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STRATUS
ENVIRONMENTAL, INC.

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August 31, 2005
Project No. 2007-0057-01

Mr. Barney Chan
Alameda County Health Care Services Agency
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

Re: Work Plan for Well Installation and In-Situ Groundwater Remediation
Former USA Service Station No. 57
10700 MacArthur Boulevard
Oakland, California

Dear Mr. Chan:

Stratus Environmental, Inc. (Stratus), on behalf of USA Gasoline Corporation (USA), has prepared this *Work Plan for Well Installation and In-Situ Groundwater Remediation* for former USA Service Station No. 57 (the site), located at 10700 MacArthur Boulevard, Oakland, California (see Figure 1). Stratus is currently completing intermittent dual phase extraction (DPE), using three existing groundwater monitoring wells (S-1, S-2, and MW-3) to extract petroleum hydrocarbon laden groundwater and soil vapors from beneath the site.

Relatively low petroleum hydrocarbon mass extraction rates have been observed during the DPE events. In order to enhance the performance of the DPE system, Stratus is proposing to install four extraction wells near the areas where the highest concentrations of petroleum hydrocarbon impact have historically been reported. The monitoring wells used for extraction have submerged screening intervals, and extend into bedrock beneath the site. The proposed extraction wells will be screened within vadose zone soils and the upper portion of the saturated zone, enabling improved recovery of residual and dissolved phase petroleum hydrocarbon mass.

Stratus is also proposing to supplement intermittent DPE with use of a full-time in-situ groundwater remediation system. Oxygen will be introduced into the saturated zone through existing wells S-1, S-2, and MW-3, using the iSOC™ system. Introduction of oxygen into the subsurface will be completed in order to increase the dissolved oxygen (DO) concentration in groundwater, and subsequently enhance biodegradation rates of petroleum hydrocarbons. Details associated with completion of the extraction well installations, and initiation of in-situ remediation using the iSOC™ system, are presented in this work plan.

SITE BACKGROUND

The site is currently an undeveloped, partially paved parcel situated on the western corner of the intersection of 108th Avenue and Foothills Boulevard in Oakland, California, approximately 400 feet west of Interstate 580. This parcel comprises the southeastern corner of the Foothills Square Shopping Center. It is our understanding that the property owner intends to re-develop the portion of the Foothills Square Shopping Center formerly occupied by the site.

USA Station 57 was closed, and the gasoline underground storage tanks (USTs) were removed, in July 1994. Approximately 775 cubic yards of impacted soil was excavated from the vicinity of the UST pit and product lines between August and October 1994. Residual petroleum hydrocarbon impact to soil appears to be limited to the immediate vicinity of the former fuel dispenser islands and USTs. The approximate former locations of the USTs and dispenser islands are shown on Figure 2.

Eight groundwater monitoring wells (S-1, S-2, and MW-3 through MW-8) were installed, and twelve exploratory soil borings (A through D and B-1 through B-8) were advanced, in order to assess the extent of subsurface petroleum hydrocarbon impact beneath the site. This site characterization work was completed between 1987 and 1995. Table 1 summarizes details pertinent to the drilling and well construction activities. The well network has been monitored and sampled on a quarterly basis since 1995. Depth to groundwater has been reported in the monitoring wells at depths ranging from approximately 7 to 21 feet below ground surface (bgs) since groundwater monitoring was initiated.

Petroleum hydrocarbon impact to soil extends to the saturated zone in the vicinity of the former UST complex and fuel dispenser islands. Total petroleum hydrocarbons as gasoline (TPHG), benzene, toluene, ethylbenzene, and total xylenes (BTEX compounds), methyl tertiary butyl ether (MTBE), and tertiary butyl alcohol (TBA) have historically been reported in groundwater samples collected beneath the site. The area of impacted groundwater is predominately situated in the vicinity of wells S-1, S-2, and MW-3. TPHG, benzene, and MTBE concentration versus time graphs for wells S-1, S-2, and MW-3, which include historical depth to groundwater data, are presented in Appendix A.

PROJECT APPROACH

DPE has generally resulted in decreased petroleum hydrocarbon concentrations in groundwater (see Figures in Appendix A), however dissolved phase concentrations remain above current water quality objectives. The three wells currently impacted with petroleum hydrocarbons (S-1, S-2, and MW-3) are screened below the static water table interface and extend into bedrock, likely inhibiting optimal recovery of petroleum hydrocarbon laden soil vapors (see Figure 3). Stratus is proposing to install four shallow screened extraction wells (EX-1 through EX-4), in the vicinity of the former fuel dispenser islands and UST complex, to enable enhanced recovery of petroleum hydrocarbons from the subsurface. The wells will be screened from approximately 5 to 25 feet bgs, extending approximately 5 to 10 feet into the saturated zone, based on recent groundwater monitoring data. Future DPE events will be completed using wells EX-1 through EX-4 for extraction.

Stratus is proposing to utilize the iSOC™ system to increase dissolved oxygen concentrations in the subsurface. iSOC™ is a commonly used in-situ bioremediation technology that delivers oxygen into the subsurface through a specially designed micro-porous mass transfer device (an iSOC™ unit) placed into a well. iSOC™ units contain microporous hollow fibers with very large surface areas, given the relatively small size (15-inches in length) of the unit. The iSOC™ system is designed to cause molecular diffusion of oxygen in the subsurface stratum, enabling dissolved oxygen concentrations to reach supersaturated concentrations without bubbling.

Natural biodegradation of hydrocarbons in the subsurface is commonly limited by the lack of adequate dissolved oxygen (DO) necessary for the growth of microorganisms that degrade the petroleum hydrocarbons. Relatively low DO concentrations (generally less than 1.5 milligrams per liter [mg/L]) have been measured in the impacted groundwater monitoring wells during historical groundwater monitoring. Use of the iSOC™ system should result in an increase in DO in groundwater beneath the site, resulting in enhanced in-situ degradation of subsurface petroleum hydrocarbons. Stratus will install iSOC™ units in existing wells S-1, S-2, and MW-3.

SCOPE OF WORK

The objectives of the proposed work are to:

- Install additional extraction wells near the area of known petroleum hydrocarbon impact in order to improve DPE system performance.
- Implement in-situ remediation by increasing DO concentrations in the saturated zone.

To accomplish these objectives, Stratus is proposing the following activities:

- Advance four (4) soil borings to approximately 25 feet bgs using 10-inch diameter hollow stem augers. These borings will be converted to 4-inch diameter extraction wells EX-1 through EX-4.
- Collect soil samples in 5-foot intervals during the advancement of each boring for lithologic comparison and chemical analysis.
- Develop the newly installed wells.

- Utilize wells EX-1 through EX-4 for extraction of soil vapors and groundwater during intermittent DPE events.
- Introduce oxygen into the subsurface through wells S-1, S-2, and MW-3 using the iSOC™ system.

The proposed scope of work has been subdivided into tasks 1 through 5. Details are provided for the activities associated with each task. All geologic work will be conducted under the direct supervision of a State of California Professional Geologist or Engineer and will be conducted in accordance with standards established by the *Tri-Regional Board Recommendations for Investigation and Evaluation of Underground Tank Sites* (April 2004) and ACHCSA guidelines. A California-licensed C-57 well driller will perform all drilling and well construction activities. Field Practices and Procedures to be utilized during implementation of the proposed work are described in Appendix B.

Task 1: Pre-field Activities

Following approval of this scope of work by the ACHCSA, the following activities will be completed:

- Obtain well installation permits from Alameda County Public Works Department (ACPWD),
- Retain and schedule a licensed C-57 drilling contactor,
- Update the health and safety plan for the site,
- Mark boring locations and contact Underground Service Alert to locate underground utilities in the vicinity of the work areas, and
- Notify ACHCSA, ACPWD, USA, and the property owner of the scheduled field activities.

Task 2: Field Activities

Task 2A: Soil Borings

A C-57-licensed well driller will advance the soil borings using a truck mounted drill rig equipped with 10-inch diameter hollow stem augers. The borings will be advanced to approximately 25 feet bgs, and completed as extraction wells as described below. The approximate location of each proposed well boring is shown on Figure 2. The actual drilling location will be based on accessibility and the location of underground utilities.

The initial 5 feet of each boring will be advanced with a hand auger and/or posthole digger to reduce the possibility of damaging underground utilities. Soil samples will be collected in 5-foot intervals using a California-type, split-spoon sampler equipped with three pre-cleaned brass tubes. The ends of the bottom-most, intact tube from each sample interval will be lined with Teflon™ sheets, capped, and sealed. Each sample will then be labeled, placed in a resealable plastic bag, and stored in an ice-chilled cooler. Strict chain-of-custody procedures will be followed from the time the samples are collected until the time the samples are relinquished to the laboratory. Soil contained in the remaining brass tubes will be screened for volatile organic compounds (VOCs) using a photo-ionization detector (PID). Stratus will record PID readings, soil types, and other pertinent geologic data on a borehole log. A minimum of two soil samples from each boring will be submitted for chemical analysis. Additional samples may be selected for chemical analysis based on soil type and field observations.

Task 2B: Extraction Well Installation

Wells EX-1 through EX-4 will be constructed using 4-inch diameter PVC casing and 20 feet 0.02-inch diameter machine slotted well screen, situated from approximately 5 to 25 feet bgs. A filter pack of #3 Lonestar™ sand will be placed in the annular space around the well casing from the bottom of the well screen to approximately one foot above the top of the well screen. Prior to placing the annular well seal, the well casing will be surged with a surge block to "seat" the filter pack around the well screen. Following well surging, approximately one foot of bentonite will be placed on top of the filter pack and hydrated with clean water to provide a transition seal for the well. Neat cement will be used to backfill the remaining annular space around the well casing. A watertight locking cap will be placed over the top of the well casing, and a traffic rated vault box will be installed around the top of the well. The actual well construction may be modified in the field based on conditions encountered at the time of the investigation.

Task 2C: Well Development

A minimum of 48 hours after installation, wells EX-1 through EX-4 will be developed by surging followed by groundwater pumping. Development will continue until the extracted groundwater appears free of suspended sediment. At least 10 well casing volumes will be evacuated from each well during development activities.

Task 2D: Waste Management

All drill cuttings and wastewater generated during the field activities will be contained in U.S. Department of Transportation-approved 55-gallon steel drums. The drums will be appropriately labeled and stored at the site pending proper disposal. A licensed contractor will transport the soil and wastewater to an appropriate facility for disposal.

Task 3: Oxygen Injection using the iSOC™ System

Oxygen will be delivered to the saturated zone through an iSOC™ unit situated in wells S-1, S-2, and MW-3. The iSOC™ unit is a specially designed micro-porous mass transfer device that delivers oxygen to the groundwater without bubbling. An oxygen supersaturation zone in created in the injection well, aiding the molecular dispersion of oxygen around the injection well. Each iSOC™ unit will be situated at the base of each well, allowing for the maximum pressure head on each sparge point. Manufacturer's literature for the iSOC™ system is provided in Appendix C.

Pure bottled oxygen will be utilized to supply oxygen to the iSOC™ units placed in the wells. A 0.25-inch diameter tube will be used to connect each iSOC™ unit to a pressurized oxygen cylinder via the iSOC™ control panel. The tubing will be situated above ground, secondarily contained within 1-inch or 2-inch diameter schedule 80 PVC piping, and connected to the control panel. The oxygen cylinder and control panel will be placed in a locked metal shed for protection. A schematic diagram illustrating the iSOC™ system to be used at this site is provided in Figure 4.

Task 4: Laboratory Methods and Monitoring Protocol

Soil samples will be forwarded to a state-certified analytical laboratory for chemical analysis. The soil samples will be analyzed for TPHG using USEPA Method 8015 DHS LUFT, and for BTEX, MTBE, TBA, 1,2-dichloroethane (1,2-DCA), di-isopropyl ether (DIPE), tertiary amyl methyl ether (TAME), and ethyl tertiary butyl ether (ETBE) using USEPA Method 8260.

Prior to initiation of oxygen injection using the iSOC™ system, a baseline groundwater sampling event, analyzing samples for non-petroleum based constituents, will be completed. Groundwater samples will be analyzed by a state-certified analytical laboratory for total dissolved solids (TDS) using USEPA Method 160.1, heterotrophic plate count using USEPA Method SM9215, nitrate, phosphate, and sulfate using USEPA Method 300.0, ferrous iron and total iron using USEPA Method 200.8, and for pH, oxidation reduction potential (ORP), and DO using field instruments. Following initiation of in-situ remediation, Stratus will initially measure pH, ORP, and DO on a weekly basis for a period of 4 weeks; these parameters will subsequently be measured on a monthly basis following the initial monitoring period. Samples will initially be collected and analyzed for TDS, heterotrophic plate count, nitrate, phosphate, sulfate, and iron on a monthly basis for a period of three months; the sampling frequency will subsequently be reduced to quarterly intervals.

Task 5: Report Preparation

A report documenting the extraction well installations will be prepared. The report will include a scaled site plan, soil boring logs, well details, soil analytical data tables, and certified analytical results. Reports documenting each DPE event will continue to be submitted. The results of groundwater sampling will be included in quarterly monitoring reports currently being submitted for the site.

