Technical Report

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APPLIED RESEARCH:
GROUND-WATER CONTAMINANT TRANSPORT AT ROCKY MOUNTAIN ARSENAL

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF ACRONYMS

BCHD	Bicyclo[2,2,1]hepta-2,5-diene
BCPD	Dicyclopentadiene
cm^3/g	cubic centimeter per gram
CMC	Critical Micelle Concentration
COC	Concentration of Organic Carbon
Coll	Colloids
CPM	p-Chlorophenylmethyl sulfide
CMP	Comprehensive Monitoring Program
DIMP	Diisopropylmethylphosphonate
DMMP	Dimethylmethylphosphonate
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EI	Electron Impact
EPA	Environmental Protection Agency (U.S.)
ft bgs	feet below ground surface
g/cm^3	gram per cubic centimeter
GAC	Granular Activated Carbon
GC/MS	Gas Chromatograph/Mass Spectrometer
GC	Gas Chromatograph
gpm	Gallons Per Minute
L	Liter
LiBr	Bithium Bromide
MBAS	Methylene Blue Active Substance
ml	milliliters
NBCS	North Boundary Containment System
OSTDS	Internal Standards
PAH	Polycyclic Aromatic Hydrocarbons
PCE	Tetrachloroethene
PID	Photo Ionization Detector
PMO	Program Manager Office
PMRMA	Program Manager, Rocky Mountain Arsenal
PPDDE	2,2-Bis(para-chlorophenyl)-1,1-dichloroethene
PPDDT	2,2-Bis(para-chlorophenyl)-1,1,1-trichloroethane
PVC	Poly Vinyl Chloride
qt	quart
RLSA	R.L. Stollar and Associates Inc.
RMA	Rocky Mountain Arsenal
SIM	Selected Ion Monitoring
SPE	Solid Phase Extraction
TCA	Trichloroethane
TCE	Trichloroethene
USGS	United States Geological Survey
UW	University of Waterloo
VOC	Volatile Organic Carbon
µg/kg	microliters per kilogram
µg/L	microgram per liter
µl	microliters

EXECUTIVE SUMMARY

An applied research project was conducted in a high-concentration, mixed-contaminant plume in Section 23 of the Rocky Mountain Arsenal. The purpose of the project was to assess the contaminant transport characteristics in the aquifer to provide information to support remedial system design. The transport behavior of the contaminants was assessed in the field by monitoring the rate at which contaminants were flushed from the aquifer by organic-free water. Organic-free water was injected into the aquifer at one well and ground water was extracted at the same rate from another well 30 feet away. The flushing rates of the organic contaminants were monitored with a cluster of short-screened monitoring wells located between the injection and extraction wells. Monitoring was conducted during a 10-day period of injection/extraction (the "forced-gradient" portion), and for approximately 2 weeks after injection/extraction ceased (the "natural-gradient" portion).

An assessment of background conditions conducted prior to extraction/injection indicated that existing contamination was stratified vertically and contained a wide range of contaminants including halogenated volatile organics, aromatic hydrocarbons, organochlorine pesticides and other, more polar, organic compounds. The total dissolved organic carbon concentration (DOC) in the ground water was approximately 100 mg/L; approximately 70 mg/L are uncharacterized by historical ground water chemistry data.

Monitoring conducted during the forced-gradient portion of the experiment revealed that, contrary to expectations, the concentrations of the measured organic contaminants were reduced at the monitoring wells to near or below detection levels, essentially at the same time that the clean water flush arrived at the monitoring points (i.e. no retardation). This occurred despite the fact that the properties and expected mobilities of the contaminants varied widely.

Laboratory retardation tests indicated that aquifer sediments obtained by coring exhibited a significant capacity for sorption. Laboratory analysis of extracts from the sediments, however, indicated that in the aquifer the sorbed component of contamination was near or below detection levels. These apparently contrasting results indicate that the increased mobility measured during the forced gradient portion of the experiment results from constituents in the ground water rather than from properties of the aquifer sediments.

Several potential ground water constituents which could cause or contribute to the observed enhanced mobility were considered:

- Colloidal material was found to be present and mobile in the aquifer. Analysis of the colloidal material indicated a significant load of sorbed contaminants per unit mass of colloid. The concentration of colloids in the ground water, however, is low enough that the net effect on contaminant migration in this aquifer is not significant.

- Surfactants were investigated in the aquifer because of their ability to increase the solubility of hydrophobic compounds. Results indicate that anionic surfactants are not present in concentrations sufficient to explain the level of mobility enhancement. Non-ionic surfactants could not be investigated during the experiment, but could be a factor in the enhanced mobility if they constitute the majority of the uncharacterized DOC. This is unlikely because non-ionic and anionic surfactants are commonly associated, so the lack of anionic surfactants suggests that the non-ionic surfactants are also unlikely to be present.

- Co-solvent effects are judged to not be a significant factor because the concentrations required to enhance contaminant mobility greatly exceed the concentrations of total DOC in the ground water.

Monitoring conducted during the natural gradient portion of the experiment revealed that contaminant concentrations in the monitoring wells rose slowly over a period of two weeks. Tracer data indicate that the concentration increases likely result from diffusion and possible advection from reservoirs of contamination which were not flushed during the forced gradient portion of the test, rather than advection of the displaced plume back to the monitoring wells. Possible reservoirs may include the underlying Denver Formation bedrock, the overlying capillary fringe, and/or thin, lower-permeability strata distributed randomly within the aquifer.

This project demonstrates that small-scale pilot tests may be conducted within existing plumes of contamination to yield contaminant transport information which can strongly facilitate the design of remediation systems. In particular, the technique of extracting, treating, and reinjecting ground water to flush contaminants from the aquifer was shown to be effective at this site. Further application of this technique could involve a specialized treatment system which takes advantage of the mobility-enhancing constituents determined to be present in the site ground water. This specialized system, ideally, would remove targeted contaminants from the ground water while allowing the mobility-enhancing agents to be reinjected with the flush. A first step toward researching such a system - lab verification of the extracting capabilities of the site ground water - will be conducted by D. Mackay and students under limited funding available at the University of Waterloo. In addition to this work, it is recommended that the unidentified fraction of the total DOC be fully characterized.

Other information gained that is applicable to remedial design includes the finding that dissolved oxygen moves conservatively through the aquifer. This suggests that oxygen could be delivered relatively easily to large volumes of the subsurface if it proved desirable to encourage in-situ aerobic bioremediation for enhancement of aquifer remediation. Additionally, the identification of potential contaminant reservoirs which remained in the aquifer after the initial flush suggests that a pulsed pumping approach might be more efficient than standard continuous pump-and-treat practices. Also, innovative and cost effective analytical systems developed and utilized during this experiment could be applied to remediation system performance monitoring, as well as general ground-water monitoring efforts, for potentially significant cost savings. Finally, the pilot study provided information on the performance of a treatment technology application (granular activated carbon) under actual site conditions.

1.0 INTRODUCTION

R.L. Stollar and Associates (RLSA), in collaboration with the University of Waterloo (UW) Centre for Groundwater Research, conducted an applied research project involving contaminant transport in ground water at Rocky Mountain Arsenal(RMA), Commerce City, Colorado. The project was conducted for, and primarily funded by, the Program Manager for Contamination Cleanup, Rocky Mountain Arsenal. Additional funding was provided by RLSA, and the UW. Other organizations that contributed to the project include the United States Geological Survey (USGS); Texas A&M University; Analytic and Remedial Technology, Inc.; and the Grundfos Pump Corporation.

1.1 THE PROBLEM

A significant challenge associated with many environmental restoration programs involves the remediation of contaminated ground water. The Environmental Protection Agency (EPA) has estimated that 45 percent of large public water systems served by ground water are contaminated with human-introduced chemicals (Miller, 1990). Consequently, the ability to remove contaminants from ground-water aquifers is important.

The ability to remove contaminants from an aquifer depends on the transport characteristics of the contaminants in the particular aquifer. Historically, contaminant transport characteristics have been estimated primarily through laboratory studies on saturated sediments. Unfortunately, laboratory results can vary considerably from the transport characteristics observed in actual aquifers. This has been observed at the RMA where the travel distances of several contaminants often exceed the travel distances expected based on laboratory tests. Variations between laboratory results and field results have also been observed in a significant number of pump and treat programs across the country which report that projected clean-up time frames will be greatly exceeded because the contaminants are removed from the aquifer at much slower rates than predicted from laboratory studies.

Inconsistencies between laboratory data and actual field observations can be at least partially attributed to the large number of complex chemical and physical processes which contribute to contaminant transport behavior in aquifers. These processes are difficult to accurately duplicate in a laboratory. They include sorption, volatilization, degradation, transformation, filtration, advection, and diffusion. The effects of these processes on contaminant transport characteristics are related to physical and chemical properties of the contaminants, the aquifer materials, and the ground water. Hence, transport characteristics can vary between contaminants in an aquifer, between aquifers for a contaminant, and, given the heterogeneous nature of many aquifer systems, between locations within an aquifer. Failure to identify the transport characteristics of contaminants in an actual aquifer can result in misapplied or ineffective remedial actions.

1.2 PURPOSE/GOALS

The purpose of this research is to assess the transport characteristics of contaminants in a complex, high-level, mixed-contaminant plume at RMA. Specific goals of the research include estimating the retardation factors of target contaminants in the aquifer, and evaluating potential in-situ transport-enhancing mechanisms. The results are intended to support remediation system design.

2.0 APPROACH/DESIGN

The transport characteristics of the contaminants in the RMA aquifer were assessed by measuring their elution rates in the presence of a constant flush of organic-free water. Similar tests have been conducted in the western tier of RMA (Mackay, 1990) and in Gloucester, Ontario (Bahr, 1989). The organic-free water was pumped into the aquifer at an injection well; contaminated water was pumped from the aquifer at an extraction well 30 ft away. The contaminated water pumped from the extraction well was treated and re-injected as the flush of organic-free water. The elution rates of the contaminants in the aquifer were measured through repeated sampling and analysis of ground water from three partially penetrating monitoring wells. The monitoring wells were located between the injection and extraction wells. Each monitoring well screened a unique interval in the aquifer. Together, the monitoring wells screened the entire thickness of the aquifer. Samples from the monitoring wells were collected and chemically analyzed during the period of extraction and injection, and for roughly two weeks after pumping was stopped. Sample frequencies at each monitoring well ranged from 1 every two hours to 1 per day, depending on the timeframe of the experiment. The pumping portion of the experiment is referred to as "forced gradient"; the non-pumping portion is referred to as "natural gradient".

The implementation of the experiment involved several elements: the selection of an appropriate site; a baseline characterization of the site (including the simultaneous development of appropriate analytical protocols), the modeling, design, and installation of a well network for injection, extraction, and monitoring; and the engineering and construction of a process system to treat and re-inject ground water.

2.1 SITE SELECTION

The RMA is a 27-square-mile industrial and military facility with a complex and extensive ground-water contamination scenario resulting from:

- many contaminant sources, some areally separated, some overlapping;
- a 40-year span of contaminant releases involving changes in waste stream make-up, discharge/spill periods, and ground-water flow patterns; and
- many contaminants.

In choosing the site for the experiment, a high level, multi-component plume was desired. Three locations were initially examined: Basin A Neck, South Plants, and Section 23 (Figure 2.1-1). The site selection process was based on the following desired characteristics:

1. Shallow depth to ground water (approximately 20 ft maximum).

   This would allow peristaltic pumps to be used to obtain the ground-water samples, and minimize drilling efforts.

2. Relatively simple hydrogeology.

   The presence of fractures, heterogeneous lithologies, nearby pumping influences, and other complexities could make the interpretation of measured elution rates difficult.

3. Contaminants of interest in the aquifer at concentrations at least an order of magnitude higher than the laboratory detection limit.

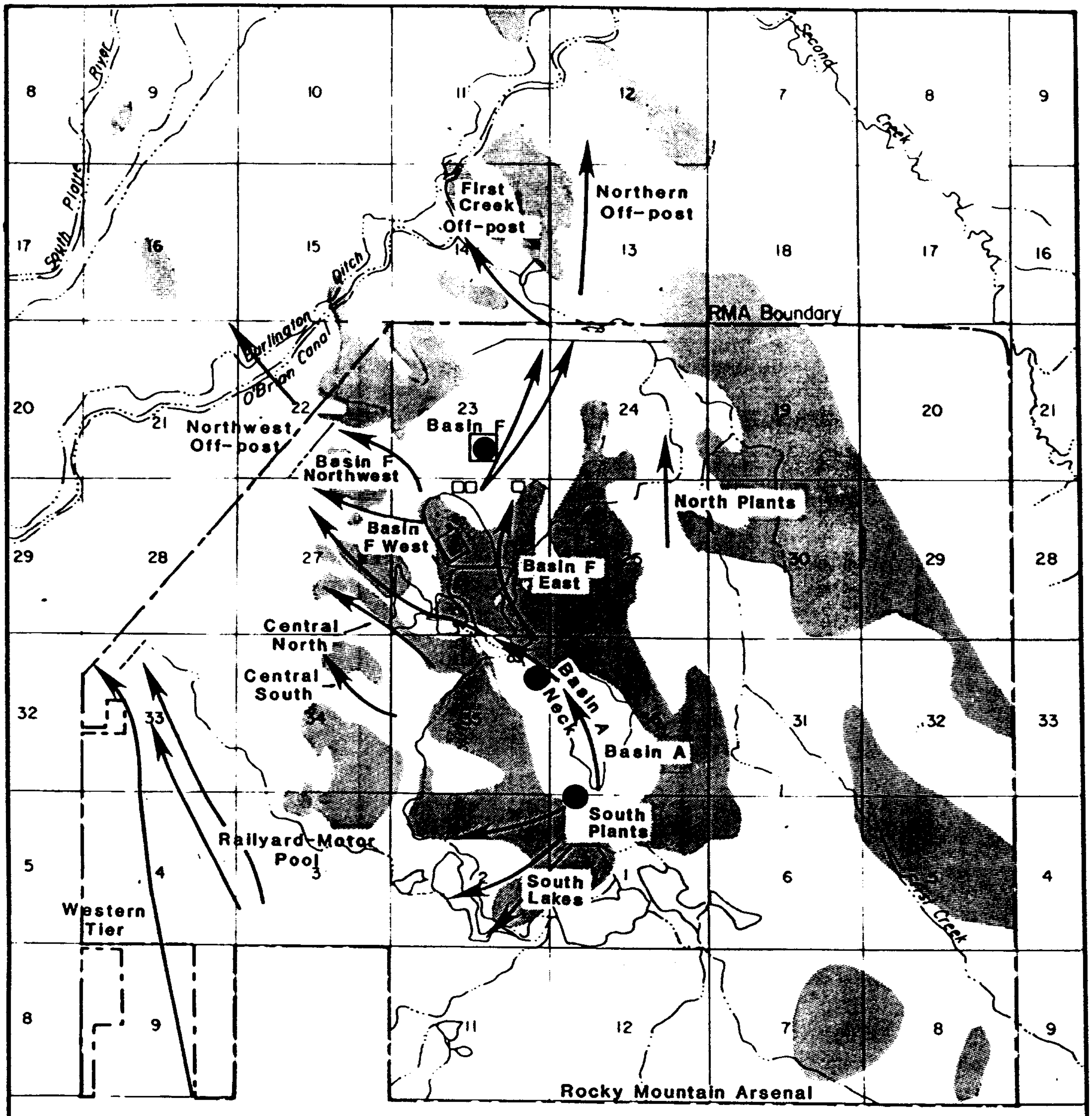
   This ensures that reliable concentration measurements can be made across a range which clearly defines an elution curve.

4. Relatively flat hydraulic gradient.

   One purpose of the extraction/injection pumping is to dominate and control ground-water flow. An initially flat gradient can generally be more easily influenced than an initially steep gradient.

5. Stable water table.

   Water table fluctuations can alter the saturated zones in the aquifer, ground-water flow rates and directions, contaminant concentrations, and pumping rates - all increase the complexity of interpreting elution measurements.



Explanation

⟵ Migration Pathway

● Potential Experiment Location

▨ Approximate Areas of Unsaturated Alluvium (Based on Fall 1989 Data)

Containment System
- Physical Barrier
- Hydraulic Barrier

⊡ Actual Experiment Location

N

0 5000 10,000 Feet

0 1000 2000 3000 Meters

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Potential & Actual Experiment Locations

Date : June 1992

Figure 2.1-1

6. Relatively permeable aquifer.

   Allows the test to be conducted in a reasonable time frame.

7. Limited saturated thickness.

   Reduces the depth of well screens, injection/extraction rates, and treatment process capacity, minimizing experimental costs and efforts.

8. Located away from plume boundaries.

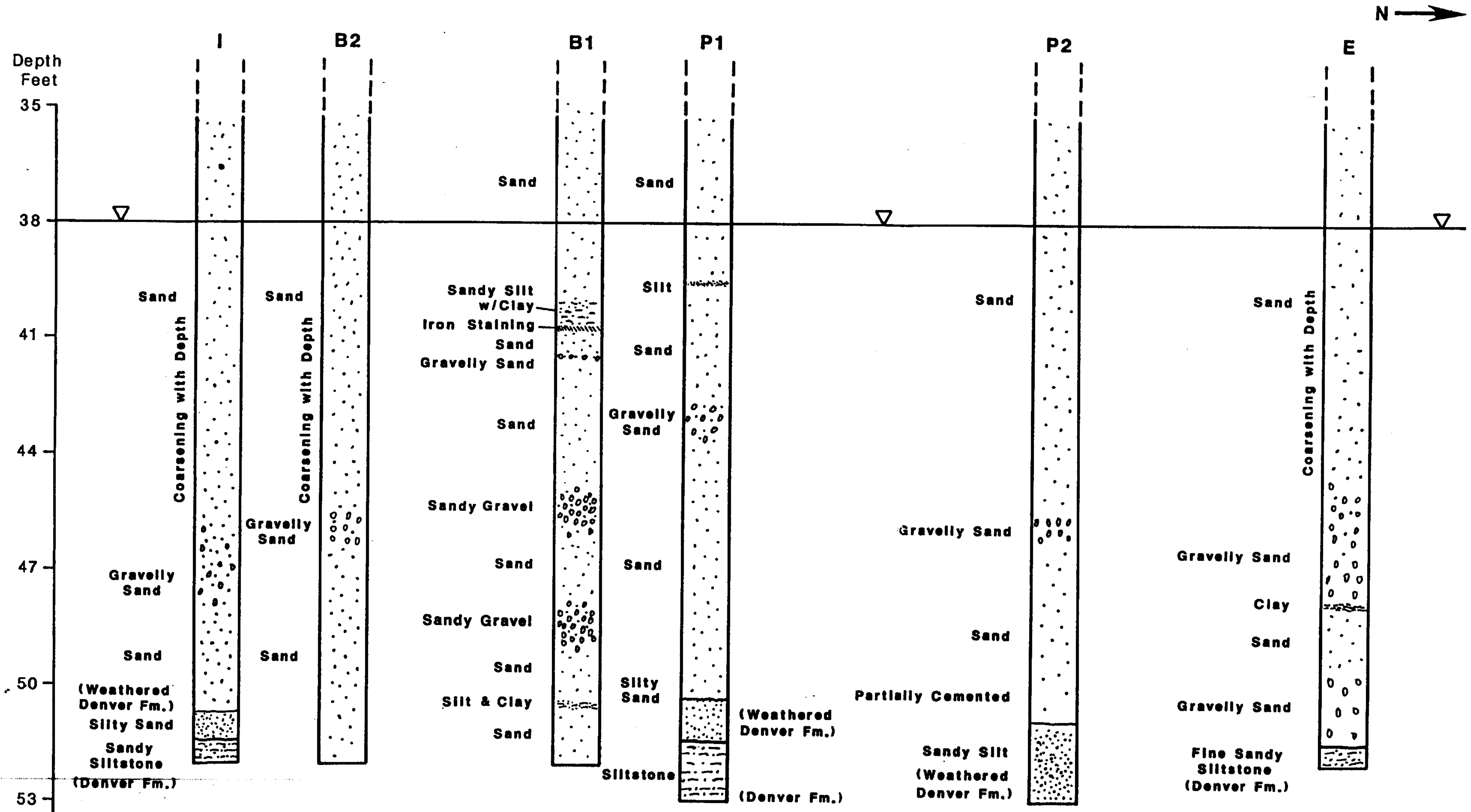
   The experiment site should include a plume volume that is laterally uniform at least over the volume expected to be impacted by the experiment.

The Basin A location was not selected because of fluctuations in water levels and flow that could be caused by the nearby ground-water intercept system. The South Plants location was not selected because it overlies the plume boundaries of several target contaminants.

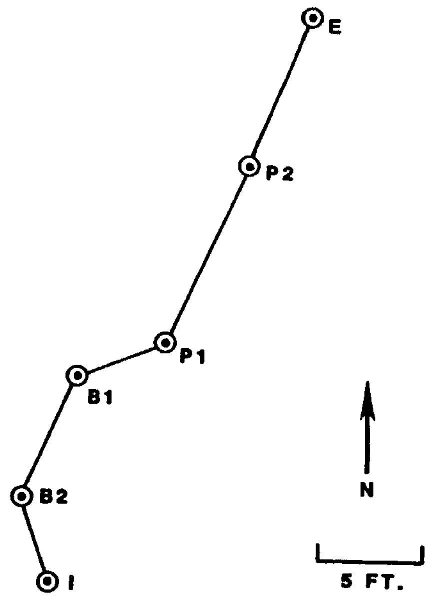
The Section 23 location was chosen as the experimental site because its characteristics most closely match the desired site characteristics. It is located in the southeastern quadrant of section 23, approximately one-quarter mile downgradient of historical Basin F (Figure 2.1-1).

2.1.1 HYDROGEOLOGY

An unconfined alluvial aquifer exhibiting a high-level, multi-component plume exists beneath the Section 23 site. The geology of the aquifer was investigated through visual logging during drilling of wells and soil borings. Figure 2.1-2 presents a schematic cross section of the site geology based on these drilling



Horizontal & Vertical Scales : 1 inch equals 3 ft.
Vertical Exageration : None
Well Bore Diameters not to Scale



Plan Orientation of Cross-Section
(See Section 2.3 for Discussion
of Well Network)

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Schematic Cross Section
of Site Geology Based on Drilling Logs

Date : June 1992	Figure 2.1-2

logs. A description of the well network is presented in Section 2.3. The geology consists of gravelly fine to medium sand with occasional thin (1 to 2 in) clay layers. The clay layers do not appear contiguous from boring to boring. Gravelly zones are more predominant between 44 and 48 feet. There appears to be a general grain size coarsening with depth between approximately 38 and 48 ft in borings I, B2, and E. The unconfined aquifer is bounded below by the Denver Formation bedrock, which consists of claystone and siltstone. The bottom foot of the unconfined aquifer exists within a zone of weathered Denver Formation claystone. The depth to water is approximately 38 ft below ground surface (bgs). The saturated thickness of the unconfined aquifer is approximately 14 ft.

One drawback to the section 23 site was the depth to water (38 ft) which precluded the use of a simplified peristaltic sampling system, and increased drilling expenses. However, this drawback was determined to be less detrimental than the drawbacks associated with the other potential sites.

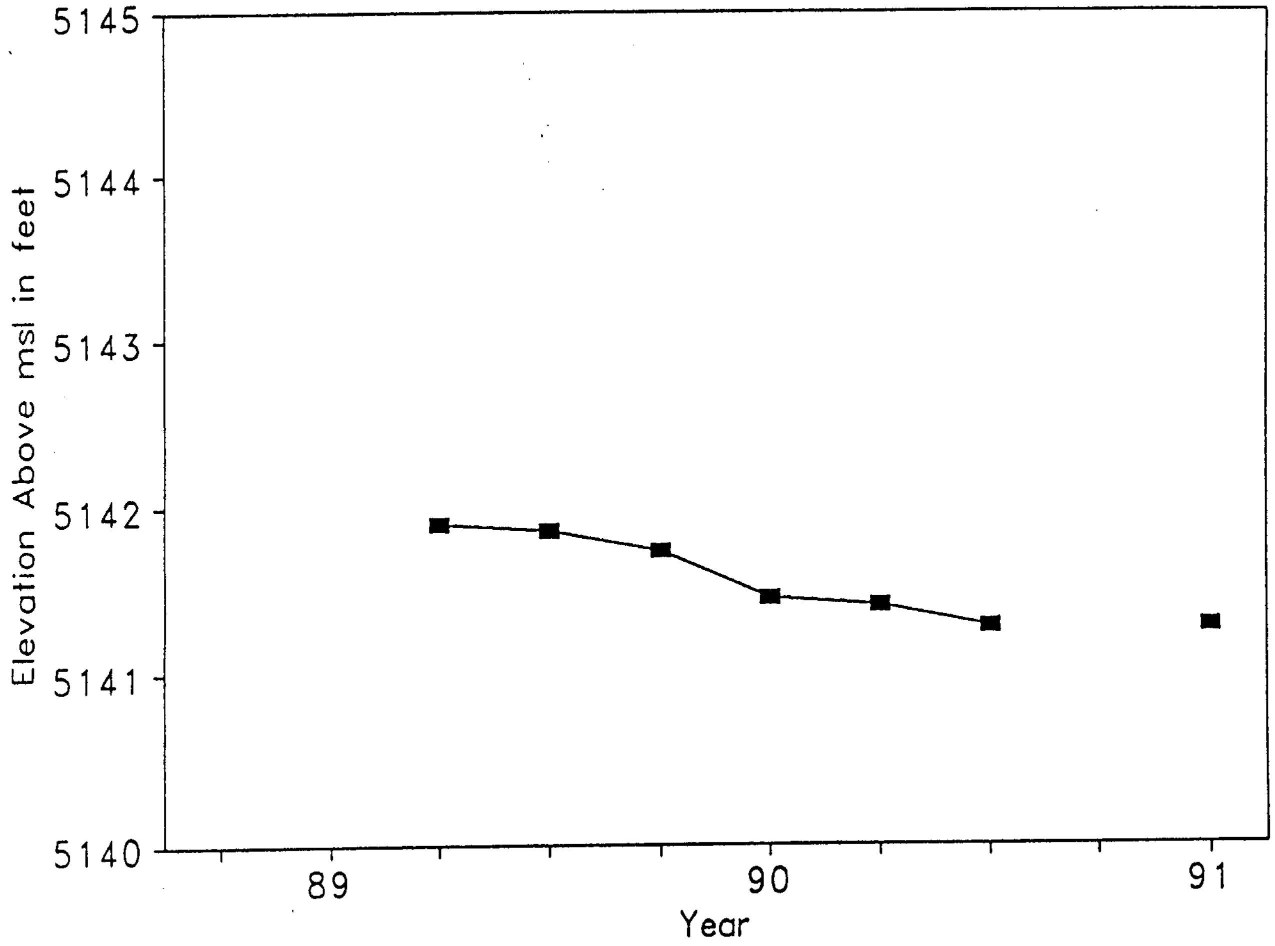
Historical information obtained from the Comprehensive Monitoring Program (CMP) (Stollar 1989, 1990, and 1991) indicates that water levels in the area are relatively stable (Figure 2.1-3). The hydraulic gradient across the site appeared, from Fall 1990 data, to be approximately 0.004 ft/ft toward the north-northeast.

Additional hydraulic information on the aquifer was provided prior to the experiment by Dr. Jim Warner of Colorado State University (Warner, 1991). Dr. Warner is modeling a ground-water containment system located approximately 3,000 ft north of the experiment site. The experimental data were gathered in 1990 and the hydraulic information supplied are based on the model calibration results:

- hydraulic conductivity: 120 to 400 ft/day
- flow velocity: approximately 0.04 ft/day
- transmissivity: approximately 3000 ft^2/day
- storage coefficient: 0.05

2.1.2 CHEMISTRY

The chemistry of the aquifer is strongly influenced by its location downgradient from a former disposal basin, Basin F (Figure 2.1-1). Basin F was used as a containment basin for RMA waste streams from 1956 to 1980.



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HYDROGRAPH : WELL 23095

Date : June 1992	Figure 2.1-3

Ground water from the aquifer exhibits a large number of contaminants with widely varying physical/chemical properties. The known contaminants include organochlorine pesticides, organophosphorous compounds, organosulfur compounds, volatile aromatics, volatile organohalogens, volatile hydrocarbons, phosphonates, metals, cations, and anions.

Historical ground-water monitoring efforts indicated the presence of high-level contaminants, including chloroform (1,000 to 10,000 µg/L), dicyclopentadiene (500+ µg/L), diisomethylphosphonate (1,000+ mg/L), organosulfur compounds (100 to 1,000 µg/L, summed), chloride (1,000+ µg/L), and fluoride (5,000+ µg/L) (RLSA, 1991). Specific historical chemical ground-water data are presented in Appendix A, which contains the most recent three years of analytical data collected from an existing, fully penetrating well (23095) in the vicinity of the experiment site.

2.2 BASELINE CHARACTERIZATION/ANALYTICAL PROTOCOLS

A baseline physical and chemical characterization of the aquifer was conducted to support the design parameters of the experiment and to facilitate the interpretation of the final results. This characterization included information on:

- Chemical composition of the ground water,
- Chemical stratification in the aquifer,
- The quantitation of contaminants sorbed on the aquifer sediments,
- The sorption capacity of the aquifer sediments,
- The presence of colloids and dissolved organic carbon, and
- The presence of surfactants in the aquifer.

Each of these aspects of the baseline characterization is discussed below. Analytical protocols were developed during the baseline characterization, and are included in the following discussions.

2.2.1 CHEMICAL COMPOSITION OF THE GROUND WATER

The measurement of contaminant elution rates during the experiment involved the periodic sampling and analysis of ground water from three monitoring wells at frequencies which ranged from one sample per hour at the beginning of the experiment to one sample per day near the end of the experiment. The development of appropriate analytical protocols for this monitoring required preliminary testing to characterize baseline ground-water chemistry in order to support methods development. The analytical protocols involved the determination of field parameters, concentrations of inorganic constituents, and concentrations of organic compounds.

2.2.1.1 Field Parameters

Field parameter data were collected from the three monitoring wells, the extraction well, and the injection well during the experiment. The field parameters consisted of pH, electric conductivity, alkalinity, dissolved oxygen, and temperature. Measurements were taken at each well approximately once every six hours during the first 72 hours of the experiment. Thereafter, field parameter measurements were conducted once per day. The measurements were obtained using a YSI model electric conductivity meter, a YSI dissolved-oxygen meter, a Beckman pH meter and thermometer, and a Hach alkalinity titration kit. The field parameter measurements from the monitoring wells provided information on the effect of the organic-free-water flush on the aquifer. The field parameter measurements from the extraction and injection wells were primarily used to monitor the effect of the treatment system on the extraction water before re-injection. Baseline field parameters were primarily measured to identify possible interferences with the analytical methods, as well as possible complications (i.e., corrosivity, salinity) with treatment and re-injection of the extraction water.

2.2.1.2 Inorganics

The inorganic analyses were conducted by the USGS National Water Quality Inorganic Laboratory. The inorganic methods and associated analytes were:

Ion Chromatography

1. chloride
2. fluoride
3. sulfate

Colorimetric

4. Bromide
5. Ammonia
6. Nitrite
7. Nitrite + Nitrate
8. Ortho Phosphate

Atomic Absorption Spectroscopy

9. sodium
10. potassium
11. magnesium
12. calcium

Descriptions of these methods can be found in Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments (USGS, 1989a).

Because bromide was used as the tracer, samples for the bromide analysis were collected and analyzed separately from the other inorganic analytes.

2.2.1.3 Organics

The organic analyses were conducted using two innovative techniques designed to allow the large number of samples generated during the experiment to be processed accurately and cost effectively. The first technique applies to the volatile organic compound (VOC) fractions which were analyzed in an on-site laboratory. Ground-water samples were pumped via a semi-automatic manifold into one of seven sample loops, each with a different volume. The appropriate sample loop was chosen based on the anticipated concentration range of volatile contaminants in the sample and the volume of the sample loop. Once the sample was pumped into the appropriate loop, it was sent to a purge and trap concentrator, then a small gas chromatograph (GC) (SRI Inc.) with a Hall/Photo Ionization Detector (PID) combination. This technique provided nearly real-time analysis for selected samples, allowing essentially continuous monitoring of the elution in the aquifer. It also allowed real-time monitoring of the performance of ground-water treatment (discussed in Section 2.4).

The second innovative technique was used to analyze samples for the semi-volatile fractions. Solid phase extraction (SPE) of the sample was conducted in the on-site lab. The SPE was conducted using a small cartridge (approximately 3 in. long, 0.5 in .diameter) filled with an 18-Carbon backbone resin. Approximately 180 ml of the sample was pumped through the SPE cartridge after preparing the cartridge with methanol and adding a surrogate mixture to the sample. The cartridges were then delivered to the laboratory for analysis on a GC/Mass Spectrometer (MS) in selected ion mode (SIM). This technique exhibited several advantages. First, a large suite of analytes was analyzed with a single run through the GC/MS. Second, once prepared, samples could be stored with an essentially unlimited holding time. This allowed the set of samples analyzed to be chosen from a much larger set of samples collected (and prepared). The samples analyzed were chosen based on the results of previous analyses. This resulted in an overall reduction in the number of samples analyzed. Although a large number of samples were collected to ensure that the elution curves could be delineated, the results from a limited initial set of screening samples were used to determine when additional samples should be analyzed to delineate the elution curves.

The organic analytes and methods are summarized below:

Volatile Fractions - Field lab: purge and trap GC

1. Chloroform
2. Bicyclo[2,2,1]hepta-2,5-diene (BCHD)
3. Dicyclopentadiene (DCPD)
4. Trichloroethane (TCA)
5. Trichloroethene (TCE)
6. Tetrachloroethene (PCE)
7. Benzene
8. Toluene
9. Xylene

Semi-Volatile Fractions - USGS Organic Lab: SPE GC/MS SIM

10. Atrazine
11. Chlordane (alpha, cis)
12. Chlordane (gamma, trans)
13. 2,2-Bis(para-chlorophenyl)-1,1-dichloroethene (PPDDE)
14. 2,2-Bis(para-chlorophenyl)-1,1,1-trichloroethane (PPDDT)
15. Dieldrin
16. Diisomethylphosphonate (DIMP)
17. Dimethylmethylphosphonate (DMMP)
18. Endrin
19. Isodrin
20. p-chlorophenylmethyl sulfide (CPM sulfide)
21. p-chlorophenylmethyl sulfone (CPM sulfone)
22. p-chlorophenylmethyl sulfoxide (CPM sulfoxide)
23. CL_5-1,3-Butadiene
24. Tetrachlorobenzene
25. Unknown Multihalogenated Compound Molecular Weight 364
26. Unknown Multihalogenated Compound Molecular Weight 378

2.2.2 CHEMICAL STRATIFICATION IN THE AQUIFER

Water samples were collected from a fully penetrating 2 in. well using a double packer system to isolate 2-ft. sections of the aquifer for sampling. The well was installed without a gravel pack to minimize short circuiting along the outside of the well during this sampling. The water samples were analyzed by the on-site VOC system and the USGS methods described in Section 2.2.1.

Figure 2.2-1 presents depth profiles of background concentrations of chloroform, DCPD and DIMP. Note the strong stratification in concentrations of chloroform and DCPD, contrasted to the rather uniform DIMP concentration with depth. Significant vertical stratification is shown in Figure 2.2-2 for CPM sulfide, CPM sulfone and CPM sulfoxide, and in Figure 2.2-3 for PCE and TCA.

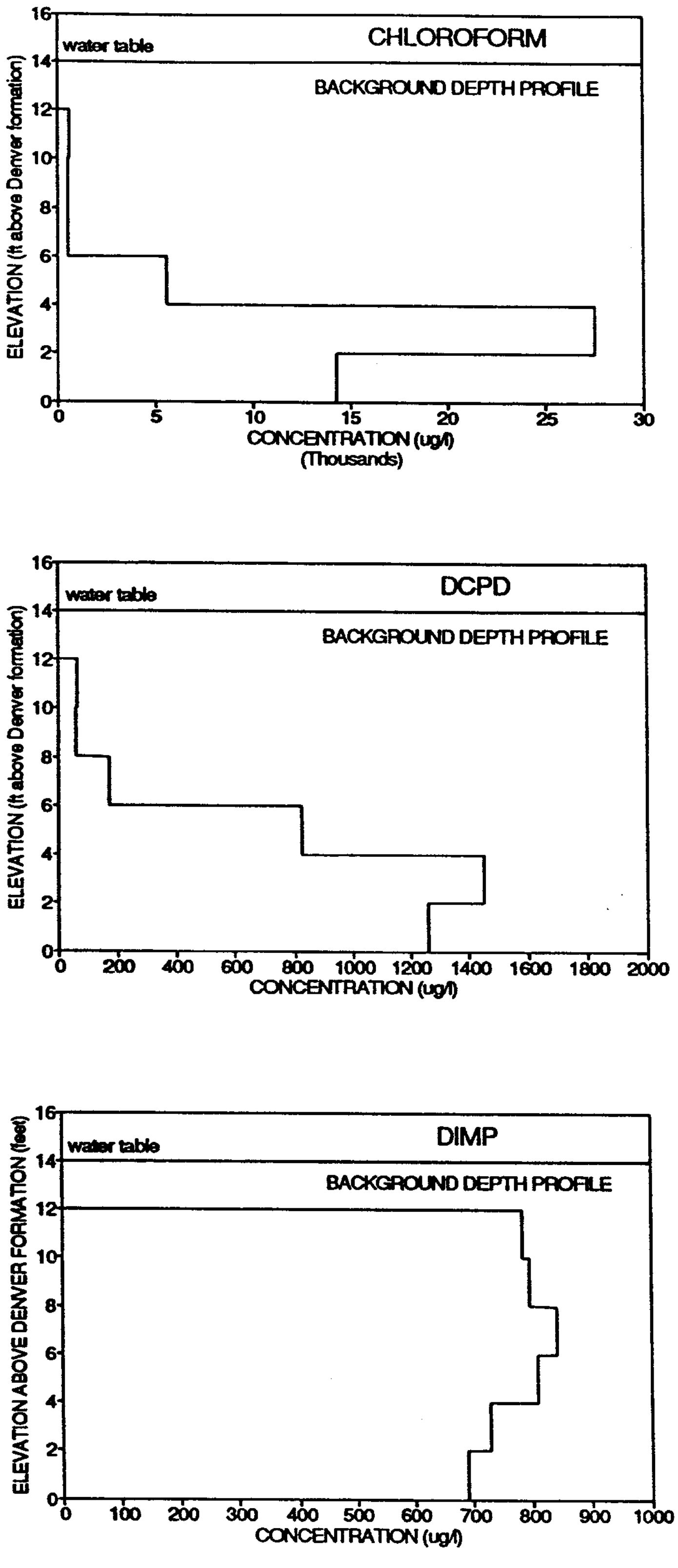


Figure 2.2-1 Depth Profiles of Background Concentrations of Chloroform, DCPD and DIMP. Note the strong stratification in concentrations of chloroform and DCPD, contrasted to the rather uniform DIMP concentration with depth.

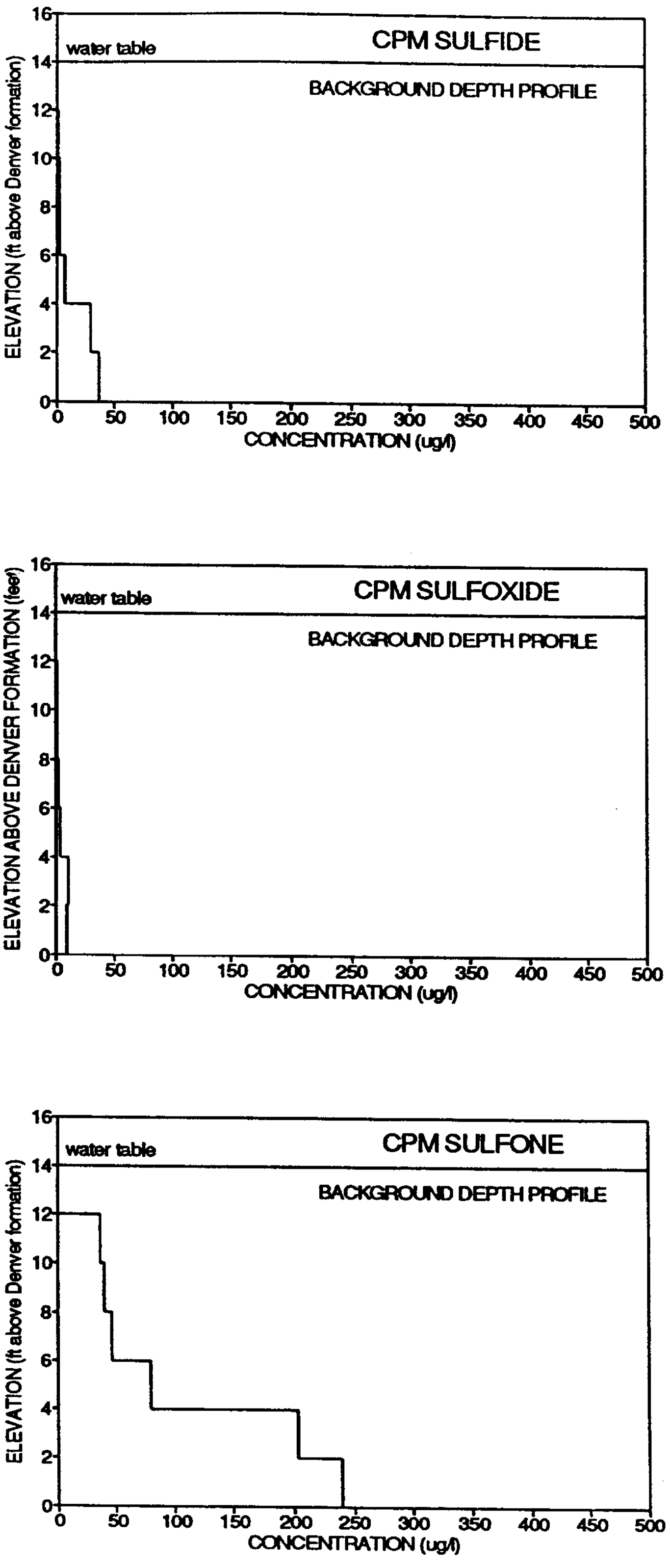


Figure 2.2-2 Depth Profiles of Background Concentrations of CPM Sulfide, CPM Sulfoxide and CPM Sulfone. Note strong vertical stratification.

