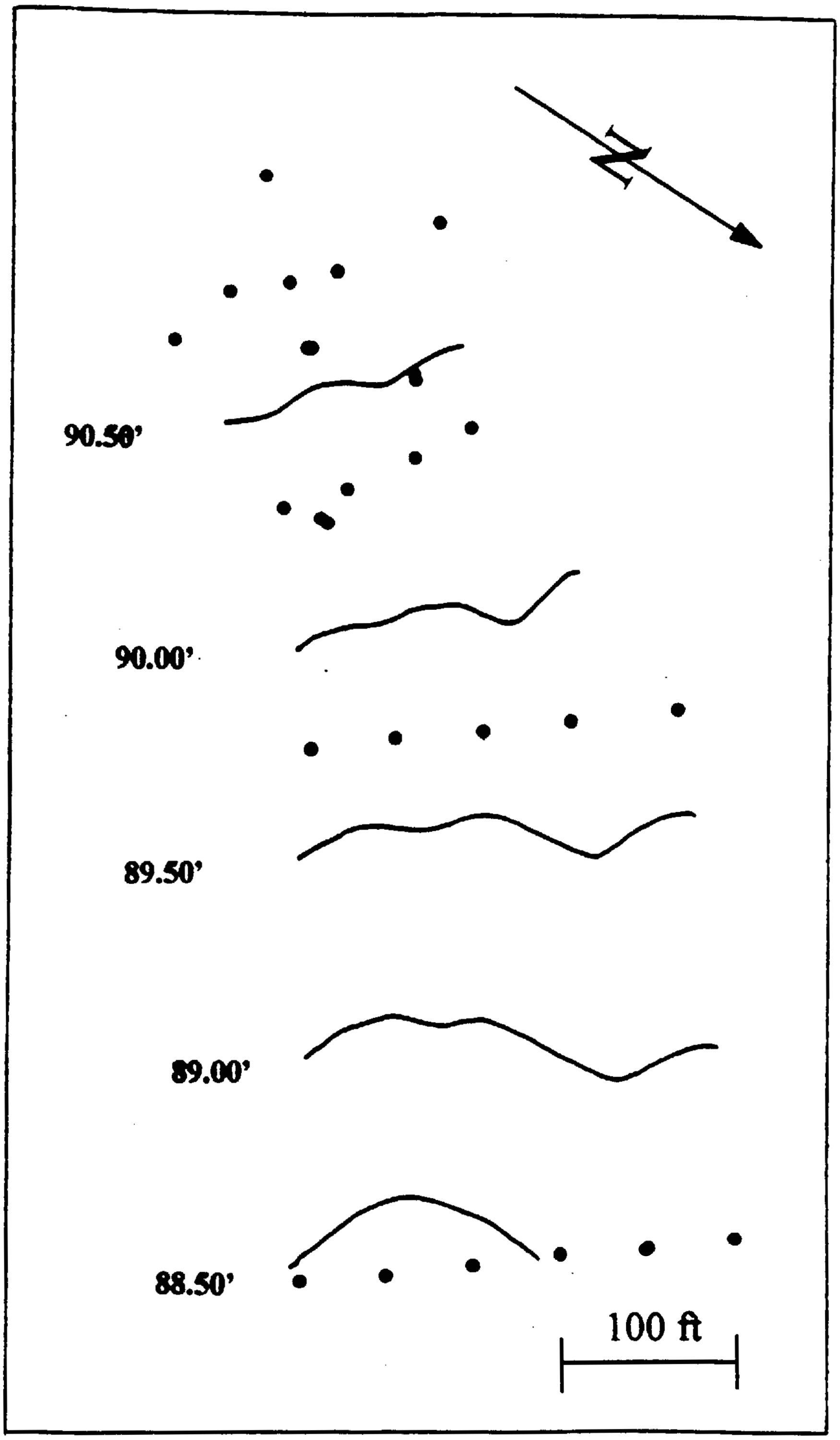
1.0 GROUNDWATER CONTOURS

Water table contours are shown for each sampling event from February 1994 to April 1995 on the following pages. Contours were derived from water table elevations by strict linear interpolation and no means of smoothing. Average water table contours for the site were developed by using the averages of monitoring data over the 1994–95 period.

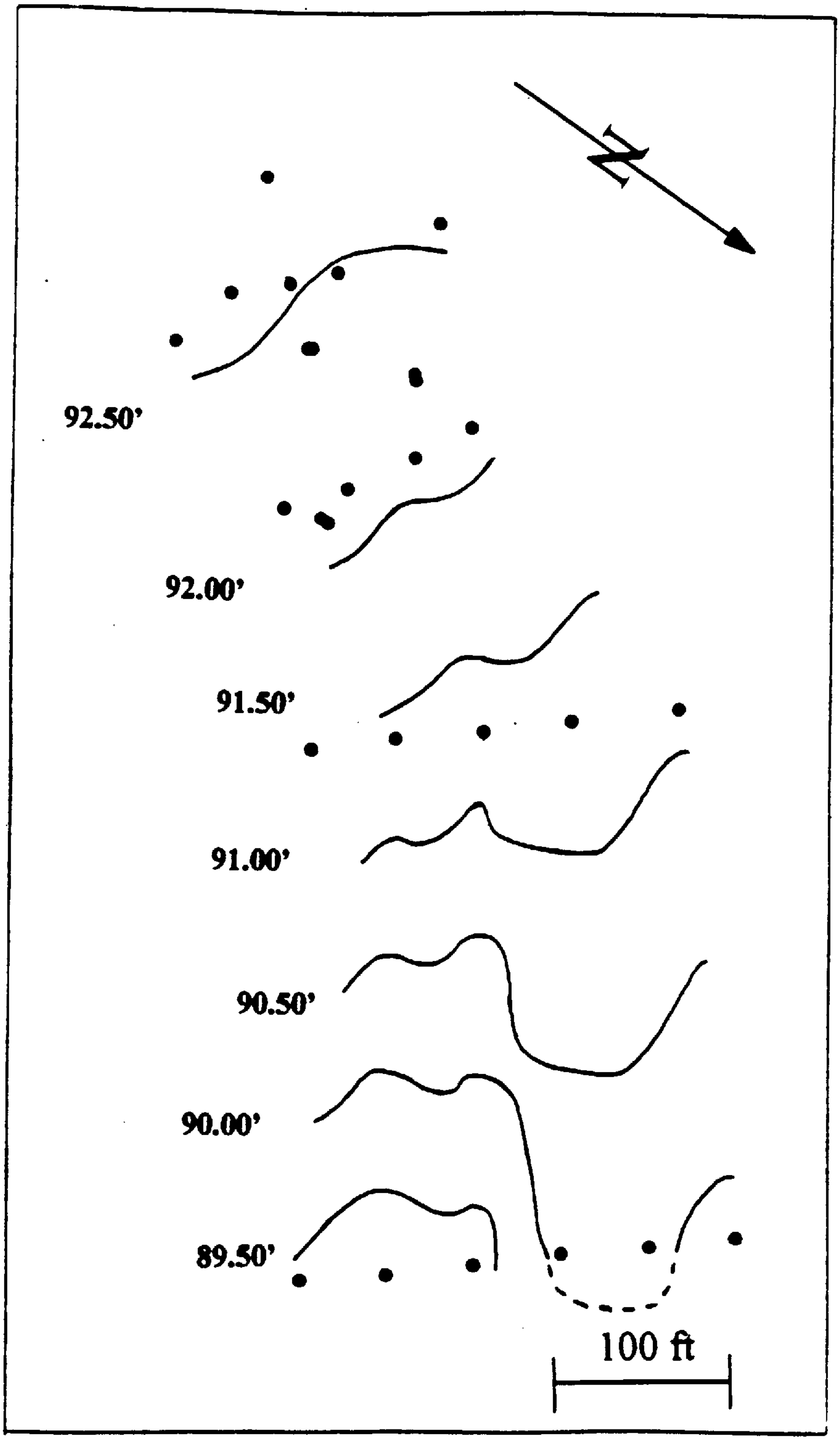
These contours were used to determine groundwater velocities and specific discharge information for use in the mass flux and computer modeling studies. Gradients were determined across each line of wells by using the distance between closest contours. Overall site gradients were determined by using the most extreme groundwater contours. Velocity was then calculated by simply using the Darcy equation with the known hydraulic conductivity (4.0 ft/day) and effective porosity (10%).

The mass balance studies required a value of specific discharge perpendicular to each line of wells. This was calculated by first approximating the angle between the direction of flow and a perpendicular from the well line. The velocity perpendicular to the well line is then the actual groundwater velocity multiplied by the cosine of this angle.

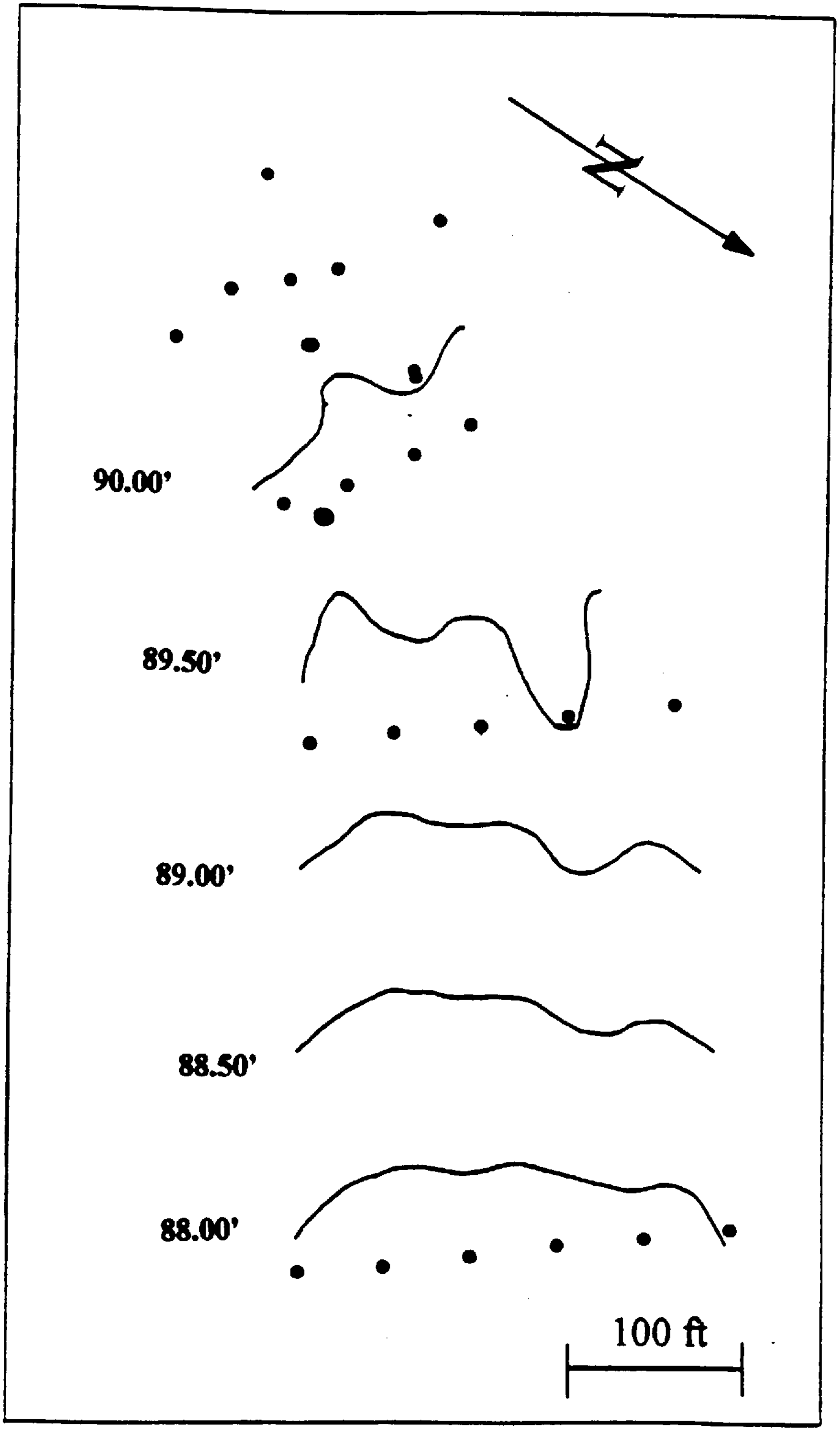
Groundwater Contours
Average from February 1994 to April 1995



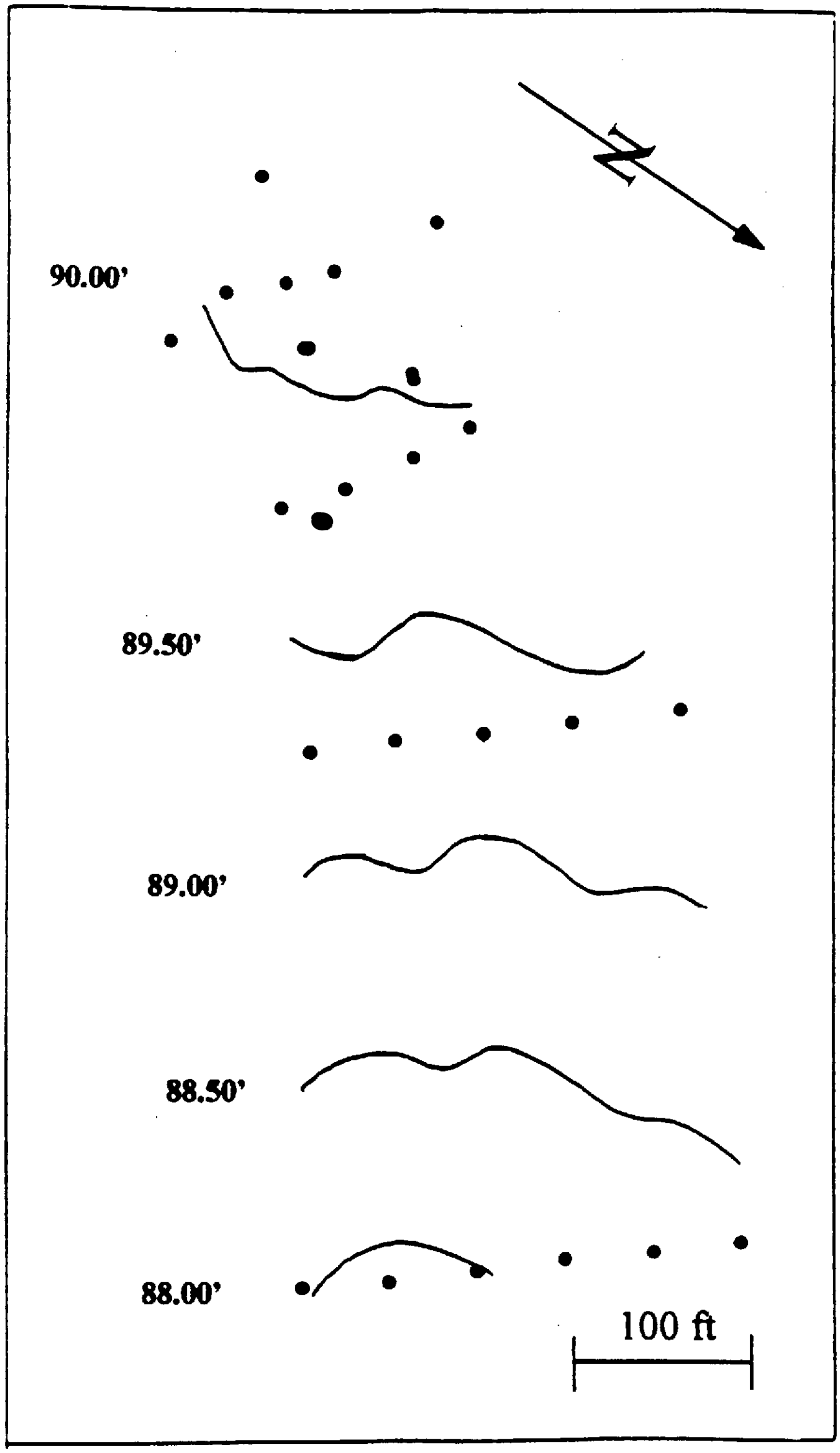
Groundwater Contours
February 1994



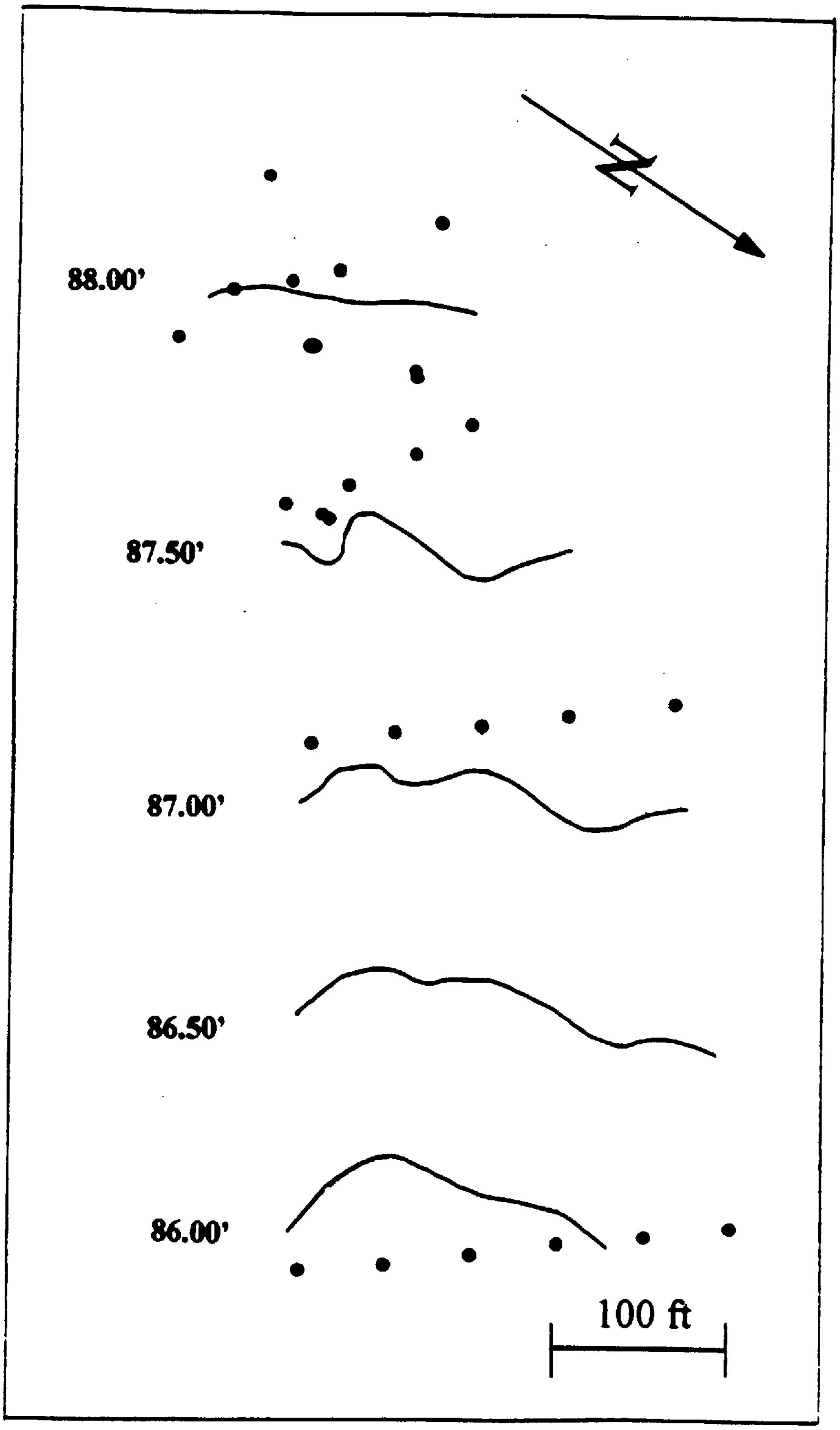
Groundwater Contours
May 1994



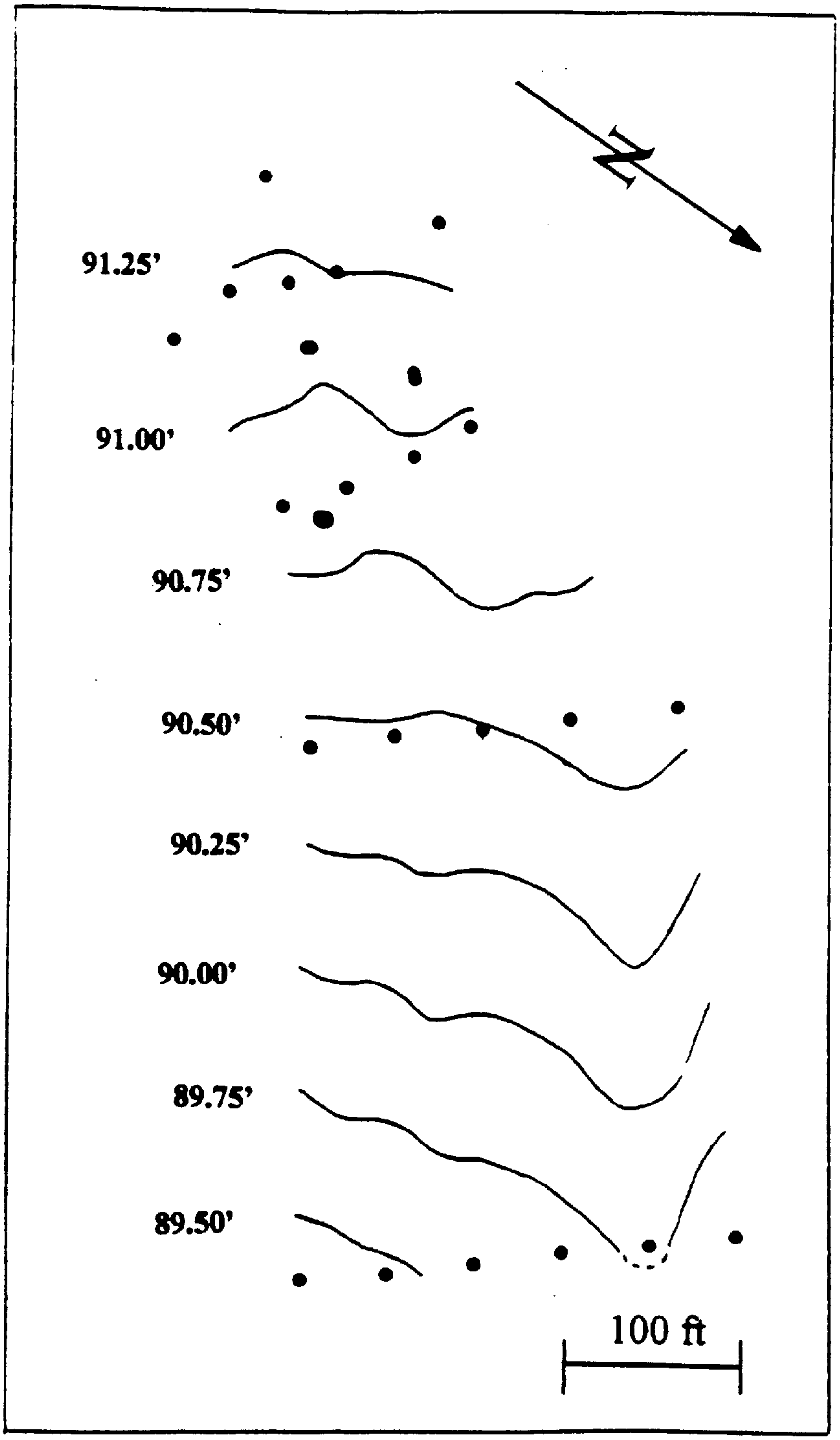
Groundwater Contours
August 1994



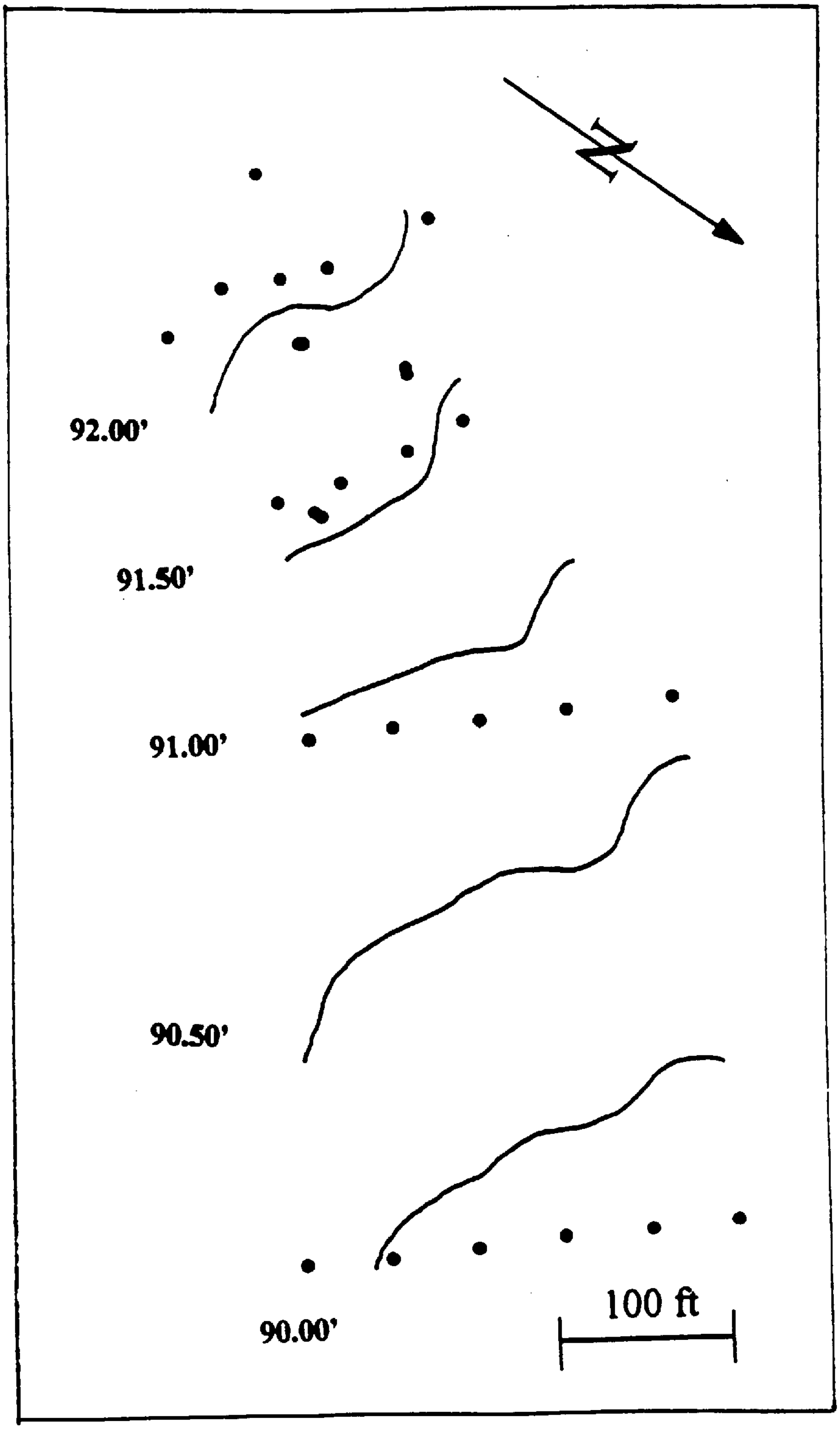
Groundwater Contours
October 1994



Groundwater Contours
January 1995



Groundwater Contours
April 1995



2.0 GROUNDWATER VELOCITIES

Groundwater Velocities

Average Water Table from February 1994 - April 1995

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00343	0.1372	1	0.1372	0.01372
Line B	0.00343	0.1372	7	0.1362	0.01362
Line C	0.00386	0.1544	0	0.1544	0.01544
Line D	0.00421	0.1684	13	0.1641	0.01641
Overall Site	0.00390	0.1560			

February, 1994

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00363	0.1452	13	0.1415	0.01415
Line B	0.00363	0.1452	12	0.1420	0.01420
Line C	0.00514	0.2056	8	0.2036	0.02036
Line D	0.00617	0.2468	20	0.2319	0.02319
Overall Site	0.00471	0.1884			

May, 1994

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00447	0.1788	12	0.1749	0.01749
Line B	0.00343	0.1372	5	0.1367	0.01367
Line C	0.00412	0.1648	4	0.1644	0.01644
Line D	0.00487	0.1948	9	0.1924	0.01924
Overall Site	0.00421	0.1684			

August, 1994

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00356	0.1424	26	0.1280	0.01280
Line B	0.00356	0.1424	26	0.1280	0.01280
Line C	0.00394	0.1576	7	0.1564	0.01564
Line D	0.00441	0.1764	12	0.1725	0.01725
Overall Site	0.00390	0.1560			

Groundwater Velocities, continued

October, 1994

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00343	0.1372	30	0.1188	0.01188
Line B	0.00343	0.1372	24	0.1253	0.01253
Line C	0.00378	0.1512	9	0.1493	0.01493
Line D	0.00421	0.1684	6	0.1675	0.01675
Overall Site	0.00378	0.1512			

January, 1995

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00309	0.1236	22	0.1146	0.01146
Line B	0.00265	0.1060	22	0.0983	0.00983
Line C	0.00299	0.1196	13	0.1165	0.01165
Line D	0.00386	0.1544	30	0.1337	0.01337
Overall Site	0.00289	0.1156			

April, 1995

Location	Gradient (ft/ft)	Velocity (ft/day)	Angle of GW Flow from Perp. to Line	Velocity Perp. to Line (ft/day)	Specific Dis. Perp. to Line ($ft^3/day/ft^2$)
Line A	0.00452	0.1808	9	0.1786	0.01786
Line B	0.00463	0.1852	9	0.1829	0.01829
Line C	0.00363	0.1452	18	0.1381	0.01381
Line D	0.00343	0.1372	24	0.1253	0.01253
Overall Site	0.00398	0.1592			

3.0 RETARDATION FACTOR CALCULATIONS

Retardation Factor Calculations for BTEX and MTBE

The basic equation for determining retardation factors is:

$$\boxed{R_f = 1 + K_d * \left(\frac{\rho_b}{n_T}\right)}$$

Where, R_f = Retardation Factor
K_d = Distribution Coefficient (cm^3/g)
ρ_b = Bulk Density of Soil (g/cm^3)
n_T = Total Porosity

The distribution coefficient can be determined with the following relation:

$$\boxed{K_d = K_{oc} * f_{oc}}$$

Where, K_{oc} = Partition Coefficient with Respect to the Organic Fraction
f_{oc} = Organic Carbon Fraction in the Soil

There are a number of empirical relations that can be used to estimate Koc for a specific compound by knowing its Kow (octanol-water partition coefficient).

We have decided to use the expression derived by Schwarzenbach and Westall (1981) which was developed primarily for methylated benzenes. This expression is as follows:

$$\boxed{\log K_{oc} = 0.72 \log K_{ow} + 0.49}$$

Having the Kow values for each of the fuel compounds, the only other parameters we need are the total porosity fraction of organic carbon and bulk density.

The total porosity of the soil at the site was determined to be approximately 0.3.
From laboratory analysis, the fraction of organic carbon in the soil was determined to be 0.00005.
The bulk density of the soil can be determined by using the following equation and a value of 2.65 for the density of the solid particles.

$$\begin{aligned} \rho_b &= \rho_s * (1 - n_T) \\ &= 2.65 * (1 - 0.3) \\ &= 1.855\ g/cm^3 \end{aligned}$$

Using these parameters, the following values of retardation were determined:

Compound	Log Kow	Log Koc	Kd (cm^3/g)	R
Benzene	2.13	2.02	0.005	1.033
Toluene	2.69	2.43	0.013	1.083
Ethylbenzene	3.15	2.76	0.029	1.177
m/p - Xylene	3.18	2.78	0.030	1.186
o - Xylene	2.77	2.48	0.015	1.094
MTBE	0.78	1.05	0.001	1.003

Retardation Factor Calculations for BTEX and MTBE

We need a weighted Kd to approximate the retardation of Total BTEX.

This will be calculated based on the observed concentrations at the source.