Schedule

ACPW

Following approval of this work plan, a well permit application package will be forwarded to ACHCSA and the work will be scheduled. Approximately 3 weeks will likely be necessary for a C-57 licensed well contractor to become available. Reports will be submitted within approximately 6 weeks of receiving all analytical results.

If you have any questions or comments concerning this work plan, please contact Gowri Kowtha at (530) 676-6001.

Sincerely,
STRATUS ENVIRONMENTAL, INC.

Scott G. Bittinger, P.G.
Project Geologist

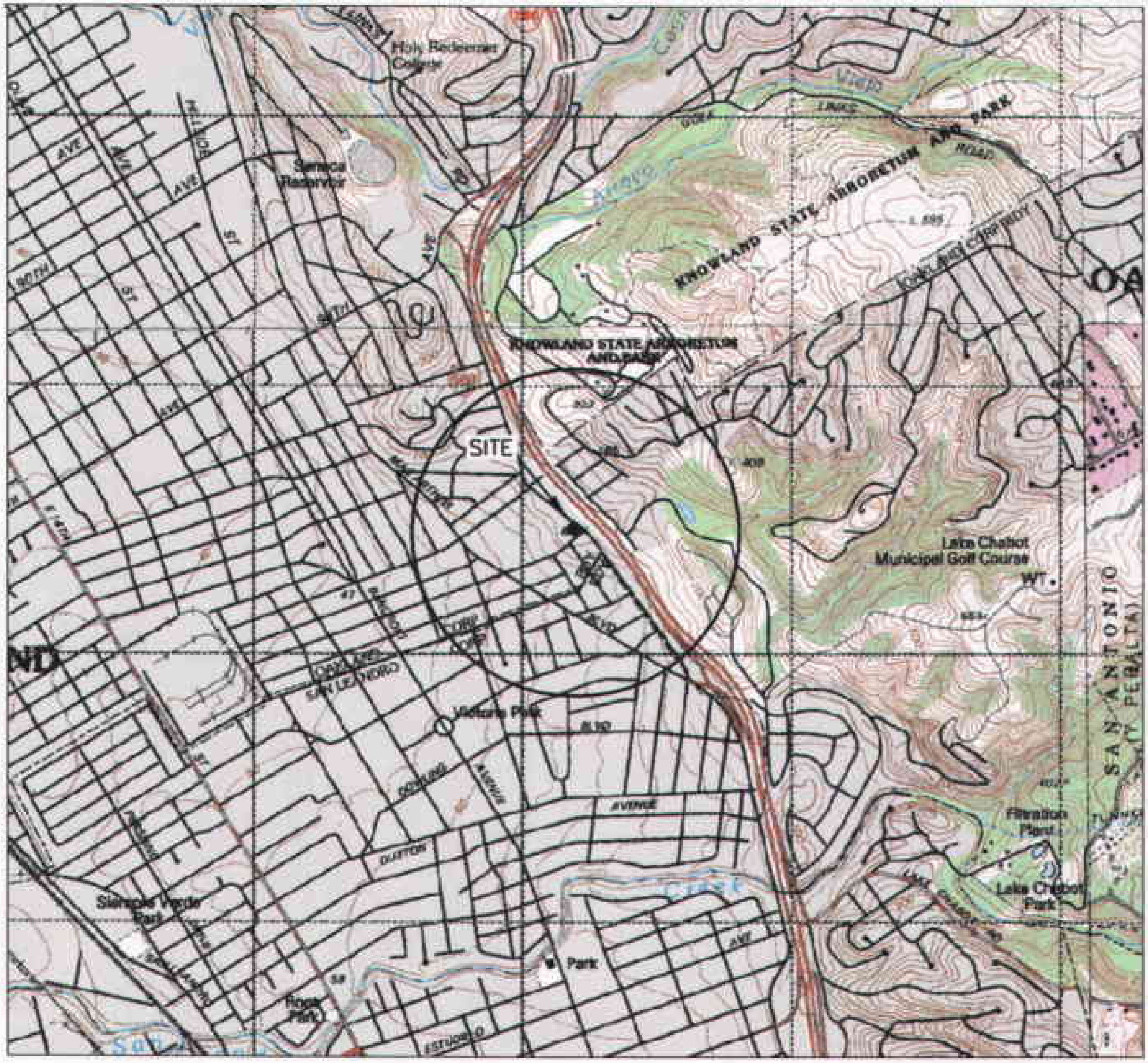
Gowri S. Kowtha, P.E.
Project Manager

Attachments:	Table 1	Drilling and Well Construction Summary
	Figure 1	Site Location Map
	Figure 2	Site Plan
	Figure 3	Geologic Cross Section A to A'
	Figure 4	iSOC™ System Detail Sheet
	Appendix A	TPHG, Benzene, and MTBE Concentration Versus Time Graphs, Wells S-1, S-2, and MW-3
	Appendix B	Field Practices and Procedures
	Appendix C	Manufacture's Literature for the iSOC™ System

cc: Mr. Charles Miller, USA Gasoline Corporation
Mr. Ken Phares, Jay-Phares Corporation
Mr. Peter McIntyre, AEI Consultants

Table 1
Drilling and Well Construction Summary
Former USA Station #57
10700 MacArthur Boulevard
Oakland, California

ID	Date	Boring Dia. (inches)	Boring Depth (feet bgs)	Casing Diameter (inches)	Casing Depth (feet bgs)	Slot Size (inches)	Screen Interval (feet bgs)
Monitoring Wells							
S-1	2/12/87	8	40	3	40	0.02	20 - 40
S-2	2/12/87	8	40	3	40	0.02	20 - 40
MW-3	2/28/95	10	44	4	44	0.02	24 -44
MW-4	11/20/95	10	40.5	4	40.5	0.02	10 - 40.5
MW-5	11/20/95	10	41	4	40	0.02	10 - 40
MW-6	11/20/95	10	40.5	4	40.5	0.02	10 - 40.5
MW-7	11/21/95	10	41	4	40	0.02	10 - 40
MW-8	11/21/95	10	35.5	4	35	0.02	10 - 35
Soil Borings							
A	2/12/87	8	20				
B	2/12/87	6	20				
C	2/12/87	6	20				
D	2/12/87	6	20				
B-1	2/28/95	8	46				
B-2	3/1/95	8	31				
B-3	3/1/95	8	21				
B-4	3/2/95	8	12				
B-5	3/2/95	8	12				
B-6	3/2/95	8	12				
B-7	3/2/95	8	12				
B-8	3/2/95	8	12				



GENERAL NOTES:
BASE MAP FROM U.S.G.S.
OAKLAND, CA
7.5 MINUTE TOPOGRAPHIC
PHOTOREVISED 1980

North

QUADRANGLE LOCATION

0 — 2000 FT

SCALE 1:24,000

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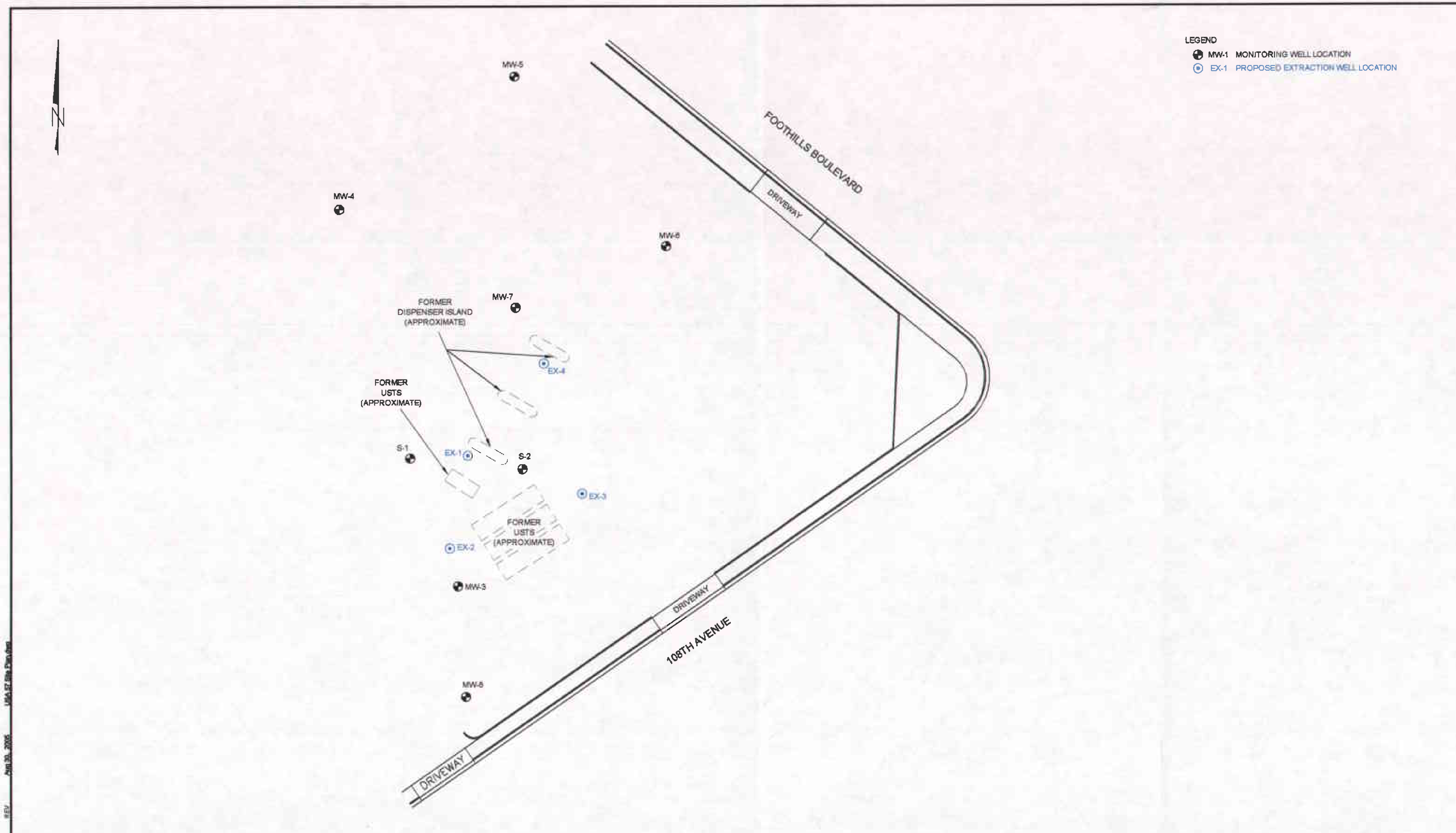
FORMER USA SERVICE STATION NO. 57
10700 MACARTHUR BOULEVARD
OAKLAND, CALIFORNIA

SITE LOCATION MAP

FIGURE
1

PROJECT NO.
2007-0057-01



STRATUS ENVIRONMENTAL, INC.