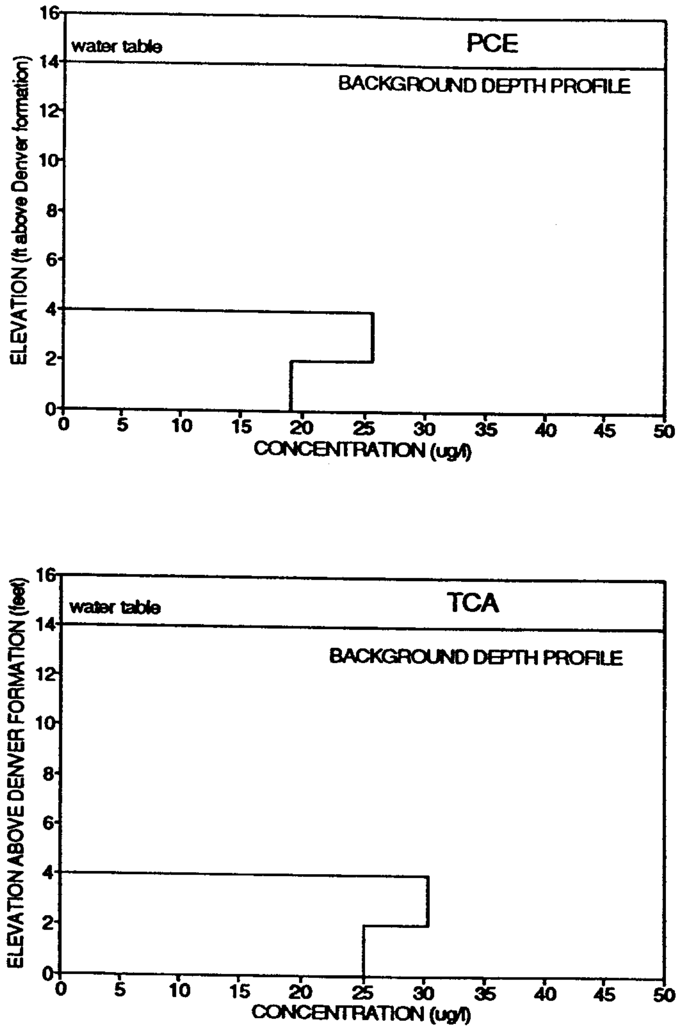


Figure 2.2-3 Depth Profiles of Background Concentrations of PCE and TCA. Note strong stratification.

2.2.3 QUANTITATION OF CONTAMINANTS SORBED ON AQUIFER SEDIMENTS

The sorbed concentrations of contaminants were investigated by analyzing extracts from six sediment cores obtained from two borings (three cores per boring). The cores were collected from depth intervals which correspond with the depth intervals of ground-water monitoring during the experiment (discussed in Section 2.3.3). The sediment samples were collected in a stainless steel split-spoon, hammer driven along two-ft runs. The runs were designed to allow preparation of composites of the sediments which would correlate with the depth intervals planned for ground-water monitoring. The composites were prepared by cutting the core at the correct depth intervals, peeling to remove exposed surfaces, and then peeling freshly exposed sediments into 1-quart (qt) wide-mouth glass jars. The samples were then prepared for analysis by conducting a 12-hour soxlet extraction at the RMA laboratory.

The extracts were delivered to the USGS National Water Quality Lab, Organics Section, for analysis of semi-volatile compounds. The sample extracts were concentrated on a steam bath at 60°C using a Kuderna-Danish/Snyder Column concentration apparatus, to a volume of about 5 milliliters (ml). The volumes were then slowly reduced to 0.9 ml by evaporation under a gentle stream of nitrogen. Next, 0.1 ml of toluene containing 6 deuterated-Polycyclic Aromatic Hydrocarbon (PAH) internal standards (ISTDs) was added to the extract prior to analysis. Two microliters (ml) of the extract was then injected for GC/MS analysis in the electron impact (EI) SIM mode. At least 3 characteristic ions were monitored for each contaminant. Calibration curves were constructed for all of the compounds, equivalent to a range of 15-500 micrograms per kilogram (µg/kg) of sediment. No special attempts were made to determine recoveries, but USGS experience suggests that the organochlorine compounds (e.g. dieldrin) would have been recovered at over 70 percent and the rest at 30-60 percent.

The initial intent was to collect and analyze one set of sediment core prior to the aquifer flush, and a second set of core immediately following the flush. The second set of cores would be collected from as close as possible to the locations of the first set of cores. The locations of the borings utilized to obtain the cores are discussed in Section 2.3.4. It was hoped that the analytical results from both sets of cores would provide insight about the sorbed component that existed prior to the experiment, and the fraction of that sorbed component that was removed during the aquifer flush. The sediment cores were to be collected from the same depth intervals screened by the monitoring wells (discussed in Section 2.3.3), allowing the results of the sediment analysis to support interpretation of the behavior of dissolved contaminants in the depth intervals monitored during the flushing process.

Table 2.2-1 lists the results for analyses of the first set of sediment cores collected prior to the aquifer flush, expressed as µg of contaminant per dry kg of sediment. These results are corrected for residual pore water present in the sediment samples. No corrections were made for potentially low analytical recovery of the sorbed mass. It is evident that the only contaminants detected were DIMP and CPM sulfone. The concentrations of the other contaminants which could be analyzed by this technique were at or below the detection limit. The below-detection level results for dieldrin are generally consistent with low or below-detection level concentrations of dieldrin measured in Section 23 sediment cores by Shell Development Company (Shell, 1991).

Unfortunately, at the time the RLSA Contaminant Transport Research sediment core analyses were done, the method was not able to quantify the concentrations of tetrachlorobenzene and the two unknown multihalogenated compounds that were later detected and quantified in water samples. Thus, the background concentrations of these compounds in the sediments was not determined. In addition, more volatile compounds (e.g. DCPD, TCE, PCE, etc.) could not be analyzed by this technique, so information is not available on the background concentrations of these compounds in the sediment.

Table 2.2-1 Background Contaminant Concentrations in Sediments (µg/kg) (Corrected for Residual Pore-Water Analyte Concentrations)

Depth interval (ft bgs)	39-43	39-43	43-47	43-47	47-51	47-51
Sample number	B1A	B2A	B1B	B2B	B1C	B2C
DIMP	83.9	116.1	46.0	37.3	44.2	64.5
CPM sulfide	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
CPM sulfoxide	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
CPM sulfone	7.1	8.1	6.6	4.1	21.0	27.8
Dieldrin	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5

Because the majority of the contaminants (including the more hydrophobic contaminants) were below the method detection limits, it was determined that collection and analysis of the second set of cores was not warranted.

These data are discussed in Section 3.0 of the report in light of the contaminant elution rates measured during the field experiment.

2.2.4 LABORATORY RETARDATION TESTS

Because the retardation of solutes during ground-water transport is caused by sorption of the solutes by the aquifer media, it is common to measure sorption using batch analyses in the laboratory as a means of estimating retardation in the field. This approach was used in the work described below, and relies on the assumptions that sorption is linear, reversible and rapid. When these assumptions are met, the ratio of the average velocity of the water to the average velocity of the solute of interest is a constant termed retardation factor (R), where R can be estimated from batch sorption analyses using the following equation:

$$R = 1 + \frac{(1 - \theta)}{\theta} \rho_s K_d$$

where θ is the porosity (-), ρ_s is the solid density of the sediments grams per cubic centimeter (g/cm^3), and K_d is the sorption distribution coefficient in cubic centimeters per gram (cm^3/g). The first two variables may be estimated or cores may be analyzed by standard methods. The batch sorption methods discussed below are used to determine the k_d.

A series of cores spanning the saturated alluvium at the field site were taken during drilling of the injection well borehole. The cores were divided into depth intervals, which were then shipped to Duke University for analysis under the supervision of Prof. W. Ball (Civil and Environmental Engineering Department). Each interval was air dried and homogenized, then split for analysis. The subsamples were analyzed by one or both of two batch methods to determine the sorption distribution coefficient for PCE.

The first method used to estimate the sorption capacity of the sediments is hereafter referred to as headspace analysis and is a modification of the approach outlined by Garbarini and Lion (1985). This method was used to estimate the degree of sorption and retardation in the field experiment. The method was used in subsequent analyses to generate more reliable estimates of the K_d for PCE. PCE was used as the model solute because 1) it is present in ground water at the site, 2) it is volatile enough for the headspace method, and 3) it is relatively easy to analyze.

In this work, the headspace analysis method was conducted as follows. For each experiment, a known mass of sediment was put in a 120-ml bottle along with a known volume of synthetic ground water (0.033 N $CaCl_2$), leaving a known volume of headspace. A known mass of PCE was then injected into the water and the bottle immediately capped with a teflon-lined septum. Similarly, an equal mass of PCE was added to a second bottle containing only water and headspace. The bottles were gently shaken for 24 hours to allow partitioning among the air, water and sediments to reach or at least closely approach equilibrium (see additional discussion below). After equilibration, 0.5 ml of headspace gas from each bottle was extracted and injected onto a Varian 3300 GC to determine gas-phase PCE concentration. Based on mass balances in each bottle, the K_d of the sample is calculated as a function of the mass of sediment, the gas and liquid volumes in the bottles, the Henry's constant of PCE, and the ratio of PCE concentrations in the headspace of the two bottles. The approach and equations for calculating K_d are described in detail by Garbarini and Lion (1985).

The second batch method is most commonly used for sorption, which will be referred to herein as water analysis. In this method, a known mass of sediments was exposed to a known volume of synthetic ground water (0.033 N $CaCl_2$) into which a known mass of PCE had been injected (creating a known initial water concentration of PCE). After 72 hours of gentle mixing to allow the PCE sorption to reach or at least closely approach equilibrium, the bottles were centrifuged to separate the solids and the water. Then 6 ml of the water was transferred to another bottle and extracted by shaking with 2.3 ml of hexane. Three µlsof the hexane extract were then injected onto a Varian 3300 GC. Comparison of the results with those of calibration standards allowed the concentration of PCE in the hexane to be determined. Given the extraction ratio, the water concentration was calculated from the hexane concentration. The sorbed mass of PCE was calculated as the difference in mass of PCE in the water before and after equilibration. The K_d (cm^3/g), was calculated as the ratio of the sorbed concentration (g PCE/g sediment) to the water concentration (g PCE/cm^3 of water).

The results of the sorption analyses are presented in Table 2.2-2, which indicates that the two methods yielded different average values on the sample interval (S1) to which both were applied. It is possible that part of the difference may be attributed to the different equilibration times; in liquid analysis, the equilibration time was 72 hours compared to 24 hours for the headspace method. From prior work with PCE sorption by sandy media from a different site (in Borden, Ontario), Ball and Roberts (1991) found that PCE equilibration required about 10 days. It may be that PCE sorption onto the sediments from the

Table 2.2-2 Laboratory Estimates of PCE Sorption Distribution Coefficient for Various Depth Intervals in the Aquifer (n=number of analyses, units of K_d are cm^3/gram)

Sample	Depth Interval	Sorption distribution coefficient (K_d)					
		Headspace analyses			Water analyses		
code	(feet bgs)	Ave.	Range	n	Ave.	Range	n
S1	37-39	0.22	0.07-0.36	6	0.37	0.21-0.59	2
S2	39-41				0.36	0.00-0.61	3
S3	41-43	0.58	0.29-1.03	3			
S4	43-45				0.28	0.08-0.40	3
S5	46-46	0.97	0.61-1.32	2			
S6	46-48				0.02	0.00-0.06	3
S7	48-50	0.56	0.50-0.62	2			
S8A	50-50.8	0.52	0.14-0.86	4			
S8B	50.8-51.5				0.02	---	1

RMA site requires similar or longer periods to reach equilibration. A longer period of equilibration should yield an apparent K_d closer to the true equilibrium value.

In both methods, the K_d estimates from replicate analyses ranged fairly widely, but the ranges for analysis of sample interval S1 from the two methods overlapped. Such variation may arise from analytical difficulties, but may also be due to real differences in the solids analyzed if the sample is not perfectly homogenized. Perfect homogenization of samples was certainly the goal, but cannot be confirmed.

It should be noted that both sets of analyses used high concentrations of PCE, on the order of several hundred µg/Liter (L) after equilibration. At lower concentrations more typical of the site (i.e. 1-50 µg/L), the sorption distribution coefficient may be higher if the sorption isotherm is nonlinear. For example, Ball and Roberts (1991) found that the K_d for PCE for a sand from another site (Borden, Ontario) was approximately 0.9 cm^3/g for low concentrations (<50 µg/L), whereas the K_d was estimated as approximately 0.6 cm^3/g for concentrations ranging up to several hundred µg/L. Without considerably more work, however, it is not possible to determine or estimate the magnitude of such an increase for sorption of PCE by the RMA sediments at the typically low solution concentrations of PCE in the aquifer.

Despite the uncertainties, it is apparent from this work that the sediments do have the ability to sorb PCE from synthetic ground water, although the measured sorption capacity varies somewhat in the aquifer. From analyses of the core strata, the porosity of the aquifer appears to range from 0.19 to 0.35, with the low values resulting from the presence of large cobbles in the analyzed cores. For cobble-free sands, the porosity probably averages on the order of 0.30. If we assume the porosity is relatively uniform and that the solid density of the sands is 2.7 g/cm^3 (approximately the density of quartz), we can use the equation above to estimate the range of retardation factors expected for PCE in the aquifer. This estimate assumes that the site conditions were well represented by the conditions in the sorption analyses (other than the PCE concentration). The estimated retardation factors for PCE range from slightly greater than 1 in the strata with low K_d to approximately 7 in the stratum with the highest average K_d (S5). As mentioned above, the retardation may conceivably be higher in the aquifer since PCE concentrations in the aquifer are lower than those used in the laboratory analyses.

The data in Table 2.2-2 may also be used to estimate the depth-averaged properties of the aquifer. Using the average of the two estimates for S1, and weighing the estimates by the depth interval of the stratum, the depth-averaged K_d for PCE in this aquifer is approximately 0.4 cm^3/g. This value is in the range of PCE K_d values estimated for other sandy aquifers; for example Ball and Roberts (1991) reported values of approximately 0.6 to 0.9 cm^3/g for various PCE concentrations and various subsamples of a large bulk sample of the sandy aquifer in Borden, Ontario.

In summary, the laboratory analyses of strata from the site indicate that the sandy sediments have the capacity to sorb PCE from synthetic ground water. The depth-averaged K_d for PCE is estimated as 0.4 cm^3/g (based on batch analyses conducted at equilibrium concentrations on the order of several hundred µg/L), but may be higher for the low PCE concentrations of interest at the site. Given the assumed solid density and measured porosity, the aquifer has the capability to retard PCE transport by a factor of approximately 3 to 4 (or more) if site conditions aside from PCE concentration are similar to those in the laboratory analyses. Furthermore, based on these analyses, it would be expected that the aquifer could more strongly retard the transport of more hydrophobic compounds such as tetrachlorobenzene, dieldrin and others present in ground water at the site. However, these expectations are based on the assumption that the complex ground-water chemistry at the site has no effect on the partitioning of contaminant between the ground water and the solids (compared to that observed with the simple synthetic ground water used in the lab tests). As is evident from results presented and discussed later, this assumption appears to be incorrect.

2.2.5 COLLOIDS/DISSOLVED ORGANIC CARBON

Traditional methods of separating a fluid phase into "particulate" and "dissolved" factors rely on physical means such as filtration or centrifugation. Filtration methods usually imply 0.4 μm filters to operationally define the dissolved fraction of the bulk fluid. Unfortunately, significant amounts of non-dissolved material are able to pass standard 0.4 μm filters; this material has been implicated in the enhanced mobilization of insoluble chemical components.

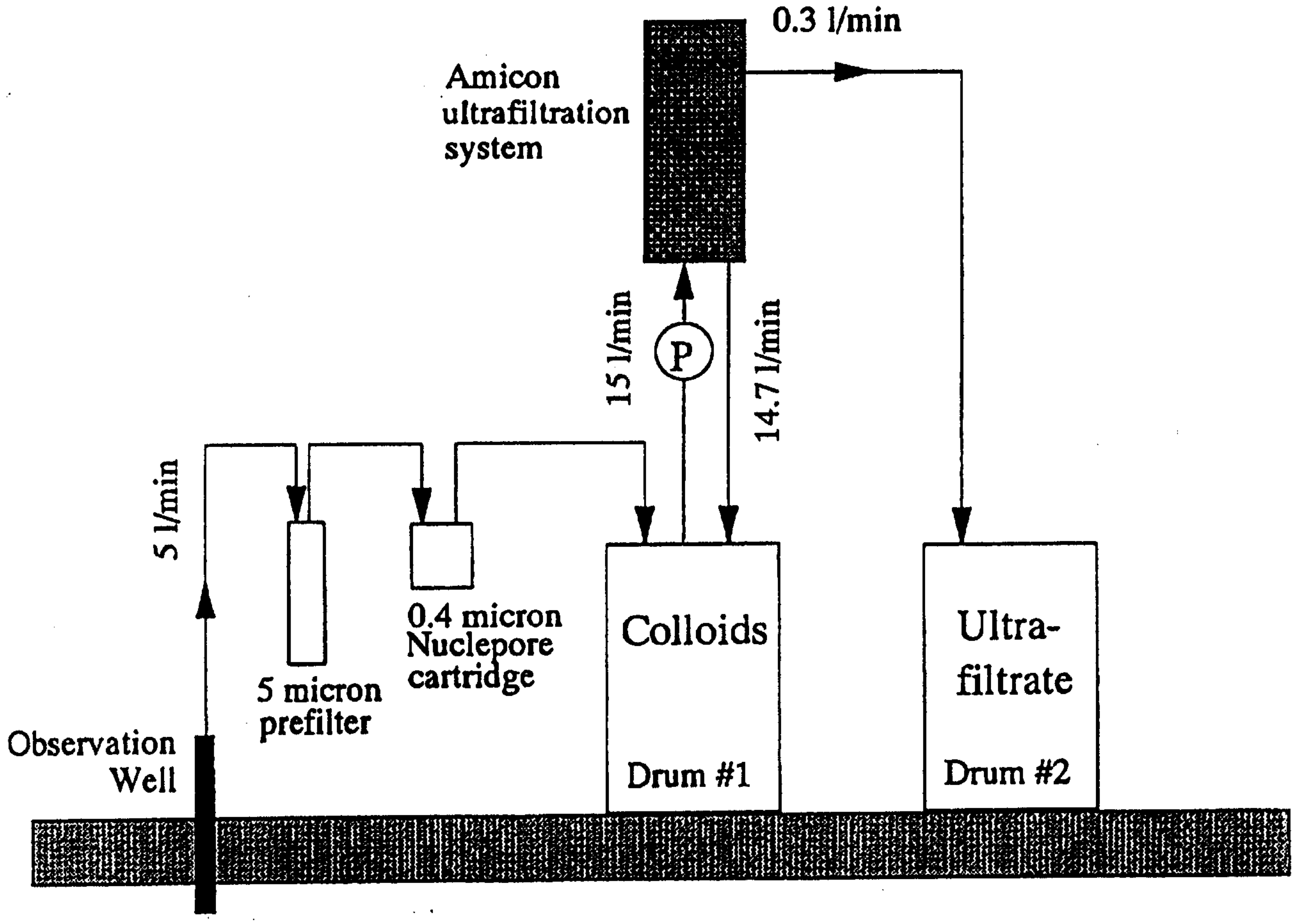
The possible role of sub-micron, non-aqueous phase material (i.e., colloids) in the transport of contaminants was investigated as part of the applied research project. This investigation involved the use of a 10,000-molecular weight cut-off ultrafilter (≈2 nm effective diameter) in series with 0.5 and 0.4 μm pre-filters, and the analysis of organic carbon and analyte concentrations in each size fraction.

2.2.5.1 Prefiltration

The colloid separation system is shown schematically in Figure 2.2-4. Groundwater was pumped from the aquifer to the surface using submersible, 2 in. Grundfos pumps. The sample was pre-filtered, using polypropylene filtration cartridges (0.5μm median pore diameter; 25 cm long, 6 cm in diameter) in series with 0.4 μm Nuclepore cartridges (12 cm long, 6.5 cm diameter, 1m^2 surface area), at a pumping flow rate of approximately 5 L/min. All pre-filtration cartridges were pre-conditioned to minimize the leaching of organic carbon from filter constituents during the pre-filtration step. The effluent was temporarily stored in a low-density, acid-washed polyethylene drum liner supported by a high-density polypropylene drum (Drum #1). Polyethylene or Tygon tubing was used for the entire pumping and filtration system.

2.2.5.2 Ultrafiltration

The 0.4 μm pre-filtered ground water, held in Drum #1, was subsequently ultra-filtered using an Amicon cross-flow, hollow-fiber ultrafiltration cartridge (Model H10P10-20) with a molecular weight cutoff of



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Schematic Diagram of
Colloid Separation System

Date: June 1992	Figure 2.2-4

10,000 Dalton. The cartridge has a surface area of 0.88 m^2, is 0.64 m in length, a diameter of 4.5 cm, an internal filter diameter 0.5 mm and consists of approximately 1,000 hollow fibers. Fluid from Drum #1 was circulated through the Amicon ultrafilter using a Masterflex peristaltic pump at a flow rate of about 15 L/min. The major portion of the pumped fluid passed unhindered through the filter, traveling through the fiber interiors and returning to Drum #1. The returned fluid is called the retentate. A small volume of the circulating fluid, however, passed through the fiber walls carrying with it constituents of 10,000 molecular weight or less. This material, the ultrafiltrate, was collected in Drum #2. With time, the volume of fluid in Drum #1 decreased and the volume in Drum #2 increased. When the volume of the fluid in Drum #1 was about 5L, the fluid was transferred to a pre-washed 5L carboy and the filtration process continued. When the volume of the retentate reached about 1L, 10 M-ohm Nanopure water was added to the carboy to the 5L level, and the ultrafiltration processes continued until the retentate was approximately 0.5-1.0L in volume. This final retentate was transferred to sample bottles, which had been cleansed of residual organic carbon, for later processing and analysis.

2.2.5.3 Dissolved Organic Carbon (DOC)

Fluid from each stage of the colloid extraction system was subsampled for DOC analysis. Subsamples were: 1) post pre-filtration, i.e., Drum #1 prior to ultrafiltration; 2) the retentate from the ultrafiltration step (i.e., colloid organic carbon, COC, concentration); 3) the ultrafiltered dosing with phosphoric acid; bottles were capped using teflon liners and filled to zero headspace. DOC and Total Organic Carbon (TOC) concentrations were determined using a Shimadzu TOC 5000 analyzer using oxidation at 680°C in the presence of a platinum catalyst.

The approximately 1L final retentate solutions were freeze-dried and the mass of colloidal material determined. Recovered colloid masses ranged from 0.56 to 6.6 g; this corresponds to colloid concentrations in the ground water ranging from 15.9 to 161 mg/L (Table 2.2-3). Background (i.e., pre-experiment) DOC concentrations were 93 mg/L (ppm), as determined from a composite sample (Wells A, B, and C). Mass balances on carbon are presented in the column headed by %PFW.

2.2.6 PRESENCE OF SURFACTANTS

The second potential contaminant-transport-enhancing mechanism investigated was surfactants which can increase the solubility of hydrophobic contaminants. Samples were collected and analyzed for anionic

Table 2.2-3 Summary of Background (pre-experiment) Colloid Information

Date	Sample	Volume (L)	DOC (mg/L) (in sample)	DOC (mg/L) in situ	SD (mg/L)	TOC(mg) (mg/L x L)	% PFW [-]	Coll(mg) (sum)	COC(mg) (sum)	Coll/COC [-]	t since inj. (h)
10/11/91	B-1PFW1	107.5	93.53	93.53	2.09	10054					
	B-1PFW2	107.5	93.23	93.23	3.72	10022					
	B-1COL	0.89	44.89	0.37	0.47	40	0.40	560	40	14.0	0
	B-1UFW	106.5	84.98	84.98	1	9050	90.30				

PFW1: Prefilter Water (original sample)
PFW2: Prefilter Water (duplicate of PFW1)
COL: Colloids
UFW: Ultra Filtrate Water
Volume: Volume of aquifer fluid in each fraction; PFW is the total volume pumped; COL is the final colloid retentate volume.
DOC: "dissolved" organic carbon concentration in each fraction.
DOC(in situ): the DOC concentration estimated to be in the aquifer fluids; e.g., for COL: DOC (in situ) = $\underline{44.89 \text{ x } 0.89}$ = 0.3
SD: standard deviation on replicate samples for DOC measurement.
TOC: total carbon in fraction volume, e.g., 93.53 mg/L x 107L = 10054 mg.
% PFW: percent of fraction relative to total; e.g., COL = 40/10054 = 0.4%.
Coll(sum): colloid mass in total sample.
COC(sum): colloid organic carbon in total sample.

surfactants by the USGS National Water Quality Inorganics Laboratory. Analytical protocols for the analysis of non-ionic surfactants could not be implemented due to funding and contractual limitations. The anionic surfactants were analyzed by using a modification of the Methylene Blue Active Substances (MBAS) method as described in "Standard Methods for the Examination of Water and Wastewater," 17th edition, (USGS, 1989). This modification reduces interference from high chloride concentrations, such as is exhibited in the site ground water.

Table 2.2.4 summarizes the results of the surfactant analyses. Two replicate samples were analyzed and contained 0.021 and 0.013 mg/L MBAS. About 80 percent of an MBAS spike added to the ground-water matrix was recovered. Additionally, four fortified reagent-water samples were prepared with known amounts of chloride and MBAS to determine the level of interference of chloride with the modified method. Chloride content from 0 to 2,500 mg/L did not appear to significantly affect the analyte recovery.

From discussions with USGS personnel and information in the scientific literature (Kile, 1989), it was determined that the types of surfactants most likely to have been used/disposed at RMA and to have migrated in ground water were anionic and nonionic. Anionic surfactants are commonly used in detergents and various industrial formulations, including pesticides. Nonionic surfactants are less common in domestic products, but are often used in pesticide and other industrial formulations, often in combination with anionic surfactants.

Table 2.2-4 Summary of Surfactant Analysis Results

Sample ID	Chloride Concentration (mg/L)	Amount MBAS added (mg/L)	Amount MBAS Analyzed (mg/L)	Recovery of Added MBAS (percent)
Site Ground water		0	.021	
Site Ground water		0	.013	
Site Ground water Spike		0.5	0.417	80
Fortified Reagent-water #1	2500	.025	0.013	53
Fortified Reagent-water #2	2500	0.50	0.443	89
Fortified Reagent-water #3		.025	.011	45
Fortified Reagent-water #4		.5	.427	85

These results suggest that there are insignificant concentrations of anionic surfactants in the ground water at the site. To have a significant effect on partitioning and mobility of contaminants ranging from chloroform to dieldrin, the scientific literature suggests that the anionic surfactants would have to be present at much higher concentrations, i.e. above their critical micelle concentrations (CMCs) which generally are on the order of 1,000 mg/L or higher. Although no data were obtained on nonionic surfactants, the fact that they are often used in combination with anionic surfactants suggests that they too are unlikely to be present in site ground water at significant concentrations. On the other hand, if all of the detected DOC at the site (approx. 100 mg/L) were nonionic surfactants, it is possible that they could exert a significant effect on contaminant partitioning and mobility since the CMC for some nonionic surfactants is at or below 100 mg/L. For reasons discussed later, further investigation of the importance of nonionic surfactants may be warranted.

2.3 WELL NETWORK

The well network for the experiment was designed to perform several functions. An extraction well was used to remove contaminated water from the aquifer. An injection well was used to deliver the clean water flush into the aquifer. A series of monitoring wells were used to collect the ground-water samples. A series of soil borings were used to obtain the sediment core for the laboratory analyses, and a series of piezometers were used to monitor the hydraulics during the experiment.

The flush of clean water through the aquifer was accomplished utilizing an injection well/extraction well combination. This method provided several advantages over the use of a single injection well:

- Increased ground-water flow control.

  The combination of an injection and extraction well reduces the potential mounding that might occur at a single injection well. The negative aspect of mounding at the injection well is that sediments above the water table, which may not have been exposed to the contaminated ground water, might be exposed to the clean-water flush. This situation could distort the measured elution rates. The addition of the extraction well provides a steeper gradient away from one side of the injection well, theoretically increasing flow away from that side of the injection well and reducing the magnitude of mounding.

Further, because the water for the injection flush is obtained from the nearby extraction well, there is no net volume gain of water in the aquifer.

The combination of injection and extraction wells also increases ground-water flow control by developing a preferred flow path in the aquifer. A single injection well would deliver flow radially to the aquifer, assuming homogeneous hydraulic conductivity in the aquifer. Because hydraulic conductivities could not be assumed homogeneous based on the lithologic descriptions and core study results discussed above, a monitoring well adjacent to a single injection well may or may not receive the anticipated flux of clean water. The use of the extraction well increased the confidence that a flux of clean water would flow through the aquifer at the monitoring points.

- Eliminated external source for injection water.

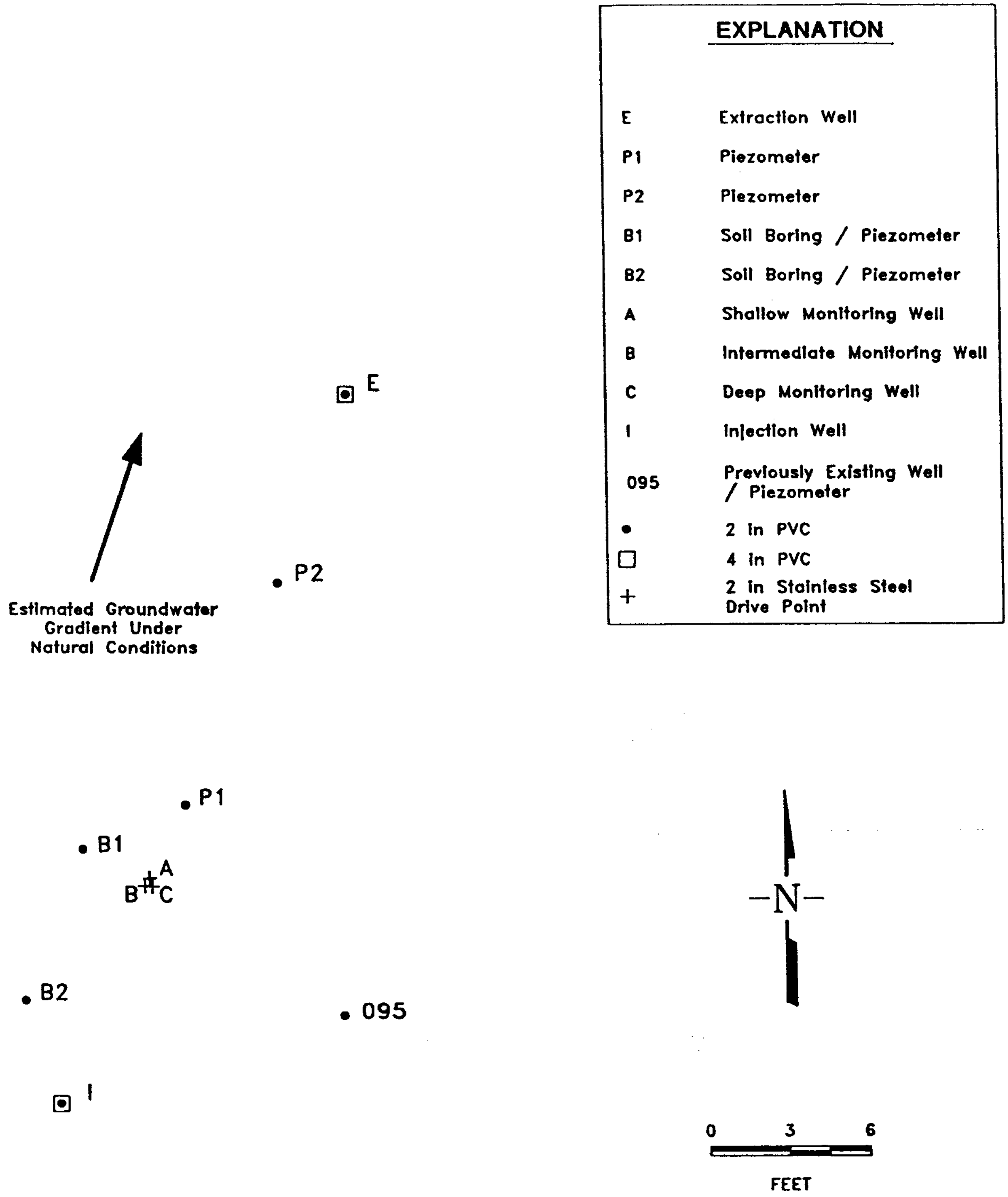
  The use of an injection well/extraction well combination precluded the necessity to obtain an external source of injection water because water pumped out of the extraction well was treated (discussed in Section 2.4) and then re-injected as the clean-water flush.

- Minimized waste management efforts.

  By treating and re-injecting the extraction water, large volumes of contaminated water did not have to be containerized, piped, or transported to disposal facilities.

The wells in the network were located designed with the aid of computer models. The extraction, injection, and monitoring wells were oriented in line with the approximated natural ground-water flow direction to minimize the potential for flow deviations from the desired flow path during the experiment (Figure 2.3-1).

Construction details for the wells in the network are in Appendix B. A brief summary is presented below.



EXPLANATION

E	Extraction Well
P1	Piezometer
P2	Piezometer
B1	Soil Boring / Piezometer
B2	Soil Boring / Piezometer
A	Shallow Monitoring Well
B	Intermediate Monitoring Well
C	Deep Monitoring Well
I	Injection Well
095	Previously Existing Well / Piezometer
●	2 in PVC
□	4 in PVC
+	2 in Stainless Steel Drive Point

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WELL NETWORK PLAN MAP

RMA TRC/692/23-1

Date: June 1992

Figure 2.3-1

2.3.1 INJECTION WELL

The injection well was drilled first and screened through the entire aquifer. Its purpose was to deliver the clean water flush into the aquifer. Preliminary information on aquifer properties was gained from lithologic logging (Section 2.1.1) and laboratory testing (Section 2.2.4) of the drill core. The information gained during the installation of the injection well contributed to the design parameters of the extraction and monitoring wells.

2.3.2 EXTRACTION WELL

The extraction well was used to pump contaminated ground water out of the aquifer. It was located 30 ft from the injection well, downgradient along the estimated natural ground-water flow path (Figure 2.3-1). The distance between the injection and extraction well was determined by integrating hydraulic conductivity estimates with pump rate limitations, the desired velocity field in the forced gradient portion of the test, and the proposed time frame of the experiment. Hydraulic conductivity was estimated based on the lithology encountered at the injection well, and modelling efforts conducted at the North Boundary Containment System (NBCS, located roughly 3000 ft to the north of the site) by Colorado State University (Warner, 1991) (Section 2.1.1). The lithology of the aquifer was logged during drilling of the extraction well. This information was used to design for the extraction well and monitoring wells. The construction of the extraction well was similar to the construction of the injection well.

2.3.3 CHEMICAL MONITORING WELLS

Chemical monitoring of the ground water was conducted at a 3-well cluster, located approximately 10 ft downgradient of the injection well (Figure 2.3-1). The distance between the monitoring cluster and the injection well was based on the flow velocities anticipated under the forced gradient, combined with the range of expected mobilities of the contaminants. Because the physical/chemical characteristics of the contaminants varied widely, it was expected that the mobility of at least some of the contaminants would be significantly retarded. The intent was to locate the chemical monitoring wells to allow monitoring of the broadest range of contaminant mobilities within the time frame of the experiment.

Each of the three wells in the cluster screened a separate, 4-ft interval in the aquifer. The screened intervals were initially planned to investigate separate lithologic zones, if present. Because the logging conducted while drilling the other wells revealed no distinct, separate lithologic zones, the aquifer was instead screened along three, roughly equal depth intervals. Well A screened the top portion of the aquifer from 38.2 to 42.2 ft bgs; well B screened the middle portion, from 42.6 to 46.6 ft bgs; and well C screened the bottom portion, from 47.0 to 51.0 ft bgs.

The monitoring points were constructed by augering one 8-in. hole to just above the top of the water table. Then three stainless steel drive points and screens (2-in. diameter) were pushed with an electric jackhammer from the bottom of the augered hole into the aquifer at the desired depth intervals. The initial plan was to hammer in the drive points with the drill rig, but the hammer impact destroyed the screens, and its force could not be reduced. Thus, a jackhammer and a set of scaffolding was substituted for the drill rig. The impact force was conveyed to the drive point tip through a drill rod installed in the well casing. This reduced the tendency to distort the screen and casing during installation. Two-in. stainless steel casing was used from the top of each drive-point screen up to 3 ft above the water table. Schedule 40 PVC casing (2-in. diameter) extended from the stainless casing to the surface. The construction details are presented in Appendix B.

2.3.4 SEDIMENT BORINGS

Two sediment borings were drilled to obtain the core needed for the quantification of the contaminants sorbed to the aquifer sediments (discussed in Section 2.2.3). The first boring was located 4 ft from the injection well; the second boring was located 10 ft from the injection well (Figure 2.3-1). The borings were located at these distances from the injection well because it was theorized that the desorption of the more highly retarded contaminants would need to be measured close to the injection well where the degree of flushing would be higher, whereas the desorption of the more mobile compounds would need to be measured farther away from the injection well where the degree of flushing would be lower. Both of the borings were located slightly offset from the predominant ground-water flow path anticipated during the flushing portion of the experiment to minimize their effect on ground-water flow between the injection and monitoring wells. A second set of cores were planned to be collected from two additional borings, each located as close to the initial borings as possible. The second set of cores were not collected because the results from the first set of cores indicated that the majority of the contaminants were not present above detection levels (discussed in Section 2.2.3).

The initial set of cores were collected prior to the aquifer flush from soil borings B1 and B2 (Figure 2.3-1).

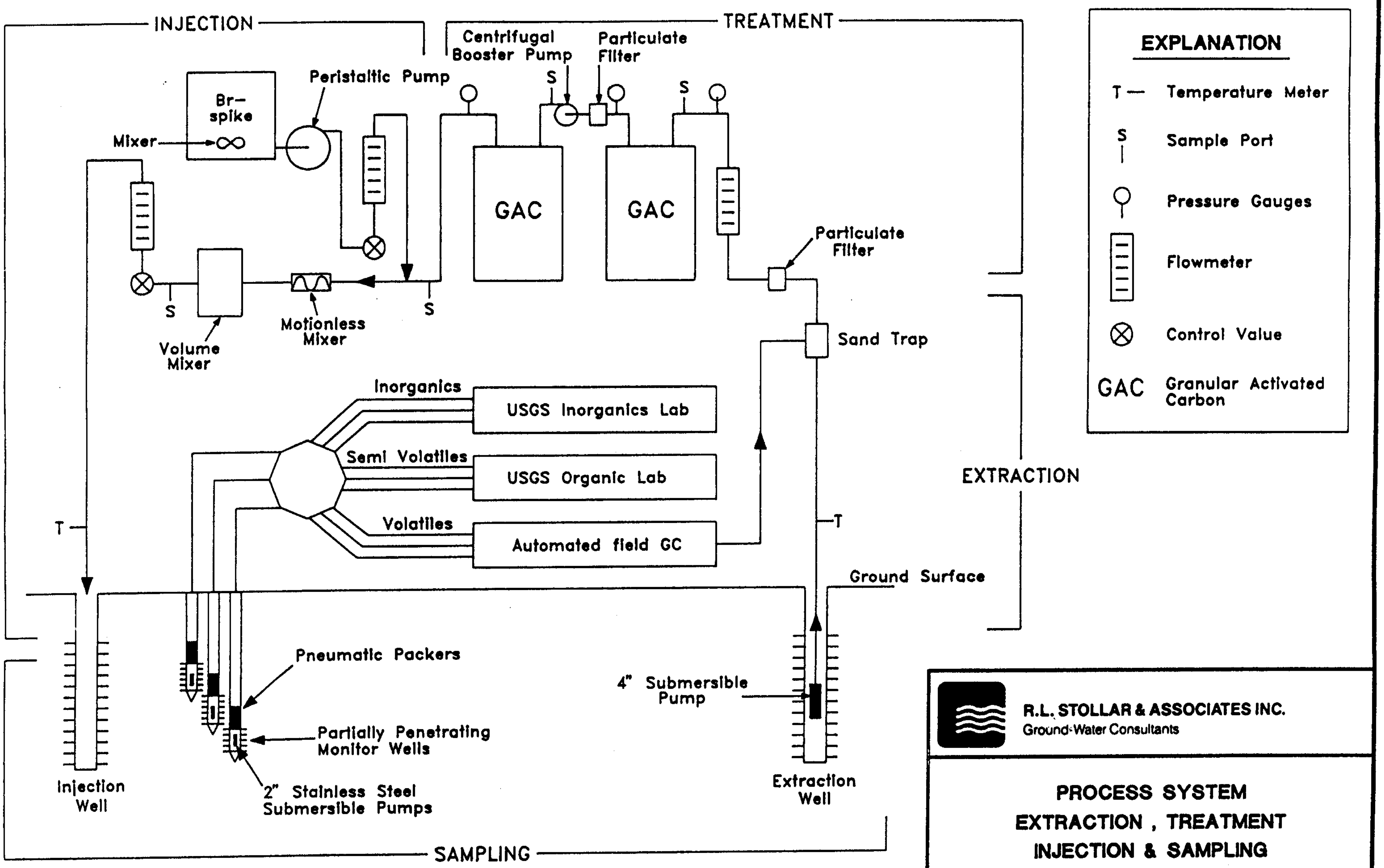
2.3.5 WATER LEVEL PIEZOMETERS

Five piezometers were used to monitor the hydraulic gradient and water level fluctuations during the experiment. One of the piezometers, (Well 23095) (Figure 2.3-1) existed prior to the experiment. Two of the piezometers were constructed by completing the two initial soil borings, B1 and B2, as wells. The last two piezometers were installed specifically to monitor water levels between the monitoring cluster and the extraction well. Water levels were not monitored in the chemical monitoring wells because the transducer cables did not fit through packers installed above the sample pumps.

The construction details of the piezometers are presented in Appendix B. All the piezometers screened the entire saturated thickness of the aquifer except Well 23095, for which construction details are inconsistent. The two piezometers which were completed in the boreholes of the sediment borings were installed without an artificial filter pack. This technique was utilized because a naturally caved aquifer would minimize the increased vertical hydraulic conductivity that an artificial filter pack can create immediately outside the screen. Because the depth discrete sampling conducted during the baseline characterization (discussed in Section 2.2.2) utilized inflatable packers on each end of a submersible pump, a reduction in vertical communication immediately outside the well screen was desirable to provide increased definition of the sample intervals. Additionally, the introduction of filter pack, bentonite, and/or grout into these boreholes would increase the risk that the sorption capacity and/or hydraulic conductivity of the sediments could be unfavorably altered. The other piezometers, P1 and P2, were installed following standard United States Army Toxic and Hazardous Materials Agency (USATHAMA) protocol.

Water level data collected from the piezometers are reviewed and compared to sorption and other chemical data in section 3.0 to describe the effect of the flow field on the experimental results. A dedicated automated system was chosen because it provided the most sensitive measurements and did not require continuous monitoring by site personnel.

