

CLEARWATER
G R O U P
Environmental Services

20976

Mr. Amir Gholami
Alameda County Environmental Health Services
Environmental Protection Division
1131 Harbor Bay Parkway, Suite 250
Alameda, CA 94502-6577

June 15, 2004

RE: *Interim Remedial Action Plan*
Eagle Gas Station
4301 San Leandro Street
Oakland, California 94601
Clearwater Group Project # ZP046B

Alameda County
JUN 21 2004
Environmental Division

Dear Mr. Gholami,

As requested, we are sending you a copy of *Interim Remedial Action Plan (IRAP)* for the Eagle Gas Station at the above referenced address. This IRAP was originally prepared on behalf of Mr. Muhammad Jamil and Ms. Farah Naz in January 2004. If there are any questions regarding the information as it is presented in the plan, please do not hesitate to contact our office at 510-307-9943 ext 236.

Sincerely,
Clearwater Group



David Mog P.E.
Principal Engineer

Enclosure

**Interim Remedial Action Plan
Eagle Gas
4301 San Leandro Street
Oakland, CA
January 14, 2004**

**Prepared For:
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And
Farah Naz
40092 Davis Street
Fremont, CA 94538**

**Prepared By:
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Pt. Richmond, CA 94801**

**Alameda County
JUL 9 2004
Environmental Health**

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- Figure 4: Proposed Well Diagram

- Table 1: Well Construction Data
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- Attachment A: KV Associates Case Study
- Attachment B: inVentures Technologies Incorporated Case Studies
- Attachment C: Illustrations of iSOC equipment and setup
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1.0 Purpose of Assessment

ACDEH requested via telephone on January 9, 2004 that an Interim Remedial Action Plan (IRAP) be prepared for the purpose of addressing the hydrocarbon contamination found in the groundwater beneath the project location.

2.0 Site Description

The site is located in the southern portion of Oakland, Alameda County, California at the south corner of San Leandro Street and High Street, approximately 1,000 feet east of Interstate Highway 880. The site is bounded by commercial property to the southeast, southwest and northwest and by the Bay Area Rapid Transit (BART) tracks to the northeast (Figure 1.) The site is predominantly underlain by clays with some clayey gravel and clayey sand at depths to approximately 10 feet below ground surface (bgs), and silty sand below 20 feet in some areas.

3.0 Background

On April 21 and 22, 1999, Clearwater, (formerly Artesian Environmental), oversaw the removal from the site of five underground storage tanks (UST) consisting of two 6,000-gallon gasoline USTs, two 4,000-gallon diesel USTs and one 300-gallon used oil UST (Figure 2.) Field observations included detection of strong petroleum odors from soils near the former UST locations. A total of five-confirmation soil samples and three groundwater samples were collected from the UST excavations. Laboratory analysis confirmed an unauthorized release of petroleum had occurred.

In a letter dated May 10, 1999, the ACDEH recommended that soil be remediated by over-excavation and that "as much groundwater as possible" be pumped from the excavation. Approximately 800 tons of petroleum-impacted soil was excavated and disposed of as Class II non-hazardous waste. Less than 1,000 gallons of petroleum-impacted groundwater was pumped and removed from the excavation. Groundwater did not recharge after the initial pumping. Existing on- and off-site structures limited the amount of soil that could be safely excavated. Soil samples collected from the

excavation walls and product piping trenches indicated some remaining petroleum and methyl tertiary butyl ether (MTBE) contamination.

On August 4 and 5, 1999, approximately 100 linear feet of product piping was removed. Vent piping from between the former USTs and the south corner of the on-site building was also removed. All piping was cut up and disposed of as scrap metal. On August 5, 1999, confirmation soil samples were collected along the piping trench. Six samples were collected from approximately three feet bgs. An additional four samples were collected, one for each of the four former fuel dispensers. Laboratory analytical results indicated the presence of hydrocarbon related contamination along the piping trenches.

On September 26, 2000 West Hazmat of Rancho Cordova, California, used a CME 75 drill rig to advance three borings to approximately 25 feet bgs (Figure 2), and collect soil samples. Each of the three borings was converted to a groundwater monitoring well using clean, flush-threaded, 2-inch diameter polyvinyl chloride (PVC) well materials (Table 1.) Soil sample analytical results are included as Table 2. On October 3 and 10, 2000, Clearwater surveyed the top of the casing elevations for each of the wells relative to an arbitrary datum, and developed the wells for monitoring. Initial groundwater samples collected from these wells contained 83,000 micrograms per liter ($\mu\text{g/L}$) to 250,000 $\mu\text{g/L}$ total petroleum hydrocarbons as gasoline, (TPHg), and 33,000 $\mu\text{g/L}$ to 400,000 $\mu\text{g/L}$ MTBE (Table 3.)

On August 3, 2001 Clearwater submitted its *Groundwater Monitoring Report, Second Quarter 2001, Sensitive Receptor Survey and Workplan for Continuing Investigation*. It was determined at that time that there are no major ecological receptors, permanent surface waters or domestic-use wells within a 2,000-foot radius of the site. The proposed scope of the workplan included the installation of eight groundwater-monitoring wells around the site to delineate the water-borne MTBE plume. In response to Clearwater's workplan, the ACDEH, in correspondence dated October 18, 2001, recommended that off-site monitoring wells not be installed for the time being. Instead, the ACDEH requested that further characterization of subsurface soils and groundwater on-site be completed prior to the installation of any off-site wells.

4.0 Proposed Remediation Methods

4.1 Groundwater Extraction and Treatment

Groundwater extraction and treatment has been proven as an effective means of controlling contaminant migration and reducing contaminant levels. Although dissolved concentrations can be reduced through groundwater extraction, this method generally will not bring dissolved contaminant concentrations to below the stringent clean-up levels identified. However, once asymptotic concentrations are reached, further reduction in concentrations generally slow down considerably, and natural attenuation becomes the primary process of contaminant reduction. The chemical properties of gasoline range hydrocarbons suggest the groundwater extraction for contaminant mass removal alone is ineffectual. It is a more useful technology in situations with MTBE contamination, because it is more soluble than gasoline hydrocarbons. The greatest benefit of groundwater extraction comes from exerting hydraulic control over a migrating plume and lowering the water table to expose soil to the effects of vapor extraction.

The water generated can sometimes be discharged untreated to local sanitary sewer districts at relatively high cost, otherwise treatment is usually required prior to discharge to either a sanitary sewer or storm sewer. If treatment is required, a remediation system will need to be designed and constructed. Due to the extremely high levels of MTBE detected in the groundwater samples collected from MW-2 (710,000 µg/L), the system must include various components for the removal of MTBE in the groundwater prior to treatment using activated granular carbon.

Clearwater will perform a brief step-drawdown test on MW-2, which allow for rough determination of sustainable flow-rates and the specific capacity of the well. The test will be performed in steps by pumping water from the well at increasing flow rates using a submersible electric pump and monitoring depth to water in the pumping well using an electric water sensor.

4.2 Chemical Oxidation (In-situ)

This technique enhances the natural microbial activity in the groundwater through the addition of dissolved oxygen. Indigenous microbes use dissolved-oxygen to naturally

breakdown hydrocarbons in groundwater. Unless an additional source of oxygen is present, microbial activity in the presence of an energy source (hydrocarbons) usually occurs faster than dissolved oxygen can be replenished naturally through groundwater recharge. If an energy source is not present, microbial activity will be minimal and dissolved-oxygen will not be depleted. As a result, microbial activity tends to deplete the oxygen in the center of dissolved hydrocarbon plumes. Once oxygen is depleted, anaerobic degradation predominates. However, anaerobic degradation rates are much lower than aerobic degradation rates. Thus, the rate at which natural biodegradation of the hydrocarbons occurs is restricted by the rate at which dissolved-oxygen can be replenished. The use of dissolved oxygen in contaminated ground water to enhance natural attenuation of gasoline constituents (MTBE, benzene, toluene, ethyl benzene and xylenes (BTEX)) has been growing as a remediation technology since the mid 1990's. Presently there are a variety of technologies available which will introduce low to moderate concentrations (10-20 ppm) of stable dissolved oxygen into ground water.

Once this elevated dissolved oxygen mixes with gasoline-contaminated ground water, natural biodegradation occurs and aerobic microorganisms consume the gasoline constituents. Enhanced bioremediation by the use of injected dissolved oxygen has been proven to be an effective technology to reduce both BTEX and MTBE. However many ground water environments that are high in ferrous iron and BOD, for example, will consume large volumes of injected dissolved oxygen before aerobic bacteria can utilize the oxygen as part of the process of consuming BTEX and MTBE. Therefore delivery of super-saturated levels of dissolved oxygen into ground water is essential to insure that an abundance of oxygen will remain for the bioremediation of BTEX and MTBE. The addition of dissolved oxygen via air injection or chemical injection (i.e. hydrogen peroxide or magnesium peroxide) to oxygenate depleted areas allows degradation to proceed aerobically at much higher rates.

4.2.1 Chemical Injection

The direct addition of liquid chemicals such as hydrogen peroxide (H_2O_2) to raise dissolved-oxygen (DO) levels can be expensive, difficult to obtain permits for, and can be difficult to control, often requiring extraction wells in addition to injection wells. However, Oxygen Release Compound[®] (ORC) is a patented magnesium peroxide compound, in a solid form that is placed in excavation backfill or in wells and borings,

and releases oxygen to naturally occurring microbes as it is hydrated. Thus, the need for controls and the expense related to weekly or daily maintenance is precluded. The additional oxygen provided by ORC stimulates aerobic microbial growth and activity. ORC is 10% oxygen by weight and approximately 4% by weight is liberated from the plugs.

Feasibility testing would have to be performed to determine if indigenous hydrocarbon degrading microbes and sufficient nutrients are present to support enhanced aerobic bioremediation.

4.2.2 Ozone Infusion

In-situ air stripping with microencapsulated ozone chemically oxidizes MTBE from contaminated groundwater with the use of fine bubbles with a high surface to volume ratio. The ozone contained within the bubble reacts extremely rapidly to chemically decompose the MTBE into simple products (alcohols, acetate and formate). The residual oxygen from the reaction encourages bioremediation, which consumes the breakdown products and converts them to carbon dioxide and water. The reaction is produced with very low ozone concentrations-molar ratios-compared to volatile organic compounds (VOC) concentrations in the groundwater. Ozone lasts approximately 20 minutes in water depending on a variety of factors.

Air and ozone are injected directly into the groundwater through specially designed spargers to create "microbubbles". The Henry's Constant which regulates the partitioning of MTBE from aqueous to gaseous state is about one-tenth that of benzene derivatives. The surface-to-volume ratio increase of over 30-fold compensates to promote rapid in-situ stripping of MTBE. MTBE is rapidly degraded with time. The rate of removal is sensitive to ozone concentration, pressure and iron silicate content. A case study provided by KV Associates is included as **Attachment A**.

4.2.3 Oxygen Infusion

A growing number of remediation contractors in the US, Canada and Brazil are utilizing a Canadian technology called in-situ Submerged Oxygen Curtain (iSOC™) that infuses oxygen, using a spargeless technique, into ground water via monitor wells. Case studies

provided by inVentures Technologies Incorporated are included as **Attachment B**. The proprietary structured polymer used in iSOC provides large surface area for gas transfer into a 15 inch by 1.75-inch probe, which is placed down a 2 or 4-inch monitor well. The probe is connected to a regulated canister supply of industrial compressed oxygen secured within a remediation compound. Oxygen infusion enriches the dissolved oxygen (DO) content of groundwater without causing aeration and volatilization of organic compounds. Super saturation levels of oxygen can be achieved in the range of 40 to 50 milligrams per liter (mg/L or ppm). This technology requires no external power, with a minimum monthly exchange of oxygen canisters. During this time, the large and continuous supply of oxygen infused into the ground water system is able to provide significant enhanced degradation of both BTEX and MTBE. The dissolved oxygen in infused from the iSOC into the monitoring well at a typical rate of 15 to 20 cubic centimeters per minute. The effective radius of influence of super-saturated ground water leaving the monitoring wells with the iSOC's is typically 10-15 feet. Illustrations of equipment and a typical setup are shown in **Attachment C**.

The iSOC technology has been reported to remediate BTEX levels in excess of 100,000 ppb at sites in Canada and Brazil. In those countries MTBE is currently not being used in gasoline. In the United States iSOC technology is being used to remediate BTEX and both MTBE and TBA.

Typically sites that are good candidates for the application of this technology are also good candidates for air sparging and soil vapor extraction (AS/SVE). The technology may be applied to sites that are not good candidates for AS/SVE, as the expected results would generally occur over a greater period of time than for the ideal project location. The success of oxygen infusion also depends on the lack of liquid phase hydrocarbons (LPH), with the presence of dissolved phase concentrations of total VOC and MTBE. The infusion system also requires the presence of a monitoring well network (2 inches in diameter or larger) that can be used for infusion and to monitor performance. The system may be installed onsite within the existing network of monitoring wells to treat the "source", or it may be used in a new network of wells installed perpendicular to the direction of groundwater movement beneath the site.

4.3 Natural Attenuation

The predominant attenuation process is intrinsic biodegradation (aerobic and anaerobic) mediated by hydrocarbon degrading bacteria. Other factors in natural attenuation include physical and chemical processes such as volatilization, dispersion, sorption and hydrolysis. Unless otherwise referenced, the following information was derived from McAllister and Chiang (1994).

In aerobic respiration, microbes utilize dissolved oxygen (DO) as an electron acceptor during hydrocarbon oxidation (degradation), producing carbon dioxide, water, and microbial biomass. The electron acceptor is a substance that facilitates the reaction by taking up the electrons released by oxidation; the electron acceptor then becomes reduced during the process of biodegradation.

The aerobic process is the most important form of biodegradation wherever DO concentrations exceed 1 to 2 mg/L. Under hypoxic conditions (0.1 to 2 mg/L DO), aerobic degradation may occur along the edges of the plume while anaerobic degradation predominates in the center of the plume.

Microbes may also degrade hydrocarbons via anaerobic processes by utilizing alternate biochemical pathways when DO concentrations are insufficient for aerobic degradation. Anaerobic degradation is much slower than the aerobic process and not all BTEX compounds are consistently degraded. Some studies indicate benzene is recalcitrant to anaerobic degradation while others have demonstrated limited degradation (Rifai et al, 1995). Anaerobic degradation generally occurs in the center of the plume where DO has been depleted by aerobic degradation. Research into the efficacy of anaerobic processes is ongoing.

Anaerobic electron acceptors include [in order of sequential use and decreasing redox potential (Eh)]:

- nitrate (NO_3^-),
- oxides of ferric iron (Fe^{3+}),
- sulfate (SO_4^{2-}),
- water.

The associated biochemical processes are: denitrification (or nitrate reduction), iron reduction, sulfate reduction, and methanogenesis. Manganese (Mn^{4+}) may also function as an electron acceptor. Nitrate and sulfate reduction do not degrade alkanes such as methane, propane, and butane.

Dissolved plume mass can be reduced by volatilization of contaminants to the vapor phase in the unsaturated zone. Normally volatilization is a negligible component of natural attenuation, however, it may contribute 5% or more of total mass loss in shallow (<15 feet), warm and/or fluctuating water table conditions in permeable soils (Rifai et al, 1995).

Mechanical/molecular mixing reduces dissolved concentrations substantially by lateral spread. No dissolved contaminant mass is removed from the system by this process. Dispersion (D) is generally modeled based on the length of the plume (x). Conservative practice calls for dispersion in the downgradient direction (longitudinal dispersivity, D_x) to be modeled at 0.1 times the plume length. Dispersion in the transverse direction (transverse dispersivity, D_y) is modeled at 0.33 times D_x ; dispersion in the vertical direction (vertical dispersivity, D_z) is modeled at 0.05 times D_x (Connor, et al., 1995).

Contaminants partition between the aqueous phase and the soil matrix. Adsorption onto the soil surface significantly retards migration but does not permanently remove BTEX which may desorb later. Carbon is the most effective sorption material in soils, and although clay minerals and amorphous minerals such as iron hydroxides also have some influence, only sorption to carbon in soil is included in most contaminant fate and transport computer models.

Sorption is controlled by the organic carbon content of soil (f_{OC}), the chemical specific organic carbon partition coefficient (K_{OC}), the soil bulk density (ρ_s), and the water content of the soil as measured by the porosity (ϕ_s). K_{OC} is a measure of the affinity of a given chemical to sorb from water onto solid organic material (Table 1). Once the porosity, bulk density, K_{OC} , and f_{OC} have been established, the retardation factor (R) for the site can be calculated as follows:

$$R = (1 + k_s * \rho_s / \phi_s) \quad \text{where: } k_s = f_{OC} * K_{OC}$$

The retardation factor is used in transport models (discussed below) as a measure of the degree to which the rate of plume migration is reduced by sorption processes.

5.0 Evaluation of Proposed Remediation Methods

Many factors must be considered when choosing the correct technology to remediate a hydrocarbon-impacted site. The amount of contamination and phase it is primarily found in, the geology and hydrogeology of the site, the location and size of the contaminant plume, the location and size of the project site, surrounding land use, sensitive receptors, clean-up goals and money.

The primary source of contamination was removed in 1999 when approximately 800 tons of petroleum-impacted soil was excavated and disposed of as Class II non-hazardous waste. Soil samples collected from the excavation walls and product piping trenches indicated some remaining petroleum and methyl tertiary butyl ether (MTBE) contamination. Since that time, groundwater samples collected from the three-groundwater monitoring wells located at the project location have indicated that the remaining sorbed-phase contamination has migrated into the groundwater.

Groundwater extraction, "pump and treat", is best used in locations of loose geologic formations such as sands and gravels. The project site is predominantly underlain by clay and clayey gravels to approximately 10 feet bgs. Clayey sands were documented to at least 20 feet bgs. During the over-excavation of contaminated soils less than 1,000 gallons of petroleum-impacted groundwater was pumped and removed from the excavation. Groundwater did not recharge after the initial pumping. The tight clay formation makes groundwater extraction undesirable as an approach to effectively remediate the project site.

The tight formation also makes Chemical Injection and Ozone Infusion impractical approaches to remediation. Fractures in clays and other low permeable sediments create preferred remedial pathways for the ORC™. The matrix of the fractured low permeable soil is unlikely to be uniformly treated. Ozone sparging works best in soil with a permeability of 10^{-1} to 10^{-5} centimeters per second (cm/sec). Clayey soils typically have a permeability of 10^{-6} cm/sec, which is considered too tight for effective use of ozone. The

ozone may also corrode metals that it comes into contact with also making it a poor choice for remediation due to the close proximity of neighboring buildings.

Natural attenuation is an impractical approach to remediation due to the extremely high levels of contamination detected in the groundwater samples from all groundwater-monitoring wells.

Enhanced bio-remediation through the use of oxygen infusion appears to be the only practical approach to groundwater remediation at the project site. The infused oxygen molecule is smaller than the ozone molecule and the water molecule; it will be able to travel further through the tight pore space of the clay, which dominates the lithology of the site. The oxygen molecule and microbes are smaller than the clay pore openings. The infused oxygen molecule provides no health or structural risks as it travels down gradient towards the neighboring buildings.

6.0 Application of the Oxygen Infusion System

6.1.1 Monitoring Well Network

Each iSOC™ unit has a treatment radius of up to 15 feet. Maximum efficiency of the iSOC™ system will require the installation of approximately nine groundwater monitoring/system wells at the project location (**Figure 3**). If maximum efficiency is not desired or deemed to costly then a minimum of six monitoring wells will be required to treat the hydrocarbon plume on the perimeter of the project site.

6.1.2 Drilling, Soil Sampling, and Analysis

Prior to conducting field activities, appropriate well installation permits will be obtained from the appropriate agencies. Underground Service Alert will be requested to identify utilities leading to the site. All field personnel on-site will review and sign the site Health and Safety plan, prepared in accordance with OSHA 1910.120, at the start of each field day. All fieldwork will be conducted in accordance with Clearwater's Field Procedures (**Attachment D**).

Under supervision of a Clearwater geologist, a C-57 licensed drilling contractor will advance the soil borings. The soil borings will be advanced sufficiently deep so that

water is encountered to approximately 25 feet bgs. Soil samples will be collected at five-foot depth intervals and retained for laboratory analysis. Portions of each soil sample will be retained for visual classification according to the Unified Soil Classification System. Soil samples will be screened for the presence of volatile hydrocarbons using a photo-ionization detector (PID). Additionally, a groundwater sample will be taken from the borehole, using a disposable or clean stainless steel bailer.

The water samples will be analyzed for concentrations of total petroleum hydrocarbons as diesel (TPHd) by EPA method 8015 modified, TPHg, BTEX, and five-fuel oxygenates; MTBE, diisopropyl ether (DIPE), tertiary butyl alcohol (TBA), tertiary amyl methyl ether (TAME) and ethyl tertiary butyl ether (ETBE) by EPA methods 8260 by a DHS-certified laboratory.

Soil cuttings and sampler rinseate will be stored on-site in labeled 55-gallons drums pending future removal and disposal.

6.1.3 Monitoring Well Installation and Survey

Clearwater will supervise the construction of the monitoring wells (proposed MW-4 through MW-12). It is assumed the wells will not be installed past a depth of approximately 25 feet bgs, however, final well construction will depend on hydrogeologic observations made at the time of drilling. Tentative well construction details are shown on Figure 4.

The wells will be constructed of clean, flush-threaded, 2-inch diameter PVC well materials. Well screen, with 0.02-inch perforations, will extend from the bottom of each boring to approximately 10 feet bgs, and blank casing will be extended to ground surface. A filter pack of Lonestar #3 sand will extend from the bottom of each boring to one foot above the screened interval. The filter pack will be sealed by a two-foot layer of hydrated bentonite. The remaining annular space will be filled with cement and a tamper-resistant box will be concreted in place over the wellhead. Clearwater will survey the top of casing elevations relative to a permanent benchmark, accurate to within ± 0.01 -feet.

6.1.4 Well Gauging, Development, Sampling, and Analysis

The new and existing wells will be monitored and sampled following installation. An electronic water level indicator, accurate to within ± 0.01 -foot, will be used to gauge depth to water. All wells will be checked for the presence of separate-phase hydrocarbons (SPH) prior to development and sampling.

The new wells will be developed by surging and bailing. Development will involve the removal of water from each well until such time that it is relatively free of sediment, and pH, temperature, and conductivity parameters have stabilized. Removal of well water for development will serve as purging prior to sampling. It is anticipated that the water volume removed will not exceed ten saturated casing volumes. The existing wells will also be purged until physical parameters stabilize prior to sampling. Groundwater monitoring and well purging information will be recorded on Gauge Data/Purge Calculations and Purge Data sheets.

Following recovery of water columns to at least 80% of their static levels, or after passage of two hours (if designated recovery levels have not occurred), groundwater samples will be collected from the monitoring well using dedicated polyethylene bailers. Samples will be decanted into laboratory-supplied containers, labeled, documented on a chain-of-custody form, and placed on ice in a cooler for transport to the project laboratory. Groundwater samples will be analyzed by Kiff Analytical LLC, a California DHS-certified laboratory, located in Davis, California, for concentrations TPHd by EPA Method 8015 modified, TPHg, BTEX, and five-fuel oxygenates by EPA Method 8260.

Purging devices will be decontaminated between wells in an Alconox® wash followed by double rinse in clean tap water to prevent cross-contamination. Rinseate will be stored on-site in labeled 55-gallons drums pending future removal and disposal.