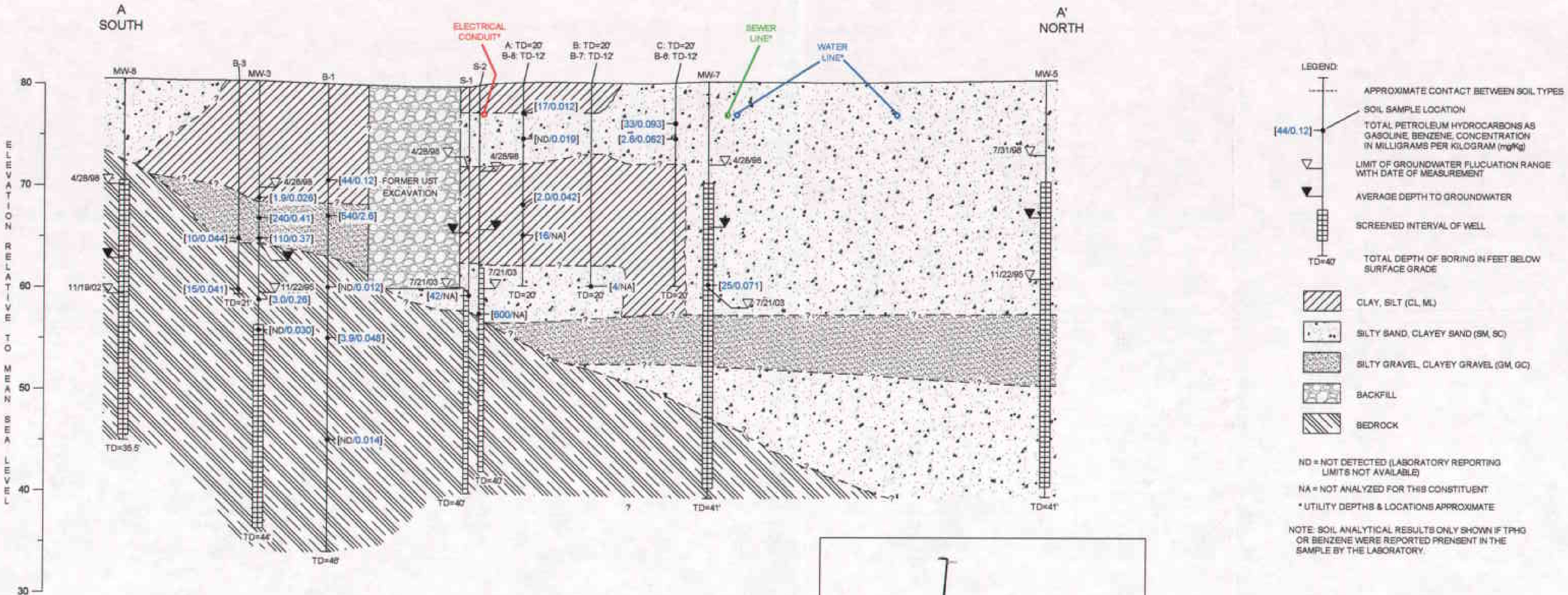
0 40 FT
HORZ. SCALE

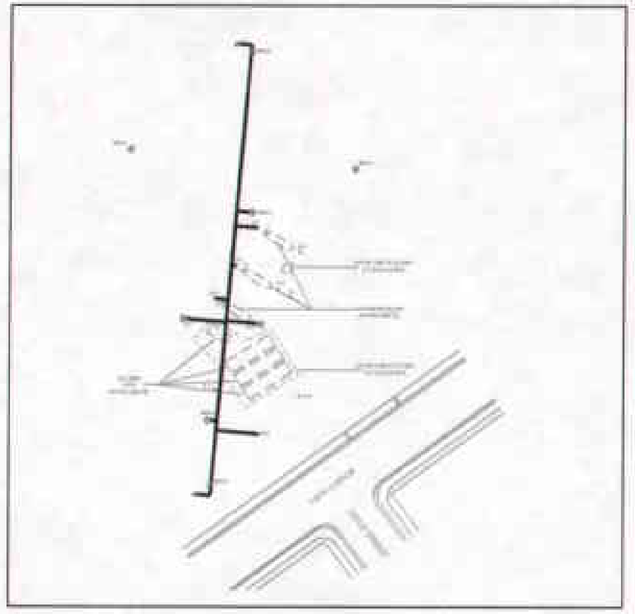
FORMER USA STATION NO. 57
10700 MACARTHUR BOULEVARD
OAKLAND, CALIFORNIA

SITE PLAN

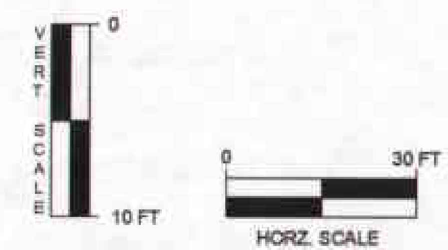
FIGURE
2

PROJECT NO.
2007-0057-01





SITE PLAN



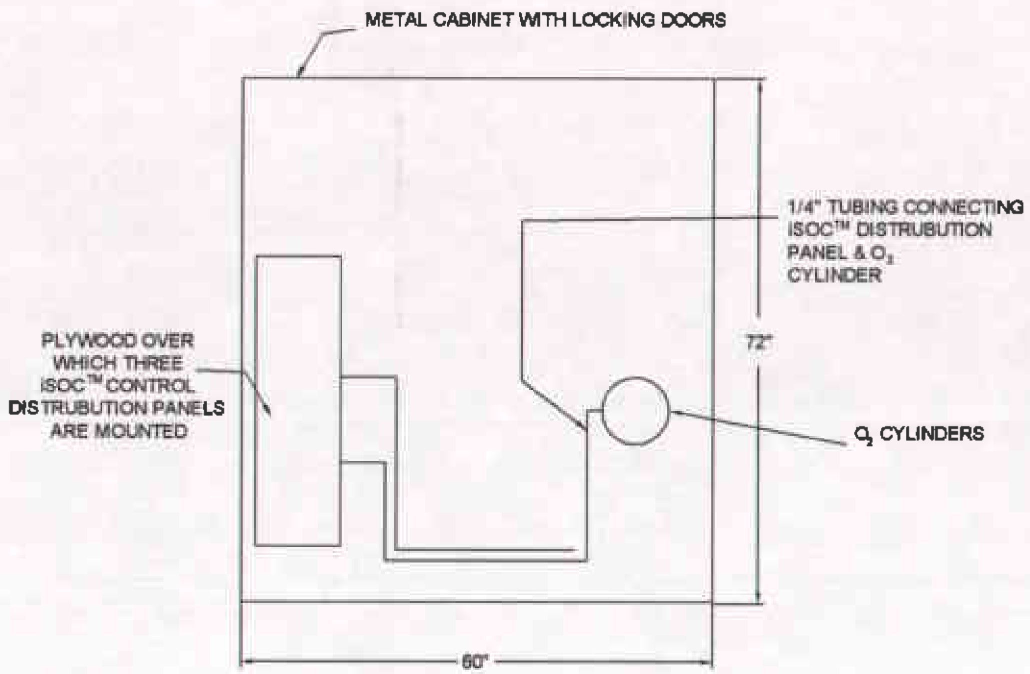
STRATUS ENVIRONMENTAL, INC.

FORMER USA SERVICE STATION NO. 57
10700 MACARTHUR BOULEVARD
OAKLAND, CALIFORNIA

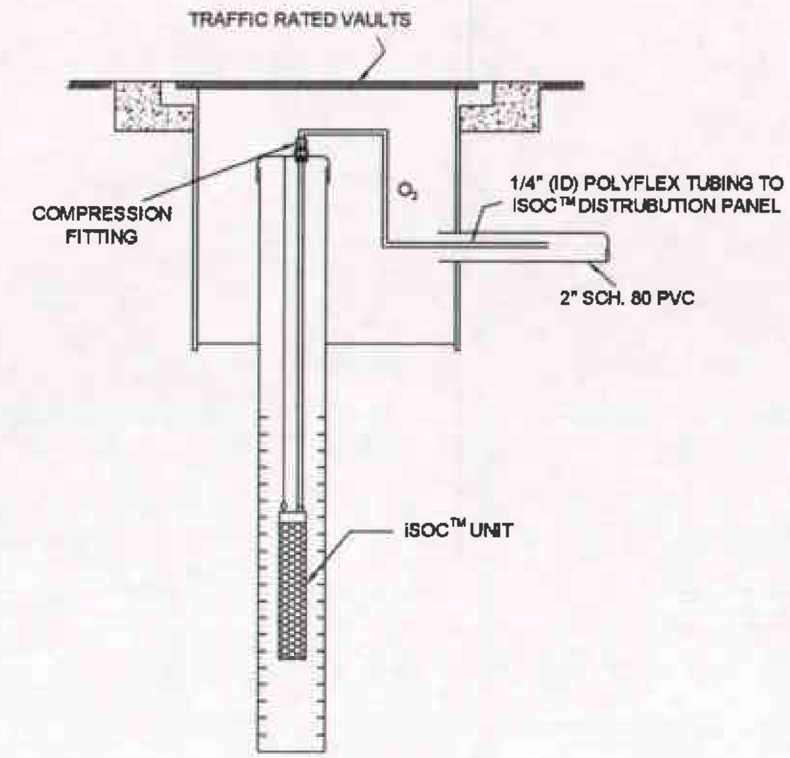
GEOLOGIC CROSS SECTION A-A'

FIGURE 3

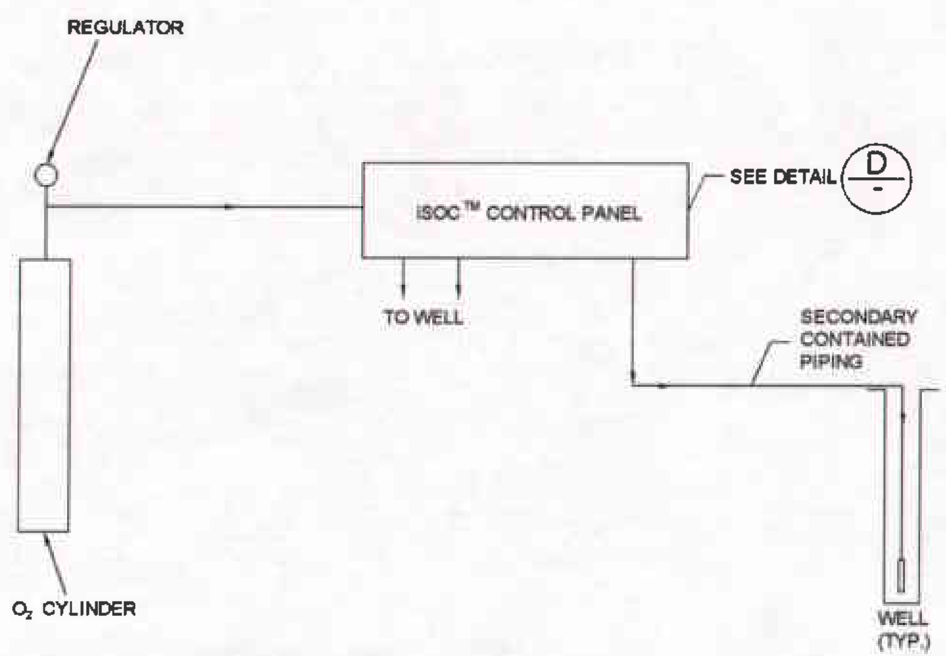
PROJECT NO. 2007-0057-01



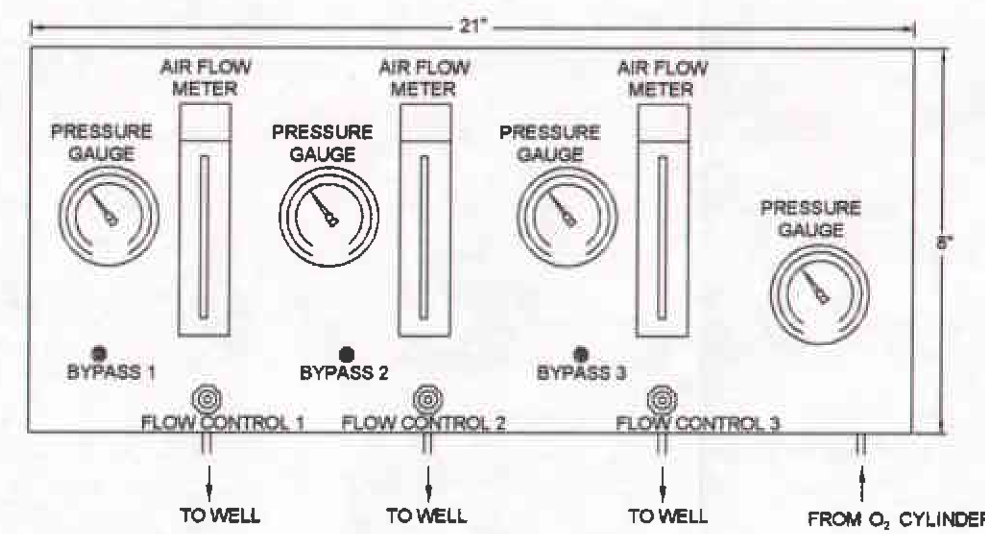
A/2 METAL HOUSE WITH LOCKING DOORS
NOT TO SCALE



