JV TASK 59 – DEMONSTRATION OF ACCELERATED IN SITU CONTAMINANT DEGRADATION BY VACUUM-ENHANCED NUTRIENT DISTRIBUTION

Final Report

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ABSTRACT

The Energy & Environmental Research Center (EERC) conducted remediation of hydrocarbon-contaminated soils and groundwater at a former Mohler Oil site in Bismarck, North Dakota. The remedial strategy was based on the application of two innovative concepts: 1) design and deployment of the mobile extraction, treatment, and injection units to overcome site limitations associated with urban settings in high-traffic areas and 2) vacuum-controlled nutrient injection within and on the periphery of an induced hydraulic and pneumatic depression.

Combined contaminant recovery since the beginning of the project in June 2003 totals over 13,600 lb (~6,170 kg) of hydrocarbons, equivalent to 2176 gallons (8236 l) of product. In situ delivery of 1504 lb (682 kg) of ionic nitrate and 540 lb (245 kg) of dissolved oxygen translates into further reduction of about 489 lb (222 kg) of benzene for the same period and provides for long-term stimulation of the natural attenuation process. In addition to contaminant recovered by extraction and reduced by in situ biodegradation, a total of 4136 lb (1876 kg) of oxygen was delivered to the saturated zone, resulting in further in situ reduction of an estimated 1324 lb (600 kg) of dissolved-phase hydrocarbons. Based on the results of the EERC demonstration, the North Dakota Department of Health approved site abandonment and termination of the corrective action.

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EXECUTIVE SUMMARY

At the request of the North Dakota Department of Health (NDDH) and the North Dakota Petroleum Tank Release Compensation Fund (NDPTRCF), the Energy & Environmental Research Center (EERC) conducted remediation of hydrocarbon-contaminated soils and groundwater at a former Mohler Oil site in Bismarck, North Dakota. The remedial strategy was based on the application of two innovative concepts: 1) design and deployment of the mobile extraction, treatment, and injection units to overcome site limitations associated with urban settings in high-traffic areas and 2) vacuum-controlled nutrient injection within and on the periphery of an induced hydraulic and pneumatic depression.

Over 13,600 lb (~6170 kg) of hydrocarbons, equivalent to 2176 gallons (8236 l) of product, has been recovered from contaminated soils and groundwater since the beginning of the project in June 2003. In situ delivery of 1504 lb (682 kg) of ionic nitrate and 540 lb (245 kg) of dissolved oxygen translates into further reduction of about 489 lb (222 kg) of benzene for the same period and provides for long-term stimulation of the natural attenuation process. In addition to contaminant recovered by extraction and reduced by in situ biodegradation, a total of 4136 lb (1876 kg) of oxygen was delivered to the saturated zone. By providing necessary electron acceptors, this volume translates into further in situ reduction of an estimated 1324 lb (600 kg) of dissolved-phase hydrocarbons.

Based on groundwater-sampling results documenting declining COC trends in the source area, stagnant plume with rate-limited release of residual contaminants, and low environmental risks, NDDH approved site abandonment and termination of corrective action.

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1.0 INTRODUCTION

At the request of the North Dakota Department of Health (NDDH) and the North Dakota Petroleum Tank Release Compensation Fund (NDPTRCF), the Energy & Environmental Research Center (EERC) conducted remediation of hydrocarbon-contaminated soils and groundwater at a former Mohler Oil site in Bismarck, North Dakota.

The overall objective of the project activities was to design, implement, and operate a vacuum-enhanced recovery/multiphase extraction (MPE) system combined with nutrient injection to reduce contaminant concentration levels in soils and groundwater at the subject site to levels that would allow for natural attenuation processes to complete in situ degradation of residual contaminants.

Characteristics of the target zone, site urban location, and high traffic required the application of highly flexible remediation technology capable of simultaneously removing contaminants in both the vapor and liquid phases. MPE combined with nutrient injection using specifically designed mobile extraction and injection systems was recommended as the technically most feasible option capable of achieving high contaminant removal rates while controlling the contaminant migration off-site. The project was initiated in March 2003. The MPE system operated between June and September 2003 and 2004. In addition to contaminants of concern (COC) recovery, simultaneous nutrient injection and plume interception in the permeable treatment barrier were conducted each spring/summer season from 2003 to 2006 to accelerate the in situ biodegradation process.

This report presents a summary of results including a description of the technology applied. More detailed information, original data sets, and primary documentation are compiled in technical progress reports provided to the sponsors and regulatory agency on a quarterly basis. The project was sponsored by NDPTRCF and the U.S. Department of Energy (DOE) and supervised by NDDH.

2.0 EXPERIMENTAL

The remedial strategy at the subject site was based on application of two innovative concepts: 1) design and deployment of the mobile extraction, treatment, and injection units to overcome site limitations associated with urban setting in high traffic areas, and 2) vacuum-controlled nutrient injection within and on the periphery of a vacuum-induced hydraulic and pneumatic depression.

Definition of the contaminated target zone, contaminant properties, and the results of the EERC pilot test indicated that remediation technology or a combination of technologies suitable for the subject site must be capable of:

- Efficiently removing contaminants from both the vadose and saturated zones in tight heterogeneous sediments with extremely low permeability.

- Creating a hydraulic impact that would allow for contaminant recovery from inaccessible plume areas and reduce/control free product (FP) and contaminant migration off-site.

- Being flexible enough to address water table fluctuation across the contaminant smear zone.

- Providing for accelerated nutrient supply to stimulate biodegradation.

- Providing nutrient supply to the permeable treatment barrier intercepting the plume to stimulate in situ contaminant degradation processes.

Additional objectives and requirements for this demonstration were:

- A flexible design and operation of mobile extraction and injection systems to overcome site limitations associated with an urban setting in high-traffic areas.

- Well field design that would not be disruptive to traffic and daily operation of facilities at the site.

3.0 RESULTS AND DOCUMENTATION

3.1 Site Characteristics

3.1.1 Site Location and Contaminant Release History

The original source area at Mohler Oil Company, Inc. (J&D Service Station), currently Mr. Muffler and Mr. Tire Services, 704 East Bowen Avenue, T138N R80W Section 4, Burleigh County, Bismarck, North Dakota, is approximately 100 × 100 ft. The documented extent of the contaminant plume is at approximately 400 × 300 ft and covers all corners of the intersection between 7th Street and Bowen Avenue. The site layout including the inferred contaminant plume is provided in Figure 1 and Appendix A.

A line leak of unknown volume discovered in April 1990 was reported to NDDH on March 18, 1992. Actions taken prior to initiation of the EERC corrective action included environmental site assessment (ESA) Phases I and II conducted by Braun Intertec, Inc., in 1992, 1993, and 1995 [1–3] and groundwater monitoring and product absorbent installation by Water Supply, Inc., in 2002 [4]. A pilot test and feasibility study for vacuum-enhanced nutrient injection were conducted by the EERC in 2002 [5].

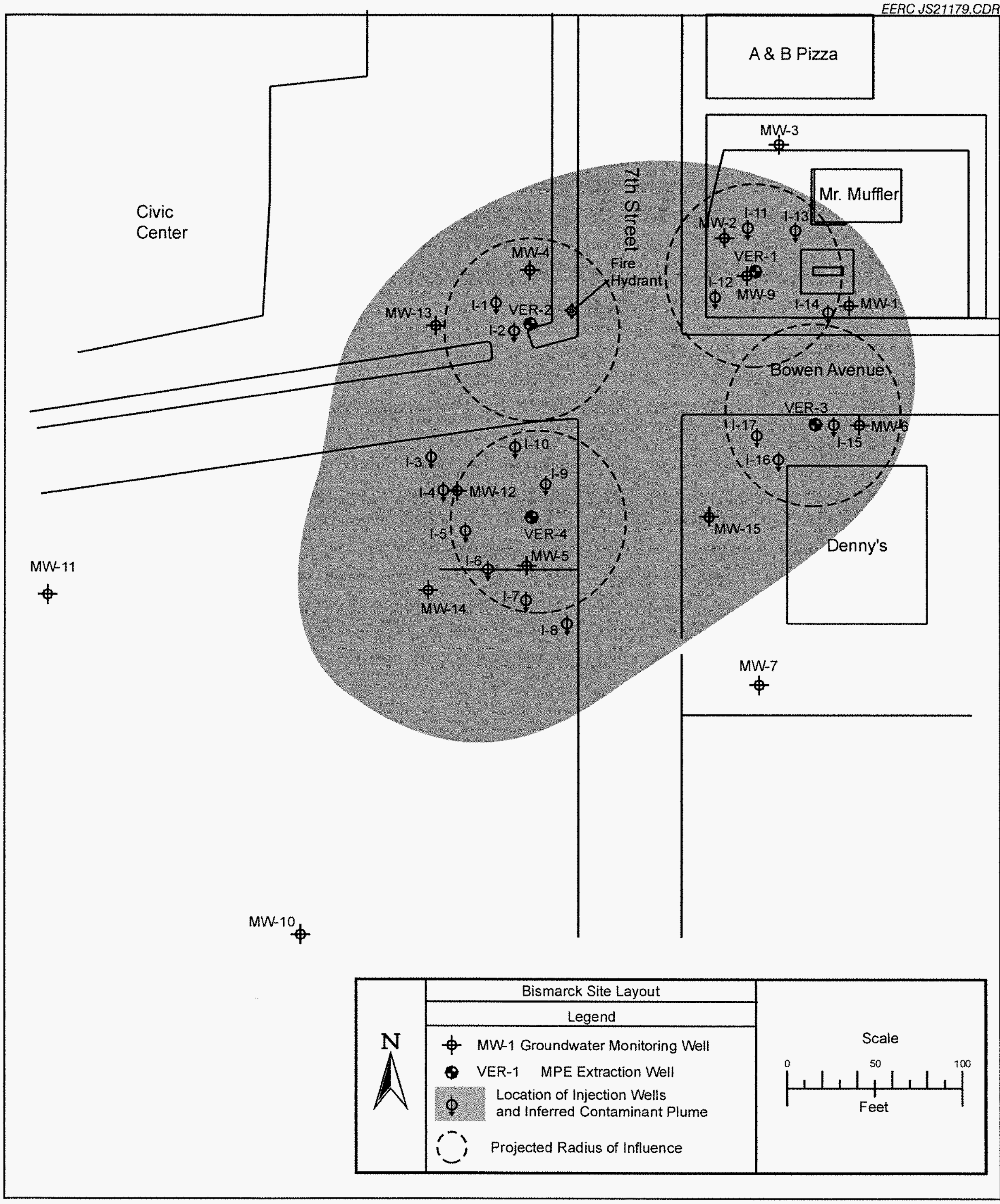


Figure 1. Site plan.

3.1.2 Hydrogeology and Contaminant Transport

The geology of the impacted area is dominated by a heterogeneous complex of clays, silts, and silty sands developed in the depositional environment on the margin of the alluvial plain and upper terrace. The sediment profile consists of up to 12 feet of fill material in the source (original contaminant release) area, underlain by 10–15-ft-thick till dominated by silty clays interbedded with thin layers of sandy silts. Till is underlain by a layer of poorly sorted fine to medium silty sand at a depth of about 25 ft.

The groundwater flow and downgradient contaminant migration is bound to discrete silty and sandy layers interbedding mostly clayey silts and silty clays that dominate the geology of the target area. The unconfined water table ranged from 13.28 to 22.51 ft below ground. The relatively abrupt gradient change on the margin of the terrace and alluvial plain may provide for partial groundwater confinement in the downgradient section of the impacted area. Water-table fluctuation during the project was about 4.7 ft, with the highest levels recorded in June 2003 and the lowest in November 2006. A summary of semiannual groundwater-monitoring data, including a water-table map, is in Appendix B.

Reflecting on-site geology, the hydraulic parameters exhibit considerable horizontal and vertical variability across the impacted area. In spite of low hydraulic conductivity for most of the sediments, contamination was detected in MW-5 (over 200 ft downgradient from the source) as early as 2 years after leak detection. Although previous undetected contaminant release cannot be ruled out, deduced transport velocity of about 100 ft/year is higher than that derived from results of hydraulic testing. Contamination as far as 300 ft from the source was confirmed in soil samples. The layers of preferential flow that allow for transport of free- and dissolved-phase contaminants off the site could have hydraulic conductivity several orders of magnitude higher than ambient till. Groundwater table fluctuation is an additional factor contributing to contaminant distribution, allowing for faster migration when the product–water interface is in more permeable materials. This factor is even more pronounced under semiconfining conditions or if the water level is as low as the sandy layer underlying the impacted area.

3.2 Remediation Systems

3.2.1 Extraction, Monitoring, and Injection Well Fields

The extraction, injection, and monitoring well fields for full-scale contaminant extraction and nutrient injection consist of four (4) extraction wells, 17 injection wells, and 14 monitoring wells. Well fields were completed May 27 – June 1, 2003. Existing wells including wells completed for the EERC pilot test [1] were integrated into the final extraction and monitoring well field (Figure 1 and Appendix A). Based on hydraulic and pneumatic response during MPE and hydraulic testing conducted in October 2002, the projected radius of influence for extraction wells was 35–50 ft. Injection wells are located on the periphery or within the projected radius of influence to allow for enhanced nutrient distribution in response to vacuum-induced depression. Wells forming a permeable treatment zone in the southwest portion of the plume are spaced approximately 20 ft apart to intercept groundwater flow and downgradient spreading of the contaminant plume (Figure 1).

Extraction well boreholes were advanced by a 6-in.-i.d. (10-in.-o.d.) hollow-stem (HS) auger. Wells were completed with 4-in.-diameter flush-threaded PVC, Schedule 40, with a 0.020-in. slot screen and No. 30 red flint pack. Extraction wells were sealed and equipped with a 1-in. PVC suction tube extending 4–6 ft below the water table (at the time of operation).

Monitoring wells were advanced using 4-in.-i.d. by 8-in.-o.d. hollowstem auger and completed as 2 in.-diameter flush-threaded PVC, Schedule 40 groundwater-monitoring wells. All extraction monitoring wells were further equipped with pressure- and water-table-monitoring ports with a ¾-in. drop tube extending to <1 ft from the bottom of the well.

Injection wells were advanced using the same drilling technology and completed with 2-in.-diameter flush-threaded PVC, Schedule 40, with a 10–15 ft of 0.020-in. slot screen. In the absence of well-defined permeable preferential pathways in tight geology, this drilling and well completion design was preferred to direct push injection points. Using the same gravel pack material, this injection well construction provides about a 6.7 times (85%) larger contact area per unit length and over 44 times (98%) larger storage volume above the water table (20 ft) than a 1.5-in.-diameter direct push injection point.

Well completion data including geologic and survey logs are provided in the Technical Progress Report for April–June 2003 [6]. Following NDDH and EERC agreement on final activities at the site from November 28, 2006, five monitoring wells, namely MW-2, MW-9, MW-13, MW-14, and MW-15, were preserved for monitoring of site conditions and natural attenuation parameters. The remaining extraction, injection, and monitoring wells including piping and manifolds in the ground will be sealed in compliance with North Dakota Administrative Code Article 33-18 and NDDH guidelines for well abandonment in April 2007.

3.2.2 Multiphase Extraction and Treatment System

In order to overcome site limitations associated with its urban location and high-traffic areas, the EERC team in cooperation with Specialty Systems Integrators, Inc., designed and constructed trailer-mounted extraction and injection systems powered by an auxiliary generator.

The mobile MPE system consists of a CoVac-300 4-stage, 15-hp, oil-free regenerative blower with a maximum rating of 205 cfm and 24.5-in. Hg (135 cfm @ 24.5-in. Hg). Recovered water and air pass through the 60-gal vapor–liquid separator (VLS) to the oil–water separator (OWS) with a 60-gal product storage tank. Water from OWS overflows to a 60-gal equalization tank, is charged in a Freije Series S treatment unit, and then pumped to a 5-stage air stripper (AS). Water from the AS is filtered and treated by GAC (granular activated carbon) prior to discharge. Offgas was treated in two vessels in series with 1000 lb of vapor carbon each prior to discharge to the atmosphere during the first month before representative offgas analyses became available. A process and instrumentation diagram for the extraction system is provided in Appendix C.

The extraction and treatment system is equipped with a NEMA 4 electric controller and a programmable logic controller (PLC) allowing for system control and data acquisition. The entire system is mounted on a 6- × 15-ft trailer platform. Basic operational parameters are summarized in Table 1.

3.2.2.1 System Performance Monitoring and Sampling

The operation of the MPE and treatment system started on June 11, 2003. Operation of the injection system started on June 18, 2003, after a sufficient hydraulic and pneumatic depression was developed around the extraction well. Performance monitoring, effluent water, and offgas sampling, including sampling of nutrient concentrations in the injected mixture were conducted on a weekly basis. The relocation of remediation systems was performed after COC trends in recovered groundwater and offgas exhibited asymptotic trends for a given extraction field.

Table 1. Operational Parameters

Extraction Well	VER-1	VER-2	VER-3	VER-4
Operated (2003)	6/10–8/5	10/15–11/1	8/5–9/3	9/4–10/15
Operated (2004)	7/14–8/31	6/1–7/8	–	9/14–10/7
Inlet Vacuum (in. Hg)	18.5–22.5	16–18	18.5–23	17–22
Wellhead Vacuum (in. H_2O)	87.3–104.9	165–170	NR[1]	141.3–144.2
Groundwater Flow (gpm)	0.4–2.2	0.9–2.4	0.1–0.6	3.1–3.6
Groundwater Recovered (gal)	167,356	101,837	118,417	111,626
Airflow (scfm)	37.4–48	32.7–39.1	24.2–41.3	21.1–42.9
Actual Time (day)	104	53	52	41
Runtime (h)	2420	807	915	542
Downtime (h)	90	463	324	441

[1] Not representative – wellhead dilution required.

3.2.2.2 System Water Quality

Samples of extracted water and treated effluent were analyzed for COC (benzene, toluene, ethylbenzene, xylenes, phenols, and total petroleum hydrocarbons [TPH] as gasoline range organics [GRO]), total iron and manganese, and suspended solids. Field measured parameters included pH, electrical conductivity (EC), and temperature.

Values representing contaminant recovery confirmed declining trends in the source area with a 95% GRO and BTEX decline in groundwater recovered between June 2003 and August 2004 (Figure 2). Contrary to the source area, relatively stable or even increasing COC concentrations were documented downgradient from the source (Figure 3) in response to vacuum-induced flow (and recovery) of residual contaminant in sediments underlying the intersection of Bowen Avenue and 7th Street. A summary of extraction and treatment data is provided in Appendix E-1; complete analytical documentation is in the respective technical progress reports. A 100% water treatment system efficiency was achieved for BTEX removal.

3.2.2.3 Offgas Quality

Offgas quality from combined exhaust was monitored using charcoal tubes and real-time monitoring of hydrocarbons, CO_2, and O_2 using a photoionization detector (PID), a flame ionization detector (FID), and a Summit hydrocarbon analyzer.