Average Concentration Values for MW-26 (medium depth) between 2/94 - 4/95:

Compound	Concentration (ug/L)	% of Total BTEX	Kd (cm^3/g)
Benzene	17218	21.60	0.005
Toluene	40137	50.35	0.013
Ethylbenzene	4305	5.40	0.029
m/p - Xylene	12190	15.29	0.030
o - Xylene	5859	7.35	0.015
Total BTEX	79709	100	

Weighted Kd for BTEX (cm^3/g)	Weighted R for BTEX
0.015	**1.094**

4.0 MONITORING WELL SUMMARY

Monitoring Well Summary, Sampson County Site, N.C.

Well #	Coordinates		Total Well Depth (ft)	Top of Casing Elevation*(ft)	Middle of Screen Elevation*(ft)	Screened Elevation Interval* (ft)
	X (ft)	Y (ft)				
1	27.02	-100.61	19.00	99.40	85.40	90.40 - 80.40
2	42.54	-24.55	19.00	98.98	84.98	89.98 - 79.98
2 d			25.90	99.01	74.11	75.11 - 73.11
3	2.89	-29.90	15.00	98.38	88.38	93.38 - 83.38
3 d			20.08	98.30	80.72	83.22 - 78.22
4	-60.87	-33.65	14.00	99.03	90.03	95.03 - 85.03
5	140.61	-27.24	14.00	98.50	89.50	94.50 - 84.50
5 d			26.00	98.37	77.37	82.37 - 72.37
6	66.66	36.51	14.00	98.06	89.06	94.06 - 84.06
6 d			26.00	97.77	76.77	81.77 - 71.77
9	-20.68	61.67	14.00	98.22	89.22	94.22 - 84.22
10 s	275.65	159.14	11.04	93.72	85.18	87.68 - 82.68
10			21.00	93.54	75.04	77.54 - 72.54
10 d			24.25	93.74	71.99	74.49 - 69.49
11 s	276.19	98.63	9.92	94.10	86.68	89.18 - 84.18
11			15.42	94.17	81.25	83.75 - 78.75
11 d			23.00	94.07	73.57	76.07 - 71.07
12 s	274.56	47.22	11.58	94.95	85.87	88.37 - 83.37
12 m			19.25	95.10	78.35	80.85 - 75.85
12 d			27.00	95.08	70.58	73.08 - 68.08
13	271.89	3.14	12.00	95.83	86.33	88.83 - 83.83
13 m			17.00	96.03	81.53	84.03 - 79.03
14	272.44	-52.95	11.00	96.77	88.27	90.77 - 85.77
14 m			14.00	96.88	85.38	87.88 - 82.88
15 s	583.98	152.96	9.92	92.33	84.91	87.41 - 82.41
15			14.92	92.60	80.18	82.68 - 77.68
15 d			19.21	92.33	75.62	78.12 - 73.12
16 s	582.57	101.74	9.83	92.39	85.06	87.56 - 82.56
16			14.77	92.72	80.45	82.95 - 77.95
16 d			17.75	92.37	77.12	79.62 - 74.62

Coordinates based on MW-26 as the origin (X=0, Y=0) with the positive X-axis towards MW-18 (Y=0).

• - Elevations are referenced from mean sea level.

Monitoring Well Summary, Sampson County Site, N.C. (continued).

Well #	Coordinates		Total Well Depth (ft)	Top of Casing Elevation*(ft)	Middle of Screen Elevation*(ft)	Screened Elevation Interval* (ft)
	X (ft)	Y (ft)				
17 s	581.12	51.22	10.17	92.76	85.09	87.59 - 82.59
17			14.79	92.83	80.54	83.04 - 78.04
17 d			19.52	92.78	75.76	78.26 - 73.26
18 s	578.32	0.00	10.17	92.83	85.16	87.66 - 82.66
18			15.17	92.77	80.10	82.60 - 77.60
18 d			17.25	92.79	78.04	80.54 - 75.54
19 s	578.32	-49.80	10.19	92.87	85.18	87.68 - 82.68
19			14.81	92.96	80.65	83.15 - 78.15
19 d			19.42	92.87	75.95	78.45 - 73.45
20 s	576.87	-98.88	10.13	92.97	85.35	87.85 - 82.85
20 d			15.08	92.93	80.35	82.85 - 77.85
21 s	131.51	-50.26	9.29	98.57	91.78	94.28 - 89.28
21 d			15.92	98.50	85.08	87.58 - 82.58
22 s	125.08	-11.70	10.08	98.23	90.65	93.15 - 88.15
22 d			16.38	98.30	84.43	86.93 - 81.93
23 g	113.27	30.07	8.92	97.86	91.44	93.94 - 88.94
23 o			14.38	97.74	85.87	88.37 - 83.37
23 y			19.50	97.74	80.74	83.24 - 78.24
23 b			23.25	97.75	77.00	79.50 - 74.50
24 s	100.42	65.42	9.08	97.65	91.07	93.57 - 88.57
24 d			18.08	97.65	82.07	84.57 - 79.57
25 s	4.52	-64.16	9.75	99.05	91.80	94.30 - 89.30
25 d			15.88	99.00	85.63	88.13 - 83.13
26 s	0.00	0.00	9.50	98.31	91.31	93.81 - 88.81
26 m			14.50	98.30	86.30	88.80 - 83.80
26 d			19.21	98.26	81.55	84.05 - 79.05

Coordinates based on MW-26 as the origin (X=0, Y=0) with the positive X-axis towards MW-18 (Y=0).

*** - Elevations are referenced from mean sea level.**

Appendix B

FIELD SAMPLING DATA

Abbreviations used in this Appendix:

BTEX AND MTBE DATA:

Day #: Julian Date from January 1, 1993
NA: sample not available
BDL: concentration below detection limits
0: concentration detected but less than 0.5 μg/L

FIELD DATA:

Tot Depth: total depth of monitoring well in feet
TOC El: top of casing elevation for each monitoring well
MOS El elevation of the middle of the screened interval for each well
DTW: depth to water table surface at each well
DO: dissolved oxygen concentrations in mg/L
CO_2: dissolved carbon dioxide concentration in mg/L
T: temperature in °C
eH: redox potential in mV
pH: sample pH
NA: sample not available

SOIL SCIENCE DATA:

All concentrations reported in mg/L
TOC: total organic carbon
NA: sample not available
< # : concentration below the specified detection limits

1.0 JULIAN DATES FOR EACH SAMPLING EVENT

Sampson County Sampling Events

Julian Date Starting at January 1, 1992

Sampling Event	Calendar Date	Julian Date
Day 0	1-Jan-92	0
1st Trip	18-Jun-92	169
1st Install	6-Jul-92	187
Jul-92	22-Jul-92	203
Aug-92	12-Aug-92	224
Oct-92	3-Oct-92	276
Nov-93	13-Nov-92	317
Jan-93	18-Jan-93	383
Feb-93	20-Feb-93	416
Apr-93	9-Apr-93	464
May-93	4-May-93	489
Jun-93	1-Jun-93	517
Jul-93	6-Jul-93	552
Aug-93	6-Aug-93	583
Oct-93	2-Oct-93	640
Nov-93	23-Nov-93	692
Feb-94	26-Feb-94	787
May-94	15-May-94	865
Aug-94	27-Aug-94	969
Oct-94	22-Oct-94	1025
Jan-95	13-Jan-95	1108
Apr-95	8-Apr-95	1193

2.0 BTEX AND MTBE DATA

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	1	NA	NA	NA	NA	NA	NA	NA
June 1, 1993	517	1	2	BDL	BDL	BDL	BDL	BDL	BDL
July 6, 1993	552	1	BDL	BDL	BDL	BDL	BDL	BDL	BDL
August 6, 1993	583	1	11	BDL	BDL	BDL	BDL	BDL	BDL
October 2, 1993	640	1	5	BDL	BDL	BDL	BDL	BDL	BDL
February 26, 1994	787	1	2	BDL	1	BDL	BDL	1	2
May 15, 1994	865	1	8	BDL	1	BDL	BDL	BDL	1
August 27, 1994	969	1	7	BDL	1	BDL	BDL	BDL	1
October 22, 1994	1025	1	4	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	1	1	BDL	BDL	BDL	BDL	BDL	1
April 8, 1995	1193	1	BDL	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	4	0	0	0	0	0	1
		Stand. Dev.	3	0	0	0	0	0	1
May 4, 1993	489	2	80	24	16	2	14	16	71
June 1, 1993	517	2	66	30	9	2	21	19	80
July 6, 1993	552	2	89	54	8	2	43	29	136
August 6, 1993	583	2	15	4	1	BDL	BDL	BDL	5
October 2, 1993	640	2	16	65	18	10	77	43	213
February 26, 1994	787	2	156	61	12	2	34	22	130
May 15, 1994	865	2	98	7	2	42	27	BDL	77
August 27, 1994	969	2	30	46	7	2	22	13	90
October 22, 1994	1025	2	31	56	4	1	14	12	88
January 13, 1995	1108	2	101	109	7	1	20	28	164
April 8, 1995	1193	2	18	14	3	1	10	6	34
		1994-95 Average	72	49	6	8	21	13	97
		Stand. Dev.	54	37	4	17	8	10	45
May 4, 1993	489	2 d	BDL	0	1	BDL	BDL	BDL	1
June 1, 1993	517	2 d	BDL	BDL	BDL	BDL	BDL	1	2
July 6, 1993	552	2 d	BDL	3	1	BDL	BDL	4	8
August 6, 1993	583	2 d	BDL	2	1	BDL	BDL	BDL	3
October 2, 1993	640	2 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
February 26, 1994	787	2 d	BDL	1	3	BDL	1	1	6
May 15, 1994	865	2 d	1	BDL	1	BDL	BDL	BDL	2
August 27, 1994	969	2 d	1	BDL	1	BDL	BDL	1	2
October 22, 1994	1025	2 d	BDL	1	BDL	BDL	BDL	BDL	2
January 13, 1995	1108	2 d	BDL	BDL	BDL	BDL	BDL	0	1
April 8, 1995	1193	2 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	0	0	1	0	0	0	2
		Stand. Dev.	1	0	1	0	0	0	2

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	3	2611	5169	8071	968	4824	2544	21576
June 1, 1993	517	3	2609	5554	7735	888	3778	2039	19994
July 6, 1993	552	3	6880	9717	12888	1561	6689	5070	35925
August 6, 1993	583	3	2426	5612	5607	BDL	803	2014	14037
October 2, 1993	640	3	2592	6370	4776	803	693	1470	14112
February 26, 1994	787	3	3071	4245	2115	468	2790	1418	11036
May 15, 1994	865	3	3589	5119	5122	968	4201	2125	17534
August 27, 1994	969	3	2649	3788	2212	387	2875	1462	10725
October 22, 1994	1025	3	3535	6072	3722	534	2844	1485	14656
January 13, 1995	1108	3	3344	4983	2654	332	2438	1305	11712
April 8, 1995	1193	3	1213	1418	771	156	1427	819	4590
		1994-95 Average	2900	4271	2766	474	2762	1436	11709
		Stand. Dev.	896	1603	1496	274	892	418	4352

May 4, 1993	489	3 d	1177	1936	2570	314	1435	782	7037
June 1, 1993	517	3 d	326	555	654	72	396	265	1943
July 6, 1993	552	3 d	782	1412	8983	77	602	698	11772
August 6, 1993	583	3 d	780	1461	606	BDL	57	BDL	2125
October 2, 1993	640	3 d	650	1536	553	38	144	513	2783
February 26, 1994	787	3 d	1438	1445	894	128	849	494	3809
May 15, 1994	865	3 d	87	497	419	54	322	213	1505
August 27, 1994	969	3 d	565	835	468	53	348	216	1921
October 22, 1994	1025	3 d	220	256	54	10	145	107	572
January 13, 1995	1108	3 d	93	69	11	2	41	39	161
April 8, 1995	1193	3 d	116	112	78	44	187	115	535
		1994-95 Average	420	536	321	49	315	197	1417
		Stand. Dev.	531	528	342	45	285	160	1345

May 4, 1993	489	4	NA	NA	NA	NA	NA	NA	NA
June 1, 1993	517	4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
July 6, 1993	552	4	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	4	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	4	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	4	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	4	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	4	BDL	BDL	1	BDL	BDL	BDL	1
October 22, 1994	1025	4	BDL	1	1	BDL	BDL	BDL	2
January 13, 1995	1108	4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	4	BDL	BDL	BDL	BDL	BDL	BDL	1
		1994-95 Average	BDL	0	0	BDL	0	BDL	1
		Stand. Dev.	BDL	0	0	BDL	0	BDL	1

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	5	26	14	1	BDL	1	8	23
June 1, 1993	517	5	31	27	1	BDL	1	15	44
July 6, 1993	552	5	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	5	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	5	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	5	443	520	21	2	25	179	748
May 15, 1994	865	5	970	1054	63	12	182	345	1658
August 27, 1994	969	5	555	677	23	7	76	264	1046
October 22, 1994	1025	5	1098	1231	19	7	83	355	1695
January 13, 1995	1106	5	876	1113	10	6	51	319	1500
April 8, 1995	1193	5	523	425	11	2	51	132	621
		1994-95 Average	744	837	25	6	78	266	1211
		Stand. Dev.	272	339	20	4	55	92	471

May 4, 1993	489	5 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	5 d	BDL	BDL	1	BDL	BDL	1	1
July 6, 1993	552	5 d	BDL	BDL	1	BDL	BDL	BDL	1
August 6, 1993	583	5 d	BDL	1	BDL	BDL	BDL	BDL	1
October 2, 1993	640	5 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
February 26, 1994	787	5 d	3	BDL	BDL	BDL	BDL	BDL	1
May 15, 1994	865	5 d	7	5	1	BDL	BDL	2	8
August 27, 1994	969	5 d	3	1	1	BDL	BDL	1	3
October 22, 1994	1025	5 d	1	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1106	5 d	1	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	5 d	46	45	2	1	6	14	67
		1994-95 Average	10	9	1	0	1	3	13
		Stand. Dev.	18	18	1	0	2	5	26

May 4, 1993	489	6	259	1625	1187	170	1997	1054	6234
June 1, 1993	517	6	249	1303	714	137	1884	955	4993
July 6, 1993	552	6	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	6	70	366	54	BDL	8	BDL	427
October 2, 1993	640	6	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	6	413	374	777	111	586	350	2199
May 15, 1994	865	6	47	63	15	8	150	91	327
August 27, 1994	969	6	1	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	6	22	24	9	2	14	14	62
January 13, 1995	1106	6	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	6	0	2	1	1	1	1	5
		1994-95 Average	81	77	134	20	125	76	432
		Stand. Dev.	164	147	315	45	233	139	875

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	6 d	BDL	9	6	1	7	5	28
June 1, 1993	517	6 d	BDL	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	6 d	BDL	BDL	1	BDL	BDL	BDL	1
August 6, 1993	583	6 d	BDL	BDL	BDL	BDL	BDL	BDL	1
October 2, 1993	640	6 d	BDL	BDL	BDL	BDL	BDL	BDL	1
February 26, 1994	787	6 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	6 d	BDL	BDL	1	BDL	BDL	BDL	1
August 27, 1994	969	6 d	2	BDL	1	BDL	BDL	1	2
October 22, 1994	1025	6 d	BDL	BDL	BDL	BDL	BDL	BDL	0
January 13, 1995	1108	6 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	6 d	BDL	2	BDL	BDL	BDL	BDL	2
		1994-95 Average	0	0	0	BDL	0	0	1
		Stand. Dev.	1	1	0	BDL	0	0	1

May 4, 1993	489	9	BDL	2	3	BDL	1	BDL	6
June 1, 1993	517	9	BDL	BDL	2	BDL	1	BDL	3
July 6, 1993	552	9	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	9	BDL	13	1	BDL	1	BDL	15
October 2, 1993	640	9	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	9	BDL	BDL	BDL	BDL	BDL	BDL	1
May 15, 1994	865	9	BDL	BDL	1	BDL	BDL	BDL	1
August 27, 1994	969	9	2	BDL	1	BDL	BDL	BDL	1
October 22, 1994	1025	9	BDL	BDL	1	BDL	BDL	BDL	2
January 13, 1995	1108	9	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	9	BDL	1	BDL	BDL	1	1	2
		1994-95 Average	0	0	1	0	0	0	1
		Stand. Dev.	1	0	0	0	0	0	1

May 4, 1993	489	10 s	BDL	BDL	BDL	BDL	1	BDL	1
June 1, 1993	517	10 s	BDL	BDL	BDL	BDL	1	1	2
July 6, 1993	552	10 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
August 6, 1993	583	10 s	BDL	3	1	BDL	BDL	BDL	3
October 2, 1993	640	10 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	10 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	10 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
August 27, 1994	969	10 s	2	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	10 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	10 s	1	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	10 s	BDL	BDL	BDL	1	BDL	BDL	1
		1994-95 Average	1	0	0	0	0	0	1
		Stand. Dev.	1	0	0	0	0	0	1

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	10	BDL	BDL	1	BDL	1	1	3
July 6, 1993	552	10	BDL	BDL	BDL	BDL	BDL	1	1
August 6, 1993	583	10	BDL	BDL	BDL	BDL	BDL	BDL	1
October 2, 1993	640	10	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	10	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	10	BDL	BDL	1	BDL	BDL	BDL	1
October 22, 1994	1025	10	BDL	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	10	BDL	BDL	BDL	1	BDL	BDL	2
		1994-95 Average	BDL	0	0	0	0	0	1
		Stand. Dev.	BDL	0	0	0	0	0	1
May 4, 1993	489	10 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	10 d	BDL	BDL	BDL	BDL	1	1	3
July 6, 1993	552	10 d	BDL	BDL	BDL	BDL	BDL	1	1
August 6, 1993	583	10 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
October 2, 1993	640	10 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
February 26, 1994	787	10 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	10 d	1	0	BDL	BDL	BDL	BDL	1
August 27, 1994	969	10 d	2	BDL	1	BDL	BDL	BDL	1
October 22, 1994	1025	10 d	1	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	10 d	1	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	10 d	BDL	BDL	BDL	1	BDL	BDL	1
		1994-95 Average	1	0	0	0	0	0	1
		Stand. Dev.	1	0	0	0	0	0	0
May 4, 1993	489	11 s	35	13	BDL	BDL	BDL	BDL	13
June 1, 1993	517	11 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
July 6, 1993	552	11 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	11 s	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	11 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	11 s	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	11 s	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	11 s	1	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	11 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	11 s	BDL	BDL	0	BDL	BDL	BDL	2
April 8, 1995	1193	11 s	BDL	BDL	0	BDL	BDL	BDL	1
		1994-95 Average	0	0	0	0	0	0	1
		Stand. Dev.	1	0	0	0	0	0	1

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	11	328	1334	33	4	144	317	1832
June 1, 1993	517	11	499	2500	82	8	326	589	3505
July 6, 1993	552	11	312	1502	59	4	190	376	2132
August 6, 1993	583	11	119	681	19	BDL	BDL	BDL	701
October 2, 1993	640	11	13	36	2	BDL	9	21	68
February 26, 1994	787	11	56	99	5	BDL	29	36	169
May 15, 1994	865	11	24	19	1	BDL	5	8	34
August 27, 1994	969	11	1	BDL	1	BDL	BDL	1	2
October 22, 1994	1025	11	BDL	1	1	BDL	1	BDL	3
January 13, 1995	1108	11	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 6, 1995	1193	11	BDL	BDL	BDL	BDL	BDL	BDL	1
		1994-95 Average	13	20	1	0	6	8	35
		Stand. Dev.	23	40	2	0	12	14	67

May 4, 1993	489	11 d	279	1009	15	2	45	193	1264
June 1, 1993	517	11 d	261	1111	17	BDL	62	245	1436
July 6, 1993	552	11 d	214	747	19	BDL	28	159	953
August 6, 1993	583	11 d	74	211	6	BDL	BDL	BDL	216
October 2, 1993	640	11 d	30	6	4	BDL	3	6	19
February 26, 1994	787	11 d	2	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	11 d	10	0	1	BDL	1	2	3
August 27, 1994	969	11 d	6	BDL	1	BDL	BDL	BDL	1
October 22, 1994	1025	11 d	4	BDL	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	11 d	2	BDL	BDL	BDL	BDL	BDL	BDL
April 6, 1995	1193	11 d	41	53	1	0	4	20	78
		1994-95 Average	11	9	0	0	1	4	14
		Stand. Dev.	15	22	0	0	1	8	31

May 4, 1993	489	12 s	52	86	1	BDL	1	29	118
June 1, 1993	517	12 s	76	82	3	BDL	2	27	114
July 6, 1993	552	12 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	12 s	240	492	8	BDL	BDL	BDL	499
October 2, 1993	640	12 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	12 s	212	312	4	1	8	80	405
May 15, 1994	865	12 s	635	935	81	3	69	313	1401
August 27, 1994	969	12 s	330	425	10	2	40	123	600
October 22, 1994	1025	12 s	101	81	2	BDL	3	33	119
January 13, 1995	1108	12 s	35	1	BDL	BDL	BDL	BDL	1
April 6, 1995	1193	12 s	502	506	8	1	8	153	676
		1994-95 Average	303	377	17	1	21	117	534
		Stand. Dev.	233	336	31	1	27	111	500

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	12 m	89	174	2	BDL	2	50	228
June 1, 1993	517	12 m	92	127	2	BDL	2	58	190
July 6, 1993	552	12 m	BDL	BDL	BDL	BDL	BDL	BDL	BDL
August 6, 1993	583	12 m	170	285	4	BDL	1	84	373
October 2, 1993	640	12 m	464	561	13	BDL	27	124	725
February 26, 1994	787	12 m	333	652	7	2	26	140	826
May 15, 1994	865	12 m	507	734	25	2	58	223	1041
August 27, 1994	969	12 m	661	985	24	5	123	277	1414
October 22, 1994	1025	12 m	197	259	3	1	13	76	351
January 13, 1995	1108	12 m	7	5	BDL	BDL	BDL	2	7
April 8, 1995	1193	12 m	289	332	2	1	8	100	443
		1994-95 Average	332	494	10	2	38	136	680
		Stand. Dev.	230	359	11	2	47	100	511
May 4, 1993	489	12 d	83	52	3	BDL	BDL	11	67
June 1, 1993	517	12 d	85	48	1	BDL	1	12	61
July 6, 1993	552	12 d	154	252	5	2	6	133	398
August 6, 1993	583	12 d	156	142	3	BDL	BDL	BDL	145
October 2, 1993	640	12 d	126	143	4	BDL	7	32	187
February 26, 1994	787	12 d	331	488	2	BDL	3	111	605
May 15, 1994	865	12 d	211	245	14	BDL	2	61	323
August 27, 1994	969	12 d	371	557	7	2	6	137	709
October 22, 1994	1025	12 d	480	694	5	1	8	177	886
January 13, 1995	1108	12 d	281	316	2	BDL	2	81	402
April 8, 1995	1193	12 d	231	226	2	1	2	68	299
		1994-95 Average	318	421	5	1	4	106	537
		Stand. Dev.	99	188	5	1	2	45	235
May 4, 1993	489	13	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	13	BDL	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	13	BDL	6	1	BDL	1	10	17
August 6, 1993	583	13	2	BDL	BDL	BDL	BDL	BDL	BDL
October 2, 1993	640	13	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	13	7	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	13	15	1	1	BDL	BDL	BDL	1
August 27, 1994	969	13	3	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	13	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	13	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	13	71	46	1	BDL	2	14	63
		1994-95 Average	19	9	0	0	0	3	13
		Stand. Dev.	30	20	0	0	1	6	28

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	13 m	0	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	13 m	1	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	13 m	3	1	1	BDL	BDL	1	2
August 6, 1993	583	13 m	7	BDL	1	BDL	BDL	BDL	1
October 2, 1993	640	13 m	32	48	1	BDL	1	14	63
February 26, 1994	787	13 m	33	2	157	1	1	2	163
May 15, 1994	865	13 m	47	24	2	BDL	BDL	8	35
August 27, 1994	969	13 m	300	324	6	1	5	96	432
October 22, 1994	1025	13 m	391	388	4	1	6	117	516
January 13, 1995	1108	13 m	317	415	4	1	16	116	551
April 8, 1995	1193	13 m	265	275	3	1	8	84	372
		1994-95 Average	225	238	29	1	6	71	345
		Stand. Dev.	149	181	63	0	6	52	205

May 4, 1993	489	14	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	14	BDL	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	14	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	14	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	14	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	14	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	14	1	BDL	2	BDL	BDL	BDL	2
August 27, 1994	969	14	1	BDL	0	BDL	BDL	BDL	1
October 22, 1994	1025	14	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	14	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	14	BDL	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	0	0	1	0	0	0	1
		Stand. Dev.	1	0	1	0	0	0	1

May 4, 1993	489	14 m	6	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	14 m	4	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	14 m	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	14 m	5	BDL	BDL	BDL	BDL	BDL	BDL
October 2, 1993	640	14 m	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	14 m	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	14 m	142	58	4	BDL	3	19	84
August 27, 1994	969	14 m	98	36	1	BDL	BDL	12	48
October 22, 1994	1025	14 m	71	13	BDL	BDL	BDL	2	16
January 13, 1995	1108	14 m	129	87	1	BDL	1	25	114
April 8, 1995	1193	14 m	139	79	1	BDL	1	23	105
		1994-95 Average	116	54	1	0	1	16	73
		Stand. Dev.	30	31	2	0	1	9	41

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	15 s	1	BDL	BDL	BDL	BDL	BDL	1
June 1, 1993	517	15 s	2	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	15 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	15 s	BDL	0	1	BDL	BDL	BDL	1
October 2, 1993	640	15 s	1	BDL	BDL	BDL	BDL	BDL	1
February 26, 1994	787	15 s	3	1	127	1	1	1	131
May 15, 1994	865	15 s	2	BDL	1	BDL	0	BDL	1
August 27, 1994	969	15 s	4	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	15 s	BDL	BDL	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	15 s	1	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	15 s	2	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	2	0	21	0	0	0	22
		Stand. Dev.	2	0	52	0	1	1	53

May 4, 1993	489	15	2	BDL	BDL	BDL	BDL	BDL	1
June 1, 1993	517	15	1	BDL	6	1	4	1	13
July 6, 1993	552	15	BDL	BDL	1	BDL	BDL	1	2
August 6, 1993	583	15	1	BDL	BDL	BDL	BDL	BDL	1
October 2, 1993	640	15	1	1	BDL	BDL	BDL	5	6
February 26, 1994	787	15	1	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	15	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	15	2	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	15	1	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	15	1	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	15	2	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	2	0	0	0	0	0	0
		Stand. Dev.	0	0	0	0	0	0	0

May 4, 1993	489	15 d	1	BDL	BDL	BDL	BDL	BDL	1
June 1, 1993	517	15 d	BDL	BDL	1	BDL	1	BDL	2
July 6, 1993	552	15 d	BDL	BDL	1	BDL	BDL	1	2
August 6, 1993	583	15 d	BDL	BDL	BDL	BDL	BDL	BDL	1
October 2, 1993	640	15 d	1	BDL	BDL	BDL	BDL	BDL	1
February 26, 1994	787	15 d	1	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	15 d	5	BDL	1	BDL	BDL	BDL	1
August 27, 1994	969	15 d	2	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	15 d	1	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	15 d	1	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	15 d	1	BDL	BDL	BDL	BDL	BDL	2
		1994-95 Average	2	0	0	0	0	0	1
		Stand. Dev.	2	0	0	0	0	0	1

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	16 s	135	2	1	BDL	BDL	BDL	3
June 1, 1993	517	16 s	108	1	1	BDL	BDL	BDL	2
July 6, 1993	552	16 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	16 s	188	2	1	BDL	BDL	BDL	2
October 2, 1993	640	16 s	143	2	1	BDL	BDL	BDL	3
February 26, 1994	787	16 s	78	1	BDL	BDL	BDL	BDL	1
May 15, 1994	865	16 s	173	3	1	BDL	BDL	1	4
August 27, 1994	969	16 s	91	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	16 s	88	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	16 s	17	BDL	BDL	BDL	BDL	BDL	1
April 8, 1995	1193	16 s	58	BDL	BDL	BDL	BDL	BDL	2
		1994-95 Average	84	1	0	0	0	0	2
		Stand. Dev.	51	1	0	0	0	0	1

May 4, 1993	489	16	166	2	1	BDL	BDL	BDL	3
June 1, 1993	517	16	134	1	BDL	BDL	BDL	BDL	2
July 6, 1993	552	16	199	31	3	1	5	73	113
August 6, 1993	583	16	223	5	1	BDL	BDL	BDL	6
October 2, 1993	640	16	164	2	1	BDL	BDL	1	4
February 26, 1994	787	16	154	1	1	BDL	BDL	BDL	2
May 15, 1994	865	16	291	78	1	BDL	1	20	100
August 27, 1994	969	16	208	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	16	147	BDL	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	16	67	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	16	78	1	BDL	BDL	BDL	BDL	2
		1994-95 Average	157	13	0	0	0	3	18
		Stand. Dev.	84	32	0	0	0	8	40

May 4, 1993	489	16 d	142	2	1	BDL	BDL	BDL	3
June 1, 1993	517	16 d	138	2	1	BDL	BDL	BDL	2
July 6, 1993	552	16 d	168	2	3	BDL	BDL	1	6
August 6, 1993	583	16 d	147	1	1	BDL	BDL	BDL	2
October 2, 1993	640	16 d	78	2	BDL	BDL	BDL	0	3
February 26, 1994	787	16 d	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	16 d	190	1	BDL	BDL	BDL	BDL	2
August 27, 1994	969	16 d	114	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	16 d	101	BDL	BDL	BDL	BDL	BDL	BDL
January 13, 1995	1108	16 d	67	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	16 d	106	1	BDL	BDL	BDL	BDL	1
		1994-95 Average	116	1	0	BDL	BDL	0	1
		Stand. Dev.	45	0	0	BDL	BDL	0	1

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	17 s	57	1	BDL	2	BDL	1	5
June 1, 1993	517	17 s	31	BDL	1	BDL	1	BDL	2
July 6, 1993	552	17 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	17 s	22	BDL	1	BDL	BDL	BDL	1
October 2, 1993	640	17 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	17 s	127	3	BDL	BDL	BDL	BDL	4
May 15, 1994	865	17 s	116	6	1	BDL	BDL	1	9
August 27, 1994	969	17 s	183	93	1	BDL	1	18	113
October 22, 1994	1025	17 s	242	174	1	BDL	1	36	213
January 13, 1995	1108	17 s	113	4	BDL	BDL	BDL	2	6
April 8, 1995	1193	17 s	124	11	BDL	BDL	BDL	3	14
		1994-95 Average	151	49	1	0	0	10	60
		Stand. Dev.	52	71	0	0	1	14	86

May 4, 1993	489	17	80	1	BDL	BDL	BDL	BDL	1
June 1, 1993	517	17	66	1	1	BDL	BDL	BDL	1
July 6, 1993	552	17	128	10	1	BDL	1	16	28
August 6, 1993	583	17	210	54	1	BDL	BDL	16	71
October 2, 1993	640	17	182	93	1	BDL	1	20	116
February 26, 1994	787	17	211	43	1	BDL	BDL	10	54
May 15, 1994	865	17	301	225	39	BDL	3	75	342
August 27, 1994	969	17	264	167	4	1	3	34	209
October 22, 1994	1025	17	320	308	2	BDL	3	66	379
January 13, 1995	1108	17	208	71	BDL	BDL	BDL	28	99
April 8, 1995	1193	17	144	46	BDL	BDL	BDL	12	59
		1994-95 Average	241	143	8	0	2	37	190
		Stand. Dev.	66	109	15	0	2	27	144

May 4, 1993	489	17 d	104	4	BDL	8	BDL	3	16
June 1, 1993	517	17 d	106	2	2	BDL	1	BDL	5
July 6, 1993	552	17 d	170	6	3	BDL	3	31	42
August 6, 1993	583	17 d	183	42	3	BDL	1	BDL	46
October 2, 1993	640	17 d	224	195	2	1	3	44	244
February 26, 1994	787	17 d	240	28	BDL	BDL	BDL	10	38
May 15, 1994	865	17 d	321	265	18	BDL	3	68	355
August 27, 1994	969	17 d	286	239	4	BDL	4	48	294
October 22, 1994	1025	17 d	273	227	2	BDL	2	49	279
January 13, 1995	1108	17 d	229	166	1	BDL	1	35	204
April 8, 1995	1193	17 d	122	85	BDL	BDL	1	22	109
		1994-95 Average	245	168	4	0	2	39	213
		Stand. Dev.	69	94	7	0	1	21	120