Prior to system implementation, a baseline-sampling event will be conducted on the onsite monitoring wells. The samples will be analyzed for TPHd, TPHg, BTEX, five-fuel oxygenates, nitrate, sulfate, ortho-phosphate, ammonia nitrogen, biological oxygen demand (BODS), and chemical oxygen demand (COD), DO, and pH. In addition, DO, redox potential conductivity (ORP), temperature, and pH measurements will be

gathered in the field. This data will be used to assess whether sufficient nutrients still exist at the site to provide the necessary conditions for biodegradation. If it is concluded that the levels do not exist, then nutrients will be added. The network of wells will continue to be monitored on a quarterly basis to evaluate remedial progress and to estimate the time needed to reach remedial target levels. The monitoring well samples will be analyzed according to USEPA Method 8260B for concentrations of TPHd, TPHg, BTEX and five-fuel oxygenates.

Trenching options will be discussed after the quantity of system wells is determined. The system tubing may be laid directly into a 2 by 12 inch saw-cut path and sealed with concrete or a larger 6 by 12 inch trench may be dug from the wells to a remediation compound that will house the system equipment. One-quarter inch flexible polyurethane tubing will be installed in the trenches and used to connect the infusion probes to the cylinders in the compound.

7.0 Equipment Requirements

Application of the infusion technology requires the use of certain equipment to monitor the airflow rate being supplied to the groundwater and regulate the pressure at which oxygen is delivered. Based on manufacturer recommendations, the system should operate at an oxygen flow rate of 15 cubic centimeters per minute (cc/min) and a pressure of 5 pounds per square inch (psi) above the maximum static water pressure.

At the infusion wells, a high range DO/ORP meter should be used; an example of this type of DO meter is an OxyQuard Handy Alpha provided by Point Four Systems, Inc. At surrounding monitoring wells, a typical DO meter will be adequate. In addition, a dual stage low flow (0-4psi) pressure regulator and a low air flow meter should be used. The type of regulator predominantly used is a Victor 270 or equivalent available from Thermadyne. The appropriate air flow meter is a Cole Parmer Model P-03217 available from Cole Parmer Instrument Company. Miscellaneous fittings and supplies are available from Environmental Bio-Systems. Compressed air cylinders can be obtained from local welding shops, such as Airgas.

8.0 Scope of Work

Upon approval of the IRAP by the ACDEH, Clearwater will initiate the previously mentioned well installation. After the new wells are installed the extent of required trenching will be apparent. The goal is to install a remediation compound in a convenient location large enough to house the compressed air cylinder (oxygen source), air flow meter and miscellaneous supplies. The remediation design layout will depend solely upon the number and location of newly installed monitoring wells. Diagrams of the remediation design will be available for review once the layout of monitoring wells has been established.

The remediation system will be connected from the probe at each infusion well location to ¼-inch OD flexible polyurethane tubing laid securely within the piping trench leading to the compound. The piping trench and associated tubing will terminate within the compound through the use of an above grade well manifold. Each individual infusion well will be attached to a pressure gauge on the manifold and include a valve to regulate the airflow. The manifold will be connected to an oxygen cylinder or a series of cylinders depending on the number of infusion wells within the system. The cylinders will also be equipped with pressure gauges to monitor the available oxygen supply.

Following startup of oxygen infusion, groundwater DO concentrations in the infusion wells will be monitored once a week until a relatively constant DO is reached in the infusion wells, DO monitoring will then be performed quarterly along with the groundwater sampling events. Each of the quarterly sampling events will consist of collecting groundwater samples from the network of monitoring wells for analysis of TPHd, TPHg, BTEX and five -fuel oxygenates using EPA Method 8260B.

After concentrations decline to levels amenable to remediation by natural -attenuation, without the aide of enhanced oxygen infusion, the gas cylinders will be disconnected. The probes will be removed from the infusion wells and quarterly monitoring will continue at the site until site closure can be considered. As a precaution the tubing for the system should remain in place until site closure is granted. This will allow for the

return use of oxygen infusion if for some reason the concentrations of petroleum related hydrocarbons spike during a quarterly monitoring event.

9.0 Proposed Schedule of Remedial Action

The proposed schedule for remedial action is provided to identify the sequence of key tasks to remediate the groundwater at the site:

- Install new network of groundwater monitoring wells
- Conduct base-line sampling event
- Bid out system installation
- Apply and secure all appropriate permits from the various Alameda County entities
- Install remediation system
- Start up system, and monitor DO levels until parameters have stabilized
- Prepare start up report
- Monitor and sample remaining network of wells, adjust infusion rates as required, until natural attenuation of the hydrocarbon plume can continue without the aide of enhanced oxygen infusion
- Continue quarterly monitoring of groundwater wells until concentrations of petroleum related hydrocarbons fall below risk based screening levels (RBSL) for threatened drinking water;\
- Once concentrations fall below RBSL, the site should continued to be monitored quarterly for one year
- If dissolved hydrocarbon concentrations remain acceptable after one year, a petition for regulatory closure will be made
- Decommission all wells and system components upon receipt of regulatory closure.

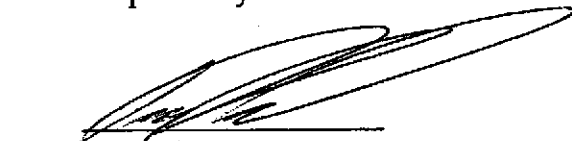
10.0 CERTIFICATION

This report was prepared under the supervision of a professional Registered Geologist in the state of California. All statements, conclusions and recommendations are based solely upon published results from previous consultants, field observations by Clearwater and laboratory analysis performed by a California State-certified laboratory related to the work performed by Clearwater.

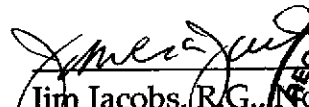
Information and interpretation presented herein are for the sole use of the client and regulating agency. The information and interpretation contained in this document should not be relied upon by a third party.

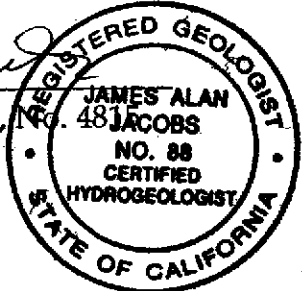
The service performed by Clearwater Group has been conducted in a manner consistent with the level of care and skill ordinarily exercised by members of our profession currently practicing under similar conditions in the area of the site. No other warranty, expressed or implied, is made.

Prepared by:


Jessica Chiaro
Project Scientist

Reviewed by:


Jim Jacobs, R.G., No. 481
C.H.G. No. 88



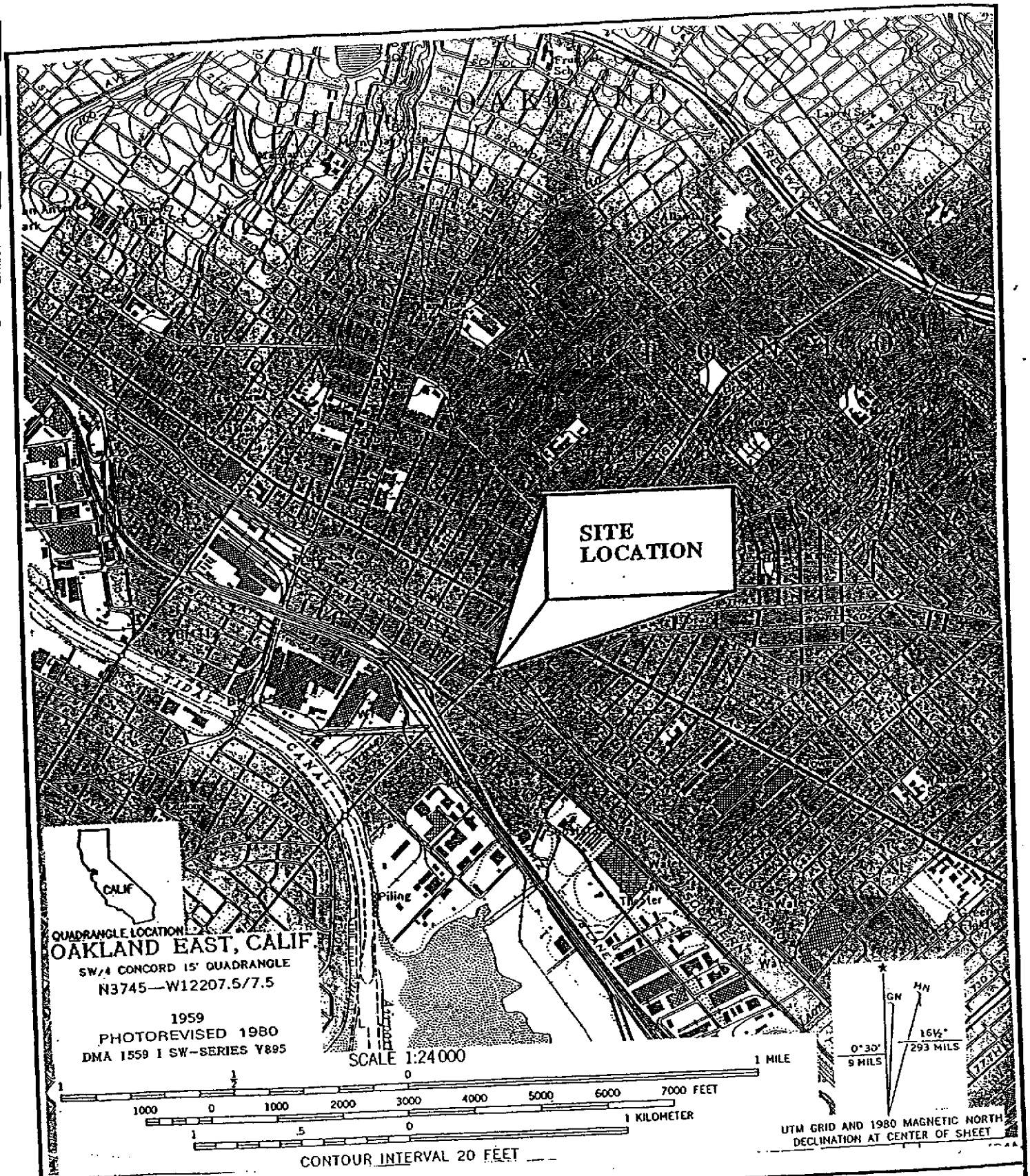
Connor, J., Nevin, P.J., Fisher, R.T., Bowers, R.I., and Newell, C.J., 1995. Tier 2 Guidance Manual for Risk-Based Corrective Action, Appendix A. Groundwater Services, Inc., Houston, TX

McAllister, P.M. and Chiang, C.Y. 1994. "A Practical Approach to Evaluating Natural Attenuation of Contaminants in Ground Water." *Groundwater Monitoring and Remediation*, Spring 1994

Rifai, H.S. et al, 1995. "Intrinsic Bioattenuation for Subsurface Restoration." In R.E. Hinchee, J.T. Wilson, and D.C. Downey (Eds.), *Intrinsic Bioremediation*, pp. 1-25 Battle Press, Columbus, OH

FIGURES

FIGURES



SITE LOCATION MAP
EAGLE GAS
 4301 SAN LEANDRO STREET
 OAKLAND, CALIFORNIA

CLEARWATER GROUP
 229 TEWKSBURY AVE. PT. RICHMOND

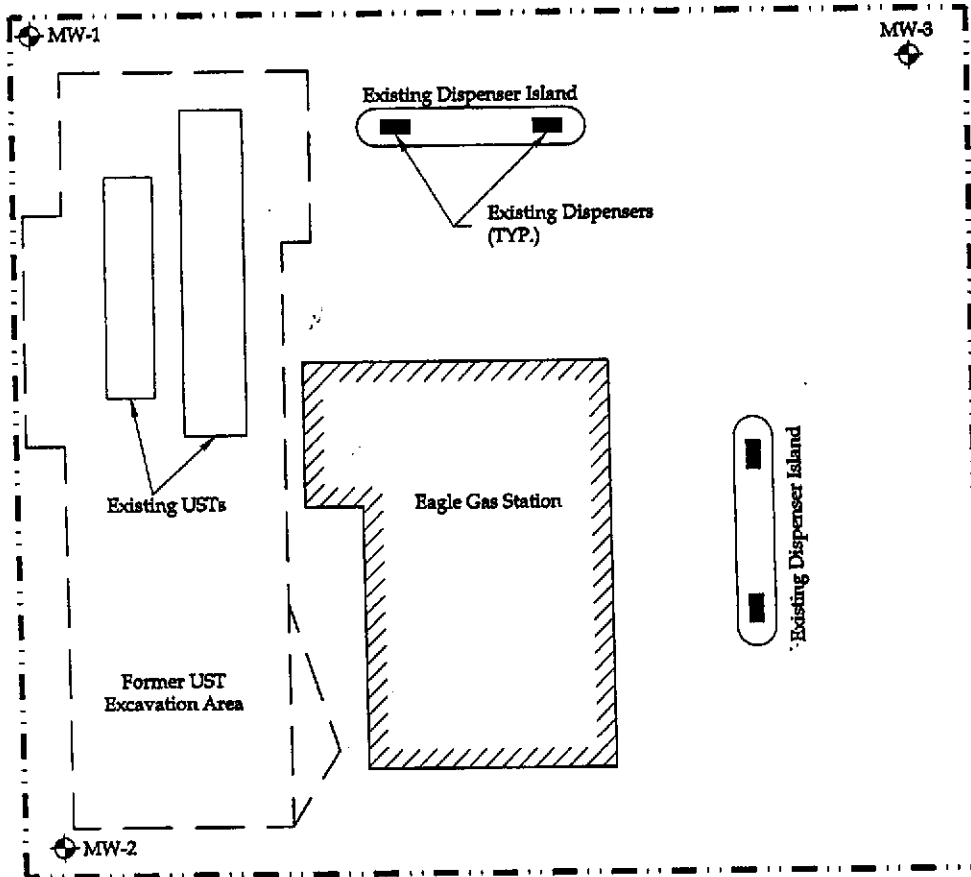
PROJECT NUMBER
 ZP046B

REPORT DATE
 AUGUST 2003

FIGURE
 1

HIGH STREET

Public Sidewalk



Adjacent Commercial Structure

Existing USTs

Former UST Excavation Area

Adjacent Commercial Structure

Eagle Gas Station

Existing Dispenser Island

Existing Dispensers (TYP.)

Existing Dispenser Island

Public Sidewalk

SAN LEANDRO STREET



LEGEND

- PROPERTY LINE
- ◆ MW-1 MONITORING WELL

SITE MAP
 Eagle Gas
 4301 San Leandro Street
 Oakland, California

CLEARWATER GROUP

Project No.
 ZP046B

Figure Date
 4/01

Figure
 2

HIGH STREET

Public Sidewalk

iSOC Treatment Perimeter
(30'-0" DIA. TYP.)

Adjacent Commercial
Structure

Existing USTs

Eagle Gas Station

Former UST
Excavation Area

Adjacent Commercial
Structure

SAN LEANDRO STREET

Public Sidewalk

MW-1

MW-3

PMW-11

PMW-10

PMW-9

PMW-4

PMW-8

PMW-5

PMW-7

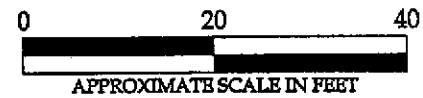
PMW-6

MW-2

Existing Dispenser Island

Existing Dispensers
(TYP.)

Existing Dispenser Island



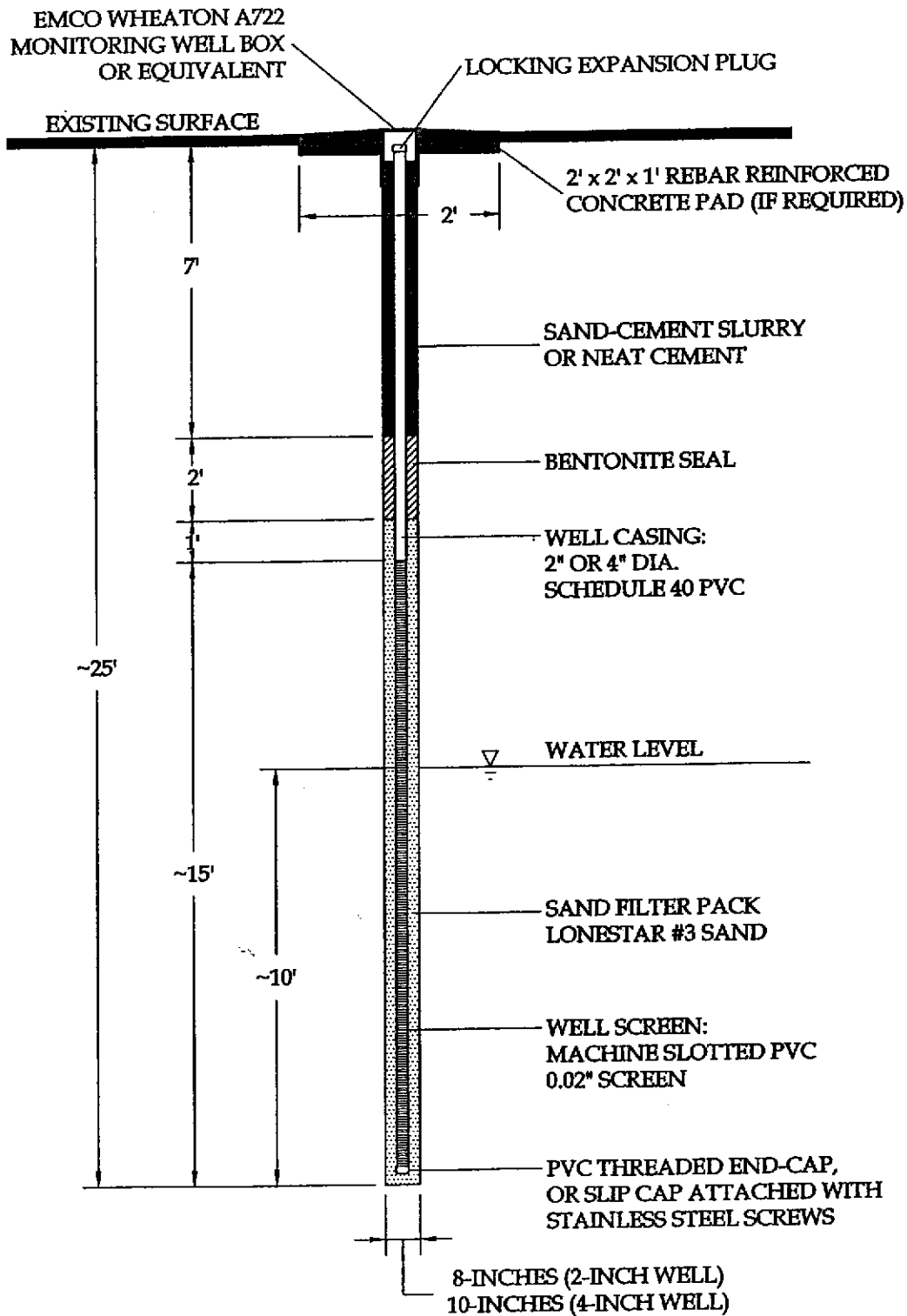
LEGEND

- - - - - PROPERTY LINE
- ⊕ MW-1 MONITORING WELL
- ⊕ PMW-4 PROPOSED MONITORING WELL

iSOC TREATMENT ZONES
Eagle Gas
4301 San Leandro Street
Oakland, California

CLEARWATER GROUP

Project No. ZP046B	Figure Date 1/04	Figure 3
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WELL CONSTRUCTION DETAIL

Eagle Gas
4301 San Leandro Street
Oakland, California

NOT TO SCALE

CLEARWATER GROUP

Project No.
ZP046B

Figure Date
1/04

Figure
4

TABLES

Table 1
WELL CONSTRUCTION DATA
Eagle Gas
 4301 San Leandro Street
 Oakland, California
 Clearwater Group Project No. ZP046A

Well I.D.	Date Installed	Borehole Diameter (inches)	Depth of Borehole (feet)	Casing Diameter (inches)	Screened Interval (feet)	Filter Pack (feet)	Bentonite Seal (feet)	Cement (feet)
MW-1	9/26/2000	8	25	2	10-25	6-25	3-6	0-3
MW-2	9/26/2000	8	25	2	10-25	6-25	3-6	0-3
MW-3	9/26/2000	8	25	2	10-25	6-25	3-6	0-3

TABLE 2
 SOIL SAMPLE ANALYTICAL RESULTS
 Eagle Gas
 4301 San Leandro Street
 Oakland, California
 Clearwater Group Project No. ZP046B

Sample ID	Sample Date	TPHd mg/Kg	TPHg mg/Kg	B mg/Kg	T mg/Kg	E mg/Kg	X mg/Kg	MTBE mg/Kg	EDB mg/Kg	1,2-DCA mg/Kg	DIPE mg/Kg	ETBE mg/Kg	TAME mg/Kg	TBA mg/Kg
CS1-7	4/21/1999	840	770	8.9	4.8	5.8	16	86	---	---	---	---	---	---
CS2-7	4/21/1999	1900	880	3.3	5.7	15	45	16	---	---	---	---	---	---
CS3-7	4/22/1999	780	1600	4.3	110	42	220	92	---	---	---	---	---	---
CS5-6.5	4/22/1999	33	20	0.22	1.8	0.54	3	52	---	---	---	---	---	---
Stockpile 1	4/22/1999	770	610	0.28	4.7	6.9	36	ND	---	---	---	---	---	---
stockpile 2	4/22/1999	670	480	0.23	2.3	3.9	18	ND	---	---	---	---	---	---
CS4-13	4/22/2000	ND	ND	ND	ND	ND	ND	0.08	---	---	---	---	---	---
CS6-3	8/5/1999	1300	4300	11	130	82	420	70	---	---	---	---	---	---
CS7-3	8/5/1999	200	50	ND	2.4	0.85	4	14	---	---	---	---	---	---
CS8-3	8/5/1999	3400	250	0.32	0.72	0.81	1	3.8	---	---	---	---	---	---
CS9-3	8/5/1999	1900	380	ND	ND	ND	ND	9.5	---	---	---	---	---	---
CS10-3	8/5/1999	350	930	ND	78	17	99	310	---	---	---	---	---	---
CS11-3	8/5/1999	5200	1400	3.2	13	25	90	62	---	---	---	---	---	---
MW1-10'bgs	9/26/2000	87	310	0.062	0.022	1.3	3.4	6.9	ND	ND	ND	ND	0.019	2.9
MW2-10'bgs	9/26/2000	210	630	0.053	0.052	2	14	1.00	ND	ND	ND	ND	ND	3.5
MW3-10'bgs	9/26/2000	ND	32	ND	ND	ND	ND	4.5	ND	ND	ND	ND	0.043	0.58

TABLE 2
 SOIL SAMPLE ANALYTICAL RESULTS
 Eagle Gas
 4301 San Leandro Street
 Oakland, California
 Clearwater Group Project No. ZP046B

Sample ID	Sample Date	TPHd mg/Kg	TPHg mg/Kg	B mg/Kg	T mg/Kg	E mg/Kg	X mg/Kg	MTBE mg/Kg	EDB mg/Kg	1,2-DCA mg/Kg	DIPE mg/Kg	ETBE mg/Kg	TAME mg/Kg	TBA mg/Kg
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NOTES:

- TPHd Total petroleum hydrocarbons as diesel by EPA Method 8015 (modified)
- TPHg Total petroleum hydrocarbons as gasoline by EPA Method 8260B
- BTEX Benzene, toluene, ethylbenzene, total xylenes by EPA Method 8260B
- MTBE Methyl tertiary butyl ether by EPA Method 8260B
- DIPE Di-isopropyl ether by EPA Method 8260B
- ETBE Ethyl tertiary butyl ether by EPA Method 8260B
- TAME Tertiary amyl methyl ether by EPA Method 8260B
- 1,2-DCA 1,2-Dichloroethane by EPA Method 8260B
- EDB Ethylene dibromide by EPA Method 8260B
- TBA Tertiary butyl alcohol by EPA Method 8260B
- mg/Kg milligrams per kilogram
- no samples collected, no data available
- ND Not detected in concentrations above laboratory reporting limit