The water levels at the site were monitored via a computer-driven datalogger with six pressure transducers. Five-pounds-per-square-inch, gauge, (psig) Druck PDCR 950 pressure transducers were placed approximately 4 feet below the water table in wells I, B1, B2, P1, P2, E, 095. The accuracy of the



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PROCESS SYSTEM
EXTRACTION , TREATMENT
INJECTION & SAMPLING

RMA TRC/692/24-1

Date: June 1992

Figure 2.4-1

transducers was rated at ±0.002 ft. A Geokon Micro 10 Datalogger was used to store the measurements, and was controlled through a portable computer located in the on-site lab. The computer software provided by Geokon was used to program the timing of the measurements. Data from the datalogger was periodically dumped to a floppy disk for backup and subsequent flow system analysis.

2.4 PROCESS SYSTEM

The process system consists of the pumps, filters, treatment canisters, piping, and related equipment that allows ground water to be pumped from the aquifer, treated, sampled and/or injected. Figure 2.4-1 schematically diagrams the components of the process system: extraction, treatment, injection, and monitoring.

2.4.1 EXTRACTION

Ground water was pumped from the extraction well using a 4-in. stainless steel electric submersible pump. The extraction rate was 4 gpm. The extraction rate was monitored with a flow meter and adjustments were made with a gate valve on the pump discharge line. Fluctuations in the flow rate were minor, estimated at ±0.2 gpm. Polyvinyl Chloride (PVC) tubing was utilized to transport the water to the surface where a sand trap and a series of filters reduced particulate matter prior to treatment.

2.4.2 TREATMENT

Downstream from the initial filters, the extracted water was routed through an activated carbon system to remove dissolved organic compounds before it was reinjected. Two Tigg C25 modular disposable activated carbon units were used. These units contain 330 pounds of 12 X 40 U.S. sieve carbon and can withstand a maximum flow of 25 gpm. The estimate of needed activated carbon capacity was based on the chemical results from historical monitoring programs (RLSA, 1989, 1990, 1991).

The number and size of the carbon units was determined by the manufacturer using the following assumptions:

1. Flow rate = 10 gpm
2. Water pH = 7

3. Water temp. = 60°F (15.6° C)
4. Total concentrations of organics = 12 mg/L (approximately 9 mg/L CCl_3 and 3 mg/L for other organics.

The canisters were connected in series to provide extra capacity. The net treatment system water pressure resulting from the combination of Granular Activated Carbon (GAC) canisters and several pre- and post-treatment filters necessitated a centrifugal booster pump that was located between the GAC canisters.

Because the manufacturer of the GAC canisters indicated that chloroform was the contaminant in the aquifer that would break through a canister first, the performance of the treatment system was monitored by frequently analyzing chloroform concentrations in water collected from sample ports located immediately upstream and downstream of each canister (Figure 2.4-1). These analyses were conducted in the field on the automated GC system discussed in Section 2.2-1. The potential for breakthrough of other unknown compounds was also monitored by collecting samples from these ports for semi-volatile analysis at the USGS laboratory. These results were not real-time, as was the on-site GC analysis for chloroform.

Note that the total organic carbon concentration of the site ground water (approximately 100 mg/L) was not known at the time the activated carbon supplier was estimating the operating parameters of the units. Initial information on DOC was later available from USGS. Since the actual DOC was about an order of magnitude higher than the value initially assumed, the estimate of activated carbon use per day was probably about an order of magnitude too low. Thus, while the two activated carbon tanks were initially expected to last about 60 days, hindsight suggests that they should have been expected to last only 6 days (about 150 hours). As determined later, the capacity of the activated carbon treatment system was indeed exceeded after about 6 days during the experiment.

The carbon treatment system did not remove salts from the extraction water. This was favorable because the natural chemistry of the treated water should ideally be the same as the aquifer water in order to control the number of variables that could affect the contaminant elution rates. Similarly, temperature variations in the process water were also minimized by enclosing and insulating the entire process system. A thermostatically controlled heat tape was used to provide a constant temperature of the process water. By maintaining consistent natural chemistry and temperature between the injected water and the aquifer water, the number of variables affecting contaminant elution rates was controlled.

2.4.3 INJECTION

The third element of the process system involved the injection of the organic-free water flush. After treatment, organic-free water was delivered to the injection well at the same rate that contaminated water was extracted (4 gpm). A lithium bromide (LiBr) tracer was added to the injection water for a period of time using a peristaltic pump drawing from a 55-gallon drum containing a concentrated LiBr solution. The drum was continuously stirred to ensure uniformity of the LiBr concentrations. The addition of the tracer solution to the flow of injection water was kept constant using a flow meter and adjusting a needle valve and/or the peristaltic pump speed. To ensure that the tracer was uniformly mixed into the injection water, an in-line motionless mixer followed by a two-liter mixing canister were utilized. Downstream of this mixing apparatus, a sample port was used to monitor the concentrations of the tracer being injected into the aquifer. The concentration of the tracer in the injected water was approximately 250 mg/L. This sample port was also used to collect samples for organic analyses to ensure that the injection water did not contain organic contaminants.

The LiBr tracer was added to the injection water at the beginning of the experiment when the injection/extraction pumping was started. In aqueous solution, the LiBr salt dissociates into lithium and bromide ions (Li+ and Br-), which can then migrate independently. Bromide (Br-) is widely used in ground-water studies as a conservative tracer since it interacts with aquifer media only to a negligible extent, and travels at the same mean velocity as the ground water. By monitoring for the Br- tracer at the monitoring wells, the arrival time of the leading edge of the organic-free flush was determined. This arrival time allows the ground-water flow velocity under the forced gradient to be estimated for each monitoring interval in the aquifer. Comparing the arrival time of the organic-free flush with the elution rates of the contaminants allows quantificaton of the contaminant transport characteristics. Flow velocities and hydraulic information about the aquifer can also be determined from the tracer information.

2.4.4 MONITORING

The fourth element of the process system involves the collection of water samples from the partially penetrating monitoring wells. A stainless steel electric submersible pump (Grundfos Rediflo 2) was installed in each of the three wells of the monitoring cluster. The pump intake was located at or slightly above the top of the screen section. Packers were used to isolate the pump and screen section from the rest of the well casing. Samples were taken after a small purge volume was pumped to remove any stagnant water in the pump, tubing, or well screen. The packers minimized the volume of purge water, the impact on the aquifer flow field, and the time required to sample. A gauge to monitor the inflation pressure in each packer was installed at the surface to ensure that the packers remained properly inflated. Stainless steel tubing was used to transport the water from the pumps up to a surface sample port. Waste water generated by purging and sampling was directed into the process system for subsequent treatment.

3.0 FIELD EXPERIMENT RESULTS

The field experiment results are presented for the forced gradient portion of the experiment in Section 3.1, and for the natural gradient portion of the experiment (after injection/extraction is ceased) in Section 3.2. Hydraulic and chemical monitoring results are discussed for each of these portions of the experiment.

3.1 FORCED-GRADIENT PORTION OF THE EXPERIMENT

The forced gradient portion of the field experiment, including ground-water extraction, treatment, and reinjection, began at 10:46 p.m. on November 3, 1991.

3.1.1 HYDRAULICS

Hydraulic effect of the forced gradient on the aquifer was monitored by 7 transducers installed in wells I, B2, B1, 095, P1, P2, and E (Figure 2.3-1). The transducers were wired to a data logger in the site trailer.

The information desired from the hydraulic monitoring included:

- nearly continuous tracking of the ground-water gradient (flow direction and slope),
- the time required for the aquifer to reach steady-state conditions following the start and/or stop of extraction/injection, and
- hydraulic conductivity estimates.

Hydraulic monitoring was initiated approximately 25 days before the start of injection/extraction in order to obtain background information on the natural ground-water gradient and the stability of the water table. The background water-level information from each well exhibits a fair amount of time-dependent variability. This variability typically involves fluctuations in calculated water levels of 0.03 ft over as little as one minute. The accuracy of the transducers is rated at ±0.002 ft over the pressure range which was encountered in each well application. Several reasons for this variability were postulated:

1. The water table is dynamic at this scale.

2. Baseline characterization activities (collecting method development samples, depth-descrete samples, testing pumps, etc.), disturbed the water table.

3. Other electrical equipment caused power supply fluctuations affecting transducer voltages.

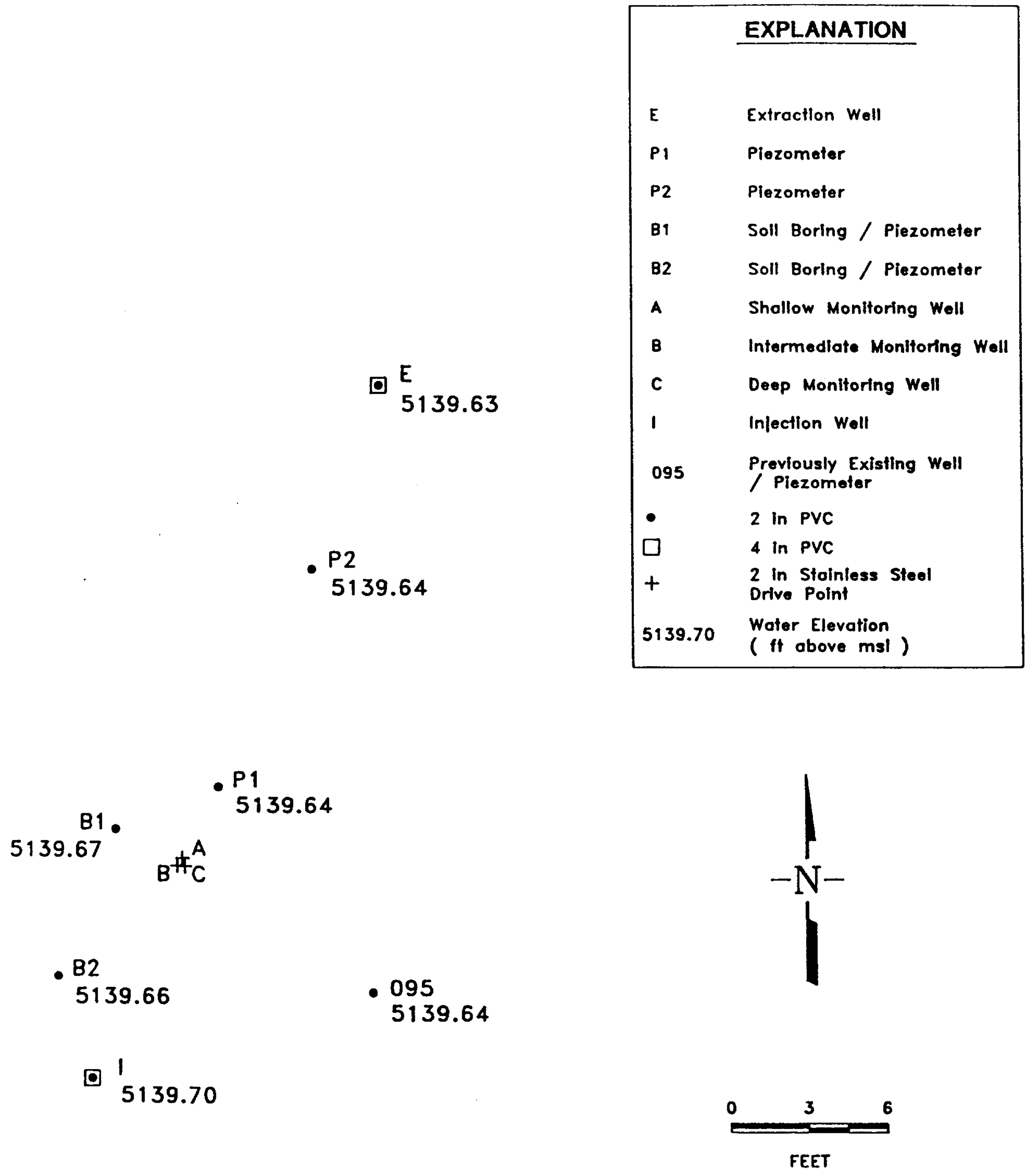
4. The site location was influenced by external factors such as pumping at the Basin F and/or boundary containment systems.

5. Random pressure disturbances occurred at ground level.

The actual cause of the water table elevation variability has not been determined.

Figure 3.1-1 presents the water level elevations measured approximately 48 hours prior to starting the extraction/injection. Water level elevations ranged from 5,139.70 ft mean sea level (msl) at Well I to 5,139.63 ft msl at Well E. It is difficult to interpret the background hydraulic gradient at the site from these data because of the extremely small elevation change exhibited across the horizontal extent of the site (30 ft), combined with the time-dependent variability. The flatness of the background water table at the site confirms the more regional estimate of 0.004 ft/ft obtained from the CMP data (RLSA, 1991; Section 2.1.1).

During the forced gradient portion of the test water level responses were minimal. Figure 3.1-2 presents the water table elevations measured 48 hours after starting the extraction/injection. The maximum elevation change occurs at the injection well (I) where water levels increased only 0.07 feet. Earlier hydraulic data indicate that this degree of water level response had occurred within three minutes from the start of extraction/injection, suggesting that a steady state was reached very quickly. This information is consistent with the hydraulic conductivity estimates (120 to 400 ft/day) discussed in section 2.1.1. However, this high hydraulic conductivity, combined with the time-dependent variability in the data, precludes accurate gradient calculations.



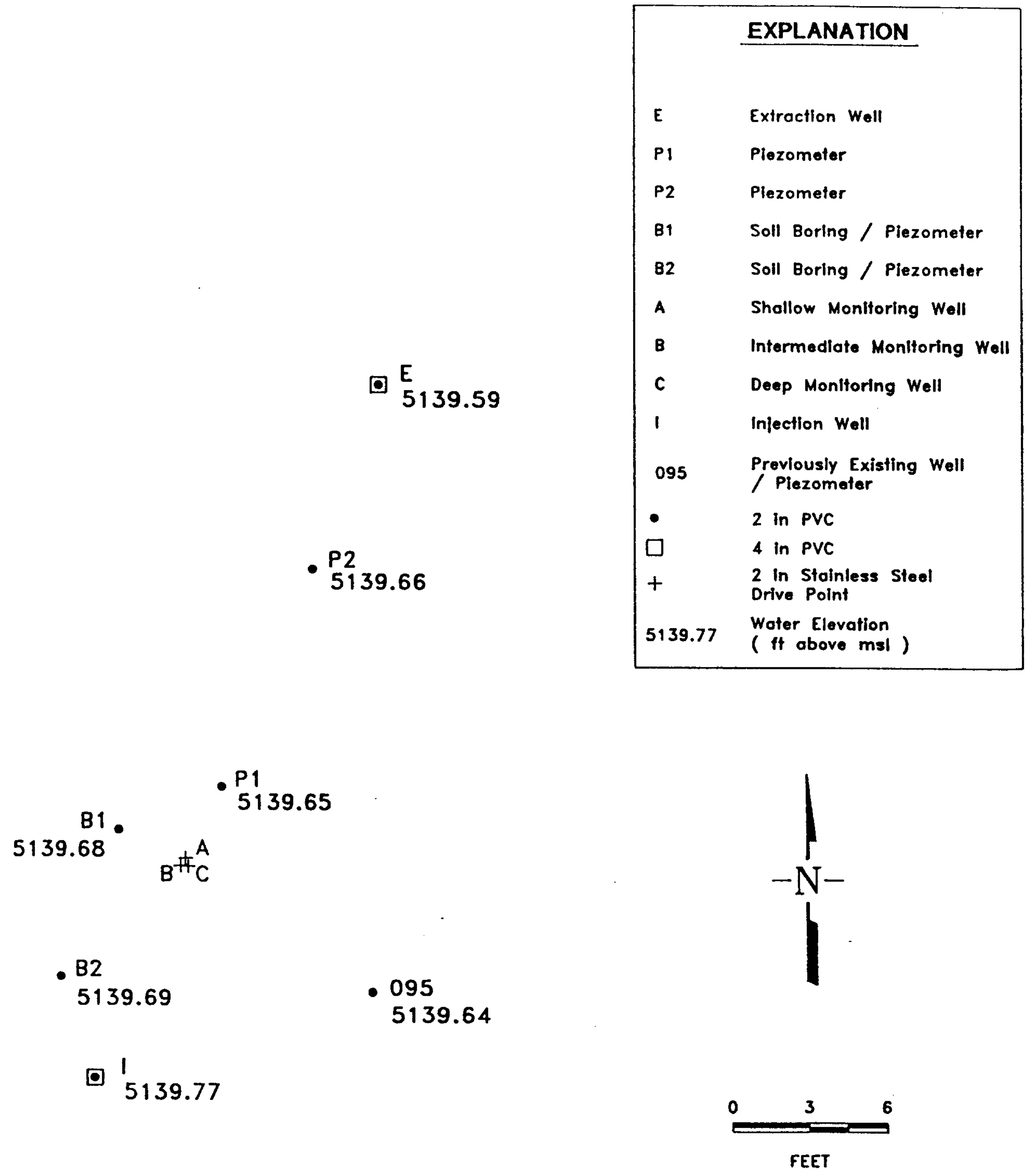
R.L. STOLLAR & ASSOCIATES INC.
Ground-Water Consultants

WATER TABLE ELEVATIONS APPROXIMATELY 48 HOURS PRIOR TO STARTING EXTRACTION / INJECTION

RMA TRC/692/31-1

Date: June 1992

Figure 3.1-1



R.L. STOLLAR & ASSOCIATES INC.
Ground-Water Consultants

WATER TABLE ELEVATIONS APPROXIMATELY 48 HOURS AFTER STARTING EXTRACTION / INJECTION

RMA TRC/692/31-2

Date: June 1992

Figure 3.1-2

3.1.2 CHEMISTRY

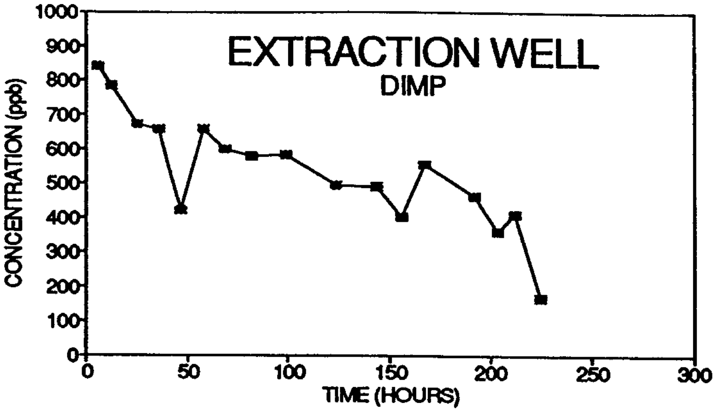
3.1.2.1 Treatment System Performance

The extracted water was reinjected after passage through a treatment train consisting of two consecutive GAC tanks with particulate filters before and after the tanks. Samples of the extracted and injected water were collected at a regular frequency.

The various frames of Figures 3.1-3 and 3.1-4 show the concentrations of several organic analytes versus time for the extraction and injection wells, respectively. Samples of water which had passed though the first GAC tank were also taken at a regular frequency in order to help identify the incipient failure of the carbon treatment system. However, since the failure occurred much earlier than anticipated (as discussed below), so the samples collected immediately downstream of the first GAC tank were of little use, and most were not analyzed.

Comparison of the frames in Figures 3.1-3 and 3.1-4 indicates that the treatment system was reducing the concentrations of the contaminants to below their detection limits for the first 125 hours of operation. This was also true for other target analytes not illustrated in Figures 3.1-3 and 3.1-4. In addition, yellowness in the contaminated ground water was absent in the injection water during this period. At about 125-150 hours, as shown in Figure 3.1-4, the carbon treatment system began to fail and the concentrations of chloroform, methylene chloride, TCA, and DIMP began to rise rapidly. These were the only detected organic analytes that broke through the carbon treatment system at significant concentrations. The failure of the treatment system was noted by on-site VOC analysis (detecting the chloroform initially) and by visual inspection of the injection water samples, which regained the yellow tint typical of the contaminated ground water at the site. The breakthrough of the organics occurred much earlier than was anticipated. The carbon supplier had estimated that the system would provide organic-contaminant-free injection water for up to 2 months; their estimate, however, was based on historical chemistry data which does not quantify the high levels of uncharacterized dissolved organic carbon, identified later in this experiment. The uncharacterized dissolved organic carbon apparently affected the efficiency of the activated carbon treatment.

When the breakthrough of the VOCs was noticed, it was not known whether any of the semivolatiles were also breaking through; such information was not obtained for several weeks after the regular turn around



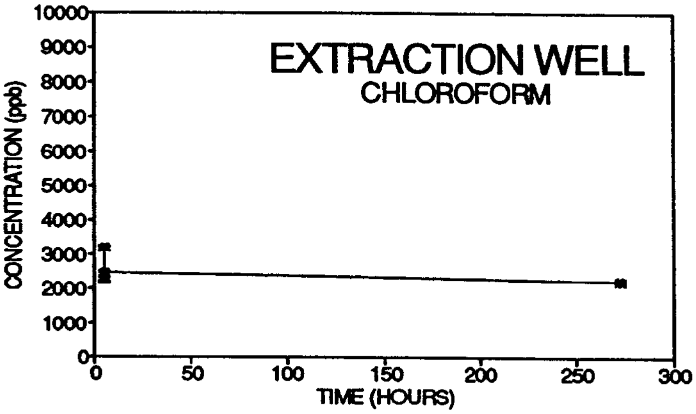
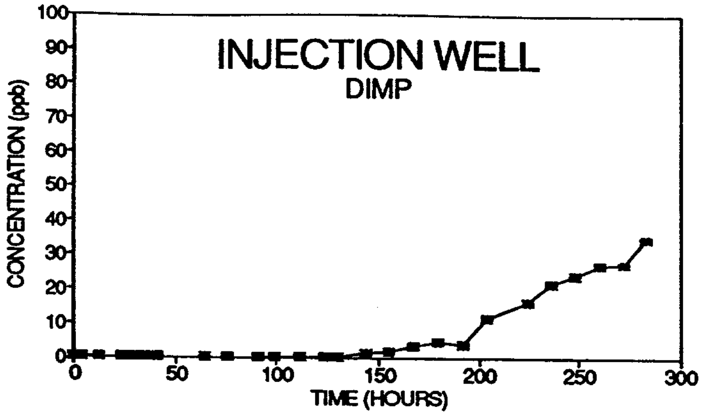
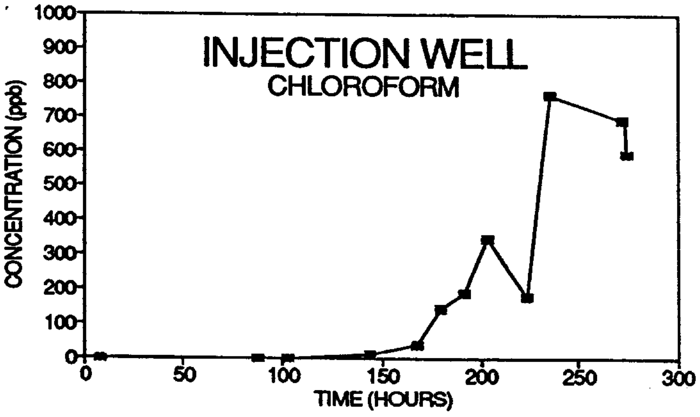


Figure 3.1-3 Concentration Histories of DIMP and Chloroform in the Extraction Well.





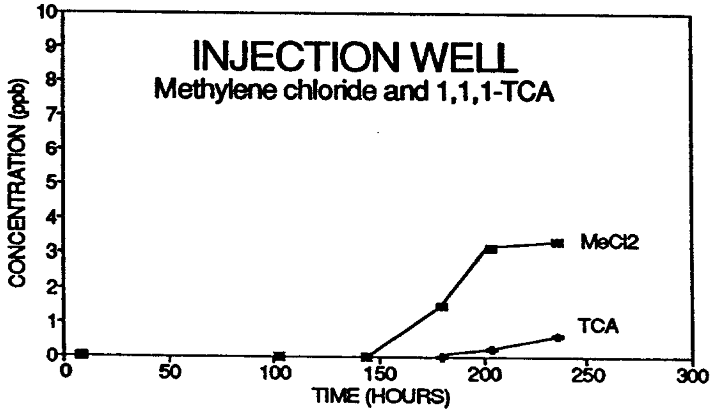


Figure 3.1-4 Concentration Histories of DIMP, Chloroform, Methylene Chloride and 1,1,1-Trichloroethane in the Injection Well. Note that the carbon treatment system reached capacity for these compounds, which were then recycled into the injection well, after about 100 hours.

time for analysis at the USGS laboratory. However, after consultation with the Program Manager's Office (PMO) project officer and others, the decision was made to stop the extraction and injection. The primary reason for this decision was to avoid reinjecting the contaminants, which would confound the interpretation of the results. A significant concern, however, was that by stopping the experiment so early, the opportunity to observe the flushing of some of the more hydrophobic and presumably less mobile contaminants would be lost. As discussed later, this concern turned out to be unwarranted.

3.1.2.2 Tracer injection

The injected water was spiked with LiBr from 0-62 hours. The bromide ion (Br^-) was included as a conservative tracer and thus is of primary interest for this report. The behavior of the lithium ion (Li^+) was primarily of academic interest; for this reason and also because the lithium analyses have yet to be completed (they are being conducted under separate funding), the lithium results are not discussed in this report.

The top frame of Figure 3.1-5 shows that the spiking system achieved the desired result, i.e., a bromide concentration in the injected water that was reasonably constant at about 275 mg/L during the spiking interval. As evident in the lower frame of Figure 3.1-5, the injected bromide began to appear in the extraction well sometime between 50 and 75 hours. Since the bromide was not removed by the activated carbon treatment system, the extracted bromide was recycled into the injection well. This recycling is the cause of the elevated bromide concentration in the injection well which exists after the initial bromide spike until about 278 hours. From 278.12 to 281.62 hours, a second spike of bromide was added to the injection line, resulting in the concentration rise to about 500 mg/L in the top frame of Figure 3.1-5. This final spike was added to aid in interpreting data collected from the monitoring points after the injection-extraction system was shut off at 281.62 hours; the period after 281.62 hours is hereafter referred to as the natural-gradient portion of the experiment.

Figures 3.1-6 and 3.1-7 present the alkalinity, dissolved oxygen (DO) and pH measured in the extraction and injection wells. Both alkalinity and pH are relatively constant in the water pumped from the extraction well and the water pumped into the injection well during the period they were measured. The DO, however, changed slightly with time in both wells. The DO in the water pumped from the extraction well started at a relatively high value, considering the background monitoring (Section 2.2.1)

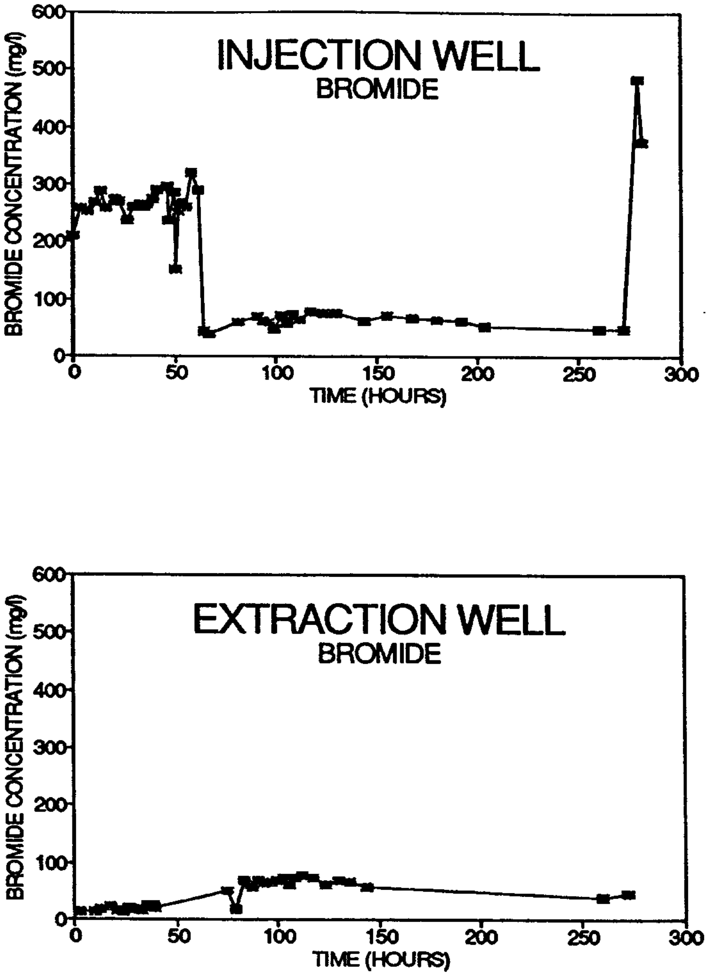
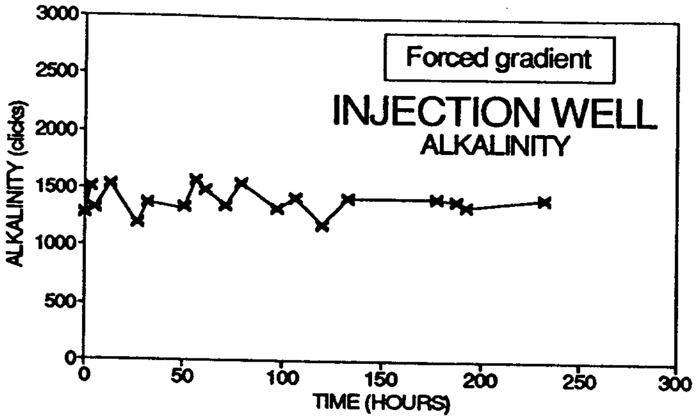


Figure 3.1-5 Concentration Histories of the Bromide Tracer in the Injection Well and the Extraction Well During the Forced-Gradient Portion of the Experiment.



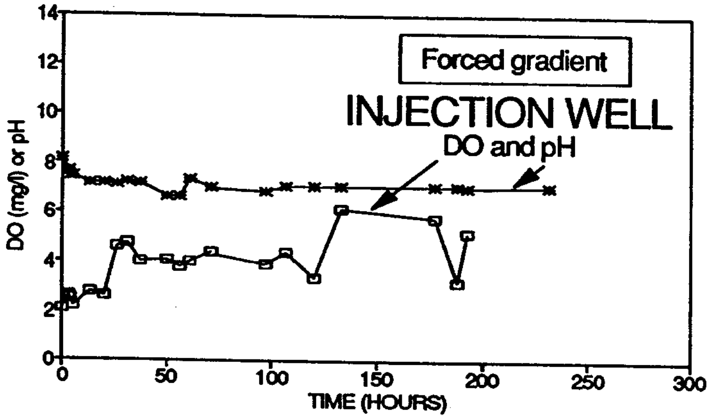
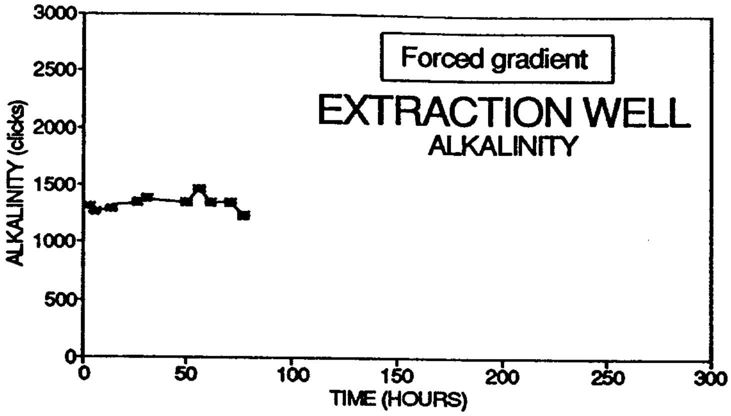


Figure 3.1-6 Concentration Histories of Alkalinity, Dissolved Oxygen (DO) and pH in the Injection Well During the Forced-Gradient Portion of the Experiment.



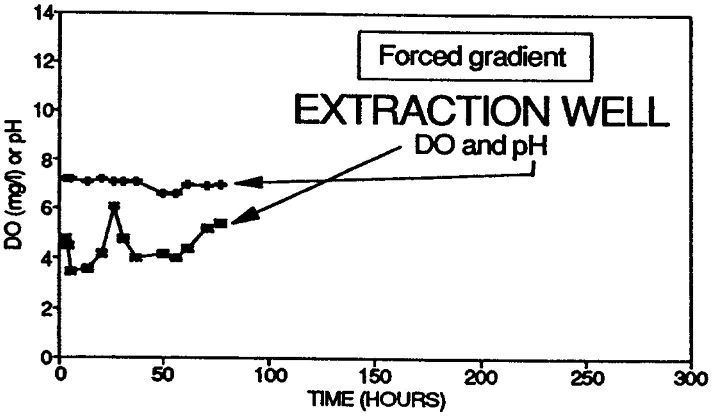


Figure 3.1-7 Concentration Histories of Alkalinity, Dissolved Oxygen (DO) and pH in the Extraction Well During the Forced-Gradient Portion of the Experiment.

which indicated that background DO was quite low (2 mg/L) throughout the aquifer. This elevated DO in the extracted water which was almost certainly due to aeration of the water within the well bore resulting from a portion of the extracted water which was wasted back into the extraction well in order to achieve an overall extraction rate of 4 gpm with a pump capable of a considerably higher flow rate. As the water cascaded back down the well bore from the surface, it would certainly have been aerated.

For the first 20 hours or so, the DO in the injected water was significantly lower than measured in the extracted water. This suggests that oxygen was consumed in the activated carbon tanks during this period. Nevertheless, the DO in the injected water was significantly higher than that within the aquifer. Thus the injected DO serves as an additional signal and, indeed, a DO increase is noted in limited samples from the extraction well after about 50 hours, at roughly the same time the bromide appears (compare DO in Figure 3.1-6 with Bromide in Figure 3.1-5). This suggests that DO may behave relatively conservatively in the aquifer, at least under the conditions and over the short time frame of this experiment. This observation is consistent with observations noted at other (although relatively uncontaminated) sites (Roberts, 1990). This observation suggests that oxygen-consuming reactions, if they occurred at all within the aquifer, were relatively insignificant during the forced-gradient portion of the experiment. Examples of potential oxygen-consuming reactions of interest would be biochemical oxidation of some of the organic constituents in the water or chemical oxidation of reduced mineral species.

3.1.2.3 Aquifer monitoring

3.1.2.3.1 Tracer advection

As mentioned previously, the aquifer chemistry was monitored via 1) a cluster of three partially-penetrating wells (A, B, and C) spanning the full aquifer thickness at one location approximately 10 ft. from the injection well, and 2) a fully-penetrating well approximately 13 ft. from the injection well.

Figure 3.1-8 presents the breakthrough curves for the bromide tracer at Wells A, B, and C. It is evident that breakthrough is fastest in Well B and slowest in Well A, indicating a slight vertical variation in hydraulic conductivity in the aquifer. In Wells B and C, the bromide concentration peaks at or near the initial injected concentration of approximately 250-300 mg/L. In Well A, the breakthrough curve appears to be made up of a series of pulses, perhaps representing different rate travel through various strata within

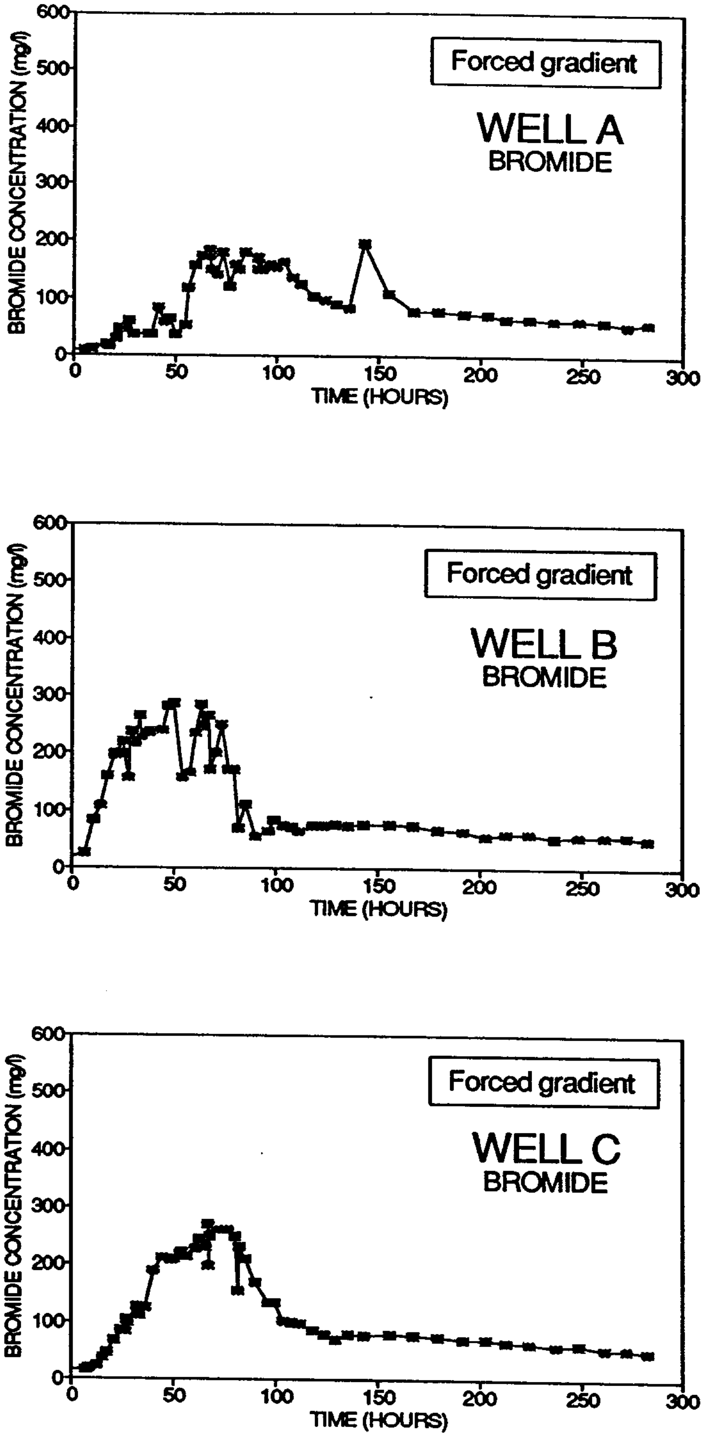


Figure 3.1-8 Bromide Breakthrough Curves for Wells A, B and C. The different positions of the breakthrough curves indicate that there is some variability in hydraulic conductivity with depth in the aquifer. Water (and bromide) travelled fastest in strata sampled by Well B; overall, travel was slowest in strata sampled by Well A.

the depth interval sampled by the well. Overall, the breakthrough curve in Well A is more dispersed than in Wells B and C, and the peak concentration does not reach the initially injected value. The breakthrough curves for all three of the wells have long tail which result from the recirculation of the bromide tracer from the extraction well into the injection well. The tails all reach the same plateau of about 60-80 mg/L as observed in the injection well. Overall, the tracer behavior in Wells A, B, and C indicates that the injected water swept through the entire vertical interval sampled by these wells, i.e. through the entire saturated thickness of the aquifer.

Figure 3.1-9 presents the breakthrough curve for bromide in Well P1. Monitoring for the Bromide Tracer at Well P1 was not started until the collection of colloidal samples, so only the falling side of the bromide pulse was detected. As was the case for Wells A, B, and C, the concentration of bromide in Well P1 drops to a plateau which represents the recirculated bromide. These limited data, indicate that the injected also swept through the entire interval sampled by Well P1, which screens the entire saturated thickness of the permeable aquifer. This also supports the conclusion that the injected water swept through the entire saturated thickness of the aquifer.

3.1.2.3.2 Changes in geochemistry

The three frames of Figure 3.1-10 present bromide, alkalinity, dissolved oxygen (DO) and pH versus time in Well A. Figures 3.1-11 and 3.1-12 present the same plots for Wells B and C, respectively. The behavior of the alkalinity is consistent with the fact that the aquifer was initially stratified with respect to alkalinity, with alkalinity increasing with depth (Section 2.2.2). The alkalinity in the extracted and injected water is in a sense an average of that in the aquifer, since the extraction well draws from the entire aquifer thickness. Thus, the alkalinity of the injected water (approximately 1500 μg/L) is higher than initially present in the upper portion of the aquifer sampled by Well A (approximately 600 μg/L). Figure 3.1-10 shows that the alkalinity in Well A gradually increases to that of the injected water, with the change occurring over the same time interval that the bromide pulse is detected.

In Well B, the initial alkalinity (approximately 900 μg/L) is lower than that of the injected water. Figure 3.1-11 shows that the alkalinity rises rapidly to that of the injected water, essentially over the same time interval that bromide breaks through at the well. In Well C (Figure 3.1-12), the initial alkalinity is higher than that of the injected well, so the alkalinity decreases to the injection value at the same time as the

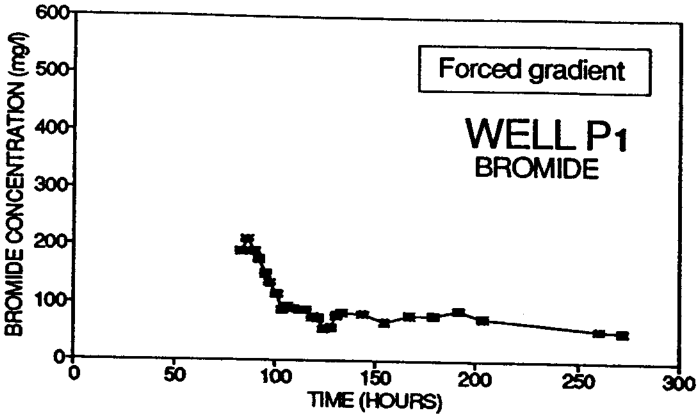


Figure 3.1-9 Bromide Breakthrough Curve for Well P1.