Offgas-sampling results using charcoal tube desorption and analyzed by gas chromatography (GC)/FID are summarized in Appendix E-2. Volatile organic contaminants (VOC) concentration trends from the 2003 extraction trial are provided in Figure 4. To overcome fluctuating airflow velocities typical of MPE systems, offgas was collected in a 1-l Tedlar bag at a rate of approximately 0.3 l/min. Charcoal tube samples were subsequently collected directly from the Tedlar bag using an SKC pump with flow regulated at 0.28 l/min. In addition, carbon dioxide and oxygen trends in extracted vapors were monitored using the Summit analyzer. The

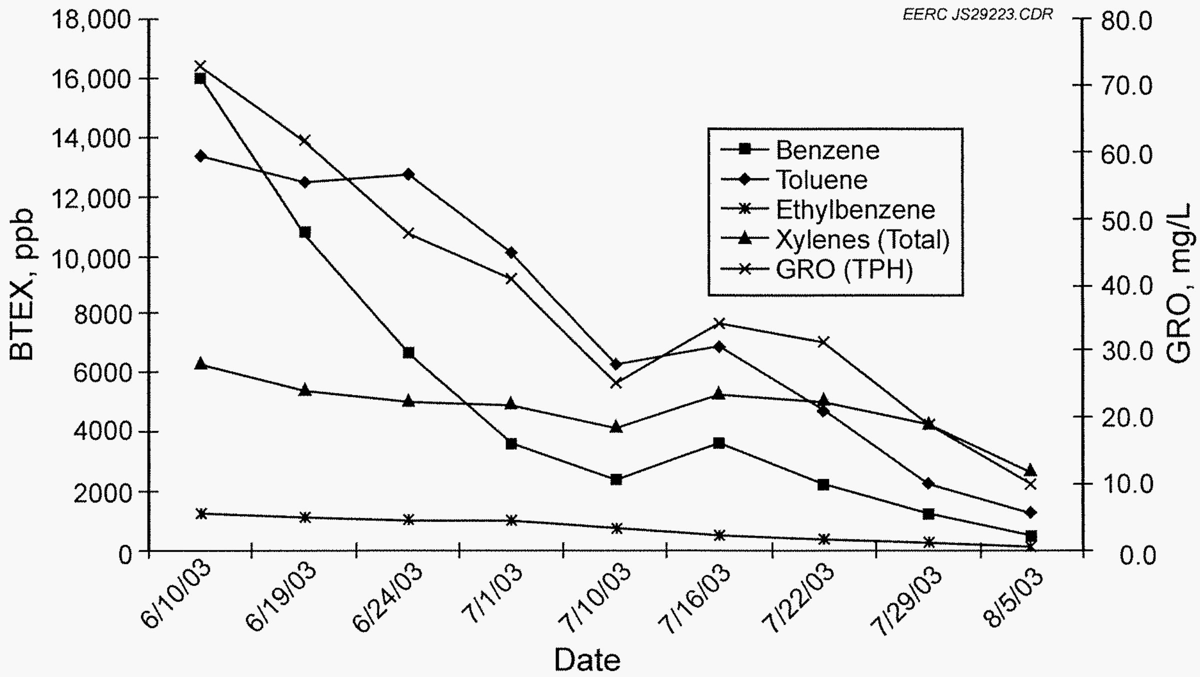


Figure 2. COC trends in extracted groundwater – source area (data from 2003).

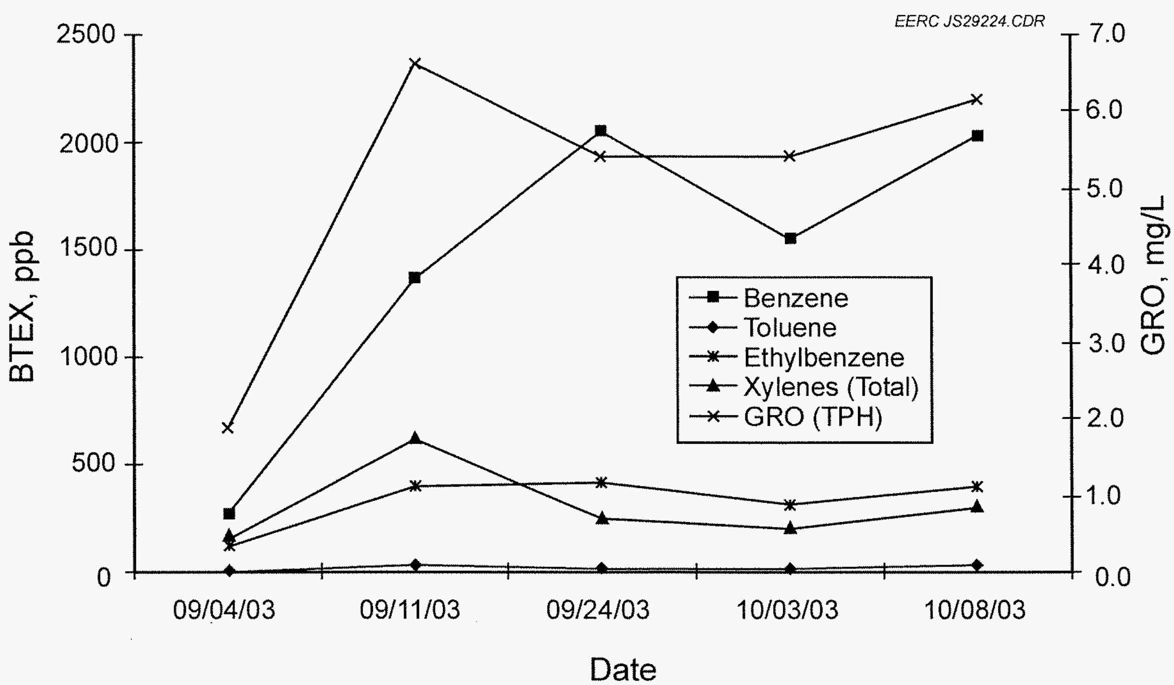


Figure 3. COC trends in extracted groundwater – downgradient area (data from 2003).

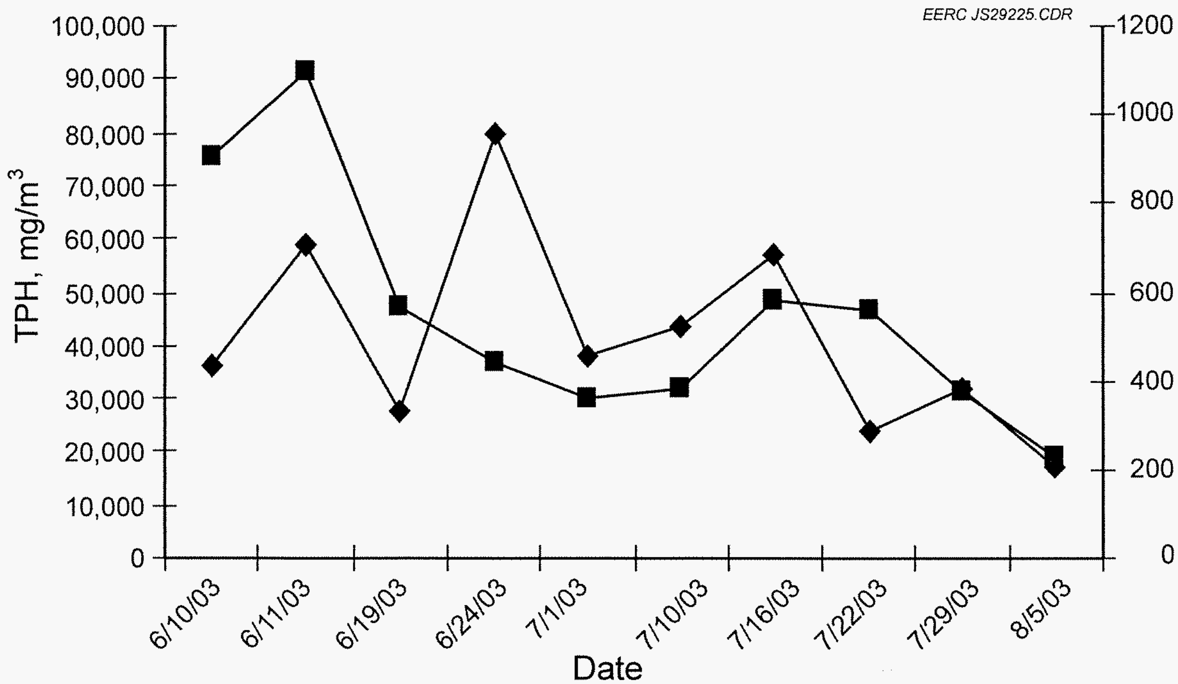


Figure 4. Hydrocarbon concentration trends in offgas – source area 2003.

mass balance for recovered VOCs and average emission loads was calculated based on results of offgas analyses and average exhaust airflow corrected to standard conditions and reported to NDDH on a quarterly basis.

Extremely high VOC concentrations peaked at 146,000 mg/m^3 (TPH) and 12,990 mg/m^3 for BTEX during the first days of extraction and indicated the presence of considerable amounts of residual FP trapped within the vadose and dewatered smear zone (Appendix E-2). VOCs in offgas typically sharply declined within several weeks of operation of a new well field and were below the NDDH required limit for VOCs of 16 lb/hr.

3.2.2.4 Hydraulic and Pneumatic Response

Groundwater table monitoring at the extraction and monitoring wells was conducted on a weekly basis during operation of remediation systems. In spite of tight site geology, pneumatic and hydraulic response in the source area was confirmed at monitoring wells as far as 58 ft. Hydraulic data indicate relatively slow response to induced gradient change, representative of tight sediments.

3.2.3 Injection System

The injection system consists of a 375-gal equalization tank allowing for continuous or batch injection feed. Water from the equalization tank is enriched with nutrients using an automatic chemical/nutrient feed pump and oxygen from a generator using pressure swing adsorption via molecular sieves to deliver oxygen into the water stream. Nutrient and oxygen-enriched water passes through a high-pressure gas liquid contactor (GLC) prior to its diversion into individual injection links. The entire system including its electronic process controllers is mounted on an enclosed trailer. A process and instrumentation diagram for the injection system is provided in Appendix C.

3.2.3.1 Injection System Performance Monitoring

Operation of the injection system in 2003 followed the relocation pattern of the MPE system, starting in the source area after a sufficient hydraulic and pneumatic depression was developed around extraction well VER-1. Formation capability to accept and conduct injected water between injection and extraction wells exceeded original expectations based on hydraulic testing. Nitrogen concentrations in injected water and groundwater extracted from well VER-1 indicate that nitrate breakthrough or recirculation of injected water occurred within the first days of injection (Appendix D-3). After MPE recovery from the first location reached asymptotic trends, the entire combined operation was relocated to the south (VER-3), southwestern (VER-4), and northwestern (VER-2) corner of the plume (Figure 1). Injection system operation in 2004–2006 focused on nutrient delivery in the southwestern portion of the plume, creating a permeable treatment barrier consisting of injection wells I-3, 4, 5, 6, 7, 8, 9, and 10 and VER-4.

City water enriched with oxygen (20–44 mg/l O_2) and nitrogen in the form of a mixture of liquid fertilizers UAN 28-0-0 (urea ammonium nitrate) and 10-34-0 (polyphosphate and ammonia nitrogen) was injected into injection wells. The average nitrogen concentration in injected water ranged from 20 to 38.8 mg/l (Appendix D-3). Background concentrations of nitrogen in groundwater upgradient from the contaminant plume documented from unimpacted well MW-3 ranged between 62 and 78 mg/l during the project. Nitrogen concentrations in most wells within the impacted area were below detection limits. Similarly, the results from injection wells forming a permeable barrier sampled in October 2004, May 2005, and October 2006 (after four injection seasons were completed) document fast nitrogen consumption, indicating both a severe deficit of electron acceptors within the plume and active biodegradation.

Over 1.7 million gallons (6.7 m^3) of O_2-oversaturated and nutrient-enriched water was injected between June 2003 and September 2006. A total of 1504 lb (682 kg) of ionic nitrate (338 lb–153.4 kg nitrogen) and 540 lb (245 kg) of oxygen was delivered to the contaminated aquifer to stimulate in situ biodegradation processes. A summary of injected volumes is provided in Table 2, mass balance estimates for primary electron acceptors (oxygen and nitrate) are presented in Appendix D-3.

Table 2. Injection Mass Summary

Season	Date Start	Date End	Water Injected (gal)	N (kg)	O_2 (kg)
2003	06/16/03	11/03/03	554,985	28.9	92.9
2004	06/08/04	10/07/04	546,261	41.7	65.0
2005	06/22/05	09/13/05	382,850	53.1	45.0
2006	06/12/06	09/06/06	282,788	29.7	41.7
Total			**1,766,884**	**153.4**	**244.6**

3.3 Contaminant Recovery and Degradation Estimates

The contaminant mass removal estimates were determined using the volumes for extracted groundwater and vapor and average VOC concentration obtained during two consecutive sampling events. A total of 499,119 gallons (1,889 m^3) of groundwater and 11 million ft^3 (~313,000 m^3) of soil vapor was extracted from recovery wells during two extraction seasons, resulting in removal of 13,630 lb (6,183 kg) of hydrocarbons prior to stripping and an additional 66.5 lb (30 kg) from the treated groundwater. The average liquid flow rate was approximately 2.1 gpm, ranging from 0.9 to 5.5 gpm, depending on performance of individual wells (Table 1); the airflow rate ranged from 21.1 to 60.2 scfm. The mass of recovered contaminant is equivalent to approximately 2176 gallons (8,236 l) of product, assuming a specific gravity for gasoline of 0.75 g/cm^3.

Total summary of contaminant recovery is in Table 3; data for mass removal calculations are provided in Appendix D; cumulative recovery is presented in Figure 5.

Table 3. MPE System Contaminant Recovery

Phase	2004	2003	
Vapor (lb)	4325	9306	
Liquid (lb)	21	45.5	
Total (lb)	4346	9351.5	13,698

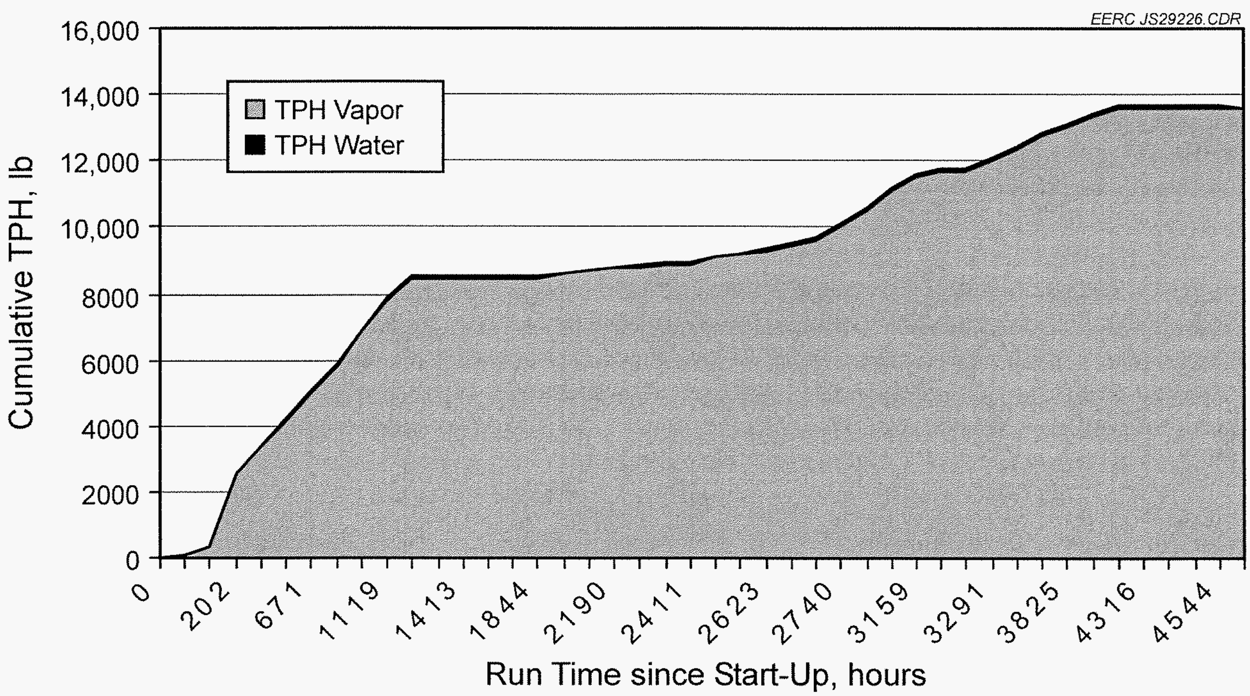


Figure 5. Total hydrocarbon removal.

Over 1.7 million gallons (6.7 m^3) of O_2-oversaturated and nutrient-enriched water was injected, delivering 1504 lb (682 kg) of ionic nitrate and 540 lb (245 kg) of dissolved oxygen to the contaminated aquifer. Based on simplified stochiometry for electron donors (petroleum hydrocarbons) and electron acceptors, a reduction of 1 mg/l of dissolved oxygen consumed by microbes results in biodegradation of 0.32 mg/l of benzene, and each 1 mg/l of ionic nitrate contributes to biodegradation of 0.21 mg/l of benzene. Injected volumes for oxygen and nitrate translate into in situ reduction of 489 lb (222 kg) of benzene and provide for long-term stimulation of the natural attenuation process. A summary of injected volumes is provided in Table 2, mass balance estimates for primary electron acceptors (oxygen and nitrate) are presented in Appendix D-3.

In addition to contaminant recovered by extraction and reduced by in situ biodegradation as a result of nutrient injection, a total of 4136 lb (1876 kg) of oxygen was delivered to the saturated zone during operation of the MPE system in 2003 and 2004, assuming 2% oxygen transfer efficiency [7] and 11 million ft^3 (313 thousand m^3) soil vapor exchanged/recovered. By providing the necessary electron acceptor and using the same stoichiometry as for injection estimates, this volume translates into further in situ reduction of 1324 lb (600 kg) of contaminant. Contaminant recovery/degradation breakdown is provided in Table 4. It is apparent that MPE technology using air as the primary contaminant carrier by far exceeds COC recovery and degradation efficiency of conventional pump-and-treat or in situ degradation based only on nutrient injection.

Table 4. Contaminant Recovery/Degradation Breakdown Estimates

	Total			
COC Recovered/Degraded	**(lb)**	**(kg)**	**(gal)**	**(%)**
Vapor Extraction	13631	6183	2178	87.9
Water Extraction	66.5	30	11	0.4
Nutrient Injection (NO_3, Dissolved O_2)	489	222	78	3.2
Degradation by Air Exchange/O_2 Delivery	1324	601	212	8.5
Total	15,111	7036	2478	100.0

3.4 Groundwater Quality Monitoring

3.4.1 Sampling Program

Monitoring and extraction wells were sampled for BTEX, GRO, and biodegradation indicators on a semiannual basis to document overall remediation system impact on groundwater quality compared to original site data collected in June 2003 (prior to system start-up). The final sampling was conducted on November 10–11, 2006.

Groundwater samples were collected using disposable PVC bailers, preserved on-site, and stored on ice prior to and during shipment. Samples for dissolved metals were filtered using 0.45-μm Geotech disposable filters. Analyses were conducted by MVTL in Bismarck, North Dakota, and New Ulm, Minnesota. Quality assurance/quality control samples included duplicates, equipment blanks, field blanks, and trip blanks for each sampling event. Field-monitored water quality parameters were measured in wells with an YSI-556 multiprobe.

3.4.2 Water Quality Trends

Consistently declining trends and 50% average COC reduction are documented from wells in the source area, namely VER-1, MW-1, MW-2, and MW-9. FP thickness downgradient from the source area was reduced in well MW-5 (sheen) but remains variable in wells MW-4 (1.8 ft) and VER-2 (1 ft, Civic Center corner) and in hydraulically isolated MW-6 (2.42 ft). COC concentrations around VER-2 and VER-4 indicate that formation of a hydraulic depression around extraction wells in response to MPE accelerated the flow (and recovery) of residual contaminant in sediments underlying the intersection of Bowen Avenue and 7th Street. Observed COC trends for wells downgradient from the source area suggest that the majority of contaminant is trapped within the smear zone underlying the noted intersection, and any downgradient migration is limited by extremely low hydraulic conductivity and limited hydraulic connectivity of potential preferential pathways in silty clays.

A contaminant isoconcentration map for BTEX indicating the geometry of the contaminant plume as of October 9, 2006, is presented in Appendix F; a summary of groundwater analyses is in Appendix G-1.

With respect to prevailing groundwater flow direction (Appendix B), location of the abandoned landfill, and occurrence of contaminated soils discovered during construction of the Civic Center, the origin of contamination in this area is likely not related only to the source area and may suggest the presence of additional contaminant source(s).

Summary tables for biodegradation indicators are provided in Appendix G-2. Compared to unimpacted wells (outside of the plume), and in spite of an increased nitrogen load in the nutrient mixture injected, biodegradation indicators persistently exhibit trends typical for an anaerobic contaminant plume with suppressed oxygen, nitrate, phosphorus, and sulfate concentrations; elevated concentrations of organic carbon; and reduced forms of iron and manganese. Analyses from monitoring wells presented in Appendix G-2 indicate that oxygen, nitrogen (both in nitrate–nitrite and ammonia form), and sulfate, as primary (high energy) electron acceptors during biodegradation, are effectively consumed within the plume area. Nitrate levels remain above nondetect levels only in the background and a few injection wells and appear to be quickly consumed by indigenous bacteria within the plume. Under prevailing reducing conditions and excess carbon (contaminants) within the contaminant plume, the deficit of electron acceptors and imbalance between C-N-P considerably reduce biodegradation potential. Increased ammonia nitrogen (representing nitrate injected and reduced to ammonia N under anaerobic conditions) is documented from wells MW-1, 2, and 9 in the source area and well MW-4, MW-12, and I-8.