TABLE 3
GROUNDWATER ELEVATIONS AND SAMPLE ANALYTICAL RESULTS
Eagle Gas
4301 San Leandro Street
Oakland, California
Clearwater Group Project No. ZP046B

Sample ID	Sample Date	TOC (feet)	DTW (feet)	GWE (feet)	TPHd (µg/L)	TPHg (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	TBA (µg/L)
MW-1	10/3/2000	18.37	8.96	9.41	460	93,000	<500	<500	<500	<500	130,000	<10,000	<10,000	<10,000	<2,000
	10/27/2000	18.37	7.27	11.1	---	---	---	---	---	---	---	---	---	---	---
	1/26/2001	18.37	7.60	10.77	1,600*	51,000	270	<100	<100	<100	77,000	<5,000	<5,000	<5,000	<20,000
	5/8/2001	18.37	7.50	10.87	470*	36,000*	<100	<100	<100	<100	15,000	<5,000	<5,000	<5,000	<20,000
	8/3/2001	18.37	7.09	11.28	2,200*	19,000*	<50	59	<50	<50	96,000	<5,000	<5,000	<5,000	<20,000
	7/1/2003	18.37	7.59	10.78	3,000	<25,000	<250	<250	<250	<250	170,000	<250	<250	980	8700
	10/1/2003	18.37	8.36	10.01	2,600	<20,000	<200	<200	<200	<200	69,000	<200	<200	270	15,000
MW-2	10/3/2000	20.28	20.26	0.02	210	250,000	<1,250	<1,250	<1,250	<1,250	400,000	<25,000	<25,000	<25,000	<100,000
	10/27/2000	20.28	13.88	6.40	---	---	---	---	---	---	---	---	---	---	---
	1/26/2001	20.28	12.10	8.18	6,000*	740,000	3,800	<500	940	1,600	1,000,000	<50,000	<50,000	<50,000	<200,000
	5/8/2001	20.28	12.05	8.23	2,100*	140,000	2,800	<250	780	640	840,000	<50,000	<50,000	<50,000	<200,000
	8/3/2001	20.28	13.30	6.98	2,600*	42,000*	1,100	63	230	130	880,000	<25,000	<25,000	<25,000	<100,000
	7/1/2003	20.28	14.98	5.30	2,200	<200,000	<2,000	<2,000	<2,000	<2,000	790,000	<2,000	<2,000	3,400	<20,000
	10/1/2003	20.28	15.99	4.29	870	<100,000	<1,000	<1,000	<1,000	<1,000	620,000	<1,000	<1,000	2,700	<20,000
MW-3	10/3/2000	18.98	---	---	120	8,300	<500	<500	<500	<500	33,000	<2,500	<2,500	<2,500	<10,000
	10/27/2000	18.98	18.75	0.23	---	---	---	---	---	---	---	---	---	---	---
	1/26/2001	18.98	13.38	5.60	900*	230,000	930	<500	<500	<500	330,000	<25,000	<25,000	<25,000	<100,000
	5/8/2001	18.98	11.82	7.16	1,100*	95,000	840	<250	<250	<250	390,000	<12,500	<12,500	<12,500	<50,000
	8/3/2001	18.98	13.44	5.54	290*	30,000*	<50	51	<50	<50	270,000	<12,500	<12,500	<12,500	<50,000
	7/1/2003	18.98	12.67	6.31	620	<50,000	<500	<500	<500	<500	230,000	<500	<500	1,800	<5,000
	10/1/2003	18.98	14.04	4.94	370	<20,000	<200	<200	<200	<200	120,000	<200	<200	1,200	<5,000

TABLE 3
GROUNDWATER ELEVATIONS AND SAMPLE ANALYTICAL RESULTS
Eagle Gas
4301 San Leandro Street
Oakland, California
Clearwater Group Project No. ZP046B

Sample ID	Sample Date	TOC (feet)	DTW (feet)	GWE (feet)	TPHd (µg/L)	TPHg (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	MTBE (µg/L)	DIPE (µg/L)	ETBE (µg/L)	TAME (µg/L)	TBA (µg/L)
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NOTES:

- TOC Top of well casing referenced to arbitrary datum
- DTW Depth to water
- GWE Groundwater elevation
- TPHd Total petroleum hydrocarbons as diesel by EPA Method 8015 (modified)
- TPHg Total petroleum hydrocarbons as gasoline by EPA Method 8260B
- BTEX Benzene, toluene, ethylbenzene, total xylenes by EPA Method 8260B
- MTBE Methyl tertiary butyl ether by EPA Method 8260B
- DIPE Di-isopropyl ether by EPA Method 8260B
- ETBE Ethyl tertiary butyl ether by EPA Method 8260B
- TAME Tertiary amyl methyl ether by EPA Method 8260B
- TBA Tertiary butyl alcohol by EPA Method 8260B
- (µg/L) Micrograms per liter
- <# Not detected in concentrations above laboratory reporting limit
- no samples collected, no data available
- * Laboratory note: "Results within quantitation range; chromatographic pattern not typical of fuel"

ATTACHMENT A

Site Specific System Set-up

A single C-Sparger® master unit with 6 Spargepoints® was installed upgradient of plume region. The unit can be installed with a dual-screened recirculation spargewell which has a lower Spargepoint® or with isolated Spargepoints®. The depth to groundwater was 2 to 3 meters. The general construction of a C-Sparger® consists of a 100 mm casing leading to a 1.5 meter screen with 0.5 meter above the water table, a blank casing which was bentonite-sealed in the annular space to prevent short-circuiting, and a lower 1.5 meter screen (10 slot). Alongside this was a 1.5 cm diameter tubing leading from the wellhead region to a 50 mm microporous Spargepoint® 46 cm long with a compression fitting situated below the lower double screen.

The predominant soil type was gravelly sands. Water table level occurred at 2 to 3 meters. The predominant contaminated region extended vertically from 1 to 3 meters deep. The Spargepoints® were installed at a depth of 10 meters.

PILOT TEST SUMMARY OF GROUNDWATER FIELD DATA											
Well ID	Date	Time	pH	Temp (°C)	Conductivity (mS/cm)	Dissolved Oxygen (mg/l)	ORP (mv)	Ferrous Iron (mg/l)	Ozone (mg/l)	Magnetic Reading (in. of water)	
MW-13	2/24/00	10:07	NM	12.9	9.10	NM	NM	1.9	NM	NM ⁽¹⁾	
	4/12/00	13:45	7.24	13.6	11.00	3.000	NM	3.4	0.06 ⁽²⁾	NM ⁽¹⁾	
	4/17/00	15:45	7.40	15.5	7.57	1.000	525	1.0	0.00	3.0	
	4/20/00	12:40	7.40	14.6	8.57	1.760	350	0.0	0.00	4.0	
	5/24/00	10:20	7.40	14.3	7.85	0.750	135 ⁽³⁾	0.0	0.00	3.0	
	5/1/00	15:10	7.20	15.7	8.21	1.000	-25*	0.0	0.00	3.0	
	6/9/00	9:15	7.10	14.9	8.66	1.000	-25*	0.0	0.27	NM**	
	5/22/00	15:05	7.40	15.7	8.83	1.250	NM*	0.0	0.22	NM**	
	MW-21	2/23/00	11:31	6.90	12.9	4.80	NM	NM	1.2	NM	NM ⁽¹⁾
		4/12/00	14:46	7.51	14.7	9.90	0.900	213	4.0	0.00	NM ⁽¹⁾
4/17/00		16:30	7.10	15.9	8.61	0.500	265	0.0	0.00	10.0	
4/20/00		11:15	7.20	15.0	8.68	1.000	690	0.0	0.00	10.0	
4/24/00		9:20	7.20	15.8	8.76	1.500	95 ⁽³⁾	0.0	0.00	8.0	
5/1/00		14:20	7.20	15.8	8.65	1.500	35	0.0	0.00	10.0	
5/8/00		10:15	7.00	15.6	8.74	2.000	NM*	0.0	0.17	NM**	
5/22/00		14:50	7.20	17.7	8.52	3.000	NM*	0.0	0.16	NM**	

Notes:
 System turned on after data collected on 4/12/00.
 * Instrument believed to be malfunctioning.
 ** System no longer running, turned off 5/8/00.
 (1) Data collected before pilot start-up.
 (2) Sample turbidity high, results may not be reliable.
 (3) Began using new ORP meter.

Figure 2. Pilot test. Summary of groundwater field data.

Procedure Documents
 Quick Results
 Initial results of the treatment were monitoring by three indicators:

- VOC

removal by groundwater sampling from monitoring wells and certified laboratory analysis.

- Dissolved oxygen (D.O.) field determination on groundwater grab samples from monitoring wells.

- Oxidation-reduction potential (ORP) field determinations on groundwater grab samples.

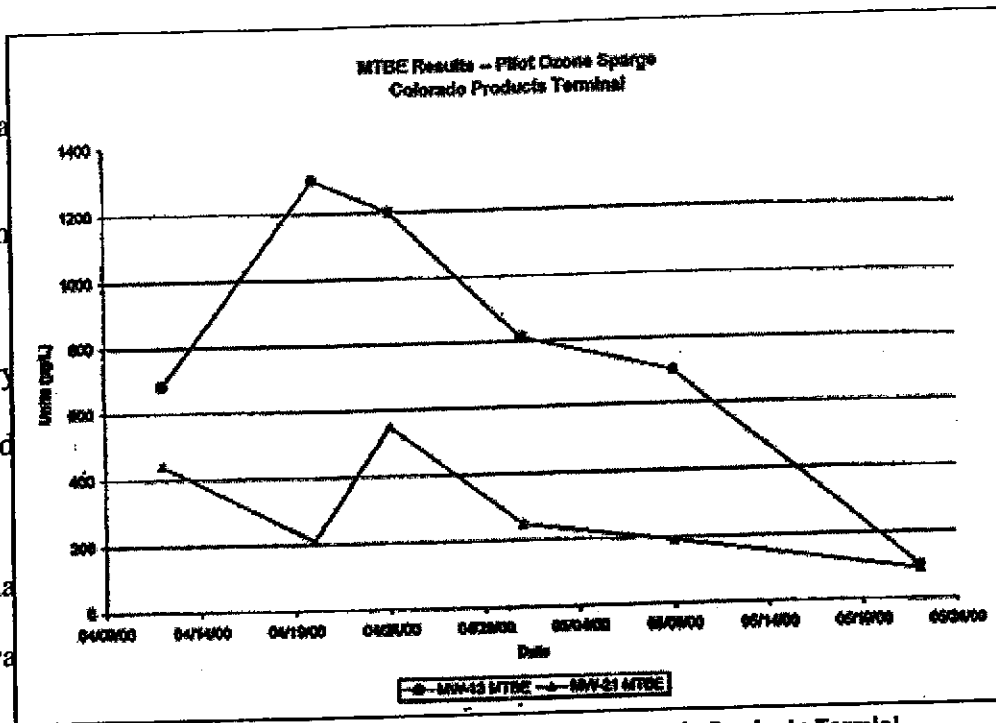


Figure 3. MTBE results. Pilot ozone sparge Colorado Products Terminal.

Groundwater sampling showed an immediate rise in concentration of MTBE and benzene due to mixing followed by a progressive drop in concentration. The agitation of the groundwater and capillary pores by the fine bubbles often strips adsorbed fractions. The mixed concentrations are often a better measure of total mass for treatment than solely the aqueous fraction. The concentrations of MTBE from monitoring wells placed at 3 meters' and 4 meters' distance from the Spargepoint® rose to 1300 and 550 ppb before converging to less than 100 ppb for a removal efficiency of 99.9% and 99.8% respectively after 5 ± weeks of operation. Benzene rose to a high of 4300 ppb before dropping to below 700 ppb for 99.8% removal efficiency over 5 ± weeks.

William B. Kerfoot, Ph.D., is President and an LSP with K-V Associates, Inc., Mashpee, Massachusetts.

Angus McGrath is a principal Geochemist with SECOR International, Inc., Oakland, California.

ATTACHMENT B

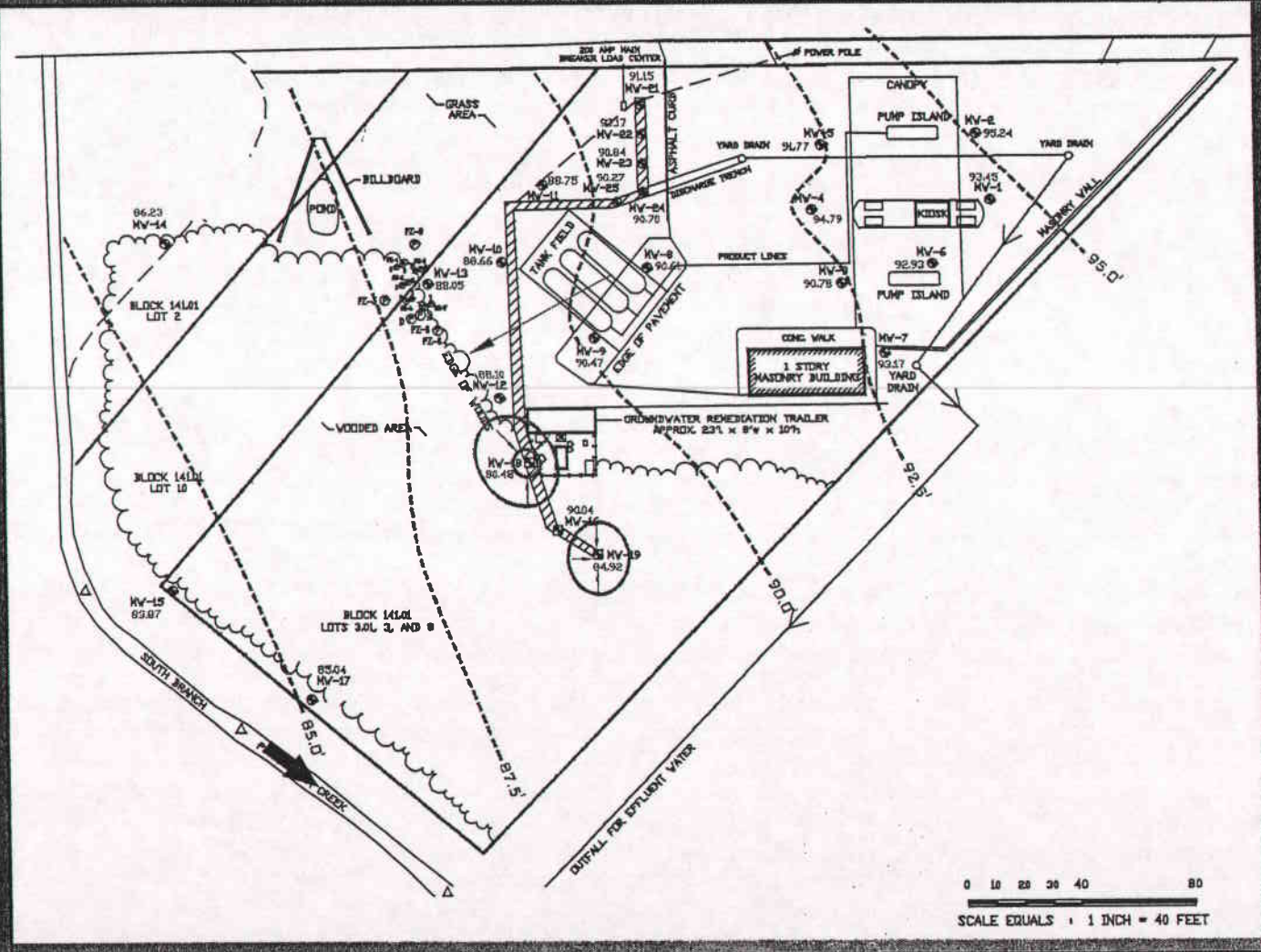


Accelerated Bioremediation &
Natural Attenuation by
*iSOC*TM
Groundwater Remediation System
Case Study- Maple Shade





DOC™ Demonstration – Site Plan





ISOC™ Demo – Site Conditions

Active service station

- Sand & silty sand underlain by silts & clays
- Depth to groundwater: 1.8 – 3.7 m below ground surface
- Groundwater velocity: 9 – 12 cm/day (conductivity 54 – 80 cm/d, gradient 0.028)
- Historical groundwater MTBE concentrations indicate slugs moving through aquifer
- Recovery wells yield up to 3.8 lpm, existing air stripper/GAC system has iron clogging problems (ferrous iron ~30 – 80 mg/l)

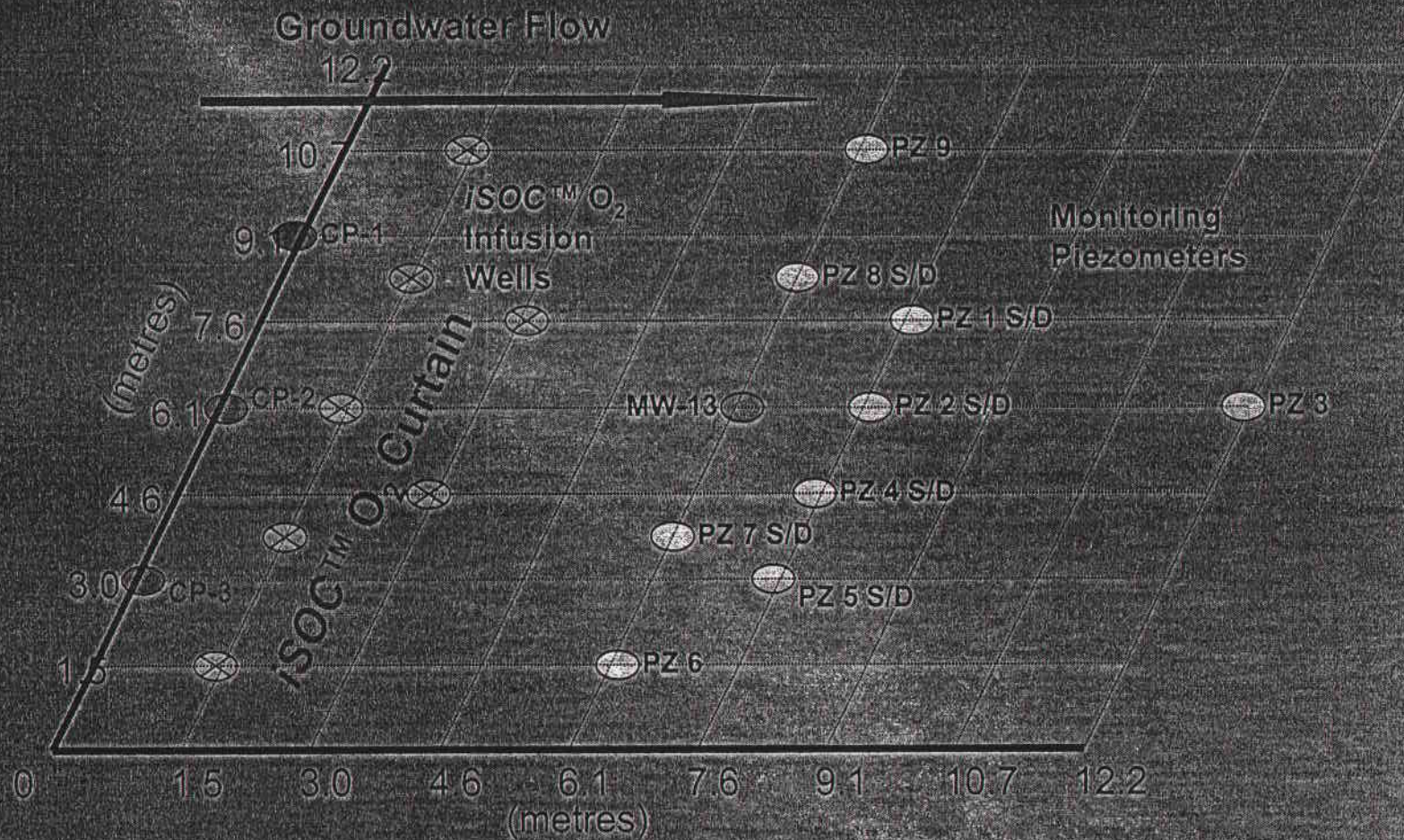


ISOC™ Demo- Baseline Conditions

- 28 wells (3 existing, 25 new) sampled for baseline event
- Wells sampled & analyzed for BTEX, MTBE, TBA, biological parameters, pH, temperature, & conductivity
- Baseline MTBE concentrations range from 3 to 7 ppm, TBA from 20 to 30 ppm, & Benzene up to 0.6 ppm
- Baseline event shows aquifer in anaerobic & reduced conditions