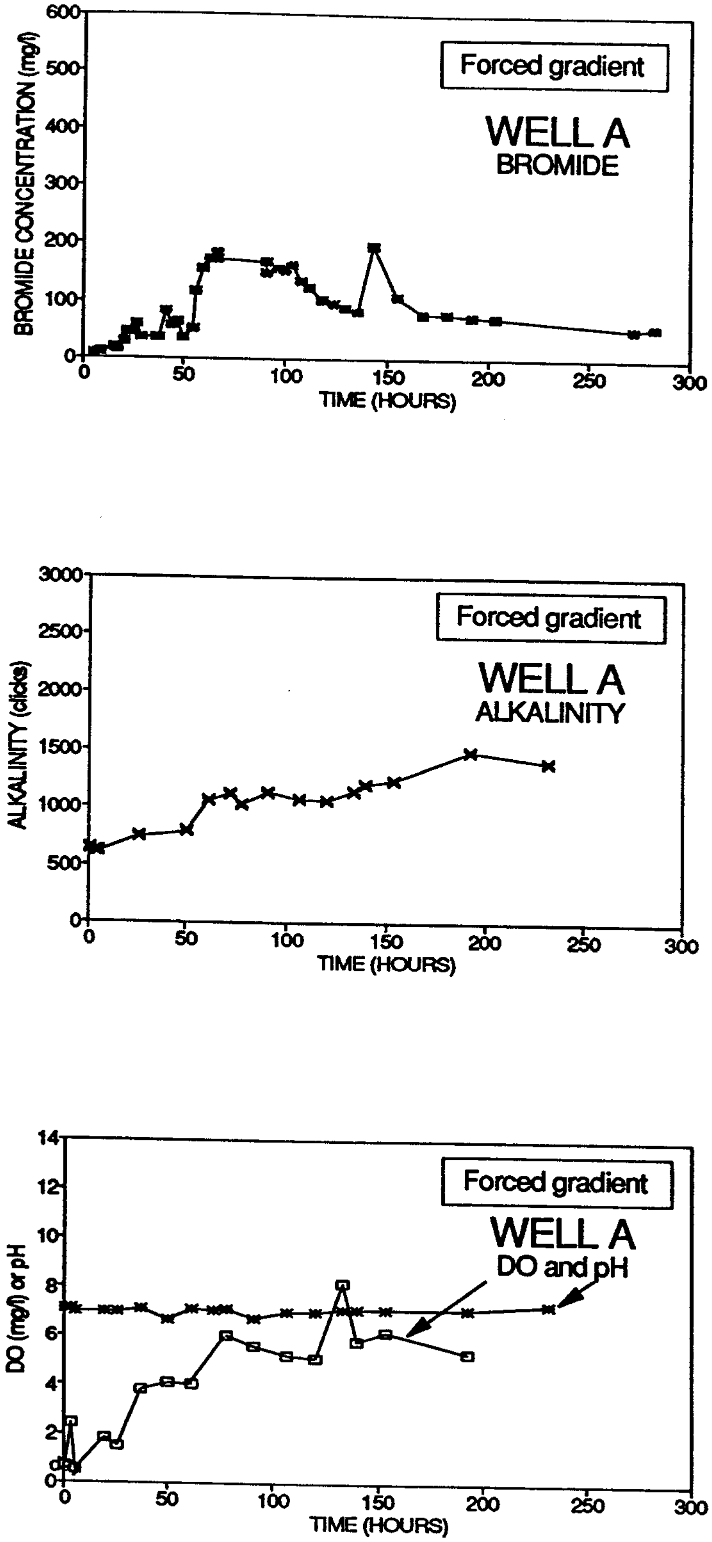


Figure 3.1-10 Concentration Histories of Bromide, Alkalinity, Dissolved Oxygen (DO) and pH at Well A During the Forced-Gradient Portion of the Experiment.

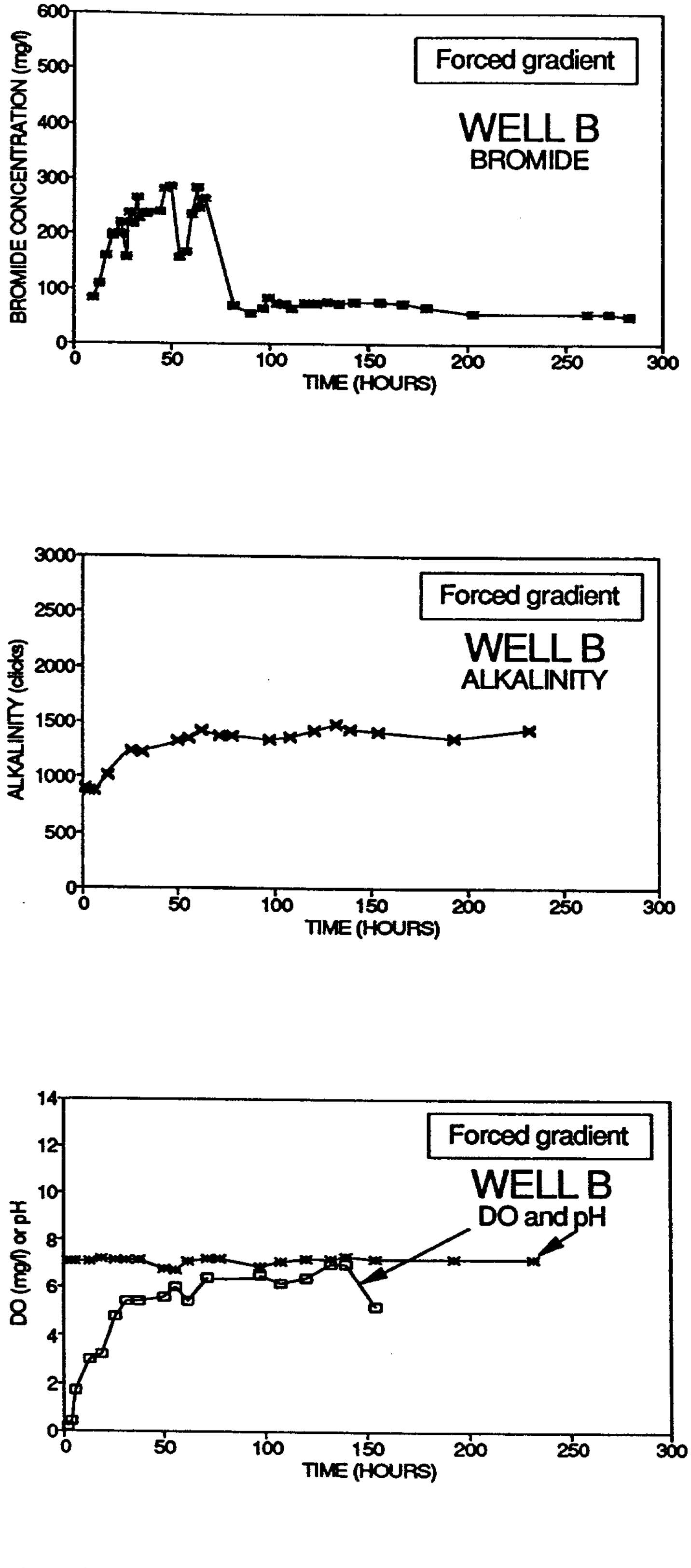
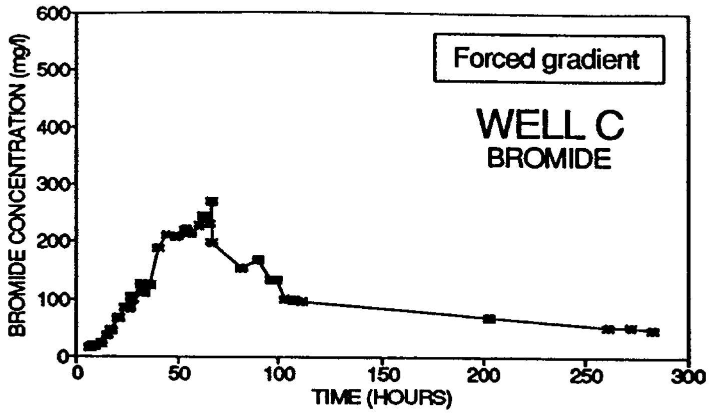
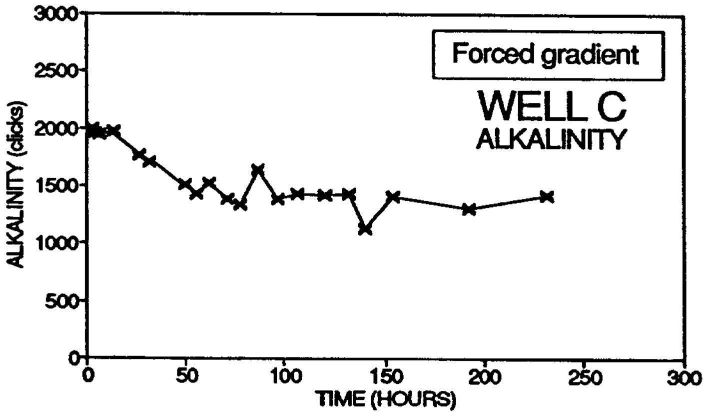


Figure 3.1-11 Concentration Histories of Bromide, Alkalinity, Dissolved Oxygen (DO) and pH at Well B During the Forced-Gradient Portion of the Experiment.





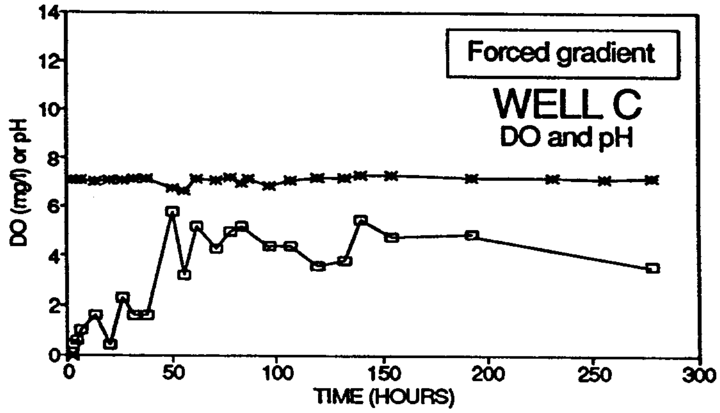


Figure 3.1-12 Concentration Histories of Bromide, Alkalinity, Dissolved Oxygen (DO) and pH at Well C During the Forced-Gradient Portion of the Experiment.

bromide breaks through. Because alkalinity is a conservative quantity, the convergence of alkalinity values reflects the depth interval mixing of extracted ground water prior to reinjection.

The behavior of DO in all three wells is similar. The initial values are very low, as found in the analyses of the depth discrete samples prior to the experiment. The DO rises in each of the wells at roughly the same time that the bromide arrives, reaching a plateau approximately equal to the DO in the injected water. This is another indication that there are no oxygen-consuming reactions occurring at a significant rate in any depth interval of the aquifer during the forced-gradient portion of the experiment.

3.1.2.3.3 Flushing of the organic contaminants

· Well A. The contaminants were flushed from the aquifer by the injected, initially contaminant-free water. Figure 3.1-13 illustrates the flushing (elution) of DIMP, CPM sulfone and dieldrin from the strata monitored by Well A. Despite the marked difference in properties (solubility, octanol-water partition coefficient, etc.) of the first two compared to those of dieldrin, the three contaminants were apparently flushed from the aquifer at essentially the same rate. Concentrations of all three contaminants began to decrease significantly at about 25 hours, roughly the same time as the bromide tracer (i.e. the injected water) began to arrive at the well (Figure 3.1-13). The concentrations of all three contaminants were reduced to very low levels by 150-200 hours, which corresponds relatively well to the concentration plateau in the bromide breakthrough curve during the same time interval (Figure 3.1-13). The low concentration tail on the DIMP elution curve beyond 150 hours resulted largely from the reinjection of DIMP due to failure of the treatment system described earlier (see Figure 3.1-4).

Figure 3.1-14 illustrates the concentration histories of chloroform, DPCD, TCE and PCE in the strata sampled by Well A. Since there was little chloroform in these strata initially, the first frame shows primarily the arrival at approximately 200 hours of the chloroform that was injected after about 150 hours due to failure of the treatment system (see Figure 3.1-4). For the other contaminants in Figure 3.1-14, which were initially present in the strata in significant concentrations, it is again observed that flushing is apparently complete after about 150 hours.

Figure 3.1-15 illustrates the flushing of tetrachlorobenzene and two multihalogenated unknowns. These, like dieldrin, would normally be expected to be retarded in their migration through the aquifer.

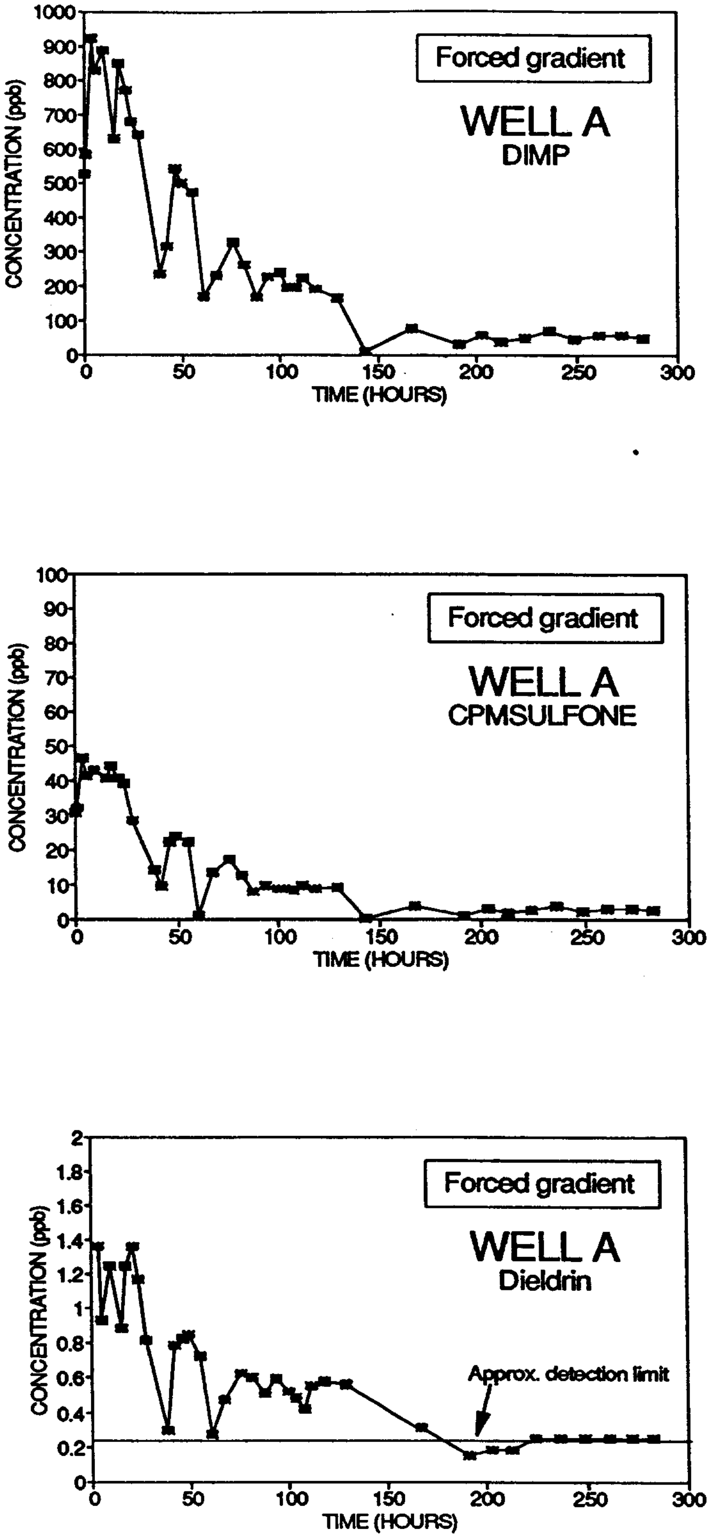
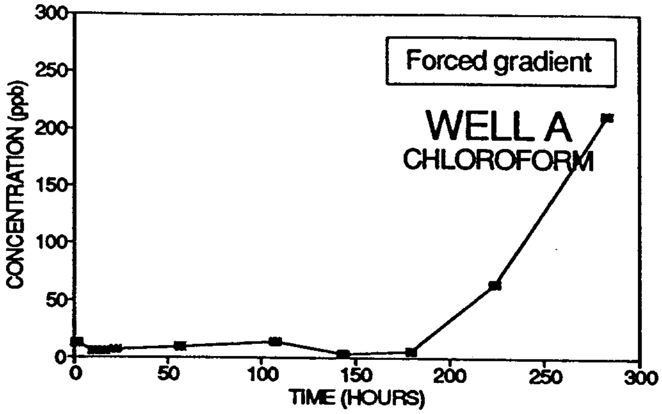
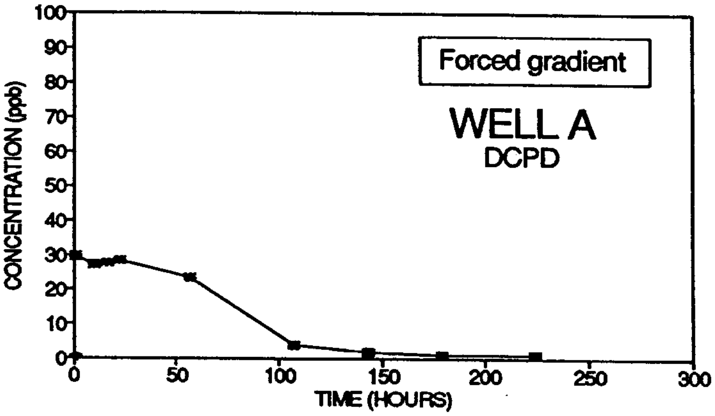


Figure 3.1-13 Elution Curves at Well A for DIMP, CPM Sulfone and Dieldrin During the Forced-Gradient Portion of the Experiment.





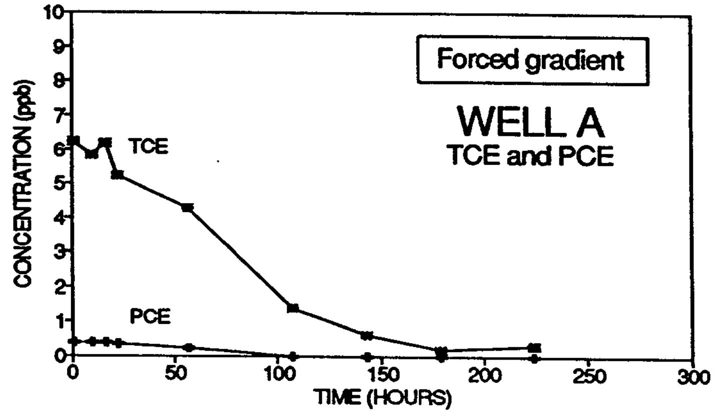
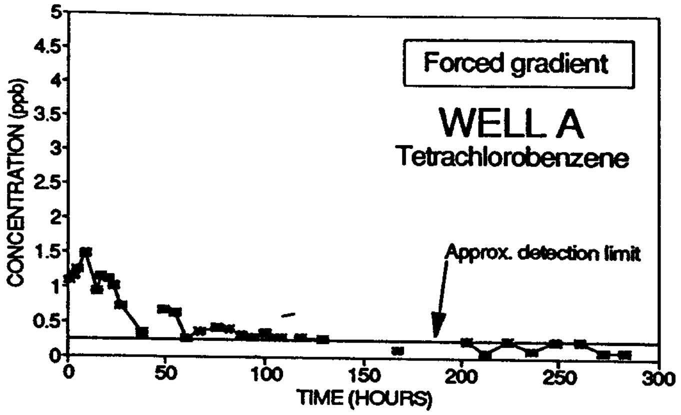
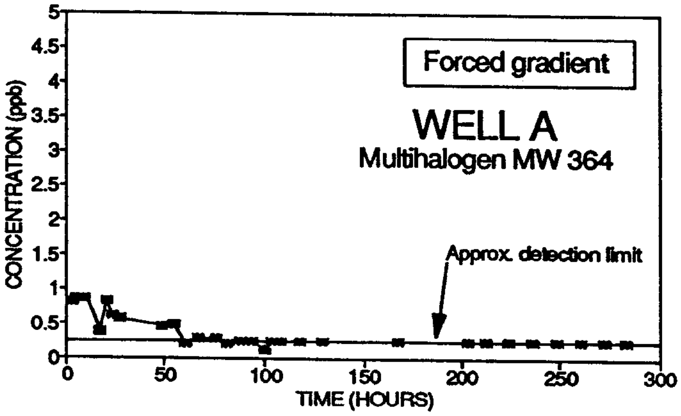


Figure 3.1-14 Elution Curves at Well A for Chloroform, Dicyclopentadiene, Trichloroethylene and Tetrachloroethylene During the Forced-Gradient Portion of the Experiment.





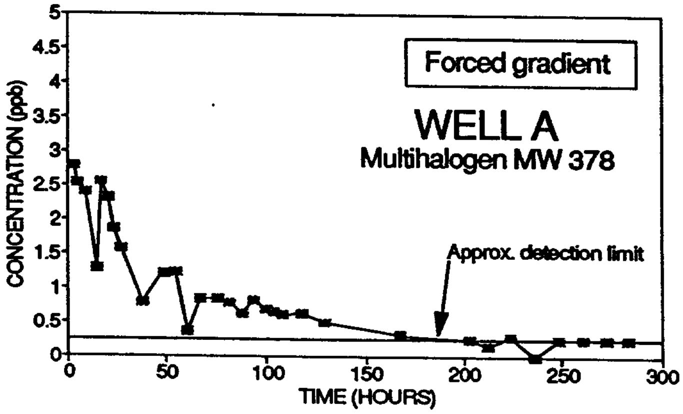


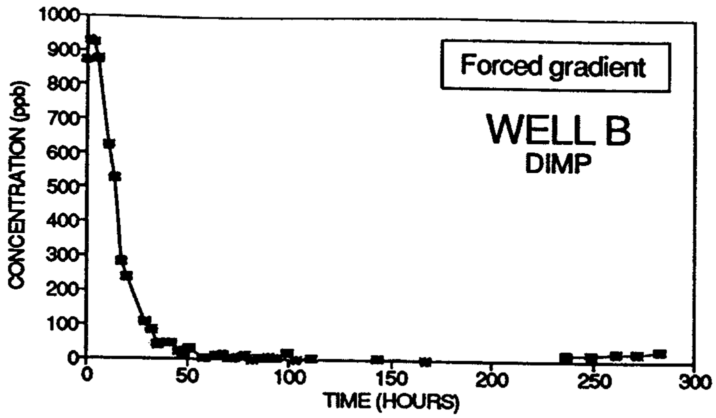
Figure 3.1-15 Elution Curves for Tetrachlorobenzene and Two Unknown Multihalogenated Compounds the During Forced-Gradient Portion of the Experiment.

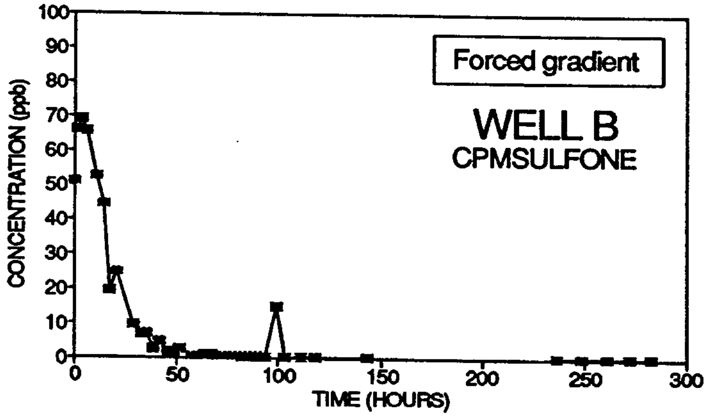
However, they too are apparently flushed from the aquifer at the same rate as the clean water migrates through. Ground-water concentrations of all three decrease to the detection limit by about 150 hours.

- Well B. Figure 3.1-16 shows the rapid elution of DIMP, CPM sulfone and dieldrin from the strata sampled by Well B. The concentrations of all three were reduced essentially to the detection limit by 50 hours, which is roughly the same time as the maximum of the bromide peak (see Figure 3.1-11). Figure 3.1-17 shows equally rapid elution of chloroform, dicyclopentadiene, trichloroethylene and tetrachloroethylene. The rise in chloroform concentrations after 150 hours is certainly a result of the reinjection of chloroform after 150 hours. The final data point for the TCE curve (approximately 270 hours) is likely to be an analytical artifact since there was no evidence that TCE was reinjected or ever broke through the treatment system. Figure 3.1-17 shows rapid elution of tetrachlorobenzene and the two unknown multihalogenated compounds; the ground-water concentrations of all three were reduced to the detection limit by about 45 hours. Although no monitoring data were available for these three compounds for the period 50-230 hours, the confirmation of non-detection thereafter (Figure 3.1-18) suggests that the elution behavior of these compounds was probably similar to that of the others.

- Well C. Figure 3.1-19 shows that the ground-water concentrations of DIMP, CPM sulfone and dieldrin are reduced in strata sampled by Well C to very low values by about 100 hours. This is roughly equal to the mean arrival time of the injected water, judging from the shape of the bromide peak and the plateaus of the alkalinity and dissolved oxygen changes in Figure 3.1-12. Figure 3.1-20 shows that elution of chloroform, dicyclopentadiene, trichloroethylene and tetrachloroethylene also occurred by about 100 hours. Figure 3.1-21 shows that the elution of tetrachlorobenzene and the two unknown multihalogenated compounds may have occurred at roughly the same rate, with the groundwater concentrations at or below the detection limit by 60 hours. Figures 3.1-22 and 3.1-23 tell the same story for several other compounds that were detected in significant concentrations only in the strata sampled by Well C: benzene, o-xylene, bicycloheptadiene, pentachloro-1,3-butadiene, CPM sulfide and CPM sulfoxide. Ground-water concentrations of these contaminants were reduced to low or non-detect values by 70-100 hours.

- Well P1. As described earlier, monitoring Well P1 was begun after 85 hours in conjunction with the collection of colloid samples. Apparently, contrary to preliminary estimated elution rates, all significant concentration decreases had occurred at Well P1 by this time. Numerous analyses of the semivolatiles confirm that the concentrations were at or below the detection limit for many of the analytes (e.g. tetrachlorobenzene, CPM sulfoxide and the unknown multihalogenated compounds). Plots of the data are therefore relatively uninteresting and are not included herein.





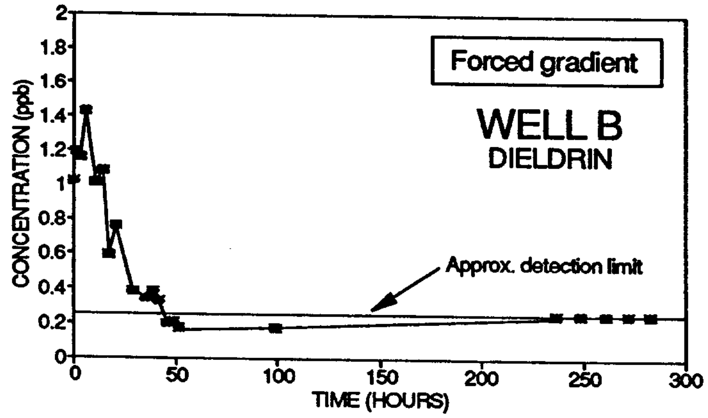


Figure 3.1-16 Elution Curves at Well B for DIMP, CPM Sulfone and Dieldrin During the Forced-Gradient Portion of the Experiment.

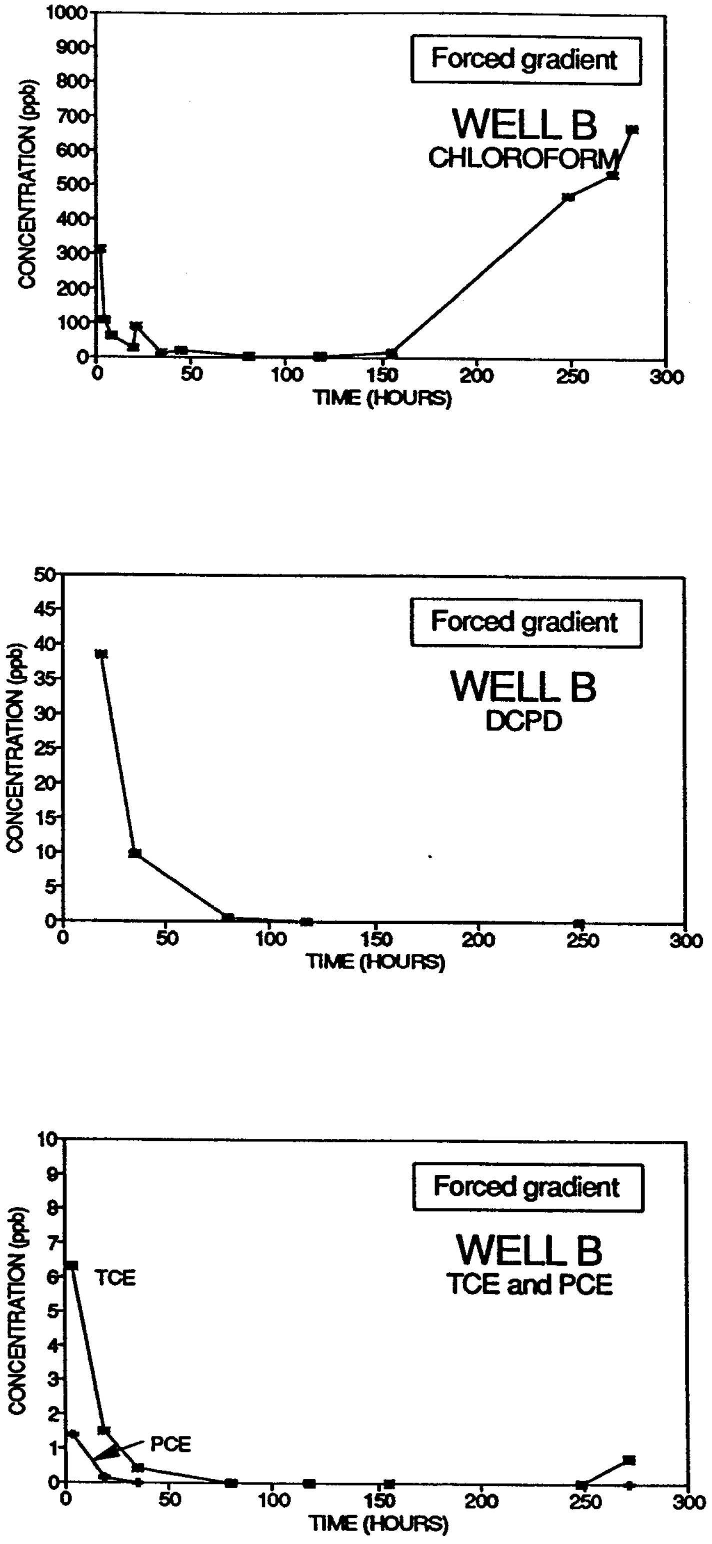
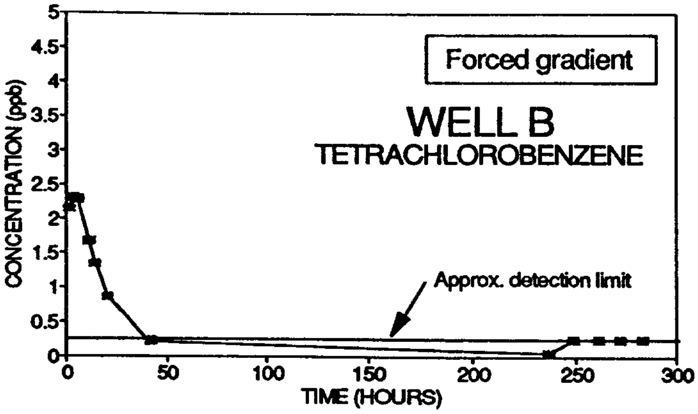
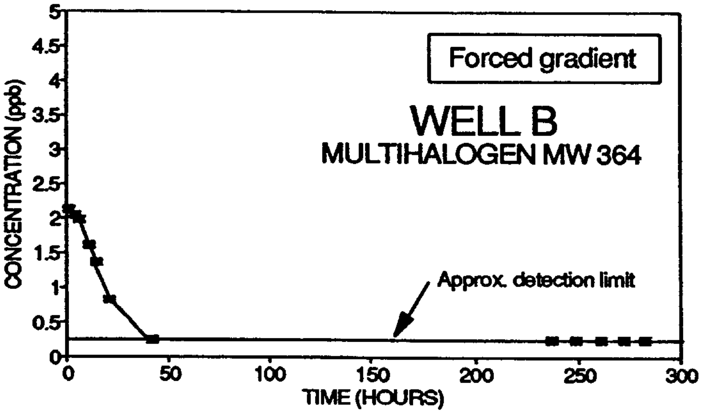


Figure 3.1-17 Elution Curves at Well B for Chloroform, Dicyclopentadiene, Trichloroethene and Tetrachloroethene During the Forced-Gradient Portion of the Experiment.





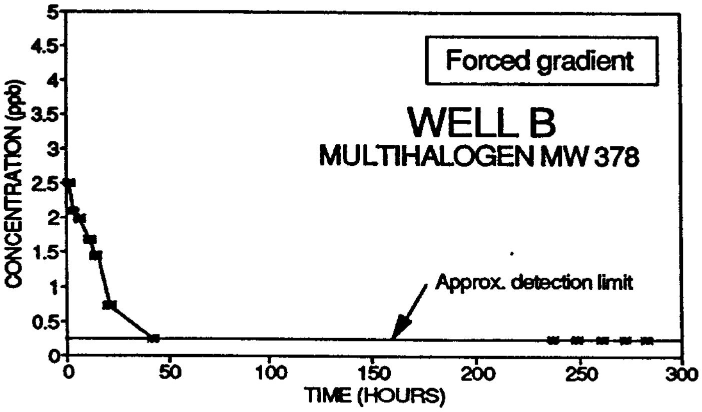
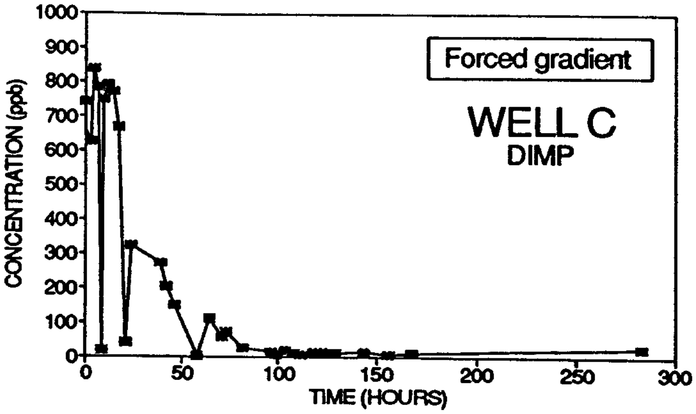
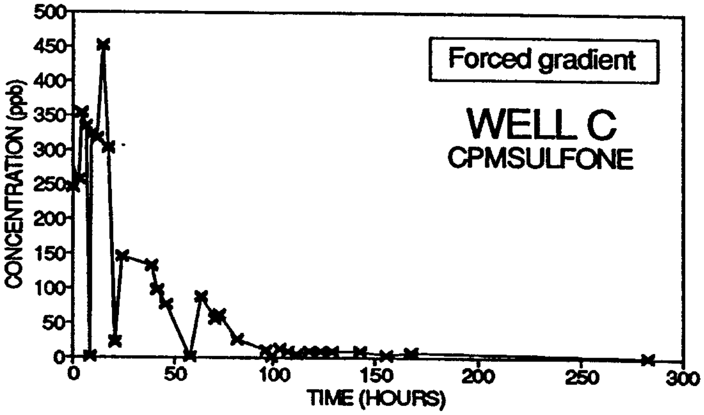


Figure 3.1-18 Elution Curves at Well B for Tetrachlorobenzene and Two Unknown Multihalogenated Compounds During Forced-Gradient Portion of Experiment.





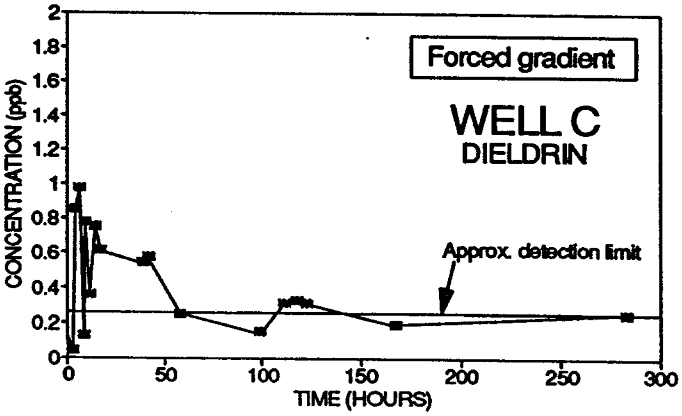
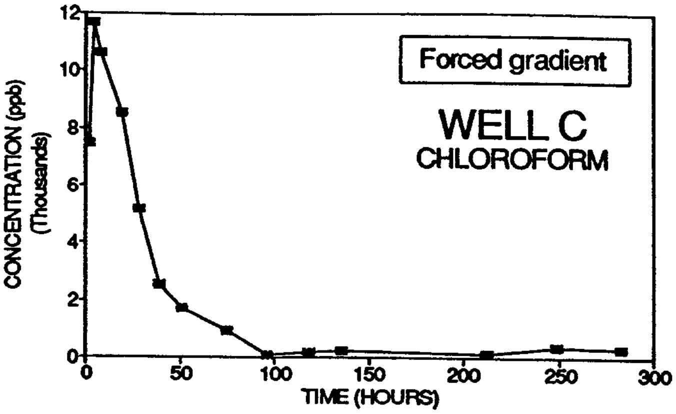
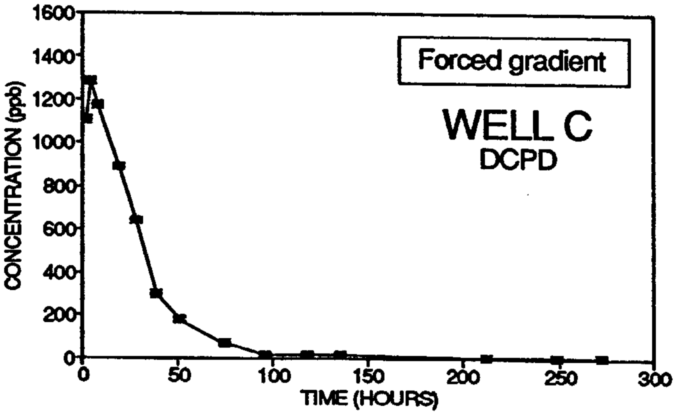


Figure 3.1-19 Elution Curves at Well C for DIMP, CPM Sulfone and Dieldrin During the Forced-Gradient Portion of the Experiment.





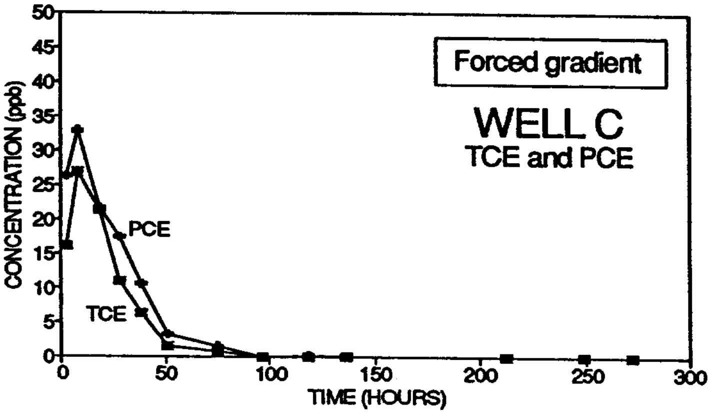


Figure 3.1-20 Elution Curves at Well C for Chloroform, Dicyclopentadiene, Trichloroethene and Tetrachloroethene During the Forced-Gradient Portion of the Experiment.

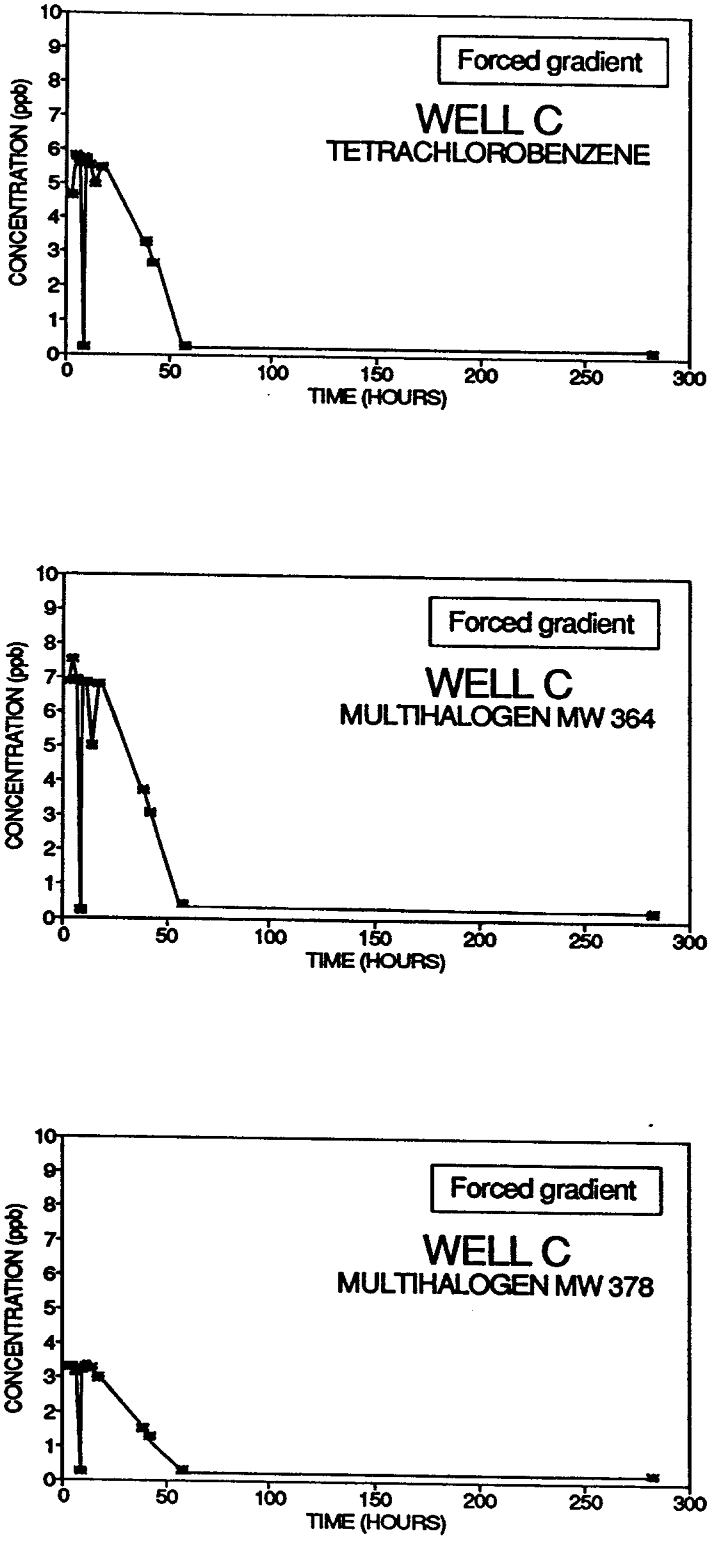


Figure 3.1-21 Elution Curves at Well C for Tetrachlorobenzene and Two Unknown Multihalogenated Compounds During the Forced-Gradient Portion of the Experiment.