3.5 Technical and Economic Summary and Discussion

The remedial strategy was based on application of two innovative concepts: 1) design and deployment of the mobile extraction, treatment, and injection units to overcome site limitations associated with urban setting in high-traffic areas and 2) vacuum-controlled nutrient injection within and on the periphery of an induced hydraulic and pneumatic depression.

High contaminant removal efficiency of dual-phase (multiphase) extraction technology is a result of a combination of simultaneous extraction of water and vapor. It follows from contaminant recovery/degradation breakdown estimates (Table 4) that vapor extraction efficiency by far exceeds that for groundwater (in this case by a factor of 205) and, to a certain extent, draws a comparison between soil vapor extraction and pump-and-treat systems. Documented high contaminant recovery using vapor as a primary carrier could not, however, be achieved without simultaneous dewatering of the targeted smear zone.

An additional advantage of dual-phase extraction is air exchange/oxygen delivery to the contaminated zone during operation of the MPE system. Because quantification of in situ oxygen partitioning between soil- and groundwater-bound contaminants and their subsequent reduction is extremely difficult, this means of degradation, albeit substantial, is often not considered by the environmental industry in mass balance estimates.

Based on project cost and total contaminant recovery of 14,187 lb per unit, the cost for contaminant recovery was $48.9/lb ($107.70/kg). If in situ degradation resulting from oxygen delivery is considered, the cost would be $44.70/lb ($98.60/kg) of contaminant recovered/degraded. The relatively high cost per unit of contaminant recovered/degraded reflects on the site location in a developed urban setting, the requirement for initial offgas treatment and a robust monitoring program, as well as site abandonment activities being integrated into the total project cost.

4.0 CONCLUSIONS

A total of 499,119 gallons (1889 m^3) of groundwater and 11 million ft^3 (~313,000 m^3) of soil vapor were extracted from recovery wells during two extraction seasons, resulting in removal of 13,630 lb (6183 kg) of hydrocarbons prior to stripping and an additional 66.5 lb (30 kg) from the treated groundwater. The mass of recovered contaminant is equivalent to 2176 gallons (8236 l) of product recovered at the site since the beginning of the project in June 2003.

In situ delivery of 1504 lb (682 kg) of ionic nitrate and 540 lb (245 kg) of dissolved oxygen conducted in 2003–2006, i.e., four injection seasons, translates into further reduction of about 489 lb (222 kg) of benzene for the same period and provides for long-term stimulation of the natural attenuation process.

In addition to contaminant recovered by extraction and reduced by in situ biodegradation as a result of direct nutrient injection, a total of 4136 lb (1876 kg) of oxygen was delivered to the saturated zone during operation of the MPE system in 2003 and 2004. By providing the necessary electron acceptor, this volume translates into further in situ reduction of an estimated 1324 lb (600 kg) of dissolved-phase hydrocarbons.

Based on groundwater-sampling results documenting declining COC trends in the source area, stagnant plume with rate-limited release of residual contaminant, and low environmental risks, NDDH approved termination of corrective action and initiation of site abandonment. Wells MW-2, 9, 13, 14, and 15 will be preserved for postclosure site monitoring.

5.0 REFERENCES

1. Braun Intertec Environmental, Inc., July 1992, Report on preliminary subsurface assessment at former J&D Service Station.

2. Braun Intertec Environmental, Inc., January 1993, Expanded subsurface assessment at former J&D Service Station in Bismarck, North Dakota.

3. Braun Intertec Environmental, Inc., January 1995, Upgradient petroleum product release investigation for former J&D Service Station.

4. Water Supply, Inc., January 2002, Monitoring at former J&D Service Station.

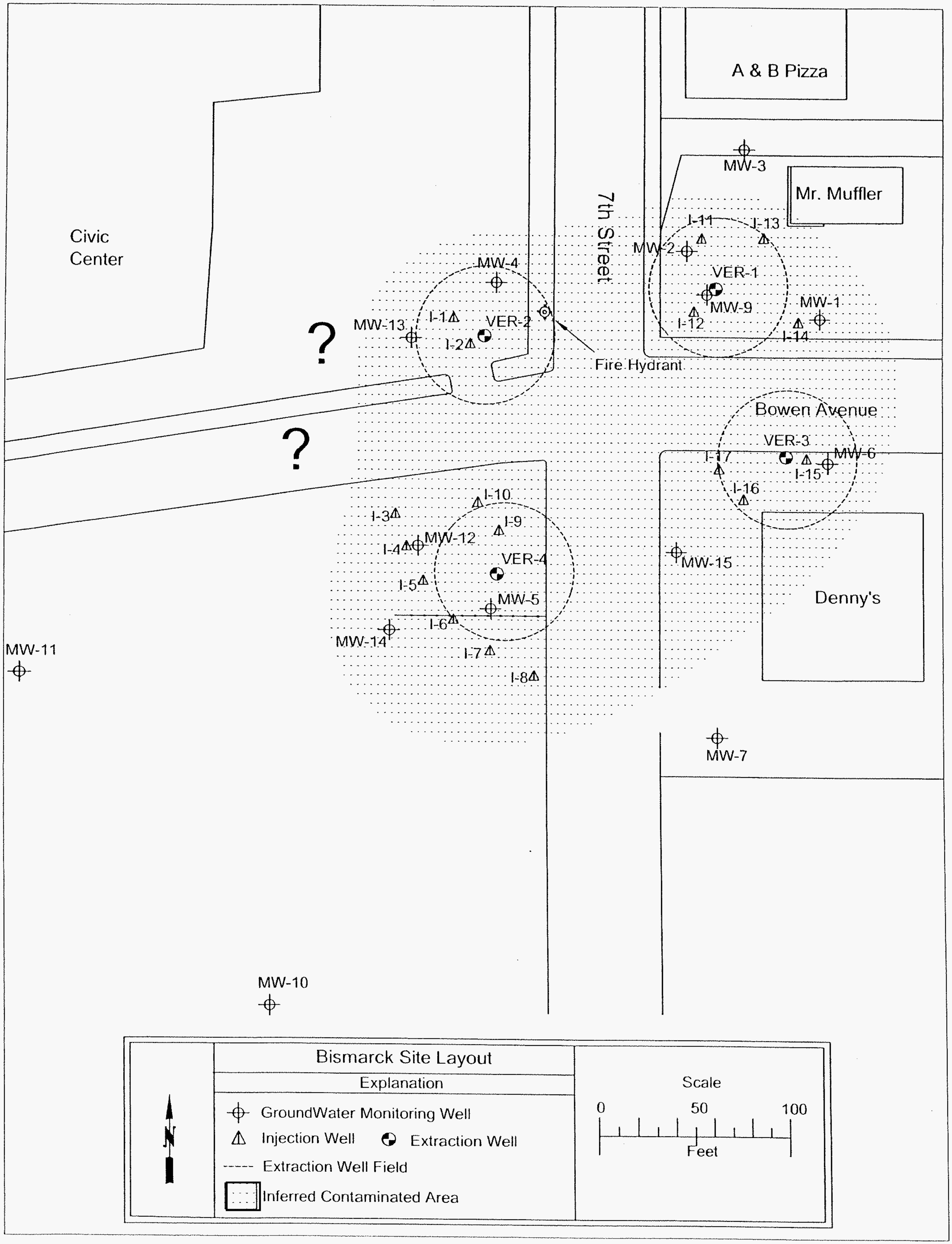
5. Solc, J., and Reilkoff, T.E., 2002, Mohler Oil – feasibility of remedial alternatives: EERC final report no. 2002-EERC-12-04.

6. Solc, J., and Reilkoff, T.E., 2003, Mohler Oil: EERC technical progress report for April–June 2003.

7. Kuo, J., 1999, Practical design calculations for groundwater and soil remediation: Boca Raton, Florida, CRC Press, LLC Lewis Publishers.

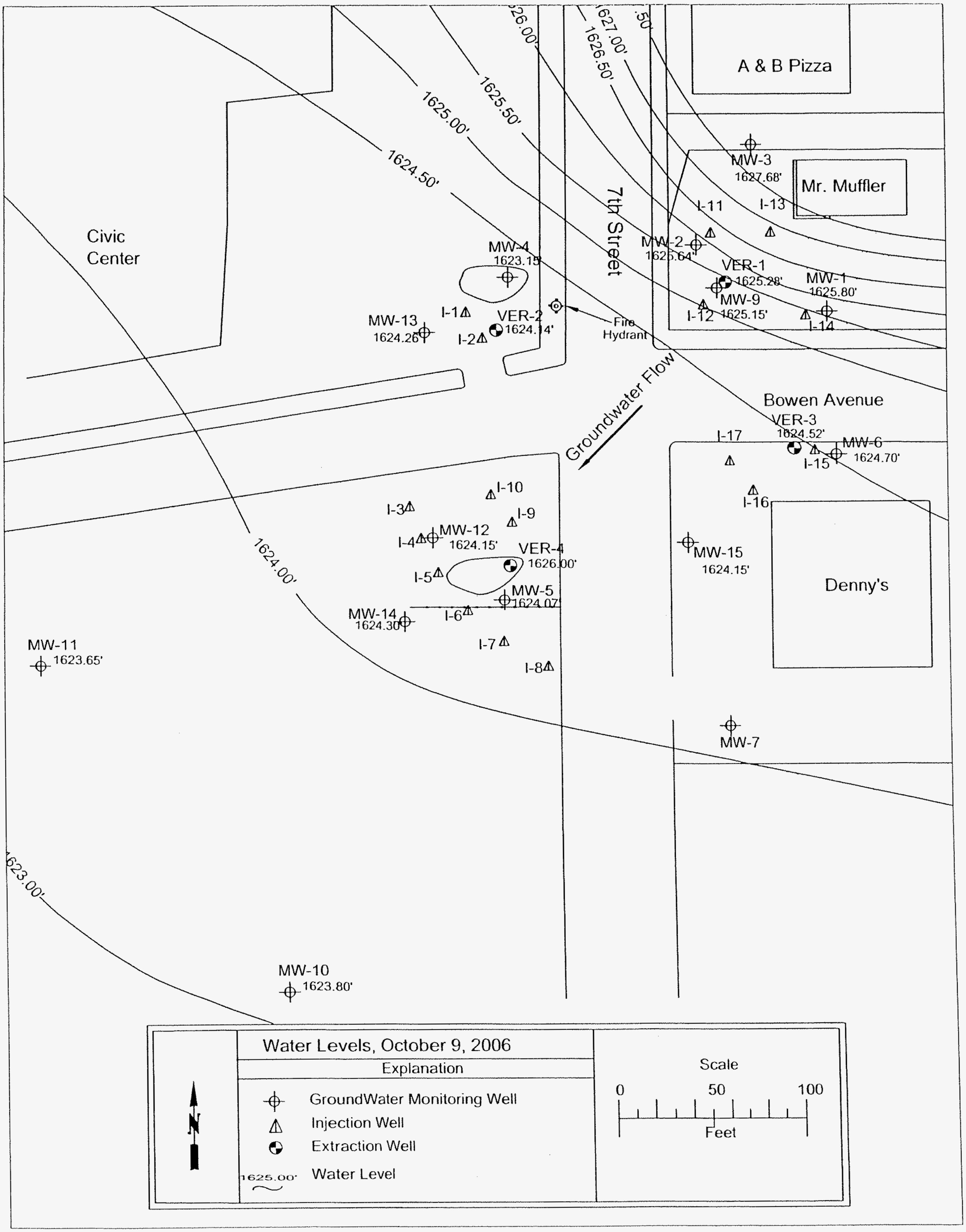
APPENDIX A

SITE PLAN AND EXTRACTION/INJECTION WELL FIELDS


A & B Pizza
Mr. Muffler
Civic Center
7th Street
Bowen Avenue
Denny's
Fire Hydrant
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-9
MW-10
MW-11
MW-12
MW-13
MW-14
MW-15
VER-1
VER-2
VER-3
VER-4
I-1
I-2
I-3
I-4
I-5
I-6
I-7
I-8
I-9
I-10
I-11
I-12
I-13
I-14
I-15
I-16
I-17
?
?
Bismarck Site Layout
Explanation
GroundWater Monitoring Well
Injection Well
Extraction Well
Extraction Well Field
Inferred Contaminated Area
Scale
0
50
100
Feet
N

APPENDIX B

GROUNDWATER TABLE MONITORING – SUMMARY OF DATA



A & B Pizza
Mr. Muffler
Civic Center
7th Street
Bowen Avenue
Denny's
Groundwater Flow
Fire Hydrant
1625.00'
1625.50'
1626.50'
1627.00'
1624.50'
1624.00'
MW-3 1627.68'
I-11
I-13
MW-2 1625.64'
VER-1 1625.28'
MW-1 1625.80'
MW-9 1625.15'
I-12
I-14
MW-4 1623.15'
MW-13 1624.26'
I-1
I-2
VER-2 1624.14'
VER-3 1624.52'
I-17
MW-6 1624.70'
I-15
I-16
I-10
I-3
I-9
MW-12 1624.15'
I-4
VER-4 1626.00'
I-5
MW-5 1624.07'
MW-14 1624.30'
I-6
I-7
I-8
MW-15 1624.15'
MW-11 1623.65'
MW-7
MW-10 1623.80'
Water Levels, October 9, 2006
Explanation
GroundWater Monitoring Well
Injection Well
Extraction Well
1625.00' Water Level
N
Scale
0 50 100
Feet

Groundwater Levels

Elevations in feet

Well ID	Ground	MP (TOC)[1]	06/16/03	08/05/03	09/03/03	10/16/03	11/19/03	04/24/04	10/23/04	05/17/05	11/19/05	05/13/06	10/09/06
VER-1	1647.11	1646.91	1627.51	NM	1627.01	1626.32	1625.57	1626.77	1626.19	1626.26	1625.82	1625.77	1625.28
VER-2	1645.08	1644.79	1626.75	1625.74	1625.14	1625.05	1624.54	1626.06	1625.23	1625.66	1624.82	1624.97	1624.14
VER-3	1645.32	1645.06	1626.97	1626.56	1628.29	1625.17	1624.69	1626.18	1625.43	1625.82	1625.04	1625.08	1624.52
VER-4	1644.15	1643.90	1626.48	1625.25	1624.66	1624.62	1624.17	1625.83	1624.91	1625.49	1624.54	1624.71	1626.00
MW-1	1646.13	1645.75	1627.65	1630.50	1627.01	1626.13	1625.65	1626.82	1626.39	1626.39	1626.00	1625.95	1625.80
MW-2	1648.45	1648.15	1627.62	1627.51	1627.31	1626.52	1625.96	1626.98	1626.56	1626.48	1626.19	1626.15	1625.64
MW-3	1648.65	1648.25	1628.86	1629.89	1629.70	1628.36	1627.86	1628.35	1628.43	1627.84	1628.11	1627.90	1627.68
MW-4	1646.04	1645.50	1626.84	1626.03	1625.95	1625.00	1624.46	1626.13	1625.30	1625.89	1624.92	1625.07	1623.15
MW-5	1643.94	1643.38	1626.34	1625.10	1624.51	1624.23	1623.86	1625.74	1624.58	1625.38	1624.45	1624.63	1624.07
MW-6	1645.14	1644.92	1627.10	1626.66	1628.10	1625.15	1624.89	1626.01	1625.51	1625.10	1624.35	1625.24	1624.70
MW-7	1643.19	1642.95	1626.15	1625.16	1624.60	1624.41	1624.07	1625.70	1624.87	1625.43	NM	NM	NM
MW-9	1647.00	1646.83	1627.31	1624.14	1626.84	1626.03	1625.48	1626.65	1626.11	1626.15	1625.68	1625.68	1625.15
MW-10	1639.86	1639.59	1626.31	1624.81	1624.22	1624.09	1623.89	1625.59	1624.61	1625.28	1624.30	1624.41	1623.80
MW-11	1642.81	1642.57	1625.62	1624.63	1624.15	1624.23	1623.82	1625.53	1626.40	1625.08	1624.13	1624.30	1623.65
MW-12	1644.84	1644.48	1626.18	1625.43	1624.68	1624.80	1624.18	1625.90	1624.93	1627.54	1624.62	1624.78	1624.15
MW-13	1645.03	1644.54	1626.65	1625.54	1624.93	1624.90	1624.35	1625.95	1625.08	1625.60	1624.73	1624.87	1624.26
MW-14	1643.43	1643.21	1625.93	1625.31	1624.84	1624.64	1624.09	1625.65	1624.89	1625.46	1624.56	1624.66	1624.30
MW-15	1644.02	1643.86	1626.65	1625.56	1625.22	1624.73	1624.24	1625.88	1625.10	1625.49	1624.68	1624.75	1624.15

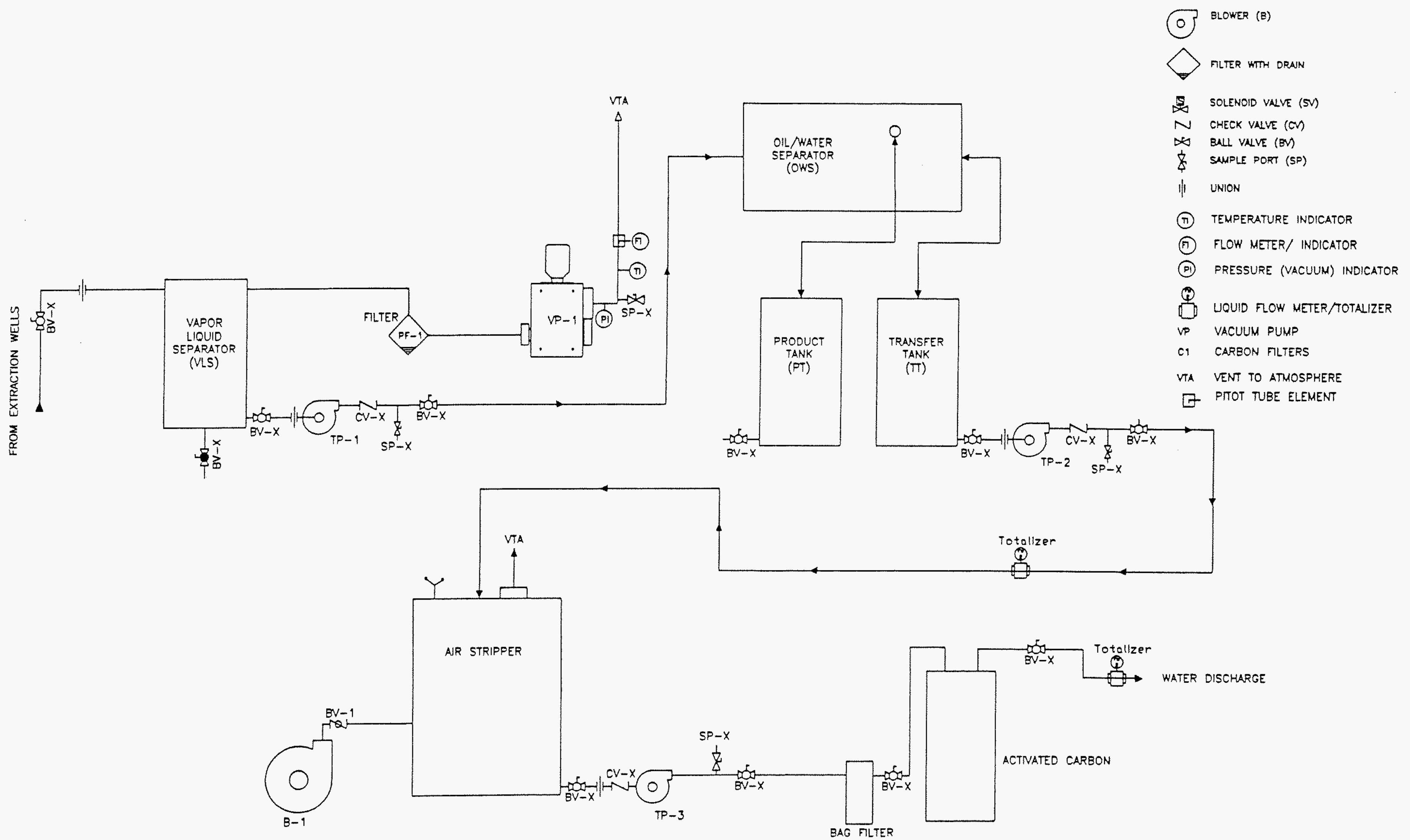
[1]MP (TOC) - measuring point after wellhead instrumentation or top of casing