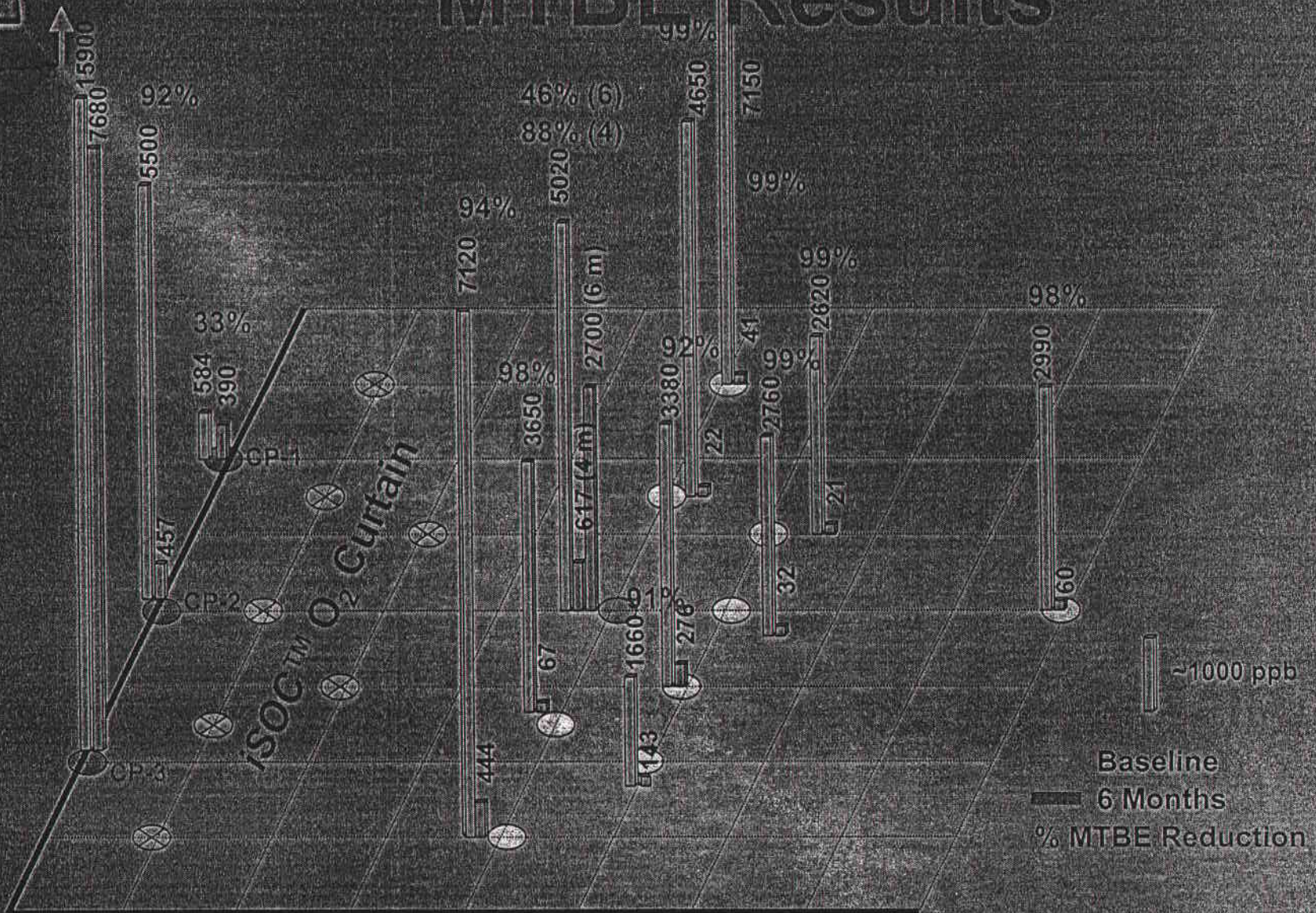


ISOC™ Demo - Treatment Area Schematic





ISOC™ Demo - MTBE Results



Case Study - Maple Shade



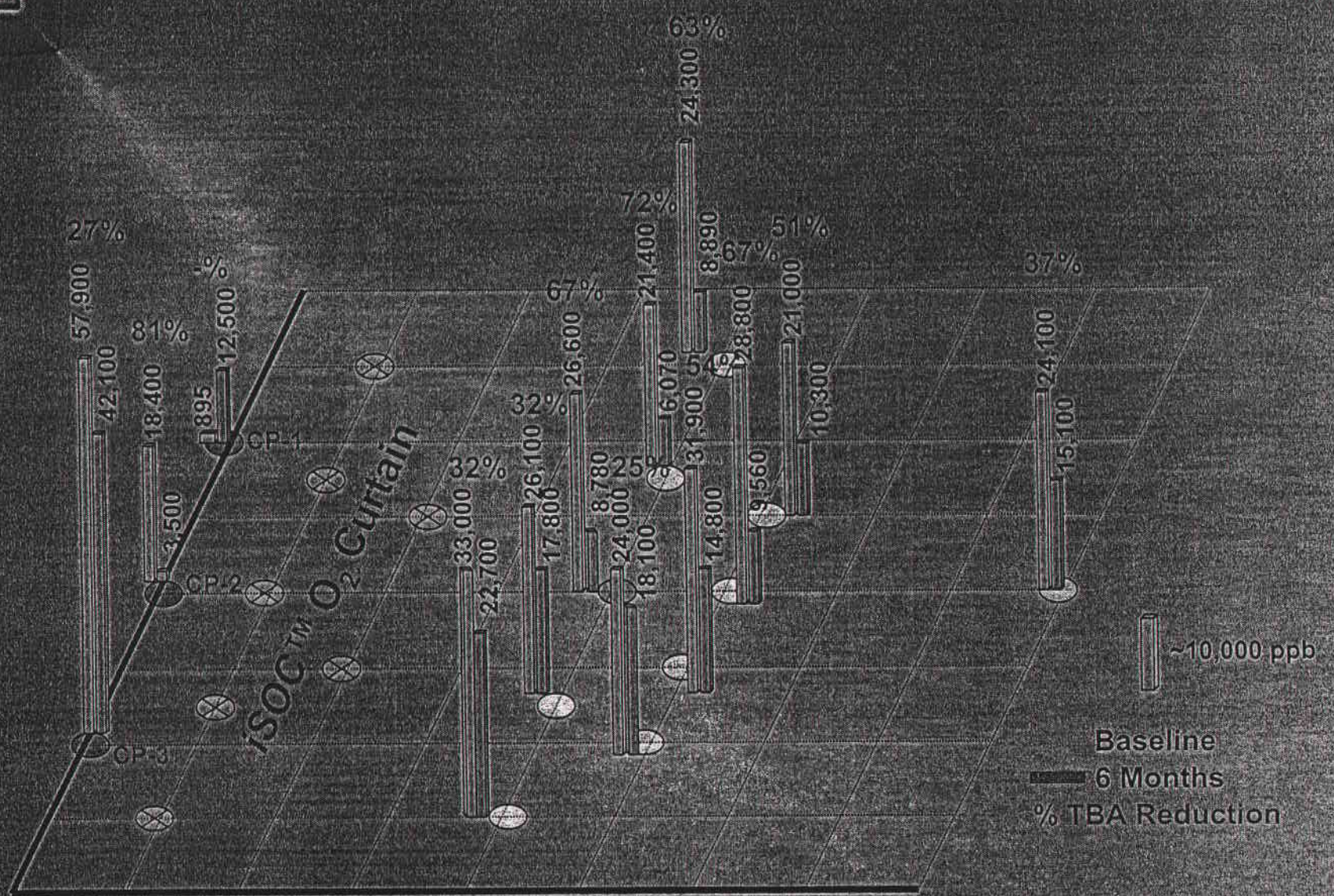
iSOC™ Demo - Benzene Results



Case Study - Maple Shade



ISOC™ Demo - TBA Results



Case Study - Maple Shade



ISOC™ Demo - Groundwater TIC Results





iSOC™ Demonstration— Conclusions

- 3 months after iSOC™ system installed, an effective barrier of DO was established
- iSOC™ O₂ barrier effective in attenuating MTBE, TBA & Benzene throughout 6-month study period
- Significant reductions downgradient of iSOC™ O₂ barrier were comparable for shallow & deep piezometers: MTBE - 89%, TBA - 54%, Benzene - >96%
- Data indicates aerobic degradation of MTBE downgradient of iSOC™ O₂ barrier—possible anaerobic biodegradation outside of test location



iSOC™ Demonstration— Conclusions

- Comparable attenuation rates estimated for MTBE & Benzene and lower attenuation rates estimated for TBA
- Reductions in MTBE, TBA & Benzene mirror decreasing trend in BOD₅ to COD, & VOC to COD ratios
- Total VOC to BOD₅ ratios indicate a significant portion of VOC's not readily degradable
- Elevated levels of ferrous iron, BOD₅, & COD did not inhibit aerobic degradation or interfere with iSOC™ system performance

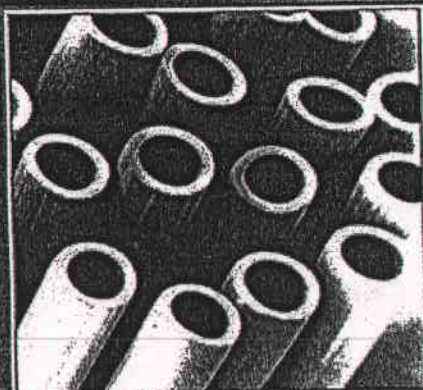
Enhanced Natural Attenuation of
MTBE & Benzene in a Low
Permeability Front Range
Colorado Site Using ISOC™
Technology

Walter S. Mulica
Global Technologies Inc., Fort Collins, CO.

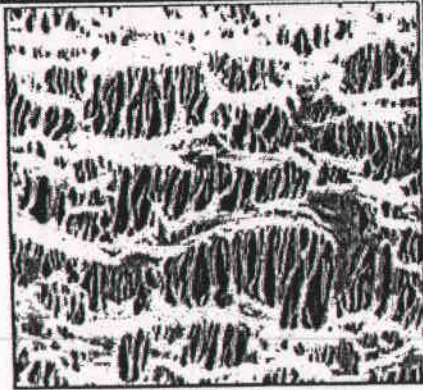
Nick Mathis
O&G Environmental, Englewood, CO.

Gas inFusion™ iSOC Technology

Microporous Hollow Fibre

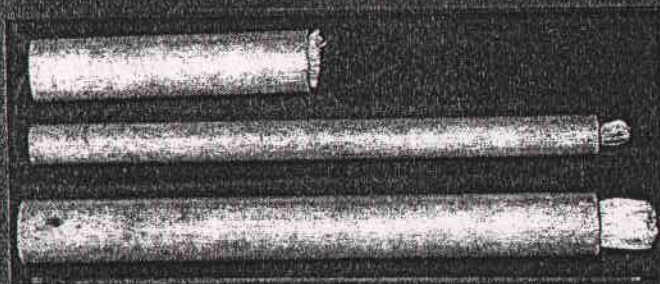
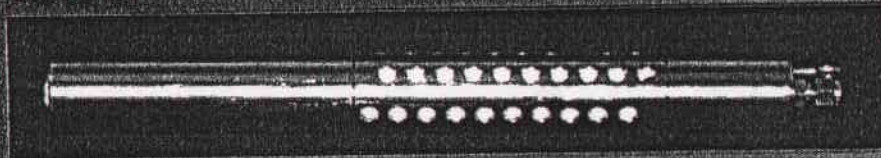


Cross Section 200 μm



Inner Surface 1 μm

iSOC™



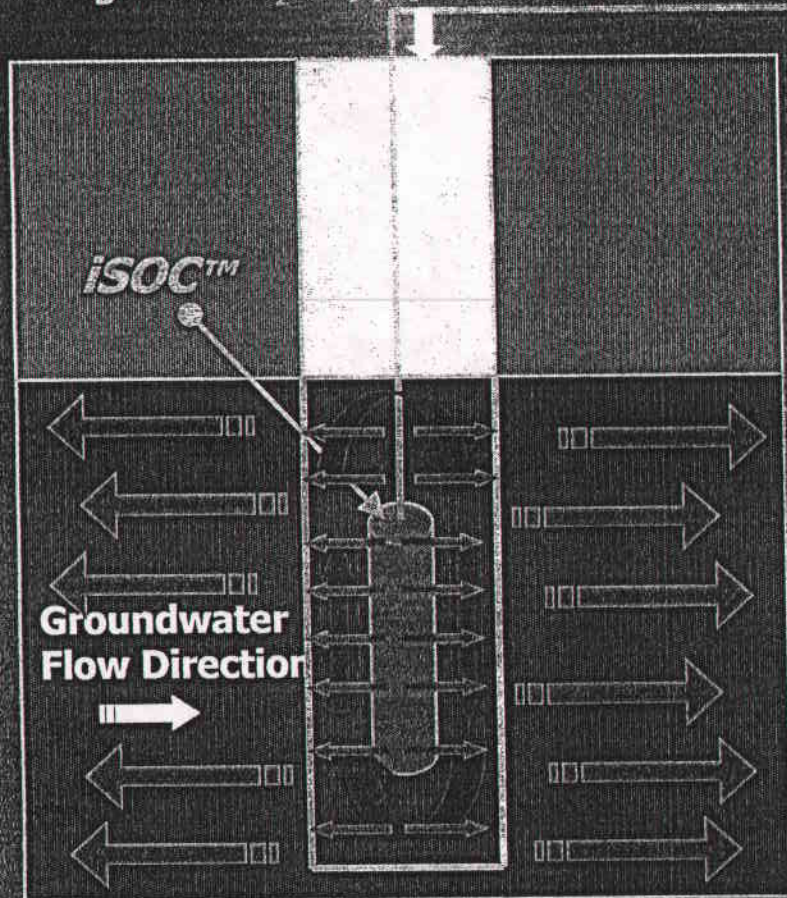
ALinear™
Valves

A patented method to:

- Effect rapid, no bubble gas transfer (infusion)
- Create DO concentrations of hundreds of PPM
- Allow long term retention of extremely high DO levels
- Virtually eliminate DO losses to atmosphere
- Achieve gas transfer efficiencies 10X better than best conventional methods
- Allow specifically designed mass transfer devices

ISOC™ Gas inFusion Process

Regulated O₂ Supply To Multiple Devices



- **ISOC™** – *in situ Submerged Oxygen Curtain*—using unique gas delivery technology
- Supersaturates well with, low decay DO— 40 to 200 PPM depending on groundwater depth
- Natural convection current fills well with uniform DO
- DO disperses well into groundwater & soil or fractured bedrock
- Enhanced bioremediation removes organics (hydrocarbons)

DOC™ Dissolved Gas Concentrations (ppm) in a Water Column

Gas Type	Water Column Depth (metres)				
	2m	3m	5m	8m	15m
Oxygen	50	54	63	75	104
Methane	27	29	34	40	56
Propane	79	86	99	119	165
Hydrogen	3	3	4	5	6
Ethane	68	74	86	103	143

Case Site History

- Industrial site in a suburb of Denver had a gasoline leak from an on-site underground storage tank during the 1990's.
- Tank was eventually removed and an extensive amount of contaminated soil near the former tank was excavated.
- Not all potentially contaminated soil was excavated due to extensive depth (12 m.) to water table.

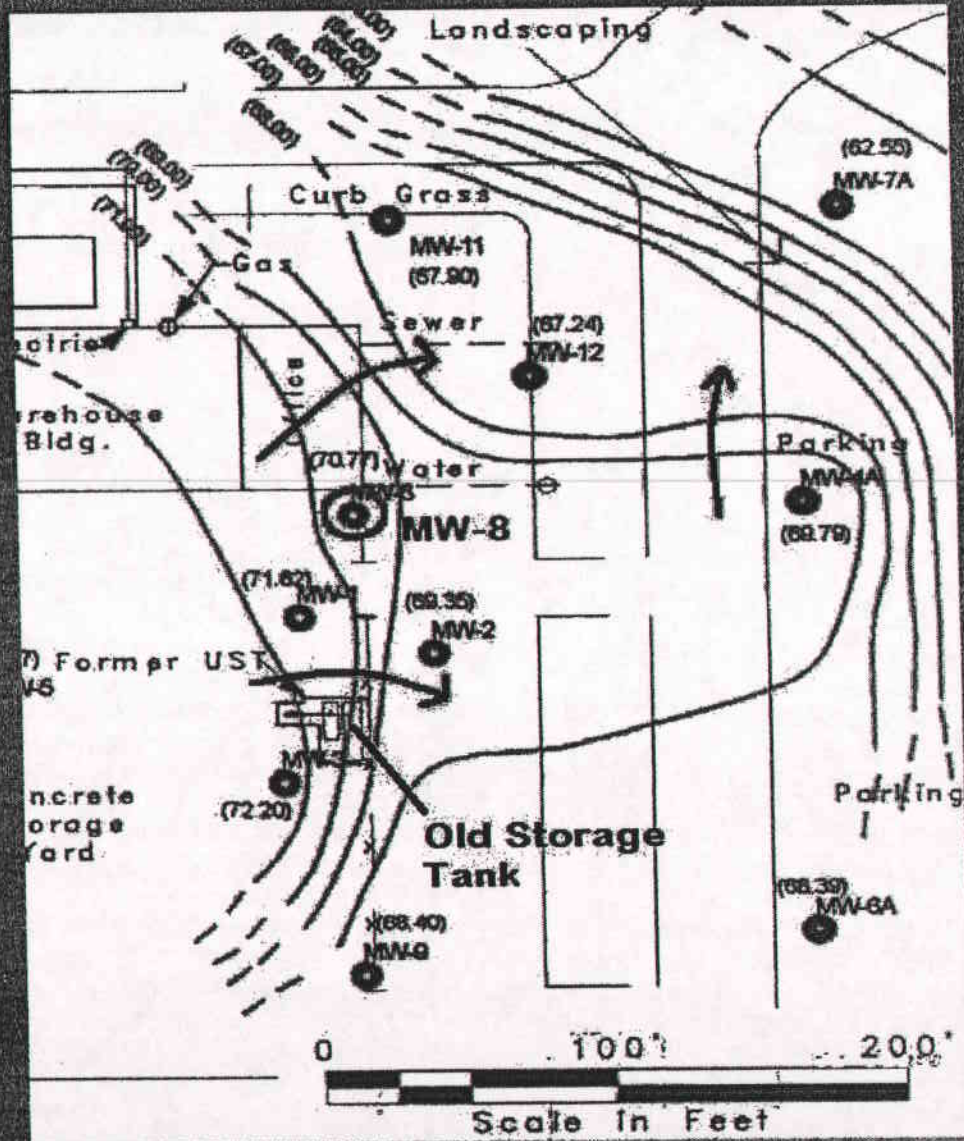
Case Site History

- A new tank was never installed
- Because of large depth to water table and low permeability silty sediments, ground water remediation proved difficult and expensive
- A soil vapor extraction system operated for years after removal of old tank
- Site geology consists of 12 m. of silty clay down to bedrock

Case Site Characteristics

MW-8 is down gradient of former tank and historically has the highest contamination on site

- Over 117,200 ppb of benzene was detected in MW-8 in 1996



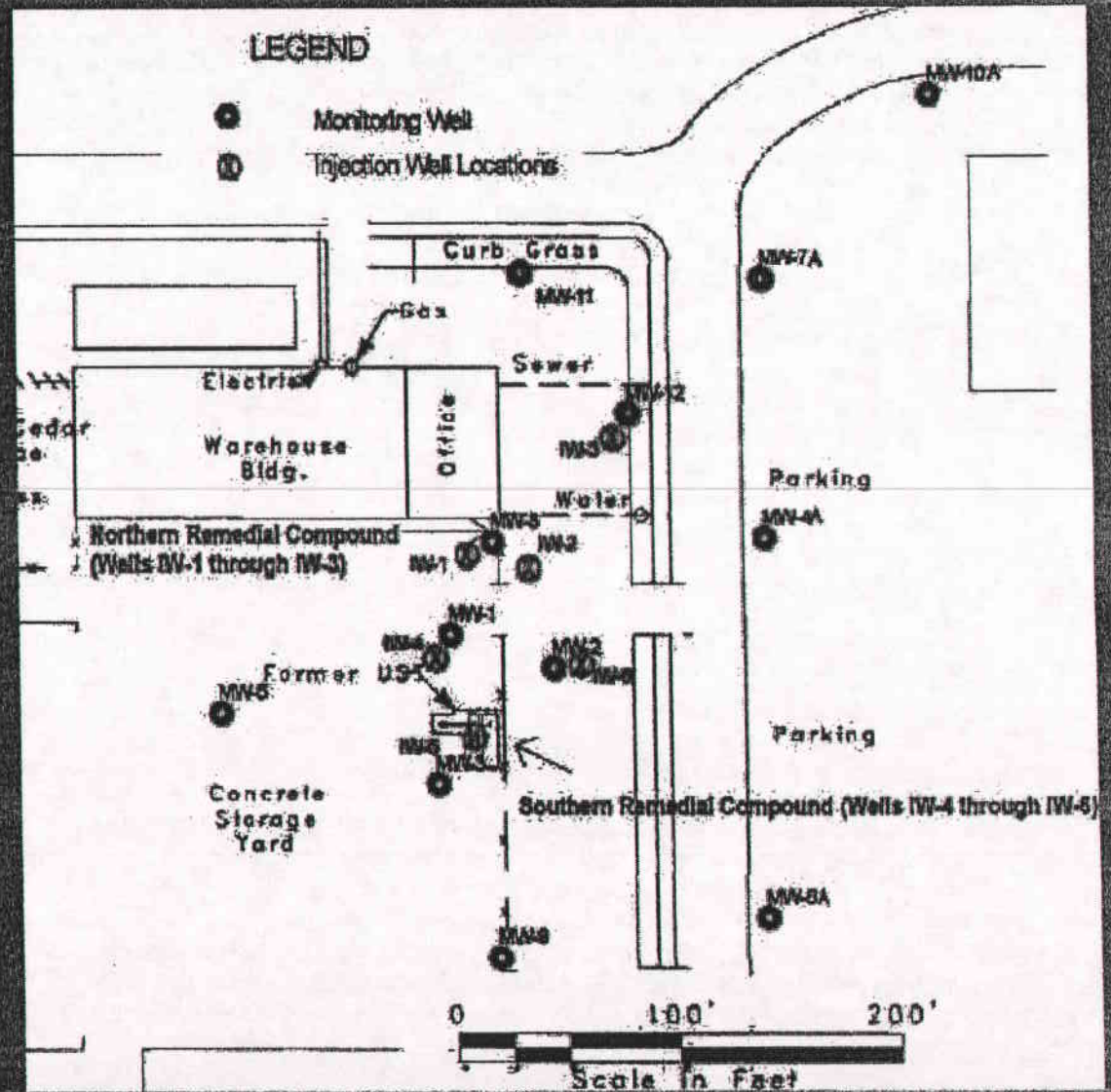
*i*SOC™ System Installation

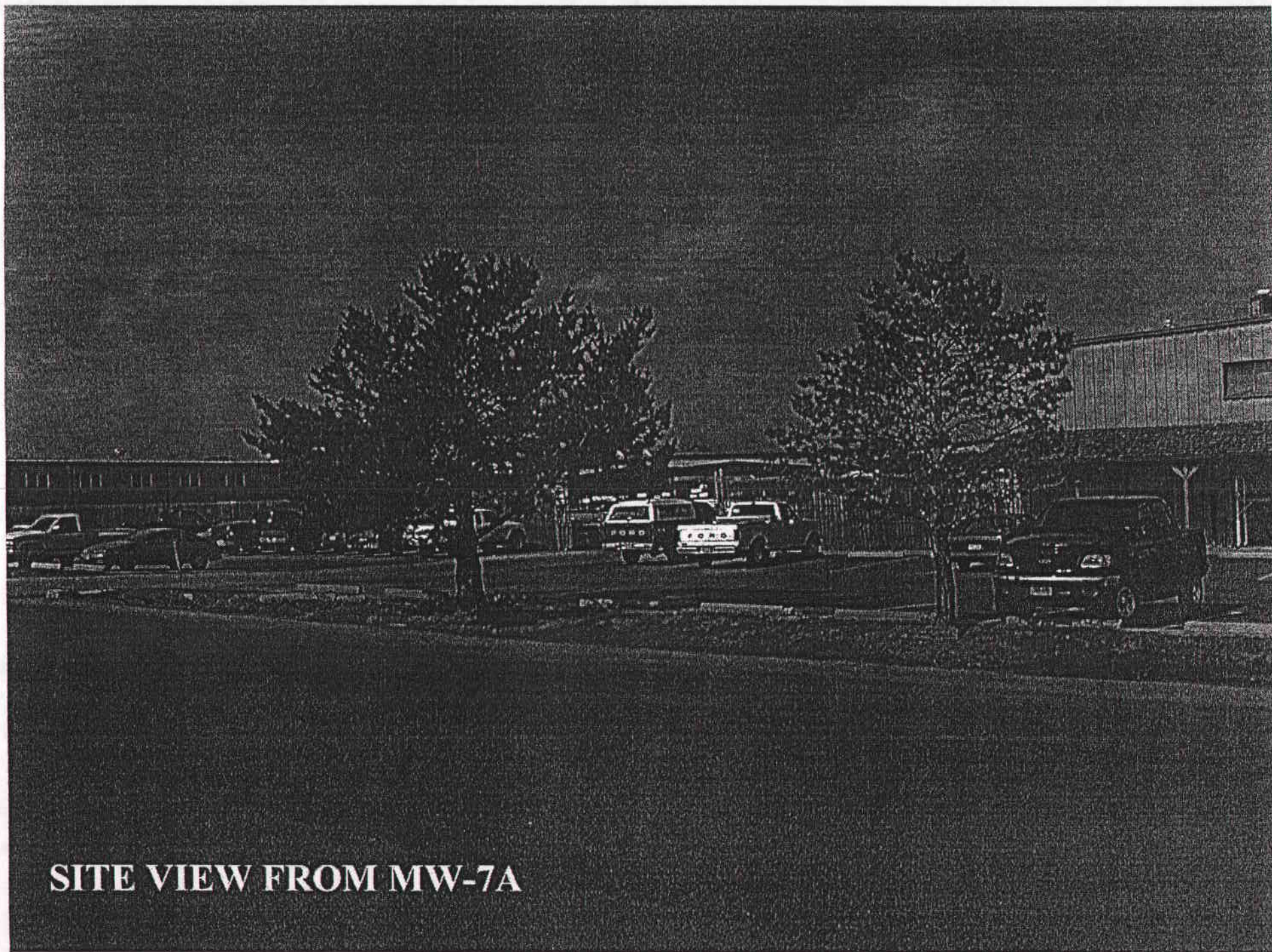
- In late 2001, the site consultant in cooperation with the state of Colorado environmental agency decided to pilot one *i*SOC™ unit in MW-8 to remediate remaining gasoline constituents
- State of Colorado required that MTBE be included in the study; 5000 – 195,000 ppb of MTBE were found in 6 sampling wells, With the highest concentration in MW-8