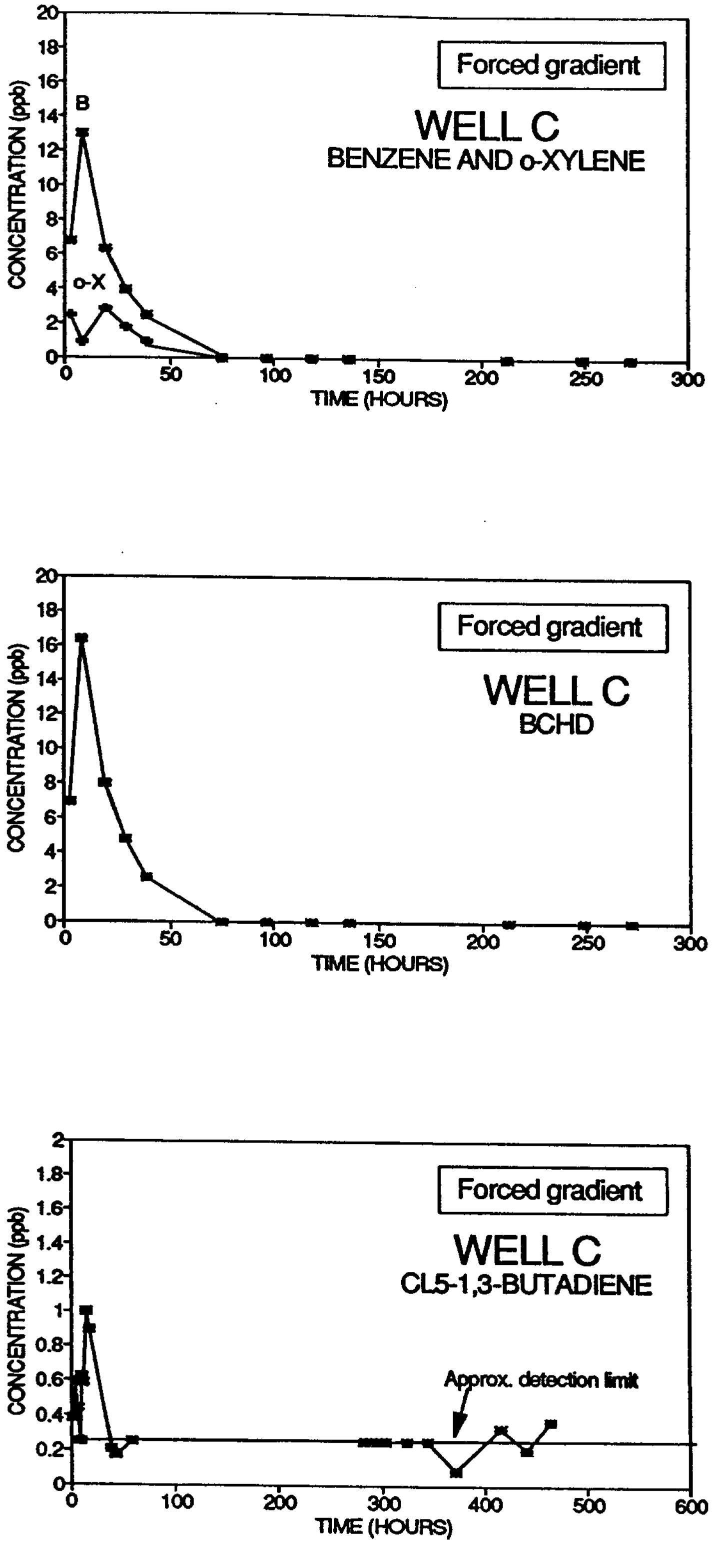


Figure 3.1-22 Elution Curves at Well C for Benzene, o-Xylene, Bicylcoheptadiene (BCHD) and an Unknown Isomer of Pentachloro-1,3-butadiene During the Forced-Gradient Portion of the Experiment.

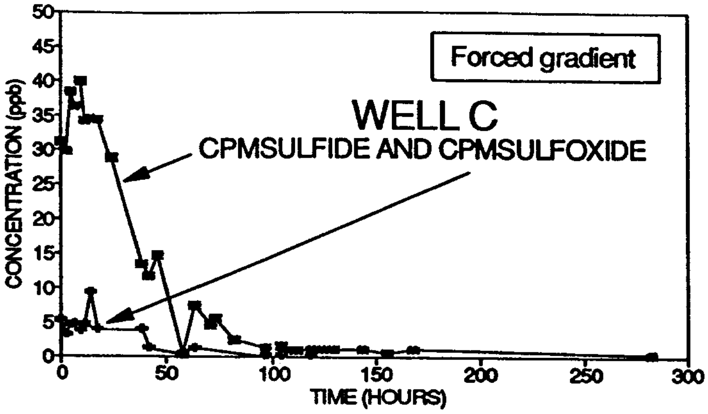


Figure 3.1-23 Elution Curves at Well C for CPM Sulfide and CPM Sulfoxide During the Forced-Gradient Portion of the Experiment.

3.1.2.3.4 Colloids

The analytical procedure for separating colloidal (10,000 Dalton <0.4 µm) material from bulk solution (discussed in Section 2.2.5) was implemented four times; 1) on the pre-experiment ground-water fluids (reported in Table 2.2-3); 2) on the injection (i.e., post-treatment) fluids; 3) at Well P1, 64 hours into the injection experiment; 4) again at P1, 114 hours into the experiment. These samples correspond to sample numbers B-1 through B-4 in Table 3.1-1.

The background DOC concentration, that is, the in situ, pre-experiment concentration, of the aquifer fluid was about 93 mg/L; the injection water had a DOC of 8.6 mg/L. In comparison, post pre-filter DOC values for the aquifer fluids sampled at 64 and 114 hours after injection show DOC levels roughly intermediate between the two end members: this suggests a mixing of injection and in situ fluid masses. Colloid organic carbon concentration values are, for both of the samples taken during the injection period, higher than are the background levels, suggesting some mobilization of colloidal material.

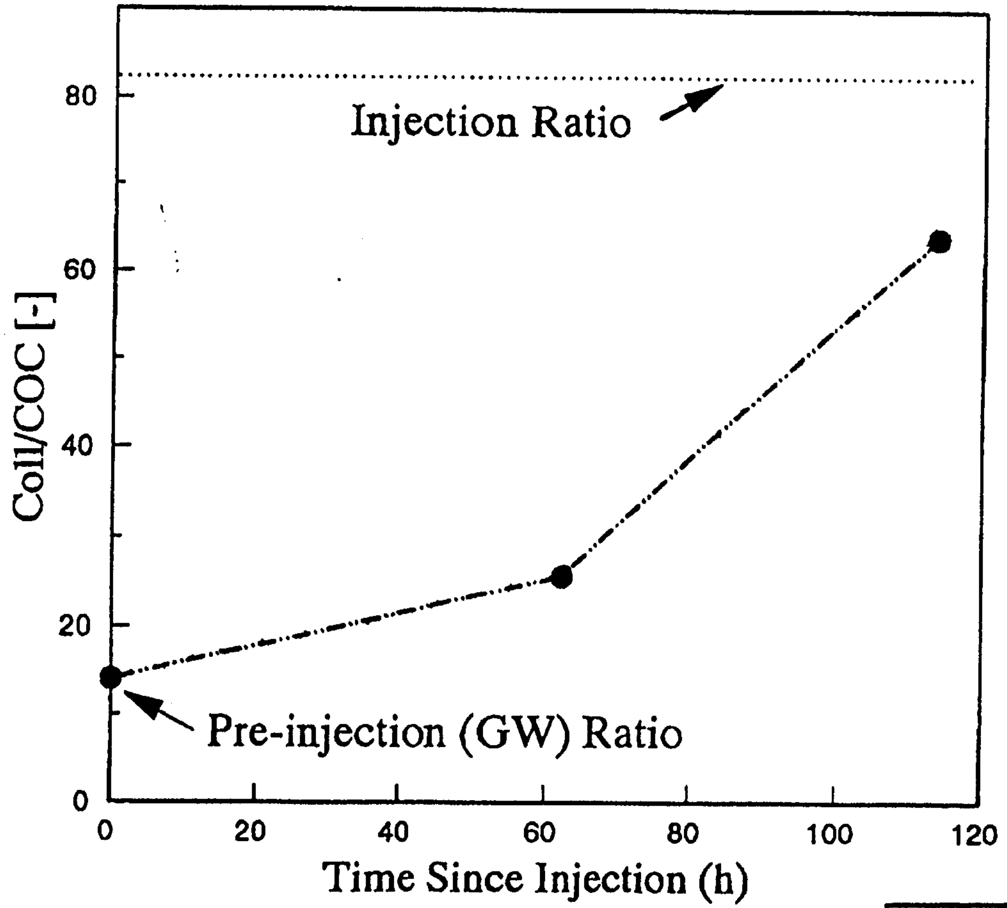
The ratio of colloid mass (Coll) to the organic carbon content of the colloids (COC) in the background (pre-injection) fluids is 14 (Table 3.1-1; 2.2-3). Natural organic material, e.g., humic and fulvic substances, have mass-to-carbon ratios of about 2.5; thus, the colloidal material of the study site is significantly carbon-poor compared to substances of natural origin. An even greater departure from natural material is seen with the colloids remaining in the post-treatment system: not only was the mass of colloidal material reduced via the treatment, but the colloids were significantly depleted in carbon content (a Coll/COC ratio of 82 compared to 14). Fluid samples taken during the injection experiment show ratios intermediate between the two end members, and exhibit a progression from the background value to the injection value, with time. Coll/COC ratios are shown as a function of time in Figure 3.1-24. These data strongly suggest that the Coll/COC ratio of the colloidal material, particularly the highly carbon-depleted injection fluid colloids, can be used to trace colloid movement through the aquifer system.

The data presented in Figure 3.1-25 are compared to those for bromide (Br), a presumably conservative tracer. Bromide breakthrough occurred more rapidly at P1 than anticipated and the data reflect the "back" side of the bromide pulse. Although the leading edge of the bromide tracer pulse is missing, the data suggest that the colloidal material is substantially retarded relative to bromide.

Table 3.1-1 Summary of Baseline Colloid Information

Date	Sample	Volume (1)	DOC (mg/L) (in sample)	DOC (mg/L) in situ	SD (mg/L)	TOC(mg) (mg/L x l)	% PFW [-]	Coll(mg) (sum)	COC(mg) (sum)	Coll/COC [-]	t since inj. (h)
10/11/91	B-1PFW1	107.5	93.53	93.53	2.09	10054					
	B-1PFW2	107.5	93.23	93.23	3.72	10022					
	B-1COL	0.89	44.89	0.37	0.47	40	0.40	560	40	14.0	0
	B-1UFW	106.5	84.98	84.98	1	9050	90.30				
11/03/91	B-2-PFW	202.9	8.65	8.65	0.32	1755					
	B-2-COL	0.68	15.87	0.1	0.26	11	0.61	885.4	11	82.0	0
	B-2UFW	201.9	14.92	14.92	0.17	3012	171.64				
11/05/91	B-3FPW	110.2	53.18	53.18	1.64	5860					
	B-3-COL	1.18	161.2	0.94	2.09	190	3.25	4880	190	25.7	64.17
	B-3-UFW	109	43.07	43.07	0.13	4695	80.11				
11/07/91	B-4-PFW	135.9	49.05	49.05	0.66	6666					
	B-4-COL	0.85	122.4	0.94	1.31	104	1.56	6642	104	63.8	113.67
	B-4-UFW	134.8	50.46	50.46	0.52	6807	102.12				

PFW1:	Prefilter Water (original sample)
PFW2:	Prefilter Water (duplicate of PFW1)
COL:	Colloids
UFW:	Ultra Filtrate Water
Volume:	Volume of aquifer fluid in each fraction; PFW is the total volume pumped; COL is the final colloid retentate volume.
DOC:	"Dissolved" organic carbon concentration in each fraction.
DOC(in situ):	The DOC concentration estimated to be in the aquifer fluids; e.g., for COL: DOC (in situ) = 44.89 x 0.89 = 0.37
SD:	Standard deviation on replicate samples for DOC measurement.
TOC:	Total carbon in fraction volume, e.g., 93.53 mg/L x 107L = 10054 mg.
% PFW:	Percent of fraction relative to total; e.g., COL = 40/10054 = 0.4%.
Coll(sum):	Colloid mass in total sample.
COC(sum):	Colloid organic carbon in total sample.



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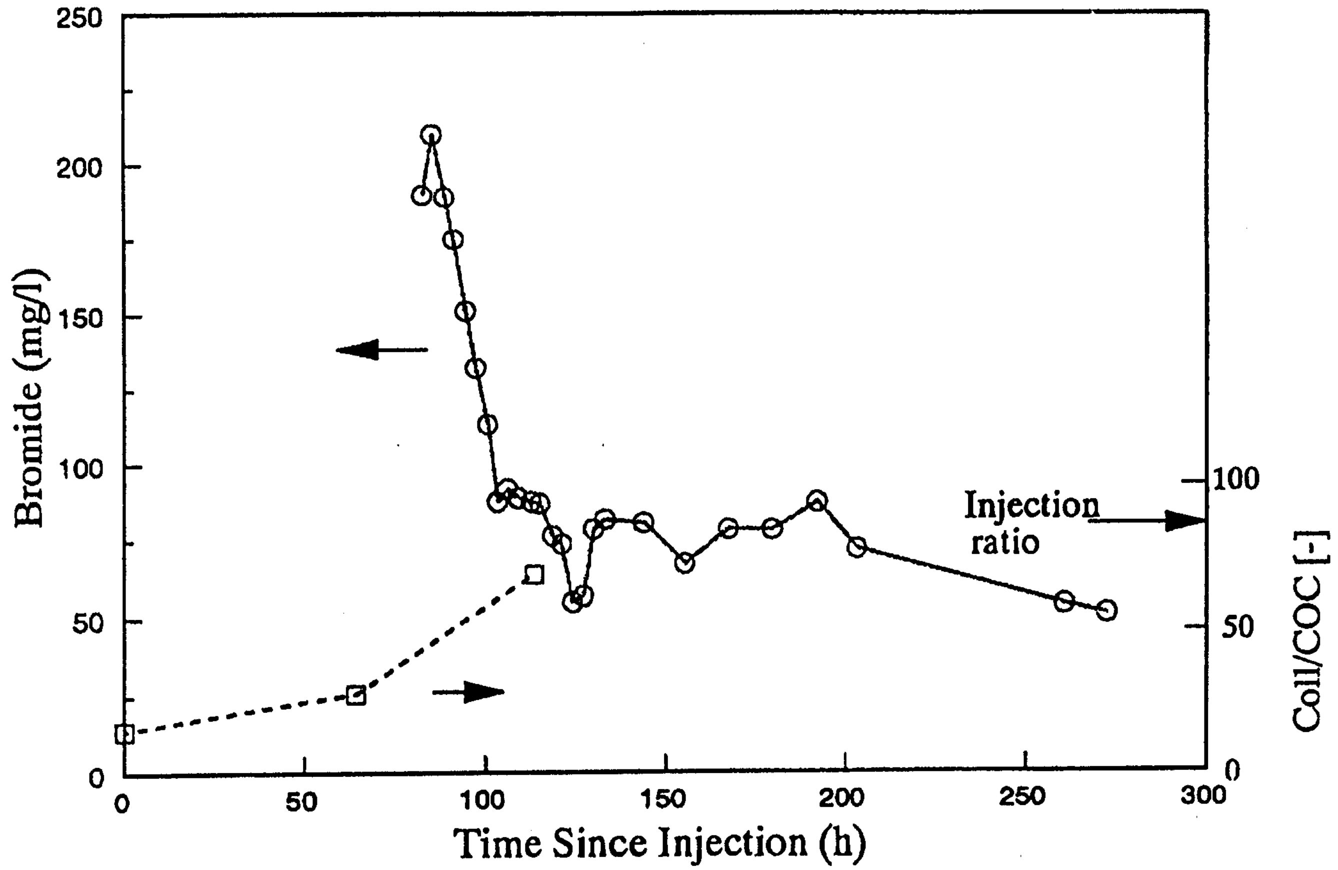
Ratio of Total Colloid Mass to
Concentration of Organic Carbon (COC)
Mass as a Function of Time

Date: June 1992	**Figure 3.1-24**



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Comparison of Colllold/COC
Ratlos with Concentrations
of the Bromide Tracer with Time

Date: June 1992	Figure 3.1-25

The four colloid samples were analyzed to characterize the sorbed component of contamination. The sorbed component of contamination was analyzed by the USGS National Water Quality Organics Laboratory. First, each colloid sample was pulverized, added to 10 mL of methylene chloride, and then sonicated for 10 minutes. The solvent was then decanted, while the sample was again added to a fresh 10 mL of methylene chloride. This procedure was repeated four times for each sample, and then the extracts from each sample were combined and filtered (0.2 microns glass fiber), producing roughly 40 mL of extract per sample. The extract was then concentrated, on a micro Kuderna-Danish condenser, to 1 to 2 mL, and then finally further concentrated to 0.1 mL using a gentle stream of nitrogen. An internal standard was then added to the extract which was then injected into the GC.

The organic analyte composition of the colloidal material is given in Table 3.1-2. All values in the table are µg compound/kg colloid mass. The colloid material contains substantial amounts of a range of compounds, including some which are highly insoluble (e.g., DDT). Table 3.1-3 presents calculated concentrations (µg/L) of target analytes associated with colloidal material. While the mass associations of the organic analytes with the colloids are, on a mass basis, significant, the extremely low colloid concentration in the ground-water results in a small contribution of the colloid phase to the distribution of the target organics in the system (i.e., dissolved, colloid and aquifer sediment). Never the less, the combination of colloid movement through the aquifer, as evidenced by the near breakthrough of the injected (high Coll/COC) colloids and the associated organic contaminants, provides documentation of the ability of colloidal material to transport insoluble materials through an aquifer system.

3.2 NATURAL-GRADIENT PORTION OF THE EXPERIMENT

The natural-gradient portion of the experiment began on November 14, 1991 at 5:47 pm, roughly 281 hours after the injection/extraction was started. At this time the injection system and extraction well pump were turned off. A second spike of LiBr tracer was injected for approximately 3.5 hours immediately preceding shut-off. This spike was intended as a signal of the shut-off point which could be monitored in the aquifer. Monitoring of both hydraulic and chemical data were continued for approximately 240 more hours (10 days) in order to investigate the post-flushing response of the aquifer.

Table 3.1-2 Organic Analysis of Colloidal Material Sampled from Well P1

Target Compound	Pre-Injection	Injection Water	Time = 63 h	Time = 114 h
Atrazine	100	<3	<2	<2
Cl_5-1,3-butadiene	40	<3	30	100
Cl_5-1,3-butadiene	50	<3	10	200
alpha-chlordane	400	10	<2	<2
gamma-chlordane	600	10	<2	<2
CPM-sulfide	<6	<3	<2	<2
CPM-sulfone	400	50	600	400
CPM-sulfoxide	<6	<3	<2	<2
C_7-H_3Cl_7	<6	<3	<2	<2
DCPD	400	<6	300	50
DDE	3200	80	<2	<2
DDT	400	<3	<2	<2
Dieldrin	<6	<3	<2	<2
DIMP	1600	4	<2	20
Endrin	<6	<3	<2	<2
Isodrin	200	70	<2	<2
Multihalogen (MW364)	20	100	80	20
Multihalogen (MW378)	100	50	30	<2
Tetrachlorobenzene	<6	4	<2	20

All values are µg compound/kg colloid mass. Pre-injection values represent composite (i.e., Wells A, B, and C), pre-experiment colloid organic loadings; injection water values correspond to post-treatment-system colloids. Values in time columns are for colloids sampled at 63 and 114 hours after the initiation of injection.

Table 3.1-3 Calculated Concentration (µg/L) of Organic Compounds Associated with Colloidal Material. Based upon a background colloid concentration of 5.2×10^{-6} kg/L*

Target Compound	Pre-Injection concentration on colloids (µg/L) (compound colloid)	In situ colloid-contaminant concentration (µg/L)
Atrazine	100	5.2×10^{-4}
Cl_5-1,3-butadiene	40	2.1×10^{-4}
Cl_5-1,3-butadiene	50	2.6×10^{-4}
alpha-chlordane	400	2.1×10^{-3}
gamma-chlordane	600	3.1×10^{-3}
CPM-sulfide	<6	—
CPM-sulfone	400	2.1×10^{-3}
CPM-sulfoxide	<6	—
C_7-H_3Cl_7	<6	—
DCPD	400	2.1×10^{-3}
DDE	3200	1.7×10^{-2}
DDT	400	2.1×10^{-3}
Dieldrin	<6	—
DIMP	1600	8.3×10^{-3}
Endrin	<6	—
Isodrin	200	1.0×10^{-3}
Multihalogen (MW364)	20	1.0×10^{-4}
Multihalogen (MW378)	100	5.2×10^{-4}
Tetrachlorobenzene	<6	—

* For example:

$$\left(\frac{100\ \mu g\ atrazine}{kg\ colloids}\right) x \left(\frac{5.2x10^{-6}\ kg\ colloids}{L}\right) = 5.2\ x\ 10^{-4}\ \mu g/L$$

3.2.1 HYDRAULICS

After the extraction/injection was ceased, the response of the aquifer as it returned to natural gradient conditions was monitored. Water-level data from this period indicate that water table elevations returned to background elevations within a few minutes of stopping the extraction/injection, except at Well E. At Well E, water levels increased immediately after stopping injection/extraction and then took 24 hours to reach the background water elevations. This behavior probably reflects a leaky valve in the extraction pump which may have allowed water in the discharge line to recharge back into the well. Aside from this observation, a situation similar to that described in Section 3.1.1 (extremely small elevation changes combined with background data variability) precluded accurate gradient calculations.

3.2.2 CHEMISTRY

3.2.2.1 Treatment System Performance

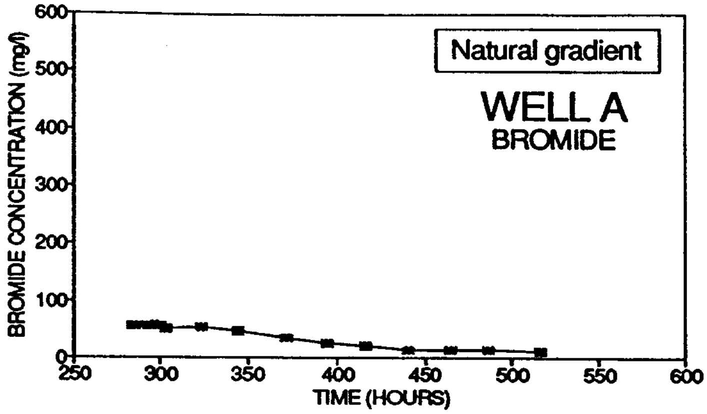
After stopping the injection/extraction, the treatment system was not used, so no monitoring was conducted.

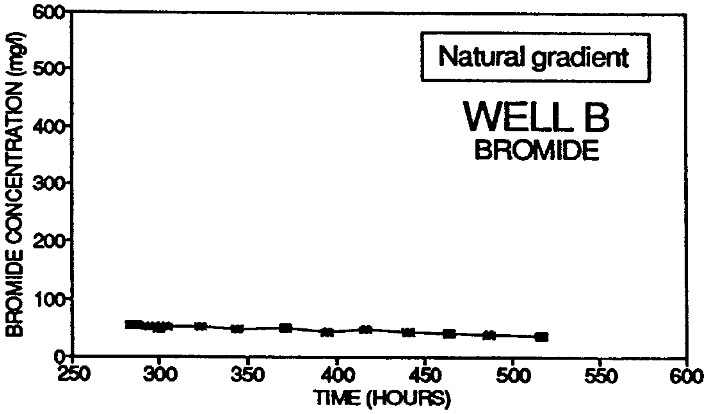
3.2.2.2 Aquifer monitoring

During the natural-gradient portion of the test, samples were periodically collected from Wells A, B and C. The wells were pumped at approximately 500 ml/min for approximately 5 minutes in order to flush the screen section and tubing. The samples were collected as usual and the pump was turned off. The following interpretations of the monitoring data are preliminary and will be corroborated by future modeling efforts and/or laboratory studies.

3.2.2.2.1 Tracer behavior

Figure 3.2-1 presents the bromide concentrations in Wells A, B and C for the natural-gradient portion of the experiment. In Well A, the bromide concentration remains for about 50 hours at the value measured at the end of the forced-gradient portion of the test, then begins to drop off slowly. In Well B, the bromide concentration remains relatively stable for 50-100 hours, with a slight decrease in concentration noticeable thereafter. The behavior of bromide in Well C is similar to that observed in Well B.





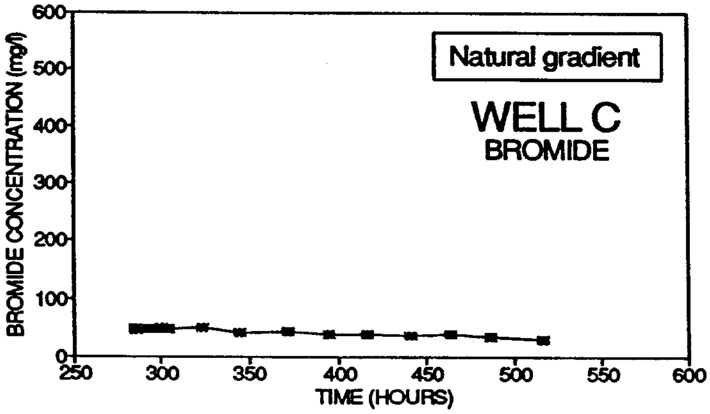


Figure 3.2-1 Bromide Concentrations in Monitoring Wells A, B and C During the Natural-Gradient Portion of the Experiment.

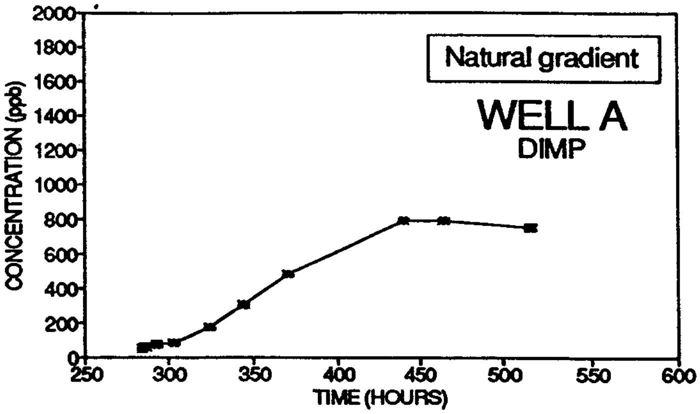
No bromide spike was detected at any of the wells during the monitored period. This suggests that the bromide spike added at the end of the forced-gradient portion of the experiment either was too narrow or dispersed to be noted or had not yet migrated to the sampling point. If the second explanation is accepted, it would imply that the average linear ground-water velocity was less than 1 foot per day, i.e. less than 10 feet in approximately 250 hours (the travel distance to Well A divided by the total time of monitoring during the natural-gradient portion of the test). This is consistent with expectations from modeling discussed in Section 2.1.1, which estimate average linear ground-water velocity at less than 0.1 ft/day.

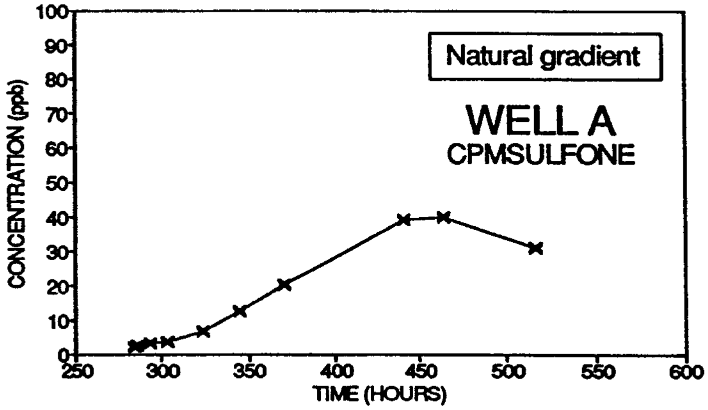
In any case, the fact that the bromide concentrations remain relatively constant in Wells B and C for approximately 250 hours suggests that the wells are not sampling contaminated water resulting from advection of the pre-existing plume. The reason for the gradual decrease in bromide concentration in Well A beginning about 50 hours into the natural-gradient portion of the test is not so clear. This issue will be addressed more in the next section.

3.2.2.2.2 Organic contaminant behavior

- Well A. Figure 3.2-2 presents the concentration histories for DIMP, CPM sulfone and dieldrin in the strata sampled by Well A. During the natural-gradient portion of the experiment, the concentrations of all three contaminants are observed to rise to roughly the values measured before beginning the forced-gradient portion of the experiment. The same is true for tetrachlorobenzene and the two unknown multihalogenated compounds (Figure 3.2-3). The DIMP increase is likely to be due in part to the DIMP that was reinjected toward the end of the forced-gradient portion of the test. However, this cannot be the only source, since the maximum reinjected DIMP concentration was approximately 35 µg/L, whereas the concentration rises to over 800 µg/L in Well A during the natural-gradient portion of the test. Presumably the source of the DIMP is the same source that causes the observed concentration increases for the other contaminants.

Because the bromide concentration during the natural-gradient portion of the experiment is not completely flushed out (Figure 3.2-1), this increase in organic concentrations is unlikely the result of the plume migrating back into the experimental zone. Thus, there are possibly sources for the contaminants within the portion of the aquifer which had been swept by the bromide-enriched injection water. Two possible





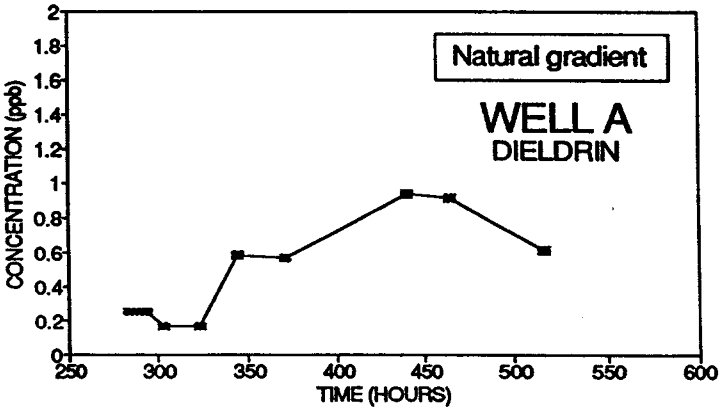


Figure 3.2-2 Concentration Histories for DIMP, CPM Sulfone and Dieldrin at Well A During the Natural-Gradient Portion of the Experiment.

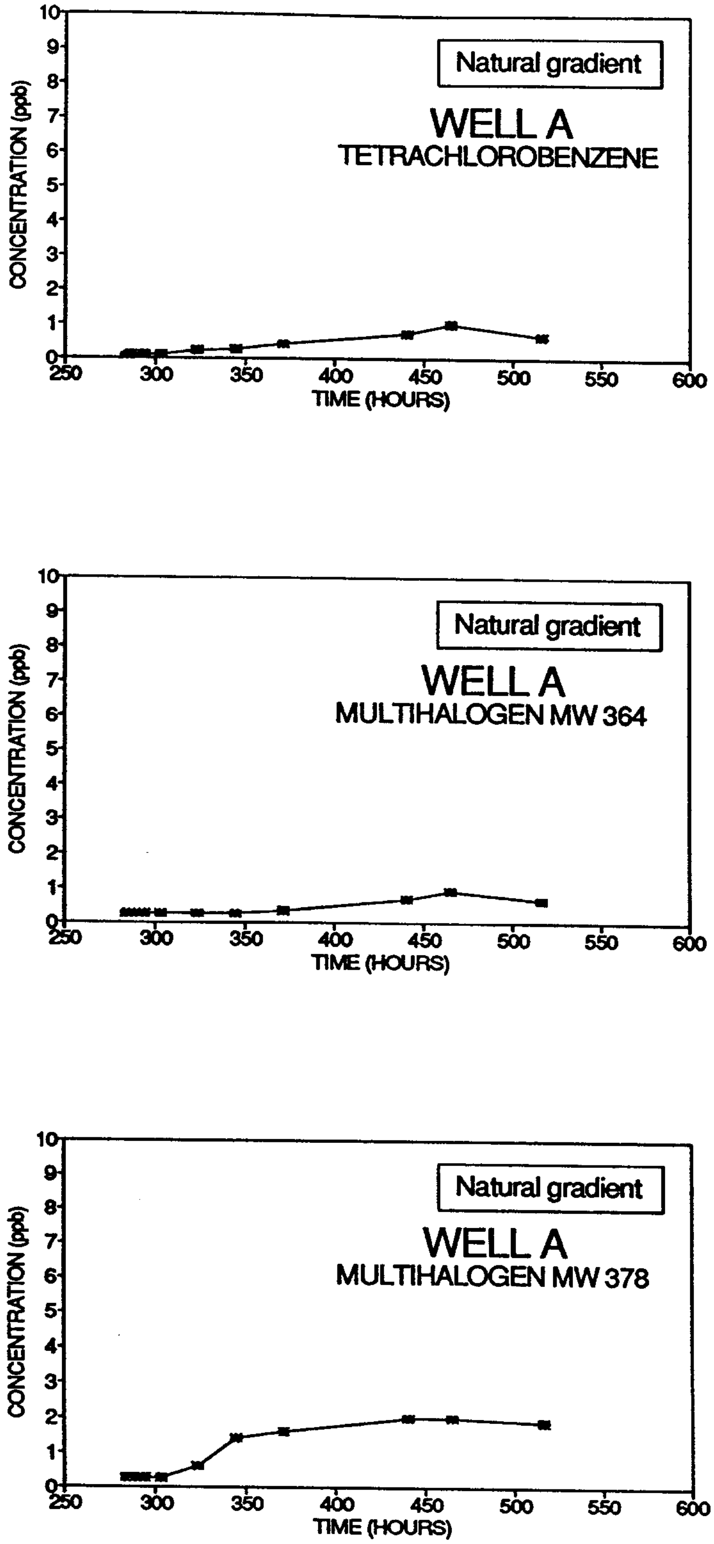


Figure 3.2-3 Concentration Histories of Tetrachlorobenzene and Two Unknown Multihalogenated Organics at Well A During the Natural-Gradient Portion of the Experiment.

sources of organic contaminant mass that might have remained after flushing of the zone with the bromide-enriched water are 1) desorption of organics sorbed to the geologic media, and 2) diffusion of the organics out of relatively low permeability layers within the medium.

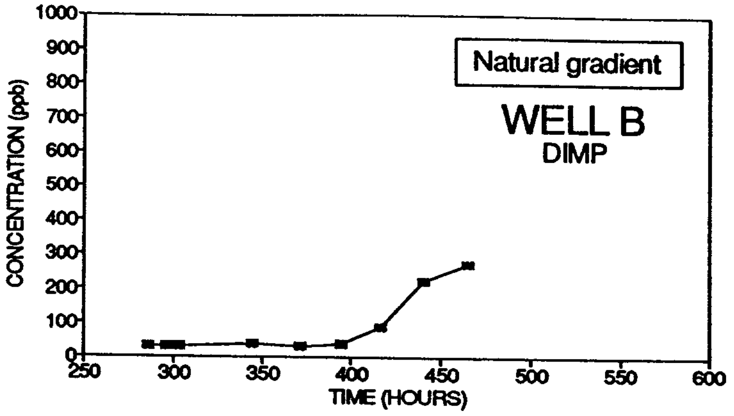
As described in Section 2.2.4, the analysis of core samples taken from the same depth horizon as sampled by Well A indicated that there were generally very low or nondetectable concentrations of contaminants associated with the geologic media. For example, CPM sulfone was detected at 3.5 and 3.8 µg/kg in two different cores. This sorbed mass is insufficient to explain the observed rise in CPM sulfone concentrations in the ground water during the natural-gradient portion of the test. The sorbed concentration is assumed to be 3.8 µg/kg (the higher of the above two values), the porosity of the aquifer is assumed to be 0.3, and the solid density of the grains is 2.7 g/cm^3, both reasonable values for a sandy aquifer. Furthermore the porosity value was estimated in this work to be on the order of 0.3. Finally, <u>all</u> of the sorbed mass is assumed to desorb instantaneously during the natural-gradient portion of the test into the pore water, which is contaminant-free due to the flushing in the forced-gradient portion of the test. The pore water concentration resulting from complete, instantaneous desorption of CPM sulfone can then be calculated as approximately 24 µg/L. This value is lower than the observed plateau value of approximately 40 µg/L. A similar calculation for DIMP yields an estimated pore water concentration from instantaneous desorption of 200 µg/L, which is also considerably lower than the observed value of 800 µg/L.

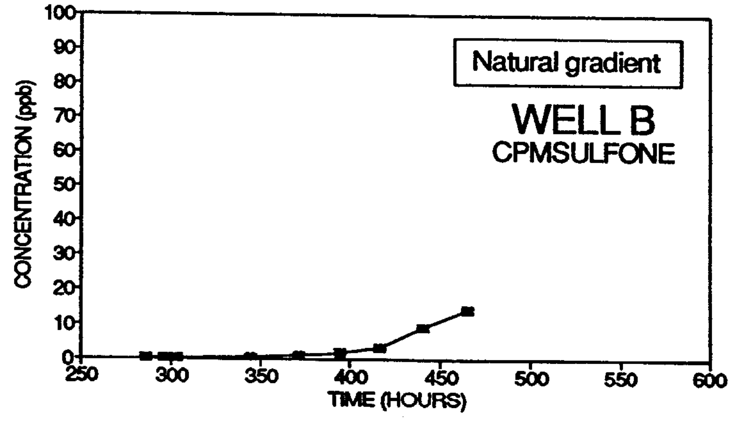
Furthermore, the simple method of estimating the solution concentrations outlined above almost certainly overstates the concentration increase expected from desorption. In reality, it is extremely unlikely that all of the sorbed mass would desorb; it is more likely that a portion of the sorbed mass would desorb to raise the solution concentration to a point at which the equilibrium ratio between solution and sorbed concentrations is similar to that before the flushing occurred (this would be the expected effect if the sorption isotherm were "linear"). Thus, the expected concentrations from desorption would be significantly lower than measured, which suggests that other sources must contribute some or all of the contaminant mass found in the pore water sampled by Well A toward the end of the natural-gradient portion of the experiment.

The other possible source is contaminant mass retained in relatively lower permeability layers within the strata sampled by Well A. These may not have been flushed by the injected water during the forced-gradient portion of the experiment, since the advective rate through these layers may have been very slow compared to the rate through adjacent, more permeable layers. Thus the contaminant mass in these layers was left behind, except for that small fraction that may have been able to diffuse from the outer portions of the lower permeability layers into the rapidly moving water in the adjacent higher permeability layers. During the natural-gradient portion of the experiment, when the ground-water flow rate through the adjacent, more permeable layers was much lower, diffusion may have been rapid enough to allow the concentrations in the more permeable layers to rise. Since the monitoring wells would draw water preferentially from these more permeable layers, this concentration rise would be detected in the monitoring results.

The hypothesis that lower-permeability layers are in contact with the strata sampled by Well A is also supported by the decrease in bromide concentrations noted in Well A during the natural-gradient portion of the experiment. Since the injected water would not flush through these lower-permeability layers, they would, at the beginning of the natural-gradient portion of the experiment, contain water with very low background concentrations of bromide. The water in the more permeable layers, on the other hand, would have the higher concentrations of bromide resulting from injection. Thus the lower-permeability layers may act as sinks for some of the bromide mass, as bromide diffuses into them. This phenomenon would gradually lower the bromide concentration in the water in the more permeable layers, explaining the results noted by monitoring Well A.

- Well B. Figure 3.2-4 shows the concentration histories of DIMP, chlorophenlymethyl sulfone and dieldrin at Well B during the natural-gradient portion of the experiment. Figure 3.2-5 presents similar information for tetrachlorobenzene and the two unknown multihalogenated compounds. If we take the last data point for the multihalogenated compound (MW 378) to be a possible artifact, the only contaminants for which concentrations rise significantly in Well B are DIMP and CPM sulfone. The rise in the DIMP concentrations to approximately 300 µg/L cannot be due only to the DIMP that was reinjected during the final 100 hours of the forced-gradient portion of the experiment, since the maximum reinjection concentration was approximately 35 µg/L. Thus there must be some other source for the DIMP that appeared in Well B. The same source presumably contributes all of the CPM sulfone, which rises to about 15 µg/L, since it was not reinjected. Since the bromide concentrations do not decrease significantly, as discussed earlier, it would appear that a source for the contaminant mass must be that sorbed to the geologic media. Calculations such as described above indicate that instantaneous desorption of all the maximum detected sorbed mass would yield about 200 µg/L of DIMP and about 35 µg/L of CPM sulfone.





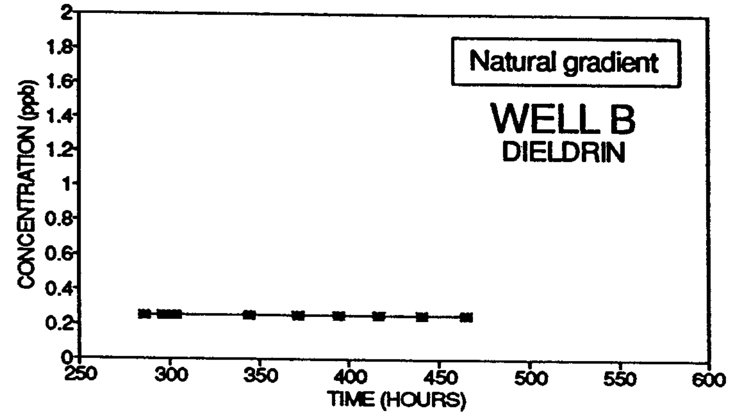
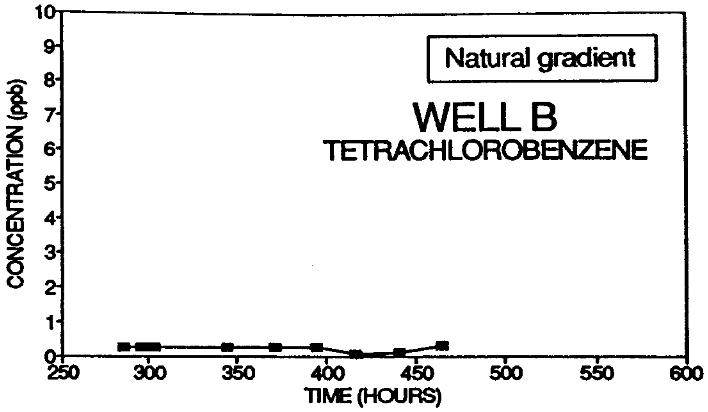
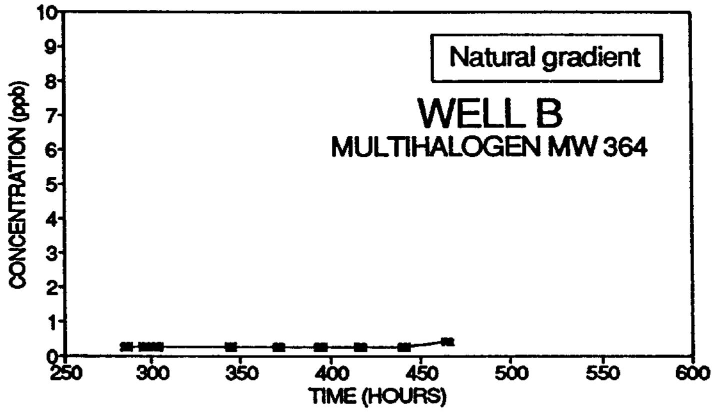


Figure 3.2-4 Concentration Histories of DIMP, CPM Sulfone and Dieldrin at Well B During the Natural-Gradient Portion of the Experiment.