NM - Not measured - Well MW-7 is inaccessible (paved over without notice)

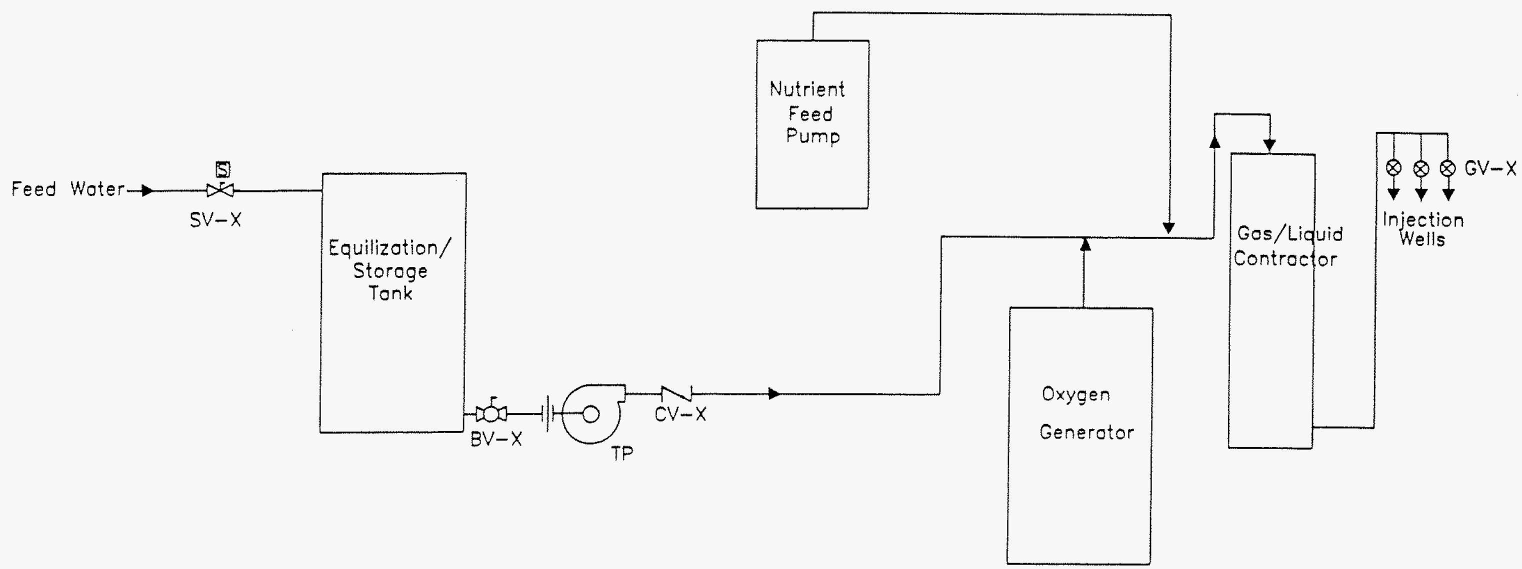
FP correction is based on specific gravity of gasoline of 0.75

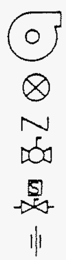
APPENDIX C

RECOVERY AND INJECTION SYSTEMS



CONTAMINANT RECOVERY AND TREATMENT SYSTEM	DRAWN BY: MV		SCALE: NTS	
	BLDR:	MOD: JS Jr.	CKR: JS	
	DATE: 12-11-2004			
PROCESS AND INSTRUMENTATION DIAGRAM	PROJECT#: CRS			
	DRAWING#: DPE-System			





NUTRIENT INJECTION SYSTEM
PROCESS FLOW DIAGRAM

DRAWN BY: TR		SCALE: NTS	
BLDR:	MOD: JS Jr	CKR: JS	
DATE: 7-29-2003			
PROJECT# Mohler Oil - Bismarck			
DRAWING# INJ-System			

APPENDIX D

MASS BALANCE WORKSHEETS

APPENDIX D-1

CONTAMINANT RECOVERY – LIQUID PHASE

CONTAMINANT RECOVERY

TPH - Liquid Phase 2003 Season

Date	Totalizer (gal)	Flow (gpm)	TPH_{water} mg/l	$BTEX_{water}$ mg/l	TPH_{mass} (lb)	$BTEX_{mass}$ (lb)
	Recovery Field VER-1					
06/10/03	1209	0.4	72.8	37.0	0.1	0.0
06/11/03	1987	0.8	52.5	24.6	0.4	0.2
06/19/03	12325	1.0	61.4	29.7	4.9	2.3
06/24/03	25345	1.7	47.5	25.5	5.9	3.0
07/01/03	44317	2.1	40.7	19.6	7.0	3.5
07/10/03	69215	2.2	25.4	13.7	6.9	3.4
07/16/03	80510	1.3	34.1	16.5	2.8	1.4
07/22/03	85176	0.5	31.1	12.4	1.3	0.6
07/29/03	97011	1.2	19.3	8.1	2.5	1.0
08/05/03	117528	1.9	11.7	4.1	2.7	1.0
	Recovery Field VER-3					
08/06/03	117599	0.1	0	0.1	0.0	0.0
08/12/03	120139	0.4	0	0.5	0.0	0.0
08/26/03	128703	0.6	0	0.0	0.0	0.0
09/03/03	135198	0.6	0.9	0.6	0.0	0.0
	Recovery Field VER-4					
09/04/03	135198	3.6	1.9	0.5	0.0	0.0
09/11/03	158645	3.6	6.6	2.4	0.8	0.3
09/24/03	176000	3.4	5.4	2.7	0.9	0.4
10/03/03	207888	3.4	5.4	2.1	1.4	0.6
10/08/03	231847	3.6	6.1	2.8	1.1	0.5
10/15/03	246824	3.1	6.1	2.8	0.8	0.3
	Recovery Field VER-2					
10/17/03	248231	0.9	24.9	11.6	0.3	0.1
10/22/03	257319	1.4	24.7	12.9	1.9	0.9
10/29/03	261330	1.7	35.2	15.3	1.0	0.5
11/01/03	271190	2.4	35.2	15.3	2.9	1.3
Total	**269,981**				**45.5**	**21.4**

CONTAMINANT RECOVERY

TPH - Liquid Phase 2004 Season

Date	Totalizer (gal)	Flow (gpm)	TPH_{water} mg/l	$BTEX_{water}$ mg/l	TPH_{mass} (lb)	$BTEX_{mass}$ (lb)
	Recovery Field VER-2					
06/01/04	20023					
06/02/04	21000	0.9	106.8	51.6	0.9	0.4
06/03/04	23899	2.3	25.46	14.1	1.6	0.8
06/09/04	43763	4.2	30.65	14.9	4.7	2.4
06/17/04	56642	1.6	26.35	14.5	3.1	1.6
06/22/04	64260	2.0	21.29	10.9	1.5	0.8
06/29/04	76025	2.0	19.31	11.0	2.0	1.1
07/07/04	92489	2.3	11.44	4.9	2.1	1.1
07/08/04	97495	2.6	11.44	4.9	0.5	0.2
	Recovery Field VER-1					
07/14/04	97495					
07/14/04	97546	0.1	5.49	2.2	0.0	0.0
07/20/04	102139	0.9	14.48	7.0	0.4	0.2
07/27/04	109470	0.7	11.44	4.9	0.8	0.4
08/05/04	119231	0.7	11.04	4.3	0.9	0.4
08/11/04	125570	0.7	8.89	3.5	0.5	0.2
08/17/04	132269	0.7	6.23	2.3	0.4	0.2
08/23/04	137900	0.7	5.41	2.0	0.3	0.1
08/31/04	148414	0.8	4.32	1.4	0.4	0.1
	Recovery Field VER-4					
09/14/04	320					
09/15/04	8698	4.0	1.89	0.6	0.1	0.0
09/22/04	19327	5.5	1.62	0.6	0.2	0.1
10/01/04	63514	4.6	0.79	0.3	0.4	0.2
10/07/04	101067	4.5	0.78	0.4	0.2	0.1
Total	**229,138**				**21.0**	**10.2**

APPENDIX D-2

CONTAMINANT RECOVERY – VAPOR PHASE

CONTAMINANT RECOVERY

TPH - Vapor Phase 2003 Season

Date	Runtime (cum. h)	Q_{air} (cfm)	Volume (1000 ft^3)	TPH_{air}[1] (mg/m^3)	$BTEX_{air}$[1] (mg/m^3)	TPH_{mass} (lb)	$BTEX_{mass}$ (lb)
	Recovery Field VER-1						
06/10/03	5.3	47.6	15	75,700	555.5	72.0	0.5
06/11/03	22.5	47.6	49	91,450	871.5	255.9	2.2
06/19/03	201.9	47.2	508	47,400	631.0	2201.6	23.7
06/24/03	327.3	42.2	317	36,850	1091.5	834.9	17.0
07/01/03	478.8	42.1	383	30,000	921.5	798.5	23.9
07/10/03	670.8	37.4	431	31,800	1239.0	831.1	28.9
07/16/03	814.1	38.5	331	48,300	1345.0	828.1	26.6
07/22/03	959.4	40.6	354	46,350	610.0	1045.6	21.5
07/29/03	1119.3	40.5	388	31,450	846.0	943.2	17.5
08/05/03	1294.9	40.5	427	19,000	531.0	672.2	18.2
	Recovery Field VER-3						
08/06/03	1307.9	24.2	19	140	37.0	0.1	0.0
08/12/03	1412.6	41.3	259	0	0.0	1.1	0.3
08/26/03	1655.9	35.7	521	0	0.0	0.0	0.0
09/03/03	1841.8	37.6	419	0	0.0	0.0	0.0
	Recovery Field VER-4						
09/04/03	1844.3	36.6	6	7,195	30.0	1.3	0.0
09/11/03	1948.9	37.4	235	9,895	88.0	125.2	0.9
09/24/03	2034.4	37.9	194	2,835	43.0	77.2	0.8
10/03/03	2190.4	42.9	402	3,375	33.0	77.9	0.9
10/08/03	2302.7	41.9	282	3,735	41.0	62.6	0.6
10/15/03	2384.2	41.9	205	3,735	41.0	47.8	0.5
	Recovery Field VER-2						
10/17/03	2411.1	32.7	53	11,600	239.0	19.1	0.4
10/22/03	2516.6	39.1	248	16,650	416.0	218.4	5.0
10/29/03	2556.1	39.1	93	11,395	224.0	81.1	1.8
11/01/03	2623.2	39.0	157	11,395	224.0	111.7	2.2
Total			**6,296**			**9,306**	**193**

CONTAMINANT RECOVERY

TPH - Vapor Phase 2004 Season

Date	Runtime (cum. h)	Q_{air} (cfm)	Volume (1000 ft^3)	TPH_{air} [1] (mg/m^3)	$BTEX_{air}$ [1] (mg/m^3)	TPH_{mass} (lb)	$BTEX_{mass}$ (lb)
	Recovery Field VER-2						
06/01/04				85,200	1661.4		
06/02/04	18.0	32.2	35	85,200	1661.4	185.3	3.6
06/03/04	38.7	31.0	38	46,200	832.5	157.4	3.0
06/09/04	116.9	31.3	147	39,400	928.0	392.6	8.0
06/17/04	251.7	27.4	222	35,300	957.2	516.5	13.0
06/29/04	413.5	31.3	304	24,900	1060.3	571.3	19.0
07/07/04	535.3	31.3	229	25,000	829.8	430.5	13.4
07/08/04	568.0	31.3	61	25,000	830.3	114.7	3.2
	Recovery Field VER-1						
07/14/04	580.9	35.6	28	34,850	137.0	40.2	0.2
07/20/04	667.5	59.2	308	27,250	862.5	321.6	9.5
07/27/04	838.5	40.4	415	19,550	611.1	335.7	19.0
08/05/04	1060.3	40.8	543	13,950	424.5	374.5	17.4
08/11/04	1202.3	40.8	348	12,000	282.7	290.8	7.6
08/17/04	1351.7	40.6	364	10,100	233.4	344.8	5.8
08/23/04	1484.5	60.2	480	16,700	801.0	219.3	15.4
08/31/04	1693.1	59.8	748	13,650	665.5	26.8	34.1
	Recovery Field VER-4						
09/15/04	1727.6	21.1	44	995	66.9	2.6	0.2
10/22/03	1759.8	21.1	41	151	7.7	0.6	0.1
10/29/03	1920.3	23.0	222	1,380	25.5	0.0	0.2
11/01/03	2060.9	22.8	192	510	10.3	0.0	0.2
Total			**4,766**			**4,325**	**173**

APPENDIX D-3

INJECTION SYSTEM

INJECTION BALANCE SHEET - SUMMARY 2003

Injection Well	Date		Water in	Total (field)	N (average)	O_2 (average)	N	O_2
(Port)	Start	End	(gal)	(gal)	(mg/l)	(mg/l)	(kg)	(kg)
I-14 (1)	06/16/03	08/21/03	87080					
I-13 (2)	06/16/03	08/21/03	73464					
I-11 (3)	06/16/03	07/23/03	38830					
I-12 (3)	07/23/03	08/21/03	48130					
VER-1(2)	08/26/03	08/26/03	1250	248754	14.3	45.0	14.8	43.0
I-15 (1)	08/21/03	09/03/03	15410					
I-16 (2)	08/21/03	09/03/03	13950					
I-17 (3)	08/21/03	09/03/03	18110	47470	16.7	45.0	3.0	8.1
I-3 (3)	09/17/03	10/08/03	40505					
I-4 (2)	09/17/03	10/08/03	44278					
I-5 (1)	09/17/03	10/15/03	49375					
I-6 (3)	09/04/03	09/17/03	18435					
I-7 (2)	09/04/03	09/17/03	15613					
I-8 (1)	09/04/03	09/17/03	20020					
I-9 (3)	10/08/03	10/15/03	3110					
I-10 (2)	10/08/03	10/15/03	17104	208440	11.5	45.3	7.2	33.9
VER-2	10/15/03	10/15/03	989					
I-1 (1)	10/16/03	11/03/03	27716					
I-2 (2)	10/16/03	11/03/03	21616	50321	20.0	43.8	3.9	7.9
Total			**554985**	**554985**			**28.9**	**92.9**

CONCENTRATIONS OF NITROGEN AND OXYGEN INJECTED - 2003

I-11, 12, 13, 14, VER-1

		06/16/03 Initial	06/18/03 17:25	06/19/03 8:25	06/24/03 16:00	07/01/03 9:43	07/22/03 18:00	08/06/03 8:20	08/21/03 13:45
N	mg/l	0	50.7	13.7	13.0	13.8	12.6	16.3	16.3
N (VLS)	mg/l		10.5	2.2	12.8	8.9	6.2	10.3	
O_2	mg/l	0	39.0	40.0	40	45	51	47	47

I-1, 2, VER-2

		10/16/03 Start 13:00	10/17/03 12:01	10/22/03 18:45	10/31/03 9:15	11/03/03 Final
N	mg/l	13.3	16.6	22.5	23.7	23.7
N (VLS)	mg/l		2.12	9.94	11.4	
O_2	mg/l	52.3	45.91	40.2	40.2	40.2

I-15, 16, 17, VER-3

		08/21/03 17:45	08/26/03 16:05	08/27/03 8:30	09/03/03 11:45
N	mg/l	16.7	16.7	16.7	16.7
N (VLS)	mg/l				14.0
O_2	mg/l	45.0	45.0	45.0	45.0

I-3, 4, 5, 6, 7, 8, 9, 10, VER-4

		09/04/03 10:05	09/04/03 17:04	09/11/03 18:40	09/17/03 18:15	09/18/03 7:50	09/24/03 10:15	10/03/03 9:00	10/08/03 11:22	10/11/03 16:45	10/15/03 10:45
N	mg/l	17.4	17.4	20.6	20.6	5.4	0.2	0.1	13.1	13.1	13.3
N (VLS)	mg/l	<0.1					0.37	0.5			
O_2	mg/l	49.1	49.1	57	57	42.8	36.8	37	37.6	37.6	52.3

VLS - Sample from Vapor Liquid Separator

INJECTION BALANCE SHEET - SUMMARY 2006

Injection Well	Date		Water in	N (average)	O_2 (average)	N	O_2
(Port)	Start	End	(gal)	(mg/l)	(mg/l)	(kg)	(kg)
I-3	06/12/06	06/28/06	6036				
I-4	06/12/06	06/28/06	28906				
I-5	06/12/06	06/22/06	11135				
I-6	06/12/06	06/22/06	10568				
I-9	06/28/06	09/06/06	36057				
I-10	06/28/06	09/06/06	127769				
VER-4	06/28/06	09/06/06	62317	26.5	33.7	29.7	41.7
Total			**282788**			**29.7**	**41.7**

CONCENTRATIONS OF NITROGEN AND OXYGEN INJECTED

		06/12/06	06/14/06	06/22/06	06/28/06	07/05/06	07/11/06	07/20/06	08/02/06	08/24/06	09/06/06
NO_2-NO_3 as N	mg/l	22.8	25	28.1	28.7	27.30	26.8	25.2	25.2	25.4	30
O_2	mg/l	33.29	45.61	37.5	42.06	29.94	33.4	44.33	36.41	25.6	8.98

INJECTION BALANCE SHEET - SUMMARY 2005

Injection Well	Date		Water in	N (average)	O_2 (average)	N	O_2
(Port)	Start	End	(gal)	(mg/l)	(mg/l)	(kg)	(kg)
I-8 (1)	06/22/05	08/31/05	7990				
I-6 (2)	06/22/05	09/13/05	90140				
I-5 (3)	06/22/05	09/13/05	101270				
I-4 (4)	06/22/05	09/13/05	71070				
I-3 (5)	06/22/05	09/13/05	112380	38.8	31.2	53.1	45
Total			**382850**			**53.1**	**45**

CONCENTRATIONS OF NITROGEN AND OXYGEN INJECTED

		06/22/05	06/23/05	06/30/05	07/04/05	07/11/05	07/22/05	07/28/05	08/02/05	08/10/05
NO_2-NO_3 as N	mg/l	21.9	23.7	37.8	30.2	28.5	34.2	38.3	0.1	44.3
O_2	mg/l	30	32	38	39	21.9	34	27	24.9	29.8

		08/17/05	08/25/05	08/31/05	09/07/05	09/13/05
NO_2-NO_3 as N	mg/l	43.8	46	49.6	52.3	53.6
O_2	mg/l	31.25	30.62	29.73	35.4	33.7

INJECTION BALANCE SHEET - SUMMARY 2004

INJ Well (Port)	Date		Water in	N (average)	O_2 (average)	N	O_2
	Start	End	(gal)	(mg/l)	(mg/l)	(kg)	(kg)
I-8 (1)	06/08/04	10/07/04	101586				
I-7 (2)	06/08/04	07/14/04	32856				
I-6 (3)	06/08/04	10/07/04	102180				
I-5 (4)	06/08/04	10/07/04	103148				
I-4 (5)	06/08/04	10/07/04	123516				
I-3 (2)	07/14/04	10/07/04	82975	21.6	31.5	41.7	65.0
Total			**546261**			**41.7**	**65.0**

[1]Average value

CONCENTRATIONS OF NITROGEN AND OXYGEN INJECTED

		06/08/04	06/09/04	06/17/04	06/22/04	06/29/04	07/07/04	07/14/04	07/20/04	07/27/04	08/05/04
NO_2-NO_3 as N	mg/l	38.6	36.4	32.8	31.6	22.5	23.6	18	17.5	19.5	17.6
O_2	mg/l	37	37	30.5	20	30.52	29.7	32	39	40.14	34.73