iSOC™ System Installation

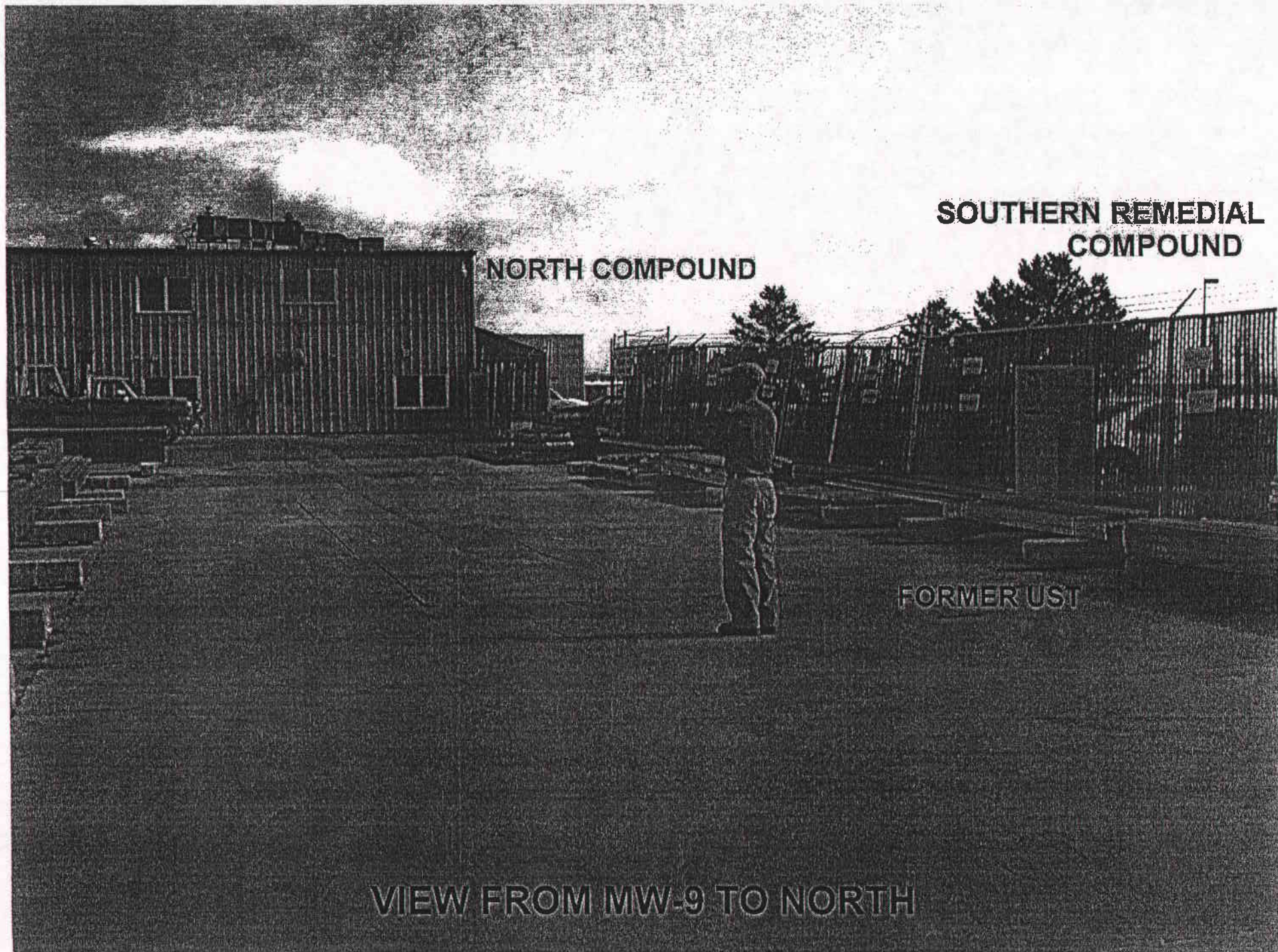
One iSOC was installed January 2002 (injection well IW-1), 15 ft up gradient of MW-8 for a period of six months proved successful

In August 2002, 5 additional iSOCs were installed in areas of highest contamination





SITE VIEW FROM MW-7A



NORTH COMPOUND

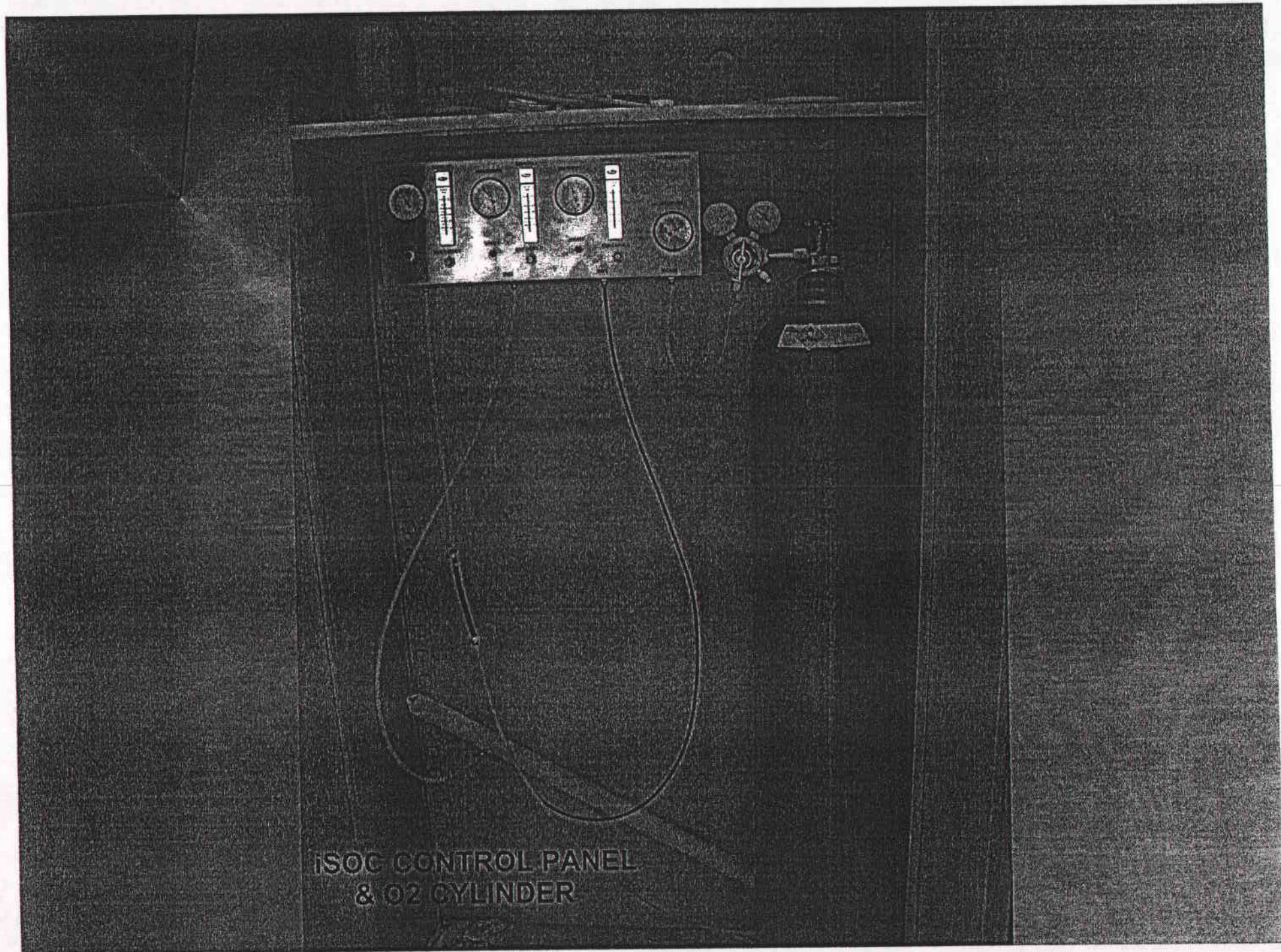
SOUTHERN REMEDIAL
COMPOUND

FORMER UST

VIEW FROM MW-9 TO NORTH

NORTHERN REMEDIAL COMPOUND





ISOC CONTROL PANEL
& O2 CYLINDER

iSOC™ System Installation

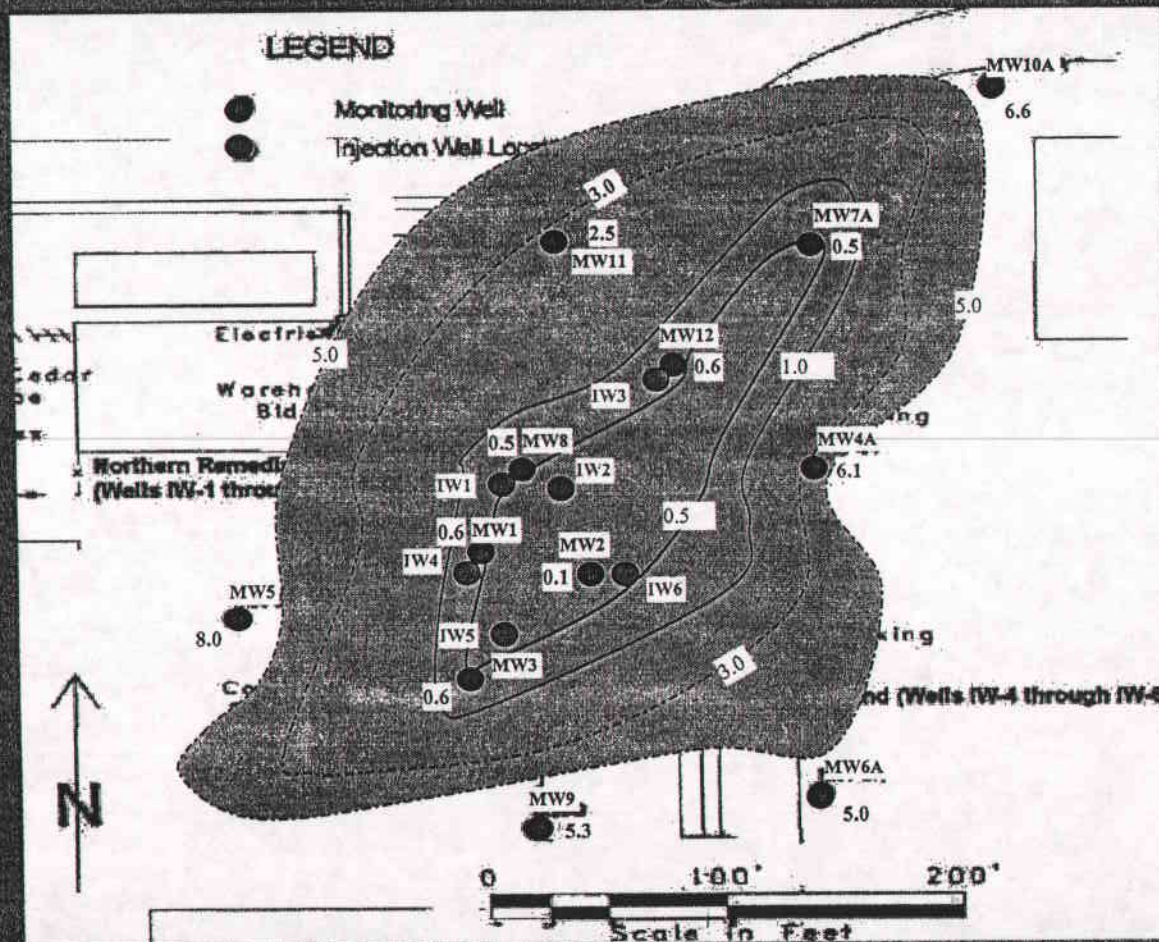
- All six *i*SOCs have been in operation since August 2002
- Injection wells are operating in well water columns of approximately 3 metres
- Industrial-grade pure oxygen is injected into wells at 15 cm³/min

Remediation Results

- Dissolved Oxygen

- Dissolved Oxygen (DO) in all six injection wells have consistently been between 45 – 60 ppm
- Dissolved oxygen concentrations between 0.5 to 1.0 ppm in areas of highest contaminations

Remediation Results Dissolved Oxygen Sept 5, 02

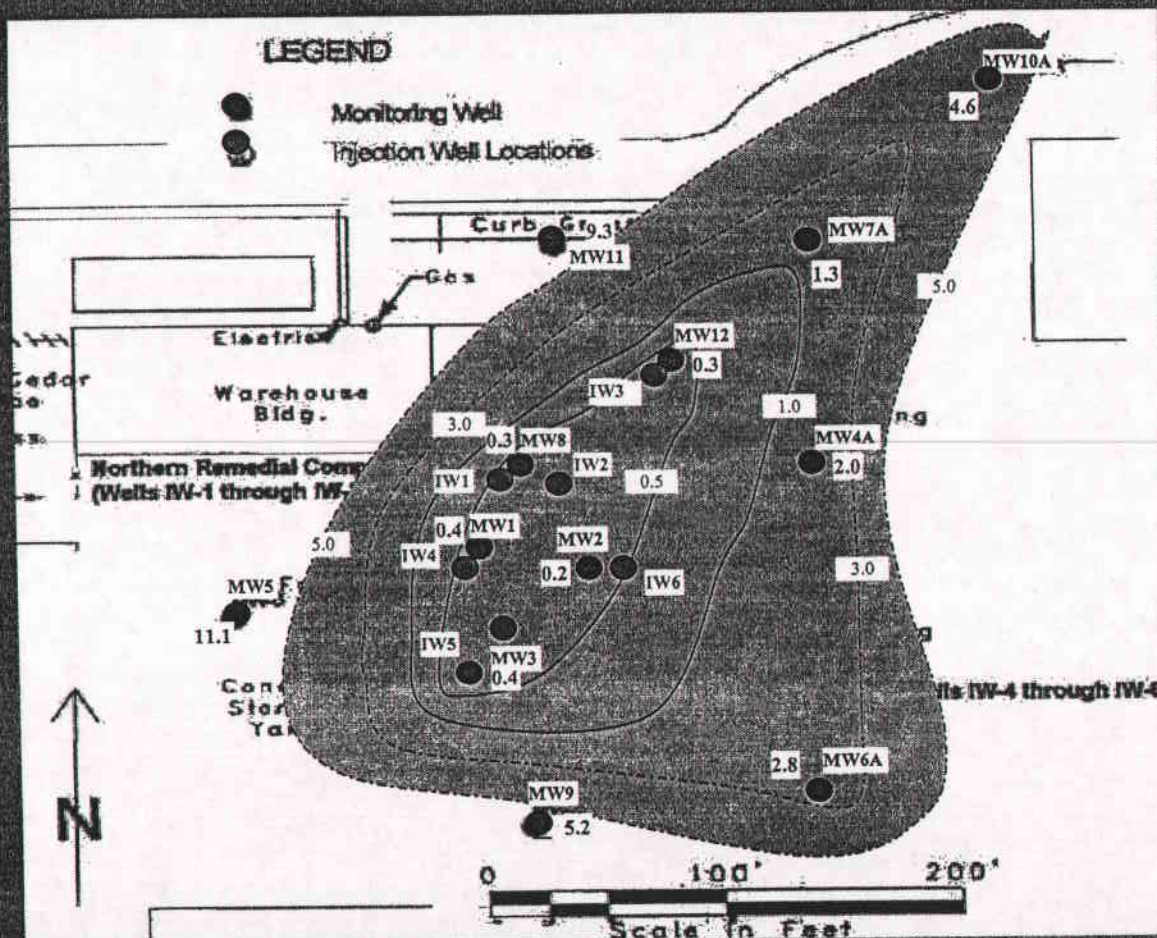


-5.0- DO Concentration Contour (ppm)

5.0 DO Concentration at monitoring well (ppm)

Remediation Results

Dissolved Oxygen Mar 3, 03



-5.0- DO Concentration Contour (ppm)

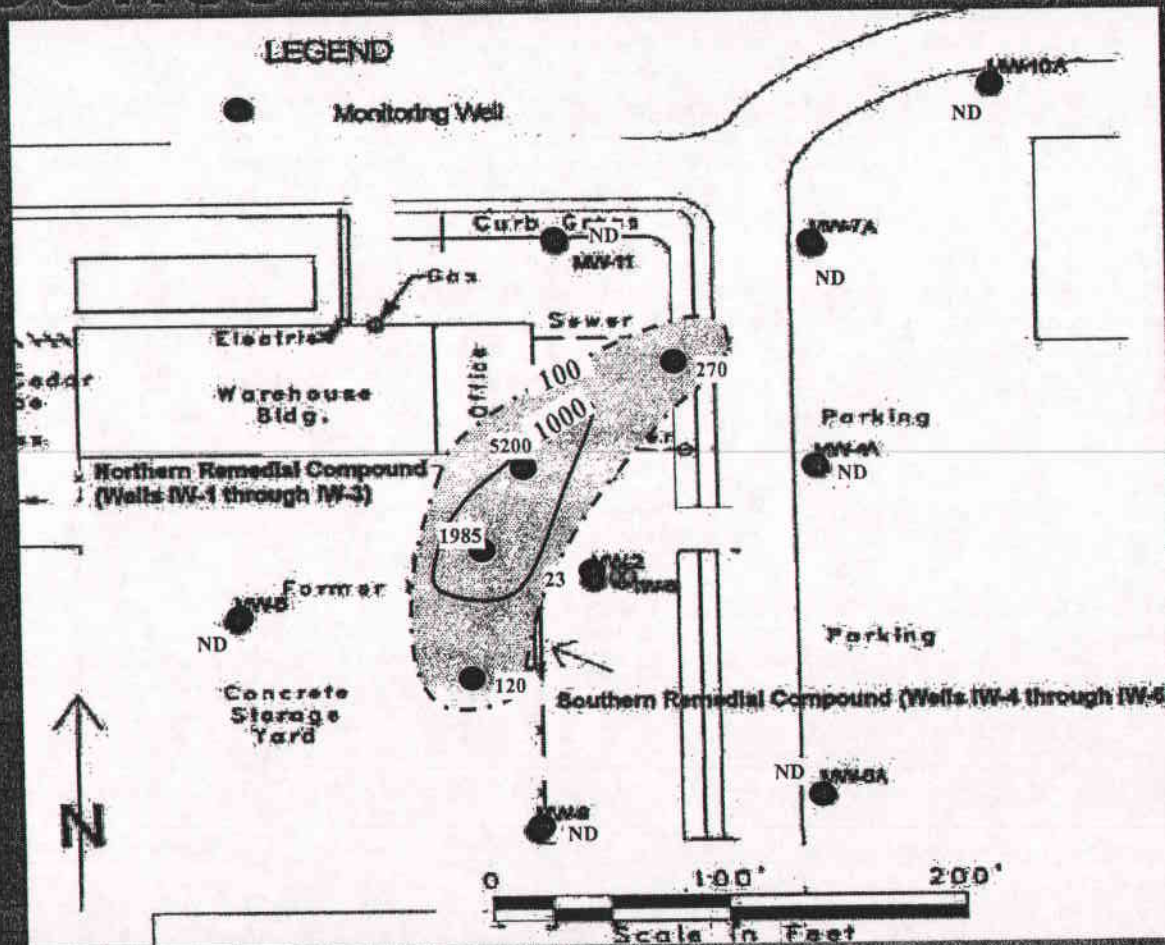
5.0 DO Concentration at monitoring well (ppm)

Remediation Results

WELL #	DATE	BENZENE	TOTAL BTEX	MTBE
1	12/3/01	1985	4525	56,600
	3/12/02	2940	620	52,400
	6/13/02	2420	4900	94,600
	9/5/02	1950	4690	59,000
	12/16/02	1360	3110	39,300
	3/3/03	1620	3756	8,000
% Change		-18.4%	-17.0%	-85.9%
2	12/3/01	23	23	73,800
	3/12/02	ND	BDL	121,300
	6/13/02	ND	BDL	103,000
	9/5/02	ND	BDL	328,000
	12/16/02	ND	BDL	128,000
	3/3/03	ND	BDL	155,000
% Change				110.0%
3	12/3/01	120	120	11,180
	3/12/02	26.3	26.3	10,910
	6/13/02	40.7	40.7	7,540
	9/5/02	21	21	5,840
	12/16/02	10.9	109	3,420
	3/3/03	8.3	8.3	3,780
% Change		-93.1%	-93.1%	-66.2%
5	All Dates	ND	BDL	ND
8	12/3/01	5200	5589	195,000
	3/12/02	350	350	96,500
	6/13/02	160	189.3	138,000
	9/5/02	330	330	489,000
	12/16/02	20	20	118,000
	3/3/03	ND	BDL	135,000
% Change		-100%	-100%	-30.8%

WELL #	DATE	BENZENE	TOTAL BTEX	MTBE
9	All Dates	ND	BDL	ND
11	All Dates	ND	BDL	ND
12	12/3/01	270	278.6	5,010
	3/12/02	195	195	4,605
	6/13/02	111	111	3,650
	9/5/02	64.5	64.5	3,380
	12/16/02	230	230	3,070
	3/3/03	439	442.3	3,780
% Change		62.6%	58.8%	-24.6%
4A	6/13/02	ND	BDL	1
	9/5/02	ND	BDL	1
	12/16/02	ND	BDL	ND
	3/3/03	ND	BDL	ND
% Change				100%
6A	All Dates	ND	BDL	ND
7A	All Dates	ND	BDL	ND
10A	All Dates	ND	BDL	ND

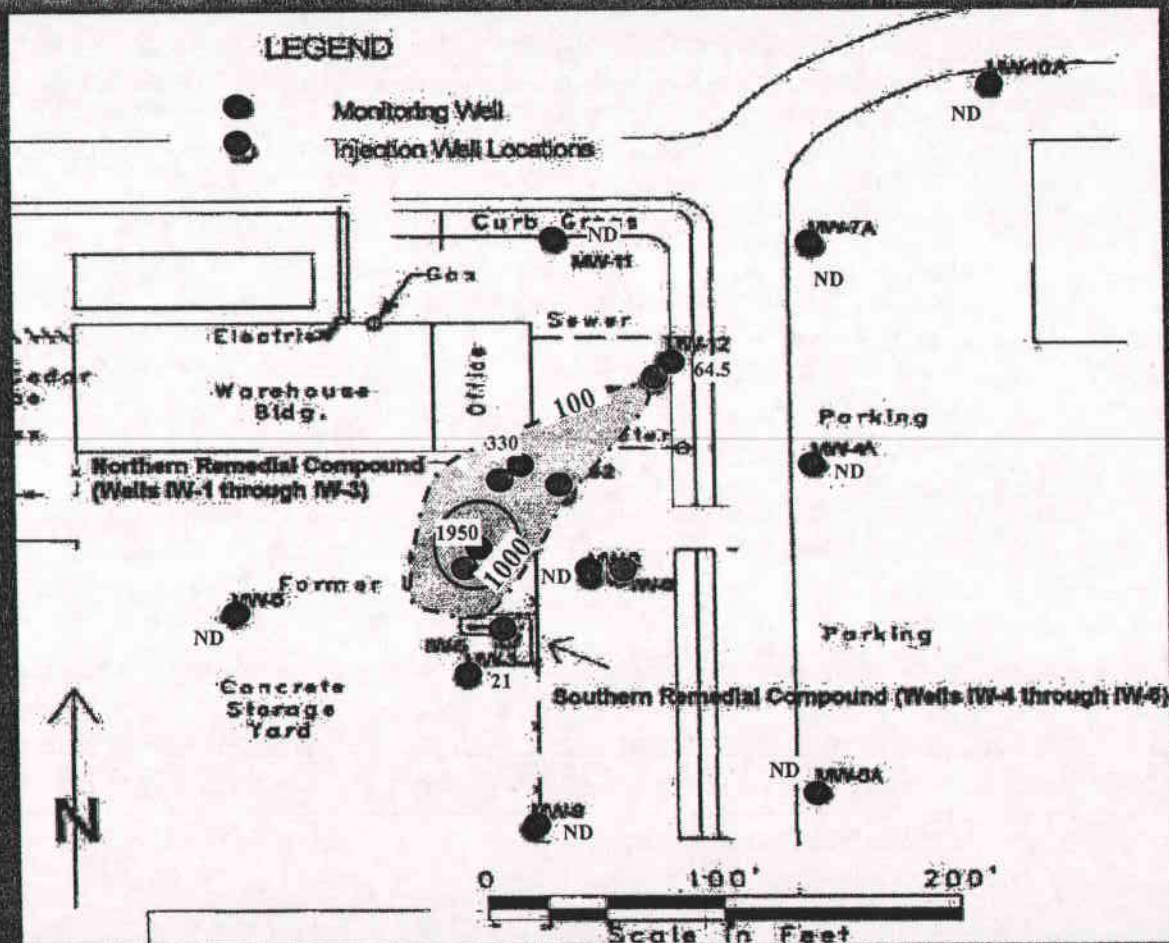
Site Benzene Concentration- Dec 3, 01



-1000- Benzene Concentration Contour (ppb)