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	18 s	17	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	18 s	6	BDL	3	BDL	1	BDL	5
July 6, 1993	552	18 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	18 s	46	3	1	BDL	BDL	8	12
October 2, 1993	640	18 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	18 s	4	BDL	BDL	BDL	BDL	BDL	1
May 15, 1994	865	18 s	110	2	BDL	BDL	BDL	BDL	2
August 27, 1994	969	18 s	45	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	18 s	111	8	BDL	BDL	BDL	2	10
January 13, 1995	1108	18 s	97	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	18 s	104	27	BDL	BDL	BDL	8	35
		1994-95 Average	79	6	0	0	0	2	8
		Stand. Dev.	44	10	0	0	0	3	14

May 4, 1993	489	18	99	1	BDL	BDL	BDL	BDL	1
June 1, 1993	517	18	68	1	2	BDL	1	BDL	5
July 6, 1993	552	18	59	1	1	BDL	BDL	1	3
August 6, 1993	583	18	149	2	1	BDL	BDL	BDL	3
October 2, 1993	640	18	105	23	1	BDL	BDL	6	30
February 26, 1994	787	18	152	47	BDL	BDL	BDL	11	59
May 15, 1994	865	18	166	40	BDL	BDL	BDL	9	50
August 27, 1994	969	18	190	125	1	BDL	1	28	155
October 22, 1994	1025	18	261	220	1	BDL	1	52	274
January 13, 1995	1108	18	136	69	BDL	BDL	1	16	85
April 8, 1995	1193	18	179	101	1	BDL	1	27	129
		1994-95 Average	181	100	1	0	1	24	125
		Stand. Dev.	44	67	1	0	0	16	83

May 4, 1993	489	18 d	97	1	BDL	BDL	BDL	BDL	1
June 1, 1993	517	18 d	114	1	1	BDL	BDL	BDL	3
July 6, 1993	552	18 d	144	2	1	BDL	1	16	20
August 6, 1993	583	18 d	174	5	1	BDL	1	9	16
October 2, 1993	640	18 d	175	103	1	BDL	1	24	129
February 26, 1994	787	18 d	169	57	1	BDL	1	13	71
May 15, 1994	865	18 d	194	89	1	BDL	1	20	111
August 27, 1994	969	18 d	264	223	2	BDL	2	52	279
October 22, 1994	1025	18 d	226	216	1	BDL	1	51	270
January 13, 1995	1108	18 d	242	191	1	BDL	1	47	241
April 8, 1995	1193	18 d	181	123	1	BDL	1	34	159
		1994-95 Average	213	150	1	0	1	36	189
		Stand. Dev.	37	70	1	0	0	17	87

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	19 s	9	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	19 s	27	BDL	6	1	2	BDL	10
July 6, 1993	552	19 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	19 s	55	1	1	BDL	BDL	5	7
October 2, 1993	640	19 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	19 s	5	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	19 s	43	1	BDL	BDL	BDL	BDL	1
August 27, 1994	969	19 s	40	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	19 s	42	BDL	BDL	BDL	BDL	BDL	BDL
January 13, 1995	1108	19 s	37	3	BDL	BDL	BDL	1	5
April 8, 1995	1193	19 s	9	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	29	1	0	0	0	0	1
		Stand. Dev.	17	1	0	0	0	0	2

May 4, 1993	489	19	15	BDL	BDL	BDL	1	BDL	1
June 1, 1993	517	19	39	BDL	3	BDL	1	BDL	4
July 6, 1993	552	19	52	1	1	BDL	2	80	85
August 6, 1993	583	19	58	1	BDL	BDL	BDL	BDL	1
October 2, 1993	640	19	69	1	1	BDL	BDL	0	2
February 26, 1994	787	19	52	BDL	BDL	BDL	BDL	BDL	1
May 15, 1994	865	19	61	BDL	BDL	BDL	BDL	BDL	1
August 27, 1994	969	19	83	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	19	35	18	BDL	BDL	0	6	25
January 13, 1995	1108	19	146	109	1	BDL	1	30	141
April 8, 1995	1193	19	42	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	70	21	0	0	0	6	28
		Stand. Dev.	41	44	0	0	0	12	56

May 4, 1993	489	19 d	28	1	BDL	BDL	BDL	BDL	1
June 1, 1993	517	19 d	6	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	19 d	36	1	1	BDL	1	6	8
August 6, 1993	583	19 d	39	1	1	BDL	BDL	5	7
October 2, 1993	640	19 d	46	1	1	BDL	BDL	BDL	2
February 26, 1994	787	19 d	46	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	19 d	41	BDL	BDL	BDL	BDL	BDL	1
August 27, 1994	969	19 d	59	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	19 d	62	2	BDL	BDL	BDL	BDL	2
January 13, 1995	1108	19 d	68	18	BDL	BDL	BDL	5	24
April 8, 1995	1193	19 d	14	BDL	BDL	BDL	BDL	BDL	BDL
		1994-95 Average	49	3	0	0	0	1	5
		Stand. Dev.	20	7	0	0	0	2	9

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	20 s	4	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	20 s	8	BDL	23	2	6	2	34
July 6, 1993	552	20 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	20 s	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	20 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	20 s	5	BDL	1	BDL	BDL	BDL	1
May 15, 1994	865	20 s	15	1	BDL	BDL	BDL	BDL	2
August 27, 1994	969	20 s	30	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	20 s	27	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	20 s	19	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	20 s	14	3	BDL	BDL	BDL	1	5
		1994-95 Average	19	1	0	0	0	0	2
		Stand. Dev.	9	1	0	0	0	1	2

May 4, 1993	489	20 d	8	BDL	BDL	BDL	BDL	BDL	1
June 1, 1993	517	20 d	10	BDL	15	2	5	1	23
July 6, 1993	552	20 d	13	2	1	BDL	2	20	24
August 6, 1993	583	20 d	15	5	1	BDL	BDL	BDL	5
October 2, 1993	640	20 d	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	20 d	7	BDL	BDL	BDL	BDL	BDL	0
May 15, 1994	865	20 d	18	BDL	BDL	BDL	BDL	BDL	1
August 27, 1994	969	20 d	38	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	20 d	26	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	20 d	24	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	20 d	6	4	BDL	BDL	BDL	1	7
		1994-95 Average	20	1	0	0	0	0	2
		Stand. Dev.	12	2	0	0	0	1	3

May 4, 1993	489	21 s	BDL	BDL	11	1	2	1	14
June 1, 1993	517	21 s	NA	NA	NA	NA	NA	NA	NA
July 6, 1993	552	21 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	21 s	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	21 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	21 s	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	21 s	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	21 s	NA	NA	NA	NA	NA	NA	NA
October 22, 1994	1025	21 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	21 s	503	1156	80	6	283	329	1654
April 8, 1995	1193	21 s	31	38	3	4	5	14	65
		1994-95 Average	267	597	42	5	144	172	959
		Stand. Dev.	334	790	55	1	196	222	1265

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	21 d	3	BDL	1	BDL	BDL	BDL	1
June 1, 1993	517	21 d	3	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	21 d	5	1	2	BDL	1	2	5
August 6, 1993	583	21 d	36	2	1	BDL	2	BDL	4
October 2, 1993	640	21 d	523	966	37	5	109	BDL	1117
February 26, 1994	787	21 d	570	653	20	10	87	202	971
May 15, 1994	865	21 d	303	225	53	28	107	119	533
August 27, 1994	969	21 d	563	612	35	2	67	170	886
October 22, 1994	1025	21 d	1168	1343	44	9	129	356	1881
January 13, 1995	1108	21 d	1056	1745	100	12	380	489	2726
April 8, 1995	1193	21 d	75	35	1	BDL	3	13	52
		1994-95 Average	623	769	42	10	129	225	1175
		Stand. Dev.	423	656	34	10	131	171	970
May 4, 1993	489	22 s	160	5	5	BDL	1	1	11
June 1, 1993	517	22 s	NA	NA	NA	NA	NA	NA	NA
July 6, 1993	552	22 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	22 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
October 2, 1993	640	22 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	22 s	356	321	108	1	63	92	585
May 15, 1994	865	22 s	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	22 s	493	477	7	1	13	152	650
October 22, 1994	1025	22 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	22 s	10	1	1	2	2	1	6
April 8, 1995	1193	22 s	426	460	4	1	14	133	612
		1994-95 Average	321	315	30	1	23	94	463
		Stand. Dev.	215	221	52	0	28	67	306
May 4, 1993	489	22 d	24	46	7	1	2	14	70
June 1, 1993	517	22 d	26	45	2	BDL	2	21	70
July 6, 1993	552	22 d	362	811	94	4	103	258	1269
August 6, 1993	583	22 d	793	11	3	BDL	4	382	400
October 2, 1993	640	22 d	133	290	4	1	6	111	412
February 26, 1994	787	22 d	979	1531	207	12	344	414	2509
May 15, 1994	865	22 d	1123	1360	88	8	282	350	2089
August 27, 1994	969	22 d	323	314	5	BDL	14	93	425
October 22, 1994	1025	22 d	61	40	1	BDL	2	11	54
January 13, 1995	1108	22 d	3	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	22 d	356	419	4	2	19	124	568
		1994-95 Average	474	611	51	4	110	165	941
		Stand. Dev.	470	668	84	5	159	176	1082

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	23 g	NA	NA	NA	NA	NA	NA	NA
June 1, 1993	517	23 g	NA	NA	NA	NA	NA	NA	NA
July 6, 1993	552	23 g	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	23 g	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	23 g	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	23 g	NA	NA	NA	NA	NA	NA	NA
May 15, 1994	865	23 g	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	23 g	NA	NA	NA	NA	NA	NA	NA
October 22, 1994	1025	23 g	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	23 g	25	8	1	BDL	2	10	20
April 8, 1995	1193	23 g	NA	NA	NA	NA	NA	NA	NA
		1994-95 Average	25	8	1	BDL	2	10	20
		Stand. Dev.	--	--	--	--	--	--	--

May 4, 1993	489	23 o	260	611	11	1	30	166	820
June 1, 1993	517	23 o	483	1416	27	3	110	413	1969
July 6, 1993	552	23 o	914	2425	138	28	520	1141	4253
August 6, 1993	583	23 o	1660	8176	786	BDL	62	2291	11315
October 2, 1993	640	23 o	321	2134	213	16	558	662	3583
February 26, 1994	787	23 o	417	706	65	3	151	209	1135
May 15, 1994	865	23 o	1826	2802	280	37	880	867	4866
August 27, 1994	969	23 o	147	755	59	4	253	404	1476
October 22, 1994	1025	23 o	1172	1886	238	11	728	979	3843
January 13, 1995	1108	23 o	226	150	7	BDL	24	100	281
April 8, 1995	1193	23 o	428	685	37	6	151	210	1088
		1994-95 Average	703	1164	114	10	365	462	2115
		Stand. Dev.	660	984	115	14	351	372	1808

May 4, 1993	489	23 y	35	45	2	BDL	5	15	67
June 1, 1993	517	23 y	84	123	6	BDL	9	33	172
July 6, 1993	552	23 y	81	617	145	4	836	580	2182
August 6, 1993	583	23 y	197	279	18	BDL	5	200	501
October 2, 1993	640	23 y	133	246	13	5	50	85	398
February 26, 1994	787	23 y	15	1	20	1	BDL	1	22
May 15, 1994	865	23 y	65	88	28	3	27	26	171
August 27, 1994	969	23 y	18	30	2	BDL	4	10	46
October 22, 1994	1025	23 y	23	29	1	BDL	3	14	47
January 13, 1995	1108	23 y	285	249	5	BDL	23	258	535
April 8, 1995	1193	23 y	8	2	BDL	BDL	BDL	1	4
		1994-95 Average	69	67	9	1	9	52	138
		Stand. Dev.	108	95	12	1	12	102	203

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	23 b	9	8	2	BDL	BDL	2	12
June 1, 1993	517	23 b	9	13	2	BDL	BDL	2	17
July 6, 1993	552	23 b	18	9	9	BDL	BDL	3	20
August 6, 1993	583	23 b	47	41	4	BDL	BDL	BDL	45
October 2, 1993	640	23 b	7	4	1	BDL	1	2	8
February 26, 1994	787	23 b	4	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	23 b	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	23 b	3	2	BDL	BDL	BDL	1	3
October 22, 1994	1025	23 b	1	2	BDL	BDL	BDL	1	3
January 13, 1995	1108	23 b	29	24	1	BDL	2	25	52
April 8, 1995	1193	23 b	2	1	BDL	BDL	BDL	BDL	1
		1994-95 Average	8	6	0	BDL	1	5	12
		Stand. Dev.	12	10	0	BDL	1	11	23
May 4, 1993	489	24 s	NA	NA	NA	NA	NA	NA	NA
June 1, 1993	517	24 s	NA	NA	NA	NA	NA	NA	NA
July 6, 1993	552	24 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	24 s	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	24 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	24 s	BDL	0	0	BDL	BDL	BDL	BDL
May 15, 1994	865	24 s	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	24 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	24 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	24 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	24 s	NA	NA	NA	NA	NA	NA	NA
		1994-95 Average	0	0	0	0	0	0	1
		Stand. Dev.	0	0	0	0	0	0	0
May 4, 1993	489	24 d	NA	NA	NA	NA	NA	NA	NA
June 1, 1993	517	24 d	BDL	BDL	16	BDL	2	2	20
July 6, 1993	552	24 d	BDL	1	10	BDL	1	2	13
August 6, 1993	583	24 d	BDL	3	2	BDL	BDL	BDL	5
October 2, 1993	640	24 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
February 26, 1994	787	24 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	24 d	BDL	1	1	BDL	BDL	BDL	1
August 27, 1994	969	24 d	1	BDL	BDL	BDL	BDL	BDL	BDL
October 22, 1994	1025	24 d	BDL	1	BDL	BDL	BDL	BDL	1
January 13, 1995	1108	24 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	24 d	BDL	BDL	BDL	BDL	BDL	BDL	1
		1994-95 Average	0	0	0	0	0	0	1
		Stand. Dev.	0	0	0	0	0	0	0

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	25 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	25 s	NA	NA	NA	NA	NA	NA	NA
July 6, 1993	552	25 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	25 s	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	25 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	25 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	25 s	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	25 s	1	BDL	BDL	BDL	BDL	BDL	1
October 22, 1994	1025	25 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	25 s	BDL	BDL	BDL	BDL	BDL	BDL	BDL
April 8, 1995	1193	25 s	BDL	BDL	BDL	BDL	BDL	BDL	1
		1994-95 Average	0	0	0	0	0	0	0
		Stand. Dev.	1	0	0	0	0	0	0
May 4, 1993	489	25 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
June 1, 1993	517	25 d	BDL	BDL	1	BDL	BDL	BDL	1
July 6, 1993	552	25 d	BDL	4	1	BDL	BDL	8	13
August 6, 1993	583	25 d	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	25 d	5	3	1	2	3	9	18
February 26, 1994	787	25 d	BDL	BDL	BDL	BDL	BDL	BDL	BDL
May 15, 1994	865	25 d	1	1	1	BDL	1	1	4
August 27, 1994	969	25 d	11	2	2	BDL	1	BDL	6
October 22, 1994	1025	25 d	25	4	1	2	3	3	13
January 13, 1995	1108	25 d	5	2	BDL	BDL	BDL	BDL	3
April 8, 1995	1193	25 d	BDL	BDL	BDL	BDL	BDL	BDL	1
		1994-95 Average	7	2	1	0	1	1	5
		Stand. Dev.	10	1	1	1	1	1	5
May 4, 1993	489	26 s	4127	12266	23629	2707	8474	4082	51178
June 1, 1993	517	26 s	BDL	161	475	50	182	531	1400
July 6, 1993	552	26 s	NA	NA	NA	NA	NA	NA	NA
August 6, 1993	583	26 s	NA	NA	NA	NA	NA	NA	NA
October 2, 1993	640	26 s	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	26 s	7241	10667	27419	3704	11365	5296	58651
May 15, 1994	865	26 s	NA	NA	NA	NA	NA	NA	NA
August 27, 1994	969	26 s	2005	11142	35183	3788	12066	5300	67498
October 22, 1994	1025	26 s	NA	NA	NA	NA	NA	NA	NA
January 13, 1995	1108	26 s	4557	9469	31378	3635	12567	5828	62878
April 8, 1995	1193	26 s	3798	8527	22770	2942	9612	4480	48331
		1994-95 Average	4400	10001	29187	3517	11408	5226	59340
		Stand. Dev.	2175	1226	5324	388	1295	557	8180

Sampling Date	Day #	MW	MTBE Conc (ug/l)	Benzene Conc (ug/l)	Toluene Conc (ug/l)	E-Benzene Conc (ug/l)	M/P-Xylene Conc (ug/l)	O-Xylene Conc (ug/l)	Total BTEX Conc (ug/l)
May 4, 1993	489	26 m	205	12519	22824	2016	5966	3059	46384
June 1, 1993	517	26 m	4303	18939	33114	3120	9637	4619	69429
July 6, 1993	552	26 m	3523	16187	32145	3198	10165	7225	68920
August 6, 1993	583	26 m	2618	11735	35054	BDL	3601	5881	56272
October 2, 1993	640	26 m	NA	NA	NA	NA	NA	NA	NA
February 26, 1994	787	26 m	10323	19697	40541	3975	11731	5598	81542
May 15, 1994	865	26 m	11654	16333	39591	3747	11316	5472	76458
August 27, 1994	969	26 m	1730	13072	32650	3004	9252	4368	62346
October 22, 1994	1025	26 m	10143	17446	43562	5394	14918	6321	87641
January 13, 1995	1108	26 m	15832	22748	49917	6578	16194	8763	104199
April 8, 1995	1193	26 m	10047	14014	34561	3133	9733	4634	66075
		1994-95 Average	9955	17218	40137	4305	12190	5859	79710
		Stand. Dev.	4588	3606	6245	1403	2797	1587	15258

May 4, 1993	489	26 d	BDL	368	586	53	134	80	1221
June 1, 1993	517	26 d	BDL	547	875	BDL	BDL	BDL	1422
July 6, 1993	552	26 d	BDL	BDL	270	BDL	BDL	233	502
August 6, 1993	583	26 d	BDL	BDL	121	BDL	BDL	BDL	121
October 2, 1993	640	26 d	48	314	777	75	209	108	1483
February 26, 1994	787	26 d	100	51	174	BDL	89	57	371
May 15, 1994	865	26 d	505	881	2189	321	831	418	4639
August 27, 1994	969	26 d	100	98	322	67	100	51	638
October 22, 1994	1025	26 d	158	261	746	75	239	114	1436
January 13, 1995	1108	26 d	92	227	559	53	175	85	1099
April 8, 1995	1193	26 d	7	3	8	3	13	6	33
		1994-95 Average	160	254	666	86	241	122	1369
		Stand. Dev.	176	323	791	119	299	149	1679

3.0 FIELD AND SOIL DATA

February 26, 1994 Sampson Co
Field Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH
1	19.00	99.40	85.40	6.83	92.57	8.80	98.00	15.90	446.20	4.43
2 d	25.90	99.01	74.11	6.67	92.34	4.90	46.00	15.60	372.00	5.43
2	19.00	98.98	84.98	6.50	92.48	2.50	82.00	15.20	346.90	5.10
3 d	20.08	98.30	80.72	5.75	92.55	2.10	86.00	14.90	324.60	4.92
3	15.00	98.38	88.38	5.83	92.55	1.50	118.00	15.20	348.10	5.27
4	14.00	99.03	90.03	NA	NA	NA	NA	NA	NA	NA
5 d	26.00	98.37	77.37	6.17	92.20	1.10	64.00	15.10	547.10	4.82
5	14.00	98.50	89.50	6.42	92.08	1.00	120.00	14.10	567.60	4.63
6 d	26.00	97.77	76.77	5.83	91.94	1.20	62.00	15.50	386.10	5.19
6	14.00	98.06	89.06	5.83	92.23	4.30	76.00	14.40	468.40	4.74
7	14.00	96.43	87.43	NA	NA	NA	NA	NA	NA	NA
8	14.00	98.41	89.41	NA	NA	NA	NA	NA	NA	NA
9	14.00	98.22	89.22	5.67	92.55	7.50	50.00	13.00	338.30	4.68
10 d	24.25	93.74	71.99	2.58	91.16	10.30	82.00	14.50	491.10	3.22
10 s	21.00	93.72	75.22	2.58	91.14	7.40	78.00	14.20	473.40	3.21
10	11.04	93.54	85.00	2.58	90.96	9.60	52.00	12.30	466.40	3.53
11 d	23.00	94.07	73.57	2.83	91.24	5.50	80.00	15.60	472.70	3.21
11 s	9.92	94.10	86.68	NA	NA	NA	NA	NA	NA	NA
11	15.42	94.17	81.25	2.83	91.34	5.90	74.00	13.70	477.60	3.28
12 d	27.00	95.08	70.58	3.92	91.16	1.10	82.00	14.70	469.50	3.44
12 m	19.25	95.10	78.35	3.75	91.35	0.80	84.00	13.80	465.50	3.33
12 s	11.58	94.95	85.87	3.67	91.28	3.60	96.00	13.90	473.60	3.30
13 m	17.00	96.03	81.53	4.42	91.61	2.60	66.00	14.20	436.60	3.43
13	12.00	95.83	86.33	4.58	91.25	7.90	70.00	13.40	445.60	3.56
14 m	14.00	96.88	85.38	NA	NA	NA	NA	NA	NA	NA
14	11.00	96.77	88.27	NA	NA	NA	NA	NA	NA	NA
15 d	19.21	92.33	75.62	6.50	85.83	4.70	96.00	15.00	488.30	3.24
15 s	9.92	92.33	84.91	2.58	89.75	5.90	78.00	13.30	519.50	3.31
15	14.92	92.60	80.18	2.67	89.93	7.80	80.00	14.20	505.70	3.49
16 d	17.75	92.37	77.12	2.33	90.04	6.80	70.00	13.40	528.70	3.34
16 s	9.83	92.39	85.06	2.25	90.14	7.80	70.00	12.80	531.80	3.33
16	14.77	92.72	80.45	2.58	90.14	4.20	84.00	13.60	527.30	3.21

February 26, 1994 Sampson Co
Field Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH
17 d	19.52	92.78	75.76	3.42	89.36	2.30	82.00	15.10	527.00	3.33
17 s	10.17	92.76	85.09	2.67	90.09	5.00	86.00	12.70	529.30	3.31
17	14.79	92.83	80.54	2.08	90.75	3.10	90.00	13.10	530.50	3.30
18 d	17.25	92.79	78.04	5.17	87.62	2.20	66.00	13.60	554.50	3.25
18 s	10.17	92.83	85.16	3.25	89.58	8.00	92.00	12.50	532.90	3.37
18	15.17	92.77	80.10	3.75	89.02	3.90	83.00	13.50	553.80	3.32
19 d	19.42	92.87	75.95	3.75	89.12	5.10	58.00	14.00	529.10	3.43
19 s	10.19	92.87	85.18	3.75	89.12	9.60	54.00	12.60	538.30	3.33
19	14.81	92.96	80.65	3.75	89.21	7.90	124.00	13.50	546.60	3.44
20 d	15.08	92.93	80.35	3.58	89.35	8.20	70.00	13.00	518.00	5.32
20 s	10.13	92.97	85.35	3.50	89.47	9.30	58.00	13.80	419.20	6.98
21 d	15.92	98.50	85.08	6.25	92.25	1.60	80.00	14.20	574.30	4.66
21 s	9.29	98.57	91.78	NA	NA	NA	NA	NA	NA	NA
22 d	16.38	98.30	84.43	6.08	92.22	1.30	104.00	14.50	527.80	4.59
22 s	10.08	98.23	90.65	6.08	92.15	5.90	94.00	13.40	512.30	4.61
23 b	23.25	97.75	77.00	5.67	92.08	5.30	70.00	15.90	541.40	4.21
23 g	8.92	97.86	91.44	NA	NA	NA	NA	NA	NA	NA
23 o	14.38	97.74	85.87	5.58	92.16	6.60	96.00	13.60	506.70	4.90
23 y	19.50	97.74	80.74	5.58	92.16	5.60	70.00	15.40	515.90	4.75
24 d	18.08	97.65	82.07	5.50	92.15	8.10	70.00	15.30	522.00	4.32
24 s	9.08	97.65	91.07	5.58	92.07	8.00	92.00	13.60	522.10	4.44
25 d	15.88	99.00	85.63	6.33	92.67	4.70	64.00	15.40	427.70	4.42
25 s	9.75	99.05	91.80	6.50	92.55	6.50	86.00	13.30	433.90	4.73
26 d	19.21	98.26	81.55	5.67	92.59	8.70	116.00	15.00	389.90	4.41
26 m	14.50	98.30	86.30	5.92	92.38	1.20	280.00	14.50	290.70	4.68
26 s	9.50	98.31	91.31	5.83	92.48	0.30	380.00	14.00	278.40	4.95

February 26, 1994 Sampson Co
Soil Science Results

Well#	pH	NO3 ppm N	NH4 ppm N	PO4 ppm P	IC ppm C	TOC ppm C	Cl ppm	Br ppm	SO4 ppm SO4	ICP-SO4 ppm SO4	Mn ppm	Mg ppm	Zn ppm	Ca ppm	Cd ppm	Cu ppm	Ni ppm	Al ppm	Fe ppm	Na ppm	Si ppm	K ppm
1	4.7	17	<0.1	<0.1	7.9	3.3	98	<0.5	0.73	<2	0.01	4.04	<0.05	3.61	<0.05	<0.05	<0.05	0.9	<.1	71.5	3.4	4.9
2	4.56	12	0.16	<0.1	9.6	9.3	50	0.56	1.1	<2	0.06	4.1	<0.05	5.91	<0.05	<0.05	<0.05	0.9	<.1	29	3.8	16
2 d	5.82	2.1	<0.1	<0.1	8.2	1.8	3.6	<0.5	<0.5	<2	0.02	0.45	<0.05	0.65	<0.05	<0.05	<0.05	0.1	<.1	6	6.5	0.8
3	5.66	21	0.44	<0.1	18	16	21	<0.5	<0.5	<2	0.04	7.74	<0.05	7.67	<0.05	<0.05	<0.05	0.2	<.1	33.2	2.7	1.1
3 d	5.06	16	0.18	<0.1	12	8.4	19	<0.5	<0.5	<2	0.03	5.25	0.05	6.14	<0.05	<0.05	<0.05	0.2	<.1	21.8	2.7	2.7
4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	4.86	12	0.26	<0.1	12	4.1	58	<0.5	0.57	<2	0.02	3.46	<0.05	2.51	<0.05	<0.05	<0.05	0.7	<.1	107	2.9	3.2
5 d	5.61	3.2	<0.1	<0.1	7.2	2.2	9.9	<0.5	2.5	3	0.24	1.45	<0.05	1.34	<0.05	<0.05	<0.05	0.1	<.1	8.8	7.1	0.9
6	4.87	16	<0.1	<0.1	11	4.7	24	<0.5	3.7	5	0.05	6.44	<0.05	9.84	<0.05	<0.05	<0.05	0.9	<.1	11.7	3.1	16.26
6 d	5.87	<0.1	<0.1	<0.1	8.5	1.3	3.3	<0.5	5.7	7	0.01	0.78	<0.05	0.76	<0.05	<0.05	<0.05	0.1	<.1	4.5	7.1	1.1
7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	4.67	12	<0.1	<0.1	4.9	2.7	19	<0.5	3.1	4	0.02	5.36	<0.05	13.2	<0.05	<0.05	<0.05	0.4	<.1	7	3.1	3.1
10 s	4.45	12	<0.1	<0.1	8.2	3	16	<0.5	<0.5	<2	0.03	5.63	<0.05	4.19	<0.05	<0.05	<0.05	1.2	<.1	9	3.5	6.9
10	4.82	8.2	<0.1	<0.1	5.5	2.4	19	<0.5	1.4	<2	0.05	4.58	<0.05	9.16	<0.05	<0.05	<0.05	0.6	<.1	5.8	2.7	3.8
10 d	3.2	12	<0.1	<0.1	7.8	1.7	17	<0.5	38	<2	0.03	5.4	<0.05	4.14	<0.05	<0.05	<0.05	1.2	<.1	9.5	3.4	6.3
11 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	4.7	15	<0.1	<0.1	9.5	3.5	22	<0.5	0.55	<2	0.04	6.62	<0.05	8.88	<0.05	<0.05	<0.05	0.5	<.1	11.3	3.3	9.4
11 d	4.54	11	<0.1	<0.1	8.4	2.3	48	<0.5	0.69	<2	0.05	5.28	<0.05	5.54	<0.05	<0.05	<0.05	0.8	<.1	11.4	4.2	4.5
12 s	4.4	14	<0.1	<0.1	12	5.3	24	<0.5	0.86	<2	0.03	5.32	<0.05	4.48	<0.05	<0.05	<0.05	0.9	<.1	35.7	3.5	3
12 m	4.66	9.7	<0.1	<0.1	11	5.3	34	<0.5	<0.5	<2	0.04	5.58	<0.05	4.68	<0.05	<0.05	<0.05	0.8	<.1	21.2	3.8	1.9
12 d	4.67	7.6	<0.1	<0.1	10	3.7	23	<0.5	<0.5	<2	0.03	3.78	<0.05	2.76	<0.05	<0.05	<0.05	0.2	<.1	17.1	4.6	<.5
13	5.11	5.8	<0.1	<0.1	8.6	2.8	42	<0.5	4.8	6	0.02	3.48	<0.05	4.42	<0.05	<0.05	<0.05	0.3	<.1	27.1	4.1	1.6
13 m	5.28	9.8	<0.1	<0.1	9.6	1.9	91	<0.5	2.7	4	0.04	4.06	<0.05	5.2	<0.05	<0.05	<0.05	0.2	<.1	63.4	5.5	2.5
14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14 m	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15 s	4.54	6.5	<0.1	<0.1	8	2.7	14	<0.5	0.84	17	0.02	3.22	<0.05	1.4	<0.05	<0.05	<0.05	0.7	<.1	12.3	3.5	<.5
15	4.15	6.5	<0.1	<0.1	8.4	1.7	16	<0.5	<0.5	<2	0.02	3.51	<0.05	1.2	<0.05	<0.05	<0.05	0.6	<.1	12.3	3.6	<.5
15 d	4.32	5.2	<0.1	<0.1	7.5	2.4	13	<0.5	4.6	5	0.01	2.44	<0.05	0.99	<0.05	<0.05	<0.05	0.7	0.2	12.7	4.3	<.5
16 s	4.56	7	<0.1	<0.1	5.6	3.5	21	<0.5	3	4	0.04	4.93	<0.05	8.09	<0.05	<0.05	<0.05	1.2	<.1	9	3.4	<.5
16	4.39	8.3	0.14	<0.1	7	3.3	17	<0.5	0.69	<2	0.03	4.1	<0.05	2.84	<0.05	<0.05	<0.05	1.2	<.1	13.1	3.5	1.3
16 d	4.44	8	<0.1	<0.1	3.6	4.2	17	<0.5	0.89	<2	0.04	4.24	<0.05	3.74	<0.05	<0.05	<0.05	1.2	<.1	13.5	3.8	0.7