		08/11/04	08/17/04	08/23/04	08/31/04	09/15/04	09/22/04	10/01/04	10/07/04
NO_2-NO_3 as N	mg/l	15.6	16.05	16.5	<0.1	22.8	23.4	16.6	19.8
O_2	mg/l	31.8	31.26	34.02	32.3	28.5	27.3	28.5	23.2

APPENDIX E

SUMMARY OF DATA – SYSTEM MONITORING

APPENDIX E-1

WATER QUALITY

WATER QUALITY MONITORING - VER-1 2003

VLS - MBTEX Scan		VLS 06/10/03	VLS 06/11/03	VLS 06/19/03	VLS 06/24/03	VLS 07/01/03	VLS 07/10/03	VLS 07/16/03	VLS 07/22/03	VLS 07/29/03	VLS 08/05/03
MTBE	ppb	<200	<200	<200	<100	<50	<100	<100	<100	<50	<50
Benzene	ppb	16000	11300	10700	6720	3610	2440	3650	2260	1220	479
Toluene	ppb	13400	8980	12500	12700	10100	6320	6970	4730	2280	1208
Ethyl Benzene	ppb	1260	737	1100	1030	968	769	559	439	210	160
Xylenes (Total)	ppb	6330	3550	5350	5040	4940	4140	5320	5020	4340	2277
Phenols (Total)	ppb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GRO (TPH)	mg/l	72.8	52.5	61.4	47.5	40.7	25.4	34.1	31.1	19.3	11.7

OWS - MBTEX Scan		OWS 06/10/03	OWS 06/11/03	OWS 06/19/03	OWS 06/24/03	OWS 07/01/03	OWS 07/10/03	OWS 07/16/03	OWS 07/22/03
MTBE	ppb	<200	<100	<200	<50	<200	<50	<101	<100
Benzene	ppb	12900	9540	9810	5760	3860	1780	3280	1730
Toluene	ppb	13300	7600	11200	11200	9130	4460	5820	3500
Ethyl Benzene	ppb	1980	655	955	932	1020	519	377	266
Xylenes (Total)	ppb	9850	3240	4740	4860	5380	3010	4520	4090
Phenols (Total)	ppb	NA	NA	NA	NA	NA	NA	NA	NA
GRO (TPH)	mg/l	82.8	41.3	55.8	42.5	48.1	18.3	28.6	24.1

AS - MBTEX Scan		AS	AS	AS	AS	AS	AS	AS	AS	AS
Flow to AS	gpm	15	1.8	4.4	4.6	5.1	6.0	6.1	6.1	6.2
		06/10/03	06/11/03	06/19/03	06/24/03	07/01/03	07/10/03	07/16/03	07/22/03	07/29/03
MTBE	ppb	12	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	ppb	98.8	1.9	3.6	5.5	6.5	1.2	2.0	<1	<1
Toluene	ppb	123	2	3.5	5	<1	2.4	3.7	1.6	<1
Ethyl Benzene	ppb	27.8	<1	11.4	2.8	3.5	<1	1.1	1.8	2
Xylenes (Total)	ppb	184	<3	9.1	5.2	4.9	<3	3.3	4.9	<3
Phenols (Total)	ppb	NA	NA	NA	NA	NA	NA	NA	NA	NA
GRO (TPH)	mg/l	2.69	0.21	1.59	1.04	1.54	<0.2	<0.3	0.27	<0.2

Discharge - MBTEX Scan		Effluent 06/10/03	Effluent 06/11/03	Effluent 06/19/03	Effluent 06/24/03	Effluent 07/01/03	Effluent 07/10/03	Effluent 07/16/03	Effluent 07/22/03	Effluent 07/29/03	Effluent 08/05/03
MTBE	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	ppb	1.5	<1	1	2.5	2.2	<1	<1	<1	<1	<1
Toluene	ppb	<1	<1	<1	2.1	1.3	<1	<1	<1	<1	<1
Ethyl Benzene	ppb	2.8	<1	2.7	2.8	3.7	<1	<1	<1	<1	<1
Xylenes (Total)	ppb	3.5	<3	<3	<3	4.0	<3	<3	3.1	<3	<3
Phenols (Total)	ppb	NA	141	214	340	160	<10	<10	<10	<10	52.2
GRO (TPH)	mg/l	0.72	<0.2	0.47	0.75	0.90	<0.2	<0.2	<0.2	<0.2	<0.2

WATER QUALITY MONITORING - VER-1 2003

Selected Parameters		VLS	VLS	VLS	VLS	VLS	VLS	VLS	VLS	VLS	VLS
		06/10/03	06/11/03	06/19/03	06/24/03	07/01/03	07/10/03	07/16/03	07/22/03	07/29/03	08/05/03
pH		7.36	7.32	7.08	7.03	6.66	7.16	7.01	6.81	7.1	6.77
EC	µS/cm	2100	2220	2196	1257	1850	1576	1678	1811	1920	1748
T	°C	13.9	16.9	16.4	15.5	23.0	24.0	22.1	19.9	27.0	18.0

Selected Parameters		OWS	OWS	OWS	OWS	OWS	OWS	OWS	OWS
		06/10/03	06/11/03	06/19/03	06/24/03	07/01/03	07/10/03	07/16/03	07/22/03
pH		7.43	7.52	7.25	7.24	5.92	7.28	7.12	7.1
EC	µS/cm	2100	2150	2131	1283	2040	1579	1659	1795
T	°C	14.0	19.6	17.6	20.2	21.4	20.0	24.8	25.3

Selected Parameters		AS	AS	AS	AS	AS	AS	AS	AS	AS
		06/10/03	06/11/03	06/19/03	06/24/03	07/01/03	07/10/03	07/16/03	07/22/03	07/29/03
pH		7.94	7.51	7.66	7.67	7.69	7.95	7.99	7.43	7.64
EC	µS/cm	2000	1880	1948	1189	1590	1509	1569	1688	1704
T	°C	18.1	21.1	17.9	18.4	23.0	21.8	22.9	21.1	27.2

Selected Parameters		Effluent	Effluent	Effluent	Effluent	Effluent	Effluent	Effluent	Effluent	Effluent	Effluent
		06/10/03	06/11/03	06/19/03	06/24/03	07/01/03	07/10/03	07/16/03	07/22/03	07/29/03	08/05/03
Fe (total)	mg/l	NA	2.77	4.3	8	4.2	1.7	0.15	<0.1	0.61	4.11
Mn (total)	mg/l	NA	1	2.38	1.26	1.12	0.26	0.55	0.64	0.41	0.94
TSS	mg/l	NA	124	121	313	111	55	<1	4	2	46
pH		7.46	7.49	7.48	7.64	7.41	8.72	7.40	7.42	8.25	7.70
EC	µS/cm	2000	1870	1994	1194	1470	1146	1443	1630	1613	1667
T	°C	18.6	24.7	19.5	18.3	23.2	23.4	23.0	22.1	27.1	21.72

VLS-Vapor/Liquid Separator Sample Port

OWS-Oil/Water Separator Sample Port

AS-Air Stripper Sample Port

NA - Not Analyzed

WATER QUALITY MONITORING 2003

VLS		VER-2			VER-3				VER-4				
		10/17/03	10/22/03	10/29/03	08/06/03	08/12/03	08/26/03	09/03/03	09/04/03	09/11/03	09/24/03	10/03/03	10/08/03
MTBE	ppb	<10	<5	<100	<5	<10	<1	<1	68.7	121.4	<1	82.4	95.5
Benzene	ppb	3,196	3,908	4,710	93	442	16.1	558.3	269.2	1365	2,045	1,542	2,026
Toluene	ppb	4,731	5,220	6,095	<5	<10	<1	6.4	7.9	31.9	23	18	31
Ethylbenzene	ppb	493	603	661	8.9	29.8	4.3	19.1	123.9	401.8	411	320	405
Xylenes (Total)	ppb	3,171	3,153	3,863	22.5	41.1	7.1	43.8	141.7	622.4	243.9	198	293
GRO (TPH)	mg/l	24.9	24.7	35.2	<1	<2	<0.2	0.9	1.9	6.6	5.4	5.4	6.1

Effluent		VER-2			VER-3				VER-4				
		10/17/03	10/22/03	10/29/03	08/06/03	08/12/03	08/26/03	09/03/03	09/04/03	09/11/03	09/24/03	10/03/03	10/08/03
MTBE	ppb	<1	<1	<1	<1	<1	<1	<1	<1	1.8	3	2	2.4
Benzene	ppb	<1	<1	<1	4.7	<1	<1	<1	9.3	<1	<1	<1	<1
Toluene	ppb	<1	<1	<1	4.5	<1	<1	<1	2.6	<1	<1	<1	<1
Ethyl Benzene	ppb	<1	<1	<1	11.7	<1	<1	<1	5.7	2.3	<1	<1	<1
Xylenes (Total)	ppb	<3	<3	<3	54.4	<3	<3	<3	10.6	<3	<3	<3	<3
Phenols (Total)	ppb	<10	<10	<10	22.8	19.4	<10	<10	<10	11.9	<10	<10	<10
GRO (TPH)	mg/l	<0.2	<0.2	<0.2	1.20	<0.2	<0.2	<0.2	1.92	0.21	<0.2	<0.2	<0.2

Effluent		VER-2			VER-3				VER-4				
		10/17/03	10/22/03	10/29/03	08/06/03	08/12/03	08/26/03	09/03/03	09/04/03	09/11/03	09/24/03	10/03/03	10/08/03
Fe (total)	mg/l	2.5	0.3	4.2	36.6	<0.1	<0.1	<0.1	2.3	0.3	0.3	1.8	0.2
Mn (total)	mg/l	0.8	0.1	0.7	4.8	0.3	0.4	0.1	1.6	1.7	1.0	1.2	0.6
TSS	mg/l	143	4	139	1180	1	12	2	181	237	49	231	33
pH		7.4	8.2	8.1	7.0	7.2	7.3	8.4	7.8	8.0	7.4	7.6	7.3
EC	μS/cm	2,920	1,667	1,700	3837	2782	3106	1907	3458	3465	2997	2,840	2,990
T	°C	11.6	16.2	16.1	21.3	24.3	26.9	18.93	24.7	16.8	12.6	15.6	13.7

VLS-Vapor/Liquid Separator Sample Port

NA - Not Analyzed

WATER QUALITY MONITORING - VER-1 2004

VLS		VLS 07/14/04	VLS 07/20/04	VLS 07/27/04	VLS 08/05/04	VLS 08/11/04	VLS 08/17/04	VLS 08/23/04	VLS 08/31/04
MTBE	ppb	<20	<20	<20	<20	<20	<20	<20	<20
Benzene	ppb	615.5	1,575.0	728.8	514.9	413.0	286.7	240.4	183.3
Toluene	ppb	436.6	2,062.0	1,455.0	1,051.0	863.0	493.2	373.7	208.9
Ethylbenzene	ppb	137.2	269.4	188.7	170.3	190.8	93.6	87.4	57.7
Xylenes (Total)	ppb	1,032	3,063	2,481	2,599	2,038	1453	1,283	902.1
Phenols (Total)	ppb	NA	NA	NA	NA	NA	NA	NA	NA
GRO (TPH)	mg/l	5.49	14.48	11.44	11.04	8.89	6.23	5.41	4.32

Effluent		Effluent 07/14/04	Effluent 07/20/04	Effluent 07/27/04	Effluent 08/05/04	Effluent 08/11/04	Effluent 08/17/04	Effluent 08/23/04	Effluent 08/31/04
MTBE	ppb	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	ppb	6.2	<1	<1	<1	<1	<1	<1	<1
Toluene	ppb	18	1.3	<1	<1	<1	<1	<1	<1
Ethyl Benzene	ppb	5.2	<1	<1	<1	<1	<1	<1	<1
Xylenes (Total)	ppb	24.8	5.2	3.2	<3	<3	<3	<3	<3
Phenols (Total)	ppb	<10	256	202	264	266	196	138	143
GRO (TPH)	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Selected Parameters		VLS 07/14/04	VLS 07/20/04	VLS 07/27/04	VLS 08/05/04	VLS 08/11/04	VLS 08/17/04	VLS 08/23/04	VLS 08/31/04
pH		7.5	7.4	7.2	7.0	7.1	7.0	7.1	7.2
EC	µS/cm	2,341	2,245	2,203	2,266	2,224	2254	2,247	2,138
T	°C	23.7	24.9	19.9	18.1	18.4	17.0	18.5	18.9

Selected Parameters		Effluent 07/14/04	Effluent 07/20/04	Effluent 07/27/04	Effluent 08/05/04	Effluent 08/11/04	Effluent 08/17/04	Effluent 08/23/04	Effluent 08/31/04
Fe (total)	mg/l	2.04	6.70	6.93	6.89	8.50	7.6	6.71	6.65
Mn (total)	mg/l	2.83	1.84	1.52	1.57	1.76	1.73	1.74	1.58
TSS	mg/l	12	212	190	392	416	550	96	123
pH		6.5	7.5	7.4	7.2	7.4	7.3	7.4	7.9
EC	µS/cm	3,051	1,910	1,968	2,007	1,987	2,012	1,975	2,097
T	°C	29.9	30.9	20.9	18.5	19.3	17.6	18.7	19.5

VLS-Vapor/Liquid Separator Sample Port

NA - Not Analyzed

WATER QUALITY MONITORING 2004

VLS		VER-2							VER-4			
		06/02/04	06/03/04	06/09/04	06/17/04	06/22/04	06/29/04	07/07/04	09/15/04	09/22/04	10/05/04	10/07/04
MTBE	ppb	<50	<5	<50	<50	<5	<50	<20	<5	<5	<1	<2
Benzene	ppb	5,547	3,778	4,279	3,867	3,000	2,920	729	490.8	511.6	236.0	219.9
Toluene	ppb	17,500	5,339	5,661	5,638	3,965	3,947	1,455	7.3	5.4	3.6	3.6
Ethylbenzene	ppb	4,545	853	870	903	741	780	189	62.1	52.8	53.6	56.9
Xylenes (Total)	ppb	24,010	4,156	4,114	4,079	3,205	3,360	2,481	79.2	58.4	46.2	94.8
Phenols (Total)	ppb	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GRO (TPH)	mg/l	106.80	25.46	30.65	26.35	21.29	19.31	11.44	1.89	1.62	0.79	0.78

Effluent		VER-2							VER-4			
		06/02/04	06/03/04	06/09/04	06/17/04	06/22/04	06/29/04	07/07/04	09/15/04	09/22/04	10/01/04	10/07/04
MTBE	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.5	2.1
Benzene	ppb	<1	<1	<1	<1	<1	<1	<1	1.1	<1	<1	<1
Toluene	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Xylenes (Total)	ppb	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Phenols (Total)	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	12.5	14.2
GRO (TPH)	mg/l	0.23	0.23	0.20	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Selected Parameters		VER-2							VER-4		
		06/03/04	06/09/04	06/17/04	06/22/04	06/29/04	07/07/04	09/15/04	09/22/04	10/01/04	10/07/04
Fe (total)	mg/l	8.06	0.16	0.1	1.82	49.7	0.39	0.61	0.92	1.47	6.90
Mn (total)	mg/l	0.39	0.1	0.07	0.41	0.95	4.2	1.23	1.21	1.06	1.22
TSS	mg/l	251	<1	<1	3	138	26.0	30	87	75	240
pH		7.64	7.43	7.92	7.1	7.08	7.43	7.2	7.2	7.0	7.4
EC	µS/cm	2,229	2,195	2,153	2,229	2,220	2,194	2,332	2,269	2,199	2,369
T	°C	19.4	15.6	15.2	23.0	21.7	15.8	14.2	13.6	13.0	13.6

APPENDIX E-2

OFFGAS QUALITY

OFFGAS QUALITY MONITORING 2004

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)	CO_2 %	O_2 (ppm)
VER-2														
06/02/04 12:32	[1]CT-60 s	0.28	51500	79600	ND	811	479	6.8	11	OL	OL	OL	0.22	12.9
06/02/04 12:34	[1]CT-60 s	0.28	60000	90800	ND	1010	943	20	42					
06/03/04 09:10	[1]CT-60 s	0.28	29700	49900	ND	604	454	13	28	OL	OL	OL	0.23	11.7
06/03/04 09:12	[1]CT-60 s	0.28	22000	42500	ND	407	118	ND	ND					
06/09/04 10:00	[1]CT-60 s	0.28	641	3530	ND	7	ND	ND	ND	OL	OL	968	0	9.48
06/09/04 10:05	[1]CT-60 s	0.28	28000	39400	ND	586	306	13	23					
06/17/04 07:30	[1]CT-60 s	0.28	30700	36000	ND	600	281	7.4	13	OL	OL	1634	0.2	25
06/17/04 07:32	[1]CT-60 s	0.28	25000	34600	ND	582	396	12	23					
06/29/04 13:00	[1]CT-60 s	0.28	18300	23900	ND	557	326	9.6	15	OL	48,500	2650	0.24	7.9
06/29/04 13:02	[1]CT-60 s	0.28	19800	25900	ND	664	482	22	45					
07/07/04 09:28	[1]CT-60 s	0.28	20900	26300	ND	507	364	21	39	OL	42500	2340	0.27	5.89
07/07/04 09:30	[1]CT-60 s	0.28	18000	23700	ND	479	231	7.6	11					

[1]Charcoal tube sample collected from Tedlar bag

GRO - Gasoline Range Organics
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FID - Flame Ionization Detector
PID - Photoionization Detector
Summit - Summit HydrocarbonAnalyzer
CT - Charcoal Tube
TB - Tedlar Bag

ND - Not Detected
OL - Over detection limit
>10,000 ppm for Summit (calibrated with hexane)
>10,000 ppm for PID (calibrated with isobuthylene)
>50,000 ppm for FID (calibrated with methane)

OFFGAS QUALITY MONITORING 2004

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)	CO_2 %	O_2 (ppm)
VER - 1														
07/14/04 21:58	[1]CT-60 s	0.28	19700	32200	ND	82	21	ND	3.6	OL	OL	1892	0.27	5.16
07/14/04 22:00	[1]CT-60 s	0.28	23800	37500	ND	109	39	4.2	11					
07/20/04 11:02	[1]CT-60 s	0.28	23100	25900	ND	355	193	355	26	OL	OL	2607	0.16	8.5
07/20/04 11:04	[1]CT-60 s	0.28	25700	28600	ND	414	315	12	55					
07/27/04 11:25	[1]CT-60 s	0.28	21700	23000	ND	313	356	19	85	9670	43320	2795	0.21	25
07/27/04 11:27	[1]CT-60 s	0.28	14100	16100	ND	226	198	5.2	20					
08/05/04 13:50	[1]CT-60 s	0.28	11100	12800	ND	158	141	4.9	15	7015	37600	2531	0.19	9.1
08/05/04 13:52	[1]CT-60 s	0.28	13400	15100	ND	197	257	15	61					
08/11/04 09:10	[1]CT-60 s	0.28	10700	12300	ND	127	155	11	40	6283	38275	2439	0.23	8.85
08/11/04 09:12	[1]CT-60 s	0.28	10100	11700	ND	110	103	5.3	14					
08/17/04 12:30	[1]CT-60 s	0.28	8600	10100	ND	104	117	10	39	5311	24450	2501	0.19	9.57
08/17/04 12:32	[1]CT-60 s	0.28	8600	10100	ND	88	86	5.8	17					
08/23/04 06:30	[1]CT-60 s	0.28	14700	16800	ND	146	253	64	309	4789	26500	2620	0.19	9.75
08/23/04 06:35	[1]CT-60 s	0.28	14500	16600	ND	140	251	71	368					
08/31/04 16:00	[1]CT-60 s	0.28	12200	13900	ND	90	200	42	345	3980	19800	352	0.18	9.83
08/31/04 16:05	[1]CT-60 s	0.28	11800	13400	ND	94	160	50	350					