1000 Benzene Concentration at monitoring well

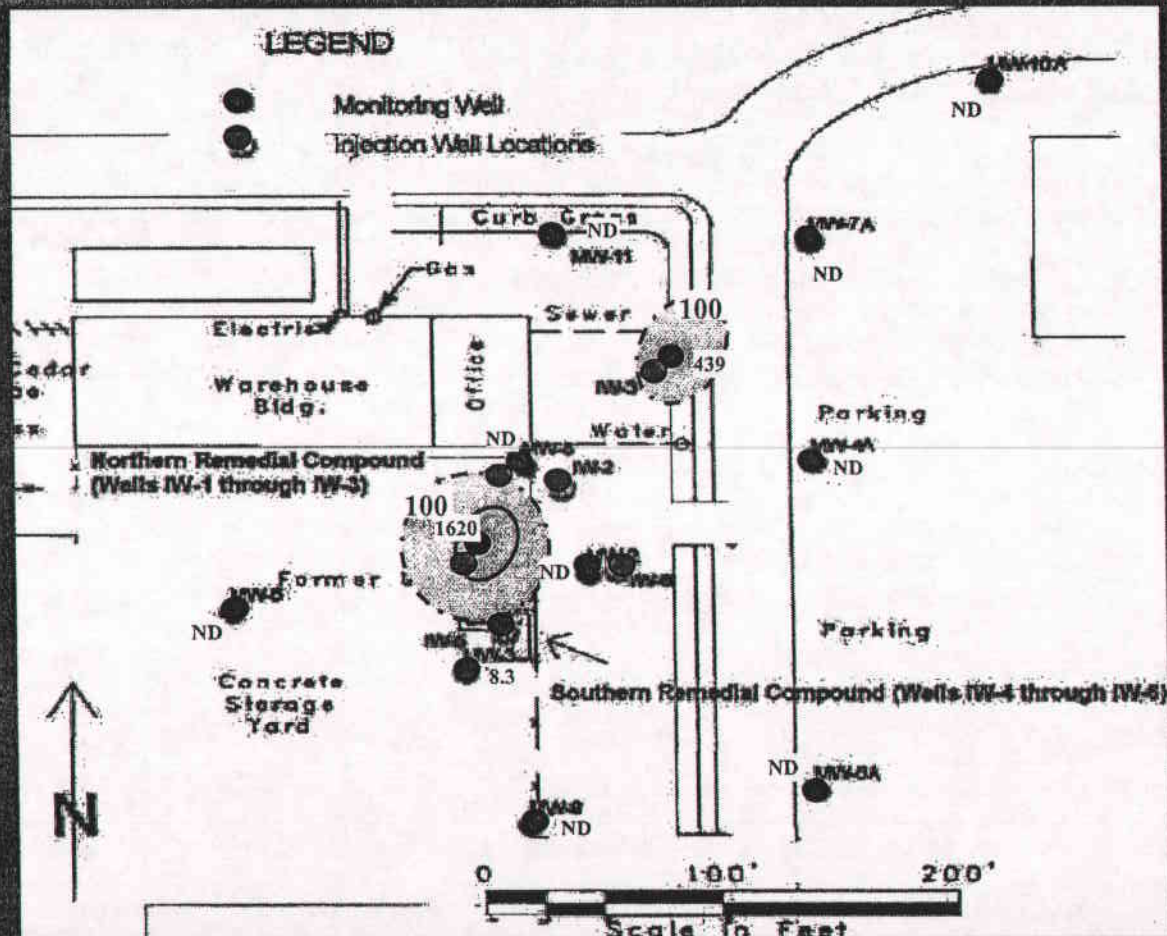
Site Benzene Concentration- Sept 5, 02



-1000- Benzene Concentration Contour (ppb)

1000 Benzene Concentration at monitoring well

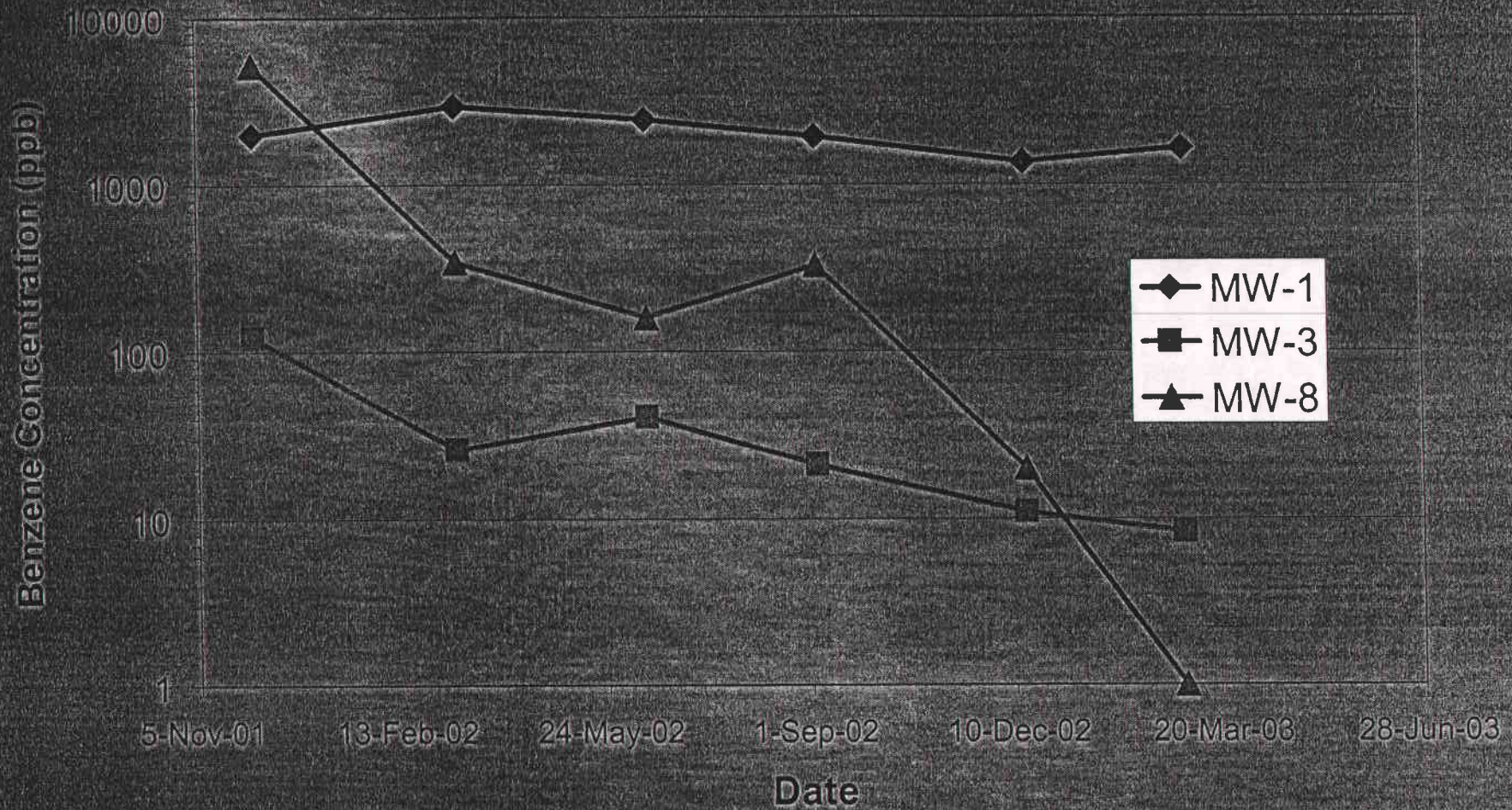
Site Benzene Concentration- Mar 3, 03



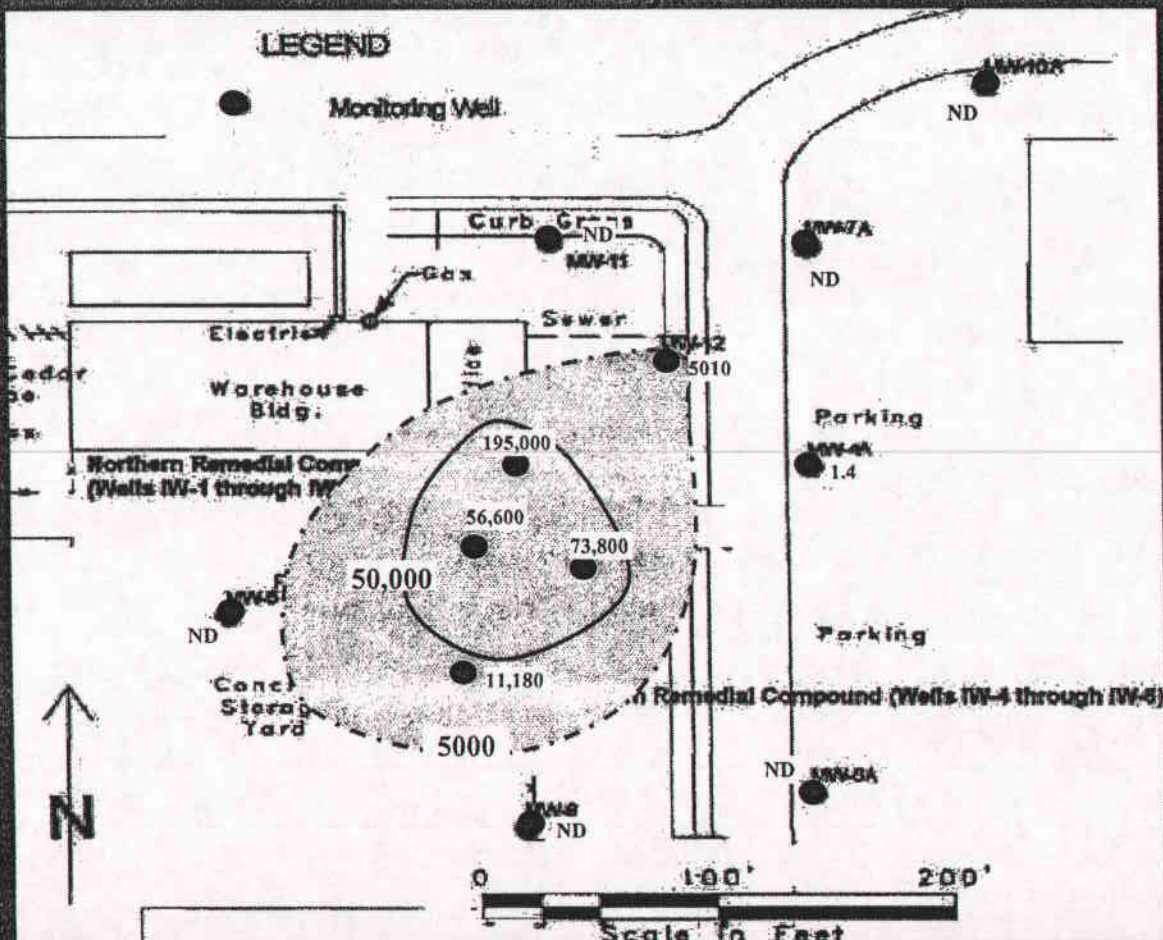
-1000- Benzene Concentration Contour (ppb)

1000 Benzene Concentration at monitoring well

Remediation Results - Benzene Reduction

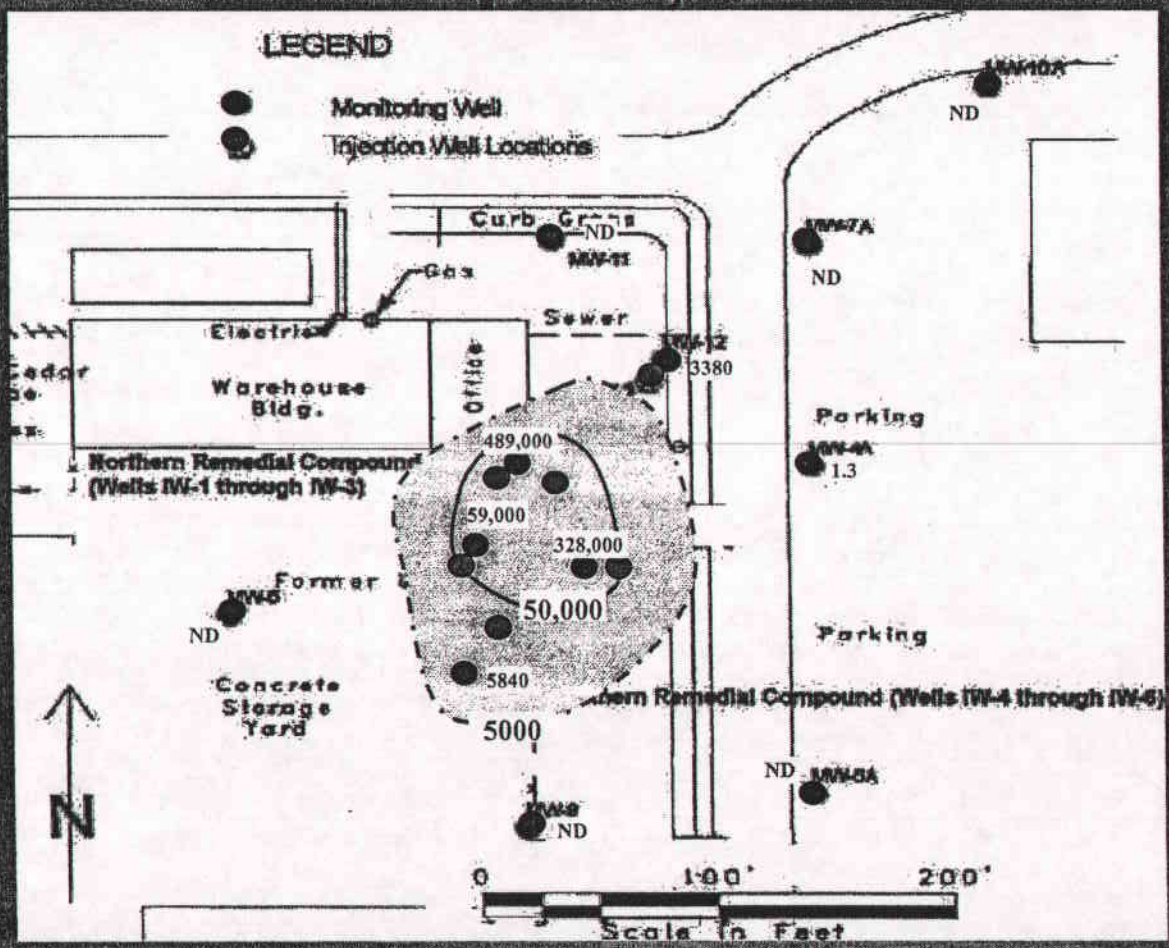


MTBE Concentration Dec 2, 01



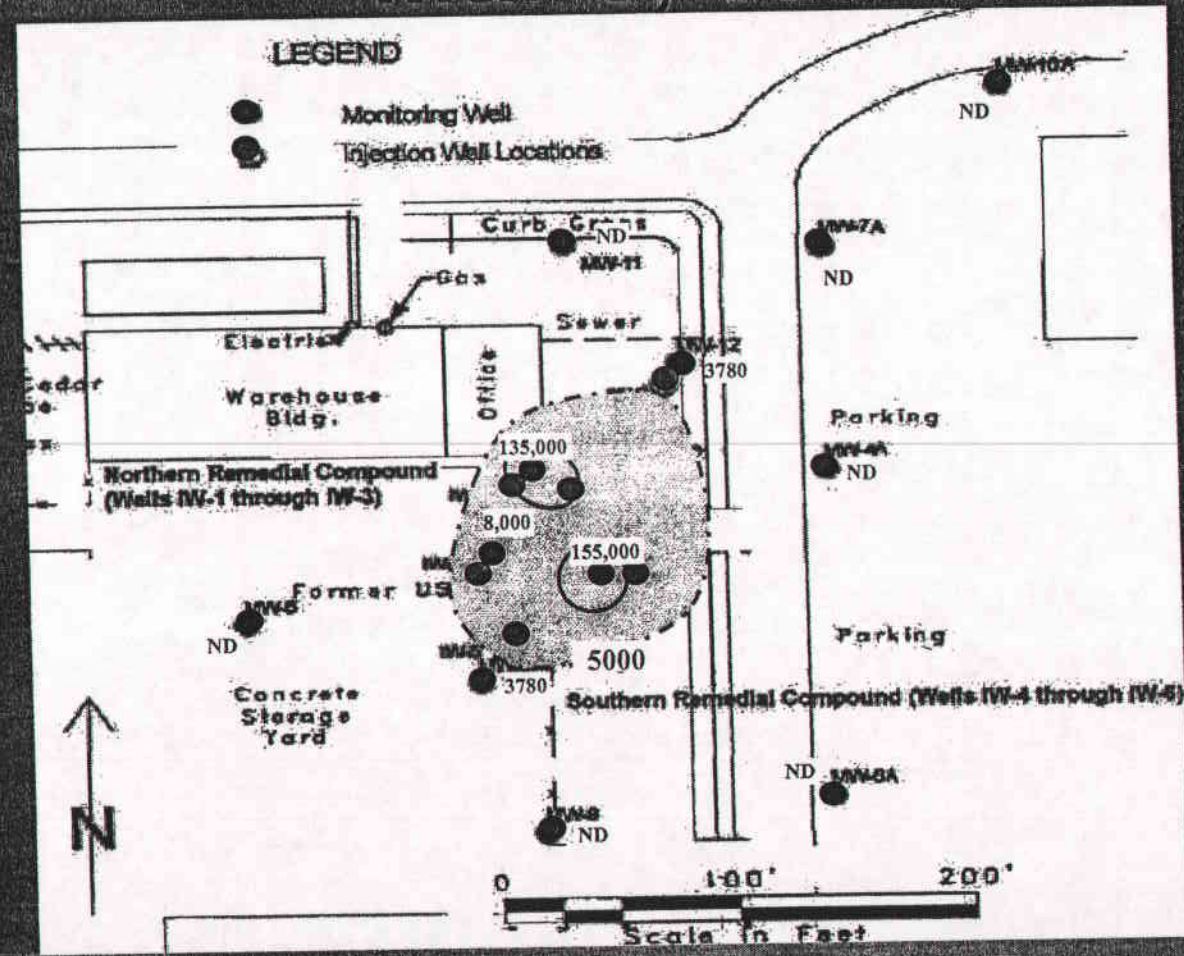
-1000- MTBE Concentration Contour (ppb)
1000 MTBE Concentration at monitoring well

MTBE Concentration- Sept 5, 02



-1000- MTBE Concentration Contour (ppb)
1000 MTBE Concentration at monitoring well

MTBE Concentration - Mar 3, 03



-1000- MTBE Concentration Contour (ppb)
1000 MTBE Concentration at monitoring well

Remediation Results - MTBE Reduction



Conclusions

- The iSOC system was successful in maintaining aerobic dissolved oxygen concentrations (0.5 to 1.0 ppm) in areas of high MTBE and benzene contamination
- Benzene concentrations across the entire site reduced between 18.4% and 100% over 6 months
- MTBE concentrations in every well but one (MW2) reduced by 24.6% to 100% over 6 months
- The iSOC system was successful in containing the contamination within the site

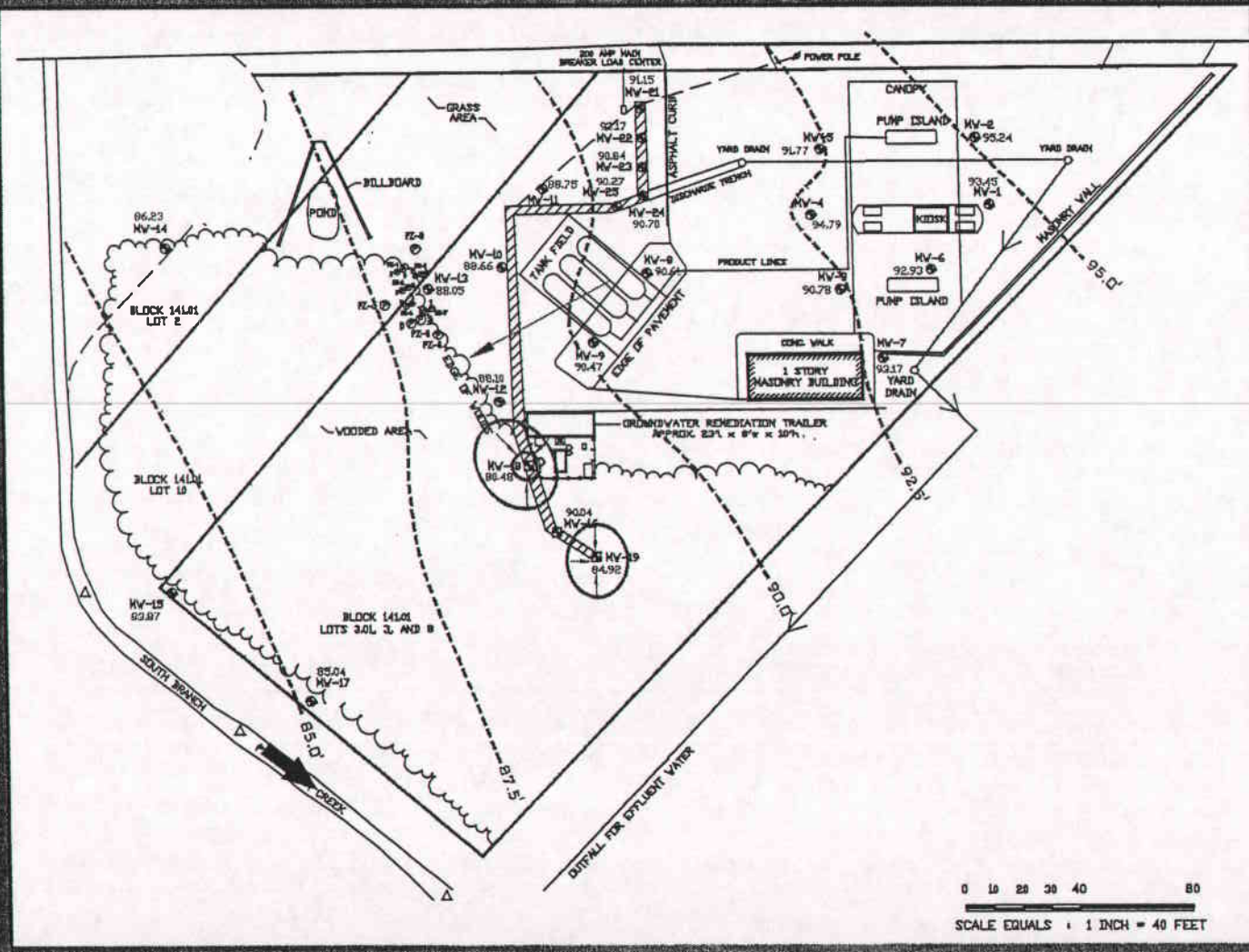


Accelerated Bioremediation &
Natural Attenuation by
*iSOC*TM
Groundwater Remediation System
Case Study- Maple Shade