B/2 WELLHEAD DETAILS (TYP.)
NOT TO SCALE



C/- PROCESS FLOW DIAGRAM
NOT TO SCALE

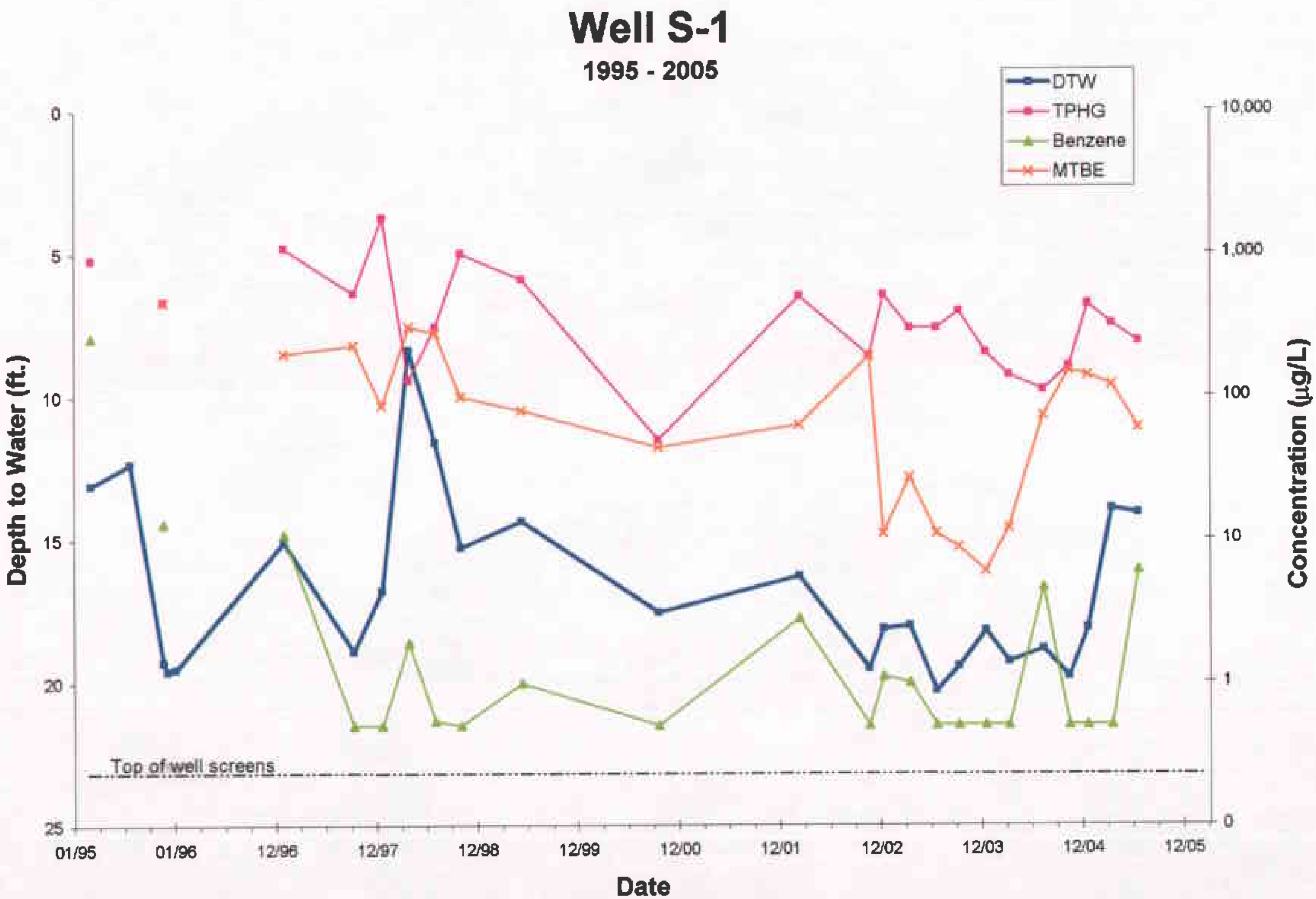


D/- iSOC™ CONTROL PANEL (TYP.)
NOT TO SCALE

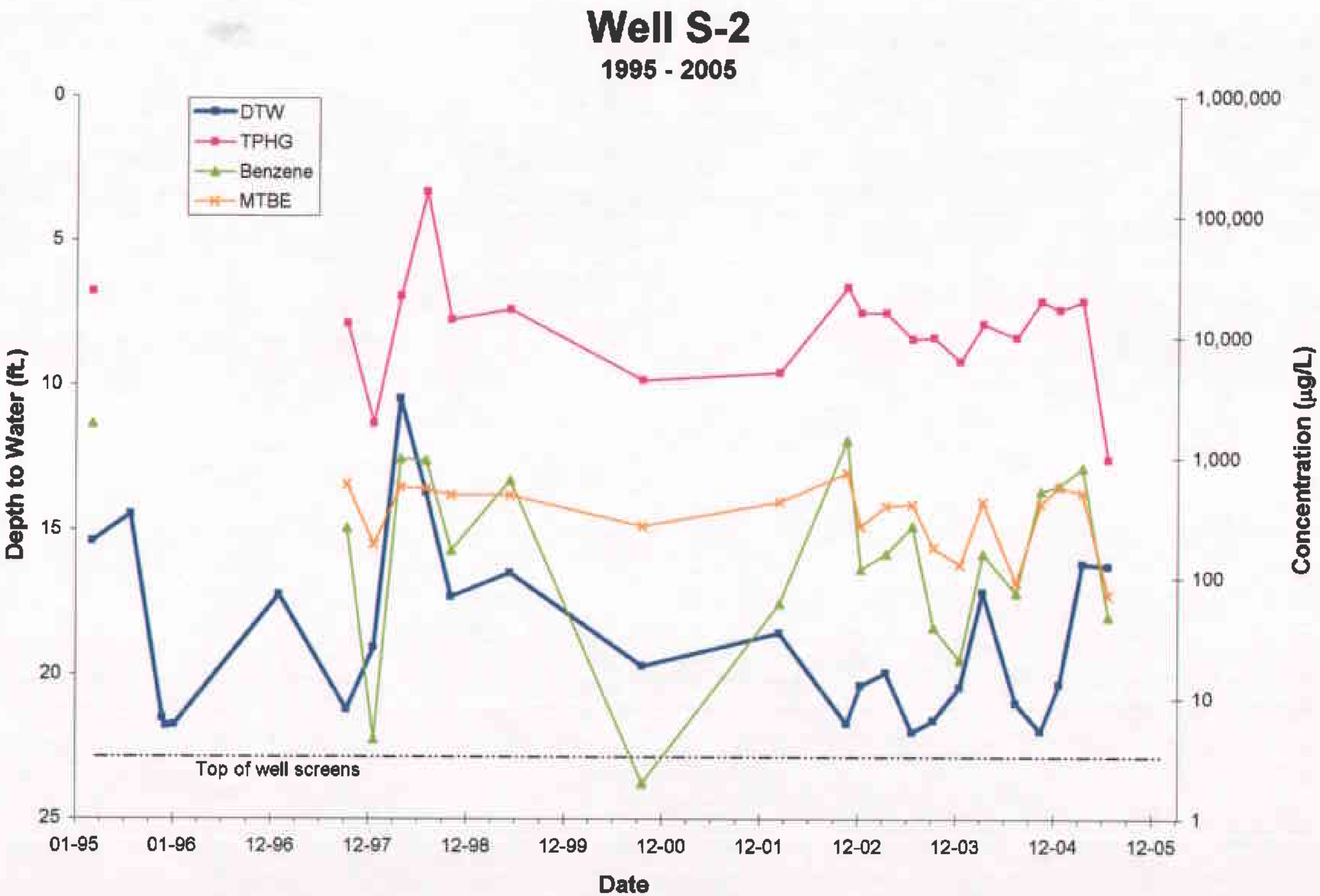
STRATUS ENVIRONMENTAL, INC.	FORMER USA STATION NO. 57 10700 MACARTHUR BOULEVARD OAKLAND, CALIFORNIA iSOC™ SYSTEM DETAIL SHEET	FIGURE 4 PROJECT NO. 2007-0057-01

APPENDIX A

TPHG, BENZENE, AND MTBE CONCENTRATION VERSUS TIME GRAPHS, WELLS S-1, S-2, AND MW-3



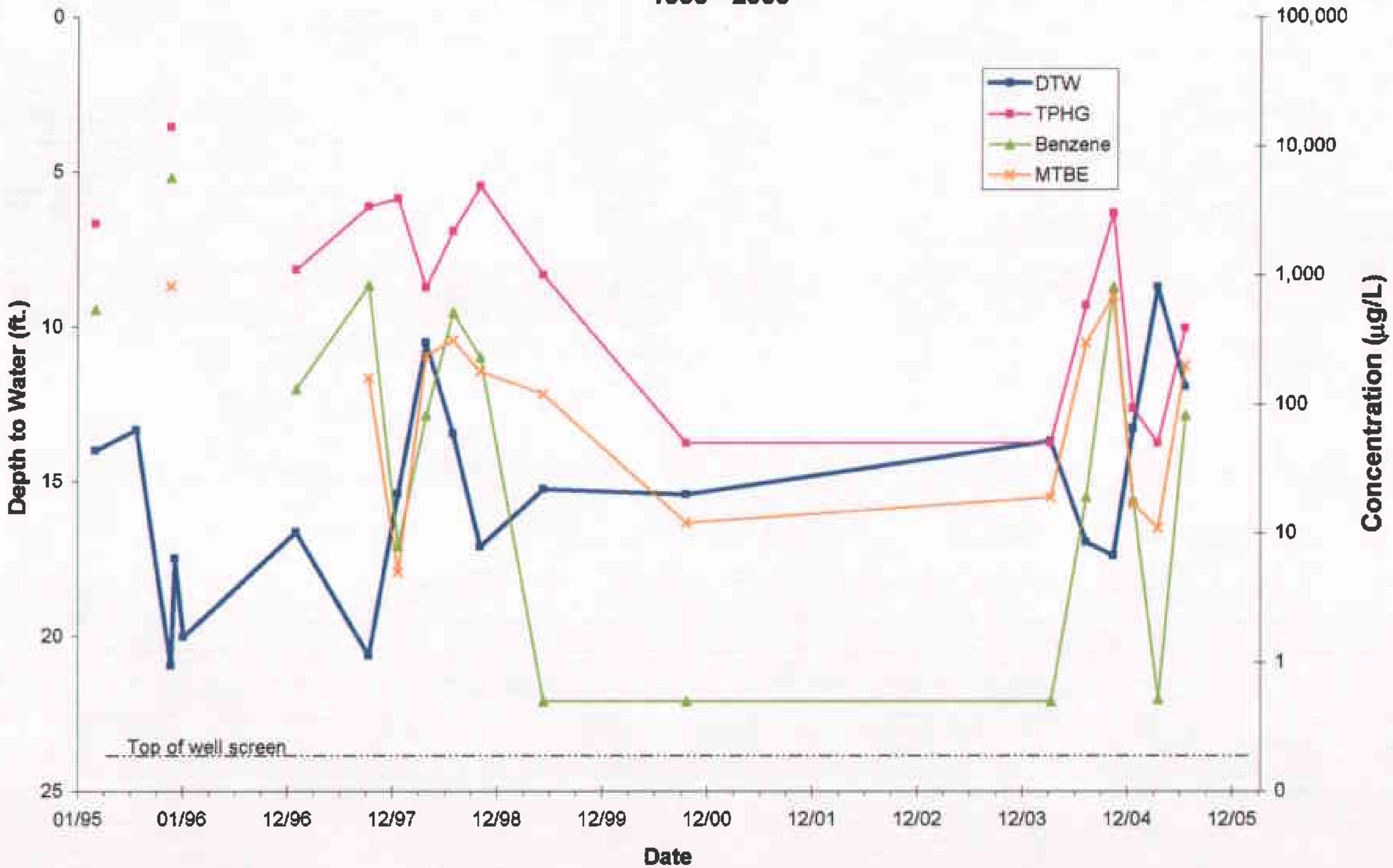
Well S-1
1995 - 2005
DTW
TPHG
Benzene
MTBE
Depth to Water (ft.)
0
5
10
15
20
25
Top of well screens
Concentration (µg/L)
10,000
1,000
100
10
1
0
01/95
01/96
12/96
12/97
12/98
12/99
12/00
12/01
12/02
12/03
12/04
12/05
Date



Well S-2
1995 - 2005
DTW
TPHG
Benzene
MTBE
Depth to Water (ft.)
0
5
10
15
20
25
Concentration (µg/L)
1,000,000
100,000
10,000
1,000
100
10
1
Top of well screens
01-95
01-96
12-96
12-97
12-98
12-99
12-00
12-01
12-02
12-03
12-04
12-05
Date

Well MW-3

1995 - 2005



APPENDIX B

FIELD PRACTICES AND PROCEDURES

FIELD PRACTICES AND PROCEDURES

General procedures used by Stratus in site assessments for drilling exploratory borings, collecting samples, and installing monitoring wells are described herein. These general procedures are used to provide consistent and reproducible results; however, some procedure may be modified based on site conditions. A California Professional Geologist or Civil Engineer supervises the following procedures.

PRE-FIELD WORK ACTIVITIES

Health and Safety Plan

Field work performed by Stratus at the site is conducted according to guidelines established in a Site Health and Safety Plan (SHSP). The SHSP is a document which describes the hazards that may be encountered in the field and specifies protective equipment, work procedures, and emergency information. A copy of the SHSP is at the site and available for reference by appropriate parties during work at the site.

Locating Underground Utilities

Prior to commencement of any work that is to be below surface grade, the location of the excavation, boring, etc., is marked with white paint as required by law. An underground locating service such as Underground Service Alert (USA) is contacted. The locating company contacts the owners of the various utilities in the vicinity of the site to mark the locations of their underground utilities. Any invasive work is preceded by hand augering to a minimum depth of five feet below surface grade to avoid contact with underground utilities.

FIELD METHODS AND PROCEDURES

Exploratory Soil Borings

Soil borings will be drilled using a truck-mounted, hollow stem auger or air rotary casing hammer drill rig. Soil samples for logging will be obtained from auger-return materials and by advancing a modified California split-spoon sampler equipped with brass or stainless steel liners into undisturbed soil beyond the tip of the auger. Soils will be logged by a geologist according to the Unified Soil Classification System and standard geological techniques. Drill cuttings well be screened using a portable photoionization detector (PID) or a flame ionization detector (FID). Exploratory soil borings not used for monitoring well installation will be backfilled to the surface with a bentonite-cement slurry pumped into the boring through a tremie pipe.

Soil sampling equipment will be cleaned with a detergent water solution, rinsed with clean water, and equipped with clean liners between sampling intervals. Augers and samplers will be steam cleaned between each boring to reduce the possibility of cross contamination. Steam cleaning effluent will be contained in 55-gallon drums and temporarily stored on site. The disposal of the effluent will be the responsibility of the client.