February 26, 1994 Sampson Co
Soil Science Results

Well#	pH	NO3 ppm N	NH4 ppm N	PO4 ppm P	IC ppm C	TOC ppm C	Cl ppm	Br ppm	SO4 ppm SO4	ICP-SO4 ppm SO4	Mn ppm	Mg ppm	Zn ppm	Ca ppm	Cd ppm	Cu ppm	Ni ppm	Al ppm	Fe ppm	Na ppm	Si ppm	K ppm
17 s	4.24	9.2	<0.1	<0.1	6.2	12	19	<0.5	2.8	2	0.07	3.84	<0.05	7.42	<0.05	<0.05	<0.05	1.4	<.1	11.8	3.8	<.5
17	4.42	9.5	<0.1	<0.1	7.6	<1.0	19	<0.5	0.94	<2	0.03	3.71	<0.05	4.89	<0.05	<0.05	<0.05	1.2	<.1	15.8	3.6	0.9
17 d	4.61	8.4	<0.1	<0.1	8	2.7	19	<0.5	<0.5	<2	0.03	3.56	<0.05	2.71	<0.05	<0.05	<0.05	0.7	<.1	17.3	3.9	<.5
18 s	4.45	1.1	<0.1	<0.1	5	9.5	43	<0.5	16	18	0.07	6.42	<0.05	15.6	<0.05	<0.05	<0.05	1.9	<.1	14.6	4.1	0.7
18	4.46	8.7	<0.1	<0.1	6	7.8	27	<0.5	1.2	<2	0.04	3.73	<0.05	4.21	<0.05	<0.05	<0.05	1	<.1	101.1	3.9	<.5
18 d	4.55	8.9	<0.1	<0.1	5.8	3.4	27	<0.5	1.1	<2	0.03	3.61	<0.05	3.05	<0.05	<0.05	<0.05	0.7	<.1	22.4	4.2	<.5
19 s	4.37	6.9	<0.1	<0.1	3.1	5.8	37	<0.5	15	17	0.05	7.66	<0.05	15.9	<0.05	<0.05	<0.05	1.2	<.1	9	3.1	2
19	4.47	9.3	<0.1	<0.1	6.4	2.6	33	<0.5	4.5	5	0.03	5.41	<0.05	6.68	<0.05	<0.05	<0.05	0.7	<.1	22	3.7	0.7
19 d	4.82	8.1	<0.1	<0.1	8.2	1.4	4.1	<0.5	0.71	3	0.02	3.7	<0.05	3.62	<0.05	<0.05	<0.05	0.5	<.1	18.1	3.7	27.1
20 s	6.47	8.1	1.5	<0.1	13	9.4	26	<0.5	7.9	7	<.01	3.65	<0.05	14	<0.05	<0.05	<0.05	0.2	<.1	27.1	<.1	<.5
20 d	4.46	12	<0.1	<0.1	5.9	2.3	29	<0.5	1.2	<2	0.02	5.31	<0.05	6.85	<0.05	<0.05	<0.05	1.3	<.1	20.5	3.1	0.8
21 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21 d	1.4	12	0.5	<0.1	8.1	4.6	NA	<0.5	0.72	<2	0.03	5.68	<0.05	5.73	<0.05	<0.05	<0.05	0.6	<.1	47.6	3.2	2.8
22 s	4.1	5.2	<0.1	<0.1	10	4.6	33	<0.5	0.72	<2	0.02	3.65	<0.05	2.11	<0.05	<0.05	<0.05	0.5	<.1	19.5	3.1	5.2
22 d	4.56	10	0.1	<0.1	3.5	5.9	33	<0.5	<0.5	<2	0.03	5.03	<0.05	5.53	<0.05	<0.05	<0.05	0.5	<.1	22	2.5	6.3
23 b	5.88	4.8	<0.1	<0.1	3.7	2.2	8.7	<0.5	<0.5	<2	0.03	1.6	<0.05	1.34	<0.05	<0.05	<0.05	0.2	<.1	11.6	6.6	1
23 g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 o	5.25	7.6	0.12	<0.1	5.5	4.6	34	<0.5	4	9	0.04	3.52	<0.05	3.9	<0.05	<0.05	<0.05	0.2	<.1	21.4	2.6	15.5
23 y	4.37	13	<0.1	<0.1	7.5	1.5	25	<0.5	<0.5	<2	0.05	6.2	<0.05	5.88	<0.05	<0.05	<0.05	1.4	<.1	12.5	4.1	15.9
24 s	4.62	20	<0.1	<0.1	8	4.7	13	<0.5	2.4	4	0.1	3.91	<0.05	5.73	<0.05	<0.05	<0.05	1	<.1	10.2	3.7	34.7
24 d	4.49	11	<0.1	<0.1	2.4	2.3	19	<0.5	0.5	<2	0.04	4.36	<0.05	5.16	<0.05	<0.05	<0.05	1	<.1	9.4	3.7	12
25 s	4.76	4.7	<0.1	<0.1	6.5	5.6	423	<0.5	8.2	7	0.02	1.37	<0.05	5.12	<0.05	<0.05	<0.05	0.4	<.1	258	3.7	7.3
25 d	4.27	10	0.4	<0.1	6.4	4.7	243	<0.5	1.4	<2	0.02	3.75	<0.05	3.98	<0.05	<0.05	<0.05	1.1	<.1	148	3.4	3.4
26 s	5.81	5.8	0.42	<0.1	49	44	17	<0.5	4.2	6	0.07	4.07	<0.05	4.42	<0.05	<0.05	<0.05	0.2	1.9	13.6	3.6	0.9
26 m	5.21	2.4	1.8	<0.1	23	32	16	<0.5	7.5	11	0.12	3.01	<0.05	5.19	<0.05	<0.05	<0.05	0.2	9.4	10.9	3.7	1.6
26 d	4.45	15	<0.1	<0.1	10	8.1	35	<0.5	<0.5	<2	0.03	4.72	<0.05	5.43	<0.05	<0.05	<0.05	2.3	<.1	10.3	3.7	22.8

May 15, 1994 Sampson Co
Field Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH
1	19.00	99.40	85.40	9.00	90.40	7.50	50.00	NA	121.10	4.33
2 d	25.90	99.01	74.11	9.10	89.91	4.00	58.00	NA	130.40	6.06
2	19.00	98.98	84.98	8.80	90.18	3.20	60.00	NA	126.70	4.47
3 d	20.08	98.30	80.72	7.90	90.40	3.80	50.00	NA	89.60	5.10
3	15.00	98.38	88.38	8.10	90.28	0.70	126.00	NA	88.60	5.31
4	14.00	99.03	90.03	NA	NA	NA	NA	NA	NA	NA
5 d	26.00	98.37	77.37	8.80	89.57	3.20	42.00	NA	75.10	4.71
5	14.00	98.50	89.50	8.80	89.70	0.50	84.00	NA	70.00	4.61
6 d	26.00	97.77	76.77	8.40	89.37	0.60	48.00	NA	134.50	5.09
6	14.00	98.06	89.06	8.00	90.06	3.60	94.00	NA	114.50	4.66
7	14.00	96.43	87.43	NA	NA	NA	NA	NA	NA	NA
8	14.00	98.41	89.41	NA	NA	NA	NA	NA	NA	NA
9	14.00	98.22	89.22	7.80	90.42	7.80	58.00	NA	121.40	4.42
10 d	24.25	93.74	71.99	4.37	89.37	7.50	56.00	NA	133.40	4.22
10 s	21.00	93.72	75.22	4.18	89.54	7.00	44.00	NA	136.90	
10	11.04	93.54	85.00	4.15	89.39	7.60	NA	NA	NA	NA
11 d	23.00	94.07	73.57	4.64	89.43	3.80	60.00	NA	131.80	4.36
11 s	9.92	94.10	86.68	4.43	89.67	8.00	NA	NA	NA	NA
11	15.42	94.17	81.25	4.75	89.42	1.80	46.00	NA	108.80	4.20
12 d	27.00	95.08	70.58	5.80	89.28	0.30	76.00	NA	75.00	4.46
12 m	19.25	95.10	78.35	5.80	89.30	0.70	62.00	NA	80.10	4.22
12 s	11.58	94.95	85.87	5.66	89.29	1.20	72.00	NA	88.90	4.33
13 m	17.00	96.03	81.53	NA	NA	1.80	50.00	NA	72.10	4.43
13	12.00	95.83	86.33	6.60	89.23	3.90	44.00	NA	94.00	5.80
14 m	14.00	96.88	85.38	7.55	89.33	1.50	50.00	NA	73.60	4.38
14	11.00	96.77	88.27	7.45	89.32	3.10	58.00	NA	79.30	5.09
15 d	19.21	92.33	75.62	5.25	87.08	3.20	28.00	15.90	101.80	4.04
15 s	9.92	92.33	84.91	4.31	88.02	4.80	58.00	16.40	107.80	4.19
15	14.92	92.60	80.18	NA	NA	NA	NA	NA	NA	NA
16 d	17.75	92.37	77.12	4.55	87.82	2.80	42.00	15.60	57.00	4.11
16 s	9.83	92.39	85.06	4.56	87.83	2.50	48.00	15.40	81.00	4.16
16	14.77	92.72	80.45	4.86	87.86	1.00	64.00	15.60	38.30	4.11

May 15, 1994 Sampson Co
Field Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH
17 d	19.52	92.78	75.76	5.07	87.71	1.60	64.00	15.50	42.80	4.32
17 s	10.17	92.76	85.09	5.03	87.73	3.10	38.00	16.00	73.00	4.15
17	14.79	92.83	80.54	5.00	87.83	2.40	54.00	15.80	30.00	4.32
18 d	17.25	92.79	78.04	5.05	87.74	0.60	54.00	14.90	31.10	4.33
18 s	10.17	92.83	85.16	5.09	87.74	3.40	44.00	15.60	61.10	4.09
18	15.17	92.77	80.10	4.99	87.78	0.60	56.00	15.20	22.50	4.31
19 d	19.42	92.87	75.95	5.19	87.68	2.70	56.00	16.00	41.10	4.40
19 s	10.19	92.87	85.18	5.12	87.75	3.40	44.00	15.80	49.00	4.18
19	14.81	92.96	80.65	5.21	87.75	3.40	50.00	15.40	54.80	4.30
20 d	15.08	92.93	80.35	5.10	87.83	4.80	70.00	15.30	40.20	4.25
20 s	10.13	92.97	85.35	5.00	87.97	5.50	43.00	15.80	45.50	4.19
21 d	15.92	98.50	85.08	8.60	89.90	0.80	64.00	NA	78.80	4.53
21 s	9.29	98.57	91.78	8.60	89.97	NA		NA		
22 d	16.38	98.30	84.43	8.40	89.90	0.70	54.00	NA	57.90	4.82
22 s	10.08	98.23	90.65	8.40	89.83	NA	NA	NA	NA	NA
23 b	23.25	97.75	77.00	NA	NA	NA	NA	NA	NA	NA
23 g	8.92	97.86	91.44	8.00	89.86	NA	NA	NA	NA	NA
23 o	14.38	97.74	85.87	7.90	89.84	0.80	72.00	NA	49.10	4.59
23 y	19.50	97.74	80.74	8.00	89.74	3.30	48.00	NA	86.00	4.50
24 d	18.08	97.65	82.07	8.20	89.45	6.60	54.00	NA	103.60	4.48
24 s	9.08	97.65	91.07	7.90	89.75	NA	NA	NA	NA	NA
25 d	15.88	99.00	85.63	8.60	90.40	5.00	30.00	NA	128.10	4.40
25 s	9.75	99.05	91.80	8.60	90.45	NA	NA	NA	NA	NA
26 d	19.21	98.26	81.55	7.90	90.36	6.00	90.00	NA	102.10	4.13
26 m	14.50	98.30	86.30	7.90	90.40	0.80	108.00	NA	94.50	4.75
26 s	9.50	98.31	91.31	7.90	90.41	NA	NA	NA	NA	NA

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Soil Science Results

Well#	pH	NO3 ppm N	NH4 ppm N	PO4 ppm P	IC ppm C	TOC ppm C	Cl ppm	Br ppm	SO4 ppm SO4	ICP-SO4 ppm SO4	Mn ppm	Mg ppm	Zn ppm	Ca ppm	Cd ppm	Cu ppm	Ni ppm	Al ppm	Fe ppm	Na ppm	Si ppm	K ppm
1	4.42	16	<0.1	<0.1	7.2	1.4	116	0.33	0.83	<2	0.01	4.44	<0.05	3.84	<0.05	<0.05	<0.05	0.9	<0.1	69.2	3.2	4.2
2	4.32	13	<0.1	<0.1	10	1.6	20	<0.2	<0.5	<2	0.03	4.54	<0.05	5.01	<0.05	<0.05	<0.05	1.2	<0.1	14.6	3.5	11.2
2 d	5.92	2.3	<0.1	<0.1	9.6	2	3.8	<0.2	0.68	<2	0.02	0.52	0.07	2.45	<0.05	<0.05	<0.05	<0.1	<0.1	7.2	5.9	4
3	5.56	22	0.36	<0.1	18	19	29	0.44	0.51	<2	0.07	10.7	<0.05	12.2	<0.05	<0.05	<0.05	0.1	0.1	29	2.6	1.1
3 d	4.46	20	0.18	<0.1	9.6	6.9	20	0.23	1.2	4	0.07	8	0.53	10.8	<0.05	<0.05	<0.05	0.3	0.1	18.1	2.9	6.3
4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	4.76	11	0.35	<0.1	14	6.7	174	<0.2	0.68	<2	0.04	3.85	<0.05	3.11	<0.05	<0.05	<0.05	0.6	<0.1	109	3.1	4.3
5 d	5.19	3.4	<0.1	<0.1	6.9	2.8	11	<0.2	3.5	4	0.26	1.61	<0.05	1.52	<0.05	<0.05	<0.05	<0.1	<0.1	9.7	6.6	1.9
6	4.87	18	<0.1	<0.1	12	3.1	24	<0.2	1.7	2	0.06	7.59	<0.05	13	<0.05	<0.05	<0.05	0.7	<0.1	11.7	2.7	14.8
6 d	5.44	<0.1	<0.1	<0.1	8	1.5	3.5	<0.2	6.7	8	0.03	0.76	<0.05	0.83	<0.05	<0.05	<0.05	<0.1	0.1	4.6	6.8	2.1
7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	4.23	17	<0.1	<0.1	6.4	4.8	16	<0.2	3.6	2	0.03	10.2	<0.05	9.13	<0.05	<0.05	<0.05	1.3	<0.1	7.1	2.9	1.5
10 s	4.33	13	<0.1	<0.1	8.2	2.1	16	<0.2	<0.5	<2	0.03	7.03	<0.05	4.79	<0.05	<0.05	<0.05	1.3	<0.1	9.2	3.4	6.1
10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10 d	4.22	13	<0.1	<0.1	8.1	1.9	16	<0.2	<0.5	<2	0.03	7.04	<0.05	4.68	<0.05	<0.05	<0.05	1.3	<0.1	8.6	3.2	5.9
11 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	4.4	15	<0.1	<0.1	9.2	3.8	26	0.22	<0.5	<2	0.03	6.65	<0.05	6.86	<0.05	<0.05	<0.05	0.9	<0.1	13.6	3.2	9.4
11 d	4.38	11	<0.1	<0.1	7.2	1.8	18	0.3	0.74	<2	0.05	5.83	0.17	5.81	<0.05	<0.05	<0.05	0.9	<0.1	12.1	4.4	5.8
12 s	4.33	12	<0.1	<0.1	12	5.8	47	0.34	1.3	11	0.04	5.02	<0.05	3.97	<0.05	<0.05	<0.05	0.9	<0.1	36.5	3.5	4.3
12 m	4.4	13	<0.1	<0.1	14	9.3	41	<0.2	0.57	<2	0.05	5.94	<0.05	5	<0.05	<0.05	<0.05	1.1	<0.1	29.5	3.7	4.6
12 d	4.64	7.6	<0.1	<0.1	11	7	19	<0.2	<0.5	21	0.04	4.1	<0.05	2.88	<0.05	<0.05	<0.05	0.2	<0.1	17.5	4.5	1.6
13	5.02	5.5	<0.1	<0.1	8.3	2.3	33	<0.2	3.2	4	0.02	3.35	<0.05	3.48	<0.05	<0.05	<0.05	0.2	<0.1	26.3	3.2	2.1
13 m	5.5	13	<0.1	<0.1	12	5.2	92	<0.2	2.4	3	0.03	4.17	<0.05	5.84	<0.05	<0.05	<0.05	0.2	0.1	73.8	4.3	3
14	5.57	0.35	<0.1	<0.1	8.5	9.2	5.7	<0.2	3.2	4	0.01	0.81	0.06	1.74	<0.05	<0.05	<0.05	0.1	<0.1	4.1	2.5	2.5
14 m	4.86	8.6	<0.1	<0.1	8.6	3.1	78	<0.2	0.67	<2	0.03	4.39	<0.05	2.75	<0.05	<0.05	<0.05	0.3	<0.1	54.8	3.3	1.7
15 s	4.33	5.4	<0.1	<0.1	7.3	1.9	16	0.5	3.5	5	0.01	2.66	<0.05	0.99	<0.05	<0.05	<0.05	0.8	<0.1	12.8	3.8	0.4
15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15 d	4.2	6.4	<0.1	<0.1	7.7	1.5	16	<0.2	0.88	<2	0.02	3.22	<0.05	1.26	<0.05	<0.05	<0.05	0.7	<0.1	11.5	3.6	0.5
16 s	4.37	7.6	<0.1	<0.1	6.8	2	16	0.3	0.66	<2	0.03	3.62	<0.05	2.61	<0.05	<0.05	<0.05	1.1	<0.1	11.7	3.6	1.2
16	4.36	7.9	<0.1	<0.1	9.2	2.2	17	<0.2	<0.5	<2	0.04	3.91	<0.05	2.37	<0.05	<0.05	<0.05	1	<0.1	13.4	3.5	0.7
16 d	3.72	7.7	<0.1	<0.1	6.2	2.2	17	0.25	8.5	<2	0.03	3.87	<0.05	2.4	<0.05	<0.05	<0.05	1	<0.1	12.4	3.6	0.9

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Soil Science Results

Well#	pH	NO3 ppm N	NH4 ppm N	PO4 ppm P	IC ppm C	TOC ppm C	Cl ppm	Br ppm	SO4 ppm SO4	ICP-SO4 ppm SO4	Mn ppm	Mg ppm	Zn ppm	Ca ppm	Cd ppm	Cu ppm	Ni ppm	Al ppm	Fe ppm	Na ppm	Si ppm	K ppm
17 s	4.26	9.4	<0.1	<0.1	5.1	5.1	18	<0.2	1.1	<2	0.06	3.81	<0.05	7.06	<0.05	<0.05	<0.05	1.6	<0.1	11.3	3.6	1.3
17	4.31	10	<0.1	<0.1	7.4	4.1	33	<0.2	1.9	<2	0.03	3.56	<0.05	2.42	<0.05	<0.05	<0.05	0.7	<0.1	25.7	3.8	1.5
17 d	4.52	9	<0.1	<0.1	8.8	4	24	<0.2	<0.5	4	0.04	3.72	<0.05	2.3	<0.05	<0.05	<0.05	0.3	<0.1	23.9	3.9	1
18 s	4.27	8.8	<0.1	<0.1	7.6	2.1	20	<0.2	3.9	5	0.05	3.95	<0.05	6.51	<0.05	<0.05	<0.05	1	<0.1	16.3	3.7	0.5
18	4.53	10	<0.1	<0.1	8.4	1.6	25	<0.2	<0.5	<2	0.02	3.38	<0.05	1.88	<0.05	<0.05	<0.05	0.5	<0.1	27.9	3.8	1.1
18 d	4.62	9.4	<0.1	<0.1	7.3	2.7	29	0.33	0.7	4	0.02	3.32	<0.05	1.91	<0.05	<0.05	<0.05	0.38	<0.1	27.1	4	1.5
19 s	4.35	10	<0.1	<0.1	6.9	2.4	21	0.33	6	7	0.03	4.55	<0.05	7.39	<0.05	<0.05	<0.05	0.9	<0.1	18.1	3.6	1.2
19	4.58	11	<0.1	<0.1	8.6	2.2	26	0.35	1.2	2	0.03	3.82	<0.05	2.49	<0.05	<0.05	<0.05	0.4	<0.1	29.6	3.8	1.6
19 d	4.87	9.2	<0.1	<0.1	6.7	7.1	29	<0.2	1.2	<2	0.02	3.32	<0.05	2.23	<0.05	<0.05	<0.05	0.1	<0.1	25.7	4.1	0.2
20 s	4.39	11	<0.1	<0.1	5.2	2.4	28	0.82	<0.5	<2	0.02	4.74	<0.05	5.32	<0.05	<0.05	<0.05	1	<0.1	22.4	3.3	1.4
20 d	4.39	12	<0.1	<0.1	7	1.6	35	0.57	<0.5	<2	0.02	4.37	<0.05	4.31	<0.05	<0.05	<0.05	1	<0.1	29.7	3.2	1
21 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21 d	4.45	13	0.31	<0.1	8	2.8	118	<0.2	<0.5	<2	0.04	5.13	<0.05	4.77	<0.05	<0.05	<0.05	0.8	<0.1	58	3.4	3.5
22 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22 d	4.77	10	0.16	<0.1	10	6.3	85	<0.2	0.74	<2	0.03	4.24	<0.05	4.53	<0.05	<0.05	<0.05	0.3	<0.1	50.5	2.8	7.1
23 b	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 o	4.8	7.8	<0.1	<0.1	9.7	10	60	0.33	1.5	3	0.03	3.94	<0.05	4.28	<0.05	<0.05	<0.05	0.6	<0.1	34.5	2.9	10.5
23 y	4.33	12	<0.1	<0.1	7.7	1.9	23	0.27	<0.5	<2	0.05	5.06	<0.05	4.94	<0.05	<0.05	<0.05	1.3	<0.1	11.3	3.8	13.8
24 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
24 d	4.45	9.6	<0.1	<0.1	6	3.7	18	0.27	<0.5	<2	0.03	4.08	<0.05	4.25	<0.05	<0.05	<0.05	1.1	<0.1	9.6	3.5	9.7
25 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25 d	4.42	12	<0.1	<0.1	4.9	2.1	121	<0.2	0.67	<2	0.02	5.13	<0.05	3.62	<0.05	<0.05	<0.05	1.4	<0.1	86.7	3.1	2
26 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26 m	5	6.6	0.29	<0.1	27	43	19	0.35	2.3	3	0.06	4.96	<0.05	3.97	<0.05	<0.05	<0.05	0.1	0.8	13.4	3.5	2.3
26 d	3.81	13	<0.1	<0.1	10	6.9	38	0.27	<0.5	<2	0.03	4.41	<0.05	5.02	<0.05	<0.05	<0.05	2.2	<0.1	10.4	3.6	23.8

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Field Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH
1	19.00	99.40	85.40	9.75	89.65	7.30	53	19.40	426.00	5.70
2 d	25.90	99.01	74.11	8.83	90.18	3.90	57	19.20	400.00	6.50
2	19.00	98.98	84.98	8.92	90.06	3.30	69	19.90	454.00	5.60
3 d	20.08	98.30	80.72	8.08	90.22	1.20	86	20.30	412.00	5.42
3	15.00	98.38	88.38	8.17	90.21	0.40	110	19.70	391.00	5.60
4	14.00	99.03	90.03	8.58	90.45	8.00	33	19.80	400.00	5.61
5 d	26.00	98.37	77.37	8.58	89.79	2.20	50	17.70	428.00	5.93
5	14.00	98.50	89.50	8.75	89.75	0.50	101	17.80	410.00	5.80
6 d	26.00	97.77	76.77	8.67	89.10	1.70	55	19.80	374.00	6.40
6	14.00	98.06	89.06	8.00	90.06	5.50	76	20.40	486.00	5.60
7	14.00	96.43	87.43	NA	NA	NA	NA	NA	NA	NA
8	14.00	98.41	89.41	NA	NA	NA	NA	NA	NA	NA
9	14.00	98.22	89.22	7.83	90.39	8.00	62	20.00	447.00	5.15
10 d	24.25	93.74	71.99	4.33	89.41	5.80	73	20.60	459.00	5.94
10 s	21.00	93.72	75.22	4.33	89.39	7.00	82	20.50	456.00	5.11
10	11.04	93.54	85.00	4.17	89.37	5.70	55	21.20	424.00	5.47
11 d	23.00	94.07	73.57	4.67	89.40	6.40	59	18.10	510.00	5.60
11 s	9.92	94.10	86.68	4.75	89.35	5.50	73	20.90	446.00	5.41
11	15.42	94.17	81.25	4.75	89.42	4.40	104	20.60	477.00	5.40
12 d	27.00	95.08	70.58	5.92	89.16	1.80	88	18.90	471.00	5.53
12 m	19.25	95.10	78.35	5.67	89.43	0.90	103	20.50	487.00	5.32
12 s	11.58	94.95	85.87	5.83	89.12	1.80	99	19.90	484.00	5.34
13 m	17.00	96.03	81.53	NA	NA	NA	NA	NA	NA	NA
13	12.00	95.83	86.33	6.50	89.33	2.40	85	20.80	354.00	5.75
14 m	14.00	96.88	85.38	7.50	89.38	1.20	73	20.10	419.00	5.30
14	11.00	96.77	88.27	7.58	89.19	2.80	93	20.80	387.00	5.80
15 d	19.21	92.33	75.62	4.47	87.86	2.40	80	17.90	321.00	4.58
15 s	9.92	92.33	84.91	4.00	88.33	6.00	61	20.80	404.00	5.06
15	14.92	92.60	80.18	4.25	88.35	6.40	76	20.30	388.00	5.01
16 d	17.75	92.37	77.12	4.17	88.20	3.70	75	20.30	330.00	4.84
16 s	9.83	92.39	85.06	4.17	88.22	4.20	83	21.10	399.00	5.39

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Field Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH
16	14.77	92.72	80.45	4.50	88.22	3.20	NA	20.60	322.00	4.67
17 d	19.52	92.78	75.76	4.83	87.95	1.90	113	20.30	325.00	5.15
17 s	10.17	92.76	85.09	4.70	88.06	3.20	77	21.30	320.70	4.79
17	14.79	92.83	80.54	4.67	88.16	1.20	71	21.20	310.00	4.77
18 d	17.25	92.79	78.04	4.83	87.96	0.30	86	20.30	350.00	4.93
18 s	10.17	92.83	85.16	4.83	88.00	4.90	62	21.00	362.00	4.74
18	15.17	92.77	80.10	4.75	88.02	2.90	83	20.80	358.00	4.98
19 d	19.42	92.87	75.95	5.08	87.79	2.50	77	19.70	345.00	5.20
19 s	10.19	92.87	85.18	4.92	87.95	4.40	70	21.10	366.00	4.82
19	14.81	92.98	80.65	5.00	87.98	3.60	75	21.20	347.00	5.30
20 d	15.08	92.93	80.35	4.92	88.01	4.40	NA	21.50	360.00	4.90
20 s	10.13	92.97	85.35	4.92	88.05	4.60	66	21.30	365.00	5.00
21 d	15.92	98.50	85.08	8.75	89.75	1.10	54	17.80	403.00	5.58
21 s	9.29	98.57	91.78	NA	NA	NA	NA	NA	NA	NA
22 d	16.38	98.30	84.43	8.50	89.80	0.80	91	17.80	449.00	5.80
22 s	10.08	98.23	90.65	8.50	89.73	2.60	76	18.50	441.00	5.55
23 b	23.25	97.75	77.00	8.00	89.75	5.00	63	17.60	451.00	5.75
23 g	8.92	97.86	91.44	NA	NA	NA	NA	NA	NA	NA
23 o	14.38	97.74	85.87	7.83	89.91	0.40	103	18.30	440.00	5.98
23 y	19.50	97.74	80.74	7.83	89.91	4.20	72	18.40	470.00	5.36
24 d	18.08	97.65	82.07	7.83	89.82	6.90	64	20.00	483.00	5.53
24 s	9.08	97.65	91.07	7.58	90.07	5.00	110	21.80	392.00	6.74
25 d	15.88	99.00	85.63	8.83	90.17	1.80	74	19.80	448.00	5.00
25 s	9.75	99.05	91.80	8.92	90.13	5.60	77	21.00	429.00	5.02
26 d	19.21	98.26	81.55	8.00	90.26	0.90	115	20.60	409.00	4.92
26 m	14.50	98.30	86.30	8.00	90.30	0.20	212	20.20	340.00	5.50
26 s	9.50	98.31	91.31	8.17	90.14	0.20	450	21.30	285.00	5.40

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Soil Science Results

Well#	pH	NO3 ppm N	NH4 ppm N	PO4 ppm P	IC ppm C	TOC ppm C	Cl ppm	Br ppm	SO4 ppm SO4	ICP-SO4 ppm SO4	Mn ppm	Mg ppm	Zn ppm	Ca ppm	Cd ppm	Cu ppm	Ni ppm	Al ppm	Fe ppm	Na ppm	Si ppm	K ppm
1	4.38	17	< 0.1	< 0.01	1.9	2.3	110	< 0.5	< 0.5	< 2	0.02	5.45	< 0.05	5.13	< 0.05	< 0.05	< 0.1	1.1	< 0.1	83.2	3.5	3.1
2	4.37	10	< 0.1	< 0.01	2.6	1.8	24.8	< 0.5	< 0.5	< 2	0.03	4.07	< 0.05	4.93	< 0.05	< 0.05	< 0.1	1.2	< 0.1	13.2	3.6	11.5
2 d	5.86	2.2	< 0.1	0.01	3.4	2.8	3.4	< 0.5	< 0.5	< 2	0.02	0.45	< 0.05	0.79	< 0.05	< 0.05	< 0.1	0.1	< 0.1	6	6	< 2
3	5.66	25	0.24	< 0.01	5.8	11.7	24.1	< 0.5	< 0.5	< 2	0.06	12.7	< 0.05	14.5	< 0.05	< 0.05	< 0.1	0.2	< 0.1	26.2	2.8	< 2
3 d	5.34	27	< 0.1	< 0.01	2..1	5.3	21.5	0.63	< 0.5	< 2	0.07	12.1	0.16	14.1	< 0.05	< 0.05	< 0.1	0.5	< 0.1	21.9	3.5	4.3
4	4.56	9.5	< 0.1	< 0.01	0.7	2.9	4.9	< 0.5	< 0.5	< 2	< 0.02	4.98	< 0.05	3.69	< 0.05	< 0.05	< 0.1	1	< 0.1	4.1	3.2	< 2
5	4.66	11	0.39	< 0.01	1.8	5.8	137	< 0.5	< 0.5	< 2	0.03	3.85	< 0.05	2.99	< 0.05	< 0.05	< 0.1	0.7	< 0.1	106	3.2	5.2
5 d	5.62	3.1	< 0.1	0.01	1.6	3.6	8.2	< 0.5	3.1	4	0.25	1.56	< 0.05	1.41	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	8.7	7	< 2
6	4.5	20	< 0.1	< 0.01	3.1	1.4	24.4	< 0.5	0.79	< 2	0.05	7.54	< 0.05	12.3	< 0.05	< 0.05	< 0.1	1.1	< 0.1	11	3	14.3
6 d	5.65	< 0.1	< 0.1	0.02	2.7	4.9	3.3	< 0.5	6.4	8	0.02	0.82	< 0.05	0.99	< 0.05	< 0.05	< 0.1	< 0.1	0.2	4.3	6.8	< 2
7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	4.3	15	< 0.1	< 0.01	1.2	1.2	17.9	< 0.5	0.79	< 2	0.03	8.53	< 0.05	8.58	< 0.05	< 0.05	< 0.1	1.6	< 0.1	6.7	3.5	< 2
10 s	3.14	12	< 0.1	< 0.01	1	3.1	39.2	< 0.5	< 0.5	< 2	0.03	7.28	< 0.05	4.57	< 0.05	< 0.05	< 0.1	1.3	< 0.1	7.7	3.7	5.4
10	5.2	6.6	< 0.1	< 0.01	5.3	16.7	20	3.47	1	< 2	0.04	3.78	< 0.05	5.14	< 0.05	< 0.05	< 0.1	0.3	< 0.1	6	3.5	5.2
10 d	4.34	12	< 0.1	< 0.01	1.9	2.7	19.8	< 0.5	< 0.5	< 2	0.03	7.35	< 0.05	4.73	< 0.05	< 0.05	< 0.1	1.3	< 0.1	7.7	3.7	5.6
11 s	5.21	1.6	< 0.1	< 0.01	2.5	4	10.3	< 0.5	6.3	7	< 0.02	1.83	< 0.05	5.34	< 0.05	< 0.05	< 0.1	< 0.1	0.1	2.9	3.4	2.7
11	3.44	15	< 0.1	< 0.01	0.7	3.9	30.4	< 0.5	< 0.5	< 2	0.04	6.92	< 0.05	7.4	< 0.05	< 0.05	< 0.1	0.8	< 0.1	8.9	3.6	10.3
11 d	3.12	11	< 0.1	< 0.01	1.4	3.2	44.4	< 0.5	0.66	< 2	0.05	5.47	< 0.05	5.64	< 0.05	< 0.05	< 0.1	0.8	< 0.1	10.7	4.7	5.3
12 s	4.22	6.7	< 0.1	< 0.01	1.3	3.8	23.6	< 0.5	< 0.5	< 2	0.03	3.3	< 0.05	2.62	< 0.05	< 0.05	< 0.1	0.5	< 0.1	18.4	3.5	3.8
12 m	4.12	8.2	< 0.1	< 0.01	1.4	4	27.6	< 0.5	< 0.5	< 2	0.03	3.93	< 0.05	3.59	< 0.05	< 0.05	< 0.1	0.6	< 0.1	22.8	3.7	4.8
12 d	4.84	7.7	< 0.1	< 0.01	3.7	3.8	21.1	< 0.5	< 0.5	< 2	0.04	4.29	< 0.05	3.1	< 0.05	< 0.05	< 0.1	0.2	< 0.1	17.7	5	< 2
13	3.26	2.1	< 0.1	0.02	1.9	1.5	40.4	< 0.5	3.5	5	0.02	1.63	< 0.05	2.03	< 0.05	< 0.05	< 0.1	< 0.1	3.2	11	3.8	< 2
13 m	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14	5.42	0.15	< 0.1	< 0.01	4.1	1.6	5.1	< 0.5	2.6	4	< 0.02	0.67	0.09	1.52	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	4.2	3.2	< 2
14 m	3.33	10	< 0.1	< 0.01	1.2	2	102	< 0.5	< 0.5	< 2	0.02	4.54	< 0.05	2.9	< 0.05	< 0.05	< 0.1	0.4	< 0.1	59	3.9	< 2
15 s	4.14	6.4	< 0.1	0.01	1.3	11.8	12.9	< 0.5	1.4	2	0.03	3.09	< 0.05	2.2	< 0.05	< 0.05	< 0.1	0.4	< 0.1	11.2	4	< 2
15	4.5	6.2	< 0.1	< 0.01	1.3	4	14.1	< 0.5	< 0.5	< 2	0.02	3.44	< 0.05	1.38	< 0.05	< 0.05	< 0.1	0.5	< 0.1	12.3	3.7	< 2
15 d	4.04	5.2	< 0.1	0.01	3.2	5	14.1	< 0.5	3.3	4	0.02	2.54	< 0.05	1.06	< 0.05	< 0.05	< 0.1	0.5	< 0.1	12.1	4.3	< 2
16 s	4.43	7.3	< 0.1	< 0.01	2.6	2.1	17	< 0.5	1	< 2	0.03	3.29	< 0.05	3.7	< 0.05	< 0.05	< 0.1	0.9	< 0.1	10.1	4	< 2
16	3.85	8	< 0.1	< 0.01	1.7	4.9	22	< 0.5	< 0.5	< 2	0.03	3.67	< 0.05	2.08	< 0.05	< 0.05	< 0.1	0.9	< 0.1	12.4	4	< 2
16 d	4.2	8.2	< 0.1	< 0.01	2.4	3	17.3	< 0.5	< 0.5	< 2	0.03	4.2	< 0.05	2.28	< 0.05	< 0.05	< 0.1	1	< 0.1	10.9	4.1	< 2