Site Plan





ISOC™ Demo— Site Conditions

- Active service station
- Sand & silty sand underlain by silts & clays
- Depth to groundwater: 1.8 – 3.7 m below ground surface
- Groundwater velocity: 9 – 12 cm/day (conductivity 54 – 80 cm/d, gradient 0.028)
- Historical groundwater MTBE concentrations indicate slugs moving through aquifer
- Recovery wells yield up to 3.8 lpm, existing air stripper/GAC system has iron clogging problems (ferrous iron ~30 – 80 mg/l)

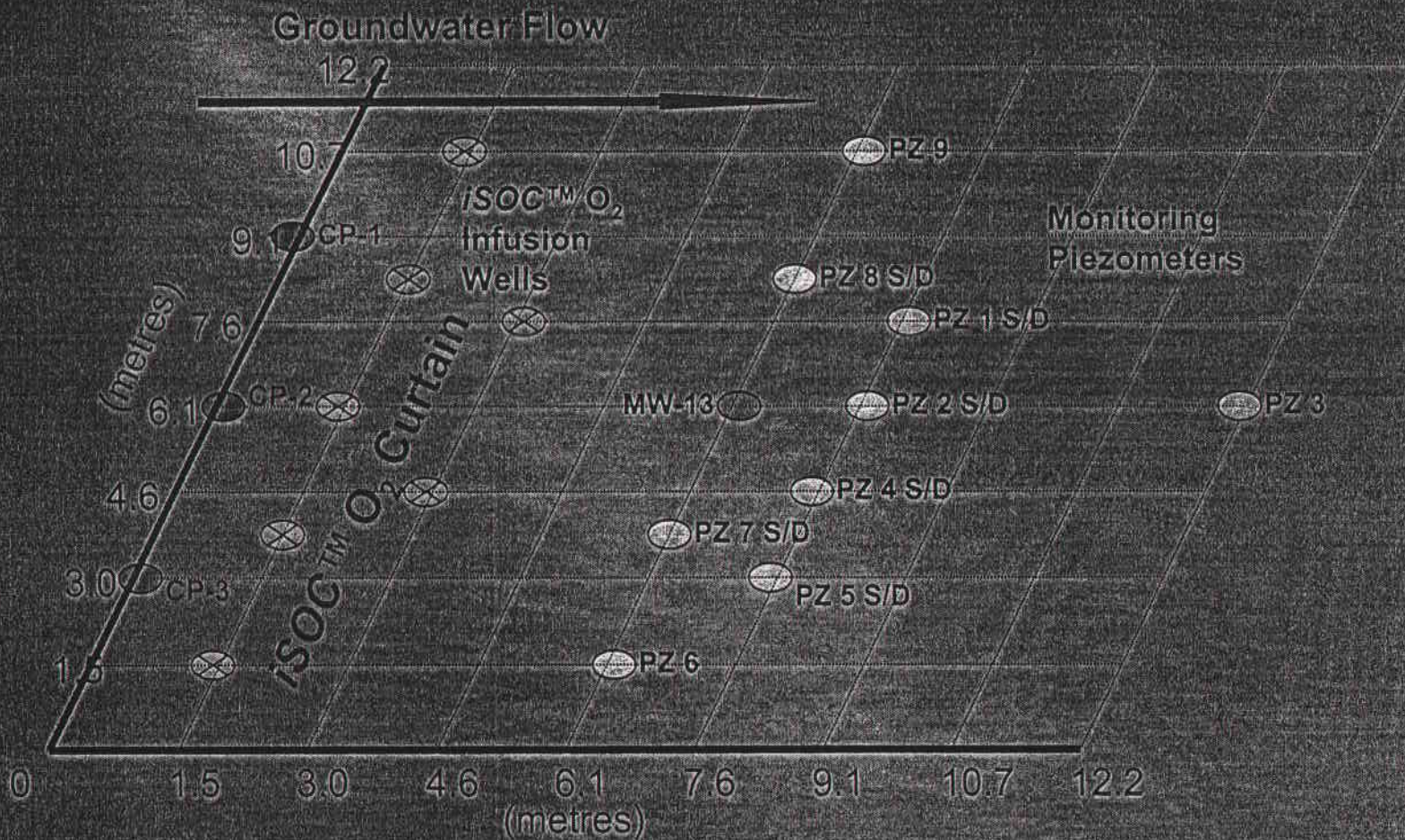


ISOC™ Demo— Baseline Conditions

- 28 wells (3 existing, 25 new) sampled for baseline event
- Wells sampled & analyzed for BTEX, MTBE, TBA, biological parameters, pH, temperature, & conductivity
- Baseline MTBE concentrations range from 3 to 7 ppm, TBA from 20 to 30 ppm, & Benzene up to 0.6 ppm
- Baseline event shows aquifer in anaerobic & reduced conditions



ISOC™ Demo - Treatment Area Schematic





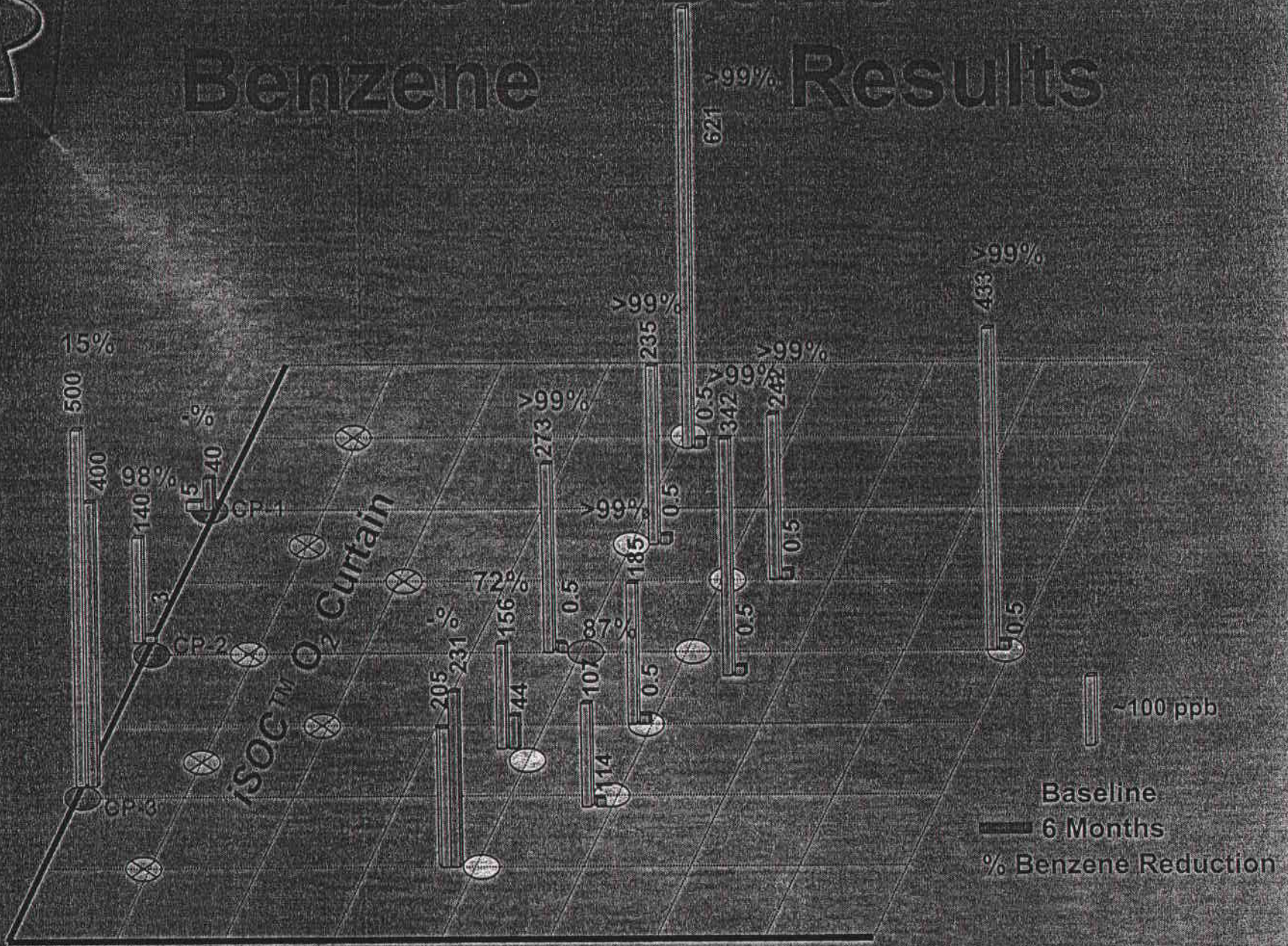
ISOC™ Demo - MTBE Results



Case Study - Maple Shade



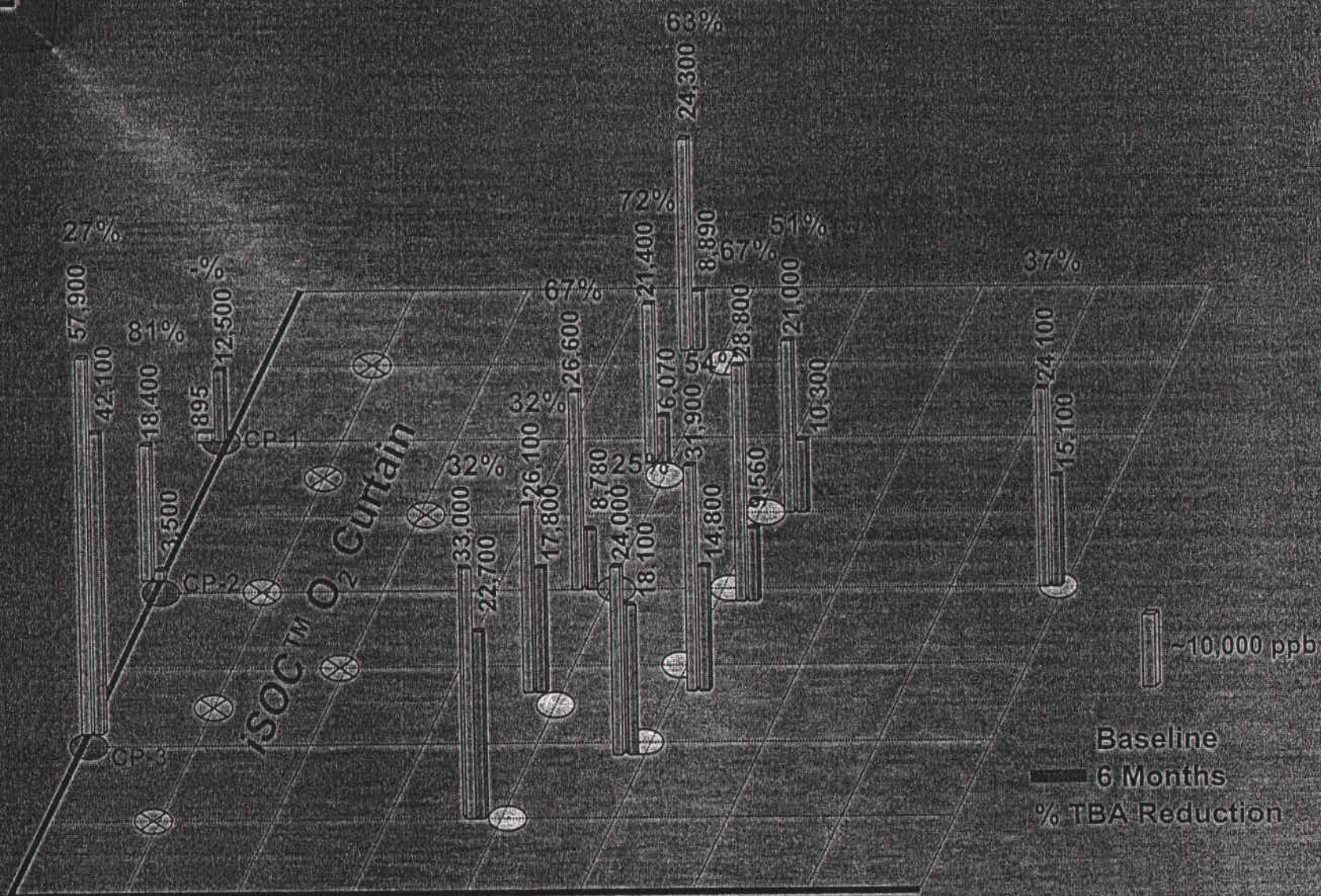
iSOC™ Demo - Benzene Results



Case Study - Maple Shade



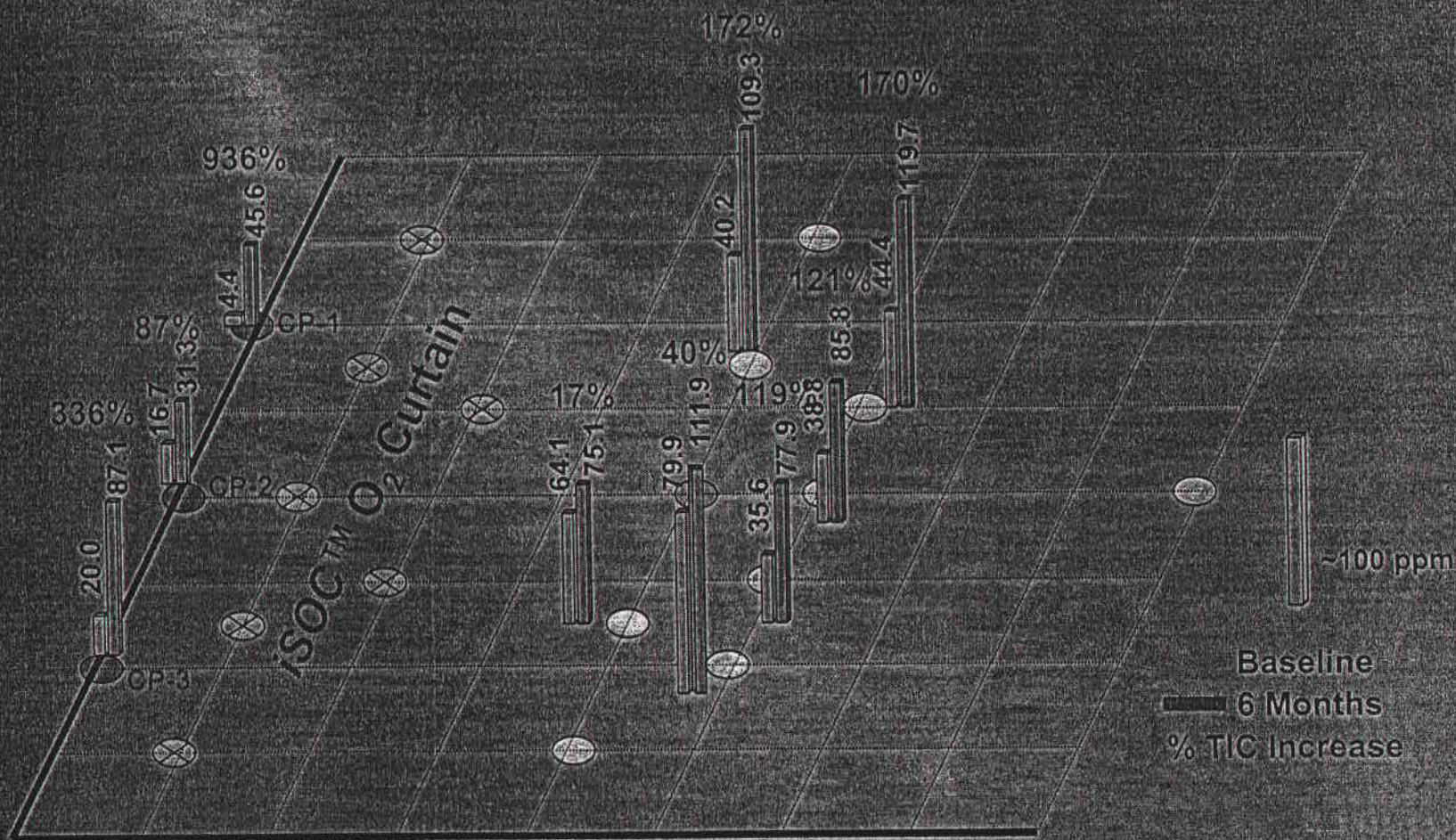
ISOC™ Demo - TBA Results



Case Study - Maple Shade



ISOC™ Demo - Groundwater TIC Results



Case Study - Maple Shade



iSOC™ Demonstration— Conclusions

- 3 months after iSOC™ system installed, an effective barrier of DO was established
- iSOC™ O₂ barrier effective in attenuating MTBE, TBA & Benzene throughout 6-month study period
- Significant reductions downgradient of iSOC™ O₂ barrier were comparable for shallow & deep piezometers: MTBE - 89%, TBA - 54%, Benzene - >96%
- Data indicates aerobic degradation of MTBE downgradient of iSOC™ O₂ barrier—possible anaerobic biodegradation outside of test location



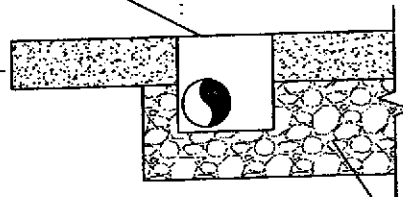
iSOC™ Demonstration— Conclusions

- Comparable attenuation rates estimated for MTBE & Benzene and lower attenuation rates estimated for TBA
- Reductions in MTBE, TBA & Benzene mirror decreasing trend in BOD₅ to COD, & VOC to COD ratios
- Total VOC to BOD₅ ratios indicate a significant portion of VOC's not readily degradable
- Elevated levels of ferrous iron, BOD₅, & COD did not inhibit aerobic degradation or interfere with iSOC™ system performance

ATTACHMENT C

Concrete cut into surfacing to 1-2 inches,
install 1/4" OD tubing, seal with concrete

Surfacing: asphalt or concrete,
typically 1 to 6 inches thick



Typical base rock: 8" min.
Class 2 AB, compacted to 95 %
relative density per ASTM D-1557

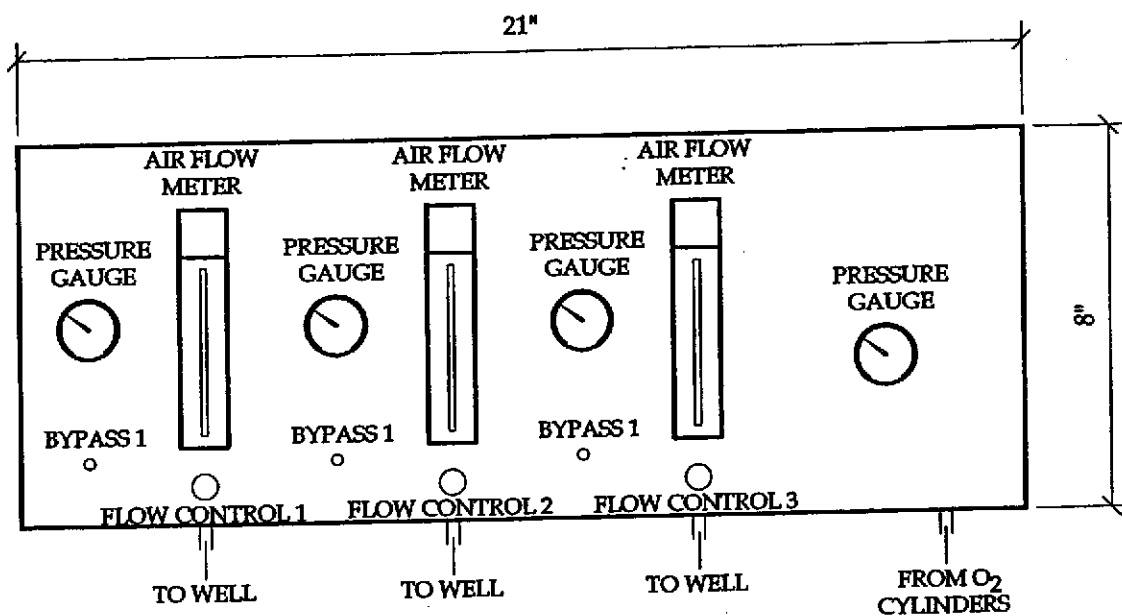
CONCRETE CUT DETAIL TO INSTALL
1/4" OD POLYURETHANE TUBING
(NOT TO SCALE)

iSOC CONCRETE CUT DETAIL
Eagle Gas
4301 San Leandro Street
Oakland, California

CLEARWATER GROUP

Project No.
ZP046B

NOT TO SCALE

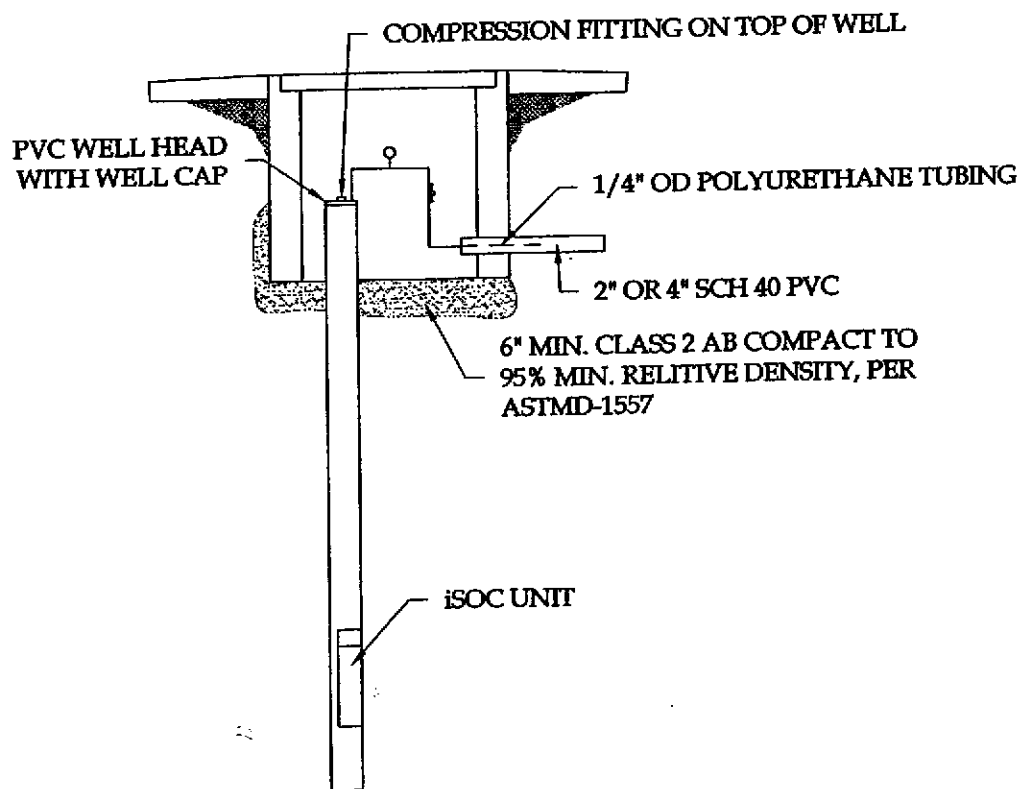


ISOC TRIPLE CONTROL PANEL DESIGN
 Eagle Gas
 4301 San Leandro Street
 Oakland, California