Soil Sample Collection

During hollow stem auger drilling, soil samples will be collected in cleaned brass, two by six inch tubes. The tubes will be set in an 18-inch-long split-barrel sampler. The sampler will be conveyed to bottom of the borehole attached to a wire-line hammer device on the drill rig. When possible, the split-barrel sampler will be driven its entire length, either hydraulically or by repeated pounding a 140-pound hammer using a 30-inch drop. The number of drops (blows) used to drive the sampler will be recorded on the boring log. The sampler will be extracted from the borehole, and the tubes containing the soil samples will be removed. Upon removal, the ends of the lowermost tube will be sealed with Teflon sheets and plastic caps. Soil samples for chemical analysis will be labeled, placed on ice, and delivered to a state-certified analytical laboratory, along with the appropriate chain-of-custody documentation. Soil samples are not normally collected during air rotary drilling.

Soil Classification

Soil samples collected in brass tubes, or drill cuttings evacuated from the borehole during air rotary drilling, will be logged on site by a geologist using the Unified Soil Classification System. Representative portions of the brass sleeve samples will be retained for further examination and for verification of the field classification. Logs of the borings indicating the depth and identification of the various strata and pertinent information regarding the method of maintaining and advancing the borehole will be prepared.

Soil Sample Screening

Soil samples selected for chemical analysis will be determined from a head-space analysis using a PID or an FID. The soil will be placed in a Ziploc® bag, sealed, and allowed to reach ambient temperature, at which time the PID probe will be inserted into the Ziploc® bag. The total volatile hydrocarbons present are detected by the PID and reported in parts per million by volume (ppmv). The PID will be calibrated to an isobutylene standard.

At least two soil samples retained from each soil boring will be submitted for chemical analysis unless otherwise specified in the scope of work. Soil samples selected for analysis typically represent the highest PID reading recorded for each soil boring and the sample just above first-encountered groundwater. Additional soil samples will be submitted based on the findings at each individual borehole and the project specific data needs.

Stockpiled Drill Cuttings and Soil Sampling

Drill cuttings generated during the drilling procedure will be stockpiled on site, placed in 55-gallon steel drums, or containerized in covered roll-off steel containers. Stockpiled drill cuttings will be placed on and covered with plastic sheeting. A sample of the soil cuttings will be submitted for chemical analysis to determine an appropriate disposal method. Stratus Environmental will recommend an appropriate facility to accept the drill cuttings based on the analytical results. The client will be responsible for disposal of the drill cuttings.

Prior to collecting soil samples, Stratus personnel will calculate the approximate volume of soil in the stockpile. The stockpile will then divided into sections, if warranted, containing the predetermined volume sampling interval. Four soil samples will be collected from the stockpile and composited into one sample by the laboratory prior to analysis. The soil samples will be collected in cleaned brass, two by six inch tubes using a hand driven sampling device. To reduce the potential for cross-contamination between samples, the sampler will be cleaned between each sampling event. Upon recovery, the sample container will be sealed at each end with Teflon sheeting and plastic caps to minimize the potential of volatilization and cross-contamination prior to chemical analysis. The soil sample will be labeled, placed on ice, and delivered to a state-certified analytical laboratory, along with the appropriate chain-of-custody documentation.

Direct Push Technology, Water Sampling

A well known example of direct push technology for water sampling is the Hydropunch®. For the purpose of this field method the term hydropunch will be used instead of direct push technology for water sampling.

The hydropunch is typically used with a drill rig. A boring is drilled with hollow stem-augers to just above the sampling zone. In some soil conditions the drill rig can push directly from the surface to the sampling interval. The hydropunch is conveyed to the bottom of the boring using drill rods. Once on bottom the hydropunch is driven a maximum of five feet. The tool is then opened by lifting up the drill rod no more than four feet. Once the tool is opened, water enters and a sample can be collected with a bailer or tubing utilizing a peristaltic pump. Soil particles larger than silt are prevented from entering the tool by a screen within the tool. The water sample is collected, labeled, and handled according to the Quality Assurance Plan.

Well Installation Procedures

Groundwater monitoring, soil vapor extraction, groundwater extraction, air sparging, and ozone injection wells, of variable diameters, are normally constructed during environmental assessment and remediation projects. Wells are normally constructed using Schedule 40 polyvinyl chloride (PVC) casing. The borehole diameter will be a minimum of four inches larger than the outside diameter of the casing.

Wells installed for environmental assessment and remediation projects are typically cased with threaded, factory-perforated and blank Schedule 40 PVC. The perforated interval consists of slotted casing, generally with 0.01, 0.02, or 0.03-inch-wide by 1.5-inch-long slots, with 42 slots per foot. A threaded or slip PVC cap is secured to the bottom of the casing. The slip cap can be secured with stainless steel screws or friction; no solvents or cements are used. Centering devices may be fastened to the casing to ensure even distribution of filter material and grout within the borehole annulus. The well casing is thoroughly washed and/or steam cleaned, or may be purchased as pre-cleaned, prior to completion.

A filter pack of graded sand will be placed in the annular space between the PVC casing and the borehole wall. Sand will be added to the borehole through the hollow stem of the augers to provide a uniform filter pack around the casing and to stabilize the borehole. The sand pack will be placed to a maximum of 2 feet above the screens, followed by a minimum 1-foot seal consisting of bentonite pellets.

Cement grout containing 5 percent bentonite or concrete will be placed above the bentonite seal to the ground surface. A concrete traffic-rated vault box will be installed over the monitoring well(s). A watertight locking cap will be installed over the top of the well casing. Reference elevations for each monitoring well will be surveyed when more than two wells will be located on site. Well elevations will be surveyed by a California licensed surveyor to the nearest 0.01-foot relative to mean sea level (MSL). Horizontal coordinates of the wells will be measured at the same time. Horizontal coordinates are normally measured in California State Plane Coordinates. Latitudes and longitudes are normally calculated for each well, per California Assembly Bill 2886 (Geotracker) requirements.

Exploratory boring logs and well construction details will be prepared for the final written report.

APPENDIX C

MANUFACTURER'S LITERATURE FOR THE ISOC^{TM} SYSTEM

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iSOC™ User Guide

iSOC™ Groundwater Oxygenation System

in situ Submerged Oxygen Curtain: another innovation from iTi's patented *Gas inFusion*™ mass transfer Technology—'elegance in simplicity'

United States Patent 6,209,855

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iSOC™ User Guide

Introduction

iSOC™ is a specially designed, highly structured, microporous mass transfer device invented and manufactured by inVentures Technologies incorporated (iTi) for use in enhanced groundwater remediation. *iSOC*™, or in situ Submerged Oxygen Curtain, is based on iTi's proprietary *Gas inFusion*™ technology, which is patented worldwide. Its inherently large surface area allows for intimate contact between oxygen and groundwater, resulting in ultra efficient mass transfer.

This user guide provides background information on how the *iSOC*™ works, what you can expect from it in performance, how to install and start it up, and how to troubleshoot its operation.

Oxygenation of Water 101

Dissolving a gas into a liquid is a 'mass transfer' operation. Mass transfer requires two things to occur:

1. First, there must be a 'driving force'. The driving force in a gas/liquid system is the difference between the amount of gas currently in the liquid, and the maximum amount of gas that that liquid can hold, or take into solution, also known as the solubility. The solubility of a gas in a liquid is governed by Henry's Law and is unique to each gas/liquid system.

2. Second, there must be a means or pathway for the gas molecules to contact the liquid stream. This is also known as 'interfacial surface area'.

***Henry's Law** states: The weight of any gas that will dissolve in a given volume of liquid, at constant temperature, is directly proportional to the pressure that the gas exerts above the liquid.*

In equation form: $C_{equil} = \alpha\, p_{gas}$

where:

C_{equil} is the concentration of gas dissolved in the liquid at equilibrium;
p_{gas} is the partial pressure of the gas above the liquid; and
α is the Henry's Law constant for the gas at the given temperature.

Conventional methods of oxygenation of water, as illustrated in Figure 1, are energy intensive processes. This is due to the fact that oxygen is only sparingly soluble in water. The solubility of atmospheric oxygen in water ranges from about 15 ppm (mg/l) at 0°C to about 7 ppm at 35°C under 1 atmosphere of pressure. Most of the critical conditions related to dissolved oxygen deficiency in biological operations, including bioremediation, occur during the summer months when temperatures are higher and solubility of oxygen is at a minimum. For this reason, it is customary to think of dissolved oxygen levels of about 6 to 8 ppm being the maximum available under critical conditions.

Because of this low solubility, there is very little 'driving force'. In order to accomplish any mass transfer on a reasonable time scale, energy is expended to create interfacial surface area. Fine bubble diffusers, or chemical oxygen production compounds, release oxygen in the form of bubbles, usually in the range of 1 to 2 mm in diameter. These small bubbles create the interfacial surface area required for mass transfer.

Despite their small size, the vast majority of the oxygen (90 to 95%) created by these methods escapes from the water surface into the atmosphere. This escaping oxygen represents a high proportion of wasted energy and wasted money.

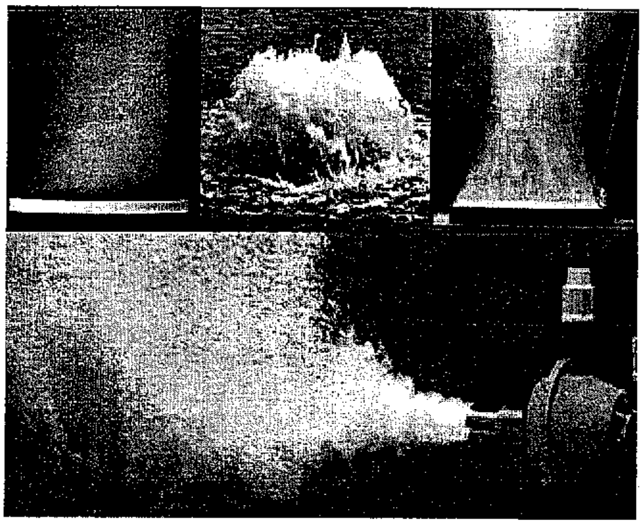


Figure 1: Conventional Oxygenation

For example, the supply of oxygen to suspended biomass in wastewater treatment represents the largest single energy consumer in an activated sludge treatment facility. Recent studies indicate that the aeration system accounts for 50% to 90% of the total power demand. According to industry experts, only about 1% of all oxygen discharged from a fine bubble diffuser is absorbed per foot of tank depth. In a 10-foot deep tank, 90% of the applied oxygen escapes to the atmosphere. Along with the escaped oxygen and air are the noxious odors and VOC's that often require scrubbing at further energy cost.

In any biological treatment process, the limited solubility of oxygen is of great importance because it governs the rate at which oxygen will be absorbed by the medium and therefore the cost of oxygenation.

Before we discuss how *Gas inFusion™* differs from these conventional means of oxygenation, we need to address the concept of how much dissolved gas a liquid can 'hold'. Earlier we described 'solubility' as the maximum amount of gas a liquid can take into solution. This level of dissolved gas 'saturation' is also used extensively and is defined conventionally.

Saturation is defined as:

I. The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Supersaturation is conventionally defined as:

I. An unstable condition of a vapor in which its density is greater than that normally in equilibrium under the given conditions; or

II. An unstable condition of a solution in which it contains a solute at a concentration exceeding saturation.

Obviously, 'supersaturation' is an unstable condition and not in equilibrium. Now, let's look at why *Gas inFusion™* redefines the concept of 'supersaturation' or more accurately, '***ultra**saturation*'.

Gas inFusion™ Intro

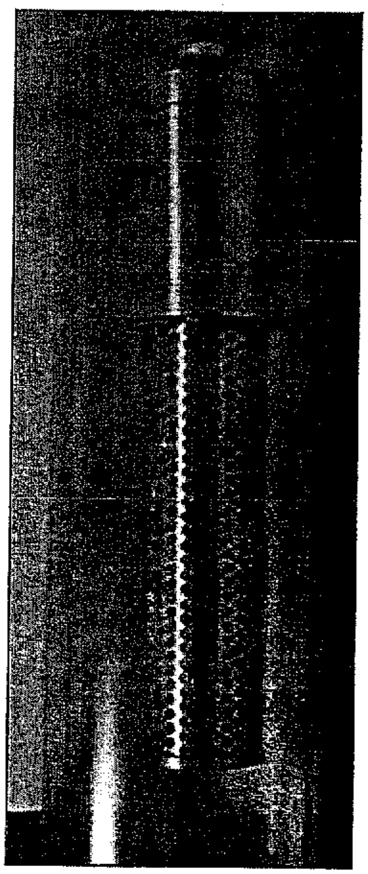


Figure 3: *iSOC™* 70 ppm DO

Gas inFusion™ is a proprietary technology (patented worldwide) developed by inVentures Technologies incorporated (iTi) for dissolving gas into liquids **without bubbles**. Figure 3 illustrates an *iSOC™* unit connected to a standard oxygen cylinder and suspended in a clear, open top column. Although this *iSOC™* is actively oxygenating the water in the column to a concentration of 70 ppm dissolved oxygen, there are no bubbles.