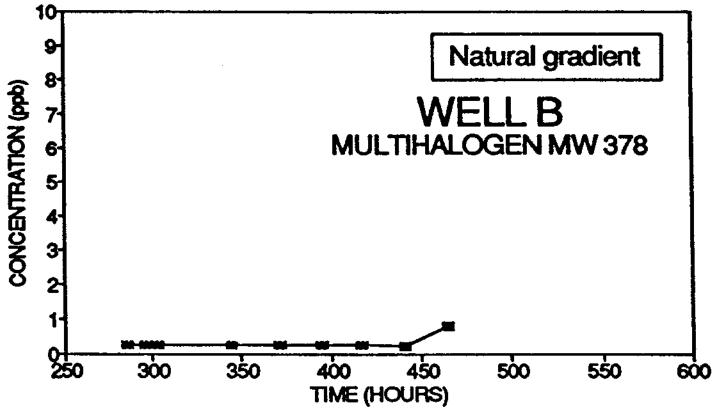
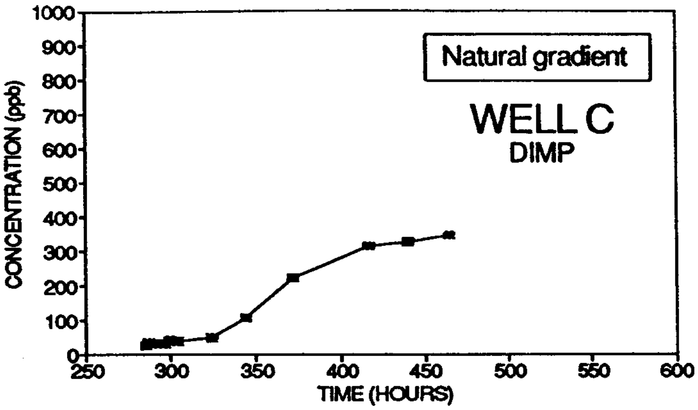


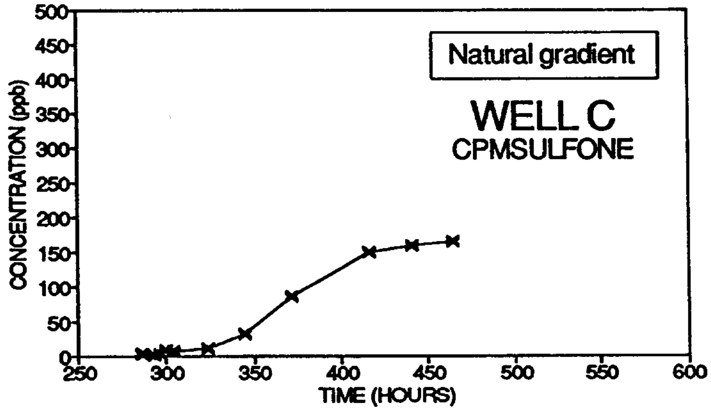
Figure 3.2-5 Concentration Histories of Tetrachlorobenzene and Two Unknown Multihalogenated Compounds at Well B During the Natural-Gradient Portion of the Experiment.

As before, however, not all of the sorbed mass would be likely to desorb instantaneously, leading to lower expected concentrations in the ground water over time.

· Well C. Figure 3.2-6 presents the concentration histories for DIMP, CPM sulfone and dieldrin at Well C during the natural-gradient portion of the experiment. Figure 3.2-7 presents the same information for tetrachlorobenzene and the two unknown multihalogenated compounds. Figure 3.2-8 presents the results for DCPD, benzene, o-xylene, TCE and PCE. For all of the compounds except dieldrin, the concentrations rise significantly during the natural-gradient portion of the experiment. However, the bromide concentrations do not decrease significantly, as discussed earlier.

Calculations again suggest that desorption of the detected sorbed mass is insufficient to lead to the observed rises in ground-water concentrations. However, a possible reservoir of contaminants for strata-sampled by Well C is the upper portion of the Denver Formation which forms the base of the aquifer. The Denver Formation is known to be weathered and somewhat permeable and potentially has significant concentrations of the contaminants in its pore water and sorbed to the solid media. Especially if an upward vertical gradient exists at the site (as have been sporadically detected elsewhere at RMA), the Denver Formation may be the source for contaminants reappearing in strata sampled by Well C during the natural-gradient portion of the experiment.





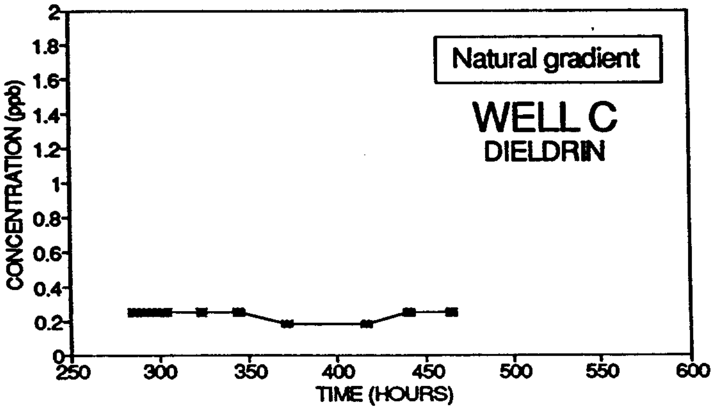


Figure 3.2-6 Concentration Histories for DIMP, CPM Sulfone and Dieldrin at Well C During the Natural-Gradient Portion of the Experiment.

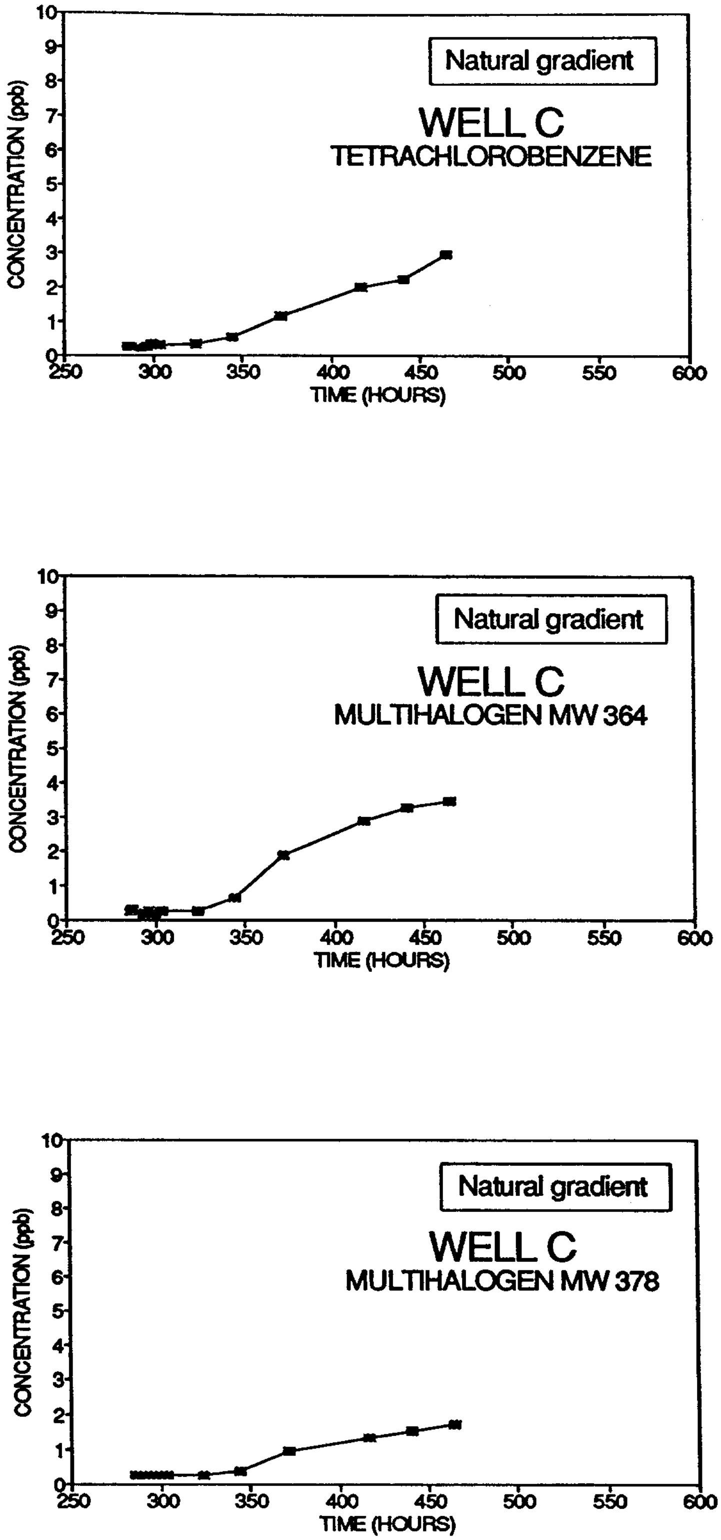
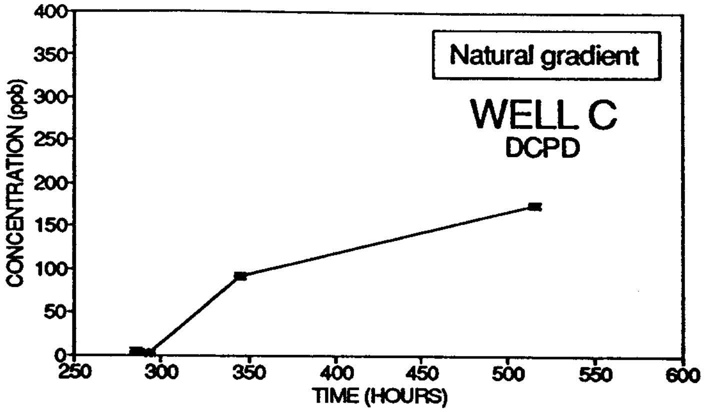
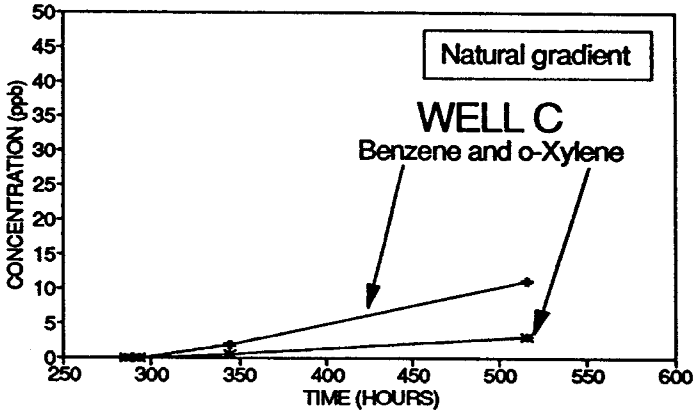


Figure 3.2-7 Concentration Histories of Tetrachlorobenzene and Two Unknown Multihalogenated Organics at Well C During the Natural-Gradient Portion of the Experiment.





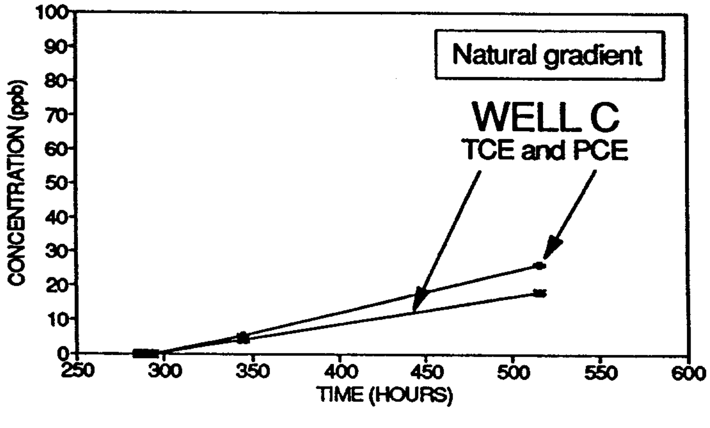


Figure 3.2-8 Concentration Histories for DCPD, Benzene, o-Xylene, TCE and PCE at Well C During the Natural-Gradient Portion of the Experiment.

4.0 SUMMARY AND IMPLICATIONS

4.1 RESULTS OF THE FIELD TEST ON FLUSHING OF ORGANIC CONTAMINANTS

An applied research project was conducted in a high-concentration, mixed-contaminant plume in Section 23 upgradient of the NBCS system at the RMA. The transport behavior of the contaminants was assessed in the field by monitoring the rate at which they were flushed from the aquifer by organic-free water. The organic-free water, obtained by treatment of ground water withdrawn from an extraction well, was returned to the aquifer through an injection well approximately 30 feet upgradient. The injection water was spiked for various periods with a conservative, nontoxic tracer. The migration rate of the tracer and the flushing rates of the organic contaminants were monitored in a cluster of short-screened monitoring wells located between the injection and extraction wells. The monitoring wells A, B, and C monitored the top third, middle third, and bottom third of the aquifer, respectively. Samples from the monitoring wells were collected and analyzed during the 10-day period of injection/extraction (the "forced-gradient" portion of the test), and for approximately 2 weeks after injection/extraction was ceased (the "natural-gradient" portion of the test).

The existing contamination was stratified vertically and contained a wide range of contaminants including halogenated VOCs, aromatic hydrocarbons, organochlorine pesticides and other, more polar, organic compounds. It is noteworthy that the total DOC concentration of the ground water (approximately 100 mg/L) was significantly higher than the sum of the concentrations of the analytes detected during historical monitoring (approximately 30 mg/L). In this work, despite some effort and identification of several previously unrecognized organic contaminants, it was not possible to determine the composition of the vast majority of the previously unidentified fraction of the DOC.

The properties and expected mobilities of the identified organic compounds varied widely. Some of the compounds would ordinarily be expected to travel at or near the velocity of the ground water (e.g. DIMP and chloroform), whereas others would ordinarily be expected to be retarded significantly in their migration due to sorption by the aquifer media (e.g. dieldrin and tetrachlorobenzene).

Contrary to expectations, during the forced-gradient portion of the test, the ground-water concentrations of all contaminants were reduced rapidly, essentially at the same time as the bromide tracer (i.e. the clean water flush) arrived at the monitoring points. There was no significant retardation of any of the contaminants based on the ground-water concentration histories. The ground-water concentrations of all contaminants were rapidly reduced to near or below the detection limit. Nevertheless, after cessation of injection/extraction, the concentrations of many of the contaminants in the monitoring wells rose slowly over a period of two weeks, in some cases to values very similar to that observed before the forced-gradient portion of the test began. These latter results suggested that after the flushing there remained contaminant mass in one or more reservoirs which could impact the ground water in the aquifer. Insight into the reasons for the observed behavior was gained from a variety of other information collected during the study, as discussed below.

Laboratory studies showed that the aquifer media was able to sorb PCE to a significant degree from synthetic ground water (with inorganic chemistry similar to site ground water, but no additional organic chemicals). Thus, the aquifer media should have been able to sorb substantial quantities of dieldrin and the other more hydrophobic organic chemicals. However, chemical analysis of samples of the aquifer sediments taken before the flushing experiment indicated that the sorbed concentrations of organic chemicals was very low, in most cases below the detection limit. These facts suggested that there were agents in the ground water which were capable of preventing significant sorption of the contaminants by the sediments.

Recently there has been considerable interest in the possibility that colloidal material in ground water may facilitate the transport (i.e. reduce the retardation) of organic chemicals. This effect would occur only if the colloidal material were mobile, strongly sorbed the contaminants, and present in relatively high concentrations. Considerable effort was made during the forced-gradient portion of the field test to monitor the movement and composition of colloidal matter in the aquifer. The results indicate clearly that colloids were present and migrate through the aquifer. Furthermore, chemical analysis of the colloids indicated that they carry a significant load of sorbed contaminants per unit mass of colloid. However, the concentration of colloids in the ground water was relatively low. Overall, the evidence from this work suggests that the colloids were not a significant factor in controlling contaminant mobility at this site. However, it is conceivable, but cannot be proven from this work, that colloidal enhancement of contaminant mobility could be significant at other sites at RMA or elsewhere if the colloid concentrations are higher.

Another potentially important mechanism for enhancement of contaminant mobility is the increase of contaminant solubility which can be caused by the presence of co-solvents such as alcohols, ketones, etc.

(Nkdei-Kizza, 1985, 1987). This effect, however, is likely to be significant only if the co-solvents are present as a significant fraction of the "ground water" (on the order of 5 percent or more, which, for methanol as an example, is on the order of 40,000 mg/L). Since the total DOC in the site ground water was on the order of 100 mg/L, it appears unlikely that the effect of co-solvent on contaminant mobility at the site is significant (unless extremely high concentrations of co-solvents are lost during processing of the samples prior to the DOC analysis).

A third potentially important mechanism for enhancement of contaminant mobility is the interaction of contaminants with surfactants in solution in ground water. The concentrations of anionic surfactants, however, were much too low to have resulted in a detectable reduction of sorption and increase in mobility. The concentrations of nonionic surfactants was not measured. If all of the DOC measured in the site ground water were nonionic surfactants, then it is conceivable that a significant effect on mobility of other contaminants could occur. It seems unlikely, however, that all of the measured DOC is nonionic surfactants. Even if it were, as long as the nonionic surfactants were assumed to be the only mobility-enhancing mechanism, theory would not predict that all of the contaminants would be unretarded, as observed. Instead, it would be expected that the retardation of each would be reduced somewhat (leading to a range of enhanced mobilities, with dieldrin still much slower than chloroform, for example).

In summary, the extensive efforts of this work were not able to pinpoint the reasons that the contaminants were so rapidly flushed from the aquifer. Nevertheless, it is clear that unknown properties of the ground water, rather than the properties of the aquifer sediments, are responsible for the insignificant concentrations of contaminants sorbed to the sediments, and the corresponding unretarded migration rate of the contaminants within the aquifer. This issue will be pursued to the extent possible by D. Mackay and students through limited funding currently available through the University of Waterloo.

The rebounding of contaminant concentrations observed during the natural-gradient portion of the test appears to be a consequence of contamination residing in portions of the subsurface around or adjacent to the flushed portion of the aquifer, which for some reason, were not flushed during the forced-gradient portion of the test. This conclusion is based on the expectation that the very low natural-gradient ground-water velocity would have been much too slow to result in the plume around the zone impacted by injection being advected back to the monitoring location. This conclusion is strengthened by the continued presence of the injected tracer in the water sampled by the monitoring points, which otherwise would have been flushed away. Thus, the reservoirs for contaminant mass which could conceivably have impacted the monitoring wells must exist within the areal extent impacted by the tracer injection. It is clear that the Denver Formation, which lies beneath the aquifer, could be a contributor of contaminants to the lower portion of the aquifer. It appears also, that the capillary fringe, or the portion of the aquifer just above it, may be a contaminant reservoir contributing contaminants to the upper portion of the aquifer. Finally, it appears possible that lower permeability strata distributed within the aquifer may also have remained unflushed after the forced-gradient portion of the experiment and then, during the natural-gradient portion of the experiment, contributed contaminants by diffusion or slight advection to the more permeable strata surrounding them. However, examination of the cores suggests that most of these strata are likely to be sandy with only slightly less permeability than the bulk of the aquifer, with occasional exceptions of thin clayey and silty strata.

4.2 IMPLICATIONS OF THE FINDINGS FROM THIS WORK

This project demonstrates that small-scale pilot tests may be conducted within existing plumes of contamination to yield insight into the processes which most significantly impact the efficiency of pump and treat remediation. In particular, the results suggest that although the contaminants were removed essentially unretarded from the permeable and highly contaminated portion of the aquifer in this work, there would appear to be value in a pulsed pumping approach to allow more efficient removal of contaminants residing in lower-permeability portions of the subsurface. If the zone at or above the water table proves to be a significant reservoir of contaminants, as suggested by this work, it may be advantageous to raise and lower the water table during remediation. However, a reservoir which is likely to contribute contaminants to the permeable aquifer over a longer term is the contaminated portion of the Denver Formation, as suggested by the results of this work.

Two innovative techniques for organic chemical analysis were successfully used in this project and may warrant consideration in other efforts at RMA. SPE followed by GC/MS analysis proved to be a relatively simple and economical way to monitor for semivolatiles. An on-site, semi-automated GC system proved useful for real-time analyses of VOCs, allowing, among other things, rapid detection of failure of the activated carbon system for treatment of the extracted water.

Probably related to the rapid failure of the activated carbon system is the determination during the experiment that much of the organic carbon load has not been characterized. This is a common observation at highly contaminated sites (Bramlett, et al, 1987). Estimates derived from historical RMA ground-water monitoring programs suggest that the dissolved organic carbon load of the ground water is roughly 30 mg/L. Organic carbon measurements obtained during the experiment indicate that the actual dissolved organic carbon load is closer to 100 μg/L. Treatment system breakthrough estimates using the actual DOC values (100 mg/L) correlate closely with the treatment system breakthrough times observed during the experiment. The uncharacterized DOC possibly contains the answer to the enhanced contaminant mobility observed during the experiment. Thus, full chemical characterization of the ground water at the site is needed prior to further remedial design efforts.

Although not of direct interest to this work, it was noted that the elevated concentrations of DO in the injected water were propagated rapidly through the aquifer. This suggests that there are not significant, rapid sinks for oxygen in the aquifer, such as reduced mineral species. Thus it appears that oxygen could be delivered relatively easily to large volumes of the subsurface to encourage in-situ aerobic biodegradation during aquifer remediation.

Lastly, there appear to be at least two types of agents in the ground water which enhance the mobility and removal rate of the identified organic contaminants. The most clearly identified agent is the colloidal matter; although the effect of the colloidal matter is quite insignificant at this site, it may not be at others. The other agent or agents are unidentified, but appear to be very significant in enhancing the mobility of the identified contaminants. In fact, the results suggest that the contaminated ground water is an extremely efficient fluid for extracting contaminants from the subsurface. This fact suggests that the ideal pump and treat remediation scheme might involve a specialized treatment system capable of removing identified and targeted contaminants without altering the extracting capabilities of the ground water. If this were possible, the treated ground water might then be reinjected to extract more contaminant mass. Implementation of this strategy would require more research to determine what components give the contaminated ground water its extracting capabilities.

5.0 REFERENCES

Ball, W. P. and P. V. Roberts. Long-Term Sorption of Halogenated Organic Chemicals by Aquifer Material. 1. Equilibrium and 2. Intraparticle Diffusion. Environmental Science and Technology, 25(7): 1223-1237 and 1237-1249, 1991.

Bahr, J. M. Analysis of Non-equilibrium Desorption of Volatile Organics During Field Test of Aquifer Decontamination. Journal of Contaminant Hydrology, vol. 4, pp. 205-222, 1989.

Bramlett, J., Furman, C., Johnson, A., Ellis, W.D., Nelson, H., and Vick, W.H. 1987. Composition of Leachates from Actual Hazardous Waste Sites. Cincinnati, OH: U.S. Environmental Protection Agency Technical Report EPA/600/2-87/043.

Garbarini, D., and Lion, L. Evaluation of Sorptive Partitioning of Nonionic Pollutants in Closed Systems by Headspace Analysis. Environmental Science and Technology, 19(11): 1122-1128, 1985.

Kile, D.E., and Chiou, C.T. Water Solubility Enhancements of DDT and Trichlorobenzene by Some Surfactants Below and Above the Critical Micelle Concentration. Environmental Science and Technology, Vol. 23, p. 832-838, 1989.

Mackay, D.M. and Thorbjarnarson, K.W. Flushing of Organic Contaminants from a Ground Water Plume at the Rocky Mountain Arsenal; Field and Laboratory Studies. UCLA School of Public Health, Environmental Science and Engineering Program Technical Report No. 90-69, Volume I (report) and Volume II (Appendices), 1990.

Miller, Tyler Jr. Living in the Environment. 6th ed. Belmont, Calif.: Wadsworth Publishers.

Nkedi-Kizza, P.P.S.C Rao and Hornsby, A. Influence of Organic Co-solvents on Sorption of Hydrophobic Organic Chemicals by Soils, Environmental Science and Technology, Vol. 19, p. 975-979, 1985.

Nkedi-Kizza, P.P.S.C Rao and Hornsby, A. Influence of Organic Co-solvents on Leaching of Hydrophobic Organic Chemicals through Soils, Environmental Science and Technology, Vol. 21, p. 1107-1111, 1987.

Roberts, P.V., Hopkins, G.D., Mackay, D.M., and Somprini, L. A Field Evaluation of In-Situ Biodegradation of Chlorinated Ethenes: Part 1, Methodology and Field Site Characterization Ground Water, 28(4): 591-604, 1990.

Shell Development Company (Shell), August 1991. Laboratory Studies on Dieldrin Transport in Soils and Ground Water. Prepared by Shell Development Company and Westhollow Research Center.

Stollar, R.L. & Associates, Inc. (RLSA), et al., 1989. Comprehensive Monitoring Program Annual Ground Water Report for 1988. Prepared for the Program Manager, Rocky Mountain Arsenal.

Stollar, R.L. & Associates, Inc. (RLSA), et al., June 1990. Comprehensive Monitoring Progam Annual Ground Water Report for 1989, Version 2.0. Prepared for the Program Manager, Rocky Mountain Arsenal.

Stollar, R.L. & Associates, Inc. (RLSA), et al., 1991. Comprehensive Monitoring Program Annual Ground Water Report for 1990. Prepared for the Program Manager, Rocky Mountain Arsenal.

United States Geological Survey (USGS), 1989a. Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments. 3rd Edition.

United States Geological Survey (USGS), 1989b. Standard Methods for the Examination of Water and Wastewater, 17th Edition.

Warner, J., Colorado State University, Spring 1991. Personal communication with Brian Myller.

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  Dietrich Whitesides - RLSA
  Todd Sullivan - RLSA
  Dan Kenney - RLSA
  Larry Hudnall -RLSA

- For long hours of preliminary design and preparation, rig oversight, and well development...

  Ed Young - RLSA

- For set-up and trouble shooting of the semi-automatic field GC...

  Gary Hopkins - Analytic and Remedial Technology

- For analytical insight, support, and responsiveness...

  Steve Zaugg - USGS National Water Quality Lab

- For coordination of the analytical requirements and last minute procurement of the LiBr tracer...

Jim Seeley - USGS National Water Quality Lab

- For Analytical Methods development support...

  Mark Sandstrom - USGS National Water Quality Lab

- For donating the organic carbon analyses and equipment for the colloid studies...

  Peter Santschi - Texas A&M University
  M. Baskaran - Texas A&M University

- For Moral Support...

  Jennifer Myller
  Lynda Smith
  Joyce Schroeder
  Christina Branch

APPENDIX A

HISTORICAL GROUND WATER CHEMICAL DATA

WELL 23095

- FALL/WINTER 1989 TO WINTER 1991
- FALL 1991

FALL/WINTER 1989 TO WINTER 1991

24-JUL-91 02:57 PM

D.P. Associates, Inc.
RMA Chemical Ground Water Report /132
Data Definition: RKPMCGW

Site Type	Site_ID	Test Name	Sample Date	Field Number	Sample Depth	Lab	Lot Number	Prep Date	Anal Date	Meth Num	Bool	Corrected Value	UOM	Acc	Flag Code	Anal Type
LL	23095	111TCE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	0.760000	UGL	0.930		C1
WELL	23095	111TCE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.020		1A
LL	23095	111TCE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.760000	UGL	0.930		C1
LL	23095	111TCE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	0.760000	UGL	0.930		C1
WELL	23095	111TCE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.090000	UGL	0.971		C1
WELL	23095	111TCE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	0.760000	UGL	0.930		C1
LL	23095	112TCE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	0.780000	UGL	0.860		C1
WELL	23095	112TCE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.070		1A
WELL	23095	112TCE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.780000	UGL	0.860		C1
LL	23095	112TCE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	0.780000	UGL	0.860		C1
LL	23095	112TCE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.630000	UGL	0.958		C1
WELL	23095	112TCE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	0.780000	UGL	0.860		C1
LL	23095	11DCE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	1.700000	UGL	0.890		C1
LL	23095	11DCE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	0.896		1A
WELL	23095	11DCE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	1.700000	UGL	0.890		C1
WELL	23095	11DCE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	1.700000	UGL	0.890		C1
LL	23095	11DCE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.850000	UGL	0.948		C1
LL	23095	11DCE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	1.700000	UGL	0.890		C1
WELL	23095	11DCLE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	0.730000	UGL	0.890		C1
LL	23095	11DCLE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	0.918		1A
LL	23095	11DCLE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.730000	UGL	0.890		C1
WELL	23095	11DCLE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	0.730000	UGL	0.890		C1
WELL	23095	11DCLE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.930000	UGL	0.919		C1
LL	23095	11DCLE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8		1.440000	UGL	0.890		C1
LL	23095	12DCE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	0.760000	UGL	0.930		C1
WELL	23095	12DCE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	500.000000	UGL	0.982		1A
LL	23095	12DCE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.760000	UGL	0.930		C1
LL	23095	12DCE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	0.760000	UGL	0.930		C1
WELL	23095	12DCE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.750000	UGL	0.924		C1
WELL	23095	12DCE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	0.760000	UGL	0.930		C1
LL	23095	12DCLE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	1.100000	UGL	0.820		C1
WELL	23095	12DCLE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	0.996		1A
WELL	23095	12DCLE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	1.100000	UGL	0.820		C1
LL	23095	12DCLE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	1.100000	UGL	0.820		C1
LL	23095	12DCLE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8		12.300000	UGL	0.960		C1
WELL	23095	12DCLE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	1.100000	UGL	0.820		C1
LL	23095	12DCLP	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	0.933		1A
LL	23095	13DCLB	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.050		1A
WELL	23095	13DCP	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	480.000000	UGL	1.050		1A
WELL	23095	13DMB	89307	M4482,83	48.0	UB	HQM008	89315	89315	AV8	LT	1.320000	UGL	0.876		C1
LL	23095	13DMB	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	0.991		1A
LL	23095	13DMB	90057	M9003,04	48.5	UB	IZA009	90067	90067	AV8		2.270000	UGL	0.876		C1
WELL	23095	13DMB	90141	N1745,46	48.0	UB	JRG005	90147	90147	AV8	LT	1.320000	UGL	0.876		C1
LL	23095	13DMB	90233	N3010	48.4	ED	GZR016	90234	90234	SS8	LT	1.040000	UGL	0.934		C1
LL	23095	13DMB	91039	N5189,90	48.0	UB	NEP013	91043	91043	AV8	LT	1.320000	UGL	0.876		C1
WELL	23095	236TCP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	1.700000	UGL	0.984		1A
WELL	23095	245TCP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	2.800000	UGL	1.120		1A
LL	23095	246TCP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	3.600000	UGL	1.080		1A
LL	23095	24DCLP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	8.400000	UGL	1.030		1A

Site Type	Site_ID	Test Name	Sample Date	Field Number	Sample Depth	Lab	Lot Number	Prep Date	Anal Date	Meth Num	Bool	Corrected Value	UOM	Acc	Flag Code	Anal Type
WELL	23095	24DMPN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	4.400000	UGL	1.220		1A
WELL	23095	24DNP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	176.000000	UGL	0.572		1A
WELL	23095	2CLEVE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	350.000000	UGL	1.290		1A
WELL	23095	2CLP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	2.800000	UGL	0.955		1A
WELL	23095	2MP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	3.600000	UGL	0.932		1A
WELL	23095	2NP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	8.200000	UGL	1.080		1A
WELL	23095	4CL3C	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	8.500000	UGL	1.100		1A
WELL	23095	4MP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	2.800000	UGL	0.878		1A
WELL	23095	4NP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	96.000000	UGL	0.664		1A
WELL	23095	ACET	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	800.000000	UGL	0.405		1A
WELL	23095	ACRYLO	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	840.000000	UGL	0.844		1A
WELL	23095	ALDRN	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		0.328000	UGL	0.861		C1
WELL	23095	ALDRN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	13.000000	UGL	0.539		1A
WELL	23095	ALDRN	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		0.880000	UGL	0.861		C1
WELL	23095	ALDRN	90141	N1751	48.0	UB	JRB005	90145	90151	KK8		0.293000	UGL	0.861	C	C1
WELL	23095	ALDRN	90233	N3016	48.4	ED	QL0016	90236	90239	MM8A	LT	0.083000	UGL	0.851		C1
WELL	23095	ALDRN	91039	N5195	48.0	UB	NET013	91042	91047	KK8	LT	0.050000	UGL	0.861		C1
WELL	23095	AS	89307	M4498	48.0	UB	HPT020	89333	89335	AX8	LT	2.350000	UGL	0.974	F	C1
WELL	23095	AS	90057	M9016	48.5	UB	JB0029	90072	90085	AX8	LT	2.350000	UGL	0.974	F	C1
WELL	23095	AS	90141	N1758	48.0	UB	JTC005	90162	90164	AX8		12.800000	UGL	0.974	F	C1
WELL	23095	AS	90233	N3023	48.4	ED	QIF016	90247	90248	VV8		23.200000	UGL	0.991		C1
WELL	23095	AS	91039	N5202	48.0	UB	NEN023	91045	91046	AX8		15.400000	UGL	0.974	F	C1
WELL	23095	ATZ	89307	M4497	48.0	UB	HQR008	89314	89318	UH11		120.000000	UGL	0.986		C1
WELL	23095	ATZ	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	5.900000	UGL	1.200		1A
WELL	23095	ATZ	90057	M9015	48.5	UB	IXR006	90064	90066	UH11	LT	4.030000	UGL	0.986		C1
WELL	23095	ATZ	91039	N5201	48.0	UB	NEU013	91042	91051	UH11		74.000000	UGL	0.986		C1
WELL	23095	BCHPD	89307	M4490	48.0	UB	HQT008	89314	89321	P8		25.000000	UGL	0.580		C1
WELL	23095	BCHPD	90141	N1753	48.0	UB	JRE005	90145	90156	P8		22.200000	UGL	0.580		C1
WELL	23095	BCHPD	91039	N5197	48.0	UB	NEW013	91042	91046	P8		19.000000	UGL	0.580		C1
WELL	23095	BRDCLM	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.100		1A
WELL	23095	BTZ	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8	LT	5.000000	UGL	0.958		C1
WELL	23095	BTZ	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8	LT	5.000000	UGL	0.958		C1
WELL	23095	BTZ	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8	LT	5.000000	UGL	0.958		C1
WELL	23095	BTZ	90233	N3015	48.4	ED	QB0016	90236	90239	PP8A	LT	1.140000	UGL	0.924		C1
WELL	23095	BTZ	91039	N5194	48.0	UB	NES013	91042	91047	AAA8	LT	5.000000	UGL	0.958		C1
WELL	23095	BTZ	91105	03611	48.0	UB	0ID006	91109	91118	AAA8	LT	5.000000	UGL	0.958		C1
WELL	23095	C2H3CL	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	1200.000000	UGL	0.835		1A
WELL	23095	C2H5CL	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	800.000000	UGL	0.972		1A
WELL	23095	C6H6	89307	M4482,83	48.0	UB	HQM008	89315	89315	AV8	LT	1.050000	UGL	0.859		C1
WELL	23095	C6H6	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.290		1A
WELL	23095	C6H6	90057	M9003,04	48.5	UB	IZA009	90067	90067	AV8		16.900000	UGL	0.859		C1
WELL	23095	C6H6	90141	N1745,46	48.0	UB	JRG005	90147	90147	AV8	LT	1.050000	UGL	0.859		C1
WELL	23095	C6H6	90233	N3010	48.4	ED	GZR016	90234	90234	SS8	GT	10.500000	UGL	0.842		C1
WELL	23095	C6H6	91039	N5189,90	48.0	UB	NEP013	91043	91043	AV8		11.000000	UGL	0.859		C1
WELL	23095	CA	89307	M4500	48.0	UB	HSX008	90022	90023	SS12		310000.000000	UGL	0.990	F	C1
WELL	23095	CA	90057	M9018	48.5	UB	JBP029	90074	90078	SS12		300000.000000	UGL	0.990	F	C1
WELL	23095	CA	90141	N1760	48.0	UB	JRW019	90163	90168	SS12		370000.000000	UGL	0.990	F	C1
WELL	23095	CA	91039	N5204	48.0	UB	NE0023	91046	91048	SS12		330000.000000	UGL	0.990	F	C1
WELL	23095	CCL3F	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.040		1A

Site Type	Site_ID	Test Name	Sample Date	Field Number	Sample Depth	Lab	Lot Number	Prep Date	Anal Date	Meth Num	Bool	Corrected Value	UOM	Acc	Flag Code	Anal Type
WELL	23095	CCL4	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	0.990000	UGL	0.910		C1
WELL	23095	CCL4	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.090		1A
WELL	23095	CCL4	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.990000	UGL	0.910		C1
WELL	23095	CCL4	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	0.990000	UGL	0.910		C1
WELL	23095	CCL4	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.690000	UGL	0.946		C1
WELL	23095	CCL4	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	0.990000	UGL	0.910		C1
WELL	23095	CD	89307	M4500	48.0	UB	HSX008	90022	90023	SS12	LT	6.780000	UGL	0.952	F	C1
WELL	23095	CD	90057	M9018	48.5	UB	JBP029	90074	90078	SS12	LT	6.780000	UGL	0.952	F	C1
WELL	23095	CD	90141	N1760	48.0	UB	JRW019	90163	90168	SS12	LT	6.780000	UGL	0.952	F	C1
WELL	23095	CD	90233	N3025	48.4	ED	QSK016	90247	90248	R9D	LT	5.000000	UGL	0.973		C1
WELL	23095	CD	91039	N5204	48.0	UB	NEO023	91046	91048	SS12	LT	6.780000	UGL	0.952	F	C1
WELL	23095	CH2CL2	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	7.400000	UGL	0.890		C1
WELL	23095	CH2CL2	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	0.990		1A
WELL	23095	CH2CL2	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8		28.500000	UGL	0.890		C1
WELL	23095	CH2CL2	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	7.400000	UGL	0.890		C1
WELL	23095	CH2CL2	90233	N3012	48.4	ED	GYR016	90242	90242	TT8		16.300000	UGL	0.979		C1
WELL	23095	CH2CL2	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8		22.500000	UGL	0.890		C1
WELL	23095	CH3BR	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	1400.000000	UGL	0.882		1A
WELL	23095	CH3CL	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	120.000000	UGL	0.879		1A
WELL	23095	CHBR3	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	1100.000000	UGL	1.090		1A
WELL	23095	CHCL3	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8		12000.000000	UGL	0.880		C1
WELL	23095	CHCL3	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21		10000.000000	UGL	1.000		1A
WELL	23095	CHCL3	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8		10000.000000	UGL	0.880		C1
WELL	23095	CHCL3	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	GT	200.000000	UGL	0.880		C1
WELL	23095	CHCL3	90233	N3012	48.4	ED	GYR016	90242	90242	TT8		11000.000000	UGL	0.928		C1
WELL	23095	CHCL3	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8		9700.000000	UGL	0.880		C1
WELL	23095	CL	89307	M4491	48.0	UB	HQV008	89313	89313	TT09		4300000.000000	UGL	0.961		C1
WELL	23095	CL	90141	N1754	48.0	UB	JTG005	90164	90164	TT09		4700000.000000	UGL	0.961		C1
WELL	23095	CL	90233	N3019	48.4	ED	QQD016	90248	90249	NN8		7600000.000000	UGL	0.993		C1
WELL	23095	CL	91039	N5198	48.0	UB	NFB013	91065	91065	TT09		5600000.000000	UGL	0.961		C1
WELL	23095	CL6CP	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		0.636000	UGL	0.802		C1
WELL	23095	CL6CP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	54.000000	UGL	1.100		1A
WELL	23095	CL6CP	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		0.950000	UGL	0.802		C1
WELL	23095	CL6CP	90141	N1751	48.0	UB	JRB005	90145	90151	KK8		0.350000	UGL	0.802	C	C1
WELL	23095	CL6CP	90233	N3016	48.4	ED	QLO016	90236	90239	MM8A	LT	0.170000	UGL	0.590		C1
WELL	23095	CLC6H5	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8	LT	8.200000	UGL	0.880		C1
WELL	23095	CLC6H5	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.040		1A
WELL	23095	CLC6H5	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.820000	UGL	0.880		C1
WELL	23095	CLC6H5	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8	LT	0.820000	UGL	0.880		C1
WELL	23095	CLC6H5	90233	N3012	48.4	ED	GYR016	90242	90242	TT8	LT	1.360000	UGL	1.010		C1
WELL	23095	CLC6H5	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	0.820000	UGL	0.880		C1
WELL	23095	CLDAN	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		5.200000	UGL	0.828		C1
WELL	23095	CLDAN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	37.000000	UGL	0.506		1A
WELL	23095	CLDAN	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8	LT	0.095000	UGL	0.828		C1
WELL	23095	CLDAN	90141	N1751	48.0	UB	JRB005	90145	90151	KK8		21.000000	UGL	0.828	C	C1
WELL	23095	CLDAN	90233	N3016	48.4	ED	QLO016	90236	90239	MM8A	LT	0.300000	UGL	0.977		C1
WELL	23095	CLDAN	91039	N5195	48.0	UB	NET013	91042	91047	KK8	LT	0.095000	UGL	0.828		C1
WELL	23095	CPMS	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8		48.500000	UGL	0.942		C1
WELL	23095	CPMS	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		109.000000	UGL	0.795		1A