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Soil Science Results

Well#	pH	NO3 ppm N	NH4 ppm N	PO4 ppm P	IC ppm C	TOC ppm C	Cl ppm	Br ppm	SO4 ppm SO4	ICP-SO4 ppm SO4	Mn ppm	Mg ppm	Zn ppm	Ca ppm	Cd ppm	Cu ppm	Ni ppm	Al ppm	Fe ppm	Na ppm	Si ppm	K ppm
17 s	4.19	9.5	< 0.1	< 0.01	2.6	4.21	23.1	< 0.5	1.2	< 2	0.05	3.57	< 0.05	6.42	< 0.05	< 0.05	< 0.1	1.3	< 0.1	12.9	4.3	< 2
17	4.25	9.6	< 0.1	< 0.01	3.8	3	24.3	< 0.5	< 0.5	< 2	0.03	3.95	< 0.05	3.31	< 0.05	< 0.05	< 0.1	0.9	< 0.1	17.9	3.9	< 2
17 d	4.37	9	< 0.1	< 0.01	1.5	4	24.6	< 0.5	< 0.5	< 2	0.03	4.43	< 0.05	2.11	< 0.05	< 0.05	< 0.1	0.7	< 0.1	19.8	4.4	< 2
18 s	3.99	9.3	< 0.1	< 0.01	1.6	5.2	27.6	0.65	2.5	3	0.05	4.33	< 0.05	9.31	< 0.05	< 0.05	< 0.1	1.4	< 0.1	11.7	4.4	< 2
18	2.91	10	< 0.1	0.01	4.2	3.2	71.2	< 0.5	0.88	< 2	0.04	3.72	< 0.05	4.15	< 0.05	< 0.05	< 0.1	0.7	< 0.1	25.3	4.1	< 2
18 d	2.98	10	< 0.1	< 0.01	1.4	2.8	67.9	< 0.5	0.8	< 2	0.02	3.43	< 0.05	1.86	< 0.05	< 0.05	< 0.1	0.4	< 0.1	29.4	4.3	< 2
19 s	3.19	11	< 0.1	< 0.01	1.2	6.2	46.5	0.77	2	3	0.03	4.25	< 0.05	3.73	< 0.05	< 0.05	< 0.1	1	< 0.1	23.5	4	< 2
19	4.16	12	< 0.1	< 0.01	3.6	2.1	39.1	< 0.5	0.64	< 2	0.02	4.03	< 0.05	2.14	< 0.05	< 0.05	< 0.1	0.5	< 0.1	32.9	4.4	< 2
19 d	2.93	9.4	< 0.1	< 0.01	1.3	2.7	82.3	< 0.5	0.82	< 2	0.02	3.08	< 0.05	1.6	< 0.05	< 0.05	< 0.1	0.3	< 0.1	28	4.1	< 2
20 s	4.02	12	< 0.1	0.01	3.3	5.4	39.9	0.84	12.7	< 2	0.02	4.15	< 0.05	4.59	< 0.05	< 0.05	< 0.1	1	< 0.1	29.6	3.9	< 2
20 d	4.09	13	< 0.1	< 0.01	1.6	5	38.7	0.63	< 0.5	< 2	0.02	4.04	< 0.05	3.99	< 0.05	< 0.05	< 0.1	0.9	< 0.1	31.5	3.8	< 2
21 s	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
21 d	4.26	11	0.41	< 0.01	1	3.7	61.7	< 0.5	< 0.5	< 2	0.03	4.83	< 0.05	4.85	< 0.05	< 0.05	< 0.1	0.9	< 0.1	39	3.1	4.2
22 s	4.7	9.8	< 0.1	< 0.01	3.3	2.9	38.3	< 0.5	< 0.5	< 2	0.03	4.43	< 0.05	4.4	< 0.05	< 0.05	< 0.1	0.5	< 0.1	24.4	3	7
22 d	4.41	10	< 0.1	< 0.01	2.1	2.3	30.8	< 0.5	< 0.5	< 2	0.03	4.09	< 0.05	4.33	< 0.05	< 0.05	< 0.1	0.4	< 0.1	21.1	2.7	5.9
23 b	4.97	7	< 0.1	< 0.01	3.1	2.4	15.8	< 0.5	< 0.5	< 2	0.04	3.08	< 0.05	2.41	< 0.05	< 0.05	< 0.1	0.1	< 0.1	11.2	5.4	2.9
23 g	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 o	5.42	8.7	0.15	< 0.01	3.7	5	NA	< 0.5	2.8	4	0.05	4.67	< 0.05	6.34	< 0.05	< 0.05	< 0.1	0.2	< 0.1	18.2	2.2	6.7
23 y	4.4	12	< 0.1	< 0.01	3.2	3.5	26.3	< 0.5	< 0.5	< 2	0.04	4.61	< 0.05	4.59	< 0.05	< 0.05	< 0.1	1.2	< 0.1	12.6	3.9	14
24 s	6.38	16	< 0.1	0.001	10.6	15	14.4	< 0.5	7.9	9	0.03	0.8	0.21	1.79	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	16.6	3.3	60.5
24 d	4.55	10	< 0.1	< 0.01	1.3	2.5	23.1	< 0.5	< 0.5	< 2	0.03	4.01	< 0.05	4.06	< 0.05	< 0.05	< 0.1	1	< 0.1	9.8	3.8	10.7
25 s	4.5	10	< 0.1	< 0.01	2.3	16.5	454	< 0.5	1.8	2	0.03	2.66	< 0.05	4.66	< 0.05	< 0.05	< 0.1	1	< 0.1	272	4.1	10.6
25 d	4.4	18	< 0.1	< 0.01	3.5	4.1	134	< 0.5	1.2	< 2	0.03	5.28	< 0.05	3.51	< 0.05	< 0.05	< 0.1	1.3	< 0.1	228	4.1	2.2
26 s	5.25	4.4	1.24	< 0.01	20.6	34	19.9	0.66	4	11	0.1	2.93	< 0.05	4.55	< 0.05	< 0.05	< 0.1	0.1	4.4	13.1	3.6	< 2
26 m	4.72	7.9	0.27	< 0.01	6.7	33.9	23.9	< 0.5	1.8	4	0.04	4.08	< 0.05	3.13	< 0.05	< 0.05	< 0.1	0.1	0.8	15.8	3.3	< 2
26 d	4.27	14	< 0.1	< 0.01	4.5	5.9	30.9	< 0.5	< 0.5	< 2	0.03	4.36	< 0.05	5.04	< 0.05	< 0.05	< 0.1	2.4	< 0.1	11	4	26.9

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Field and Soil Science Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH	NO3 ppm N	NO2 ppm N	TOC ppm C	Cl ppm
1	19.00	99.40	85.40	11.42	87.98	7.30	73	19.70	442.00	4.21	16.6	< 0.1	14.5	104
2 d	25.90	99.01	74.11	11.06	87.93	3.60	54	18.20	403.00	5.12	2.16	< 0.1	28.6	3.6
2	19.00	98.98	84.98	11.08	87.90	2.30	76	19.00	398.00	4.15	11.5	< 0.1	16.3	22.1
3 d	20.08	98.30	80.72	10.33	87.97	0.60	69	19.90	394.00	4.60	17.15	0.11	24.7	19.6
3	15.00	98.38	88.38	10.33	88.05	0.20	205	20.00	341.00	5.18	19.86	0.67	32.4	29.7
4	14.00	99.03	90.03	10.75	88.28	7.40	33	19.50	416.00	4.37	14.66	< 0.1	16.5	6.6
5 d	26.00	98.37	77.37	10.75	87.62	2.90	55	17.10	419.00	4.72	3.12	< 0.1	11.5	9.3
5	14.00	98.50	89.50	10.92	87.58	0.50	103	18.20	418.00	4.41	10.63	0.32	12.3	138
6 d	26.00	97.77	76.77	10.00	87.77	3.00	74	18.20	265.00	5.38	< 0.1	< 0.1	23.1	3.3
6	14.00	98.06	89.06	10.17	87.89	0.40	88	19.60	440.00	4.46	18.63	< 0.1	29.4	22.3
7	14.00	98.43	87.43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	14.00	98.41	89.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	14.00	98.22	89.22	10.00	88.22	7.60	66	19.90	448.00	4.26	15.71	< 0.1	18.2	16.1
10 d	24.25	93.74	71.99	6.50	87.24	6.10	67	19.20	446.00	4.27	12.01	< 0.1	11.4	15.8
10 s	21.00	93.72	75.22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	11.04	93.54	85.00	6.33	87.21	3.40	62	19.40	432.00	4.61	6.25	< 0.1	35.7	15.5
11 d	23.00	94.07	73.57	6.83	87.24	4.90	54	18.20	445.00	4.41	11.39	< 0.1	32.2	19.1
11 s	9.92	94.10	86.68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	15.42	94.17	81.25	6.92	87.25	4.50	64	19.20	440.00	4.29	14.16	< 0.1	8.7	19.1
12 d	27.00	95.06	70.56	8.06	87.00	0.50	59	18.40	403.00	4.54	7.9	0.16	27	23
12 m	19.25	95.10	78.35	7.92	87.18	0.40	88	19.00	415.00	4.29	10.43	0.11	47	31.4
12 s	11.58	94.95	85.87	7.83	87.12	0.40	74	19.20	398.00	4.37	7.6	< 0.1	64.3	25.7
13 m	17.00	96.03	81.53	8.92	87.11	0.70	65	19.50	389.00	4.47	9.91	< 0.1	22.1	90.7
13	12.00	95.83	86.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14 m	14.00	96.88	85.38	9.75	87.13	0.30	74	19.90	407.00	4.46	10.11	< 0.1	63.4	77.5
14	11.00	96.77	88.27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15 d	19.21	92.33	75.62	6.33	86.00	6.90	54	18.60	457.00	3.89	5.35	< 0.1	7.1	15.1
15 s	9.92	92.33	84.91	6.17	86.16	5.20	65	19.50	440.00	4.32	6.43	< 0.1	6	14.3
15	14.92	92.60	80.18	6.42	86.18	6.30	66	19.30	470.00	4.08	6.33	< 0.1	68	17
16 d	17.75	92.37	77.12	6.33	86.04	3.30	66	18.10	503.00	4.00	8.28	< 0.1	4.7	15.7
16 s	9.83	92.39	85.06	6.33	86.06	2.20	61	19.50	473.00	4.00	7.55	< 0.1	5.7	14.3
16	14.77	92.72	80.45	6.58	86.14	2.10	74	19.30	480.00	4.00	8.03	< 0.1	8	16.1

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Field and Soil Science Data

Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH	NO3 ppm N	NO2 ppm N	TOC ppm C	Cl ppm
17 d	19.52	92.78	75.76	6.92	85.86	0.20	78	19.00	448.00	4.14	9.41	< 0.1	7.3	23.7
17 s	10.17	92.76	85.09	6.83	85.93	1.50	57	19.50	460.00	4.04	9.57	< 0.1	8.6	21.3
17	14.79	92.83	80.54	6.83	86.00	0.30	86	19.40	459.00	4.08	9.69	0.1	7.4	24.4
18 d	17.25	92.79	78.04	6.92	85.87	0.30	78	19.40	437.00	4.34	9.48	< 0.1	20.1	33.7
18 s	10.17	92.83	85.16	7.00	85.83	2.00	96	19.60	450.00	3.98	9.95	< 0.1	42.7	24
18	15.17	92.77	80.10	6.92	85.85	0.40	89	19.50	450.00	4.72	10.28	< 0.1	12.6	32.4
19 d	19.42	92.87	75.95	7.25	85.62	1.30	72	19.30	445.00	4.23	9.46	< 0.1	13.8	33.8
19 s	10.19	92.87	85.16	7.08	85.79	3.20	73	19.70	471.00	4.08	11.51	< 0.1	30.5	31.9
19	14.81	92.96	80.65	7.17	85.79	1.90	75	19.70	460.00	4.16	11.56	< 0.1	16.9	40.7
20 d	15.08	92.93	80.35	7.08	85.85	3.30	65	19.70	424.00	4.12	11.95	< 0.1	14.2	42.8
20 s	10.13	92.97	85.35	7.00	85.97	3.30	71	19.90	470.00	4.10	12.41	< 0.1	17.8	35.4
21 d	15.92	98.50	85.08	10.92	87.58	0.40	91	17.60	412.00	4.26	12.2	0.26	21.4	41
21 s	9.29	98.57	91.78	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
22 d	18.38	98.30	84.43	10.75	87.55	1.60	75	17.80	422.00	4.48	10.72	< 0.1	17	26
22 s	10.08	98.23	90.65	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 b	23.25	97.75	77.00	10.00	87.75	3.90	62	17.80	421.00	4.75	6.39	< 0.1	12.8	12.6
23 g	8.92	97.88	91.44	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 o	14.38	97.74	85.87	10.00	87.74	0.50	119	18.60	379.00	4.95	4.93	0.33	22.9	36.4
23 y	19.50	97.74	80.74	10.00	87.74	4.20	65	18.10	431.00	4.40	11.3	< 0.1	42.1	23.6
24 d	18.08	97.65	82.07	9.92	87.73	6.80	65	18.60	455.00	4.20	9.77	< 0.1	40.2	20.5
24 s	9.08	97.65	91.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25 d	15.88	99.00	85.63	11.00	88.00	2.20	59	20.00	424.00	4.21	12.72	< 0.1	21.7	155
25 s	9.75	99.05	91.80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26 d	19.21	98.26	81.55	10.17	88.09	1.00	102	19.70	400.00	4.05	14.21	< 0.1	19.1	34.6
26 m	14.50	98.30	86.30	10.25	88.05	0.30	225	20.20	297.00	4.81	6.9	0.17	34.5	16
26 s	9.50	98.31	91.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH	NO3 ppm N	NO2 ppm N	TOC ppm C	Cl ppm	SO4 ppm SO4
1	19.00	99.40	85.40	8.25	91.15	6.10	NA	18.30	219.00	4.52	18.00	< 0.1	17.50	143.00	0.98
2 d	25.90	99.01	74.11	NA	NA	0.40	NA	17.50	190.00	5.23	2.20	< 0.1	6.10	3.70	< 0.5
2	19.00	98.98	84.98	7.92	91.06	4.20	NA	17.50	222.00	4.42	12.00	< 0.1	5.70	27.90	< 0.5
3 d	20.08	98.30	80.72	7.17	91.13	0.70	NA	17.40	204.00	4.80	15.00	< 0.1	6.40	21.40	< 0.5
3	15.00	98.38	88.38	7.17	91.21	0.40	NA	17.70	144.00	5.36	16.00	0.29	21.60	19.70	< 0.5
4	14.00	99.03	90.03	7.58	91.45	7.60	NA	17.10	243.00	4.94	10.00	< 0.1	4.60	4.80	1.50
5 d	26.00	98.37	77.37	7.50	90.87	1.90	NA	17.10	274.00	4.74	3.10	< 0.1	1.70	9.00	3.60
5	14.00	98.50	89.50	7.67	90.83	0.40	NA	16.40	268.00	4.40	10.00	0.23	7.60	143.00	0.55
6 d	26.00	97.77	76.77	NA	NA	0.40	NA	17.50	190.00	5.23	< 0.1	< 0.1	4.20	3.30	6.60
6	14.00	98.06	89.06	7.00	91.06	5.40	NA	16.90	237.00	4.74	16.00	< 0.1	4.10	21.60	0.64
7	14.00	96.43	87.43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	14.00	98.41	89.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	14.00	98.22	89.22	6.83	91.39	7.10	NA	17.30	232.00	4.70	16.00	< 0.1	5.50	19.10	0.76
10 d	24.25	93.74	71.99	3.17	90.57	6.10	55	15.80	438.00	4.37	11.00	< 0.1	1.60	17.10	< 0.5
10 s	21.00	93.72	75.22	3.17	90.55	5.90	57	15.80	415.00	4.39	11.00	< 0.1	2.70	17.20	< 0.5
10	11.04	93.54	85.00	3.25	90.29	8.20	47	14.40	447.00	4.65	4.20	< 0.1	2.80	23.40	4.10
11 d	23.00	94.07	73.57	3.50	90.57	4.00	NA	16.60	458.00	4.29	12.00	< 0.1	6.00	21.70	1.10
11 s	9.92	94.10	86.68	3.25	90.85	4.70	NA	13.20	375.00	4.80	4.70	< 0.1	3.40	17.00	6.70
11	15.42	94.17	81.25	3.58	90.59	6.00	NA	14.90	426.00	4.32	13.00	< 0.1	3.20	20.80	< 0.5
12 d	27.00	95.08	70.58	4.75	90.33	0.60	NA	17.00	405.00	4.48	8.70	< 0.1	4.30	25.10	< 0.5
12 m	19.25	95.10	78.35	4.58	90.52	4.20	NA	16.80	442.00	4.24	15.00	< 0.1	14.70	25.80	0.69
12 s	11.58	94.95	85.87	4.50	90.45	2.30	NA	16.70	430.00	4.35	6.40	< 0.1	7.00	21.30	< 0.5
13 m	17.00	96.03	81.53	5.58	90.45	1.10	NA	17.40	350.00	4.51	8.70	< 0.1	4.40	45.40	3.20
13	12.00	95.83	86.33	5.33	90.50	5.60	NA	16.10	402.00	4.71	1.80	< 0.1	5.60	17.80	6.50
14 m	14.00	96.88	85.38	6.33	90.55	0.60	NA	18.20	293.00	4.52	9.20	< 0.1	2.60	59.60	< 0.5
14	11.00	96.77	88.27	6.42	90.35	6.00	NA	16.20	311.00	5.21	0.24	< 0.1	11.00	6.30	4.10
15 d	19.21	92.33	75.62	3.00	89.33	3.30	62	16.80	415.00	3.94	5.80	< 0.1	12.50	17.00	3.00
15 s	9.92	92.33	84.91	2.83	89.50	7.10	32	16.80	370.00	4.40	7.50	< 0.1	7.80	29.00	3.40
15	14.92	92.60	80.18	2.83	89.77	4.50	55	16.70	388.00	4.06	6.50	< 0.1	2.40	18.00	< 0.5
16 d	17.75	92.37	77.12	2.58	89.79	5.10	63	16.30	423.00	4.10	8.60	< 0.1	12.10	22.00	0.72
16 s	9.83	92.39	85.06	2.58	89.81	6.60	37	15.90	376.00	5.17	8.20	< 0.1	11.70	32.10	4.40
16	14.77	92.72	80.45	2.92	89.80	4.50	43	16.00	406.00	4.30	8.60	< 0.1	17.40	24.40	1.70
17 d	19.52	92.78	75.76	3.25	89.53	1.00	70	16.80	409.00	4.18	10.00	< 0.1	10.90	23.30	0.64
17 s	10.17	92.76	85.09	3.08	89.68	2.60	78	15.20	416.00	4.47	9.40	< 0.1	2.40	23.20	1.70

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Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH	NO3 ppm N	NO2 ppm N	TOC ppm C	Cl ppm	SO4 ppm SO4
17	14.79	92.83	80.54	3.08	89.75	0.80	76	16.30	420.00	4.18	9.80	< 0.1	6.00	24.40	0.72
18 d	17.25	92.79	78.04	3.25	89.54	1.10	75	16.10	395.00	4.26	9.50	< 0.1	7.50	33.60	0.68
18 s	10.17	92.83	85.16	3.17	89.66	2.70	80	15.10	422.00	4.26	9.80	< 0.1	5.40	32.90	3.40
18	15.17	92.77	80.10	3.25	89.52	2.80	78	16.10	422.00	4.23	9.80	< 0.1	9.50	35.40	2.40
19 d	19.42	92.87	75.95	3.67	89.20	1.50	72	16.70	420.00	4.35	9.20	< 0.1	4.50	37.00	0.69
19 s	10.19	92.87	85.18	3.42	89.45	4.60	62	14.90	413.00	4.41	10.00	< 0.1	2.30	40.60	4.40
19	14.81	92.96	80.65	3.50	89.46	2.90	86	14.80	414.00	4.38	11.00	< 0.1	2.10	45.40	1.50
20 d	15.08	92.93	80.35	3.58	89.35	2.80	63	16.00	428.00	4.36	12.00	< 0.1	3.90	46.30	1.20
20 s	10.13	92.97	85.35	3.58	89.39	3.80	61	15.30	431.00	4.39	11.00	< 0.1	5.10	39.30	1.90
21 d	15.92	98.50	85.08	7.67	90.83	0.30	NA	16.70	297.00	4.37	6.90	0.52	6.90	33.00	< 0.5
21 s	9.29	98.57	91.78	7.67	90.90	0.60	NA	16.00	300.00	4.50	8.40	0.21	8.70	29.90	5.30
22 d	16.38	98.30	84.43	7.42	90.88	3.90	NA	16.50	281.00	4.35	12.00	< 0.1	4.90	26.70	0.58
22 s	10.08	98.23	90.65	7.42	90.81	3.70	NA	15.80	281.00	4.43	12.00	< 0.1	4.50	31.70	0.52
23 b	23.25	97.75	77.00	6.75	91.00	2.70	NA	17.60	262.00	4.51	6.20	< 0.1	3.20	13.30	< 0.5
23 g	8.92	97.86	91.44	6.83	91.03	5.90	NA	16.50	263.00	5.02	5.60	< 0.1	22.60	35.70	8.30
23 o	14.38	97.74	85.87	6.75	90.99	0.70	NA	16.80	227.00	5.13	14.00	< 0.1	8.60	28.40	3.10
23 y	19.50	97.74	80.74	6.83	90.91	0.70	NA	17.40	271.00	4.17	9.50	< 0.1	13.20	25.70	< 0.5
24 d	18.08	97.65	82.07	6.67	90.98	5.60	NA	18.00	213.00	4.66	9.60	< 0.1	10.70	20.10	< 0.5
24 s	9.08	97.65	91.07	6.67	90.98	4.90	NA	16.50	219.00	5.10	20.00	< 0.1	5.40	13.50	1.50
25 d	15.88	99.00	85.63	7.83	91.17	3.00	NA	18.20	206.00	4.46	11.00	< 0.1	12.60	68.40	< 0.5
25 s	9.75	99.05	91.80	7.83	91.22	5.60	NA	17.20	207.00	4.56	6.30	< 0.1	7.00	311.00	1.40
26 d	19.21	98.26	81.55	7.00	91.26	1.90	NA	17.00	223.00	4.34	16.00	< 0.1	6.20	41.80	< 0.5
26 m	14.50	98.30	86.30	7.00	91.30	0.40	NA	17.10	122.00	5.05	8.50	0.11	26.10	19.00	2.50
26 s	9.50	98.31	91.31	7.00	91.31	0.40	NA	16.30	130.00	4.98	4.50	< 0.1	36.90	20.90	3.70

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Well #	Tot Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH	NO3 ppm N	NO2 ppm N	TOC ppm C	Cl ppm	SO4 ppm SO4
1	19.00	99.40	85.40	7.17	92.23	7.20	48	16.20	555.00	4.00	12.00	<0.1	2.50	71.40	1.10
2 d	25.90	99.01	74.11	7.17	91.84	3.00	54	16.80	491.00	3.30	2.30	<0.1	1.70	3.40	<0.5
2	19.00	98.98	84.98	7.08	91.90	4.50	82	15.40	535.00	2.70	12.00	<0.1	9.20	26.20	0.84
3 d	20.08	98.30	80.72	6.25	92.05	0.40	80	15.50	421.00	4.70	12.00	<0.1	1.80	21.30	0.53
3	15.00	98.38	88.38	6.25	92.13	0.70	129	15.60	355.00	5.00	19.00	<0.1	9.70	25.10	0.53
4	14.00	99.03	90.03	6.83	92.20	6.40	25	15.00	478.00	5.20	7.90	<0.1	2.90	3.80	3.20
5 d	26.00	98.37	77.37	6.75	91.62	1.80	48	15.60	513.00	4.70	3.30	<0.1	1.00	8.10	2.90
5	14.00	98.50	89.50	6.92	91.58	0.70	58	14.10	508.00	4.50	8.00	<0.1	3.40	95.60	0.58
6 d	26.00	97.77	76.77	6.08	91.69	0.90	61	16.70	389.00	5.00	<0.1	<0.1	3.00	3.00	6.80
6	14.00	98.06	89.06	6.33	91.73	0.50	107	15.20	502.00	4.10	9.70	0.11	7.30	24.80	3.30
7	14.00	96.43	87.43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	14.00	98.41	89.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	14.00	98.22	89.22	6.25	91.97	7.00	52	14.50	488.00	4.70	14.00	<0.1	2.30	17.00	6.00
10 d	24.25	93.74	71.99	3.08	90.66	6.10	65	15.70	524.00	4.50	10.00	<0.1	5.30	14.80	<0.5
10 s	21.00	93.72	75.22	3.08	90.64	6.00	64	15.00	530.00	3.60	11.00	<0.1	3.10	15.20	<0.5
10	11.04	93.54	85.00	3.00	90.54	4.40	58	14.50	322.00	3.50	8.30	<0.1	6.90	16.70	1.30
11 d	23.00	94.07	73.57	3.25	90.82	3.00	51	16.20	505.00	4.70	14.00	<0.1	3.50	21.50	<0.5
11 s	9.92	94.10	86.68	3.25	90.85	1.60	48	14.50	510.00	4.80	4.40	<0.1	4.50	13.50	8.20
11	15.42	94.17	81.25	3.42	90.75	4.80	61	15.10	505.00	4.20	10.00	<0.1	9.20	18.00	4.00
12 d	27.00	95.08	70.58	4.33	90.75	0.20	80	16.70	489.00	3.30	7.90	<0.1	4.60	24.00	<0.5
12 m	19.25	95.10	78.35	4.25	90.85	0.20	68	15.10	490.00	3.00	9.50	<0.1	4.10	30.40	<0.5
12 s	11.58	94.95	85.87	4.17	90.78	0.90	98	15.30	480.00	4.30	10.00	<0.1	4.60	56.60	<0.5
13 m	17.00	96.03	81.53	5.17	90.86	0.30	89	15.70	493.00	2.80	7.90	<0.1	5.50	44.40	2.00
13	12.00	95.83	86.33	5.00	90.83	2.90	68	14.70	487.00	3.10	4.60	<0.1	5.60	24.10	3.40
14 m	14.00	96.88	85.38	5.83	91.05	0.50	81	15.50	503.00	2.30	10.00	<0.1	3.90	80.70	<0.5
14	11.00	96.77	88.27	6.00	90.77	1.30	60	14.90	477.00	3.40	0.24	<0.1	8.90	6.10	4.00
15 d	19.21	92.33	75.62	2.67	89.66	2.70	54	15.40	646.00	2.90	5.90	<0.1	11.00	15.50	2.60
15 s	9.92	92.33	84.91	2.58	89.75	5.20	59	14.30	536.00	2.30	6.50	<0.1	<1.0	15.30	<0.5
15	14.92	92.60	80.18	2.83	89.77	5.20	74	14.70	569.00	2.90	6.60	<0.1	1.40	15.30	<0.5
16 d	17.75	92.37	77.12	2.67	89.70	2.40	59	14.90	608.00	3.50	8.80	<0.1	10.80	NA	<0.5
16 s	9.83	92.39	85.06	2.67	89.72	2.00	68	14.40	642.00	3.40	8.70	<0.1	2.70	18.30	0.56
16	14.77	92.72	80.45	2.92	89.80	2.20	72	14.50	650.00	3.40	9.20	<0.1	5.50	17.60	<0.5
17 d	19.52	92.78	75.76	3.08	89.70	0.80	75	15.10	596.00	3.70	9.30	<0.1	6.10	22.70	<0.5
17 s	10.17	92.76	85.09	2.92	89.84	1.30	87	14.10	630.00	2.90	9.90	<0.1	10.70	23.10	0.82

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Well #	Tol Depth	TOC El	MOS El	DTW	GWT El	DO	CO2	T	eH	pH	NO3 ppm N	NO2 ppm N	TOC ppm C	Cl ppm	SO4 ppm SO4
17	14.79	92.83	80.54	3.00	89.83	0.80	85	14.40	642.00	3.20	9.60	<0.1	5.50	23.70	0.59
18 d	17.25	92.79	78.04	2.92	89.87	0.30	78	14.30	533.00	3.40	9.50	<0.1	11.60	27.10	1.40
18 s	10.17	92.83	85.16	2.92	89.91	1.20	60	13.80	559.00	3.40	9.50	<0.1	2.80	28.60	4.50
18	15.17	92.77	80.10	2.92	89.85	0.40	75	14.20	568.00	3.40	10.00	<0.1	11.00	27.90	0.84
19 d	19.42	92.87	75.95	3.00	89.87	2.10	67	14.80	539.00	3.60	9.80	<0.1	7.60	28.10	1.30
19 s	10.19	92.87	85.18	2.92	89.95	4.70	70	14.00	565.00	3.50	8.80	<0.1	6.40	43.80	10.40
19	14.81	92.96	80.65	2.92	90.04	2.70	73	14.10	542.00	3.60	10.00	<0.1	5.30	40.50	3.20
20 d	15.08	92.93	80.35	2.75	90.18	5.00	72	15.20	536.00	3.30	12.00	<0.1	5.00	26.90	<0.5
20 s	10.13	92.97	85.35	2.67	90.30	4.20	65	14.10	550.00	3.40	12.00	<0.1	14.70	27.30	0.80
21 d	15.92	98.50	85.08	6.83	91.67	0.90	107	14.10	510.00	4.30	18.00	<0.1	1.70	237.00	1.70
21 s	9.29	98.57	91.78	6.83	91.74	1.20	86	13.60	487.00	6.00	16.00	0.15	2.20	201.00	1.40
22 d	16.38	98.30	84.43	6.58	91.72	0.40	92	14.80	513.00	3.45	13.00	0.15	4.60	28.40	1.10
22 s	10.08	98.23	90.65	6.67	91.56	1.20	75	13.80	505.00	4.30	11.00	<0.1	3.30	26.90	0.99
23 b	23.25	97.75	77.00	6.08	91.67	4.10	59	15.90	525.00	3.40	7.50	<0.1	31.80	15.00	0.53
23 g	8.92	97.86	91.44	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
23 o	14.38	97.74	85.87	6.17	91.57	1.20	80	14.80	507.00	3.40	9.10	<0.1	4.70	24.80	5.50
23 y	19.50	97.74	80.74	6.17	91.57	5.00	65	14.90	543.00	2.90	11.00	<0.1	<1.0	22.40	<0.5
24 d	18.08	97.65	82.07	6.25	91.40	5.70	52	15.70	507.00	2.90	10.00	<0.1	3.00	19.00	<0.5
24 s	9.08	97.65	91.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25 d	15.88	99.00	85.63	6.83	92.17	4.20	67	16.00	537.00	3.90	14.00	<0.1	3.40	237.00	0.75
25 s	9.75	99.05	91.80	7.00	92.05	5.10	63	15.40	530.00	4.10	8.20	<0.1	25.20	254.00	2.20
26 d	19.21	98.26	81.55	6.17	92.09	5.00	99	15.60	510.00	3.90	14.00	<0.1	10.10	28.10	<0.5
26 m	14.50	98.30	86.30	6.17	92.13	0.30	220	15.20	378.00	4.70	8.90	0.22	39.70	16.10	2.00
26 s	9.50	98.31	91.31	6.17	92.14	0.20	300	15.20	336.00	4.90	8.10	0.15	31.30	18.20	2.40

Appendix C

MODELING WITH BIOPLUME II

1 .0 INPUT PARAMETERS AND GRID DEVELOPMENT

BIOPLUME II Input Parameters

A complete listing of all input data for the Total BTEX simulation can be found in the output file shown in Appendix C.2.0. This section will go through a description and necessary calculations for the more important input parameters.