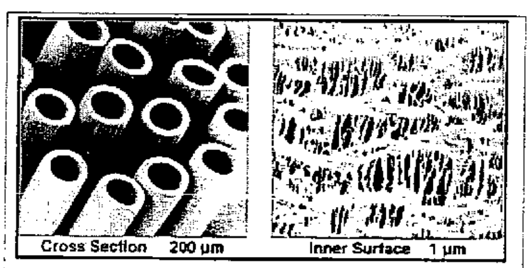


Figure 2: Microporous Hollow Fibre

Microporous hollow fibre, illustrated in Figure 2, is employed to provide the interfacial area needed to accomplish efficient mass transfer. The fibre provides an enormous surface area for mass transfer—in excess of 7000 m^2 per m^3—and is hydrophobic. This means that water will not pass through the pores of the fibre. Gas, on the other hand, fills the pores of the fibre. Maintaining a gas pressure less than the liquid pressure ensures that ultra efficient mass transfer takes place without a bulk passage of gas into the liquid. Bulk transfer of gas creates bubbles. ***Gas inFusion™* is mass transfer without bubbles**.

Henry's Law still governs the 'driving force' for this mass transfer. Increasing the pressure of the system raises the solubility of the gas and allows for greater levels of dissolved oxygen to be achieved.

Supersaturation, as created by *Gas inFusion™*, differs significantly from conventional conditions, and the conventional definition described above, as it achieves dissolved oxygen concentrations of hundreds of ppm in water in a relatively stable condition. Rather than escaping from the water surface, *Gas inFusion™* supersaturation creates a 'nascent' supply of dissolved oxygen that remains in a dissolved state until utilized by a biomass. The decay of even very high dissolved oxygen concentrations in the hundreds of ppm has been demonstrated to be several days. Obviously, this unique method of water oxygenation becomes ultra efficient in both biomass utilization and energy savings.

iSOC™ Intro

iSOC™ is a specially designed, highly structured, microporous mass transfer device invented and manufactured by inVentures Technologies incorporated (iTi) for use in enhanced groundwater remediation. ***iSOC™***, or **i**n situ **S**ubmerged **O**xygen **C**urtain, is based on iTi's proprietary *Gas inFusion™* technology. Its inherently large surface area allows for intimate contact between oxygen and groundwater, resulting in ultra efficient mass transfer.

The *iSOC™* unit, illustrated in Figure 4, is made of stainless steel and is 1.62 inches in diameter and about 15 inches in length. The sizing is to allow the *iSOC™* to be placed inside 2 inch diameter groundwater monitoring wells.

The top of the unit is equipped with a 'push-loc' fitting to accommodate the ¼ inch diameter Polyflow tubing used to connect the unit to a source of pressurized oxygen, usually a liquid oxygen cylinder. Although the tubing and fitting will support a considerable tensile strength, a 'lifting eye' is also installed on the top of the unit. A wire may be attached to this eye to enable removal from the well if the tubing or push-loc fitting is broken.

The center part of the unit, with the holes, is the area from which the oxygen is 'infused' into the groundwater.

The bottom section of the *iSOC™* unit drains and collects any water which may occur in the infusion section due to improper operating conditions. The drain fitting on the bottom allows this water to be drained and the unit to be 'blown' clear.

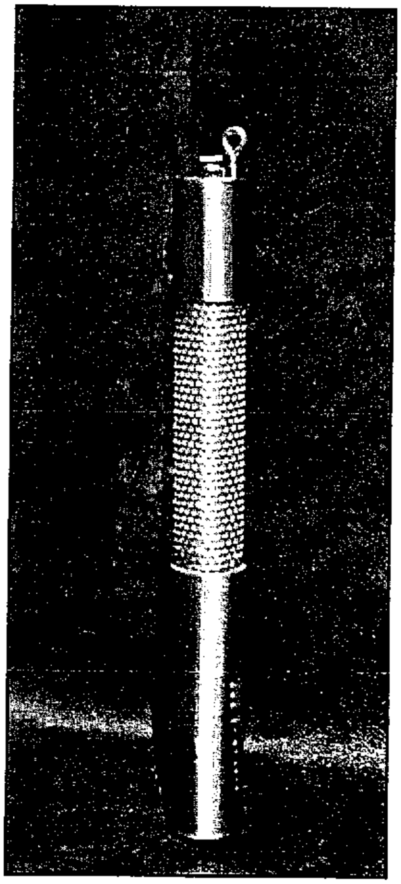


Figure 4: iSOC™ Unit

iSOC™ Performance

Due to the enormous surface area presented by the *iSOC*™ device, an oxygen saturated zone is quickly established around the device at the bottom of the groundwater well. The actual oxygen content achieved through use of the *iSOC*™ is governed by the depth of water/gas pressure on the unit. Remember Henry's Law discussed earlier?

This saturated zone spreads up and throughout the well, and diffuses out of the well. Higher in the well, the head pressure begins to fall. This results in water that is no longer saturated, but is now **supersaturated**. As defined previously, conventionally produced supersaturation is unstable and effectively unattainable. However with *Gas inFusion*™, the release of oxygen from this supersaturated state is such an extremely slow process, from such a high dissolved concentration, that a relatively stable supersaturated state is created. This is especially true in the absence of other bubbles. An excess of bubbles actually works to strip out dissolved gas from a liquid, as bubbles tend to grow on bubbles.

Anything in nature is always working toward an equilibrium state. The supersaturation 'half-life', i.e., the time required for the level of saturation between normal solubility and this ultra-high level of *Gas inFusion*™ supersaturation to be reduced by one-half, was demonstrated to be up to 7 days in a 10' by 2" column. This results in a '**nascent**' supply of oxygen that is readily transferred to lower dissolved oxygen groundwater entering the well zone, or that is consumed for biological treatment by biomass.

As a function of the ground-water flow rate, the graph illustrated in Figure 5 indicates the expected dissolved oxygen concentrations that each groundwater well equipped with an *iSOC*™ can be expected to reach. This example assumes the water depth to be 10 feet with the *iSOC*™ located at the bottom of the well. Obviously, as the groundwater flow rate increases to very high levels, the achievable dissolved oxygen concentration is reduced.

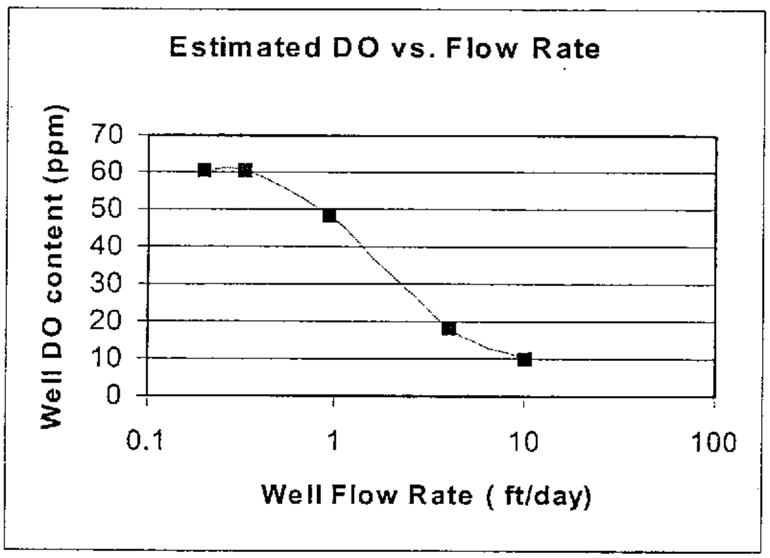


Figure 5: Estimated *iSOC*™ DO vs. Flow Rate

Due to a natural mixing effect of the oxygenated water in the groundwater well, the dissolved oxygen concentrations should be relatively equal throughout the depth of the well. Once the *iSOC*™ is first installed in a well, it takes a little while for the dissolved oxygen concentration to build up to maximum levels. Figures 6 and 7 illustrate a short duration test of some 100 hours, recording the dissolved oxygen concentration at various depths in a well over time from start up. Figure 6 shows a log time scale to indicate that it took about 16 hours (~1000 minutes) for the *iSOC*™ to maximize the dissolved oxygen concentration in the well to 35 ppm. Figure 7, with a conventional time scale, illustrates that once the maximum oxygen level was attained, it remained relatively constant over time. Also, note that the oxygen concentrations at 1-foot intervals were roughly the same.

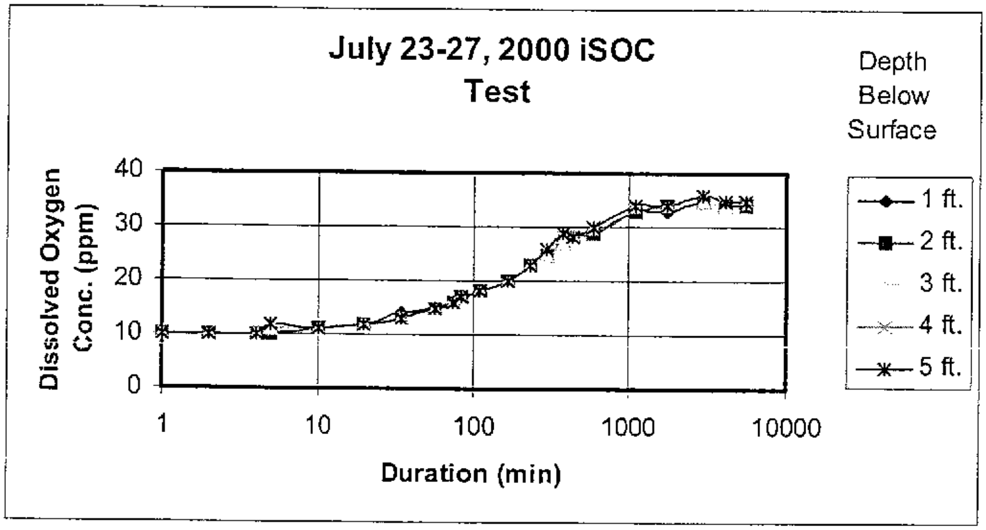


Figure 6: iSOC Performance Start Up

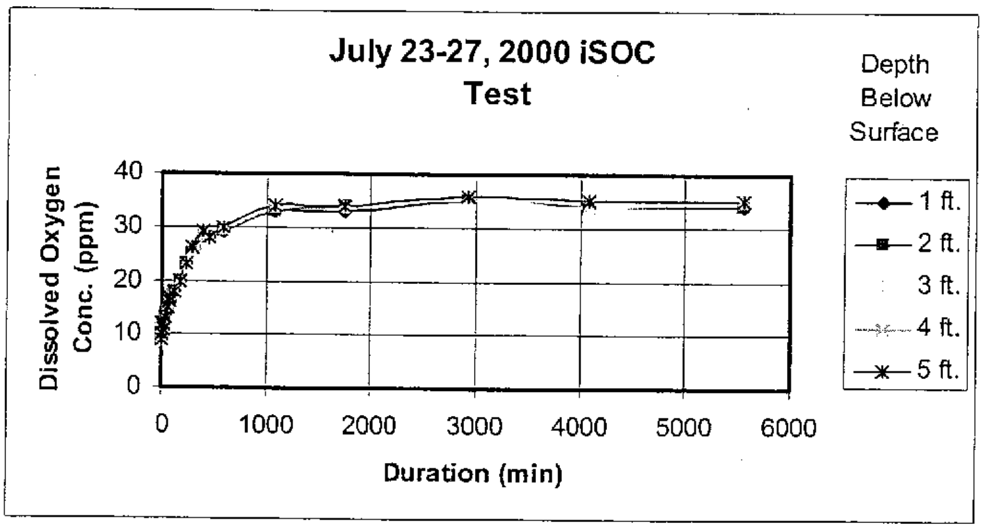


Figure 7: ***iSOC*™ Performance**

As described earlier, the maximum attainable *iSOC*™ dissolved oxygen concentration is determined by the gas and water depth pressure over the *iSOC*™ unit (Henry's Law), and the groundwater flow rate. In the Installation & Start Up Procedures, an equation is provided to determine the maximum head pressure created by the depth of water over the *iSOC*™ unit. The gas pressure from the oxygen cylinder is then adjusted to be slightly above this calculated maximum head.

iSOC™ will deliver about 43 PPM of dissolved oxygen (DO) per atmosphere of head pressure on the *iSOC*™ unit. Based on standard atmospheric pressure of 14.7 psi at sea level to about 10 psi at 10,000 feet elevation, an *iSOC*™ unit positioned at the bottom of a well with a water depth of 35 feet—roughly 2 atmospheres—can be expected to deliver in the order of 86 PPM DO. This is simply based on the atmospheric pressure of 14.7 psi plus the water head pressure of 15.2 psi creating a total pressure of 29.9 psi, or about 2 atmospheres.