OFFGAS QUALITY MONITORING 2004

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)	CO_2 %	O_2 (ppm)
VER - 4														
09/15/04 18:50	[1]CT-60 s	0.28	859	1010	ND	58	ND	7.2	6.2	263	malfunct	450	0.04	malfunct
09/15/04 18:55	[1]CT-60 s	0.28	836	979	ND	48	ND	7.8	6.5					
09/23/04 08:05	[1]CT-60 s	0.28	39	77	ND	3.5	ND	ND	ND	282	364	292	0.05	25
09/23/04 08:05	[1]CT-60 s	0.28	179	225	ND	10	ND	1	0.93					
10/01/04 13:30	[1]CT-60 s	0.28	955	1300	ND	20	ND	ND	ND	527	1325	malfunct	0	25
10/01/04 13:32	[1]CT-60 s	0.28	1100	1460	ND	31	ND	ND	ND					
10/07/04 10:05	[1]CT-60 s	0.28	756	1020	ND	13	ND	4.5	3	253	320	267	0.04	malfunct
10/07/04 10:05	[1]CT-60 s	0.28	ND	ND	ND	ND	ND	ND	ND					

[1]Charcoal tube sample collected from Tedlar bag

GRO - Gasoline Range Organics
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Summit - Summit HydrocarbonAnalyzer
CT - Charcoal Tube
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ND - Not Detected
OL - Over detection limit
>10,000 ppm for Summit (calibrated with hexane)
>10,000 ppm for PID (calibrated with isobuthylene)
>50,000 ppm for FID (calibrated with methane)

OFFGAS QUALITY MONITORING 2003

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector
Data represent combined VOC concentrations for extraction well VER-1 (June 10 - August 5), VER-3 (August 6 - September 3)
VER-4 (September 4 - October 8), and VER-2 (October 17 - October 21, 2003)

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)
VER-1												
6/10/03 20:05	CT-30 s	0.28	19,600	58,700	ND	277	45	ND	ND	29,015	OL	OL
6/10/03 20:07	CT-30 s	0.28	33,400	92,700	ND	591	198	ND	ND	29,015	OL	OL
6/11/03 13:55	CT-30 s	0.28	30,500	81,900	ND	559	106	ND	ND	29,004	OL	OL
6/11/03 13:57	CT-30 s	0.28	38,000	101,000	ND	857	221	ND	ND	29,004	OL	OL
06/19/03 10:27	[1,2]CT-60 s	0.28	25,300	36,200	ND	661	245	9.6	ND	14,000	OL	OL
06/19/03 10:35	TB		60,000	71,300	ND	1,700	1,750	147	504	14,000	OL	OL
06/19/03 10:37	TB		13,600	15,400	ND	393	578	57	226	14,000	OL	OL
06/19/03 10:37	[1,2]CT-30 s	0.28	50,800	74,600	ND	1,360	257	ND	ND	14,000	OL	OL
06/19/03 10:39	[1,2]CT-30 s	0.28	7,060	11,000	ND	786	387	ND	ND	14,000	OL	OL
06/19/03 10:43	[1]CT-30 s	0.28	8,190	46,800	ND	385	218	ND	12	14,000	OL	OL
06/19/03 10:45	[1]CT-30 s	0.28	5,480	48,000	ND	274	338	12	23	14,000	OL	OL
6/24/03 16:18	[1,2]CT-30 s	0.28	125,000	146,000	ND	3,870	6,940	500	1,680	11,873	OL	1,575
6/24/03 16:20	[1,2]CT-30 s	0.28	82,900	96,300	ND	1,560	3,390	194	605	11,873	OL	1,575
6/24/03 16:37	[1]CT-30 s	0.28	34,100	40,900	ND	907	169	ND	ND	11,873	OL	1,575
6/24/03 16:38	[1]CT-30 s	0.28	24,900	32,800	ND	1,000	107	ND	ND	11,873	OL	1,575
7/1/03 11:20	[1,2]CT-30 s	0.28	7,880	10,000	ND	113	33	ND	ND	11,780	OL	OL
7/1/03 11:25	[1,2]CT-30 s	0.28	11,600	14,300	ND	175	63	ND	ND	11,780	OL	OL
7/1/03 11:30	[1]CT-30 s	0.28	22,300	27,700	ND	389	296	ND	ND	11,780	OL	OL
7/1/03 11:30	[1]CT-30 s	0.28	26,100	32,300	ND	518	640	ND	ND	11,780	OL	OL
7/10/03 16:30	[1,2]CT-30 s	0.28	6,080	8,040	ND	86	36	ND	ND	14,106	OL	1,680
7/10/03 16:32	[1,2]CT-30 s	0.28	8,470	10,900	ND	144	81	ND	ND	14,106	OL	1,680
7/10/03 16:40	[1]CT-30 s	0.28	25,700	30,900	ND	483	541	ND	ND	14,106	OL	1,680
7/10/03 16:43	[1]CT-30 s	0.28	27,500	32,700	ND	564	871	19	ND	14,106	OL	1,680

OFFGAS QUALITY MONITORING 2003

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector
Data represent combined VOC concentrations for extraction well VER-1 (June 10 - August 5), VER-3 (August 6 - September 3)
VER-4 (September 4 - October 8), and VER-2 (October 17 - October 21, 2003)

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)
VER-1 (continued)												
7/16/03 9:10	[1]CT-60 s	0.28	33,000	41,100	ND	543	356	6.7	12	20,867	OL	1,718
7/16/03 9:12	[1]CT-60 s	0.28	46,000	55,500	ND	821	861	29	61	20,867	OL	1,718
7/22/03 0:00	[1]CT-60 s	0.28	35,300	42,600	ND	257	203	4.8	16	20,695	OL	1,600
7/22/03 0:00	[1]CT-60 s	0.28	42,600	50,100	ND	314	361	14	50	20,695	OL	1,600
07/29/03 06:30	[1]CT-60 s	0.28	24,700	30,000	ND	344	325	8.3	42	15,600	OL	1,725
07/29/03 06:30	[1]CT-60 s	0.28	27,600	32,900	ND	421	450	14	88	15,600	OL	1,725
08/05/03 12:47	[1]CT-60 s	0.28	15,200	17,900	ND	186	186	7.5	39	NM	OL	1,499
08/05/03 12:49	[1]CT-60 s	0.28	17,100	20,100	ND	228	298	18	99	NM	OL	1,499

[1]Charcoal tube sample collected from Tedlar bag
[2]Sample collected in tedlar bag inside dessicator on vacuum side of the bower. Because of short collection time in dessicator (2-5s) these samples are not conisdered representative.

GRO - Gasoline Range Organics
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PID - Photoionization Detector
Summit - Summit HydrocarbonAnalyzer
CT - Charcoal Tube
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ND - Not Detected
OL - Over detection limit
>10,000 ppm for Summit (calibrated with hexane)
>10,000 ppm for PID (calibrated with isobuthylene)
>50,000 ppm for FID (calibrated with methane)

OFFGAS QUALITY MONITORING 2003

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector
Data represent combined VOC concentrations for extraction well VER-1 (June 10 - August 5), VER-3 (August 6 - September 3)
VER-4 (September 4 - October 8), and VER-2 (October 17 - October 21, 2003)

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)
VER-3												
08/06/03 12:46	[1]CT-60 s	0.28	236	279	ND	18	16	ND	5.7	NM	15.8	14.5
08/06/03 12:48	[1]CT-60 s	0.28	ND	ND	ND	14	14	ND	6.7	NM	15.8	14.5
08/12/03 13:40	[1]CT-60 s	0.28	ND	ND	ND	ND	ND	ND	ND	NM	20.7	21.6
08/12/03 13:40	[1]CT-60 s	0.28	ND	ND	ND	ND	ND	ND	ND	NM	20.7	21.6
08/26/03 17:27	[1]CT-60 s	0.28	ND	ND	ND	ND	ND	ND	ND	8	14.3	13.6
08/26/03 17:28	[1]CT-60 s	0.28	ND	ND	ND	ND	ND	ND	ND			
09/03/03 11:25	[1]CT-60 s	0.28	ND	ND	ND	ND	ND	ND	ND	0	9.2	9

[1]Charcoal tube sample collected from Tedlar bag

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>10,000 ppm for Summit (calibrated with hexane)
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OFFGAS QUALITY MONITORING 2003

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector
Data represent combined VOC concentrations for extraction well VER-1 (June 10 - August 5), VER-3 (August 6 - September 3)
VER-4 (September 4 - October 8), and VER-2 (October 17 - October 21, 2003)

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)
VER-4												
09/04/03 12:54	[1]CT-60 s	0.28	3600	5580	ND	20	ND	ND	ND	2778	3826	633
09/04/03 12:57	[1]CT-60 s	0.28	5960	8810	ND	36	ND	3.7	ND			
09/11/03 18:30	[1]CT-60 s	0.28	5930	9090	ND	71	ND	ND	ND	4199	3852	868
09/11/03 18:40	[1]CT-60 s	0.28	7060	10700	ND	95	ND	5	4.2			
09/24/03 09:36	[1]CT-60 s	0.28	1370	2420	ND	20	13	ND	ND	1265	2865	460
09/24/03 09:41	[1]CT-60 s	0.28	1940	3250	ND	31	19	ND	3.8			
10/03/03 14:55	[1]CT-60 s	0.28	2310	3730	ND	38	4.1	ND	ND	1465	4020	NM
10/03/03 15:05	[1]CT-60 s	0.28	1920	3020	ND	23	ND	ND	ND			
10/08/03 14:10	[1]CT-60 s	0.28	2210	3690	ND	33	3.7	ND	ND	1565	4065	673
10/08/03 14:20	[1]CT-60 s	0.28	2370	3780	ND	42	ND	3.8	ND			

[1]Charcoal tube sample collected from Tedlar bag

GRO - Gasoline Range Organics
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CT - Charcoal Tube
TB - Tedlar Bag

ND - Not Detected
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>10,000 ppm for Summit (calibrated with hexane)
>10,000 ppm for PID (calibrated with isobuthylene)
>50,000 ppm for FID (calibrated with methane)

OFFGAS QUALITY MONITORING 2003

Organic Vapors By Charcoal Tube Desorption, Summit Analyzer, Flame Ionization Detector, and Photo Ionization Detector
Data represent combined VOC concentrations for extraction well VER-1 (June 10 - August 5), VER-3 (August 6 - September 3)
VER-4 (September 4 - October 8), and VER-2 (October 17 - October 21, 2003)

Date/Time	Collection Interval	Sampling Flow Rate (L/min)	GRO (mg/m^3)	TPH (mg/m^3)	MTBE (mg/m^3)	Benzene (mg/m^3)	Toluene (mg/m^3)	Ethyl Benzene (mg/m^3)	Xylenes (mg/m^3)	Summit (ppm)	FID (ppm)	PID (ppm)
VER-2												
10/17/03 12:25	[1]CT-60 s	0.28	5970	11300	ND	132	69	ND	ND	5560	2922	1130
10/17/03 12:28	[1]CT-60 s	0.28	6430	11900	ND	155	111	3.6	7.3			
10/22/03 19:43	[1]CT-60 s	0.28	9760	16200	ND	231	121	ND	9	8153	3543	1771
10/23/03 19:45	[1]CT-60 s	0.28	10500	17100	ND	257	189	7.9	17			
10/29/03 12:10	[1]CT-60 s	0.28	5670	9790	ND	110	44	ND	ND	8000	3543	1327
10/29/03 12:10	[1]CT-60 s	0.28	7910	13000	ND	188	101	ND	4.4			

[1]Charcoal tube sample collected from Tedlar bag

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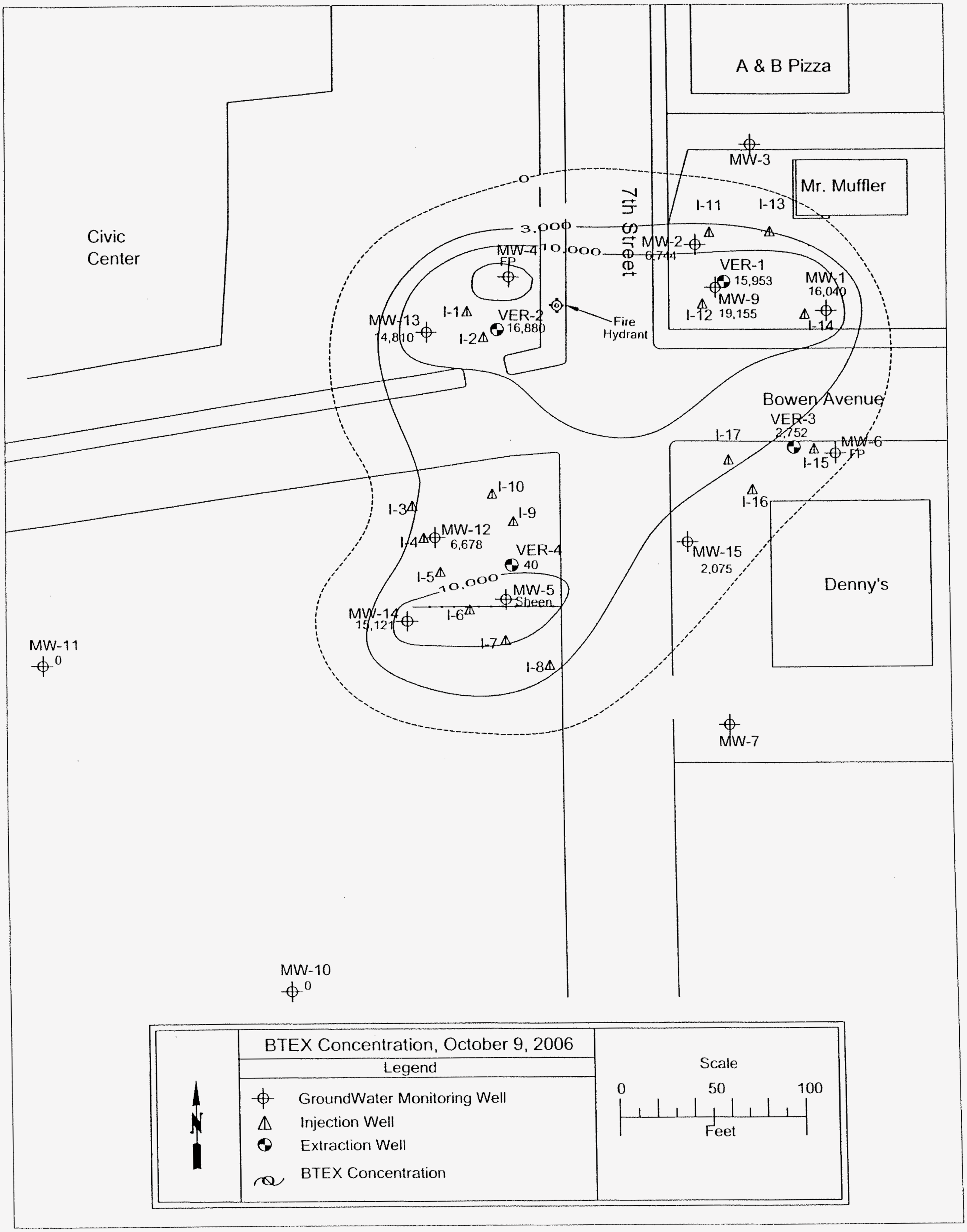
TB - Tedlar Bag

ND - Not Detected
OL - Over detection limit
>10,000 ppm for Summit (calibrated with hexane)
>10,000 ppm for PID (calibrated with isobuthylene)
>50,000 ppm for FID (calibrated with methane)

APPENDIX F

COC ISOCONCENTRATION MAP



A & B Pizza
MW-3
Mr. Muffler
Civic Center
7th Street
0
3,000
10,000
I-11
I-13
MW-2
6,744
MW-4
FP
VER-1
15,953
MW-1
16,040
MW-9
19,155
I-12
I-14
MW-13
14,810
I-1
I-2
VER-2
16,880
Fire Hydrant
Bowen Avenue
VER-3
2,752
I-17
MW-6
FP
I-15
I-16
I-10
I-3
I-9
I-4
MW-12
6,678
VER-4
40
MW-15
2,075
Denny's
I-5
MW-5
Sheen
MW-14
15,121
I-6
I-7
I-8
MW-11
0
MW-7
MW-10
0
BTEX Concentration, October 9, 2006
Legend
GroundWater Monitoring Well
Injection Well
Extraction Well
BTEX Concentration
Scale
0
50
100
Feet
N

APPENDIX G

GROUNDWATER QUALITY MONITORING – SUMMARY OF DATA

APPENDIX G-1

COC IN GROUNDWATER

GROUNDWATER QUALITY MONITORING

Extraction Wells

Well ID	Date	MTBE ppb	Benzene ppb	Toluene ppb	Ethylbenz. ppb	Xylenes (total) ppb	GRO (TPH) mg/l	BTEX mg/l	BTEX Trend
VER-1	06/10/03	<1000	14,600	9,960	2,550	11,450	<200	38,560	
VER-1	11/19/03	<200	14,000	10,260	2,752	13,670	88.5	40,682	
VER-1	04/25/04	<200	13,890	10,410	2,842	13,800	88.5	40,942	
VER-1	10/23/04	<200	6,998	3,877	1,683	8,345	58.4	20,903	
VER-1	05/17/05	291	6,078	2,926	2,209	9,641	68.7	20,854	▼
VER-1	11/19/05	<200	4,358	1,690	2,863	11,200	74.7	20,111	
VER-1	05/12/06	<100	3,619	796	2,747	10,160	56.7	17,322	
VER-1	10/10/06	<100	2,792	889	2,680	9,544	47.9	15,953	
VER-2	07/02/03	<20	4,000	2,890	518	1,630	19.4	9,038	
VER-2	11/19/03	<100	4,642	7,813	1,419	7,760	67.3	21,634	
VER-2	04/25/04	0.04 ft Free Product						0	
VER-2	10/23/04	<100	2,089	2,178	144	5,525	43.1	9,936	
VER-2	05/17/05	87.3	3,173	1,611	690	2,331	24.8	7,805	▲
VER-2	11/19/05	<100	5,399	4,319	943	3,937	32.3	14,598	
VER-2	05/12/06	<50	6,013	5,305	1,076	4,450	35.5	16,844	
VER-2	10/10/06	1.02 ft Free Product							
VER-3	07/02/03	<20	10,500	55	444	551	<60	11,550	
VER-3	11/19/03	<100	5,039	<100	117	336	10.8	5,492	
VER-3	04/25/04	<25	3,759	<25	77	155	7.4	3,992	
VER-3	10/23/04	<25	2,931	<25	85	141	8.4	3,157	
VER-3	05/17/05	47	4,236	29	169	158	10.2	4,591	▼
VER-3	11/19/05	<50	4,946	61	293	241	11.6	5,541	
VER-3	05/12/06	<20	4,637	27	264	92	9.3	5,020	
VER-3	10/10/06	<20	2,491	<20	261	<60	7.0	2,752	
VER-4	07/02/03	227	4,530	141	250	486	9.4	5,407	
VER-4	11/19/03	<200	10,320	281	857	2,048	27.3	13,507	
VER-4	04/25/04	<200	7,960	<200	465	756	24.3	9,181	
VER-4	10/23/04	<50	6,483	76	<50	699	14.4	7,258	
VER-4	05/17/05	55.1	4,909	<50	264	280	12.7	5,452	▼
VER-4	11/19/05	<100	11,080	141	1,466	1,385	30.4	14,072	
VER-4	05/12/06	<50	5,553	<50	745.2	384.8	15.92	6,683	
VER-4	10/10/06	<1	33	<1	<1	7.5	0.65	40	