Aquifer Thickness:

Field data from the various depth wells suggest that the contaminant plume has an approximate thickness of 15 ft.

Transmissivity:

Transmissivity equals hydraulic conductivity multiplied by aquifer thickness. BIOPLUME requires this with units of square feet per second.

$$\begin{aligned} k &= \left(4.0 \frac{ft}{day}\right)\left(\frac{1\ day}{24\ hr}\right)\left(\frac{1\ hr}{3600\ s}\right) = 4.629 \times 10^{-5}\ {}^{ft}\!/_{s} \\ T &= k \times D \\ &= \left(4.629 \times 10^{-5}\ {}^{ft}\!/_{s}\right)(15\,ft)) \\ &= 6.9444 \times 10^{-4}\ {}^{ft^2}\!/_{s} \end{aligned}$$

Water Table Gradient and Constant Head Values:

The overall water table gradient from field data between February-1994 and April-1995 was calculated as being approximately 0.004 ft. This value was used to initially set up the constant head cells at the top and bottom of the BIOPLUME grid. The constant head values were then adjusted until the modeled values adequately represented the average field values and plume behavior. Actual constant head values can be found in the output file in Appendix C.2.0.

Source Location and Time Since Release:

For the chloride plume, the source was located at MW-25. This corresponds to cell (X = 7, Y = 7) in the BIOPLUME grid. As in the analytical solution, the time since release was approximated at 50 years.

For the gasoline plume, the source was located at MW-26. This corresponds to cell (X = 10, Y = 7) in the BIOPLUME grid. As in the analytical solution, the time since release was approximated at 11 years (1984).

Source and Oxygen Concentrations:

The concentrations of contaminant and oxygen do not need to be entered in BIOPLUME with specific units. Since the model will include their reaction in a specific ratio, it is only important that the units provided are the same for both species. Another consideration is that concentrations entered with more significant figures will provide output with more significant figures.

It was determined from field data that the site had a background oxygen concentration of approximately 7 mg/L. This value was selected as the initial oxygen level prior to release of contamination. It was also used to specify the concentration of oxygen entering the site from the top row of constant head cells.

To increase the number of digits in BIOPLUME output, the concentrations values were multiplied by 100. While the input oxygen level in Appendix C.2.0 is 700, this value actually represents 7.00 mg/L. Output contaminant concentrations were also divided by 100 to get units of mg/L.

Recharge and Injection Rate:

One of the common problems with the use of BIOPLUME is radial flow of contaminants from the source. This can occur when the injection rate at the source is too large for the established site hydrology. Instead of flowing directly downgradient, the concentrated solution can mound up at the source and results in radial flow.

As this was not desired, the following procedure was used to assure strictly downgradient flow at the source. The first step was to specify a value of recharge for all cells except the one containing the source. The next step was to determine the injection rate that corresponds to the recharge rate. Following these steps made sure that the same amount of liquid would be added to each cell and prevents mounding at any location in the grid.

Having established the constant head cells already, it was determined that a recharge value of $3\times10^{-10}\ {}^{ft}\!/_{s}$ would not adversely affect the groundwater table values or plume behavior. This recharge value was assigned to all cells other than the source. The corresponding injection rate for the source was determined with the cell dimensions as shown below:

$$
\begin{aligned}
Recharge &= 3\times10^{-10}\ {}^{ft}\!/_{s} \\
InjectionRate &= \left(3\times10^{-10}\ {}^{ft}\!/_{s}\right)(25\ ft\times30\ ft) \\
&= 2.25\times10^{-7}\ {}^{ft^3}\!/_{s}
\end{aligned}
$$

Retardation Parameters:

Retardation factors were calculated for each of the fuel compounds in Appendix A.3.0. Using a weighted average of the observed concentrations at the source, an approximate retardation factor was also determined for Total BTEX at the site. In summary, the weighted distribution coefficient was 0.015 grams per cubic centimeter, and the weighted retardation factor was 1.094.

To account for retardation in BIOPLUME, values of porosity, bulk density, and distribution coefficient must be entered for the contaminant and are used in the following equation:

$$R_f = 1 + K_d * \left(\frac{\rho_b}{n_T}\right)$$

$Where, R_f = Retardation\ Factor$

$K_d = Distribution\ Coefficient\ (cm^3/g)$

$\rho_b = Bulk\ Density\ of\ Soil\ (g/cm^3)$

$n_T = Total\ Porosity$

The problem with BIOPLUME is that it only takes one value of porosity. For general groundwater flow development, it is desired to have the effective porosity entered into the model. As shown above, however, it is the total porosity which will make a more appropiate determination of retardation effects. The objective is to enter a value of the distribution coefficient that makes BIOPLUME determine the correct retardation with the entered effective porosity. This will not be the true value of the distribution coefficient, but will be used only for BIOPLUME. Using the above relation and knowing the actual retardation factor, a value of the distribution coefficient to be entered in the model can be determined in the following equation:

$$K_{d-BIO} = (R_f - 1) * \left(\frac{n_e}{\rho_b}\right)$$

$Where,\ K_{d-BIO} = Distribution\ Coefficient\ for\ BIOPLUME\ (cm^3/g)$

$R_f = Known\ Retardation\ Factor$

$\rho_b = Bulk\ Density\ of\ Soil\ Entered\ in\ BIOPLUME\ (g/cm^3)$

$n_e = Effective\ Porosity\ Entered\ in\ BIOPLUME$

Using the values given in Appendix A.3.0,

$$K_{d-BIO} = (1.094 - 1) * \left(\frac{0.1}{1.855}\right) = 0.00505\ {cm^3}/{g}$$

BIOPLUME II Grid Development for the Sampson Co. Site

Coordinates Based on MW - 26
as the Origin (X=0, Y=0) and the
Longitudinal Axis Towards MW - 18 (Y=0)

Well #	X - coordinate	Y - coordinate
1	27.02	-100.61
2	42.54	-24.55
3	2.89	-29.90
4	-60.87	-33.65
5	140.61	-27.24
6	66.66	36.51
7	247.77	17.76
8	230.82	-143.98
9	-20.68	61.67
10	275.65	159.14
11	276.19	98.63
12	274.56	47.22
13	271.89	3.14
14	272.44	-52.95
15	583.98	152.96
16	582.57	101.74
17	581.12	51.22
18	578.32	0.00
19	578.32	-49.80
20	576.87	-98.88
21	131.51	-50.26
22	125.08	-11.70
23	113.27	30.07
24	100.42	65.42
25	4.52	-64.16
26	0.00	0.00

Coordinates Recalculated with the Same
Axis, but so that Cpordinates are Positive
MW - 4 (X=0), and MW - 1 (Y=0)

Well #	X - coordinate	Y - coordinate
1	87.89	0.00
2	103.41	76.06
3	63.76	70.71
4	0.00	66.96
5	201.48	73.37
6	127.53	137.12
9	40.19	162.28
10	336.52	259.75
11	337.06	199.24
12	335.43	147.83
13	332.76	103.75
14	333.31	47.66
15	644.85	253.57
16	643.44	202.35
17	641.99	151.83
18	639.19	100.61
19	639.19	50.81
20	637.74	1.73
21	192.38	50.35
22	185.95	88.91
23	174.14	130.68
24	161.29	166.03
25	65.39	36.45
26	60.87	100.61

Grid Development for 30 ft per Cell in X
and 25 ft per Cell in Y
with the Upper-Left Cell as X=1, and Y=1

X Cell #	Y Cell #	X Cell #	Y Cell #
3.93	1.00	4	1
4.45	4.04	4	4
3.13	3.83	3	4
1.00	3.68	1	4
7.72	3.93	8	4
5.25	6.48	5	6
2.34	7.49	2	7
12.22	11.39	12	11
12.24	8.97	12	9
12.18	6.91	12	7
12.09	5.15	12	5
12.11	2.91	12	3
22.50	11.14	22	11
22.45	9.09	22	9
22.40	7.07	22	7
22.31	5.02	22	5
22.31	3.03	22	3
22.26	1.07	22	1
7.41	3.01	7	3
7.20	4.56	7	5
6.80	6.23	7	6
6.38	7.64	6	8
3.18	2.46	3	2
3.03	5.02	3	5

Within a 30 by 20 Cell Grid
(Starting at Cell X=4, Y=5)

X Cell #	Y Cell #
8	6
8	9
7	9
5	9
12	9
9	11
6	12
16	16
16	14
16	12
16	10
16	8
26	16
26	14
26	12
26	10
26	8
26	6
11	8
11	10
11	11
10	13
7	7
7	10

Actual BIOPLUME II Grid Shown in Figure 6.1.

2.0 OUTPUT FILE FOR MODELING TOTAL BTEX

```
1                           BIOPLUME II
1CONTAMINANT TRANSPORT UNDER THE INFLUENCE OF OXYGEN LIMITED BIODEGRADATION
0   BTEX Simulation

0                     I N P U T    D A T A
0                       GRID DESCRIPTORS

              NX     (NUMBER OF COLUMNS)  =    20
              NY     (NUMBER OF ROWS)     =    30
              XDEL   (X-DISTANCE IN FEET) =    25.0
              YDEL   (Y-DISTANCE IN FEET) =    30.0
0                       TIME  PARAMETERS

              NTIM   (MAX. NO. OF TIME STEPS)        =      1
              NPMP   (NO. OF PUMPING PERIODS)        =      1
              PINT   (PUMPING PERIOD IN YEARS)       =     11.000
              TIMX   (TIME INCREMENT MULTIPLIER)     =       .00
              TINIT  (INITIAL TIME STEP IN SEC.)     =      0.
0                   HYDROLOGIC AND CHEMICAL PARAMETERS

              S       (STORAGE COEFFICIENT)          =       .000000
              POROS   (EFFECTIVE POROSITY)           =       .100
              BETA    (LONGITUDINAL DISPERSIVITY) =      40.0
              DLTRAT  (RATIO OF TRANSVERSE TO
                       LONGITUDINAL DISPERSIVITY)    =       .13
              ANFCTR  (RATIO OF T-YY TO T-XX)        =      1.000000
0                       EXECUTION PARAMETERS

              NITP   (NO. OF ITERATION PARAMETERS) =     7
              TOL    (CONVERGENCE CRITERIA - ADIP) =      .0010
              ITMAX  (MAX.NO.OF ITERATIONS - ADIP) =   100
              CELDIS (MAX.CELL DISTANCE PER MOVE
                        OF PARTICLES - M.O.C.)     =      .500
              NPMAX  (MAX. NO. OF PARTICLES)       =   5400
              NPTPND (NO. PARTICLES PER NODE)      =     9
1
0                       PROGRAM OPTIONS

              NPNT   (TIME STEP INTERVAL FOR
                      COMPLETE PRINTOUT)        =    1
              NPNTMV (MOVE INTERVAL FOR CHEM.
                      CONCENTRATION PRINTOUT)   =    0
              NPNTVL (PRINT OPTION-VELOCITY
                      0=NO; 1=FIRST TIME STEP;
                      2=ALL TIME STEPS)         =    0
              NPNTD  (PRINT OPTION-DISP.COEF.
                      0=NO; 1=FIRST TIME STEP;
                      2=ALL TIME STEPS)         =    0
              NUMOBS (NO. OF OBSERVATION WELLS
                      FOR HYDROGRAPH PRINTOUT)  =    0
              NREC   (NO. OF PUMPING WELLS)     =    1
              NCODES (FOR NODE IDENT.)          =    1
              NPNCHV (PUNCH VELOCITIES)         =    0
              NPDELC (PRINT OPT.-CONC. CHANGE)  =    0
0                       REACTION TERMS

              DK      (DISTRIBUTION COEFFICIENT)  =   .50500E-02
              RHOB    (BULK DENSITY OF SOLIDS)    =   .18550E+01
              RF      (RETARDATION FACTOR)        =   .10937E+01
              THALF   (HALF LIFE OF DECAY,IN SEC)=   .00000E+00
              DECAY   (DECAY CONSTANT=LN 2/THALF)=   .00000E+00
0                       DECAY TERMS

              DEC1  (ANAEROBIC DECAY COEFF. ) =   .50000E-02
              DEC2  (REAERATION DECAY COEFF.) =   .00000E+00
1                 STEADY-STATE FLOW
```

```
    TIME INTERVAL (IN SEC) FOR SOLUTE-TRANSPORT SIMULATION =   .34713E+09

0          LOCATION  OF  PUMPING  WELLS

           X   Y   RATE(IN CFS)   CONC.   CONC(02)

          10   7  < -.23E-06   1500000      .00

0          AREA OF ONE CELL =     750.0
0          X-Y SPACING:
              25.000
              30.000
ITRANSMISSIVITY MAP (FT*FT/SEC)

   0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
   0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
```

```
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04
   6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  6.94E-04  0.00E+00
   0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
   0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
1AQUIFER THICKNESS (FT)

       .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0   .0
       .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0   .0
1DIFFUSE RECHARGE AND DISCHARGE (FT/SEC)

   0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
   0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
   0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
  -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
```

```
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10
 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10 -3.00E-10  0.00E+00
  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
1PERMEABILTY MAP (FT/SEC)

  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  0.00E+00
  0.00E+00  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05  4.63E-05
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 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
0         NO. OF FINITE-DIFFERENCE CELLS IN AQUIFER =  504

          AREA OF AQUIFER IN MODEL =  .37800E+06  SQ. FT.


          NZCRIT  (MAX. NO. OF CELLS THAT CAN BE VOID OF
                   PARTICLES;  IF EXCEEDED, PARTICLES ARE REGENERATED)  =  10

1NODE IDENTIFICATION MAP


   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
    0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  0
    0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0     NO. OF NODE IDENT. CODES SPECIFIED =  1
0          THE FOLLOWING ASSIGNMENTS HAVE BEEN MADE:
     CODE NO.     LEAKANCE     SOURCE CONC.     O2 CONC      RECHARGE
0        1        .100E+01          .00          700.00
1VERTICAL PERMEABILITY/THICKNESS (FT/(FT*SEC))

    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
    1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
    0.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00
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 1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  1.00E+00  0.00E+00
 0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
 0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
1WATER TABLE

  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0. 92. 92. 92. 92. 92. 91. 91. 91. 91. 91. 91. 91. 91. 91. 91. 91. 91. 91.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
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  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
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  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88. 88.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
1HEAD DISTRIBUTION - ROW
 NUMBER OF TIME STEPS =      0
          TIME(SECONDS) =   .00000
          TIME(DAYS)    =   .00000E+00
          TIME(YEARS)   =   .00000E+00

0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000  91.7500000  91.7000000  91.6500000  91.6000000  91.5000000  91.4000000  91.3500000  91.3000000  91.3000000
0  91.2500000  91.2500000  91.2000000  91.1500000  91.1000000  91.0500000  91.0000000  90.9500000  90.9000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
0    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000    .0000000
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0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000 88.4500000 88.4000000 88.3500000 88.2500000 88.1500000 88.0500000 87.9500000 87.8500000 87.8000000
0  87.9000000 88.0000000 88.1000000 88.2000000 88.2500000 88.3000000 88.3500000 88.4000000 88.4500000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
1ITERATION PARAMETERS
               .323594E-02
               .841395E-02
               .218776E-01
               .568853E-01
               .147911
               .384592
               1.00000
               .000000
               .000000
               .000000
               .000000
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               .000000
               .000000
               .000000
               .000000
               .000000
               .000000
               .000000
               .000000
1CONCENTRATION OF CONTAMINANT

 NUMBER OF TIME STEPS =      0
          TIME(SECONDS) =  .00000
    CHEM.TIME(SECONDS) =  .00000E+00
    CHEM.TIME(DAYS)    =  .00000E+00
          TIME(YEARS)  =  .00000E+00
    CHEM.TIME(YEARS)   =  .00000E+00
   NO. MOVES COMPLETED =      0

 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
1CONCENTRATION OF OXYGEN

 NUMBER OF TIME STEPS =      0
          TIME(SECONDS) =   .00000
     CHEM.TIME(SECONDS) =   .00000E+00
     CHEM.TIME(DAYS)    =   .00000E+00
          TIME(YEARS)   =   .00000E+00
     CHEM.TIME(YEARS)   =   .00000E+00
   NO. MOVES COMPLETED =      0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700  700    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

```
0

   N =   1
   NUMBER OF ITERATIONS =   21
 1HEAD DISTRIBUTION - ROW
  NUMBER OF TIME STEPS =    1
         TIME(SECONDS) =   .34713E+09
         TIME(DAYS)    =   .40178E+04
         TIME(YEARS)   =   .11000E+02

0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0    .0000000 91.7499998 91.6999998 91.6499999 91.5999998 91.4999999 91.4000000 91.3499999 91.3000000 91.2999999
0  91.2500000 91.2499999 91.1999999 91.1499999 91.0999999 91.0499999 91.0000000 90.9500000 90.9000000   .0000000
0    .0000000 91.5276985 91.5038926 91.4679781 91.4223848 91.3620186 91.3009012 91.2530748 91.2137326 91.1867108
0  91.1550979 91.1296881 91.0944370 91.0558057 91.0164226 90.9777858 90.9413723 90.9095965 90.8874826   .0000000
0    .0000000 91.3394860 91.3252349 91.3000051 91.2660876 91.2251554 91.1826979 91.1439649 91.1097543 91.0800625
0  91.0512929 91.0235783 90.9937741 90.9627289 90.9318068 90.9024149 90.8761775 90.8552933 90.8429294   .0000000
0    .0000000 91.1711600 91.1615098 91.1435398 91.1189158 91.0895402 91.0581905 91.0274027 90.9983302 90.9711486
0  90.9450309 90.9195387 90.8939584 90.8685337 90.8440393 90.8215254 90.8022717 90.7878442 90.7799371   .0000000
0    .0000000 91.0163662 91.0094970 90.9964699 90.9783759 90.9565693 90.9326779 90.9081710 90.8839812 90.8604991
0  90.8376646 90.8154239 90.7937191 90.7728028 90.7532216 90.7357310 90.7212298 90.7107376 90.7051944   .0000000
0    .0000000 90.8712423 90.8662285 90.8565870 90.8430263 90.8264518 90.8079013 90.7883277 90.7684550 90.7487573
0  90.7292841 90.7103791 90.6921891 90.6749992 90.6592445 90.6454761 90.6343057 90.6263812 90.6222478   .0000000
0    .0000000 90.7328499 90.7290673 90.7217655 90.7114191 90.6986083 90.6840299 90.6683437 90.6521028 90.6357289
0  90.6195105 90.6037309 90.5886475 90.5745610 90.5618355 90.5508830 90.5421250 90.5360091 90.5328608   .0000000
0    .0000000 90.5994927 90.5965933 90.5909800 90.5829712 90.5729457 90.5613945 90.5487945 90.5355749 90.5221085
0  90.5087366 90.4957130 90.4833068 90.4718032 90.4615094 90.4527403 90.4457911 90.4409834 90.4385286   .0000000
0    .0000000 90.4699459 90.4676978 90.4633232 90.4570460 90.4491249 90.4399191 90.4297823 90.4190441 90.4079925
0  90.3971015 90.3864478 90.3763110 90.3669531 90.3586326 90.3515953 90.3460529 90.3422397 90.3402966   .0000000
0    .0000000 90.3432056 90.3414308 90.3379777 90.3330117 90.3267107 90.3193473 90.3111942 90.3025193 90.2935874
0  90.2846778 90.2759929 90.2677518 90.2601719 90.2534645 90.2478214 90.2433962 90.2403695 90.2388358   .0000000
0    .0000000 90.2186210 90.2172049 90.2144565 90.2105015 90.2054620 90.1995537 90.1929927 90.1859954 90.1787797
0  90.1715602 90.1645300 90.1578754 90.1517755 90.1463997 90.1418953 90.1383715 90.1359736 90.1347666   .0000000
0    .0000000 90.0957114 90.0945746 90.0923686 90.0891942 90.0851374 90.0803773 90.0750901 90.0694522 90.0636420
0  90.0578341 90.0521925 90.0468710 90.0420137 90.0377530 90.0341984 90.0314216 90.0295396 90.0285952   .0000000
0    .0000000 89.9740542 89.9731274 89.9713304 89.9687501 89.9654517 89.9615908 89.9573168 89.9527768 89.9481189
0  89.9434865 89.9390136 89.9348223 89.9310236 89.9277158 89.9249742 89.9228381 89.9213989 89.9206792   .0000000
0    .0000000 89.8533278 89.8525511 89.8510513 89.8489100 89.8461824 89.8430121 89.8395328 89.8358731 89.8321591
0  89.8285096 89.8250309 89.8218148 89.8189396 89.8164698 89.8144479 89.8128824 89.8118397 89.8113233   .0000000
0    .0000000 89.7333201 89.7326426 89.7313421 89.7295016 89.7271772 89.7245119 89.7216359 89.7186700 89.7157273
0  89.7129076 89.7102925 89.7079435 89.7059050 89.7042055 89.7028518 89.7018199 89.7011492 89.7008239   .0000000
0    .0000000 89.6138887 89.6132583 89.6120573 89.6103780 89.6082901 89.6059493 89.6034962 89.6010565 89.5987398
0  89.5966327 89.5947938 89.5932531 89.5920164 89.5910706 89.5903804 89.5898840 89.5895886 89.5894567   .0000000
0    .0000000 89.4949622 89.4943144 89.4930938 89.4914141 89.4893749 89.4871622 89.4849448 89.4828687 89.4810516
0  89.4795729 89.4784686 89.4777322 89.4773230 89.4771752 89.4772010 89.4772911 89.4774115 89.4774965   .0000000
0    .0000000 89.3765834 89.3758378 89.3744455 89.3725598 89.3703349 89.3680120 89.3658134 89.3639269 89.3624932
0  89.3615913 89.3612323 89.3613638 89.3618832 89.3626550 89.3635212 89.3643089 89.3649278 89.3652735   .0000000
0    .0000000 89.2589124 89.2579666 89.2562005 89.2538323 89.2511059 89.2483574 89.2459002 89.2439962 89.2428306
0  89.2424894 89.2429529 89.2441044 89.2457545 89.2476692 89.2495924 89.2512627 89.2525118 89.2531823   .0000000
0    .0000000 89.1422027 89.1409002 89.1384672 89.1352210 89.1315430 89.1279230 89.1248242 89.1226320 89.1216086
0  89.1218570 89.1233122 89.1257610 89.1288844 89.1323053 89.1356282 89.1384676 89.1405526 89.1416562   .0000000
0    .0000000 89.0269390 89.0250302 89.0214786 89.0167571 89.0114555 89.0063030 89.0020025 88.9991415 88.9981106
0  88.9990422 89.0017970 89.0060065 89.0111506 89.0166412 89.0218863 89.0263323 89.0295751 89.0312894   .0000000
0    .0000000 88.9140585 88.9111947 88.9058527 88.8987468 88.8907974 88.8831054 88.8767525 88.8726569 88.8714267
0  88.8732420 88.8778284 88.8845508 88.8925671 88.9009750 88.9089130 88.9156079 88.9204676 88.9230257   .0000000
0    .0000000 88.8048909 88.8005480 88.7924186 88.7815615 88.7694045 88.7576201 88.7478881 88.7416787 88.7399891
0  88.7430832 88.7504164 88.7608682 88.7730602 88.7856213 88.7973402 88.8071777 88.8142947 88.8180348   .0000000
0    .0000000 88.7014923 88.6948038 88.6823375 88.6656575 88.6469103 88.6286182 88.6133861 88.6036249 88.6010948
0  88.6062522 88.6179466 88.6341148 88.6524604 88.6709153 88.6878863 88.7020900 88.7124345 88.7179447   .0000000
0    .0000000 88.6074973 88.5972476 88.5782053 88.5525662 88.5236036 88.4950516 88.4708428 88.4549919 88.4509633
0  88.4598402 88.4788683 88.5040629 88.5315451 88.5581892 88.5822528 88.6024412 88.6174035 88.6255616   .0000000
0    .0000000 88.5278965 88.5120802 88.4833794 88.4440433 88.3995005 88.3550276 88.3160579 88.2891258 88.2820376
0  88.2986002 88.3307012 88.3705104 88.4116333 88.4489738 88.4819825 88.5101247 88.5318980 88.5445609   .0000000
0    .0000000 88.4704441 88.4446060 88.4028866 88.3420613 88.2743673 88.2061562 88.1430176 88.0937643 88.0781348
0  88.1140655 88.1705140 88.2341447 88.2962454 88.3450667 88.3877634 88.4259974 88.4586509 88.4811677   .0000000
0    .0000000 88.4500000 88.4000000 88.3500000 88.2500001 88.1500001 88.0500001 87.9500001 87.8500002 87.8000004
```

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0 87.9000002 88.0000001 88.1000001 88.2000000 88.2500001 88.3000001 88.3500001 88.4000000 88.4500000   .0000000
0   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
0   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
1HEAD DISTRIBUTION - ROW
 NUMBER OF TIME STEPS =     1
       TIME(SECONDS) =   .34713E+09
       TIME(DAYS) <  =   .40178E+04
       TIME(YEARS)   =   .11000E+02

0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0 92 92 92 92 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 92 92 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91  0
0  0 91 91 91 91 91 91 91 91 91 91 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  0
0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
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0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
0  0 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89 89  0
0  0 89 89 89 89 89 88 88 88 88 88 88 89 89 89 89 89 89 89  0
0  0 89 89 88 88 88 88 88 88 88 88 88 88 88 88 88 89 89 89  0
0  0 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88  0
0  0 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
1DRAWDOWN
      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
      0  -91  -91  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90    0
      0  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90    0
      0  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90    0
      0  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90    0
      0  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90    0
      0  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90    0
      0  -90  -90  -90  -90  -90  -90  -90  -90  -90  -90  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89  -89    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -88  -88  -88  -87  -87  -87  -87  -87  -87  -88  -88  -88  -88  -88  -88  -88    0
      0  -88  -88  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -88  -88  -88    0
```

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      0  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87  -87    0
      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0  CUMULATIVE MASS BALANCE -- (IN FT**3)


    RECHARGE AND INJECTION      =  -.39365E+05
    PUMPAGE AND E-T WITHDRAWAL  =   .00000E+00
    CUMULATIVE  NET  PUMPAGE    =  -.39365E+05
    WATER RELEASE FROM STORAGE  =   .00000E+00
    LEAKAGE INTO AQUIFER        =   .43334E+06
    LEAKAGE OUT OF AQUIFER      =  -.47133E+06
    CUMULATIVE  NET  LEAKAGE    =  -.37994E+05
0       MASS BALANCE RESIDUAL   =   1371.4
        ERROR  (AS PERCENT)     =   .29054

0  RATE MASS BALANCE -- (IN C.F.S.)


    LEAKAGE INTO AQUIFER        =   .12483E-02
    LEAKAGE OUT OF AQUIFER      =  -.13578E-02
    NET LEAKAGE    (QNET)       =  -.10945E-03
    RECHARGE AND INJECTION      =  -.11340E-03
    PUMPAGE AND E-T WITHDRAWAL  =   .00000E+00
    NET WITHDRAWAL   (TPUM)     =  -.11340E-03
1           STABILITY CRITERIA --- M.O.C.