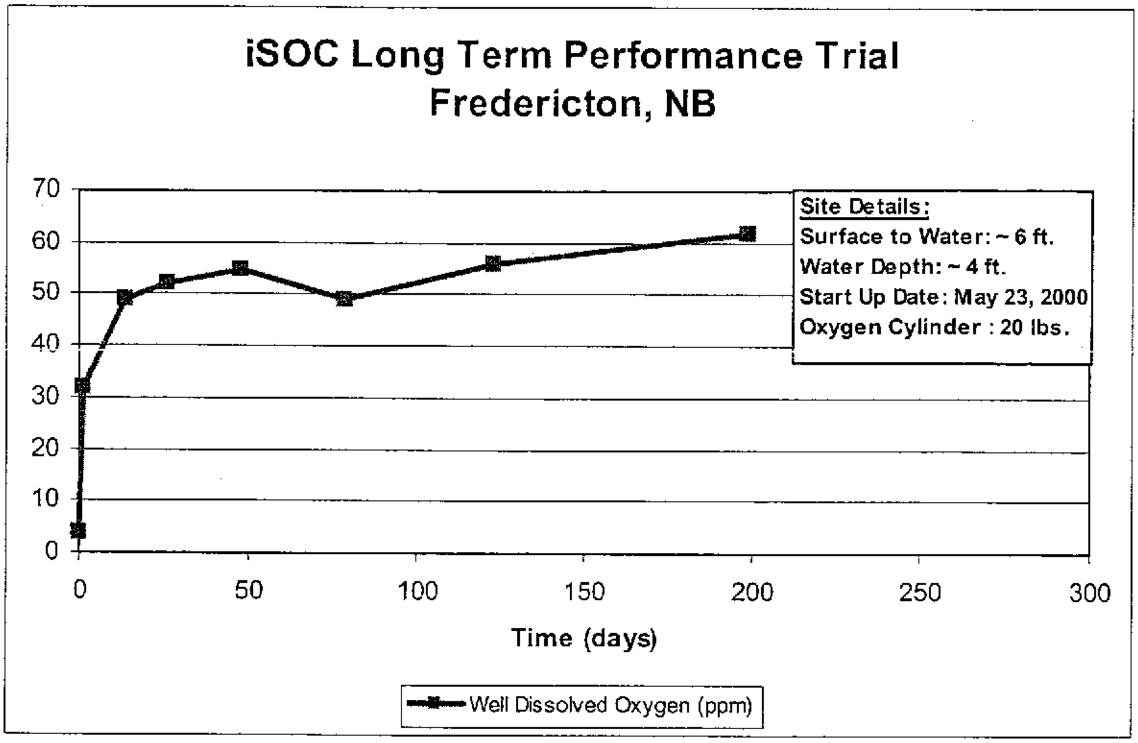


Figure 8: *iSOC*™ Long Term Performance Trial

iSOC™ Long Term Performance

iSOC™ provides a low maintenance, low cost solution to the oxygenation of groundwater for remediation purposes. Once set up according to recommended procedures (See Equipment Set Up and Installation & Start Up Procedures), *iSOC*™ continues to perform with only a periodic check.

Figure 8 illustrates the results of an ongoing long-term performance trial. As shown, this *iSOC*™ unit, installed on May 23, 2000, continues to generate 50 to 60 ppm of DO in 4 feet of groundwater at a 10 foot depth over the charted 7 months and continues to date. The unit has never been removed from the well, nor has it required any adjustment following initial set up.

This trial clearly demonstrates the reliability and low maintenance of *iSOC*™—based on a technology that is elegantly simple.

Equipment Set Up

iSOC™ is a passive groundwater *Gas inFusion*™ device manufactured by iTi. The actual groundwater remediation system design and specification incorporating *iSOC*™ devices is the responsibility of the remediation consultant.

Figure 9 illustrates a typical schematic for equipment setup for use of an *iSOC*™. For best results, the oxygen cylinder should be equipped with a two-stage, **low-flow** pressure regulator, such as an Air Liquide Blueshield BLU-104 **oxygen** regulator. In order to maintain accurate control over the very low oxygen flows, a **low-flow** rotameter (flow meter) such as Cole Parmer Model 03217-00, or Dwyer Model RMA-151-SSV, should be connected in series between the *iSOC*™ unit and the pressure regulator. The rotameter should be equipped with a fine control needle valve. For convenience, it is also recommended that a ¼ inch bypass valve be installed parallel to the rotameter (See Figure 9). To ensure proper operation, the flow rotameter must deliver oxygen from a pressurized source (cylinder) at reliable, controllable rates of less than 10 cc/min. The flow rate must be stable on a continuous basis.

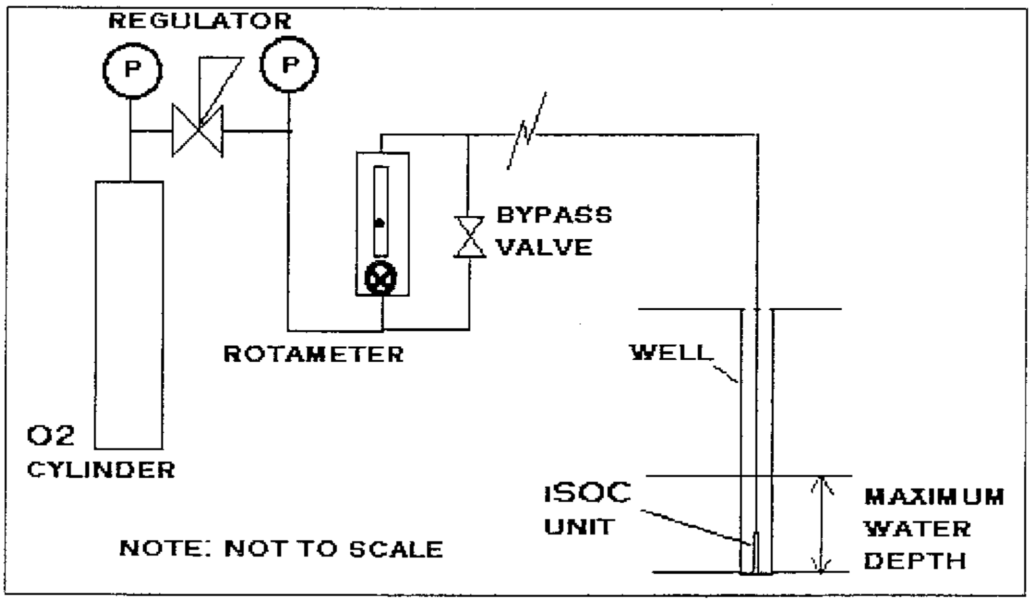
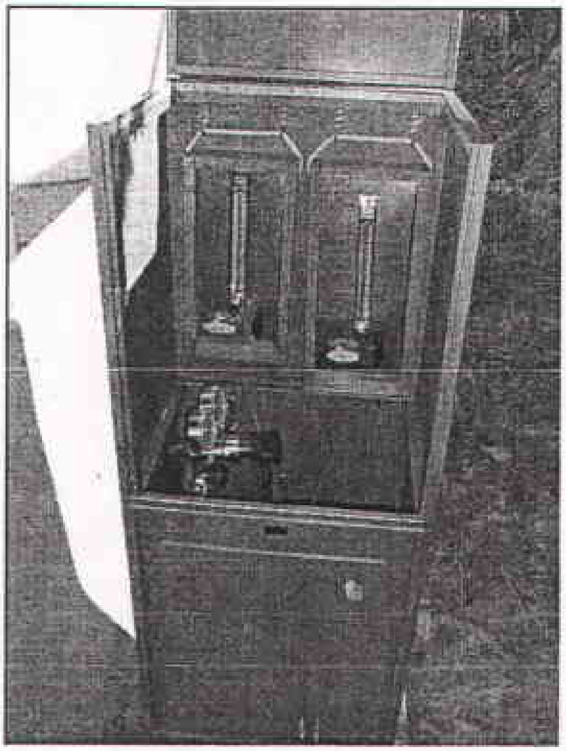


Figure 9: *iSOC*™ Equipment Setup Schematic

The actual equipment setup design and specification varies with site conditions, number of *iSOC*™s employed, and the preference of the consultant and/or client. Figures 10 to 15 illustrate different approaches to equipment layout and installation used in groundwater remediation systems based on *iSOC*™.



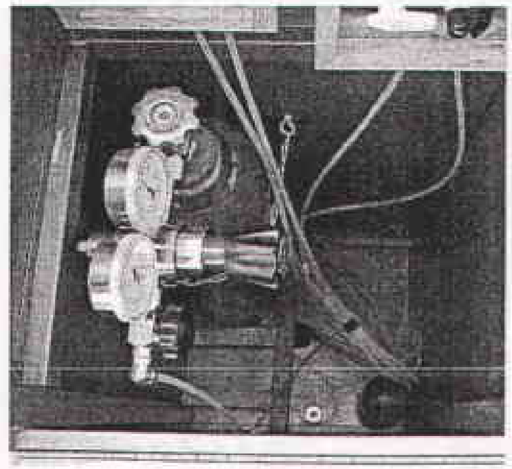


Figure 10: Example *iSOC*™ O_2 Equipment Installation

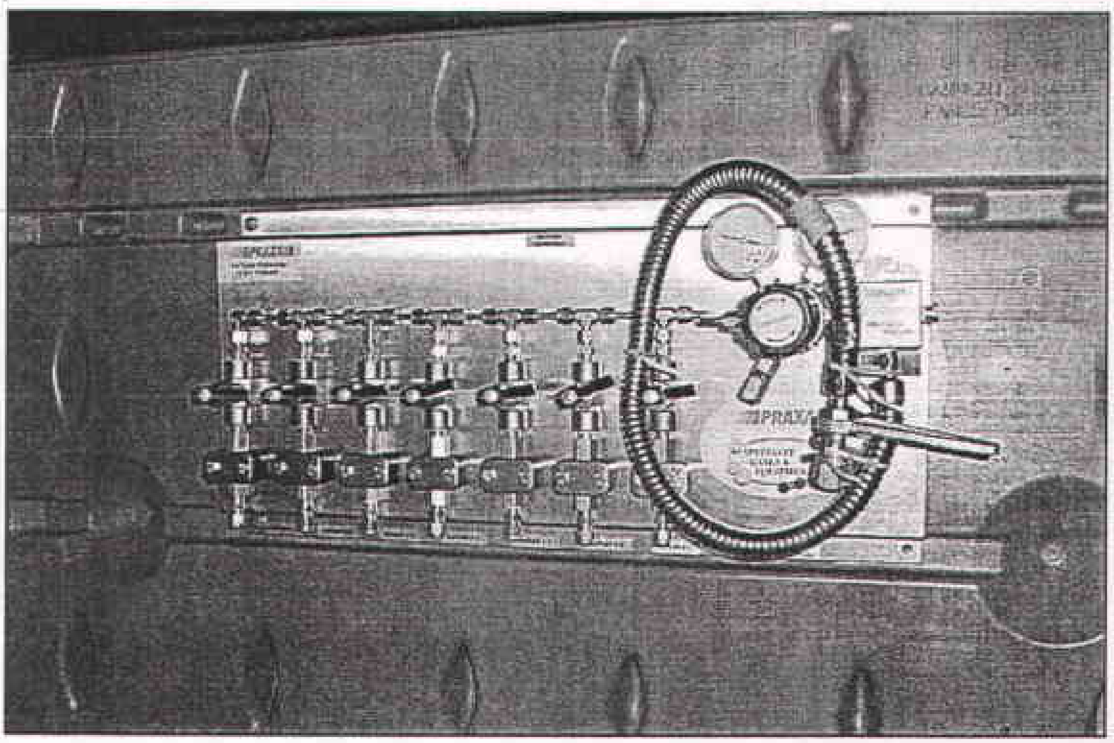
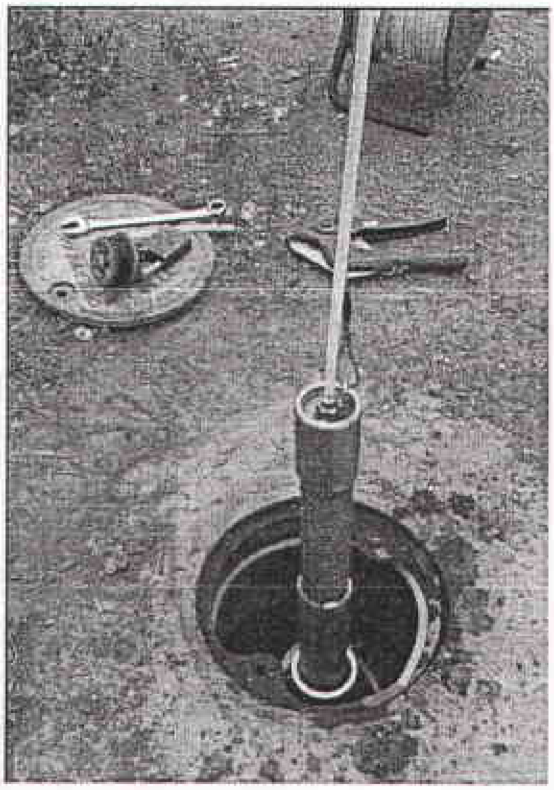