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WELL	23095	CPMS	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8		40.400000	UGL	0.942		C1
WELL	23095	CPMS	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8		32.000000	UGL	0.942		C1
WELL	23095	CPMS	90233	N3015	48.4	ED	QBO016	90236	90239	PP8A		210.000000	UGL	0.908		C1
WELL	23095	CPMS	91039	N5194	48.0	UB	NES013	91042	91047	AAA8		38.400000	UGL	0.942		C1
WELL	23095	CPMS	91105	O3611	48.0	UB	OID006	91109	91118	AAA8		38.100000	UGL	0.942		C1
WELL	23095	CPMSO	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8		150.000000	UGL	0.963		C1
WELL	23095	CPMSO	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	15.000000	UGL	0.684		1A
WELL	23095	CPMSO	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8		150.000000	UGL	0.963		C1
WELL	23095	CPMSO	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8		180.000000	UGL	0.963		C1
WELL	23095	CPMSO	90233	N3015	48.4	ED	QBO016	90236	90239	PP8A	LT	1.980000	UGL	0.932		C1
WELL	23095	CPMSO	91039	N5194	48.0	UB	NES013	91042	91047	AAA8		22.700000	UGL	0.963		C1
WELL	23095	CPMSO	91105	O3611	48.0	UB	OID006	91109	91118	AAA8	LT	120.000000	UGL	0.963		C1
WELL	23095	CPMSO2	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8		360.000000	UGL	1.160		C1
WELL	23095	CPMSO2	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		352.000000	UGL	0.795		1A
WELL	23095	CPMSO2	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8		270.000000	UGL	1.160		C1
WELL	23095	CPMSO2	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8		190.000000	UGL	1.160		C1
WELL	23095	CPMSO2	90233	N3015	48.4	ED	QBO016	90236	90239	PP8A		520.000000	UGL	0.823		C1
WELL	23095	CPMSO2	91039	N5194	48.0	UB	NES013	91042	91047	AAA8		220.000000	UGL	1.160		C1
WELL	23095	CPMSO2	91105	O3611	48.0	UB	OID006	91109	91118	AAA8		230.000000	UGL	1.160		C1
WELL	23095	CR	89307	M4500	48.0	UB	HSX008	90022	90023	SS12	LT	16.800000	UGL	1.010	F	C1
WELL	23095	CR	90057	M9018	48.5	UB	JBP029	90074	90078	SS12	LT	16.800000	UGL	1.010	F	C1
WELL	23095	CR	90141	N1760	48.0	UB	JRW019	90163	90168	SS12	LT	16.800000	UGL	1.010	F	C1
WELL	23095	CR	90233	N3025	48.4	ED	QSK016	90247	90248	R9D	LT	22.000000	UGL	0.960		C1
WELL	23095	CR	91039	N5204	48.0	UB	NEO023	91046	91048	SS12		26.400000	UGL	1.010	F	C1
WELL	23095	CU	89307	M4500	48.0	UB	HSX008	90022	90023	SS12		50.400000	UGL	0.958	F	C1
WELL	23095	CU	90057	M9018	48.5	UB	JBP029	90074	90078	SS12		47.700000	UGL	0.958	F	C1
WELL	23095	CU	90141	N1760	48.0	UB	JRW019	90163	90168	SS12		41.800000	UGL	0.958	F	C1
WELL	23095	CU	90233	N3025	48.4	ED	QSK016	90247	90248	R9D		31.800000	UGL	0.978		C1
WELL	23095	CU	91039	N5204	48.0	UB	NEO023	91046	91048	SS12		86.200000	UGL	0.958	F	C1
WELL	23095	CYN	90233	N3021	48.4	ED	QXM014	90242	90243	CN1	LT	8.900000	UGL	0.954		C1
WELL	23095	DBCP	89307	M4486	48.0	UB	HQO008	89313	89314	AY8	LT	0.195000	UGL	0.991		C1
WELL	23095	DBCP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	12.000000	UGL	0.841		1A
WELL	23095	DBCP	90057	M9007	48.5	UB	IXU006	90061	90061	AY8	LT	0.195000	UGL	0.991		C1
WELL	23095	DBCP	90141	N1749	48.0	UB	JQZ005	90144	90144	AY8	LT	0.195000	UGL	0.991		C1
WELL	23095	DBCP	90233	N3014	48.4	ED	QHF016	90235	90235	Q8	LT	0.130000	UGL	0.904		C1
WELL	23095	DBRCLM	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.190		1A
WELL	23095	DCLB	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	200.000000	UGL	1.070		1A
WELL	23095	DCPD	89307	M4490	48.0	UB	HQT008	89314	89321	P8		1200.000000	UGL	0.550		C1
WELL	23095	DCPD	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	5.500000	UGL	0.794		1A
WELL	23095	DCPD	90141	N1753	48.0	UB	JRE005	90145	90156	P8		1100.000000	UGL	0.550		C1
WELL	23095	DCPD	90233	N3018	48.4	ED	GXP016	90240	90242	R8		650.000000	UGL	0.930		C1
WELL	23095	DCPD	91039	N5197	48.0	UB	NEW013	91042	91046	P8		1100.000000	UGL	0.550		C1
WELL	23095	DDVP	89307	M4497	48.0	UB	HQR008	89314	89318	UH11	LT	0.384000	UGL	0.891		C1
WELL	23095	DDVP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	8.500000	UGL	1.150		1A
WELL	23095	DDVP	90057	M9015	48.5	UB	IXR006	90064	90066	UH11	LT	0.384000	UGL	0.891		C1
WELL	23095	DDVP	90141	N1757	48.0	UB	JRC005	90145	90161	UH11	LT	0.384000	UGL	0.891		C1
WELL	23095	DDVP	91039	N5201	48.0	UB	NEU013	91042	91051	UH11	LT	0.384000	UGL	0.891		C1
WELL	23095	DIMP	89307	M4489	48.0	UB	HQS008	89314	89318	AT8		580.000000	UGL	0.908		C1
WELL	23095	DIMP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	GT	200.000000	UGL	1.060		1A

Site Type	Site_ID	Test Name	Sample Date	Field Number	Sample Depth	Lab	Lot Number	Prep Date	Anal Date	Meth Num	Bool	Corrected Value	UOM	Acc	Flag Code	Anal Type
WELL	23095	DIMP	90057	M9010	48.5	UB	IXT006	90064	90068	AT8		750.000000	UGL	0.908		C1
WELL	23095	DIMP	90141	N1752	48.0	UB	JRD005	90145	90150	AT8		310.000000	UGL	0.908		C1
WELL	23095	DIMP	90233	N3017	48.4	ED	QA0016	90239	90262	QQ8		1100.000000	UGL	0.994		C1
WELL	23095	DITH	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8		74.000000	UGL	0.853		C1
WELL	23095	DITH	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		50.000000	UGL	1.100		1A
WELL	23095	DITH	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8		57.000000	UGL	0.853		C1
WELL	23095	DITH	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8		43.000000	UGL	0.853		C1
WELL	23095	DITH	90233	N3015	48.4	ED	QB0016	90236	90239	PP8A		52.000000	UGL	1.100		C1
WELL	23095	DITH	91039	N5194	48.0	UB	NES013	91042	91047	AAA8		49.000000	UGL	0.853		C1
WELL	23095	DITH	91105	03611	48.0	UB	OID006	91109	91118	AAA8		42.000000	UGL	0.853		C1
WELL	23095	DLDRN	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8	LT	0.050000	UGL	1.120		C1
WELL	23095	DLDRN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	26.000000	UGL	1.250		1A
WELL	23095	DLDRN	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		5.600000	UGL	1.120		C1
WELL	23095	DLDRN	90233	N3016	48.4	ED	QLO016	90236	90239	MM8A		1.600000	UGL	1.020	C	C1
WELL	23095	DMDS	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8	LT	0.550000	UGL	0.955		C1
WELL	23095	DMDS	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8	LT	0.550000	UGL	0.955		C1
WELL	23095	DMDS	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8	LT	0.550000	UGL	0.955		C1
WELL	23095	DMDS	91105	03611	48.0	UB	OID006	91109	91118	AAA8	LT	0.550000	UGL	0.955		C1
WELL	23095	DMMP	89307	M4489	48.0	UB	HQS008	89314	89318	AT8	LT	0.188000	UGL	0.925		C1
WELL	23095	DMMP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	130.000000	UGL	0.179		1A
WELL	23095	DMMP	90057	M9010	48.5	UB	IXT006	90064	90068	AT8	LT	0.188000	UGL	0.925		C1
WELL	23095	DMMP	90141	N1752	48.0	UB	JRD005	90145	90150	AT8	LT	0.188000	UGL	0.925		C1
WELL	23095	DMMP	90233	N3017	48.4	ED	QA0016	90239	90262	QQ8	LT	16.300000	UGL	1.050		C1
WELL	23095	ENDRN	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		0.689000	UGL	1.220		C1
WELL	23095	ENDRN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	18.000000	UGL	0.979		1A
WELL	23095	ENDRN	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		17.000000	UGL	1.220		C1
WELL	23095	ENDRN	90233	N3016	48.4	ED	QLO016	90236	90239	MM8A	LT	0.120000	UGL	1.060		C1
WELL	23095	ENDRN	91039	N5195	48.0	UB	NET013	91042	91047	KK8	LT	0.050000	UGL	1.220		C1
WELL	23095	ETC6H5	89307	M4482,83	48.0	UB	HQM008	89315	89315	AV8	LT	1.370000	UGL	0.946		C1
WELL	23095	ETC6H5	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.000		1A
WELL	23095	ETC6H5	90057	M9003,04	48.5	UB	IZA009	90067	90067	AV8	LT	1.370000	UGL	0.946		C1
WELL	23095	ETC6H5	90141	N1745,46	48.0	UB	JRG005	90147	90147	AV8	LT	1.370000	UGL	0.946		C1
WELL	23095	ETC6H5	90233	N3010	48.4	ED	GZR016	90234	90234	SS8		2.030000	UGL	0.950		C1
WELL	23095	ETC6H5	91039	N5189,90	48.0	UB	NEP013	91043	91043	AV8	LT	1.370000	UGL	0.946		C1
WELL	23095	F	89307	M4491	48.0	UB	HQV008	89313	89313	TT09		22000.000000	UGL	0.971		C1
WELL	23095	F	90141	N1754	48.0	UB	JTG005	90164	90164	TT09		24000.000000	UGL	0.971		C1
WELL	23095	F	90233	N3019	48.4	ED	QQD016	90248	90249	NN8		9000.000000	UGL	1.110		C1
WELL	23095	F	91039	N5198	48.0	UB	NFB013	91065	91065	TT09		10000.000000	UGL	0.971		C1
WELL	23095	HG	89307	M4499	48.0	UB	HRU008	89334	89334	CC8		0.175000	UGL	1.000	F	C1
WELL	23095	HG	90057	M9017	48.5	UB	IZP030	90066	90067	CC8		0.251000	UGL	1.000	F	C1
WELL	23095	HG	90141	N1759	48.0	UB	JTD005	90164	90164	CC8		0.758000	UGL	1.000	F	C1
WELL	23095	HG	90233	N3024	48.4	ED	GWS016	90243	90243	WW8	LT	0.500000	UGL	0.993		C1
WELL	23095	HG	91039	N5203	48.0	UB	NEM023	91043	91043	CC8		0.102000	UGL	1.000	F	C1
WELL	23095	ISODR	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		0.579000	UGL	0.819		C1
WELL	23095	ISODR	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	7.800000	UGL	0.582		1A
WELL	23095	ISODR	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		7.600000	UGL	0.819		C1
WELL	23095	ISODR	90141	N1751	48.0	UB	JRB005	90145	90151	KK8	LT	0.051000	UGL	0.819		C1
WELL	23095	ISODR	90233	N3016	48.4	ED	QLO016	90236	90239	MM8A	LT	0.056000	UGL	0.772		C1
WELL	23095	K	89307	M4500	48.0	UB	HSX008	90022	90023	SS12		47500.000000	UGL	0.945	F	C1

S..e Type	Site_ID	Test Name	Sample Date	Field Number	Sample Depth	Lab	Lot Number	Prep Date	Anal Date	Meth Num	Bool	Corrected Value	UOM	Acc	Flag Code	Anal Type
W L	23095	K	90057	M9018	48.5	UB	JBP029	90074	90078	SS12		52500.000000	UGL	0.945	F	C1
WELL	23095	K	90141	N1760	48.0	UB	JRW019	90163	90168	SS12		57000.000000	UGL	0.945	F	C1
WF'L	23095	K	90233	60600*12	48.4	ED	QJH016	90290	90291	XX8		46300.000000	UGL	0.828		C1
W L	23095	K	91039	N5204	48.0	UB	NE0023	91046	91048	SS12		49500.000000	UGL	0.945	F	C1
WELL	23095	MEC6H5	89307	M4482,83	48.0	UB	HQM008	89315	89315	AV8	LT	1.470000	UGL	0.906		C1
WELL	23095	MEC6H5	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.000		1A
W .	23095	MEC6H5	90057	M9003,04	48.5	UB	IZA009	90067	90067	AV8		9.580000	UGL	0.906		C1
W .	23095	MEC6H5	90141	N1745,46	48.0	UB	JRG005	90147	90147	AV8	LT	1.470000	UGL	0.906		C1
WELL	23095	MEC6H5	90233	N3010	48.4	ED	GZR016	90234	90234	SS8	LT	2.100000	UGL	0.932		C1
WC''L	23095	MEC6H5	91039	N5189,90	48.0	UB	NEP013	91043	91043	AV8	LT	1.470000	UGL	0.906		C1
WE .	23095	MEK	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	1000.000000	UGL	0.435		1A
WELL	23095	MG	89307	M4500	48.0	UB	HSX008	90022	90023	SS12		211000.000000	UGL	0.942	F	C1
WELL	23095	MG	90057	M9018	48.5	UB	JBP029	90074	90078	SS12		223000.000000	UGL	0.942	F	C1
WE .	23095	MG	90141	N1760	48.0	UB	JRW019	90163	90168	SS12		236000.000000	UGL	0.942	F	C1
WE .	23095	MG	91039	N5204	48.0	UB	NE0023	91046	91048	SS12		262000.000000	UGL	0.942	F	C1
WELL	23095	MIBK	89307	M4490	48.0	UB	HQT008	89314	89321	P8	LT	4.900000	UGL	0.650		C1
WE	23095	MIBK	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	140.000000	UGL	0.779		1A
WE	23095	MIBK	90141	N1753	48.0	UB	JRE005	90145	90156	P8	LT	4.900000	UGL	0.650		C1
WELL	23095	MIBK	90233	N3018	48.4	ED	GXP016	90240	90242	R8	LT	12.900000	UGL	0.890		C1
ELL	23095	MIBK	91039	N5197	48.0	UB	NEW013	91042	91046	P8	LT	4.900000	UGL	0.650		C1
WE	23095	MLTHN	89307	M4497	48.0	UB	HQR008	89314	89318	UH11		2.990000	UGL	0.891		C1
WE..	23095	MLTHN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	21.000000	UGL	0.893		1A
WELL	23095	MLTHN	90057	M9015	48.5	UB	IXR006	90064	90066	UH11	LT	0.373000	UGL	0.891		C1
WE	23095	MLTHN	91039	N5201	48.0	UB	NEU013	91042	91051	UH11		2.820000	UGL	0.891		C1
WE	23095	NA	89307	M4500	48.0	UB	HSX008	90022	90023	SS12		3200000.000000	UGL	0.942	F	C1
ELL	23095	NA	90057	M9018	48.5	UB	JBP029	90074	90078	SS12		3900000.000000	UGL	0.942	F	C1
E!	23095	NA	90141	N1760	48.0	UB	JRW019	90163	90168	SS12		3500000.000000	UGL	0.942	F	C1
E	23095	NA	91039	N5204	48.0	UB	NE0023	91046	91048	SS12		3500000.000000	UGL	0.942	F	C1
ELL	23095	NIT	89307	M4495	48.0	UB	HRS008	89333	89334	LL8		5200.000000	UGL	0.989		C1
WELL	23095	NIT	90057	M9013	48.5	UB	IZK030	90072	90073	LL8		2300.000000	UGL	0.989		C1
WE	23095	NIT	90141	N1755	48.0	UB	JRR038	90155	90156	LL8		7100.000000	UGL	0.989		C1
WEL	23095	NIT	90233	N3020	48.4	ES	SMN016	90257	90257	TF22		10000.000000	UGL	0.999		C1
WELL	23095	NIT	91039	N5199	48.0	UB	NEL023	91057	91058	LL8		30000.000000	UGL	0.989		C1
WEL	23095	OXAT	89307	M4487	48.0	UB	HQP008	89313	89314	AAA8		17.600000	UGL	0.932		C1
WEL	23095	OXAT	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	27.000000	UGL	0.916		1A
ELL	23095	OXAT	90057	M9008	48.5	UB	IXS006	90064	90067	AAA8		15.000000	UGL	0.932		C1
ELL	23095	OXAT	90141	N1750	48.0	UB	JRA005	90145	90150	AAA8		16.300000	UGL	0.932		C1
EL	23095	OXAT	90233	N3015	48.4	ED	QBO016	90236	90239	PP8A		20.800000	UGL	0.965		C1
EL	23095	OXAT	91105	O3611	48.0	UB	OID006	91109	91118	AAA8		4.540000	UGL	0.932		C1
ELL	23095	PB	89307	M4500	48.0	UB	HSX008	90022	90023	SS12	LT	43.400000	UGL	0.980	F	C1
EL	23095	PB	90057	M9018	48.5	UB	JBP029	90074	90078	SS12	LT	43.400000	UGL	0.980	F	C1
EL	23095	PB	90141	N1760	48.0	UB	JRW019	90163	90168	SS12	LT	43.400000	UGL	0.980	F	C1
ELL	23095	PB	90233	N3025	48.4	ED	QSK016	90247	90248	R9D	LT	52.000000	UGL	0.936		C1
ELL	23095	PB	91039	N5204	48.0	UB	NE0023	91046	91048	SS12	LT	43.400000	UGL	0.980	F	C1
ELL	23095	PCP	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	9.100000	UGL	1.040		1A
ELL	23095	PHENOL	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	2.200000	UGL	0.401		1A
LL	23095	PPDDE	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		16.000000	UGL	0.917		C1
LL	23095	PPDDE	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	14.000000	UGL	1.040		1A
ELL	23095	PPDDE	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		6.100000	UGL	0.917		C1

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WELL	23095	PPDDE	90141	N1751	48.0	UB	JRB005	90145	90151	KK8		1.700000	UGL	0.917	C	C1
WELL	23095	PPDDE	90233	N3016	48.4	ED	QL0016	90236	90239	MM8A	LT	0.092000	UGL	0.977		C1
WELL	23095	PPDDT	89307	M4488	48.0	UB	HQQ008	89314	89316	KK8		0.263000	UGL	0.906		C1
WELL	23095	PPDDT	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	18.000000	UGL	0.951		1A
WELL	23095	PPDDT	90057	M9009	48.5	UB	IXQ006	90064	90065	KK8		6.700000	UGL	0.906		C1
WELL	23095	PPDDT	90141	N1751	48.0	UB	JRB005	90145	90151	KK8		3.000000	UGL	0.906	C	C1
WELL	23095	PPDDT	90233	N3016	48.4	ED	QL0016	90236	90239	MM8A	LT	0.120000	UGL	0.915		C1
WELL	23095	PRTHN	89307	M4497	48.0	UB	HQR008	89314	89318	UH11	LT	0.647000	UGL	0.790		C1
WELL	23095	PRTHN	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	37.000000	UGL	0.684		1A
WELL	23095	PRTHN	90057	M9015	48.5	UB	IXR006	90064	90066	UH11	LT	0.647000	UGL	0.790		C1
WELL	23095	PRTHN	90233	N3022	48.4	ES	PG0016	90240	90242	UN07	LT	0.250000	UGL	0.983		C1
WELL	23095	PRTHN	91039	N5201	48.0	UB	NEU013	91042	91051	UH11		26.100000	UGL	0.790		C1
WELL	23095	SO4	89307	M4491	48.0	UB	HQV008	89313	89313	TT09		1800000.000000	UGL	0.856		C1
WELL	23095	SO4	90141	N1754	48.0	UB	JTG005	90164	90164	TT09		1700000.000000	UGL	0.856		C1
WELL	23095	SO4	90233	N3019	48.4	ED	QQD016	90248	90249	NN8		1500000.000000	UGL	1.000		C1
WELL	23095	SO4	91039	N5198	48.0	UB	NFB013	91065	91065	TT09		2000000.000000	UGL	0.856		C1
WELL	23095	SUPONA	89307	M4497	48.0	UB	HQR008	89314	89318	UH11		0.930000	UGL	0.889		C1
WELL	23095	SUPONA	89307	M4494	48.0	UB	HQX002	89314	89319	UM25	LT	19.000000	UGL	0.630		1A
WELL	23095	SUPONA	90057	M9015	48.5	UB	IXR006	90064	90066	UH11	LT	0.787000	UGL	0.889		C1
WELL	23095	SUPONA	90141	N1757	48.0	UB	JRC005	90145	90161	UH11	LT	0.787000	UGL	0.889		C1
WELL	23095	SUPONA	91039	N5201	48.0	UB	NEU013	91042	91051	UH11	LT	0.787000	UGL	0.889		C1
WELL	23095	TCLEA	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	150.000000	UGL	0.992		1A
WELL	23095	TCLEE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8		31.000000	UGL	0.910		C1
WELL	23095	TCLEE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.080		1A
WELL	23095	TCLEE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8		18.500000	UGL	0.910		C1
WELL	23095	TCLEE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8		2.430000	UGL	0.910		C1
WELL	23095	TCLEE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8		24.600000	UGL	1.070		C1
WELL	23095	TCLEE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8		22.000000	UGL	0.910		C1
WELL	23095	TRCLE	89307	M4484,85	48.0	UB	HQN008	89315	89315	N8		21.000000	UGL	0.910		C1
WELL	23095	TRCLE	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	100.000000	UGL	1.000		1A
WELL	23095	TRCLE	90057	M9005,06	48.5	UB	IZB009	90067	90067	N8	LT	0.560000	UGL	0.910		C1
WELL	23095	TRCLE	90141	N1747,48	48.0	UB	JRH005	90147	90147	N8		0.776000	UGL	0.910		C1
WELL	23095	TRCLE	90233	N3012	48.4	ED	GYR016	90242	90242	TT8		17.200000	UGL	0.984		C1
WELL	23095	TRCLE	91039	N5191,92	48.0	UB	NEQ013	91043	91043	N8	LT	0.560000	UGL	0.910		C1
WELL	23095	UNK136	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21		4900.000000	UGL	0.000	S	1A
WELL	23095	UNK533	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		6.000000	UGL	0.000	S	1A
WELL	23095	UNK547	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK551	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK556	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		200.000000	UGL	0.000	S	1A
WELL	23095	UNK557	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		5.000000	UGL	0.000	S	1A
WELL	23095	UNK559	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
WELL	23095	UNK559	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	D	1A
WELL	23095	UNK561	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
WELL	23095	UNK562	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		5.000000	UGL	0.000	S	1A
WELL	23095	UNK564	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
WELL	23095	UNK565	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
WELL	23095	UNK569	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		4.000000	UGL	0.000	S	1A
WELL	23095	UNK570	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK571	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A

ite	Site_ID	Test Name	Sample Date	Field Number	Sample Depth	Lab	Lot Number	Prep Date	Anal Date	Meth Num	Bool	Corrected Value	UOM	Acc	Flag Code	Anal Type
ELL	23095	UNK572	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		30.000000	UGL	0.000	D	1A
ELL	23095	UNK572	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		7.000000	UGL	0.000	D	1A
[illegible]	23095	UNK572	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
[illegible]	23095	UNK574	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
ELL	23095	UNK577	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
[illegible]	23095	UNK577	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
[illegible]	23095	UNK579	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		5.000000	UGL	0.000	D	1A
ELL	23095	UNK581	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		50.000000	UGL	0.000	S	1A
WELL	23095	UNK581	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		60.000000	UGL	0.000	S	1A
WELL	23095	UNK582	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		400.000000	UGL	0.000	S	1A
WELL	23095	UNK583	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		30.000000	UGL	0.000	S	1A
WELL	23095	UNK584	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		7.000000	UGL	0.000	S	1A
WELL	23095	UNK585	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		7.000000	UGL	0.000	S	1A
WELL	23095	UNK585	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		80.000000	UGL	0.000	S	1A
WELL	23095	UNK588	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		30.000000	UGL	0.000	D	1A
WELL	23095	UNK590	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		80.000000	UGL	0.000	S	1A
WELL	23095	UNK590	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		5.000000	UGL	0.000	D	1A
WELL	23095	UNK591	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		7.000000	UGL	0.000	S	1A
WELL	23095	UNK591	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		4.000000	UGL	0.000	D	1A
WELL	23095	UNK595	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		8.000000	UGL	0.000	S	1A
WELL	23095	UNK595	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK596	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		30.000000	UGL	0.000	D	1A
WELL	23095	UNK602	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
WELL	23095	UNK605	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		30.000000	UGL	0.000	S	1A
WELL	23095	UNK607	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		4.000000	UGL	0.000	S	1A
WELL	23095	UNK607	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		7.000000	UGL	0.000	S	1A
WELL	23095	UNK610	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		6.000000	UGL	0.000	D	1A
WELL	23095	UNK612	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		6.000000	UGL	0.000	S	1A
WELL	23095	UNK616	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		10.000000	UGL	0.000	S	1A
WELL	23095	UNK619	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		7.000000	UGL	0.000	S	1A
WELL	23095	UNK622	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK624	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		4.000000	UGL	0.000	S	1A
WELL	23095	UNK625	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK626	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		9.000000	UGL	0.000	S	1A
WELL	23095	UNK629	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		4.000000	UGL	0.000	S	1A
WELL	23095	UNK632	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	UNK634	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		4.000000	UGL	0.000	S	1A
WELL	23095	UNK634	89307	M4494	48.0	UB	HQX002	89314	89319	UM25		20.000000	UGL	0.000	S	1A
WELL	23095	XYLEN	89307	M4482,83	48.0	UB	HQM008	89315	89315	AV8	LT	1.360000	UGL	0.889		C1
WELL	23095	XYLEN	89307	M4492,93	48.0	UB	HQW002	89319	89319	UM21	LT	200.000000	UGL	1.010		1A
WELL	23095	XYLEN	90057	M9003,04	48.5	UB	IZA009	90067	90067	AV8	LT	1.360000	UGL	0.889		C1
WELL	23095	XYLEN	90141	N1745,46	48.0	UB	JRG005	90147	90147	AV8	LT	1.360000	UGL	0.889		C1
WELL	23095	XYLEN	90233	N3010	48.4	ED	GZR016	90234	90234	SS8		2.150000	UGL	0.932		C1
WELL	23095	XYLEN	91039	N5189,90	48.0	UB	NEP013	91043	91043	AV8		1.700000	UGL	0.889		C1
WELL	23095	ZN	89307	M4500	48.0	UB	HSX008	90022	90023	SS12	LT	18.000000	UGL	0.969	F	C1
WELL	23095	ZN	90057	M9018	48.5	UB	JBP029	90074	90078	SS12		20.200000	UGL	0.969	F	C1
WELL	23095	ZN	90141	N1760	48.0	UB	JRW019	90163	90168	SS12	LT	18.000000	UGL	0.969	F	C1
WELL	23095	ZN	90233	N3025	48.4	ED	QSK016	90247	90248	R9D	LT	20.000000	UGL	0.962		C1
WELL	23095	ZN	91039	N5204	48.0	UB	NEO023	91046	91048	SS12	LT	18.000000	UGL	0.969	F	C1

Number of chemical records printed: 390

24-JUL-91 03:16 PM

D.P. Associates, Inc.
RMA Chemical Reject Report
Data Definition: RKPMREJ

Site Type	Site_ID	Test Name	Sample Date	Meth Num	Lab	Lot Number	Bool	Unc Mant	Unc Exp	UOM	Dil Mant	Dil Exp	Perc Moist	Acc	Corr Mant	Corr Exp	Corrected Value	Anal Type
WELL	23095	ATZ	90141	UH11	UB	JRC005		9.26	1	UGL				.986	9.39	1	93.90000	C1
WELL	23095	CL6CP	91039	KK8	UB	NET013		2.82	-1	UGL				.802	3.52	-1	0.35200	C1
WELL	23095	CYN	89307	TF20	UB	HQU008		7.25	0	UGL				1.01	7.18	0	7.18000	C1
WELL	23095	CYN	90057	TF20	UB	IXY006	LT	5.00	0	UGL				1.01	5.00	0	5.00000	C1
WELL	23095	CYN	90141	TF20	UB	JRF005		6.65	0	UGL				1.01	6.58	0	6.58000	C1
WELL	23095	CYN	91039	TF34	UB	NEX013	LT	5.00	0	UGL				1.02	5.00	0	5.00000	C1
WELL	23095	DBCP	91039	AY8	UB	NER013	LT	1.95	-1	UGL				.991	1.95	-1	0.19500	C1
WELL	23095	DIMP	91039	AT8	UB	NEV013		5.71	0	UGL	1.0	2		.908	6.3	2	630.00000	C1
WELL	23095	DLDRN	90141	KK8	UB	JRB005		2.26	-1	UGL	1.0	1		1.12	2.0	0	2.00000	C1
WELL	23095	DLDRN	91039	KK8	UB	NET013		3.20	-1	UGL	1.0	1		1.12	2.9	0	2.90000	C1
WELL	23095	DMDS	90233	PP8A	ED	QB0016	LT	1.16	0	UGL				1.02	1.16	0	1.16000	C1
WELL	23095	DMDS	91039	AAA8	UB	NES013	LT	5.50	-1	UGL				.955	5.50	-1	0.55000	C1
WELL	23095	DMMP	91039	AT8	UB	NEV013	LT	1.88	-1	UGL				.925	1.88	-1	0.18800	C1
WELL	23095	ENDRN	90141	KK8	UB	JRB005		8.31	-1	UGL				1.22	6.81	-1	0.68100	C1
WELL	23095	ISODR	91039	KK8	UB	NET013		4.49	-1	UGL				.819	5.48	-1	0.54800	C1
WELL	23095	MLTHN	90141	UH11	UB	JRC005		2.81	0	UGL				.891	3.15	0	3.15000	C1
WELL	23095	OXAT	91039	AAA8	UB	NES013		1.22	1	UGL				.932	1.31	1	13.10000	C1
WELL	23095	PPDDE	91039	KK8	UB	NET013		3.85	-1	UGL	1.0	1		.917	4.2	0	4.20000	C1
WELL	23095	PPDDT	91039	KK8	UB	NET013		8.34	-1	UGL	1.0	1		.906	9.2	0	9.20000	C1
WELL	23095	PRTHN	90141	UH11	UB	JRC005		2.82	1	UGL				.790	3.57	1	35.70000	C1

Number of chemical records printed: 20

*** End of Report ***

FALL 1991

06/29/92

LEVEL 3

RMA CMP Analytical Results

Site ID	Sample Date	Sample Depth	Parameter	Value		Flag	Units	Dilution	Method
23095	91105	48.0	111TCE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	111TCE	LT	.760000		UGL		N8
23095	91105	48.0	112TCE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	112TCE	LT	.780000		UGL		N8
23095	91105	48.0	11DCE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	11DCE	LT	1.700000		UGL		N8
23095	91105	48.0	11DCLE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	11DCLE	LT	.730000		UGL		N8
23095	91105	48.0	123TCB	LT	5.800000		UGL		UM25
23095	91105	48.0	124TCB	LT	2.400000		UGL		UM25
23095	91105	48.0	12DCE	LT	500.000000		UGL	100.000000	UM21
23095	91105	48.0	12DCE	LT	.760000		UGL		N8
23095	91105	48.0	12DCLB	LT	1.200000		UGL		UM25
23095	91105	48.0	12DCLE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	12DCLE		7.840000		UGL		N8
23095	91105	48.0	12DCLP	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	12DPH	LT	13.000000		UGL		UM25
23095	91105	48.0	13DCLB	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	13DCLB	LT	3.400000		UGL		UM25
23095	91105	48.0	13DCP	LT	480.000000		UGL	100.000000	UM21
23095	91105	48.0	13DMB	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	13DMB	LT	1.320000		UGL		AV8
23095	91105	48.0	14DCLB	LT	1.500000		UGL		UM25
23095	91105	48.0	236TCP	LT	1.700000		UGL		UM25
23095	91105	48.0	245TCP	LT	2.800000		UGL		UM25
23095	91105	48.0	246TCP	LT	3.600000		UGL		UM25
23095	91105	48.0	24DCLP	LT	8.400000		UGL		UM25
23095	91105	48.0	24DMPN	LT	4.400000		UGL		UM25
23095	91105	48.0	24DNP	LT	176.000000		UGL		UM25
23095	91105	48.0	24DNT	LT	5.800000		UGL		UM25
23095	91105	48.0	26DNA	LT	8.800000		UGL		UM25
23095	91105	48.0	26DNT	LT	6.700000		UGL		UM25
23095	91105	48.0	2CLEVE	LT	350.000000		UGL	100.000000	UM21
23095	91105	48.0	2CLP	LT	2.800000		UGL		UM25
23095	91105	48.0	2CNAP	LT	2.600000		UGL		UM25
23095	91105	48.0	2MNAP	LT	1.300000		UGL		UM25
23095	91105	48.0	2MP	LT	3.600000		UGL		UM25
23095	91105	48.0	2NP	LT	8.200000		UGL		UM25
23095	91105	48.0	33DCBD	LT	5.000000		UGL		UM25
23095	91105	48.0	35DNA	LT	21.000000		UGL		UM25
23095	91105	48.0	3NANIL	LT	15.000000		UGL		UM25
23095	91105	48.0	3NT	LT	2.900000		UGL		UM25
23095	91105	48.0	4BRPPE	LT	22.000000		UGL		UM25
23095	91105	48.0	4CL3C	LT	8.500000		UGL		UM25
23095	91105	48.0	4CLPPE	LT	23.000000		UGL		UM25
23095	91105	48.0	4MP	LT	2.800000		UGL		UM25
23095	91105	48.0	4NP	LT	96.000000		UGL		UM25
23095	91105	48.0	ABHC	LT	5.300000		UGL		UM25
23095	91105	48.0	ACET	LT	800.000000		UGL	100.000000	UM21
23095	91105	48.0	ACRYLO	LT	840.000000		UGL	100.000000	UM21
23095	91105	48.0	AENSLF	LT	23.000000		UGL		UM25
23095	91105	48.0	ALDRN	LT	13.000000		UGL		UM25
23095	91105	48.0	ANAPNE	LT	5.800000		UGL		UM25
23095	91105	48.0	ANAPYL	LT	5.100000		UGL		UM25
23095	91105	48.0	ANTRC	LT	5.200000		UGL		UM25
23095	91105	48.0	AS		16.100000	F	UGL		AX8
23095	91105	48.0	ATZ	LT	5.900000		UGL		UM25

Site ID	Sample Date	Sample Depth	Parameter	Value		Flag	Units	Dilution	Method
23095	91105	48.0	ATZ		88.900000		UGL		UH11
23095	91105	48.0	B2CEXM	LT	6.800000		UGL		UM25
23095	91105	48.0	B2CIPE	LT	5.000000		UGL		UM25
23095	91105	48.0	B2CLEE	LT	.680000		UGL		UM25
23095	91105	48.0	B2EHP	LT	7.700000		UGL		UM25
23095	91105	48.0	BAANTR	LT	9.800000		UGL		UM25
23095	91105	48.0	BAPYR	LT	14.000000		UGL		UM25
23095	91105	48.0	BBFANT	LT	10.000000		UGL		UM25
23095	91105	48.0	BBHC	LT	17.000000		UGL		UM25
23095	91105	48.0	BBZP	LT	28.000000		UGL		UM25
23095	91105	48.0	BCHPD		12.700000		UGL		P8
23095	91105	48.0	BENSLF	LT	42.000000		UGL		UM25
23095	91105	48.0	BGHIPY	LT	15.000000		UGL		UM25
23095	91105	48.0	BKFANT	LT	10.000000		UGL		UM25
23095	91105	48.0	BRDCLM	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	BRMCIL	LT	2.900000		UGL		UM25
23095	91105	48.0	BZALC	LT	4.000000		UGL		UM25
23095	91105	48.0	C13DCP	ND	500.000000	R	UGL	100.000000	UM21
23095	91105	48.0	C2AVE	ND	1000.000000	R	UGL	100.000000	UM21
23095	91105	48.0	C2H3CL	LT	1200.000000		UGL	100.000000	UM21
23095	91105	48.0	C2H5CL	LT	800.000000		UGL	100.000000	UM21
23095	91105	48.0	C6H6	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	C6H6		11.800000		UGL		AV8
23095	91105	48.0	CA		300000.000000	F	UGL	10.000000	SS12
23095	91105	48.0	CCL3F	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	CCL4	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	CCL4	LT	.990000		UGL		N8
23095	91105	48.0	CD	LT	6.780000	F	UGL		SS12
23095	91105	48.0	CH2CL2	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	CH2CL2	LT	7.400000		UGL		N8
23095	91105	48.0	CH3BR	LT	1400.000000		UGL	100.000000	UM21
23095	91105	48.0	CH3CL	LT	120.000000		UGL	100.000000	UM21
23095	91105	48.0	CHBR3	LT	1100.000000		UGL	100.000000	UM21
23095	91105	48.0	CHCL3		8200.000000		UGL	100.000000	UM21
23095	91105	48.0	CHCL3		9400.000000		UGL	100.000000	N8
23095	91105	48.0	CHRY	LT	7.400000		UGL		UM25
23095	91105	48.0	CL	GT	5000000.000000		UGL	500.000000	TT09
23095	91105	48.0	CL6BZ	LT	12.000000		UGL		UM25
23095	91105	48.0	CL6CP	LT	54.000000		UGL		UM25
23095	91105	48.0	CL6ET	LT	8.300000		UGL		UM25
23095	91105	48.0	CLC6H5	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	CLC6H5	LT	.820000		UGL		N8
23095	91105	48.0	CLDAN	LT	37.000000		UGL		UM25
23095	91105	48.0	CPMS		38.100000		UGL		AAA8
23095	91105	48.0	CPMS		239.000000		UGL		UM25
23095	91105	48.0	CPMSO	LT	15.000000		UGL		UM25
23095	91105	48.0	CPMSO2		230.000000		UGL	10.000000	AAA8
23095	91105	48.0	CPMSO2		264.000000		UGL		UM25
23095	91105	48.0	CR	LT	16.800000	F	UGL		SS12
23095	91105	48.0	CS2	ND	500.000000	R	UGL	100.000000	UM21
23095	91105	48.0	CU		93.000000	F	UGL		SS12
23095	91105	48.0	CYN	LT	5.000000		UGL		TF34
23095	91105	48.0	DBAHA	LT	12.000000		UGL		UM25
23095	91105	48.0	DBCP	LT	12.000000		UGL		UM25
23095	91105	48.0	DBCP		.200000		UGL		AY8
23095	91105	48.0	DBHC	ND	3.000000	R	UGL		UM25
23095	91105	48.0	DBRCLM	LT	100.000000		UGL	100.000000	UM21

LEVEL 3

RMA CMP Analytical Results

Site ID	Sample Date	Sample Depth	Parameter	Value		Flag	Units	Dilution	Method
23095	91105	48.0	DBZFUR	LT	5.100000		UGL		UM25
23095	91105	48.0	DCLB	LT	200.000000		UGL	100.000000	UM21
23095	91105	48.0	DCPD	GT	300.000000		UGL		UM25
23095	91105	48.0	DCPD		910.000000		UGL	10.000000	P8
23095	91105	48.0	DDVP	LT	8.500000		UGL		UM25
23095	91105	48.0	DDVP	LT	.384000		UGL		UH11
23095	91105	48.0	DEP	LT	5.900000		UGL		UM25
23095	91105	48.0	DIMP	GT	200.000000		UGL		UM25
23095	91105	48.0	DIMP		570.000000		UGL	100.000000	AT8
23095	91105	48.0	DITH		42.000000		UGL	10.000000	AAA8
23095	91105	48.0	DITH		42.700000		UGL		UM25
23095	91105	48.0	DLDRN	LT	26.000000		UGL		UM25
23095	91105	48.0	DMMP	LT	130.000000		UGL		UM25
23095	91105	48.0	DMMP	LT	.188000		UGL		AT8
23095	91105	48.0	DMP	LT	2.200000		UGL		UM25
23095	91105	48.0	DNBP	LT	33.000000		UGL		UM25
23095	91105	48.0	DNOP	LT	1.500000		UGL		UM25
23095	91105	48.0	ENDRN	LT	18.000000		UGL		UM25
23095	91105	48.0	ENDRNA	LT	5.000000		UGL		UM25
23095	91105	48.0	ESFSO4	LT	50.000000		UGL		UM25
23095	91105	48.0	ETC6H5	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	ETC6H5	LT	1.370000		UGL		AV8
23095	91105	48.0	F		18000.000000		UGL	10.000000	TT09
23095	91105	48.0	FANT	LT	24.000000		UGL		UM25
23095	91105	48.0	FLRENE	LT	9.200000		UGL		UM25
23095	91105	48.0	HCBD	LT	8.700000		UGL		UM25
23095	91105	48.0	HG		.235000	F	UGL		CC8
23095	91105	48.0	HPCL	LT	38.000000		UGL		UM25
23095	91105	48.0	HPCLE	LT	28.000000		UGL		UM25
23095	91105	48.0	ICDPYR	LT	21.000000		UGL		UM25
23095	91105	48.0	ISODR	LT	7.800000		UGL		UM25
23095	91105	48.0	ISOPHR	LT	2.400000		UGL		UM25
23095	91105	48.0	K		44200.000000	F	UGL		SS12
23095	91105	48.0	LIN	LT	7.200000		UGL		UM25
23095	91105	48.0	MEC6H5	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	MEC6H5	LT	1.470000		UGL		AV8
23095	91105	48.0	MEK	LT	1000.000000		UGL	100.000000	UM21
23095	91105	48.0	MEXCLR	LT	11.000000		UGL		UM25
23095	91105	48.0	MG		239000.000000	F	UGL		SS12
23095	91105	48.0	MIBK	LT	140.000000		UGL	100.000000	UM21
23095	91105	48.0	MIBK	LT	4.900000		UGL		P8
23095	91105	48.0	MIREX	LT	24.000000		UGL		UM25
23095	91105	48.0	MLTHN	LT	21.000000		UGL		UM25
23095	91105	48.0	MLTHN		4.260000		UGL		UH11
23095	91105	48.0	MNBK	ND	1000.000000	R	UGL	100.000000	UM21
23095	91105	48.0	NA		3600000.000000	F	UGL	100.000000	SS12
23095	91105	48.0	NAP	LT	.500000		UGL		UM25
23095	91105	48.0	NB	LT	3.700000		UGL		UM25
23095	91105	48.0	NIT		31000.000000		UGL	500.000000	LL8
23095	91105	48.0	NNDMEA	LT	9.700000		UGL		UM25
23095	91105	48.0	NNDNPA	LT	6.800000		UGL		UM25
23095	91105	48.0	NNDPA	LT	3.700000		UGL		UM25
23095	91105	48.0	OXAT		4.540000		UGL		AAA8
23095	91105	48.0	OXAT	LT	27.000000		UGL		UM25
23095	91105	48.0	PB	LT	43.400000	F	UGL		SS12
23095	91105	48.0	PCP	LT	9.100000		UGL		UM25
23095	91105	48.0	PHANTR	LT	9.900000		UGL		UM25