0     FLUID VELOCITIES
  VMAX =  1.85E-06     VMAY =  3.72E-06
  VMXBD=  1.85E-06     VMYBD=  4.29E-06
0     EFFECTIVE SOLUTE VELOCITIES
  VMAX =  1.69E-06     VMAY =  3.40E-06
  VMXBD=  1.69E-06     VMYBD=  3.92E-06
0     EFFECTIVE OXYGEN VELOCITIES
  VMAX =  1.85E-06     VMAY =  3.72E-06
  VMXBD=  1.85E-06     VMYBD=  4.29E-06
0 TMV (MAX. INJ.) =    .66055E+07
  TIMV (CELDIS)   =    .34947E+07
0 TIMV =  3.49E+06     NTIMV =     99     NMOV =   100

   TIM (N)   =   .34713E+09
   TIMEVELO  =   .34713E+07
   TIMEDISP  =   .22201E+07
0 TIMV =  2.21E+06     NTIMD =   156     NMOV =   157
0          THE LIMITING STABILITY CRITERION IS BETA
0          NO. OF PARTICLE MOVES REQUIRED TO COMPLETE THIS TIME STEP  =  157
All particle moves were not included in this output.
0  NP1        =          5214          IMOV(02) =          157
   TIM(N)    =   .34713E+09          TIMV      =    .22110E+07          SUMTCH =   .34713E+09
1CONCENTRATION OF CONTAMINANT

 NUMBER OF TIME STEPS =      1
        DELTA T       =   .34713E+09
        TIME(SECONDS) =   .34713E+09
   CHEM.TIME(SECONDS) =   .34713E+09
   CHEM.TIME(DAYS)    =   .40177E+04
        TIME(YEARS)   =   .11000E+02
   CHEM.TIME(YEARS)   =   .11000E+02
  NO. MOVES COMPLETED =   157

0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    9  154    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0  236 1066   35    0    0    0    0    0    0    0    0    0
```

```
  0    0    0    0    0    0    0    0    0  438 3745  766    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0  245 2152  958   88    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0  106 1132  729  183    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0   32  622  551  220    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0  368  398  193    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    2  246  262  113    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0  155  172   71    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0   88  112   46    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0   40   68   29    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0   16   39   10    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0   20    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    5    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

 CHEMICAL MASS BALANCE

       MASS IN BOUNDARIES      =  .00000E+00
       MASS OUT BOUNDARIES     = -.26221E+02
       MASS PUMPED IN          =  .23431E+09
       MASS PUMPED OUT         =  .00000E+00
       MASS LOST W. BIODEG.    =  .50584E+07
       MASS LOST BY RADIO. DCY=   .00000E+00
       MASS LOST BY ANAER. DCY= -.22844E+09
       MASS LOST BY REAER. DCY=   .00000E+00
       MASS ADSORBED ON SOLIDS=   .21519E+07
       INITIAL MASS ADSORBED   =  .00000E+00
       INFLOW MINUS OUTFLOW    =  .23431E+09
       INITIAL MASS DISSOLVED  =  .00000E+00
       PRESENT MASS DISSOLVED  =  .17913E+08
       CHANGE MASS DISSOLVED   =  .22972E+08
       CHANGE TOTL.MASS STORED=   .25123E+08
     COMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULATION:
       MASS BALANCE RESIDUAL   = -.19245E+08
       ERROR  (AS PERCENT)     = -.82131E+01
1CONCENTRATION OF OXYGEN

 NUMBER OF TIME STEPS =      1
        DELTA T        =   .34713E+09
        TIME(SECONDS)  =   .34713E+09
   CHEM.TIME(SECONDS)  =   .34713E+09
   CHEM.TIME(DAYS)     =   .40177E+04
        TIME(YEARS)    =   .11000E+02
   CHEM.TIME(YEARS)    =   .11000E+02
  NO. MOVES COMPLETED =    157
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0  698  697  695  689  679  663  639  610  643  647  687  692  693  695  696  696  696  695    0
  0    0  697  695  693  686  673  645  596  539  557  621  664  684  688  691  692  692  691  690    0
  0    0  695  693  690  682  664  618  520  366  328  522  618  662  678  685  687  688  687  686    0
  0    0  692  691  687  678  654  593  394    0    0  322  578  634  661  676  682  684  684  683    0
  0    0  690  688  684  673  649  579  321    0    0    0  471  586  632  663  675  680  681  681    0
  0    0  688  686  681  669  639  558  258    0    0    0  194  493  598  648  667  675  677  678    0
  0    0  685  683  677  663  629  554  297    0    0    0    0  393  558  623  656  670  674  674    0
  0    0  683  680  673  658  623  545  347    0    0    0    0  268  485  601  645  664  670  672    0
  0    0  680  677  669  651  611  536  375    0    0    0    0  198  450  574  633  657  666  669    0
  0    0  677  674  666  645  599  512  357   39    0    0    0  158  418  551  618  650  663  667    0
  0    0  674  671  661  639  592  502  333    0    0    0    0  143  390  525  599  642  659  664    0
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 0    0  671  667  656  633  587  496  334   36    0    0    0  127  361  495  583  636  655  661    0
 0    0  669  664  651  626  579  491  335   97    0    0    0  117  339  476  580  630  651  658    0
 0    0  666  660  647  618  566  485  347  151    0    0    0  125  332  476  572  623  647  655    0
 0    0  663  657  643  613  557  464  327  154    0    0    0  159  328  468  563  617  642  652    0
 0    0  661  655  639  608  550  456  320  161    0    0    9  154  324  460  555  611  639  650    0
 0    0  658  652  636  603  546  452  321  173   44    0   45  170  320  454  548  606  635  647    0
 0    0  656  649  632  599  541  450  325  187   70   23   67  180  320  449  544  602  633  645    0
 0    0  654  647  630  596  538  449  330  202   97   55   93  193  324  448  541  599  630  643    0
 0    0  653  645  628  594  537  451  337  218  121   82  116  211  333  451  540  597  629  642    0
 0    0  651  644  626  594  539  457  348  234  145  110  144  233  349  458  542  597  628  641    0
 0    0  650  643  626  595  546  469  366  255  172  142  174  272  372  474  549  600  628  640    0
 0    0  650  643  630  603  555  485  393  277  200  178  212  311  403  495  561  607  629  641    0
 0    0  650  644  630  604  562  500  404  309  226  204  248  337  420  508  571  611  632  642    0
 0    0  651  646  634  615  576  518  435  342  260  246  284  384  461  532  583  618  636  644    0
 0    0  653  649  640  624  597  544  473  377  296  289  347  425  501  564  604  627  642  647    0
 0    0  658  656  648  638  619  580  512  429  345  344  408  474  538  588  622  640  649  654    0
 0    0  678  672  663  655  644  616  566  506  390  421  488  540  575  615  639  654  663  670    0
 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

 CHEMICAL MASS BALANCE FOR OXYGEN

        MASS IN BOUDARIES       =   .30334E+09
        MASS OUT BOUNDARIES     =  -.30347E+09
        MASS PUMPED IN          =   .19683E+07
        MASS PUMPED OUT         =   .00000E+00
        MASS LOST W. BIODEG.    =   .15175E+08
        INFLOW MINUS OUTFLOW    =   .18369E+07
        INITIAL MASS DISSOLVED  =   .39690E+09
        PRESENT MASS DISSOLVED  =   .27501E+09
        CHANGE MASS DISSOLVED   =  -.10672E+09
        CHANGE TOTL.MASS STORED =  -.10672E+09
      COMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULATION FOR OXYGEN:
        MASS BALANCE RESIDUAL   =   .10855E+09
        ERROR  (AS PERCENT)     =   .35556E+02
      COMPARE INITIAL MASS STORED WITH CHANGE IN MASS STORED FOR OXYGEN:
        ERROR  (AS PERCENT)     =  -.27477E+02
1   BTEX Simulation