Figure 11: Example Multiple *iSOC*™ O_2 Distribution Panel



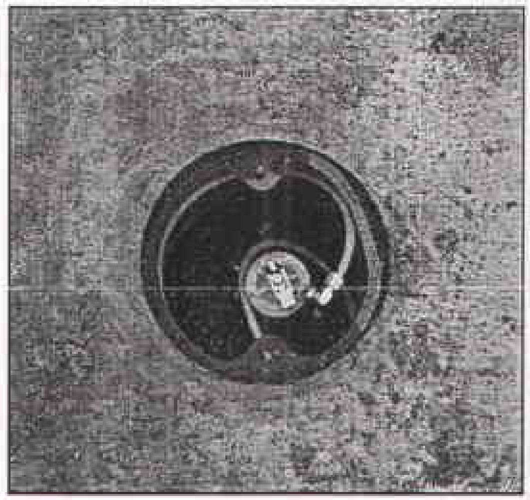


Figure 12: Example *iSOC*™ Well Insertion & Wellhead Details

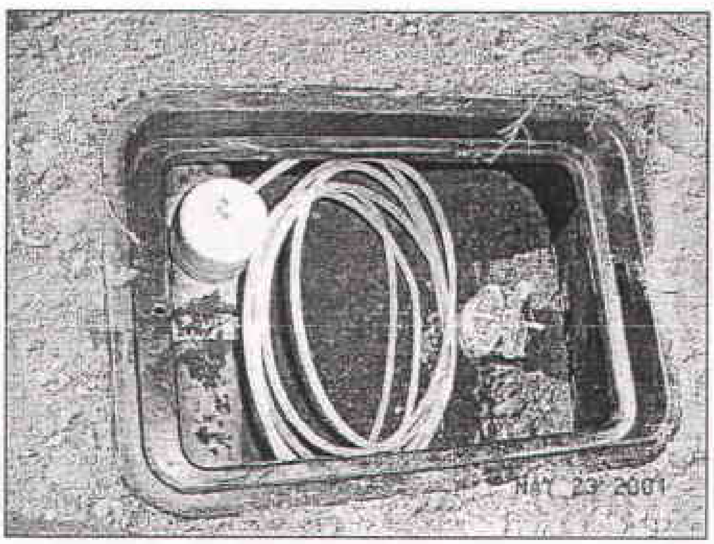


Figure 13: Example *iSOC*™ Wellhead Details

Again, these are examples only. The actual *iSOC*™ installation details will be determined by the design remediation consultant. However, the installation should incorporate both equipment protection from vandalism and easy access features for maintenance and/or monitoring.

Installation & Start Up Procedures

Step 1:
Determine the maximum (head) pressure to which the unit will be subjected. Use the following equation:

Head (psi) = max water depth (ft) / 2.306

Please note that the maximum water depth is **not** the depth of the well itself, but is the **depth of water** in the well.

Step 2:
Install the necessary oxygen supply and control equipment as described above.

Other than protecting the equipment from severe weather and vandalism, the most appropriate installation is flexible and is usually designed to fit the specific site.

Figure 14 illustrates an *iSOC™* installation being completed on an active gasoline service station in Brazil. Note that both the oxygen cylinder and the oxygen control lines and valves are installed in lockable cabinets existing at the station.

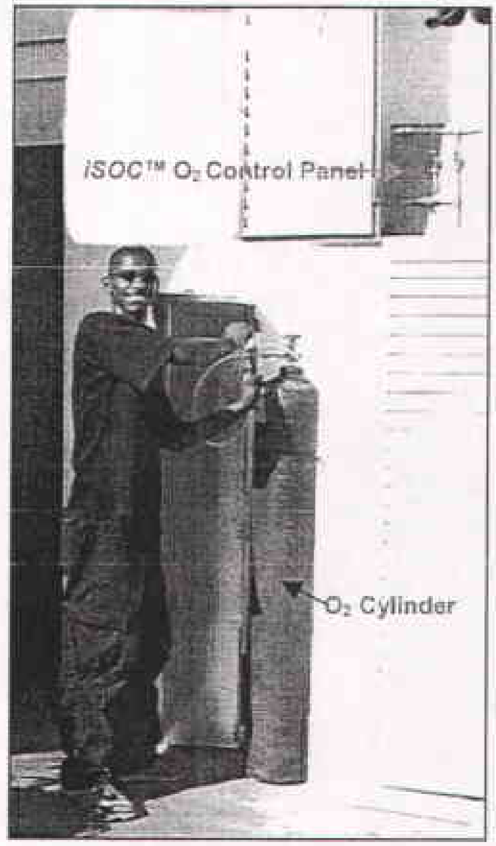


Figure 14: Example *iSOC* O_2 Equipment Installation

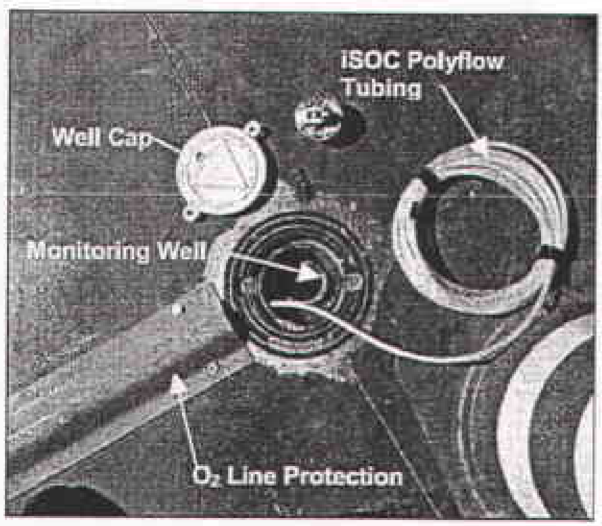


Figure 15: Example *iSOC™* Wellhead Details

Figure 15 illustrates a 2 inch diameter monitoring well, on the traffic area of the same Brazilian service station, ready for *iSOC™* installation.

Note the oxygen supply Polyflow tubing entering the monitoring well from the line protection channel. While this approach uses surface mounted O_2 line protection, Figures 12 and 13 illustrate below ground O_2 line installation in headers.

Both approaches result in *iSOC™* remediation of groundwater beneath an active traffic area.

Step 3:

Connect the Polyflow tubing to the *iSOC*. Be sure that the ¼ inch tubing (plastic nylon or polyethylene) is firmly pushed into the 'push-loc' fitting on the top of the *iSOC™* (See Figure 16).

If desired, fasten a lifting wire to the lifting eye on top of the unit.

Lower the *iSOC™* unit to the bottom of the well (See Figs. 12 & 17). Note the lifting line attachment for safe and easy insertion and removal.

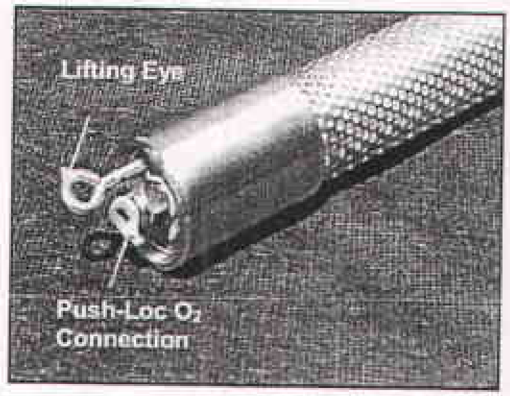


Figure 16: *iSOC™* O_2 Connection

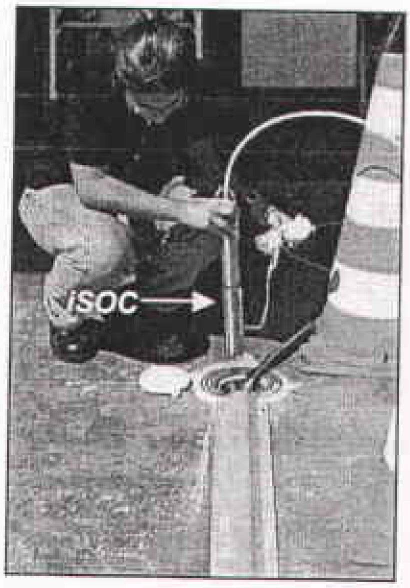


Figure 17: *iSOC™* Well Insertion

Step 4:

With the bypass valve open, open the oxygen cylinder and adjust the regulator to **6-8 psi above the calculated maximum head** (See Step 1).

Within a few minutes, the system should be purged of air and filled only with oxygen.

Now, reduce the regulator pressure to **1 to 2 psi above the maximum head pressure** and close the bypass valve.

Step 5:

Open the valve on the rotameter. Adjust the valve until the flow indicator 'ball' reads between 60-80 on the scale. This is equivalent to about 7 cc/min. It is not necessary that the 60 to 80 setting be maintained, but it is necessary to maintain the rotameter indicator ball 'on scale' or mid-range.

Step 6:

Test fittings for leaks using leak detector solution.

Step 7:

Although the *iSOC™* unit is now functioning, it is imperative that the operation of the unit be monitored several times over the first few days to ensure proper operation. At the very low oxygen pressure and flow required by *iSOC™*, a series of adjustments over a few days following start up is often needed to be sure that the regulator pressure has not dropped below the head pressure and that the rotameter reading is still on scale.

Relative to the volume of tubing in the system, the actual amount of gas flow is quite low. Systems such as these respond extremely slowly to small, downward adjustments of flow valves. It is easy to inadvertently turn the rotameter valve off and still have the rotameter ball register a flow for a period of time. This is why iTi recommends that the flow be initially set to 'mid-range'. It allows time for the system to adjust to the valve setting.

Changes in groundwater elevation in the well will affect this setup, requiring regular inspections and adjustments. If the oxygen feed rate has dropped to zero, and the DO reading in the well is below that expected, the *iSOC*™ unit will have to be pulled from the well and drained (See Troubleshooting Section).

In order to prevent a cessation of oxygen flow due to flooding, **iTi recommends that a minimum gas flow of 1-2 cc/min be maintained at all times**. This represents only 2-4 grams of oxygen per day. It should be noted that this extremely small amount of 'excess oxygen' will be released in the form of single large bubbles. Large bubbles exhibit extremely poor mass transfer characteristics. As a result, they will contribute virtually nothing to raising dissolved oxygen levels in the well. **These periodic large bubbles do however promote higher diffusion rates within the well itself and lead to more uniform dissolved oxygen levels throughout the depth of the well.**

It must also be noted that too much 'excess oxygen' flow will not only result in unnecessary wastage, but also can negatively impact the performance of the *iSOC*™ by stripping out the otherwise supersaturated oxygen levels near the top of the well. This is why iTi recommends that the oxygen flow rate always be maintained 'on scale'.

Multiple *iSOC*™ units can be operated from a single source of pressurized oxygen. However, each unit must be installed with its own separate rotameter and bypass valve. In the case of multiple units, the 'maximum water depth' of Step 1 refers to the well with the largest expected head pressure.

Since most commercially available DO (dissolved oxygen) meters are not capable of reading DO concentrations above say 10 to 15 ppm, a special high-range DO meter and probe is required to accurately monitor the DO concentrations created by *iSOC*™ in the application and downstream wells. One such meter is the Oxyguard Alpha High Range Oxygen Meter (See Fig. 19) from Point Four Systems Inc. of Port Moody, British Columbia, Canada (Tel: 604-936-9936; Fax: 604-936-9937; e-mail: sales@pointfour.com; Web: www.pointfour.com. Point Four has representation in many parts of the world.

Troubleshooting

The unit will continue to operate as long as it is not deprived of oxygen. If it is, a vacuum in the *iSOC*™ unit can occur. This can result in water being drawn into the microporous structure, effectively eliminating the large surface area, and reducing or stopping mass transfer. The two major causes are the regulator and the rotameter. As stated above, at very low pressures and very low flows, a series of adjustments over a few days following start up is often needed just to be sure that the regulator pressure has not dropped to below the head pressure, and that the rotameter is still reading on scale. Sometimes it is necessary to 'tap' the rotameter to make sure that the ball is not stuck in the tube. It is not necessary that the rotameter be maintained at 60-80, only that it remain on scale at all times.

Should the *iSOC*™ unit be deprived of oxygen, pull it up to the surface to drain any water from the infusion structure. By removing the drain plug (See Figure 18), drain all water from the device. **With the plug still removed, and the bypass valve open**, set the regulator at 10-15 psi and blow out any water still remaining in the unit. This will take several minutes. Reinstall the drain plug. The unit is now ready for start up.

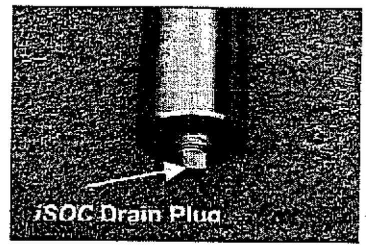


Figure 18: *iSOC*™ Drain Plug

It is highly recommended that oxygen flow to the unit be confirmed on a weekly or biweekly schedule and that dissolved oxygen readings in the well be taken at this time as well (See Fig. 19).

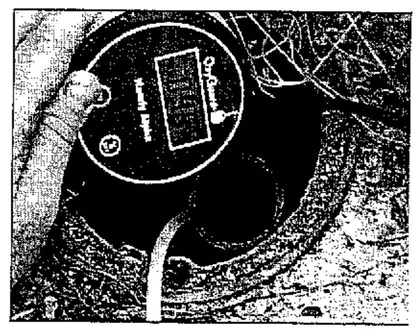


Figure 19: Measuring *iSOC*™ DO

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