GROUNDWATER QUALITY MONITORING

Monitoring Wells

Well ID	Date	MTBE ppb	Benzene ppb	Toluene ppb	Ethylbenz. ppb	Xylenes (total) ppb	GRO (TPH) mg/l	BTEX mg/l	BTEX Trend
MW-1	06/10/03	<500	27,600	1,530	641	14,200	110.0	43,971	
MW-1	11/19/03	<200	12,090	513	<200	8705	56.7	21,308	
MW-1	04/25/04	<250	13,600	969.9	328.3	10140	60.9	25,038	
MW-1	10/23/04	<250	14,130	485.8	<250	13,090	78.1	27,706	
MW-1	05/17/05	512	12,120	428.6	175.8	9,998	54.9	22,722	▼
MW-1	11/19/05	469.6	11,520	346.1	178.1	11,770	64.40	23,814	
MW-1	05/12/06	<100	10,740	234.9	190.5	9,775	49.72	20,940	
MW-1	10/10/06	537.4	7,066	111.1	<100	8,863	47.24	16,040	
MW-2	06/10/03	<100	2,560	4,590	1,470	15,700	69.0	24,320	
MW-2	11/19/03	<100	2,268	4367	1691	14690	75.3	23,016	
MW-2	04/25/04	<200	1,068	2924	1193	10910	49.4	16,095	
MW-2	10/23/04	<200	461	1836	1281	15290	75.6	18,868	
MW-2	05/17/05	265.6	209	769.3	737.4	6401	28.0	8,116	▼
MW-2	11/19/05	<200	221	448.2	915.4	7852	41.68	9,436	
MW-2	05/12/06	<50	121	266.2	1092	7978	37.95	9,457	
MW-2	10/10/06	497.1	50	88.5	714.3	5891	31.47	6,744	
MW-3	06/10/03	<1	<1	<1	<1	<3	<0.2	0	
MW-3	11/19/03	<1	<1	<1	<1	<3	<0.2	0	
MW-3	04/25/04	<1	<1	<1	<1	<3	<0.2	0	
MW-3	10/23/04	<1	<1	<1	<1	<3	<0.2	0	
MW-3	05/17/05	<1	1.2	1.5	<1	<3	<0.2	0	▼
MW-3	11/19/05	<1	<1	<1	<1	<3	<0.2	0	
MW-3	05/12/06	<1	<1	<1	<1	<3	<0.2	0	
MW-3	10/10/06	<1	<1	<1	<1	<3	<0.2	0	
MW-4	07/01/03	<200	9,470	7,680	1,120	3,510	49.5	21,780	
MW-4	11/20/03	<200	14,140	14,490	1,794	6,948	102.7	37,372	
MW-4	04/25/04	1 ft Free Product							
MW-4[1]	10/23/04	<250	17,090	21,290	3,711	15,400	110.0	57,491	▲
MW-4	05/17/05	361	11,940	12,270	2,840	11,480	87.7	38,530	
MW-4	11/19/05	<500	11,010	13,690	2,752	11,700	107.7	39,152	
MW-4	05/12/06	<200	11,900	9,707	1,863	7,202	74.5	30,672	
MW-4	10/10/06	1.8 ft Free Product							
MW-5 FP	07/01/03	2.5 ftFree Product							
MW-5	11/20/03	<250	19,390	704	4,744	10,790	111.9	35,628	
MW-5 FP	04/25/04	0.04 Free Product							
MW-5[1]	10/23/04	<250	14,010	814.9	7,601	16,690	87.9	39,116	
MW-5	05/17/05	531.9	9,414	479.6	3,839	9,062	91.3	22,795	▼
MW-5[1]	11/19/05	<10	10,580	370.5	3,979	7,206	77.9	22,136	
MW-5	05/12/06	<100	10,880	<100	3,160	3,282	45.3	17,322	
MW-5[1]	10/10/06	0.05 Free Product							
MW-6	07/01/03	1 ft Free Product							
MW-6	11/20/03	<200	5,665	241	2,917	7,492	67.4	16,315	
MW-6 FP	04/25/04	0.25 ft Free Product							
MW-6 FP	10/23/04	0.83ft Free Product							
MW-6 FP	05/17/05	1.2 ft Free Product							–
MW-6 FP	11/19/05	0.37 ft Free Product							
MW-6	05/12/06	<1	68.5	3	53	156	0.9	281	
MW-6	10/10/06	2.42 ft Free Product							

GROUNDWATER QUALITY MONITORING
Monitoring Wells (continued)

Well ID	Date	MTBE ppb	Benzene ppb	Toluene ppb	Ethylbenz. ppb	Xylenes (total) ppb	GRO (TPH) mg/l	BTEX mg/l	BTEX Trend
MW-7	07/01/03	<1	<1	<1	<1	<3	<0.2	0	
MW-7	11/20/03	<1	<1	<1	<1	<3	<0.2	0	
MW-7	04/25/04	<1	7.2	3.3	14.0	77.7	0.2	102	-
MW-7	10/23/04	<1	<1	<1	<1	<3	<0.2	0	
MW-7	05/17/05	<1	<1	<1	<1	<3	<0.2	0	
MW-9	06/10/03	<100	42,900	17,600	2,730	8,910	121.0	72,140	
MW-9	11/19/03	<500	22,370	14,460	2,910	10,950	79.4	50,690	
MW-9	04/25/04	<250	14,340	8,630	2,241	8,388	60.2	33,599	
MW-9	10/23/04	<250	12,710	2,046	1,368	4,569	57.7	20,693	
MW-9	05/17/05	81.9	7,854	1,998	1,759	5,775	29.6	17,386	▼
MW-9	11/19/05	<500	9,904	2,863	3,197	10,850	61.6	26,814	
MW-9	05/12/06	<100	7,359	2,103	2,610	8,117	51.4	20,189	
MW-9	10/10/06	553.4	6,643	2,235	2,705	7,572	54.7	19,155	
MW-10	07/01/03	<1	<1	<1	<1	<3	<0.2	0	
MW-10	11/20/03	<1	<1	<1	<1	<3	<0.2	0	
MW-10	04/25/04	<1	<1	<1	<1	<3	<0.2	0	
MW-10	10/23/04	<1	<1	<1	<1	<3	<0.2	0	
MW-10	05/17/05	<1	3	2	2	5	<0.2	12	-
MW-10	11/19/05	<1	<1	<1	<1	<3	<0.2	0	
MW-10	05/12/06	<1	<1	<1	<1	<3	<0.2	0	
MW-10	10/10/06	<1	<1	<1	<1	<3	<0.2	0	
MW-11	07/01/03	<1	<1	<1	<1	<3	<0.2	0	
MW-11	11/20/03	<1	<1	<1	<1	<3	<0.2	0	
MW-11	04/25/04	<1	<1	<1	<1	<3	<0.2	0	
MW-11	10/23/04	<1	<1	<1	<1	<3	<0.2	0	
MW-11	05/17/05	<1	1	<1	<1	<3	<0.2	1	-
MW-11	11/19/05	<1	<1	<1	<1	<3	<0.2	0	
MW-11	05/12/06	<1	<1	<1	<1	<3	<0.2	0	
MW-11	10/10/06	<1	<1	<1	<1	<3	<0.2	0	
MW-12	07/01/03	<10	1,380	<10	131	116	3.67	1,627	
MW-12	11/20/03	<10	786	10.7	79.2	99.7	4.2	976	
MW-12	04/25/04	<20	1,504	<20	112	141.2	5.7	1,757	
MW-12	10/23/04	<5	618	<5	<5	<15	1.2	618	
MW-12	05/17/05	<10	1,052	<10	15.8	<30	2.3	1,068	▲
MW-12	11/19/05	<20	1,794	<20	<20	<60	4.5	1,794	
MW-12	05/12/06	<1	1,992	<1	<1	<3	3.5	1,992	
MW-12	10/10/06	71	6,636	5.4	16.3	20.1	15.5	6,678	
MW-13	07/01/03	<50	5,220	5740	974	3,160	34.5	15,094	
MW-13	11/20/03	<100	7,270	6064	991	3341	48.7	17,666	
MW-13	04/25/04	<100	9,981	3503	1352	2564	39.9	17,400	
MW-13	10/23/04	<100	5,733	4791	<100	4256	51.2	14,780	
MW-13	05/17/05	<200	8,978	5567	1112	2911	51.9	18,568	-
MW-13	11/19/05	<200	9,455	6594	1329	3681	50.1	21,059	
MW-13	05/12/06	<100	5,784	2446	960.3	1699	25.9	10,889	
MW-13	10/10/06	<20	8,324	3445	1137	1904	36.3	14,810	
MW-14	07/01/03	<250	19,800	<250	1010	1,340	<50	22,150	
MW-14	11/20/03	<200	16,740	277.8	204	1950	52.4	19,172	
MW-14	04/25/04	<20	11,170	106.7	1128	1195	22.9	13,600	
MW-14	10/23/04	<20	11,450	151.4	1429	1266	25.6	14,296	
MW-14	05/17/05	<200	12,130	262.5	1294	965.3	40.8	14,652	▼
MW-14	11/19/05	<200	13,520	243.6	1762	1092	36.9	16,618	
MW-14	05/12/06	<100	11,670	114.1	1726	961.7	30.1	14,472	
MW-14	10/10/06	262	11,720	<100	2134	1267	36.1	15,121	

GROUNDWATER QUALITY MONITORING

Monitoring Wells (continued)

Well ID	Date	MTBE ppb	Benzene ppb	Toluene ppb	Ethylbenz. ppb	Xylenes (total) ppb	GRO (TPH) mg/l	BTEX mg/l	BTEX Trend
MW-15	07/01/03	<100	7,410	<100	380	2,710	26.2	10,500	
MW-15	11/20/03	<100	6,000	<100	470	2283	28.9	8,753	
MW-15	04/25/04	<25	3,627	<25	259.4	731.4	13.6	4,618	
MW-15	10/23/04	<25	3,103	<25	210.2	707.6	12.1	4,021	
MW-15	05/17/05	73	1,921	<50	293.2	739.9	<10	2,954	▼
MW-15	11/19/05	<50	2,808	<50	439.2	986.6	11.7	4,234	
MW-15	05/12/06	<10	2,358	13	430.2	880.8	10.6	3,682	
MW-15	10/10/06	<10	1,412	<10	291.6	370.9	7.5	2,075	

[1]FP sheen

GROUNDWATER QUALITY MONITORING

Injection Wells

Well ID	Date	MTBE ppb	Benzene ppb	Toluene ppb	Ethylbenz. ppb	Xylenes (total) ppb	GRO (TPH) mg/l
I-1	07/02/03	<20	1,550	2,010	224	935	9.42
I-2	07/02/03	<20	2,370	2,590	302	1,260	12.9
I-3	07/02/03	<10	2,020	101	322	921	8.1
I-4	07/02/03	<1	1,100	6.9	66.5	253	3.35
I-5	07/02/03	<10	985	17.7	87.1	119	2.78
I-6	07/02/03	<10	11,900	109	916	864	28.7
I-7	07/02/03	<5	4,770	61.8	597	368	12.6
I-8	07/02/03	<20	5,460	179	2270	2,920	27.8
I-8	11/19/03	<1	70.4	2.9	1	8.9	0.89
I-8	04/25/04	<1	104.8	4.8	46.1	126	2.389
I-8	05/17/05	6.7	16.1	<1	<1	<3	0.25
I-8	10/10/06	19	95.9	<1	<1	4.1	0.896
I-9	07/02/03	254	1,340	11.4	58.7	178	3.52
I-10	07/02/03	121	480	21.8	56.1	206	1.89
I-11	06/10/03	<50	1,790	141	69.5	7,360	30.8
I-12	06/10/03	<200	38,500	10,900	1590	7,220	103.0
I-13	06/10/03	<10	969	27.4	190	653	13.1
I-14	06/10/03	<500	36,500	1,960	2090	3,470	100.0
I-15	07/02/03	<10	4,710	24.5	54.5	202	<20
I-16	07/02/03	<10	7,810	86.8	987	573	<40
I-17	07/02/03	<20	9,360	87.2	952	2,040	<50

APPENDIX G-2

BIODEGRADATION INDICATORS

COC AND SELECTED BIODEGRADATION INDICATORS

		MW-1 06/10/03	MW-1 11/19/03	MW-1 04/25/04	MW-1 10/23/04	MW-1 05/17/05	MW-1 11/19/05	MW-1 05/12/06	MW-1 10/10/06	MW-2 06/10/03	MW-2 11/19/03	MW-2 04/25/04	MW-2 10/23/04	MW-2 05/17/05	MW-2 11/19/05	MW-2 05/12/06	MW-2 10/10/06
MTBE	ppb	<500	<200	<250	<250	512	469.6	<100	537.4	<100	<100	<200	<200	265.6	<200	<50	497.1
Benzene	ppb	27600	12090	13,600	14,130	12,120	11,520	10740	7066	2560	2268	1,068	461	209	221	121.2	50.1
Toluene	ppb	1530	513	969.9	485.8	428.6	346.1	234.9	111.1	4590	4367	2924	1836	769.3	448.2	266.2	88.5
Ethyl Benzene	ppb	641	<200	328.3	<250	175.8	178.1	190.5	<100	1470	1691	1193	1281	737.4	915.4	1092	714.3
Xylenes Total)	ppb	14200	8705	10140	13,090	9,998	11,770	9775	8863	15700	14690	10910	15290	6401	7852	7978	5891
GRO (TPH)	mg/l	110.0	56.7	60.9	78.1	54.9	64.40	49.72	47.24	69.0	75.3	49.4	75.6	28.0	41.68	37.95	31.47
Sulfate	mg/l	246	397	358	425	395	285	268	301	598	602	564	736	530	400	238	179
Nitrate-Nitrite as N	mg/l	14.8	5.74	1.67	16.4	11.7	8.84	10.1	8.48	1.58	0.19	<0.1	0.15	0.4	0.94	0.63	1.17
Ammonia-Nitrogen as N	mg/l	<0.1	0.7	0.54	0.36	0.19	0.15	0.16	0.14	<0.1	1.46	1.54	2.28	1.4	1	1.26	1.08
Phosphorus P (total)	mg/l	0.76	1.27	0.54	20.4	0.32	3.59	1.11	0.21	2.1	1.73	1.47	1.46	1.58	0.66	0.26	0.11
COD	mg/l	201	151	138	122	141	134	185	110	300	163	128	108	90.2	35.1	84.3	27.1
BOD	mg/l	78.3	119	41	145	39	66.9	55.9	26	116	142	40	57.3	75.8	60.7	40.2	12.3
TOC	mg/l	50.8	35.8	34	33	32	39.5	34.5	14	21.5	37.7	24	29	18	14	16	13
Fe (total)	mg/l	23.9	37.6	12.5	181	10.9	105	34.4	4.42	54	40.5	28.7	119	63	21	18	6.58
Fe (dissolved)	mg/l	0.71	0.24	1.73	<0.1	0.32	<0.1	0.34	0.15	0.98	2.42	6.3	2.17	7.1	4.49	5.69	3.64
Mn (total)	mg/l	4.32	4.09	4.84	10	5.9	7.93	6.46	6.08	4.72	4.80	5.47	7.90	7.00	5.53	4.84	5.04
Mn (dissolved)	mg/l	4.52	3.91	4.86	5.29	6	5.87	5.8	6.3	4.11	4.20	5.21	5.32	5.50	5.26	5.4	5.48
DO	(mg/l)	0.95	0.24	5.10	0.13	0.47	0.23	0.49	1.38	0.37	0.43	2.36	0.14	0.57	0.18	0.4	0.49
ORP	(mV)	144.8	-51.3	-123.6	-4.7	-21	-14.7	-10.4	203.2	47.9	-107.8	-132.0	-35.9	-134.5	-138.6	-186	-272.7
EC	(µS/cm)	2845	2114	2082	2541	2489	2667	2565	2560	2619	2111	2680	2818	2517	2474	2364	2354
pH		6.47	6.65	6.60	7.41	7.84	7.69	6.42	6.64	6.54	6.64	6.68	7.71	8.88	8.48	6.38	6.71
Temperature	(°C)	11.71	13.88	12.90	13.58	12.84	13.25	12.89	13.18	12.03	14.67	14.46	15.49	14.77	14.21	13.85	13.72

COD - Chemical Oxygen Demand
BOD - Biological Oxygen Demand
TOC - Total Organic Carbon
DO - Dissolved Oxygen
ORP - Oxidation/Reduction Potential
EC - Electrical Conductivity
NM - Not Measured
FP - Free Product

COC AND SELECTED BIODEGRADATION INDICATORS (continued)

		MW-3 06/10/03	MW-3 11/19/03	MW-3 04/25/04	MW-3 10/23/04	MW-3 05/17/05	MW-3 11/19/05	MW-3 05/12/06	MW-3 10/10/06	MW-4 07/01/03	MW-4 11/20/03	MW-4 10/23/04	MW-4 05/17/05	MW-4 11/19/05	MW-4 05/12/06
MTBE	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<200	<200	<250	361	<500	<200
Benzene	ppb	<1	<1	<1	<1	1.2	<1	<1	<1	9,470	14,140	17,090	11,940	11,010	11,900
Toluene	ppb	<1	<1	<1	<1	1.5	<1	<1	<1	7,680	14,490	21,290	12,270	13,690	9,707
Ethyl Benzene	ppb	<1	<1	<1	<1	<1	<1	<1	<1	1,120	1,794	3,711	2,840	2,752	1,863
Xylenes (Total)	ppb	<3	<3	<3	<3	<3	<3	<3	<3	3,510	6,948	15,400	11,480	11,700	7,202
GRO (TPH)	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	49.5	102.7	110.0	87.7	107.7	74.51
Sulfate	mg/l	664	572	624	578	644	530	624	576	54	6.51	FP	31.3	27.9	15
Nitrate-Nitrite as N	mg/l	76	62	76.9	62.8	77.2	71.2	77.8	76	<0.1	<0.1		<0.1	<0.1	<0.1
Ammonia-Nitrogen as N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	0.21		0.14	0.22	0.14
Phosphorus P (total)	mg/l	7.84	2.15	0.84	5.36	9.14	0.63	2.02	0.15	1.2	0.9		2.6	2.35	0.63
COD	mg/l	<1	14.9	1.9	12.5	5.5	17.4	19.2	2.1	147	202		230	185	276
BOD	mg/l	<2	2.05	<6	<2	<2	<2	<2	<2	45.9	85.2		71.6	110	63.9
TOC	mg/l	2.8	3.8	2.8	3.4	2.6	2.3	2.6	3.8	33.4	60.1		59	57	62
Fe (total)	mg/l	171	89	10.4	180	152	32.3	61.4	28.2	42	42		56	83.8	49.9
Fe (dissolved)	mg/l	<0.1	<0.1	0.18	<0.1	<0.1	<0.1	<0.1	<0.1	31.9	35.5		22.5	40.5	31
Mn (total)	mg/l	3.16	2.26	0.78	3.5	4.5	0.93	1.55	0.74	3.16	2.71		2.9	2.96	2.7
Mn (dissolved)	mg/l	0.38	0.29	0.36	0.21	0.46	0.34	0.42	0.29	3.35	2.86		2.61	2.35	2.35
DO	(mg/l)	0.78	0.35	2.39	1.36	0.3	0.18	0.43	0.5	0.24	0.41	FP	0.30	1.35	0.5
ORP	(mV)	146.8	214.6	-83.8	67.4	30.3	22.6	-39.7	287.4	-78.2	-114.7	FP	-82.1	-54.1	-135.7
EC	(µS/cm)	2873	2223	2572	2256	3177	2951	3219	1981	2595	2537	FP	2596	2908	2683
pH		6.63	6.96	6.82	6.09	7.31	7.42	6.58	6.91	6.27	6.38	FP	8.15	7.40	6.24
Temperature	(°C)	12.10	13.23	12.28	12.91	12.34	13.01	12.78	13.47	11.73	11.28	FP	11.55	11.43	11.86

COD - Chemical Oxygen Demand
BOD - Biological Oxygen Demand
TOC - Total Organic Carbon
DO - Dissolved Oxygen
ORP - Oxidation/Reduction Potential
EC - Electrical Conductivity
NM - Not Measured
FP - Free Product

COC AND SELECTED BIODEGRADATION INDICATORS (continued)