LEVEL 3

RMA CMP Analytical Results

Site ID	Sample Date	Sample Depth	Parameter	Value		Flag	Units	Dilution	Method
23095	91105	48.0	PHENOL	LT	2.200000		UGL		UM25
23095	91105	48.0	PPDDD	LT	18.000000		UGL		UM25
23095	91105	48.0	PPDDE	LT	14.000000		UGL		UM25
23095	91105	48.0	PPDDT	LT	18.000000		UGL		UM25
23095	91105	48.0	PRTHN	LT	37.000000		UGL		UM25
23095	91105	48.0	PRTHN	LT	.647000		UGL		UH11
23095	91105	48.0	PYR	LT	17.000000		UGL		UM25
23095	91105	48.0	SO4		1700000.000000		UGL	250.000000	TT09
23095	91105	48.0	STYR	ND	500.000000	R	UGL	100.000000	UM21
23095	91105	48.0	SUPONA	LT	19.000000		UGL		UM25
23095	91105	48.0	SUPONA	LT	.787000		UGL		UH11
23095	91105	48.0	T13DCP	ND	500.000000	R	UGL	100.000000	UM21
23095	91105	48.0	TCLEA	LT	150.000000		UGL	100.000000	UM21
23095	91105	48.0	TCLEE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	TCLEE		20.300000		UGL		N8
23095	91105	48.0	TRCLE	LT	100.000000		UGL	100.000000	UM21
23095	91105	48.0	TRCLE		10.100000		UGL		N8
23095	91105	48.0	UNK559		20.000000	S	UGL		UM25
23095	91105	48.0	UNK571		30.000000	S	UGL		UM25
23095	91105	48.0	UNK572		20.000000	S	UGL		UM25
23095	91105	48.0	UNK574		30.000000	S	UGL		UM25
23095	91105	48.0	UNK579		40.000000	S	UGL		UM25
23095	91105	48.0	UNK581		40.000000	S	UGL		UM25
23095	91105	48.0	UNK581		400.000000	D	UGL		UM25
23095	91105	48.0	UNK583		30.000000	S	UGL		UM25
23095	91105	48.0	UNK585		90.000000	S	UGL		UM25
23095	91105	48.0	UNK587		80.000000	S	UGL		UM25
23095	91105	48.0	UNK595		50.000000	S	UGL		UM25
23095	91105	48.0	UNK605		30.000000	S	UGL		UM25
23095	91105	48.0	XYLEN	LT	200.000000		UGL	100.000000	UM21
23095	91105	48.0	XYLEN		1.820000		UGL		AV8
23095	91105	48.0	ZN	LT	18.000000	F	UGL		SS12

APPENDIX B

WELL CONSTRUCTION INFORMATION

- DRILLING LOGS/WELL CONSTRUCTION LOGS
- SURVEY DATA

DRILLING LOGS/WELL CONSTRUCTION LOGS

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

SITE TYPE: BORING
SITE ID: Injection well
SHEET 1 OF 3

PROJECT NAME AND LOCATION	RMA - Tracer
PROJECT NUMBER	1170
ELEVATION AND DATUM	
DRILLING COMPANY	Layne - western
DRILLER	Dallas Werner
DATE AND TIME STARTED	9/5/91 1130
DATE AND TIME COMPLETED	9/6/91 0745
DRILLING EQUIPMENT: METHOD	CME - 75 truck mounted
COMPLETION DEPTH	52.0
TOTAL NO. OF SAMPLES	8
SIZE AND TYPE OF BIT	6¾ ID Augers
NO. OF SAMPLES: BULK	
NO. OF SAMPLES: SS	8
DRIVE	
LABORATORY	9
DRILLING FLUID	None
WATER LEVEL: FIRST	38'
WATER LEVEL: AFTER 24 HOURS	38'
SAMPLER HAMMER	2.5" ID hydraulic hammer
TYPE	Split Spoon
DRIVING WT.	~~140~~ 150
DROP	30
HYDROGEOLOGIST/DATE	Ed Young / 9/5/91
CHECKED BY/DATE	

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1	Auger Cuttings				light brown fine SAND, little silt			80	20	Dry		10yR 4/6	
2		2.0											
3		3.0											
4	Auger Cuttings				light brown silty fine SAND, trace clay, trace coarse sand			70	30	Dry		10yr 4/4	
5		5.0											
6													Reduce to 4¼ auger
7													
8													
9													
10					Same (no sample)								
11													
12													
13													
14													
15	Auger Cuttings				Same			70	30	Dry		10yr 4/4	

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	Injection well

SHEET 2 OF 3

DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
15													
16													
17													
18													
19													
20													
21													
22													
23	Auger Cuttings				light brown fine Sandy SILT, little clay			40	60	Dry		10yr 4/4	Augers at 25'
24													
25													
26													
27	Auger Cuttings				light brown silty fine SAND			50	50	Dry		10yr 5/4	
28													
29	Auger Cuttings				light brown silty coarse to fine sand, trace gravel		5	65	30	Damp		10yr 4/4	
30													
31													
32													
33													
34	Auger Cuttings				light brown medium to fine SAND little coarse sand, trace gravel trace silt		5	90	5	Damp		10yr 5/4	
35													

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	Injection well

SHEET 3 OF 3

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
35													
36													
37													
		37.0		15	light brown coarse to fine								(water at 38')
38	S1		1.69	35	SAND, little gravel, subrounded		10	85	5	wet		10yr 5/4	shipped
				30	grains								
39		39.0		30									
		39.0		5	light brown coarse to fine								
40	S2		1.55	10	SAND, subrounded, coarser			100		wet		10yr 5/4	shipped
				15	towards bottom of spoon								
41		41.0		13									
		41.0		14	light brown coarse to fine								
42	S3		1.28	25	SAND less fine sand than			100		wet		10yr 5/4	shipped
				23	above, subrounded								
43		43.0		20									
		43.0		4	light brown coarse to fine								
44	S4		1.33	11	SAND, trace gravel, becoming		5	95		wet		10yr 5/4	shipped
				20	coarser with depth								
45		45.0		30									
		45.0		17	light brown coarse to fine sand								Flowing Sand
46	S5	46.0	.65	50	little gravel, cobble in tip		10	90		wet		10yr.5/4	see picture shipped
		46.0		6	subrounded								
47	S6		1.35	12	light brown coarse to fine sand		5	95		wet		10yr 5/4	shipped
				24	trace gravel								
48		48.0		30	Becomes medium to fine sand		5	95		wet		10yr 4/4	
		48.0		6	trace gravel at 47.0 ft								
49	S7		1.47	30	light brown medium to fine sand to			100		wet		10yr 4/4	shipped
				20	48.2 ft.								
50		50.0		40	light brown coarse to fine sand		10	90		wet		10yr 5/4	
		50.0		10	little gravel, subrounded								
51	S8A		1.63	24	to 50.~~8~~5								shipped
	S8B			28	50.8 to 51.~~4~~5 brown-gray mottled			60	40	wet			shipped
52		52.0		40	silty medium to fine sand with .2'								
					seams of coarse to fine sand								
53					little gravel (weathered Denver Fm)								
					51.~~4~~5-51.6 gray-brown fine			20	80	moist		10yr 5/2	
54					sandy silt, little clay								
55					TD = 52.0 ft.								

R. L. STOLLAR & ASSOCIATES, INC.

WELL CONSTRUCTION SUMMARY

SITE TYPE

WELL	Injection well

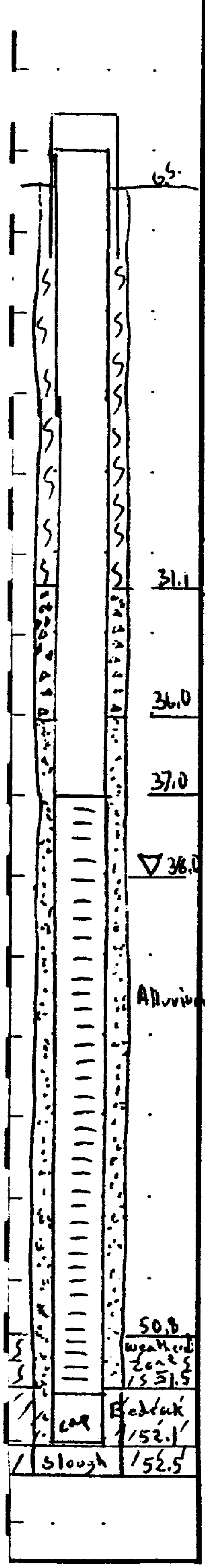
PROJECT RMA - Tracer

PERSONNEL Ed Young

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING



DRILLING SUMMARY

TOTAL DEPTH 52.5 ft.

BOREHOLE DIAMETER 10" ±

DRILLER Dallas Werner

RIG CME-75 truck mounted

BIT(S) 6 1/4" HSA

DRILLING FLUID None

SURFACE CASING

WELL DESIGN

BASIS: [✓ GEOLOGIC LOG] GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1 40'

C2

C3

C4

SCREEN S1 15'

S2

S3

S4

FILTER MATERIAL: 10/20 Silica Sand

SEAL: "Hole Plug" Bentonite chips

GROUT: Cement/Bentonite

OTHER:

CONSTRUCTION TIME LOG

TASK	START DATE	START TIME	FINISH DATE	FINISH TIME
DRILLING:	9/5/91	1130	9/6/91	0745
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:	9/6/91	0915	9/6/91	0950
FILTER:	9/6/91	0950	9/6/91	1023
SEAL:	9/6/91	1023	9/6/91	1035
GROUT:	9/6/91	1125	9/6/91	1150
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

SITE TYPE: BORING
SITE ID: Extraction well
SHEET 1 OF 3

PROJECT NAME AND LOCATION	RMA - Tracer
PROJECT NUMBER	1170
ELEVATION AND DATUM	
DRILLING COMPANY	Layne Western
DRILLER	Dallas Werner
DATE AND TIME STARTED	9/11/91 0910
DATE AND TIME COMPLETED	9/11/91 1430
DRILLING EQUIPMENT: METHOD	CME 75 truck mounted
COMPLETION DEPTH	52.5
TOTAL NO. OF SAMPLES	7
SIZE AND TYPE OF BIT	6 1/4" HSA
NO. OF SAMPLES: BULK	
NO. OF SAMPLES: SS	7
DRIVE	
LABORATORY	
DRILLING FLUID	None
WATER LEVEL: FIRST	~37
AFTER ____ HOURS	
SAMPLER HAMMER TYPE	Hydraulic
DRIVING WT.	150
DROP	30"
HYDROGEOLOGIST/DATE	Ed Young 9/11/91
CHECKED BY/DATE	

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1													
2	Auger Cuttings				light brown silty medium to fine SAND, trace clay			70	30	Dry		10yr 4/4	
3													
4													
5		5.0 5.0											
6													Very hard
7	Auger Cuttings				light brown silty medium to fine SAND, trace clay, trace coarse sand			70	30	Dry		10yr 4/4	
8													
9													
10		10.0 10.0											
11					Same								
12	Auger Cuttings												
13													
14													
15		15.0											

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	Extraction well

SHEET 2 OF 3

DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
15													
16													
17													
18													
19													
20		20.0											
21	Auger												
22	Cuttings				light brown silty, fine SAND,			60	40	Dry		10yr 4/4	
					little clay								
23													
24													
25		25.0			light brown silty medium to fine			50	50	Damp		10yr 5/4	
					SAND, little clay								Drilling Hard
26	Auger												to 27'
27	Cuttings												↓
28													
29													
30		30.0											
31													
32					very little cuttings								
					returned to surface								Gravels
33													
34													
35													

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	Extraction well

SHEET 3 OF 3

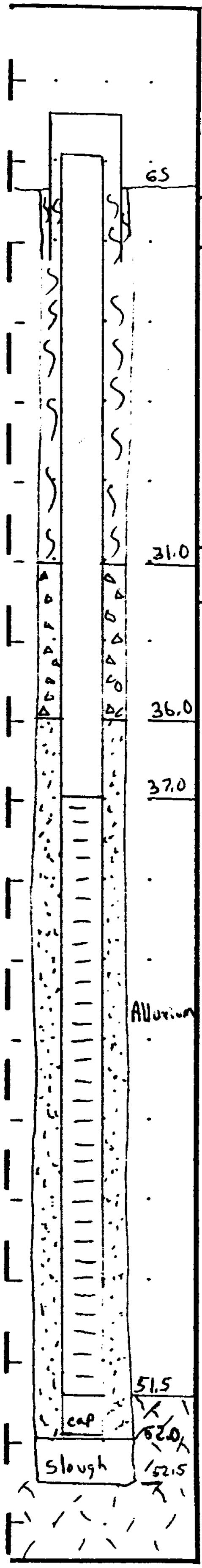
DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
35													
36													
37													
		37.0		19	light brown coarse to fine		5	85	10	wet		10yr 5/4	water at 37.2'
38	S1		1.7'	23	SAND, little silt, little gravel								
				19	subrounded grains more fines								
39		39.0		18	at top								
		39.0		4	light brown coarse to fine		5	95		wet		10yr 5/4	
40	S2		1.5'	8	sand, trace gravel. finer								
				12	towards bottom of spoon								
41		41.0		20	subrounded grains								
		41.0		3	light brown coarse to fine			100		wet		10yr 5/4	Sand running into
42	S3		0.7'	3	SAND. subrounded grains								augers
				6									
43		43.0		7									
		43.0		2	light brown coarse to fine		10	90		wet		10yr 5/4	
44	S4		0.9	3	SAND, little gravel. coarser								
				20	towards bottom, cobble in nose								
45		45.0		25	of spoon. Subrounded grains								
		45.0		1	light brown coarse to fine SAND		20	80		wet		10yr 5/4	
46	S5		1.1'	5	little gravel, one cobble								
				35	subrounded grains								
47		47.0		42									
	S6A	47.0		5	47.0 to 47.8 Same		20	80		wet		10yr 5/4	
48	S6B		1.2	10	47.8 ~~bottom~~ 47.9 ~~gray~~ brown CLAY,				100	wet		10yr 4/4	
				12	little silt								
49	S6C	49.0		20	47.9 - 48.2 light brown coarse to		20	80		wet		10yr 5/4	
		49.0		—	fine SAND, little gravel little silt								flowing Sand
50	S7A		2.9'	—	~~Silt~~ Sampled inside Augers - Resample w/ 5.0' split spoon								
				—	Same as above to 51.5		20	80		wet		10yr 5/4	
51				—	Gravely zone from 49.7 to 51.2		30	70		wet		10yr 5/4	
				—	Top of Denver formation								
52	S7B	52.0		—	at 51.5 gray-brown fine		~~20~~	~~80~~ 20	80	moist		10yr 5/2	
					sandy SILT, little clay								
53													
					T.D. 52.0								
54													
55													

R. L. STOLLAR & ASSOCIATES, INC.

WELL CONSTRUCTION SUMMARY

SITE TYPE

WELL	Extraction well



PROJECT RMA - Tracer

PERSONNEL Ed Young

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING

DRILLING SUMMARY

TOTAL DEPTH 52.5

BOREHOLE DIAMETER 10" ±

DRILLER Dallas Werner

RIG CME - 75 truck mounted

BIT(S) 6 1/4" HSA

DRILLING FLUID None

SURFACE CASING 8"x8"x5' stainless steel

WELL DESIGN

BASIS: [✓ GEOLOGIC LOG] GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1 40' 4" PVC

C2

C3

C4

SCREEN S1 15' .010 slot PVC (4")

S2

S3

S4

FILTER MATERIAL: 10/20 Silica sand

SEAL: "Hole Plug" Bentonite chips

GROUT: cement/bentonite

OTHER:

CONSTRUCTION TIME LOG

TASK	START		FINISH	
	DATE	TIME	DATE	TIME
DRILLING:	9/11/91	0910	9/11/91	1430
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:	9/11/91	1445	9/11/91	1500
FILTER:	9/11/91	1500	9/11/91	1540
SEAL:	9/11/91	1540	9/11/91	1600
GROUT:	9/11/91	1640	9/11/91	1700
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS

FOPM23 / JAN 88

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

SITE TYPE: BORING
SITE ID: P1

SHEET 1 OF 3

PROJECT NAME AND LOCATION	RMA - Tracer
PROJECT NUMBER	1170
ELEVATION AND DATUM	
DRILLING COMPANY	Layne - western
DRILLER	Dallas Weiner
DATE AND TIME STARTED	9/12/91 1040
DATE AND TIME COMPLETED	9/12/91 1415
DRILLING EQUIPMENT: METHOD	CME 75 truck mounted
COMPLETION DEPTH	53.0
TOTAL NO. OF SAMPLES	8
SIZE AND TYPE OF BIT	3 3/4" HSA
NO. OF SAMPLES: BULK	
NO. OF SAMPLES: SS	8
NO. OF SAMPLES: DRIVE	
NO. OF SAMPLES: LABORATORY	
DRILLING FLUID	None
WATER LEVEL: FIRST	36.9'
WATER LEVEL: AFTER ____ HOURS	
SAMPLER HAMMER TYPE	hydraulic
DRIVING WT.	150
DROP	30
HYDROGEOLOGIST/DATE	Ed Young 9/12/91
CHECKED BY/DATE	

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1	Auger Cuttings												
2					Light brown silty medium to fine SAND			70	30	Dry		10yr	5/6 ~~4/4~~
3													
4													
5		5.0 5.0											
6													
7	Auger Cuttings				light brown silty medium to fine SAND, trace clay.			70	30	Dry		10yr	5/6
8													
9													
10		10.0 10.0											
11													
12	Auger Cuttings				light brown silty medium to fine SAND, trace clay			60	40	Dry		10yr	5/6
13													
14													
15		15.0											

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE: BORING SITE ID: P1

SHEET 2 OF 3

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	SA	FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
15		15.0											
16													
17	Auger Cuttings				light brown fine sandy SILT, trace clay			40	60	dry		10yr 5/4	
18													
19													
20		20.0											
21													
22	Auger Cuttings				light brown fine sandy SILT, trace clay			40	60	Dry		10yr 5/4	
23													
24													
25		25.0											
26													
27					Same								
28													
29													
30		30.0			Becomes gravely at 31.0								
31													
32					brown medium to fine SAND little silt								
33													
34													
35													

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	F1

SHEET 3 OF 3

DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
35													
36													
		36.0		11	light brown coarse to fine		10	90		Dry to wet		10yr 5/4	
37	S1		1.7'	28	SAND, little gravel, subrounded								water at 36.9'
				38	grains								
38		38.0		28									
		38.0		3	light brown coarse to fine SAND			90	10	wet			
39	S2		1.7'	8	little silt, slight color change								
				10	at 39.0 10yr 5/4 to 10yr 5/6								
40		40.0		11	1/2" fine sandy SILT layer at 39.6'			40	60	wet			
		40.0		3	light brown coarse to fine SAND			100		wet			
41	S3		1.6'	8	color change at 41.0 to a darker								
				12	orange-brown becomes coarser at		10	90		wet			
42		42.0		20	41.0 with little gravel subrounded								
		42.0		4	light brown coarse to fine		10	90		wet			
43	S4		1.2'	8	SAND, trace gravel, relatively finer								
				18	42.6 to 42.8 gravely from 42.8 to								
44		44.0		20	43.2 subrounded								
	S5	44.0	~~29~~	24	light brown coarse to fine SAND		20	80		wet			
45		45.0	.6 ~~1~~	27	little gravel subrounded								
		~~45~~		~~31~~									
46				~~23~~									
		46.0		21 ~~38~~	light brown coarse to fine SAND		20	80		wet			
47	S6		1.3'	23 ~~45~~	little gravel, subrounded								
				38									
48		48.0		41									
		48.0		17	light brown coarse to fine SAND		10	90		wet			
49	S7		0.9	27	trace gravel, subrounded								
				30									
50		50.0		35									
		50.0		27	Same to 50.3								
51	S8	50.5		30	50.3 to 50.5 weathered zone		10	70	20	wet			
					iron staining. Silty coarse to								
52					fine SAND, little gravel								
					Bedrock at 51.5'								
53					TD = 53.0'								
54													
55													

R. L. STOLLAR & ASSOCIATES, INC.

WELL CONSTRUCTION SUMMARY

SITE TYPE

WELL	P1

PROJECT RMA-Tracer

PERSONNEL Ed Young

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING

DRILLING SUMMARY

TOTAL DEPTH 53.0

BOREHOLE DIAMETER 7.0" ±

DRILLER Dallas Werner

RIG CME 75 truck mounted

BIT(S) 3 3/4 HSA

DRILLING FLUID None

SURFACE CASING 8"x8"x5' stainless steel

WELL DESIGN

BASIS: GEOLOGIC LOG
GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1 2" Blank 40'

C2

C3

C4

SCREEN S1 2" .010 slot 15'

S2

S3

S4

FILTER MATERIAL: 10/20 silica sand

SEAL: Bentonite Pellets

GROUT: Cement/Bentonite

OTHER:

CONSTRUCTION TIME LOG

TASK	START		FINISH	
	DATE	TIME	DATE	TIME
DRILLING:	9/12/91	1040	9/12/91	1415
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:	9/12/91	1425	9/12/91	1430
FILTER:	9/12/91	1430	9/12/91	1510
SEAL:	9/12/91	1510	9/12/91	1530
GROUT:	9/12/91	1610	9/12/91	1630
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

SITE TYPE: BORING
SITE ID: P2
SHEET 1 OF 3

PROJECT NAME AND LOCATION: RMA - Tracer
PROJECT NUMBER: 1170
ELEVATION AND DATUM:
DRILLING COMPANY: Layne - western
DRILLER: Dallas weiner
DATE AND TIME STARTED: 9/13/91 0840
DATE AND TIME COMPLETED: 9/13/91 1130
DRILLING EQUIPMENT: METHOD: CME 75, truck mounted
COMPLETION DEPTH:
TOTAL NO. OF SAMPLES: 8
SIZE AND TYPE OF BIT: 3 3/4 HSA
NO. OF SAMPLES: BULK: SS 8 DRIVE: LABORATORY:
DRILLING FLUID: None
WATER LEVEL: FIRST 37.0 AFTER ____ HOURS
SAMPLER HAMMER
TYPE Hydraulic DRIVING WT. 150 DROP 30
HYDROGEOLOGIST/DATE: Ed Young 9/13/91
CHECKED BY/DATE:

DEPTH, FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1													
2													
3	Auger Cuttings				light brown silty fine SAND			70	30	Dry		10yr 5/6	
4													
		5.0											
		5.0											
6													
7													
	Auger Cuttings				light brown silty medium to fine SAND			70	30	Dry		10yr 5/6	
9													
		10.0											
11													
12	Auger cuttings				light brown silty medium to fine SAND, trace clay			60	40	Dry		10yr 5/6	
13													
14													
		15.0											

R. L. STOLLAR & ASSOCIATES, INC.

WELL LOG

Project No.
Well/Boring No. P2
Combo/Key No.

Project Name and Location	Elevation	Coordinates	Township Range Section
Drilling Company	Driller	Date and Time Started Date and Time Completed	
Drilling Equipment		Total Drilled Depth	Completion Depth
Drilling Method	Boring Diameter	Sampler / No of Samples	Cal / SS
Size and Type of Casing		Water Elevation / First	Completion / 24 Hrs
Type of Perforation	From To (Ft-BGS)	Pack Size and Type	From To (Ft-BGS)
Type of Seal	From To (Ft-BGS)	Hydrogeologist	Checked By/Date

Depth (feet)	Description	USCS Symbol	Lithology	Piezometer Installation	Water Content	Estimate % of GR	SA	FI	Blow Counts	Remarks (Drill Rate, Odor, Sample No, etc.)
15										
	Auger cuttings light brown silty medium to fine sand, trace clay 10yr 5/4					Dry	60	40		
20										
	Auger cuttings light brown fine sandy SILT, trace clay 10yr 5/6					Damp	40	60		
25										
	Auger cuttings light brown silty fine SAND trace clay 10yr 5/6					Dry	60	40		
30	Auger cuttings light brown medium to fine SAND 10yr 4/6						100			Hit gravel & cobbles at ≈32'
35										

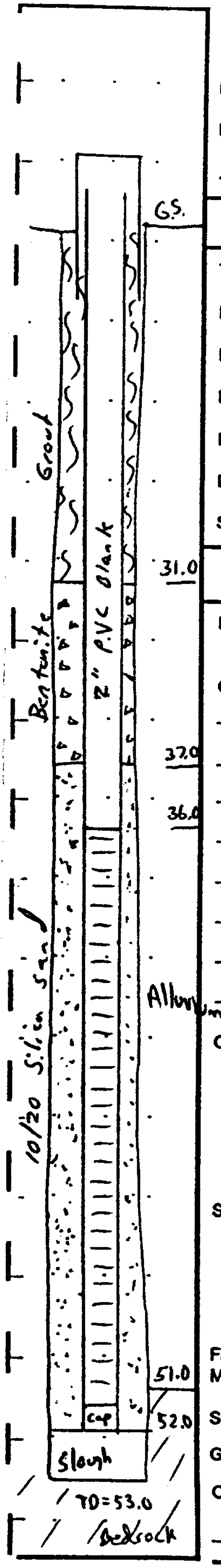
FOPM47/2

?. L. STOLLAR & ASSOCIATES, INC.

WELL CONSTRUCTION SUMMARY

SITE TYPE

WELL	P2



PROJECT RMA - Tracer

PERSONNEL Ed Young

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING

DRILLING SUMMARY

TOTAL DEPTH 53.0

BOREHOLE DIAMETER 7" ±

DRILLER Dallas Werner

RIG CME-75 truck mounted

BIT(S) 3 3/4" HSA

DRILLING FLUID None

SURFACE CASING 8" x8" x5' stainless steel

WELL DESIGN

BASIS: GEOLOGIC LOG
GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1 2.0" Blank PVC 40'

C2

C3

C4

SCREEN S1 2.0" PVC .010 slot 15'

S2

S3

S4

FILTER MATERIAL: 10/20 silica sand

SEAL: Bentonite Pellets

GROUT: Cement / Bentonite

OTHER:

CONSTRUCTION TIME LOG

TASK	START		FINISH	
	DATE	TIME	DATE	TIME
DRILLING:	9/13/91	0840	9/13/91	1130
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:	9/13/91	1140	9/13/91	1145
FILTER:	9/13/91	1145	9/13/91	1230
SEAL:	9/13/91	1230	9/13/91	1250
GROUT:	9/13/91	1330	9/13/91	1350
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS

FOPM23 / JAN 88

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

SITE TYPE: BORING
SITE ID: SB 1

SHEET 1 OF 3

PROJECT NAME AND LOCATION: RMA - Tracer
PROJECT NUMBER: 1170
ELEVATION AND DATUM:
DRILLING COMPANY: Layne - Western
DRILLER: Dallas Werner
DATE AND TIME STARTED: 9/18/91 1110
DATE AND TIME COMPLETED: 9/18/91 1415
DRILLING EQUIPMENT: METHOD: CME 75, truck mounted
COMPLETION DEPTH: 52.0'
TOTAL NO. OF SAMPLES: 4
SIZE AND TYPE OF BIT: 3 3/4 HSA
NO. OF SAMPLES: BULK: SS: 4 DRIVE: LABORATORY:
DRILLING FLUID: None
WATER LEVEL: FIRST: 38' AFTER ____ HOURS
SAMPLER HAMMER
TYPE: Hydraulic DRIVING WT. 150 DROP 30
HYDROGEOLOGIST/DATE: Ed Young 9/18/91
CHECKED BY/DATE:

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1													
2													
3	Auger cuttings				light brown silty fine SAND, trace clay			60	40	moist		10yr 5/4	
4													
5		5.0 5.0											
6													
7													
8	Auger cuttings				Light brown silty fine SAND			60	40	Dry		10yr 5/6	
9													
10		10.0											
11													
12													
13	Auger cuttings				light brown silty medium to fine SAND, trace clay			60	40			10yr 5/6	
14													
15		15.0											

?. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	SB1

SHEET 2 OF 3

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	SA	FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
15		15.0											
16													
17	Auger Cuttings				light brown silty medium to fine SAND, trace clay			50	50	moist		10yr 5/6	
18													
19													
20		20.0 20.0											
21													
22	Auger Cuttings				light brown silty fine SAND, trace clay			60	40	Dry		10yr 4/4	
23													
24													
25		25.0 25.0											
26													
27	Auger Cuttings				light brown sity coarse to fine SAND, trace gravel trace clay		5	55	40	moist		10yr 5/4	
28													
29													
30		30.0											
31													
32	Auger Cuttings				light brown coarse to fine SAND, little silt, little gravel		20	60	20	Dry		10yr 5/3	
33													
34													
35		35.0											

FORM [illegible] / JAN 1988

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

SITE TYPE	SITE ID
BORING	SB2

SHEET 1 OF 3

PROJECT NAME AND LOCATION RMA - Tracer	PROJECT NUMBER 1170	ELEVATION AND DATUM	
DRILLING COMPANY Layne - Western	DRILLER Dallas Weiner	DATE AND TIME STARTED 9/18/91 1635	DATE AND TIME COMPLETED 9/18/91 1920
DRILLING EQUIPMENT: METHOD CME 75, truck mounted		COMPLETION DEPTH 52.0'	TOTAL NO. OF SAMPLES 5
SIZE AND TYPE OF BIT 3 3/4" HSA		NO. OF SAMPLES: BULK: SS: 5	DRIVE: LABORATORY:
DRILLING FLUID None		WATER LEVEL: FIRST	AFTER ____ HOURS
SAMPLER HAMMER TYPE Hydraulic DRIVING WT. 150 DROP 30		HYDROGEOLOGIST/DATE Ed Young 9/18/91	CHECKED BY/DATE

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	SA	FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1													
2	Auger cuttings				Brown silty fine SAND, little silt, trace clay			60	40	moist		10yr 5/4	
3													
4													
5		5.0 5.0											
6													
7	Auger cuttings				light brown silty fine SAND trace coarse sand			70	30	Dry		10yr 7/6	
8													
9													
10		10.0											
11													
12	Auger cuttings				Light brown silty medium to fine SAND, trace clay					moist		10yr 5/6	
13													
14													
15		15.0											

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER ~~SB2~~ 1170

SITE TYPE: BORING

SITE ID: SB2

SHEET 2 OF 3

DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
15		15.0											
16													
17													
18	Auger Cuttings				light brown silty medium to fine SAND, trace clay			60	40	moist			10yr 5/4
19													
20		20.0 20.0											
21													
22													
23	Auger Cuttings				light brown silty fine SAND, trace clay			50	50	moist		10yr 5/3	
24													
25		25.0 25.0											
26													
27													
28	Auger Cuttings				light brown silty medium to fine SAND, trace clay			50	50	moist		10yr 5/3	
29													
30		30.0 30.0											
31													
32													
33	Auger Cuttings				light brown medium to fine SAND, trace coarse sand			100		Dry		10yr	
34													
35		35.0											

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER ~~SB2~~ 1170

SITE TYPE: BORING   SITE ID: SB2

SHEET 3 OF 3

DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
35		35.0											
36													
37	Auger				light brown coarse to fine		5	95		moist ~~dry~~			
	Cuttings				SAND, ~~little~~ trace gravel								
38													
39		39.0											
				9	Medium to fine SAND, little			100		wet			
40				23	Coarse Sand to 39.7								
	SB2A		1.5'	32	Coarse to fine SAND to 40.0			100		wet			
41				33	Coarse to fine SAND, trace								Redrove 2' spoon
				25	gravel to 41.5		10	90		wet			from 41 to 43'
42				10	Coarse to fine SAND, trace								Recovered .7'
				10	gravel								
43		43.0		19									
		43.0		12	Coarse to fine SAND to			100		wet			
44	SB2B		1.4'	14	44.0 Coarse to fine SAND,								
				16	trace gravel to 44.4		10	90		wet			
45		45.0		28									
		45.0		13	Coarse to fine SAND			100		wet			
46	SB2B		1.3'	17	to 45.6 . gravely								
				28	Coarse to fine SAND to		40	60		wet			
47		47.0		37	46.3								
		47.0		9									
48	SB2C		0.8'	19	Coarse to fine SAND		10	90		wet			
				29	trace gravel near tip								
49		49.0		39									
		49.0		27	Coarse to fine SAND		10	90		wet			
50	SB2C			29	trace gravel								
				29									
51		51.0		15									
52					Auger to 52.0'								
53													
54													
55													

I. L. STOLLAR & ASSOCIATES, INC.

WELL CONSTRUCTION SUMMARY

SITE TYPE

WELL	SBZ

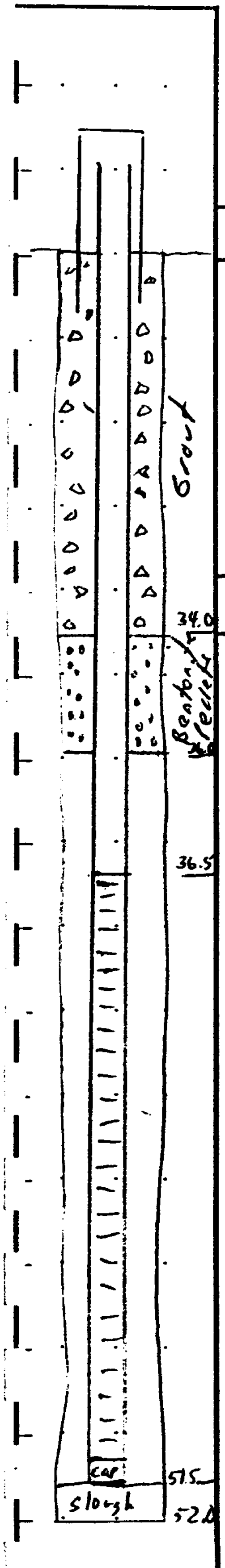
PROJECT RMA – Tracer

PERSONNEL Ed Young

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING



DRILLING SUMMARY

TOTAL DEPTH 52.0

BOREHOLE DIAMETER 7.0" ±

DRILLER Dallas Werner

RIG CME -75

BIT(S) 3 3/4 HSA

DRILLING FLUID None

SURFACE CASING 4" x 4" x 5' metal

WELL DESIGN

BASIS: [✓ GEOLOGIC LOG] GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1 40' 2" PVC Blank

C2

C3

C4

SCREEN S1 15' 2" PVC 0010 slot

S2

S3

S4

FILTER MATERIAL: None (see comments)

SEAL: Bentonite Pellets

GROUT: Cement / Bentonite

OTHER:

CONSTRUCTION TIME LOG

TASK	START		FINISH	
	DATE	TIME	DATE	TIME
DRILLING:	9/18/91	1635	9/18/91	1920
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:	9/18/91	1930	9/18/91	1930
FILTER:	NONE (see comments)			
SEAL:	~~9/18/91~~	9/19/91	~~9/18/91~~	9/19/91
GROUT:	9/19/91		9/19/91	
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS

Borehole allowed to collapse around well screen. Silica sand (10/20) placed from 38 to 36 ft. bgs.

Screen and Blank steam cleaned before installation.

Bentonite pellets hydrated with 5 gallons of water.

FOPM23 / JAN 88

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FIELD LOG OF BORING

SITE TYPE BORING SITE ID ~~MW~~ MC (Monitoring Cluster)

SHEET 1 OF 3

PROJECT NAME AND LOCATION RMA - Tracer	PROJECT NUMBER 1170	ELEVATION AND DATUM	
DRILLING COMPANY Layne - Western	DRILLER Dallas Werner	DATE AND TIME STARTED 9/16/91 0925	DATE AND TIME COMPLETED
DRILLING EQUIPMENT: METHOD CME 75, truck mounted		COMPLETION DEPTH	TOTAL NO. OF SAMPLES None
SIZE AND TYPE OF BIT 3 3/4", 8 1/4" HSA		NO. OF SAMPLES: BULK SS	DRIVE LABORATORY
DRILLING FLUID None		WATER LEVEL: FIRST	AFTER ____ HOURS
SAMPLER HAMMER TYPE DRIVING WT. DROP		HYDROGEOLOGIST/DATE Ed Young	CHECKED BY/DATE

DEPTH/FEET	SAMPLES: TYPE AND NUMBER	SAMPLES: INTERVAL	SAMPLES: RECOVERY	SAMPLES: BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF: GR	ESTIMATED PERCENT OF: SA	ESTIMATED PERCENT OF: FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
0		0.0											
1													
2	Auger Cuttings				light brown fine sandy SILT trace clay			40	60	moist		10yr	4/4
3													
4													
5		5.0 5.0											
6													
7	Auger Cuttings				light brown silty medium to fine SAND			70	30	Dry		10yr	4/4
8													
9													
10		10.0 10.0											
11													
12	Auger Cuttings				light brown medium to fine sandy SILT trace clay			40	60	moist		10yr	5/6
13													
14													
15		15.0											

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FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE	SITE ID
BORING	MC

SHEET 2 OF 3

DEPTH/FEET	SAMPLES				DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF			MOISTURE	CONSISTENCY	COLOR	COMMENTS
	TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT			GR	SA	FI				
15		15.0											
16													
17	Auger cutting				light brown medium to fine sandy SILT, trace clay			40	60	moist		10yr 4/4	
18													
19													
20		20.0 20.0											
21													
22	Auger cuttings				light brown silty fine SAND trace clay (less than above)			60	40	Dry		10yr 4/4	
23													
24													
25		25.0 25.0											
26													
27	Auger Cuttings				light brown medium to fine Sandy SILT, trace clay			30	70	moist		10yr 5/3	
28													
29													
30		30.0 30.0											
31													
32	Auger cuttings				light brown medium to fine SAND, little coarse sand			100				10yr 4/4	
33													
34													
35		35.0											

R. L. STOLLAR & ASSOCIATES, INC.

FIELD LOG OF BORING

CONTINUATION SHEET: PROJECT NUMBER 1170

SITE TYPE: BORING SITE ID: MC

SHEET 3 OF 3

DEPTH/FEET	SAMPLES TYPE AND NUMBER	INTERVAL	RECOVERY	BLOW COUNT	DESCRIPTION	USCS SYMBOL	ESTIMATED PERCENT OF GR	SA	FI	MOISTURE	CONSISTENCY	COLOR	COMMENTS
35	Auger cuttings				light brown coarse to fine SAND			100		Dry		10yr 4/4	
36													
37					TD with 3 3/4" Augers = ~~320'~~ 37.0'								
38													
39													
40													
1													
2													
3													
4													
5													
6													
7													
8													
9													
0													
1													
2													
3													
4													
5													

R. L. STOLLAR & ASSOCIATES, INC.

WELL CONSTRUCTION SUMMARY

SITE TYPE

WELL	MW cluster

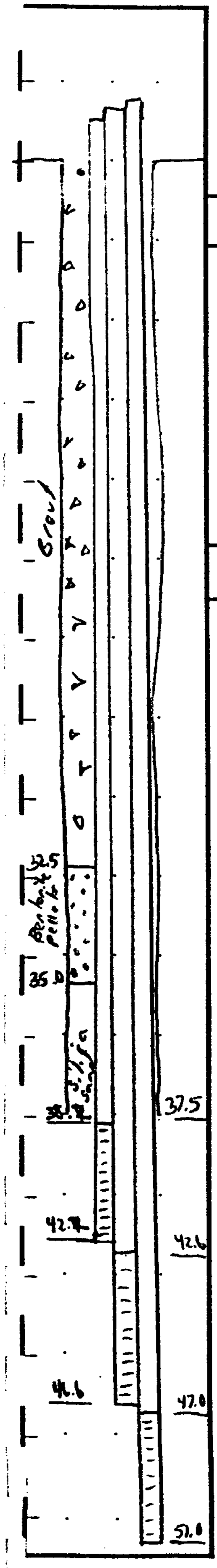
PROJECT RMA - Tracer

PERSONNEL

LOCATION OR COORDS.

ELEVATION: GROUND LEVEL

TOP OF CASING



DRILLING SUMMARY

TOTAL DEPTH 37.5'

BOREHOLE DIAMETER 12" ±

DRILLER Dallas Werner

RIG CME-75

BIT(S) 8 1/4" HSA

DRILLING FLUID None

SURFACE CASING 12"x12" stainless steel

WELL DESIGN

BASIS: [✓ GEOLOGIC LOG]
GEOPHYSICAL LOG

CASING STRING (S): C = CASING S = SCREEN

CASING C1

C2

C3

C4

SCREEN S1 4.0' 2" .010 slot Stainless Steel

S2 4.0' 2" .010 slot stainless steel

S3 4.0' 2" .010 slot stainless steel

S4

FILTER MATERIAL: Natural soil ✗

SEAL: Bentonite Pellets

GROUT: Cement / Bentonite

OTHER:

CONSTRUCTION TIME LOG

TASK	START		FINISH	
	DATE	TIME	DATE	TIME
DRILLING:	9/16		9/16	
GEOPHYSICAL LOGGING:				
SCREEN PLACEMENT:	9/20		9/20	
FILTER:				
SEAL:	9/24		9/24	
GROUT:	9/24		9/24	
DEVELOPMENT:				
OTHER:				

WELL DEVELOPMENT

COMMENTS

Drive points driven in place with a jackhammer. Blank casing is stainless steel until above water table then PVC

SURVEY DATA

GEONEX

GEONEX North American Operations, Inc.
1215 S. Huron, Denver, CO 80223

R.L. STOLLAR & ASSOCIATES
WELL LOCATION SECTION 23 - ROCKY MOUNTAIN ARSENAL
SEPTEMBER 27, 1991

STATE PLANE COORDINATES - COLORADO NORTH ZONE - US FEET - NAD27
ELEVATIONS IN US FEET NGVD 1929

PT#	NORTHING	EASTING	ELEVATION		DESCRIPTION
201	192109.8689	2181023.8373	5177.951	CONCRETE	# 1 - INJECTION WELL (I)
			5180.086	TOP OF CASING	
			5180.111	TOP OF PVC	
202	192113.7852	2181022.5956	5177.685	GROUND	# 2 - PIEZOMETER (P1)
			5179.836	TOP OF CASING	
			5179.913	TOP OF PVC	
203	192119.4567	2181024.9543	5177.601	GROUND	# 3 - PIEZOMETER (P2)
			5179.758	TOP OF CASING	
			5179.694	TOP OF PVC	
204	192118.0926	2181027.2427	5177.551	GROUND	# 4 - MONITORING CLUSTER -(B)
			5179.415	TOP OF CASING	
			5179.602	TOP OF PVC	
205	192118.3925	2181027.4176	5177.551	GROUND	# 5 - MONITORING CLUSTER -(A)
			5179.415	TOP OF CASING	
			5179.603	TOP OF PVC	
206	192118.0926	2181027.5926	5177.551	GROUND	# 6 - MONITORING CLUSTER -(C)
			5179.415	TOP OF CASING	
			5179.573	TOP OF PVC	
207	192113.1974	2181034.7442	5177.603	CONCRETE	# 7 - PIEZOMETER (23095)
			5179.808	TOP OF PVC	
208	192121.2064	2181028.8382	5177.571	GROUND	# 8 - PIEZOMETER (B2)
			5180.175	TOP OF CASING	
			5180.000	TOP OF PVC	
209	192129.7152	2181032.5419	5177.690	CONCRETE	# 9 - PIEZOMETER (B1)
			5180.057	TOP OF CASING	
			5180.999	TOP OF PVC	
210	192136.8979	2181035.5271	5177.599	CONCRETE	#10 - EXTRACTION WELL (E)
			5179.824	TOP OF CASING	
			5179.856	TOP OF PVC	

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