CLEARWATER GROUP

Project No.
 ZP046B

NOT TO SCALE

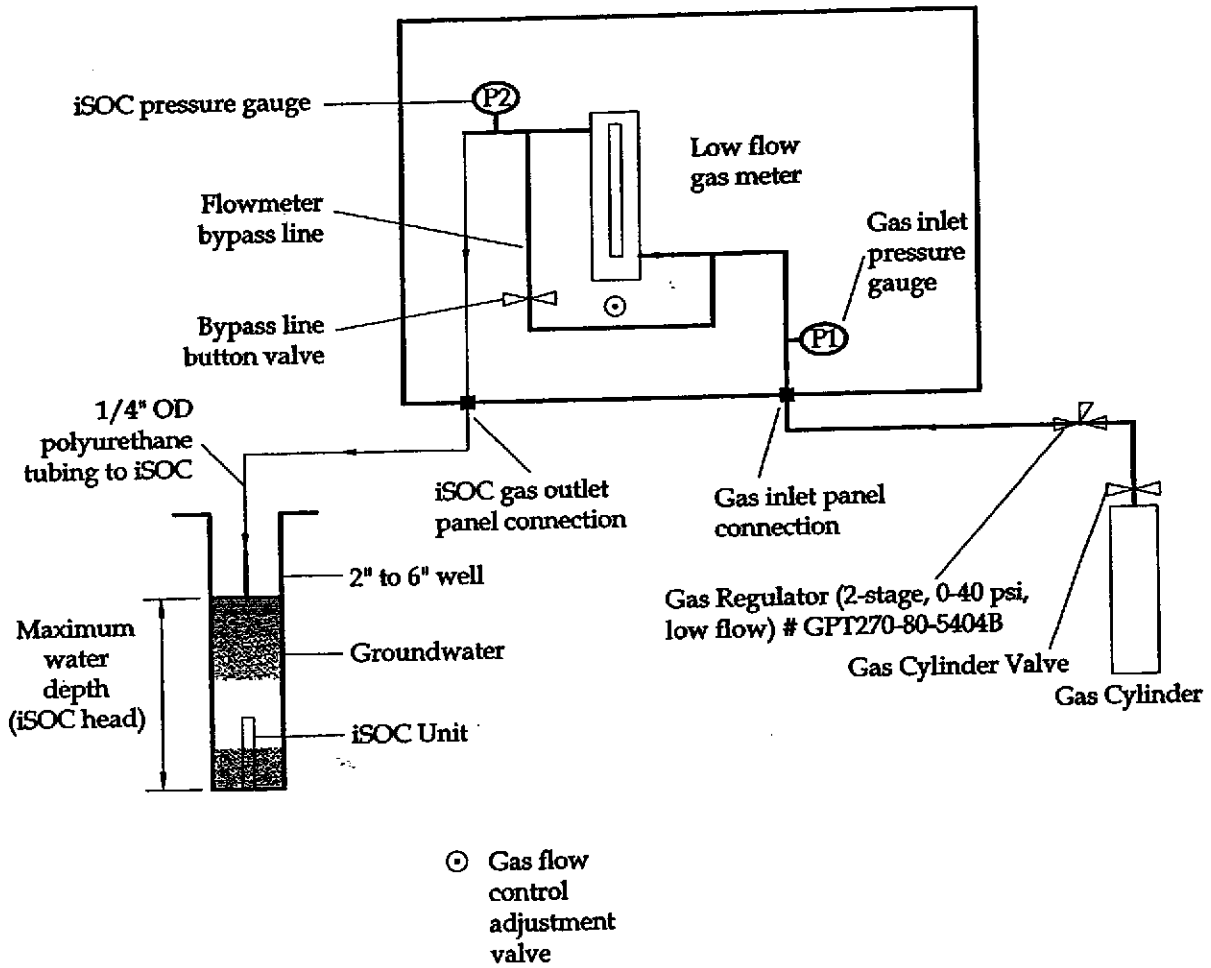


iSOC WELL DETAILS
 Eagle Gas
 4301 San Leandro Street
 Oakland, California

CLEARWATER GROUP

Project No.
 ZP046B

NOT TO SCALE



iSOC FLOW DIAGRAM
 Eagle Gas
 4301 San Leandro Street
 Oakland, California

CLEARWATER GROUP

Project No.
 ZP046B

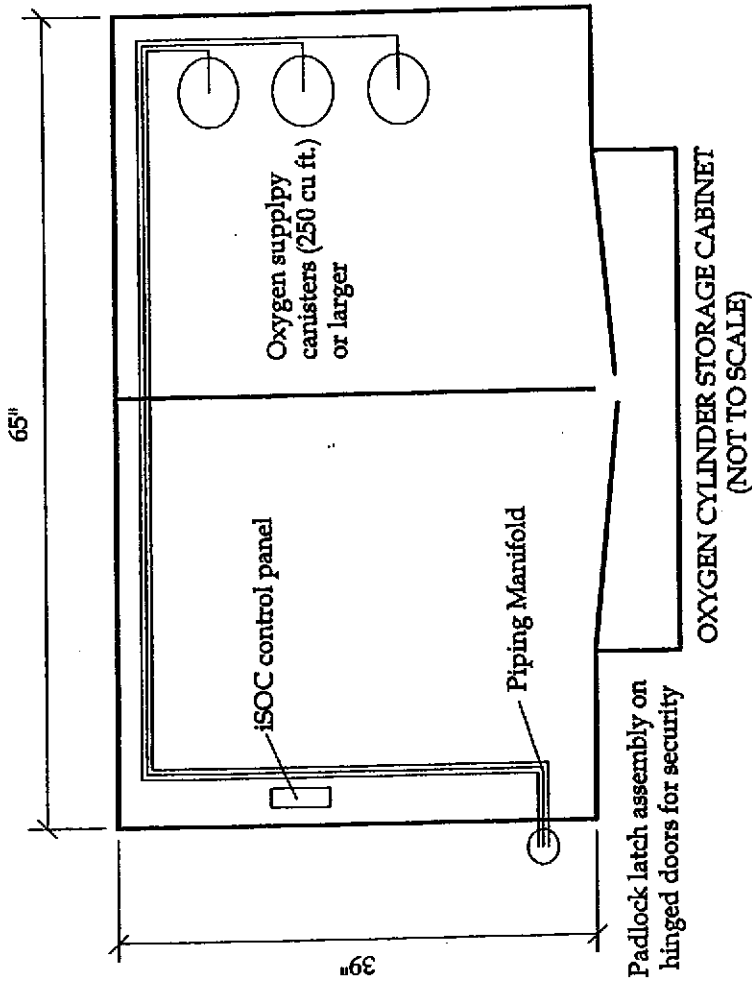
NOT TO SCALE

OXYGEN CYLINDER STORAGE CABINET:

#CSC2V-AL
Capacity: 10-20 cylinders
Height: 70"
Width: 65"
Depth: 39"
Weight: 148 lbs

Construction:
Aluminum 14 gauge expanded metal sides,
11 gauge solid top.
Security: padlock latch

Conforms to: OSHA
Subpart 1910.110 and NFPA 58-79 standards
Natural Aluminum Finish



Padlock latch assembly on hinged doors for security

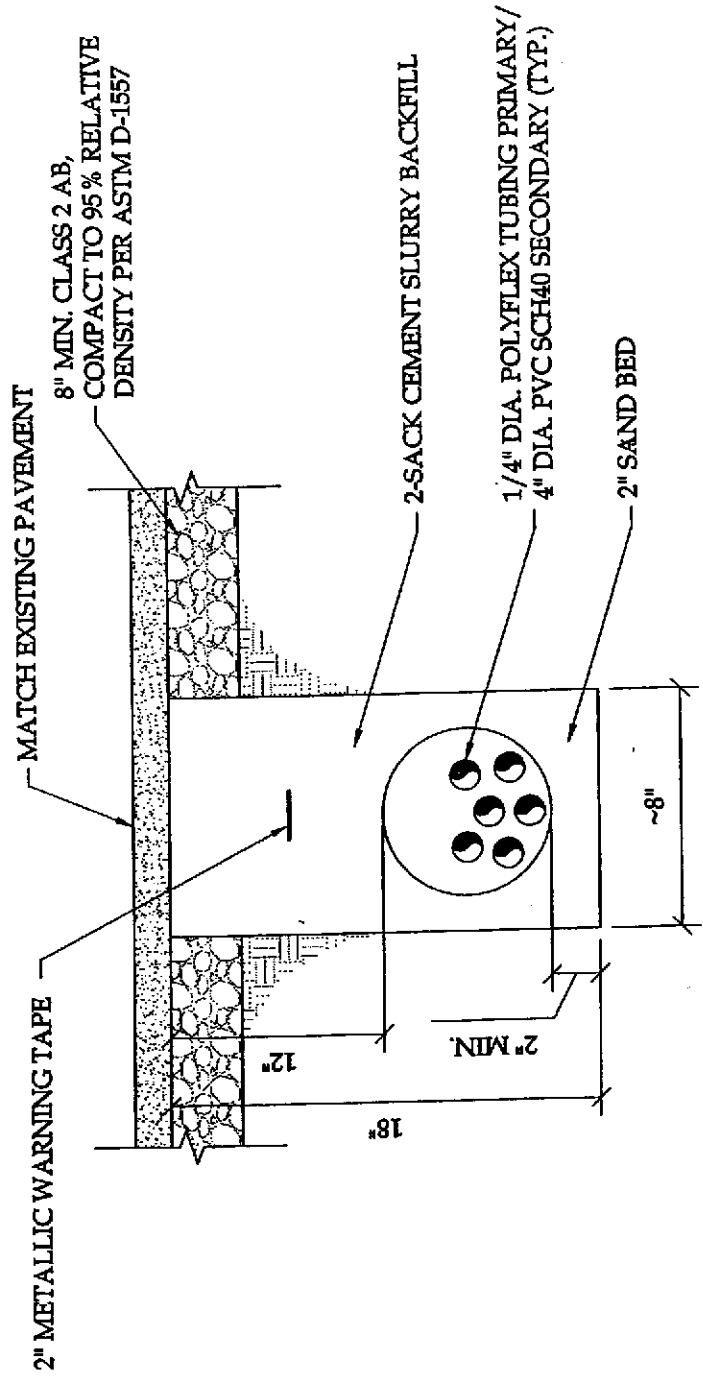
OXYGEN CYLINDER STORAGE CABINET
(NOT TO SCALE)

iSOC SECURITY STORAGE DESIGN
Eagle Gas
4301 San Leandro Street
Oakland, California

CLEARWATER GROUP

Project No.
ZF046B

NOT TO SCALE



CLEARWATER GROUP	
Project No. ZP046B	NOT TO SCALE

ISOC TRENCH DETAIL
 Eagle Gas
 4301 San Leandro Street
 Oakland, California

ATTACHMENT D

CLEARWATER GROUP

Soil Borehole Drilling, Monitoring Well Installation and Development, and Groundwater Sampling Field Procedures

Drilling and Soil Sampling

Permits, Site Safety Plan, Utility Clearance

Clearwater Group obtains all the required permits, unless otherwise contractually directed. Clearwater prepares a site specific Site Safety Plan detailing site hazards, site safety and control, decontamination procedures, and emergency response procedures to be employed throughout the defined phase of work. At least 48 hours prior to drilling, Underground Service Alert (USA) or an equivalent agency is notified of the planned work. Clearwater, attempts to locate all underground and above ground utilities by site inspection (in conjunction with its subcontractors and knowledgeable site managers, if available), and review of site as-built drawings. Clearwater may employ a private, professional utility locator to refine the site utility inspection.

Drilling Equipment

All soil borings are drilled using a truck-mounted hollow-stem auger drill rig, unless site conditions warrant a different drilling method. Subsurface conditions permitting, the first five feet of each boring is advanced using a hand-auger or post-hole digger. All drilling equipment is inspected daily and maintained in safe working condition by the operator. All down-hole drilling equipment is steam cleaned prior to arriving on site. Working components of the drill rig near the borehole, as well as augers and drill rods are thoroughly steam cleaned between each boring location. All CLEARWATER drilling and sampling methods are consistent with ASTM Method D-1452-80, and local, state and federal regulations.

Soil Sampling and Lithologic Description

Whenever possible, the first Clearwater boring to be drilled at a site is continuously cored to obtain a complete lithologic description. Otherwise, soil samples are typically collected every 5 feet to the total depth explored, using brass tubes fitted in a California-modified split spoon sampler. If copper or zinc contamination is the subject of the investigation, stainless steel liners are used instead of brass. Additional soil samples may be collected based upon significant changes in lithology or in areas of obvious soil contamination. During soil sample collection, the split spoon sampler is driven 18 to 24 inches past the lead auger by a 140-pound hammer falling a minimum of 30 inches. The number of blows necessary to drive the sampler and the amount of soil recovered is recorded on the Field Exploratory Soil Boring Log. The soil sampler and liners are cleaned with an Alconox® solution and rinsed with tap water prior to each sampling event. New liners are used whenever a soil sample may be retained for laboratory analysis.

Soil samples selected for laboratory analysis are sealed on both ends with teflon tape and plastic end caps. The samples are labeled, documented on a chain-of-custody form and placed in a cooler for transport to a state certified analytical laboratory. Soil contained in remaining liners is removed for lithologic descriptions (according to the Unified Soil Classification System). Additional soil is screened for organic vapors by placing approximately 30 grams of soil in a sealed plastic bag or a glass jar sealed with aluminum foil. The bag or jar is left undisturbed for approximately 15 minutes, in the sun if possible. The head space in the bag is accessed in a manner to minimize entry of outside air, and is tested for total organic vapor using a calibrated organic vapor meter (OVM). The results of the field screening are noted with the lithologic descriptions on the Field Exploratory Soil Boring Log.

On encountering an impermeable (clayey) layer three feet or more in thickness below a saturated permeable layer, where the impermeable layer is considered to be a possible confining layer for an underlying aquifer, drilling is halted until a decision to proceed is obtained from the project manager. This process minimizes the chance of introducing contamination to an underlying, clean aquifer.

Soil Waste Management

Soil cuttings are stockpiled on and covered with plastic sheeting to control runoff, or contained in 55-gallon D.O.T.-approved drums on site. Waste soil is sampled to chemically profile it for disposable, and hauled by a

licensed waste hauler to an appropriate landfill. All waste stored on site is properly labeled at the time of production.

Soil Boring Abandonment

Soil borings which are not to be converted into monitoring wells are sealed to the ground surface using neat cement or sand-cement slurry in accordance with federal, state and local regulations. Native soil may be used to fill the top two to three feet for cosmetic purposes, as permitted.

Monitoring Well Installation

Well Casing, Screen and Filter Pack Construction

All well construction is performed in accordance with Department of Water Resources "California Well Standards" and all requirements of local oversight agencies. Soil borings to be converted into single-cased monitoring wells are a minimum of eight inches in diameter for 2-inch diameter wells and a minimum of ten inches in diameter for 4-inch diameter wells. Monitoring wells are constructed with schedule 40, threaded, polyvinyl chloride (PVC) casing unless site geochemistry or contamination necessitates an alternative material. The wells are constructed with factory-slotted screen and threaded end caps.

The screened interval is placed such that it extends approximately ten feet into the water bearing zone, and at least five feet above the expected maximum water level. The screened interval may extend less than five feet above the maximum water level, only to prevent intersection of the screened interval with the top of the confining layer of a confined aquifer, or where the water table is too shallow to allow this construction.

A graded sand filter pack is placed in the annular space across the screened interval and extended approximately one to two feet above the screen, as site conditions permit, so as to prevent extension of the sand pack into an overlying water-bearing unit. The well screen slot size is the maximum size capable of retaining 90% of the filter pack. Typically, 0.010-inch screen is used where the formation is predominantly clay and/or silt or poorly-graded fine sand. 0.020-inch screen is used where the formation is predominantly well-graded or medium to coarse sand and/or gravel.

The filter pack grade (mean grain size) is selected according to native sediment type as follows: a) for poorly graded fine sand or silt/clay - 4 times the 70% retained grain size of the formation b) for medium to coarse sand, gravel or well graded sediments - 6 times the 70% retained grain size. Since results of particle size analysis are not always available, Clearwater often selects screen size and filter pack on the basis of general site stratigraphy, and specifically the finest significantly thick layer of sediment to be screened. Commonly selected grades are Lone Star® 3, 2/12 or 2/16 (or equivalent) with 0.020-inch slotted screen and Lone Star® 1/20 with 0.010-inch slotted screen.

Well Seal and Completion

A minimum two foot seal of bentonite is placed above the sand pack. The bentonite seal is hydrated by either formation water or potable water. Neat cement or a cement/bentonite grout mixture seals the remaining annular space to the surface. If bentonite is used in the grout mixture, it does not exceed 5% by weight. The grout is placed using a tremie pipe, if the top of the bentonite is more than 20 feet below grade, or if water is present in the boring above the bentonite seal. A watertight locking cap and protective traffic-rated vault box is installed on top of each well. Well construction details are presented on the Field Exploratory Soil Boring Log. Following completion of a well, Clearwater completes and submits, or ensures that the driller has sufficient information to complete and submit, the state-required Well Completion Report or equivalent document.

Well Development

All newly installed wells are developed prior to sampling to remove fine grained sediments from the well and stabilize the filter pack and the disturbed aquifer materials. Development takes place prior to or at least 24 hours after setting the seal on the well, unless otherwise directed by a local oversight agency. Well development consists of surging with a surge block and removing water from the well with either a pump or bailer, until the well is free of sediment, or until at least 10 well casing volumes have been removed. Depth to bottom is measured to determine casing volume. If the well is sampled immediately following development, temperature, pH, specific

conductance and turbidity (qualitative) are monitored during well development (see section "Groundwater Sampling"). All development equipment is cleaned prior to use and between wells with an Alconox® solution, then rinsed in potable water. All data collected during development are recorded on the Well Development Data Sheet and, if necessary, the Purging Data Sheet.

Well Surveying

All well elevations are surveyed at the north side of the top of casing to the nearest ± 0.01 foot. The exact survey point (at the center of the survey rod or, if the casing stub is uneven, the point of contact between casing and rod) is clearly marked and maintained on the casing rim. Elevations are referenced either to mean sea level or to a project datum. A project datum is typically chosen so as to minimize the possibility of its' later disturbance. For instance, fire hydrants are commonly selected. Where required, the wells are surveyed by a licensed land surveyor, relative to mean sea level.

Groundwater Sampling

Groundwater Monitoring

Prior to beginning, a decontamination area is established. Decontamination procedures consist of scrubbing downhole equipment in an Alconox® solution wash (wash solution is pumped through any purging pumps used), and rinsing in a first rinse of potable water and a second rinse of potable water or deionized water if the latter is required. Any non-dedicated down hole equipment is decontaminated prior to use.

Prior to purging and sampling a well, the static water level is measured to the nearest 0.01 feet with an electronic water sounder. Depth to bottom is typically measured once per year, at the request of the project manager, and during Clearwater's first visit to a site. If historical analytical data are not available, with which to establish a reliable order of increasing well contamination, the water sounder and tape will be decontaminated between each well. If floating separate-phase hydrocarbons (SPH) are suspected or observed, SPH is collected using a clear, open-ended product bailer, and the thickness is measured to the nearest 0.01 feet in the bailer. SPH may alternatively be measured with an electronic interface probe. Any monitoring well containing a measurable thickness of SPH before or during purging is not additionally purged and no sample is collected from that well. Wells containing a hydrocarbon sheen are sampled unless otherwise specified by the project manager. Field observations such as well integrity as well as water level measurements and floating product thicknesses are noted on the Gauging Data/Purge Calculations form.

Well Purging

Each monitoring well to be sampled is purged using either a PVC bailer or a submersible pump. Physical parameters (pH, temperature and conductivity) of the purge water are monitored during purging activities to assess if the water sample collected is representative of the aquifer. If required, parameters such as dissolved oxygen, turbidity, salinity etc. are also measured. Samples are considered representative if parameter stability is achieved. Stability is defined as a change of less than 0.25 pH units, less than 10% change in conductivity in micro mhos, and less than 1.0 degree centigrade (1.8 degrees Fahrenheit) change in temperature. Parameters are measured in a discreet sample decanted from the bailer separately from the rest of the purge water. Parameters are measured at least four times during purging; initially, and at volume intervals of one well volume. Purging continues until three well casing volumes have been removed or until the well completely dewater. Wells which dewater or demonstrate a slow recharge, may be sampled after fewer than three well volumes have been removed. Well purging information is recorded on the Purge Data sheet. All meters used to measure parameters are calibrated daily. Purge water is sealed, labeled, and stored on site in D.O.T.-approved 55-gallon drums. After being chemically profiled, the water is removed to an appropriate disposal facility by a licensed waste hauler.

Groundwater Sample Collection

Groundwater samples are collected immediately after purging or, if purging rate exceeds well recharge rate, when the well has recharged to at least 80% of its static water level. If recharge is extremely slow, the well is allowed to recharge for at least two hours, if practicable, or until sufficient volume has accumulated for sampling. The well is sampled within 24 hours of purging or repurged. Samples are collected using polyethylene bailers, either disposable or dedicated to the well. Samples being analyzed for compounds most sensitive to volatilization are collected first. Water samples are placed in appropriate laboratory-supplied containers, labeled, documented on a chain of custody form and placed on ice in a cooler for transport to a state-certified analytical laboratory. Analytical detection limits match or surpass standards required by relevant local or regional guidelines.

Quality Assurance Procedures

To prevent contamination of the samples, Clearwater personnel adhere to the following procedures in the field:

- A new, clean pair of latex gloves are put on prior to sampling each well.
- Wells are gauged, purged and groundwater samples are collected in the expected order of increasing degree of contamination based on historical analytical results.
- All purging equipment will be thoroughly decontaminated between each well, using the procedures previously described at the beginning of this section.
- During sample collection for volatile organic analysis, the amount of air passing through the sample is minimized. This helps prevent the air from stripping the volatiles from the water. Sample bottles are filled by slowly running the sample down the side of the bottle until there is a convex meniscus over the mouth of the bottle. The lid is carefully screwed onto the bottle such that no air bubbles are present within the bottle. If a bubble is present, the cap is removed and additional water is added to the sample container. After resealing the sample container, if bubbles still are present inside, the sample container is discarded and the procedure is repeated with a new container.

Laboratory and field handling procedures may be monitored, if required by the client or regulators, by including quality control (QC) samples for analysis with the groundwater samples. Examples of different types of QC samples are as follows:

- Trip blanks are prepared at the analytical laboratory by laboratory personnel to check field handling procedures. Trip blanks are transported to the project site in the same manner as the laboratory-supplied sample containers to be filled. They are not opened, and are returned to the laboratory with the samples collected. Trip blanks are analyzed for purgable organic compounds.
- Equipment blanks are prepared in the field to determine if decontamination of field sampling equipment has been effective. The sampling equipment used to collect the groundwater samples is rinsed with distilled water which is then decanted into laboratory-supplied containers. The equipment blanks are transported to the laboratory, and are analyzed for the same chemical constituents as the samples collected at the site.
- Duplicates are collected at the same time that the standard groundwater samples are being collected and are analyzed for the same compounds in order to check the reproducibility of laboratory data. They are typically only collected from one well per sampling event. The duplicate is assigned an identification number that will not associate it with the source well.

Generally, trip blanks and field blanks check field handling and transportation procedures. Duplicates check laboratory procedures. The configuration of QC samples is determined by Clearwater depending on site conditions and regulatory requirements.