1   BTEX Simulation
```

3.0 CALIBRATIONS FOR THE WATER TABLE AND CHLORIDE, MTBE, AND TOTAL BTEX PLUMES

Calibration of the Observed Water Table
Using the BIOPLUME II Model

Well	Observed Water Table (ft)	Modeled Water Table (ft)	Model Error (ft)
1	90.66	90.70	0.04
2	90.57	90.65	0.08
3	90.73	90.77	0.04
4	90.96	91.00	0.04
5	90.27	90.19	-0.08
6	90.49	90.51	0.02
9	90.82	90.82	0.00
10	89.72	89.70	-0.02
11	89.81	89.71	-0.10
12	89.69	89.71	0.02
13	89.74	89.72	-0.02
14	89.75	89.72	-0.03
15	88.60	88.58	-0.02
16	88.63	88.53	-0.10
17	88.54	88.48	-0.06
18	88.39	88.45	0.06
19	88.32	88.47	0.15
20	88.48	88.52	0.04
21	90.35	90.31	-0.04
22	90.31	90.29	-0.02
23	90.35	90.28	-0.07
24	90.30	90.38	0.08
25	90.75	90.81	0.06
26	90.76	90.75	-0.01

Sum of ABS Error 1.198	**Sum of Error** 0.055
Average of ABS Error 0.050	**Maximum Error** 0.151
Stand. Dev. of ABS Error 0.036	**RMS of Error** 0.061

Average Water Table Map (ft)

2/94 - 4/95

Calibration of Dispersivities with the Chloride Plume Using the BIOPLUME II Model

Transverse Dispersivity (ft)	10
Longitudinal Dispersivity (ft)	40

Source Concentration (mg/L)	120,000
Injection Rate (cfs)	2.25E-07

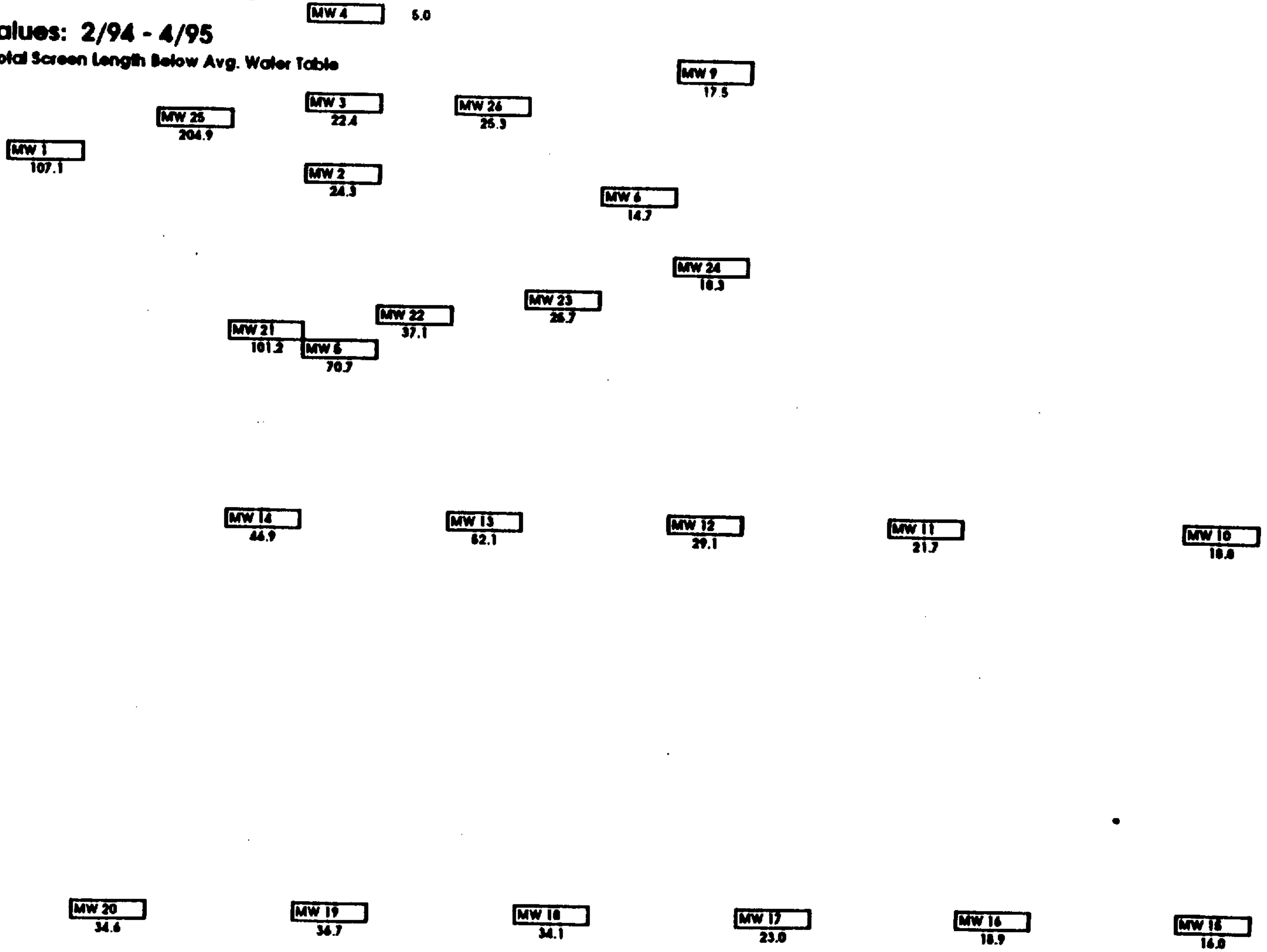
Well	Field Concentrations (mg/L)	Modeled Concentrations (mg/L)	Model Error (mg/L)
1	107	69	-38
2	24	55	31
3	22	39	17
4	5	15	10
5	71	69	-2
6	15	24	9
9	18	8	-10
10	19	9	-10
11	22	15	-7
12	29	29	0
13	52	50	-2
14	47	65	18
15	16	12	-4
16	19	18	-1
17	23	29	6
18	34	40	6
19	37	45	8
20	35	41	6
21	101	88	-13
22	37	48	11
23	26	31	5
24	18	12	-6
25	205	191	-14
26	25	22	-3

Sum of ABS Error 237	Sum of Error 17
Average of ABS Error 10	Maximum Error -38
Stand. Dev. of ABS Error 9	RMS of Error 13

Chloride Concentration Map (ug/L)

Average Values: 2/94 - 4/95

Averaged over Total Screen Length Below Avg. Water Table



Chloride Calibration in BIOPLUME II (Transverse Dispersivity 10 ft, Including a 5 mg/L background chloride concentration)

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	6	6	6	7	7	7	7	6	6	5	5	5	5	5	5	5	5	0
0	6	6	7	8	9	9	9	8	7	6	6	5	5	5	5	5	5	5	0
0	6	7	8	11	14	16	13	10	8	7	6	6	5	5	5	5	5	5	0
0	7	8	10	15	24	32	22	$\boxed{15}$	10	8	7	6	6	5	5	5	5	5	0
0	7	9	12	22	43	75	40	23	16	10	$\boxed{8}$	6	6	6	5	5	5	5	0
0	9	10	16	29	64	$\boxed{191}$	85	$\boxed{39}$	$\boxed{22}$	13	9	7	6	6	5	5	5	5	0
0	10	12	19	33	$\boxed{69}$	146	103	$\boxed{55}$	31	18	12	9	7	6	6	5	5	5	0
0	11	14	21	37	65	115	105	61	39	$\boxed{24}$	15	10	8	7	6	6	5	5	0
0	13	16	23	39	65	101	95	66	44	27	18	$\boxed{12}$	9	7	6	6	5	5	0
0	15	18	25	39	62	87	$\boxed{88}$	$\boxed{69}$	$\boxed{48}$	$\boxed{31}$	20	14	10	8	7	6	6	5	0
0	16	20	27	39	59	80	$\boxed{82}$	$\boxed{69}$	51	35	23	16	11	9	7	6	6	6	0
0	18	22	29	40	55	72	77	68	53	38	26	18	13	9	7	6	6	6	0
0	20	23	31	42	55	69	72	67	54	40	29	20	14	10	8	7	6	6	0
0	21	25	32	43	55	66	68	63	52	40	29	20	14	11	8	7	6	6	0
0	23	26	33	43	54	63	$\boxed{65}$	60	$\boxed{50}$	39	$\boxed{29}$	21	$\boxed{15}$	11	$\boxed{9}$	7	7	6	0
0	24	27	34	43	52	60	62	58	50	40	30	22	16	12	9	8	7	6	0
0	25	28	34	43	51	58	60	56	49	40	31	23	17	13	10	8	7	7	0
0	27	30	35	42	50	55	57	55	48	40	31	24	18	14	11	9	7	7	0
0	28	31	36	42	49	54	55	53	47	40	32	24	19	14	11	9	8	7	0
0	29	31	36	42	48	52	54	52	46	39	32	25	19	15	12	9	8	7	0
0	30	32	36	42	47	51	52	50	45	39	32	25	20	15	12	10	8	8	0
0	31	33	36	41	46	49	50	48	44	38	32	25	20	15	12	10	9	8	0
0	31	33	36	40	44	47	48	47	43	37	31	24	19	15	12	10	9	8	0
0	31	33	36	39	43	46	47	46	42	36	30	24	19	15	12	10	9	8	0
0	31	32	35	38	$\boxed{41}$	44	$\boxed{45}$	44	$\boxed{40}$	35	$\boxed{29}$	23	$\boxed{18}$	15	$\boxed{12}$	10	9	9	0
0	30	31	34	36	39	41	43	42	38	33	27	21	17	14	12	10	9	9	0
0	28	29	31	33	36	39	40	40	36	30	25	19	16	13	11	9	9	8	0
0	18	22	25	28	31	35	38	38	32	26	21	17	14	11	10	9	8	7	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Chloride Calibration in BIOPLUME II (Transverse Dispersivity 5 ft, including a 5 mg/L background chloride concentration)

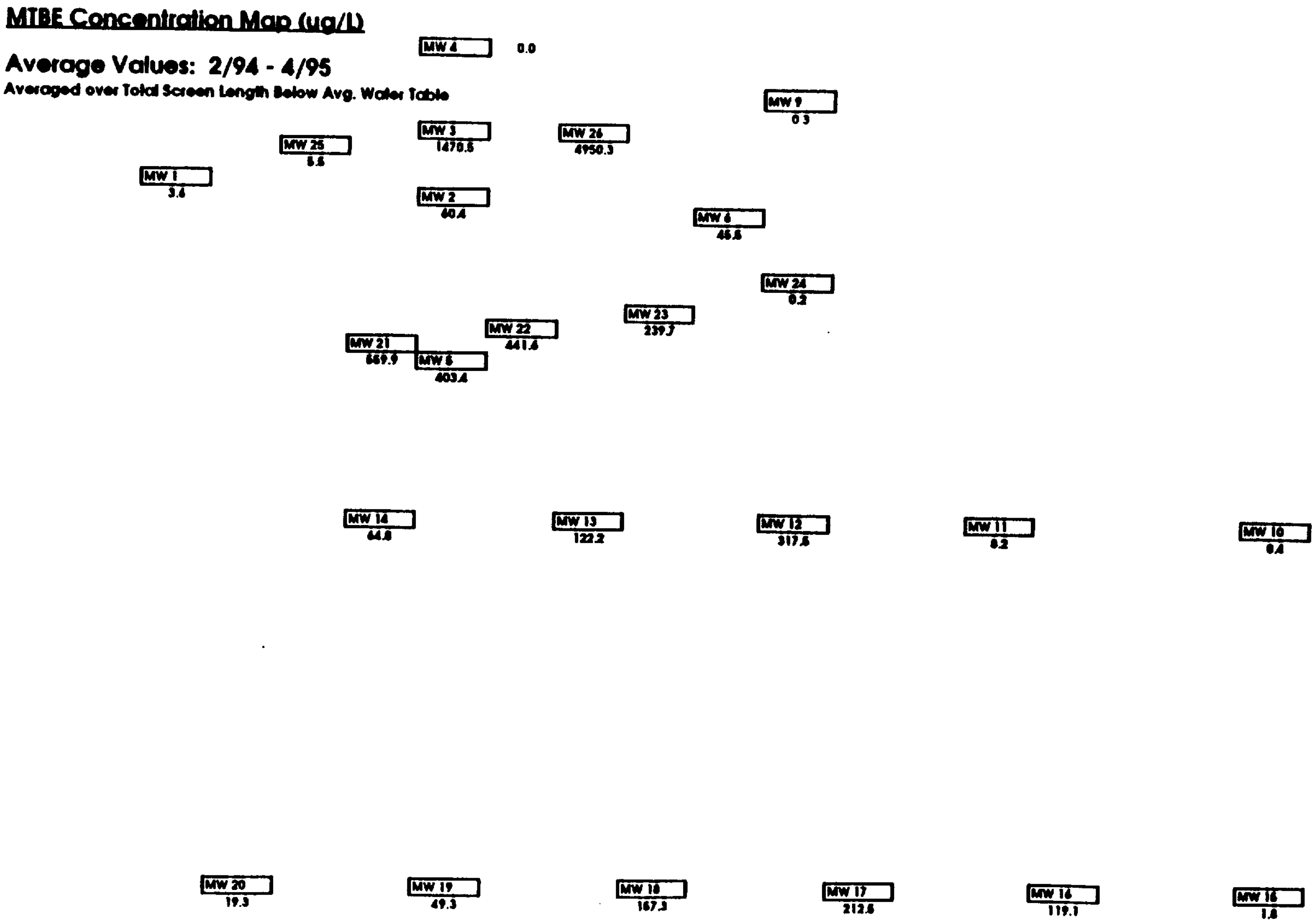
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	5	6	7	7	8	7	7	5	5	5	5	5	5	5	5	5	5	0
0	5	6	7	8	10	11	9	7	6	5	5	5	5	5	5	5	5	5	0
0	6	6	8	11	16	19	12	9	7	6	5	5	5	5	5	5	5	5	0
0	6	7	9	15	29	42	23	13	8	6	6	5	5	5	5	5	5	5	0
0	6	7	10	21	46	93	49	19	11	8	6	6	5	5	5	5	5	5	0
0	6	8	12	23	62	231	95	35	16	10	7	6	5	5	5	5	5	5	0
0	7	8	13	28	69	186	124	51	23	12	8	6	6	5	5	5	5	5	0
0	7	9	14	29	68	152	129	64	29	15	9	7	6	5	5	5	5	5	0
0	8	10	16	30	62	130	121	76	38	19	11	8	6	6	5	5	5	5	0
0	9	11	18	30	60	114	116	84	46	24	14	9	7	6	5	5	5	5	0
0	9	12	20	34	57	104	110	88	52	28	16	10	7	6	5	5	5	5	0
0	10	13	22	38	64	100	105	91	58	33	19	11	8	6	6	5	5	5	0
0	11	14	23	39	65	94	100	83	54	33	19	12	8	6	6	5	5	5	0
0	12	15	24	40	64	89	95	80	55	35	21	13	9	7	6	5	5	5	0
0	13	16	25	40	62	85	91	78	57	36	23	14	9	7	6	5	5	5	0
0	14	17	26	41	61	81	87	77	58	39	24	15	10	8	6	6	5	5	0
0	15	19	27	41	60	77	83	75	58	40	26	16	11	8	6	6	5	5	0
0	15	20	28	42	59	74	80	74	58	41	27	18	12	8	7	6	5	5	0
0	16	21	29	42	58	72	77	72	58	42	28	18	12	9	7	6	5	5	0
0	17	22	30	43	57	70	75	70	57	42	29	19	13	9	7	6	6	5	0
0	18	22	31	43	56	68	72	68	56	42	29	20	13	10	7	6	6	5	0
0	19	23	31	42	54	65	70	65	55	42	29	20	14	10	7	6	6	5	0
0	19	23	30	40	50	61	67	64	54	41	27	19	13	9	7	6	6	5	0
0	20	23	29	39	48	58	64	62	52	40	28	19	13	9	7	6	6	6	0
0	20	23	28	36	46	55	61	59	49	38	27	18	13	9	7	6	6	6	0
0	20	22	26	32	41	50	56	56	47	36	24	17	12	9	7	6	6	6	0
0	19	20	23	28	34	42	50	51	43	31	21	15	11	8	7	6	6	6	0
0	14	15	19	22	27	34	43	47	39	27	18	12	10	7	6	6	6	5	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Calibration of Decay Rate for the MTBE Plume Using the BIOPLUME II Model

Transverse Dispersivity (ft)	**5**	**Source Concentration (mg/L)**	**1,200**
Longitudinal Dispersivity (ft)	**40**	**Decay Rate (1/d)**	**0.0016**

Well	Field Concentrations (mg/L)	Modeled Concentrations (mg/L)	Model Error (mg/L)
1	0.00	0.02	0.02
2	0.06	0.82	0.76
3	1.47	0.84	-0.63
4	0.00	0.33	0.33
5	0.40	0.42	0.02
6	0.05	1.58	1.53
9	0.00	0.12	0.12
10	0.00	0.02	0.02
11	0.01	0.11	0.10
12	0.32	0.38	0.06
13	0.12	0.38	0.26
14	0.06	0.12	0.06
15	0.00	0.01	0.01
16	0.12	0.03	-0.09
17	0.21	0.07	-0.14
18	0.16	0.08	-0.08
19	0.05	0.03	-0.02
20	0.02	0.01	-0.01
21	0.56	0.17	-0.39
22	0.44	1.13	0.69
23	0.24	1.13	0.89
24	0.00	0.26	0.26
25	0.01	0.06	0.05
26	4.95	4.11	-0.84

Sum of ABS Error 7.38	**Sum of Error** 2.98
Average of ABS Error 0.31	**Maximum Error** 1.53
Stand. Dev. of ABS Error 0.39	**RMS of Error** 0.49



MTBE Concentration Map (ug/L)

Average Values: 2/94 - 4/95

Averaged over Total Screen Length Below Avg. Water Table

MTBE Calibration in BIOPLUME II (Transverse Dispersivity of 5 ft)

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0.01	0.01	0.02	0.04	0.02	0.02	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0.01	0.02	0.04	0.07	0.07	0.03	0.01	0	0	0	0	0	0	0	0
0	0	0	0	0	0.01	0.03	0.08	0.16	0.19	0.09	0.03	0.01	0	0	0	0	0	0	0
0	0	0	0	0	0.01	0.05	0.13	$\boxed{0.33}$	0.51	0.22	0.05	0.01	0	0	0	0	0	0	0
0	0	0	0	0.01	0.02	0.05	0.18	0.63	1.55	0.55	$\boxed{0.12}$	0.03	0.01	0	0	0	0	0	0
0	0	0	0	0.01	0.02	$\boxed{0.06}$	0.23	$\boxed{0.84}$	$\boxed{4.11}$	1.51	0.33	0.08	0.02	0.01	0	0	0	0	0
0	0	0	0	0.01	$\boxed{0.02}$	0.06	0.22	$\boxed{0.82}$	2.9	1.76	0.47	0.14	0.04	0.01	0	0	0	0	0
0	0	0	0	0.01	0.02	0.06	0.2	0.65	2	$\boxed{1.58}$	0.61	0.22	0.07	0.02	0.01	0	0	0	0
0	0	0	0	0.01	0.02	0.06	0.16	0.5	1.5	1.45	0.69	$\boxed{0.26}$	0.08	0.03	0.01	0	0	0	0
0	0	0	0	0.01	0.02	0.06	$\boxed{0.17}$	0.49	$\boxed{1.13}$	$\boxed{1.13}$	0.65	0.28	0.1	0.03	0.01	0	0	0	0
0	0	0	0	0.01	0.02	0.06	0.16	$\boxed{0.42}$	0.92	0.92	0.6	0.3	0.12	0.04	0.01	0	0	0	0
0	0	0	0	0.01	0.02	0.06	0.15	0.36	0.72	0.76	0.55	0.3	0.13	0.05	0.02	0	0	0	0
0	0	0	0	0.01	0.02	0.05	0.13	0.31	0.59	0.65	0.5	0.29	0.13	0.06	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.05	0.11	0.24	0.45	0.55	0.45	0.26	0.12	0.05	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.05	$\boxed{0.12}$	0.24	$\boxed{0.38}$	0.46	$\boxed{0.38}$	0.23	$\boxed{0.11}$	0.05	$\boxed{0.02}$	0.01	0	0	0
0	0	0	0	0.01	0.02	0.05	0.11	0.21	0.34	0.38	0.32	0.2	0.1	0.05	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.05	0.1	0.19	0.29	0.32	0.27	0.18	0.1	0.05	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.05	0.09	0.16	0.24	0.27	0.23	0.16	0.09	0.04	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.04	0.08	0.14	0.2	0.22	0.19	0.14	0.08	0.04	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.04	0.07	0.12	0.17	0.18	0.16	0.12	0.07	0.04	0.02	0.01	0	0	0
0	0	0	0	0.01	0.02	0.03	0.06	0.1	0.14	0.16	0.14	0.1	0.06	0.03	0.02	0.01	0	0	0
0	0	0	0	0.01	0.01	0.03	0.06	0.09	0.12	0.13	0.12	0.08	0.05	0.03	0.01	0.01	0	0	0
0	0	0	0	0.01	0.01	0.02	0.05	0.08	0.1	0.11	0.1	0.07	0.04	0.02	0.01	0	0	0	0
0	0	0	0	0.01	0.01	0.02	0.04	0.07	0.09	0.09	0.08	0.06	0.04	0.02	0.01	0	0	0	0
0	0	0	0	0	$\boxed{0.01}$	0.02	$\boxed{0.03}$	0.06	$\boxed{0.08}$	0.08	$\boxed{0.07}$	0.04	$\boxed{0.03}$	0.01	$\boxed{0.01}$	0	0	0	0
0	0	0	0	0	0.01	0.01	0.03	0.05	0.06	0.06	0.05	0.03	0.02	0.01	0	0	0	0	0
0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.05	0.04	0.02	0.01	0.01	0	0	0	0	0
0	0	0	0	0	0	0	0.01	0.02	0.04	0.04	0.02	0.01	0.01	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

MTBE Calibration in BIOPLUME II (Transverse Dispersivity of 10 ft)

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0.01	0.01	0.02	0.03	0.02	0.02	0.01	0	0	0	0	0	0	0	0
0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.06	0.04	0.02	0.01	0	0	0	0	0	0	0
0	0	0	0	0.01	0.02	0.04	0.08	0.14	0.16	0.09	0.05	0.02	0.01	0	0	0	0	0	0
0	0	0	0	0.01	0.03	0.06	0.15	$\boxed{0.32}$	0.46	0.23	0.11	0.05	0.02	0.01	0	0	0	0	0
0	0	0	0.01	0.01	0.03	0.09	0.24	0.64	1.25	0.5	$\boxed{0.22}$	0.09	0.04	0.02	0.01	0	0	0	0
0	0	0	0.01	0.02	0.04	$\boxed{0.11}$	0.31	$\boxed{0.98}$	$\boxed{3.37}$	1.06	0.4	0.17	0.07	0.03	0.01	0.01	0	0	0
0	0	0	0.01	0.02	$\boxed{0.05}$	0.13	0.34	$\boxed{0.89}$	2.13	1.42	0.61	0.27	0.11	0.05	0.02	0.01	0	0	0
0	0	0	0.01	0.02	0.06	0.13	0.32	0.72	1.48	$\boxed{1.3}$	0.67	0.32	0.14	0.06	0.03	0.01	0	0	0
0	0	0.01	0.01	0.03	0.06	0.13	0.3	0.6	1.08	1.04	0.66	$\boxed{0.35}$	0.17	0.08	0.03	0.01	0.01	0	0
0	0	0.01	0.01	0.03	0.06	0.13	$\boxed{0.26}$	0.49	$\boxed{0.8}$	$\boxed{0.83}$	0.61	0.36	0.18	0.09	0.04	0.02	0.01	0	0
0	0	0.01	0.01	0.03	0.06	0.13	0.25	$\boxed{0.42}$	0.63	0.67	0.52	0.33	0.18	0.09	0.05	0.02	0.01	0.01	0
0	0.01	0.01	0.01	0.03	0.06	0.12	0.22	0.36	0.51	0.54	0.44	0.31	0.18	0.1	0.05	0.02	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.06	0.11	0.19	0.3	0.41	0.44	0.38	0.28	0.18	0.1	0.05	0.03	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.05	0.1	0.16	0.25	0.33	0.36	0.32	0.25	0.17	0.1	0.05	0.03	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.05	0.09	$\boxed{0.14}$	0.21	$\boxed{0.27}$	0.3	$\boxed{0.27}$	0.22	$\boxed{0.15}$	0.09	$\boxed{0.05}$	0.03	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.05	0.08	0.13	0.18	0.23	0.25	0.23	0.18	0.13	0.08	0.05	0.03	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.05	0.08	0.12	0.16	0.19	0.2	0.19	0.15	0.11	0.07	0.04	0.02	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.05	0.07	0.1	0.14	0.16	0.17	0.16	0.13	0.1	0.07	0.04	0.02	0.01	0.01	0
0	0.01	0.01	0.02	0.03	0.04	0.06	0.09	0.12	0.14	0.14	0.13	0.11	0.08	0.06	0.04	0.02	0.01	0.01	0
0	0.01	0.01	0.01	0.02	0.04	0.06	0.08	0.1	0.12	0.12	0.11	0.09	0.07	0.05	0.03	0.02	0.01	0.01	0
0	0.01	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.1	0.1	0.1	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0
0	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.08	0.09	0.08	0.07	0.05	0.04	0.02	0.02	0.01	0.01	0
0	0.01	0.01	0.01	0.02	0.02	0.04	0.05	0.06	0.07	0.07	0.07	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0
0	0	0.01	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.06	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0
0	0	0	0.01	0.01	$\boxed{0.02}$	0.02	$\boxed{0.03}$	0.04	$\boxed{0.05}$	0.05	$\boxed{0.05}$	0.04	$\boxed{0.03}$	0.02	$\boxed{0.01}$	0.01	0.01	0	0
0	0	0	0.01	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0	0	0
0	0	0	0	0.01	0.01	0.01	0.02	0.03	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0	0	0	0
0	0	0	0	0	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Calibration of Anaerobic Decay Rate for the BTEX Plume Using the BIOPLUME II Model

Transverse Dispersivity (ft)	5
Longitudinal Dispersivity (ft)	40

Source Concentration (mg/L)	15,000
Anaerobic Decay Rate (1/d)	0.0050

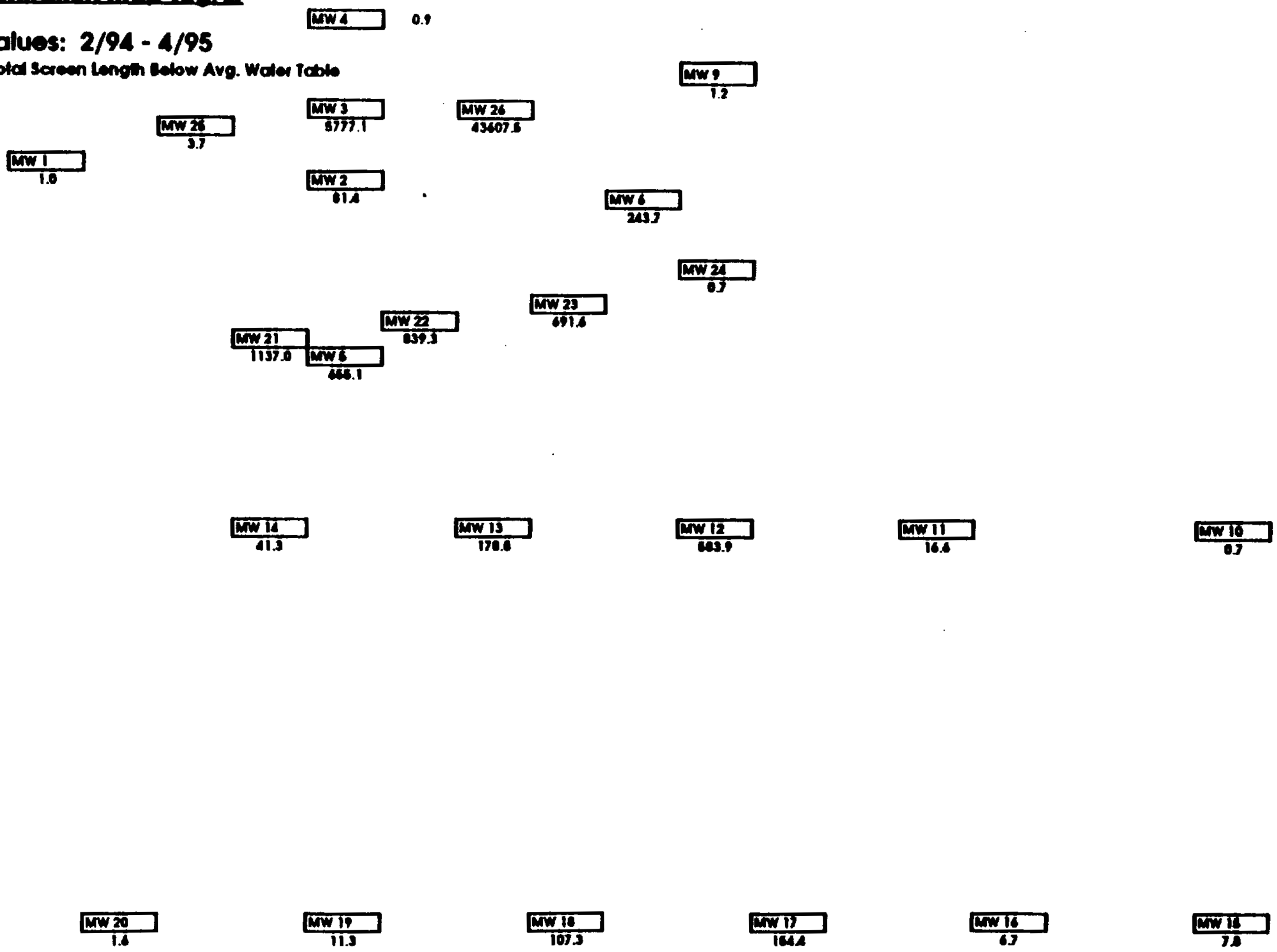
Well	Field Concentrations (mg/L)	Modeled Concentrations (mg/L)	Model Error (mg/L)
1	0.00	0.00	0.00
2	0.08	2.45	2.37
3	5.78	4.38	-1.40
4	0.00	0.09	0.09
5	0.66	0.02	-0.64
6	0.24	7.29	7.05
9	0.00	0.00	0.00
10	0.00	0.00	0.00
11	0.02	0.00	-0.02
12	0.58	0.10	-0.48
13	0.18	0.16	-0.02
14	0.04	0.00	-0.04
15	0.01	0.00	-0.01
16	0.01	0.00	-0.01
17	0.15	0.00	-0.15
18	0.11	0.00	-0.11
19	0.01	0.00	-0.01
20	0.00	0.00	0.00
21	1.14	0.00	-1.14
22	0.84	3.68	2.84
23	0.69	3.98	3.29
24	0.00	0.00	0.00
25	0.00	0.00	0.00
26	43.61	37.45	-6.16

Sum of ABS Error 25.83	**Sum of Error** 5.45
Average of ABS Error 1.08	**Maximum Error** 7.05
Stand. Dev. of ABS Error 1.96	**RMS of Error** 2.20

BTEX Concentration Map (ug/L)

Average Values: 2/94 - 4/95

Averaged over Total Screen Length Below Avg. Water Table



Total BTEX Calibration in BIOPLUME II

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0.09	1.54	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2.36	10.66	0.35	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	4.38	37.45	7.66	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2.45	21.52	9.58	0.88	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1.06	11.32	7.29	1.83	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0.32	6.22	5.51	2.2	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	3.68	3.98	1.93	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0.02	2.46	2.62	1.13	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1.55	1.72	0.71	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0.88	1.12	0.46	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0.4	0.68	0.29	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0.16	0.39	0.1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Resulting Oxygen Distribution from the BTEX Calibration in BIOPLUME II

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	6.98	6.97	6.95	6.89	6.79	6.63	6.39	6.1	6.43	6.47	6.87	6.92	6.93	6.95	6.96	6.96	6.96	6.95	0
0	6.97	6.95	6.93	6.86	6.73	6.45	5.96	5.39	5.57	6.21	6.64	6.84	6.88	6.91	6.92	6.92	6.91	6.9	0
0	6.95	6.93	6.9	6.82	6.64	6.18	5.2	3.66	3.28	5.22	6.18	6.62	6.78	6.85	6.87	6.88	6.87	6.86	0
0	6.92	6.91	6.87	6.78	6.54	5.93	3.94	0	0	3.22	5.78	6.34	6.61	6.76	6.82	6.84	6.84	6.83	0
0	6.9	6.88	6.84	6.73	6.49	5.79	3.21	0	0	0	4.71	5.86	6.32	6.63	6.75	6.8	6.81	6.81	0
0	6.88	6.86	6.81	6.69	6.39	5.58	2.58	0	0	0	1.94	4.93	5.98	6.48	6.67	6.75	6.77	6.78	0
0	6.85	6.83	6.77	6.63	6.29	5.54	2.97	0	0	0	0	3.93	5.58	6.23	6.56	6.7	6.74	6.74	0
0	6.83	6.8	6.73	6.58	6.23	5.45	3.47	0	0	0	0	2.68	4.85	6.01	6.45	6.64	6.7	6.72	0
0	6.8	6.77	6.69	6.51	6.11	5.36	3.75	0	0	0	0	1.98	4.5	5.74	6.33	6.57	6.66	6.69	0
0	6.77	6.74	6.66	6.45	5.99	5.12	3.57	0.39	0	0	0	1.58	4.18	5.51	6.18	6.5	6.63	6.67	0
0	6.74	6.71	6.61	6.39	5.92	5.02	3.33	0	0	0	0	1.43	3.9	5.25	5.99	6.42	6.59	6.64	0
0	6.71	6.67	6.56	6.33	5.87	4.96	3.34	0.36	0	0	0	1.27	3.61	4.95	5.83	6.36	6.55	6.61	0
0	6.69	6.64	6.51	6.26	5.79	4.91	3.35	0.97	0	0	0	1.17	3.39	4.76	5.8	6.3	6.51	6.58	0
0	6.66	6.6	6.47	6.18	5.66	4.85	3.47	1.51	0	0	0	1.25	3.32	4.76	5.72	6.23	6.47	6.55	0
0	6.63	6.57	6.43	6.13	5.57	4.64	3.27	1.54	0	0	0	1.59	3.28	4.68	5.63	6.17	6.42	6.52	0
0	6.61	6.55	6.39	6.08	5.5	4.56	3.2	1.61	0	0	0.09	1.54	3.24	4.6	5.55	6.11	6.39	6.5	0
0	6.58	6.52	6.36	6.03	5.46	4.52	3.21	1.73	0.44	0	0.45	1.7	3.2	4.54	5.48	6.06	6.35	6.47	0
0	6.56	6.49	6.32	5.99	5.41	4.5	3.25	1.87	0.7	0.23	0.67	1.8	3.2	4.49	5.44	6.02	6.33	6.45	0
0	6.54	6.47	6.3	5.96	5.38	4.49	3.3	2.02	0.97	0.55	0.93	1.93	3.24	4.48	5.41	5.99	6.3	6.43	0
0	6.53	6.45	6.28	5.94	5.37	4.51	3.37	2.18	1.21	0.82	1.16	2.11	3.33	4.51	5.4	5.97	6.29	6.42	0
0	6.51	6.44	6.26	5.94	5.39	4.57	3.48	2.34	1.45	1.1	1.44	2.33	3.49	4.58	5.42	5.97	6.28	6.41	0
0	6.5	6.43	6.26	5.95	5.46	4.69	3.66	2.55	1.72	1.42	1.74	2.72	3.72	4.74	5.49	6	6.28	6.4	0
0	6.5	6.43	6.3	6.03	5.55	4.85	3.93	2.77	2	1.78	2.12	3.11	4.03	4.95	5.61	6.07	6.29	6.41	0
0	6.5	6.44	6.3	6.04	5.62	5	4.04	3.09	2.26	2.04	2.48	3.37	4.2	5.08	5.71	6.11	6.32	6.42	0
0	6.51	6.46	6.34	6.15	5.76	5.18	4.35	3.42	2.6	2.46	2.84	3.84	4.61	5.32	5.83	6.18	6.36	6.44	0
0	6.53	6.49	6.4	6.24	5.97	5.44	4.73	3.77	2.96	2.89	3.47	4.25	5.01	5.64	6.04	6.27	6.42	6.47	0
0	6.58	6.56	6.48	6.38	6.19	5.8	5.12	4.29	3.45	3.44	4.08	4.74	5.38	5.88	6.22	6.4	6.49	6.54	0
0	6.78	6.72	6.63	6.55	6.44	6.16	5.66	5.06	3.9	4.21	4.88	5.4	5.75	6.15	6.39	6.54	6.63	6.7	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix D

MODELING WITH THE ANALYTICAL SOLUTION

1.0 INPUT PARAMETERS

Analytical Solution Input Parameters

Plume Specific Parameters:

Chloride Plume

The distance between MW-1 and MW-25 was used as the approximate source width.

The screening interval of the medium depth well for MW-25 was used as the approximate source depth.

The chloride at the site was believed to have originated from a 'salting house' located behind the current home over 50 yrs ago.

Gasoline Plume

The distance between MW-3 and MW-26 was used as the approximate source width.

Since both the short and medium depth wells of MW-26 have shown significant contamination, the screening interval for both was used to approximate the source depth.

A best estimate for the time of spill has been placed at the year 1984.

Plume Specific Parameters	Chloride Plume	Gasoline Plume
Finite Planar Source Width Y (ft)	40	25
Finite Planar Source Depth Z (ft)	5	8
Time Since Start of Release t (yr)	50	11

Site Specific Parameters:

The longitudinal, transverse, and vertical dispersivities were first estimated as follows:

alpha-x as approximately one tenth of the contaminant flow length,
alpha-y as approximately one tenth of alpha-x,
alpha-z as approximately one tenth of alpha-y.

With these estimations the following were used as initial dispersities:

alpha-x = 60 ft.
alpha-y = 6 ft.
alpha-z = 0.6 ft.

The chloride plume was used to calibrate the dispersivities and the following values were used for all of the analytical solution modeling.

Site Specific Parameters	Value
Longitudinal Dispersivity alpha x (ft)	60
Transverse Dispersivity alpha y (ft)	4
Vertical Dispersivity alpha z (ft)	0.15

Compound Specific Parameters:

Each of the following source concentrations, Co, were approximated from field data.

Transport velocities, v, were calculated using the average groundwater velocity shown in Appendix A.2.0 and the retardation factors for each compound shown in Appendix A.3.0.

The equation is:

$$Vc = Vg / Rf$$

	Compound Specific Parameters	
Compound	**Source Concentration Co (mg/L)**	**Transport Velocity v (ft/yr)**
Chloride	**500**	**57.0**
MTBE	**11**	**57.0**
Benzene	**19**	**55.3**
Toluene	**46**	**52.8**
Ethylbenzene	**6**	**48.3**
m/p - Xylene	**14**	**47.9**
o - Xylene	**7**	**52.3**
Total BTEX	**90**	**52.1**

2.0 X AND Y DISTANCES TO MONITORING WELLS

X and Y Locations of Monitoring Wells for the Analytical Solution

Output from the analytical solution was compared to field values at the following monitoring wells.

Line A: MW-25 (Chloride), or MW-26(Gasoline).

Line B: MW-21, MW-5, MW-22, MW-23, and MW-24.

Line C: MW-14, MW-13, MW-12, MW-11, and MW-10.

Line D: MW-20, MW-19, MW-18, MW-17, MW-16 and MW-15.

X and Y values for the above monitoring wells were determined for both the chloride and gasoline plumes.

CHLORIDE PLUME:

Locate the Chloride Source 5 ft. behind MW-25.

Centerline Locations for Each Line of Wells

Line A: MW-25
Line B: Between MW-21 and MW-5
Line C: Between MW-14 and MW-13
Line D: MW-19

Coordinates Based on MW-26
as the Origin (X=0, Y=0) and the
Longitudinal Axis Towards MW-18 (Y=0)

Well #	X (ft)	Y (ft)
5	140.61	-27.24
10	275.65	159.14
11	276.19	98.63
12	274.56	47.22
13	271.89	3.14
14	272.44	-52.95
15	583.98	152.96
16	582.57	101.74
17	581.12	51.22
18	578.32	0.00
19	578.32	-49.80
20	576.87	-98.88
21	131.51	-50.26
22	125.08	-11.70
23	113.27	30.07
24	100.42	65.42
25	4.52	-64.16
26	0.00	0.00

Approximate Location from the Sourc

Monitoring Well	X Location (ft)	Y Location (ft)
MW-25	5	0
MW-21	131.5	-11.5
MW-5	140.6	11.5
MW-22	125.1	27
MW-23	113.3	68.8
MW-24	100.4	104.2
MW-14	275	-28.1
MW-13	275	28.1
MW-12	275	72.3
MW-11	275	123.7
MW-10	275	184.2
MW-20	580	-49.1
MW-19	580	0
MW-18	580	49.8
MW-17	580	101.1
MW-16	580	151.6
MW-15	580	202.8

GASOLINE PLUME:

Locate the Gasoline Source 5 ft. behind MW-26.

Centerline Locations for Each Line of Wells

Line A:	MW-26
Line B:	MW-22
Line C:	MW-12
Line D:	Between MW-18 and MW-17

Coordinates Based on MW-26
as the Origin (X=0, Y=0) and the
Longitudinal Axis Towards MW-18 (Y=0)

Well #	X (ft)	Y (ft)
5	140.61	-27.24
10	275.65	159.14
11	276.19	98.63
12	274.56	47.22
13	271.89	3.14
14	272.44	-52.95
15	583.98	152.96
16	582.57	101.74
17	581.12	51.22
18	578.32	0.00
19	578.32	-49.80
20	576.87	-98.88
21	131.51	-50.26
22	125.08	-11.70
23	113.27	30.07
24	100.42	65.42
25	4.52	-64.16
26	0.00	0.00

Approximate Location from the Source

Monitoring Well	X Location (ft)	Y Location (ft)
MW-26	5	0
MW-21	136.5	-38.5
MW-5	145.6	-15.5
MW-22	130.1	0
MW-23	118.3	41.8
MW-24	105.4	77.2
MW-14	280	-100.3
MW-13	280	-44.2
MW-12	280	0
MW-11	280	51.4
MW-10	280	111.9
MW-20	585	-124.6
MW-19	585	-74.5
MW-18	585	-25.7
MW-17	585	25.7
MW-16	585	76.2
MW-15	585	127.4

3.0 CALIBRATIONS FOR CHLORIDE, MTBE, TOTAL BTEX, AND EACH OF THE INDIVIDUAL BTEX COMPOUNDS

Calibration of Analytical Solution Dispersivities with the Chloride Plume

Chloride Source Concentration Co (mg/L)	500
Longitudinal Dispersivity alpha-x (ft)	60.0
Transverse Dispersivity alpha-y (ft)	4.0
Vertical Dispersivity alpha-z (ft)	0.15

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 25	361	504
140 ft MW - 5	124	131
275 ft MW - 14	80	74
580 ft MW - 19	38	39

LINE B:	MW - 21	MW - 5	MW - 22	MW - 23	MW - 24
Field Values (mg/L)	116	124	38	37	20
Modeled Plume (mg/L)	131	124	106	21	5
Model Error (mg/L)	15	0	68	-16	-15

Sum of Error
51.3

Sum of ABS Error
113.3

RMS of Error
32.5

LINE C:	MW - 14	MW - 13	MW - 12	MW - 11	MW - 10
Field Values (mg/L)	80	73	33	29	21
Modeled Plume (mg/L)	63	63	28	8	5
Model Error (mg/L)	-17	-10	-5	-21	-16

Sum of Error
-69.2

Sum of ABS Error
69.2

RMS of Error
14.9

Calibration of Analytical Solution Dispersivities with the Chloride Plume

Chloride Source Concentration Co (mg/L)	500
Longitudinal Dispersivity alpha-x (ft)	60.0
Transverse Dispersivity alpha-y (ft)	4.0
Vertical Dispersivity alpha-z (ft)	0.15

Comparison of Maximum Observed Concentrations with Modeled Values

Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 25	361	504
140 ft MW - 5	124	131
275 ft MW - 14	80	74
580 ft MW - 19	38	39

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	37	38	37	25	20	17
Modeled Plume (mg/L)	31	39	31	17	8	5
Model Error (mg/L)	-6	1	-6	-8	-12	-12

Sum of Error
-41.9

Sum of ABS Error
44.1

RMS of Error
8.3

Calibration of MTBE Decay Rate in the Analytical Solution

MTBE Source Concentration Co (mg/L)	11.0

Decay Rate Calibrated to Lines B and C (1/yr)	0.501

(This is the average of decay rates which minimize the sum of absolute error for Lines B and C)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	**Field Values (mg/L)**	**Modeled Plume (mg/L)**
5 ft from Source MW - 26	9.95	10.14
140 ft MW - 5	0.744	1.030
280 ft MW - 12	0.332	0.238
585 ft MW - 17	0.245	0.017

LINE B:	**MW - 21**	**MW - 5**	**MW - 22**	**MW - 23**	**MW - 24**
Field Values (mg/L)	0.623	0.744	0.474	0.703	0.000
Modeled Plume (mg/L)	0.562	0.874	1.160	0.560	0.057
Model Error (mg/L)	-0.061	0.130	0.686	-0.143	0.057

Sum of Error 0.669

Sum of ABS Error 1.076

RMS of Error 0.321

LINE C:	**MW - 14**	**MW - 13**	**MW - 12**	**MW - 11**	**MW - 10**
Field Values (mg/L)	0.116	0.225	0.332	0.014	0.001
Modeled Plume (mg/L)	0.027	0.156	0.238	0.134	0.016
Model Error (mg/L)	-0.089	-0.069	-0.094	0.120	0.015

Sum of Error -0.118

Sum of ABS Error 0.387

RMS of Error 0.085

Calibration of MTBE Decay Rate in the Analytical Solution

MTBE Source Concentration Co (mg/L)	11.0

Decay Rate Calibrated to Line D (1/yr)	0.084

(This is the decay rate which minimizes the sum of absolute error for Line D)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	9.95	10.36
145 ft MW - 5	0.744	1.969
280 ft MW - 12	0.332	0.916
585 ft MW - 17	0.245	0.228

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	0.020	0.070	0.213	0.245	0.157	0.002
Modeled Plume (mg/L)	0.044	0.127	0.213	0.213	0.124	0.041
Model Error (mg/L)	0.024	0.057	0.000	-0.032	-0.033	0.039

Sum of Error
0.055

Sum of ABS Error
0.186

RMS of Error
0.035

Calibration of Benzene Decay Rate in the Analytical Solution

Benzene Source Concentration Co (mg/L)	**19.0**

Decay Rate Calibrated to Lines B and C (1/yr)	**0.732**

(This is the average of decay rates which minimize the sum of absolute error for Lines B and C)

Comparison of Maximum Observed Concentrations with Modeled Values

Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	17.22	17.32
120 ft MW - 23	1.164	1.715
260 ft MW - 12	0.494	0.214
585 ft MW - 17	0.168	0.008

LINE B:	MW - 21	MW - 5	MW - 22	MW - 23	MW - 24
Field Values (mg/L)	0.769	0.837	0.611	1.164	0.000
Modeled Plume (mg/L)	0.706	1.074	1.478	0.734	0.077
Model Error (mg/L)	-0.063	0.237	0.867	-0.430	0.077

Sum of Error
0.688

Sum of ABS Error
1.674

RMS of Error
0.448

LINE C:	MW - 14	MW - 13	MW - 12	MW - 11	MW - 10
Field Values (mg/L)	0.055	0.238	0.494	0.020	0.000
Modeled Plume (mg/L)	0.024	0.140	0.214	0.120	0.014
Model Error (mg/L)	-0.031	-0.098	-0.280	0.100	0.014

Sum of Error
-0.295

Sum of ABS Error
0.524

RMS of Error
0.141

Calibration of Benzene Decay Rate in the Analytical Solution

Benzene Source Concentration Co (mg/L)	19.0

Decay Rate Calibrated to Line D (1/yr)	0.210

(This is the decay rate which minimizes the sum of absolute error for Line D)

Comparison of Maximum Observed Concentrations with Modeled Values

Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	17.22	17.78
120 ft MW - 23	1.164	3.309
280 ft MW - 12	0.494	0.983
585 ft MW - 17	0.168	0.161

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	0.001	0.021	0.150	0.168	0.014	0.000
Modeled Plume (mg/L)	0.031	0.090	0.150	0.150	0.087	0.029
Model Error (mg/L)	0.030	0.069	0.000	-0.018	0.073	0.029

Sum of Error
0.183

Sum of ABS Error
0.219

RMS of Error
0.045

Calibration of Toluene Decay Rate in the Analytical Solution

Toluene Source Concentration Co (mg/L)	46.0

Decay Rate Calibrated to Lines B and C (1/yr)	4.550

(This is the average of decay rates which minimize the sum of absolute error for Lines B and C)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	**Field Values (mg/L)**	**Modeled Plume (mg/L)**
5 ft from Source MW - 26	40.14	37.60
120 ft MW - 23	0.114	0.304
280 ft MW - 12	0.018	0.001
585 ft MW - 17	0.008	0.000

LINE B:	**MW - 21**	**MW - 5**	**MW - 22**	**MW - 23**	**MW - 24**
Field Values (mg/L)	0.042	0.025	0.051	0.114	0.000
Modeled Plume (mg/L)	0.087	0.109	0.210	0.135	0.019
Model Error (mg/L)	0.045	0.084	0.159	0.021	0.019

Sum of Error 0.329
Sum of ABS Error 0.329
RMS of Error 0.084

LINE C:	**MW - 14**	**MW - 13**	**MW - 12**	**MW - 11**	**MW - 10**
Field Values (mg/L)	0.002	0.004	0.018	0.001	0.000
Modeled Plume (mg/L)	0.000	0.001	0.001	0.001	0.000
Model Error (mg/L)	-0.002	-0.003	-0.017	0.000	0.000

Sum of Error -0.022
Sum of ABS Error 0.022
RMS of Error 0.008

Calibration of Toluene Decay Rate in the Analytical Solution

Toluene Source Concentration Co (mg/L)	46.0

Decay Rate Calibrated to Line D (1/yr)	1.050

(This is the decay rate which minimizes the sum of absolute error for Line D)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	40.14	41.30
120 ft MW - 23	0.114	2.897
280 ft MW - 12	0.018	0.224
585 ft MW - 17	0.008	0.003

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	0.000	0.000	0.001	0.008	0.000	0.000
Modeled Plume (mg/L)	0.001	0.002	0.003	0.003	0.002	0.001
Model Error (mg/L)	0.001	0.002	0.002	-0.005	0.002	0.001

Sum of Error
0.002

Sum of ABS Error
0.012

RMS of Error
0.002

Calibration of Ethylbenzene Decay Rate in the Analytical Solution

Ethylbenzene Source Concentration Co (mg/L)	6.0

Decay Rate Calibrated to Line B (1/yr)	5.600

(This is the decay rate which minimizes the sum of absolute error for Line B)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	4.31	4.76
120 ft MW - 23	0.010	0.019
280 ft MW - 12	0.002	0.000
585 ft MW - 17	0.000	0.000

LINE B:	MW - 21	MW - 5	MW - 22	MW - 23	MW - 24
Field Values (mg/L)	0.010	0.006	0.004	0.010	0.000
Modeled Plume (mg/L)	0.005	0.006	0.013	0.009	0.001
Model Error (mg/L)	-0.005	0.000	0.009	-0.001	0.001

Sum of Error
0.004

Sum of ABS Error
0.016

RMS of Error
0.005

LINE C:	MW - 14	MW - 13	MW - 12	MW - 11	MW - 10
Field Values (mg/L)	0.000	0.001	0.002	0.000	0.000
Modeled Plume (mg/L)	0.000	0.000	0.000	0.000	0.000
Model Error (mg/L)	0.000	-0.001	-0.002	0.000	0.000

Sum of Error
-0.003

Sum of ABS Error
0.003

RMS of Error
0.001

Calibration of Ethylbenzene Decay Rate in the Analytical Solution

Ethylbenzene Source Concentration Co (mg/L)	6.0

Decay Rate Calibrated to Line C (1/yr)	2.505

(This is the decay rate which minimizes the sum of absolute error for Line C)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	**Field Values (mg/L)**	**Modeled Plume (mg/L)**
5 ft from Source MW - 26	4.31	5.11
120 ft MW - 23	0.010	0.107
280 ft MW - 12	0.002	0.002
585 ft MW - 17	0.000	0.000

LINE B:	**MW - 21**	**MW - 5**	**MW - 22**	**MW - 23**	**MW - 24**
Field Values (mg/L)	0.010	0.006	0.004	0.010	0.000
Modeled Plume (mg/L)	0.035	0.047	0.080	0.047	0.006
Model Error (mg/L)	0.025	0.041	0.076	0.037	0.006

Sum of Error
0.185

Sum of ABS Error
0.185

RMS of Error
0.044

LINE C:	**MW - 14**	**MW - 13**	**MW - 12**	**MW - 11**	**MW - 10**
Field Values (mg/L)	0.000	0.001	0.002	0.000	0.000
Modeled Plume (mg/L)	0.000	0.001	0.002	0.001	0.000
Model Error (mg/L)	0.000	0.000	0.000	0.001	0.000

Sum of Error
0.001

Sum of ABS Error
0.002

RMS of Error
0.000

Calibration of m,p - Xylene Decay Rate in the Analytical Solution

m,p - Xylene Source Concentration Co (mg/L)	14.0

Decay Rate Calibrated to Lines B and C (1/yr)	1.600

(This is the average of decay rates which minimize the sum of absolute error for Lines B and C)

Comparison of Maximum Observed Concentrations with Modeled Values

Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	12.19	12.26
120 ft MW - 23	0.365	0.484
280 ft MW - 12	0.038	0.017
585 ft MW - 17	0.002	0.000

LINE B:	MW - 21	MW - 5	MW - 22	MW - 23	MW - 24
Field Values (mg/L)	0.144	0.078	0.110	0.365	0.000
Modeled Plume (mg/L)	0.175	0.247	0.385	0.210	0.024
Model Error (mg/L)	0.031	0.169	0.275	-0.155	0.024

Sum of Error 0.344

Sum of ABS Error 0.654

RMS of Error 0.161

LINE C:	MW - 14	MW - 13	MW - 12	MW - 11	MW - 10
Field Values (mg/L)	0.001	0.006	0.038	0.006	0.000
Modeled Plume (mg/L)	0.002	0.011	0.017	0.009	0.001
Model Error (mg/L)	0.001	0.005	-0.021	0.003	0.001

Sum of Error -0.011

Sum of ABS Error 0.032

RMS of Error 0.010

Calibration of m,p - Xylene Decay Rate in the Analytical Solution

m,p - Xylene Source Concentration Co (mg/L)	14.0

Decay Rate Calibrated to Line D (1/yr)	0.936

(This is the decay rate which minimizes the sum of absolute error for Line D)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	12.19	12.58
120 ft MW - 23	0.365	0.898
280 ft MW - 12	0.038	0.071
585 ft MW - 17	0.002	0.001

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	0.000	0.000	0.001	0.002	0.000	0.000
Modeled Plume (mg/L)	0.000	0.001	0.001	0.001	0.001	0.000
Model Error (mg/L)	0.000	0.001	0.000	-0.001	0.001	0.000

Sum of Error
0.001

Sum of ABS Error
0.003

RMS of Error
0.001

Calibration of o - Xylene Decay Rate in the Analytical Solution

o - Xylene Source Concentration Co (mg/L)	7.0

Decay Rate Calibrated to Lines B and C (1/yr)	0.790

(This is the average of decay rates which minimize the sum of absolute error for Lines B and C)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	5.86	6.35
120 ft MW - 23	0.462	0.568
280 ft MW - 12	0.136	0.061
585 ft MW - 17	0.039	0.002

LINE B:	MW - 21	MW - 5	MW - 22	MW - 23	MW - 24
Field Values (mg/L)	0.225	0.266	0.165	0.462	0.000
Modeled Plume (mg/L)	0.230	0.347	0.485	0.243	0.026
Model Error (mg/L)	0.005	0.081	0.320	-0.219	0.026

Sum of Error
0.213

Sum of ABS Error
0.651

RMS of Error
0.177

LINE C:	MW - 14	MW - 13	MW - 12	MW - 11	MW - 10
Field Values (mg/L)	0.016	0.071	0.136	0.008	0.000
Modeled Plume (mg/L)	0.007	0.040	0.061	0.035	0.004
Model Error (mg/L)	-0.009	-0.031	-0.075	0.027	0.004

Sum of Error
-0.084

Sum of ABS Error
0.145

RMS of Error
0.036

Calibration of o - Xylene Decay Rate in the Analytical Solution

o - Xylene Source Concentration Co (mg/L)	7.0

Decay Rate Calibrated to Line D (1/yr)	0.255

(This is the decay rate which minimizes the sum of absolute error for Line D)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	Field Values (mg/L)	Modeled Plume (mg/L)
5 ft from Source MW - 26	5.86	6.53
120 ft MW - 23	0.462	1.114
280 ft MW - 12	0.136	0.294
585 ft MW - 17	0.039	0.039

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	0.000	0.006	0.036	0.039	0.003	0.000
Modeled Plume (mg/L)	0.007	0.021	0.036	0.036	0.021	0.007
Model Error (mg/L)	0.007	0.015	0.000	-0.003	0.018	0.007

Sum of Error
0.045

Sum of ABS Error
0.051

RMS of Error
0.011

Calibration of Total BTEX Decay Rate in the Analytical Solution

BTEX Source Concentration Co (mg/L)	**90.0**

Decay Rate Calibrated to Lines B and C (1/yr)	**1.504**

(This is the average of decay rates which minimize the sum of absolute error for Lines B and C)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	**Field Values (mg/L)**	**Modeled Plume (mg/L)**
5 ft from Source MW - 26	79.71	79.44
120 ft MW - 23	2.115	3.770
280 ft MW - 12	0.680	0.169
585 ft MW - 17	0.213	0.001

LINE B:	**MW - 21**	**MW - 5**	**MW - 22**	**MW - 23**	**MW - 24**
Field Values (mg/L)	1.175	1.211	0.941	2.115	0.001
Modeled Plume (mg/L)	1.396	2.004	3.047	1.631	0.185
Model Error (mg/L)	0.221	0.793	2.106	-0.484	0.184

Sum of Error
2.820

Sum of ABS Error
3.788

RMS of Error
1.037

LINE C:	**MW - 14**	**MW - 13**	**MW - 12**	**MW - 11**	**MW - 10**
Field Values (mg/L)	0.073	0.345	0.680	0.035	0.001
Modeled Plume (mg/L)	0.019	0.110	0.169	0.095	0.011
Model Error (mg/L)	-0.054	-0.235	-0.511	0.060	0.010

Sum of Error
-0.730

Sum of ABS Error
0.870

RMS of Error
0.254

Calibration of Total BTEX Decay Rate in the Analytical Solution

BTEX **Source Concentration** **Co (mg/L)**	**90.0**

Decay Rate **Calibrated to Line D** **(1/yr)**	**0.395**

(This is the decay rate which minimizes the sum of absolute error for Line D)

Comparison of Maximum Observed Concentrations with Modeled Values		
Distance (ft from source)	**Field Values (mg/L)**	**Modeled Plume (mg/L)**
5 ft from Source MW - 26	79.71	83.28
120 ft MW - 23	2.115	11.714
280 ft MW - 12	0.680	2.376
585 ft MW - 17	0.213	0.203

LINE D:	**MW - 20**	**MW - 19**	**MW - 18**	**MW - 17**	**MW - 16**	**MW - 15**
Field Values (mg/L)	0.002	0.028	0.189	0.213	0.018	0.001
Modeled Plume (mg/L)	0.039	0.113	0.189	0.189	0.110	0.037
Model Error (mg/L)	0.037	0.085	0.000	-0.024	0.092	0.036

Sum of Error	0.225
Sum of ABS Error	0.273
RMS of Error	0.056

Comparison of Analytical Solution Modeling Procedures for BTEX:

Modeled Total BTEX Plume vs. Sum of Modeled BTEX Compounds

LINE B:	MW - 21	MW - 5	MW - 22	MW - 23	MW - 24
Field Values (mg/L)	1.175	1.211	0.941	2.115	0.001
Modeled BTEX Plume (mg/L)	1.396	2.004	3.047	1.631	0.185
Sum of Modeled BTEX Compounds (mg/L)	1.103	1.640	2.354	1.215	0.134

Sum of ABS Error
3.788

Sum of ABS Error
2.947

LINE C:	MW - 14	MW - 13	MW - 12	MW - 11	MW - 10
Field Values (mg/L)	0.073	0.345	0.680	0.035	0.001
Modeled BTEX Plume (mg/L)	0.019	0.110	0.169	0.095	0.011
Sum of Modeled BTEX Compounds (mg/L)	0.032	0.185	0.284	0.159	0.018

Sum of ABS Error
0.870

Sum of ABS Error
0.738

LINE D:	MW - 20	MW - 19	MW - 18	MW - 17	MW - 16	MW - 15
Field Values (mg/L)	0.002	0.028	0.189	0.213	0.018	0.001
Modeled BTEX Plume (mg/L)	0.039	0.113	0.189	0.189	0.110	0.037
Sum of Modeled BTEX Compounds (mg/L)	0.038	0.113	0.188	0.188	0.110	0.036

Sum of ABS Error
0.273

Sum of ABS Error
0.274

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