		MW-5 11/20/03	MW-5 10/23/04	MW-5 05/17/05	MW-5 11/19/05	MW-5 05/12/06	MW-5 10/10/06	MW-6 11/20/03	MW-6 05/12/06	MW-7 07/01/03	MW-7 11/20/03	MW-7 04/25/04	MW-7 10/23/04	MW-7 05/17/05
MTBE	ppb	<250	<250	531.9	<10	<100	FP sheen	<200	<1	<1	<1	<1	<1	<1
Benzene	ppb	19,390	14,010	9,414	10,580	10,880		5,665	68.5	<1	<1	7.2	<1	<1
Toluene	ppb	704	814.9	479.6	370.5	<100		241	3	<1	<1	3.3	<1	<1
Ethyl Benzene	ppb	4,744	7,601	3,839	3,979	3,160		2,917	53.4	<1	<1	14.0	<1	<1
Xylenes (Total)	ppb	10,790	16,690	9,062	7,206	3,282		7,492	155.6	<3	<3	77.7	<3	<3
GRO (TPH)	mg/l	111.9	87.9	91.3	77.9	45.26		67.4	0.874	<0.2	<0.2	0.238	<0.2	<0.2
Sulfate	mg/l	416	FP	399	960	924	FP sheen	894	841	353	538	79.7	51.4	47.2
Nitrate-Nitrite as N	mg/l	<0.1		0.25	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonia-Nitrogen as N	mg/l	<0.1		0.32	0.27	0.13		0.51	0.28	0.8	0.44	1.04	0.23	1.04
Phosphorus P (total)	mg/l	0.15		1.11	4.57	0.28		1.97	0.59	1.2	1.45	3.3	9.82	1.47
COD	mg/l	140		87.4	97.4	105		84.7	58.3	193	15.3	30.6	24.9	6.8
BOD	mg/l	262		123	95	52.4		138	76.5	5.11	4.3	62	58.3	46.6
TOC	mg/l	33.9		18	28	27.5		19.2	14.5	4.6	4.8	7.5	7.8	4.2
Fe (total)	mg/l	6.5		23.5	72	14.2		57	9.73	39	33.6	61	204	44
Fe (dissolved)	mg/l	3.1		4.9	2.6	5.25		2.01	2.52	7.6	6.6	2.19	0.16	5.6
Mn (total)	mg/l	3.77		3.46	5.46	5.75		3.41	3.09	2.63	1.52	2.58	3.78	1.82
Mn (dissolved)	mg/l	3.57		3.62	4.64	5.45		2.78	3.75	1.66	1.32	0.99	0.21	1.21
DO	(mg/l)	NM	FP	0.82	Sheen	0.45	2.57	FP	NR	0.28	0.26	2.02	4.7	0.3
ORP	(mV)			-82.7		-163.3	-240.4		NR	-40.4	-67.9	-108.7	10	-80
EC	(µS/cm)			2802		2952	3348		NR	1935	2265	305	248	248
pH				8.3		6.4	7.05		NR	6.80	7.01	7.45	7.89	7.8
Temperature	(°C)			12.4		13.1	14.31		NR	11.24	11.72	11.42	11.31	11.3

COD - Chemical Oxygen Demand
BOD - Biological Oxygen Demand
TOC - Total Organic Carbon
DO - Dissolved Oxygen
ORP - Oxidation/Reduction Potential
EC - Electrical Conductivity
NM - Not Measured
FP - Free Product

COC AND SELECTED BIODEGRADATION INDICATORS (continued)

		MW-9 06/10/03	MW-9 11/19/03	MW-9 04/25/04	MW-9 10/23/04	MW-9 05/17/05	MW-9 11/19/05	MW-9 05/12/06	MW-9 10/10/06	MW-10 07/01/03	MW-10 11/20/03	MW-10 04/25/04	MW-10 10/23/04	MW-10 05/17/05	MW-10 11/19/05	MW-10 05/12/06	MW-10 10/10/06
MTBE	ppb	<100	<500	<250	<250	81.9	<500	<100	553.4	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	ppb	42900	22370	14,340	12,710	7,854	9,904	7359	6643	<1	<1	<1	<1	3	<1	<1	<1
Toluene	ppb	17600	14460	8,630	2,046	1,998	2,863	2103	2235	<1	<1	<1	<1	2	<1	<1	<1
Ethyl Benzene	ppb	2730	2910	2,241	1,368	1,759	3,197	2610	2705	<1	<1	<1	<1	2	<1	<1	<1
Xylenes (Total)	ppb	8910	10950	8,388	4,569	5,775	10,850	8117	7572	<3	<3	<3	<3	5	<3	<3	<3
GRO (TPH)	mg/l	121.0	79.4	60.19	57.7	29.6	61.6	51.38	54.74	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sulfate	mg/l	10.5	144	61.2	201	40.9	46.3	23.2	36.6	2350	2170	2160	2170	2140	2030	1960	2010
Nitrate-Nitrite as N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	8.69	6.41	7.46	4.68	4.79	3.37	3.17	2.96
Ammonia-Nitrogen as N	mg/l	2.25	3.96	4.52	3.32	3	3.46	3.37	3.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphorus P (total)	mg/l	2.07	1.84	1.96	22.4	2.02	3.35	3.88	0.41	2.99	7.2	6.83	15.3	0.95	4.89	1.61	0.98
COD	mg/l	199	264	272	161	182	187	185	169	45.6	19.8	22.1	17.4	26.9	36.8	25.7	20.4
BOD	mg/l	112	78.2	72	58	70.3	120	44.1	30.4	<2	2.4	<6	<2	<2	<6	<2	<2
TOC	mg/l	38	66	65	50	50	61	54	55	8.5	10.1	9.2	9.6	10	9.5	7.5	8.5
Fe (total)	mg/l	50	33.6	42	268	39.9	54.2	31.2	27.5	95	235	98	420	25.9	152	60.1	32
Fe (dissolved)	mg/l	10.4	8.9	8.7	15	11.6	14.1	16.6	16.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mn (total)	mg/l	4.41	3.18	4.52	8.3	4.9	5.38	4.53	4.58	2.16	3.96	2.38	7.4	1.16	2.33	1.56	1.21
Mn (dissolved)	mg/l	4.56	3.14	3.92	3.38	4.7	4.87	4.33	4.45	0.97	0.97	0.95	0.75	0.91	0.98	1	0.86
DO	(mg/l)	0.29	0.38	6.26	0.1	0.43	0.21	0.47	7.7	0.25	0.29	2.54	0.17	1.04	0.38	0.89	1.12
ORP	(mV)	-40.5	-124.1	-120.1	-75.1	-94.2	-89.5	-115.0	-299.1	203.5	222.1	-114.3	37.8	40	49.4	250.1	267.5
EC	(µS/cm)	2071	1630	3451	2251	2326	2699	2459	2529	4132	4775	5111	4717	4775	5191	3261	3628
pH		6.52	6.68	6.40	7.74	7.64	8.11	6.47	6.59	6.73	7.03	6.91	6.89	7.06	7.07	6.37	6.6
Temperature	(°C)	11.94	15.77	11.61	16.83	15.29	14.54	14.21	13.97	10.17	11.75	10.93	11.83	10.23	12.1	11.05	12.77

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TOC - Total Organic Carbon
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ORP - Oxidation/Reduction Potential
EC - Electrical Conductivity
NM - Not Measured
FP - Free Product

COC AND SELECTED BIODEGRADATION INDICATORS (continued)

		MW-11 07/01/03	MW-11 11/20/03	MW-11 04/25/04	MW-11 10/23/04	MW-11 05/17/05	MW-11 11/19/05	MW-11 05/12/06	MW-11 10/10/06	MW-12 07/01/03	MW-12 11/20/03	MW-12 04/25/04	MW-12 10/23/04	MW-12 05/17/05	MW-12 11/19/05	MW-12 05/12/06	MW-12 10/10/06
MTBE	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<10	<10	<20	<5	<10	<20	<1	69.8
Benzene	ppb	<1	<1	<1	<1	1	<1	<1	<1	1,380	786	1,504	618.3	1,052	1,794	1,992	6,988
Toluene	ppb	<1	<1	<1	<1	<1	<1	<1	<1	<10	10.7	<20	<5	<10	<20	<1	<10
Ethyl Benzene	ppb	<1	<1	<1	<1	<1	<1	<1	<1	131	79.2	112	<5	15.8	<20	<1	<10
Xylenes (Total)	ppb	<3	<3	<3	<3	<3	<3	<3	<3	116	99.7	141.2	<15	<30	<60	<3	<30
GRO (TPH)	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	3.67	4.2	5.666	1.2	2.3	4.5	3.5	18.18
Sulfate	mg/l	2230	3090	2770	2670	2130	2300	2220	2370	393	262	241	186	212	231	238	300
Nitrate-Nitrite as N	mg/l	0.42	1.4	2.3	1.19	2	3.06	2.78	4.22	<0.1	<0.1	0.3	5.72	5.48	22.2	36.8	3.31
Ammonia-Nitrogen as N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	0.79	1.01	15.9	16.1	32	56	31.6
Phosphorus P (total)	mg/l	5.96	13.8	5.33	5.49	2.56	3.18	2.43	0.62	3.56	6.36	2.9	9.68	4.2	3.21	0.92	0.72
COD	mg/l	127	32.9	36.7	9.7	15.4	32.9	45.2	30.5	21.1	6.8	29.1	17.1	46.2	30.2	24.1	50.8
BOD	mg/l	<2	4.6	<6	<2	<2	<2	<2	<2	3.21	9.9	7.65	25.7	11.6	4.52	3.62	13.2
TOC	mg/l	26.7	15	14	16	12	14	12	14.5	15.7	5.7	10	6.4	6.5	16	6	18
Fe (total)	mg/l	15.7	275	69	264	70	51.4	49.3	23.5	64	132	65	66	42	46	16.4	13.3
Fe (dissolved)	mg/l	<0.1	<0.1	1.09	0.27	<0.1	0.19	0.18	0.37	<0.1	<0.1	0.37	<0.1	<0.1	<0.1	<0.1	6.54
Mn (total)	mg/l	3.95	5.4	2.36	5	2.56	1.98	1.7	1.57	4.8	3.6	3.19	2.21	1.9	1.38	0.88	2.96
Mn (dissolved)	mg/l	1.17	1.35	1.17	1.28	1.63	1.62	1.44	1.48	3.07	1.21	2.02	0.49	1.11	0.69	0.82	2.92
DO	(mg/l)	0.28	0.66	8.21	0.15	0.43	0.43	0.72	0.6	0.32	0.49	3.34	0.14	0.56	0.21	0.43	0.64
ORP	(mV)	283.0	232.6	132.7	32.7	47.5	46.7	250.4	265.4	67.2	16.2	6.9	31.8	29.1	1.5	48	-273.4
EC	(µS/cm)	6155	7070	7235	8556	7255	8420	7691	65	3018	1717	1982	1545	1600	2255	1829	1884
pH		6.69	6.84	6.88	6.88	6.97	7.01	6.31	6.53	6.27	6.71	6.53	7.32	7.48	7.67	6.5	6.77
Temperature	(°C)	11.35	11.62	11.52	11.71	11.29	12.01	11.67	12.32	10.55	13.12	11.83	15.32	13.44	16.5	14.32	14.25

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ORP - Oxidation/Reduction Potential
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NM - Not Measured
FP - Free Product

COC AND SELECTED BIODEGRADATION INDICATORS (continued)

		MW-13 07/01/03	MW-13 11/20/03	MW-13 04/25/04	MW-13 10/23/04	MW-13 05/17/05	MW-13 11/19/05	MW-13 5/12/06	MW-13 10/10/06	MW-14 07/01/03	MW-14 11/20/03	MW-14 04/25/04	MW-14 10/23/04	MW-14 05/17/05	MW-14 11/19/05	MW-14 5/12/06	MW-14 10/10/06
MTBE	ppb	<50	<100	<100	<100	<200	<200	<100	<20	<250	<200	<20	<20	<200	<200	<100	261.5
Benzene	ppb	5,220	7,270	9,981	5,733	8,978	9,455	5784	8324	19,800	16,740	11,170	11,450	12,130	13,520	11,670	11,720
Toluene	ppb	5740	6064	3503	4791	5567	6594	2446	3445	<250	277.8	106.7	151.4	262.5	243.6	114.1	<100
Ethyl Benzene	ppb	974	991	1352	<100	1112	1329	960.3	1137	1010	204	1128	1429	1294	1762	1726	2134
Xylenes (Total)	ppb	3160	3341	2564	4256	2911	3681	1699	1904	1340	1950	1195	1266	965.3	1092	961.7	1267
GRO (TPH)	mg/l	34.5	48.7	39.93	51.2	51.9	50.1	25.94	36.27	<50	52.4	22.88	25.6	40.8	36.9	30.06	36.1
Sulfate	mg/l	15.9	19.4	20.1	20.4	10.9	13.3	17.1	16.3	1240	1210	1110	1160	1130	1120	1120	1060
Nitrate-Nitrite as N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ammonia-Nitrogen as N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phosphorus P (total)	mg/l	0.22	0.7	0.37	0.28	0.2	0.15	<0.1	<0.1	1.74	2.53	0.33	1.42	1.06	0.57	0.59	0.23
COD	mg/l	92	115	119	78.7	126	105	76.2	79.5	108	143	106	47.7	82	110	82.7	98
BOD	mg/l	24.4	44.6	18	16.8	35.8	25.1	18.1	21.9	28.9	49	23.5	24.5	48.2	32.4	22.3	24.1
TOC	mg/l	23.1	30.7	28	2.7	30	27	24	32	22.5	30.7	25	26	27	28.5	25.5	30
Fe (total)	mg/l	6.2	8	3.3	6.3	6.5	7.36	6.07	8.75	43	80	5.5	34.6	22.5	8.43	7.24	4.26
Fe (dissolved)	mg/l	1.73	0.74	1.27	1.57	3.07	4.46	7.03	8.58	<0.1	0.14	0.17	0.38	0.9	1.27	1.28	2.08
Mn (total)	mg/l	4.8	5.3	6.86	8	7.5	6.58	6.33	7.06	3.08	4.12	4.73	4.5	4.3	3.66	3.74	4.18
Mn (dissolved)	mg/l	5	5.8	7.13	6.26	7.1	6.77	6.78	7.45	2.28	3.64	5.07	2.85	4.5	3.52	4.28	4.69
DO	(mg/l)	0.43	0.49	6.65	0.2	0.4	0.28	0.55	0.94	0.51	0.46	10.19	0.38	1.07	2.01	0.95	1.42
ORP	(mV)	154.3	-62.0	-135.4	-32.9	-24.7	-70.6	-105.1	-332.7	107.0	-41.1	34.0	-6.9	20.9	-53.5	-64.5	-180.2
EC	(µS/cm)	3367	2072	2179	3779	3443	3767	4013	3563	4188	4010	4357	4078	2245	4370	4025	3733
pH		6.20	6.39	6.69	7.37	7.63	7.84	5.95	6.72	6.30	6.55	6.50	7.26	7.72	7.28	6.04	6.65
Temperature	(°C)	11.10	12.01	14.97	11.31	11.43	11.66	11.8	12.43	10.57	11.63	11.79	12.32	12.45	13.31	12.43	13.91

COD - Chemical Oxygen Demand
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TOC - Total Organic Carbon
DO - Dissolved Oxygen
ORP - Oxidation/Reduction Potential
EC - Electrical Conductivity
NM - Not Measured
FP - Free Product

COC AND SELECTED BIODEGRADATION INDICATORS (continued)

		MW-15 07/01/03	MW-15 11/20/03	MW-15 04/25/04	MW-15 10/23/04	MW-15 05/17/05	MW-15 11/19/05	MW-15 05/12/06	MW-15 10/10/06	I-8 07/02/03	I-8 11/19/03	I-8 05/17/05	I-8 10/10/06
MTBE	ppb	<100	<100	<25	<25	73	<50	<10	<10	<20	<1	6.7	19
Benzene	ppb	7,410	6,000	3,627	3,103	1,921	2,808	2358	1412	5460	70.4	16.1	95.9
Toluene	ppb	<100	<100	<25	<25	<50	<50	13	<10	179	2.9	<1	<1
Ethyl Benzene	ppb	380	470	259.4	210.2	293.2	439.2	430.2	291.6	2270	1	<1	<1
Xylenes (Total)	ppb	2710	2283	731.4	707.6	739.9	986.6	880.8	370.9	2920	8.9	<3	4.1
GRO (TPH)	mg/l	26.2	28.9	13.58	12.1	<10	11.7	10.56	7.509	27.8	0.89	0.25	0.896
Sulfate	mg/l	1380	1350	840	445	796	792	856	838	157	282	126	194
Nitrate-Nitrite as N	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	7.17	3.75	0.5
Ammonia-Nitrogen as N	mg/l	<0.1	<0.1	0.22	0.19	0.1	0.12	0.15	0.15	<0.1	21.1	12.5	28.4
Phosphorus P (total)	mg/l	1.52	1.6	1	0.3	0.83	0.19	0.15	0.12	4.53	50.8	246	87.2
COD	mg/l	95.3	100	59.7	49.4	79.5	26.7	71.3	60.9	214	21.5	82.2	14.9
BOD	mg/l	32.4	33.2	18.6	13.4	41.3	14.9	11.7	6.36	26.9	6	97.8	3.13
TOC	mg/l	31.8	31.9	19	18	20	23	23	23	21.5	14.4	6	31
Fe (total)	mg/l	43	53	22.5	8.7	29	7.02	5.66	4.06	105	144	108	68.2
Fe (dissolved)	mg/l	<0.1	0.59	0.81	0.3	2	3.31	3.83	4.16	<0.1	<0.1	<0.1	<0.1
Mn (total)	mg/l	3.95	5.2	4.91	6	6.6	6.38	5.67	6.05	4.24	4.50	1.41	1.3
Mn (dissolved)	mg/l	3.43	5.5	4.86	4.89	6.6	6.13	6.24	6.1	2.27	0.35	<0.5	0.18
DO	(mg/l)	0.26	0.43	4.10	0.25	0.59	0.3	0.55	1.42	0.20	3.82	NM	NM
ORP	(mV)	145.3	-49.2	-100.6	-20	-43	-49.3	-86	-339.2	111.8	148.4		
EC	(μS/cm)	3797	3820	2902	4384	4161	4055	3857	3220	1782	940		
pH		6.28	6.38	6.46	7.42	7.44	7.74	6.02	6.52	6.19	6.94		
Temperature	(°C)	10.13	11.82	11.10	11.5	10.82	12.07	11.69	12.37	10.87	14.07		

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Nitrogen in Injection Wells

Well ID	Date	Nitrate-Nitrite as N mg/l	Well ID	Date	Nitrate-Nitrite as N mg/l
I-1	07/02/03	20.8	**I-9**	07/02/03	4.42
I-1	04/24/04	5.95	**I-9**	04/24/04	<0.1
I-1	10/09/06	<0.1	**I-9**	10/23/04	<0.1
I-2	07/02/03	22.2	**I-9**	10/10/06	4.2
I-2	04/24/04	2.96	**I-10**	07/02/03	5.93
I-2	10/09/06	<0.1	**I-10**	04/24/04	<0.1
I-3	07/02/03	<0.1	**I-10**	10/23/04	<0.1
I-3	04/24/04	<0.1	**I-10**	10/10/06	2.64
I-3	10/10/06	6.9	**I-11**	06/10/03	23.4
I-4	07/02/03	0.1	**I-11**	04/24/04	11.6
I-4	04/24/04	<0.1	**I-11**	10/10/06	0.71
I-4	10/10/06	14.3	**I-12**	06/10/03	<0.1
I-5	07/02/03	7.65	**I-12**	04/24/04	<0.1
I-5	04/24/04	0.49	**I-12**	10/10/06	<0.1
I-5	10/10/06	18.1	**I-13**	06/10/03	6.33
I-6	07/02/03	2.88	**I-13**	04/24/04	6.29
I-6	04/24/04	<0.1	**I-13**	10/10/06	0.4
I-6	10/23/04	0.28	**I-14**	06/10/03	<0.1
I-6	10/10/06	0.29	**I-14**	04/24/04	<0.1
I-7	07/02/03	7.96	**I-14**	10/10/06	<0.1
I-7	04/24/04	4.73	**I-15**	07/02/03	6.06
I-7	10/23/04	4.06	**I-15**	04/24/04	<0.1
I-7	10/10/06	<0.1	**I-15**	10/09/06	<0.1
I-8	07/02/03	<0.1	**I-16**	07/02/03	4.38
I-8	11/19/03	7.17 (5.91 D)	**I-16**	04/24/04	<0.1
I-8	04/24/04	0.11	**I-16**	10/09/06	<0.1
I-8	10/23/04	0.59	**I-17**	07/02/03	0.13
I-8	05/17/05	12.5	**I-17**	04/24/04	<0.1
I-8	10/10/06	0.5	**I-17**	10/09/06	<0.1