gPRO

Groundwater Pressurized Remediation Optimizer

for Enhanced Bioremediation

Active High Rate Dissolved Gas Substrate Delivery

- gPRO High Pressure (HP) and gPRO Low Pressure (LP) systems rapidly infuse gases up to saturation in high flow water systems
- gPRO HP for ex situ infusion at or above ambient pressure
- gPRO LP for ex situ or in situ applications at ambient pressure

gPRO Market Applications

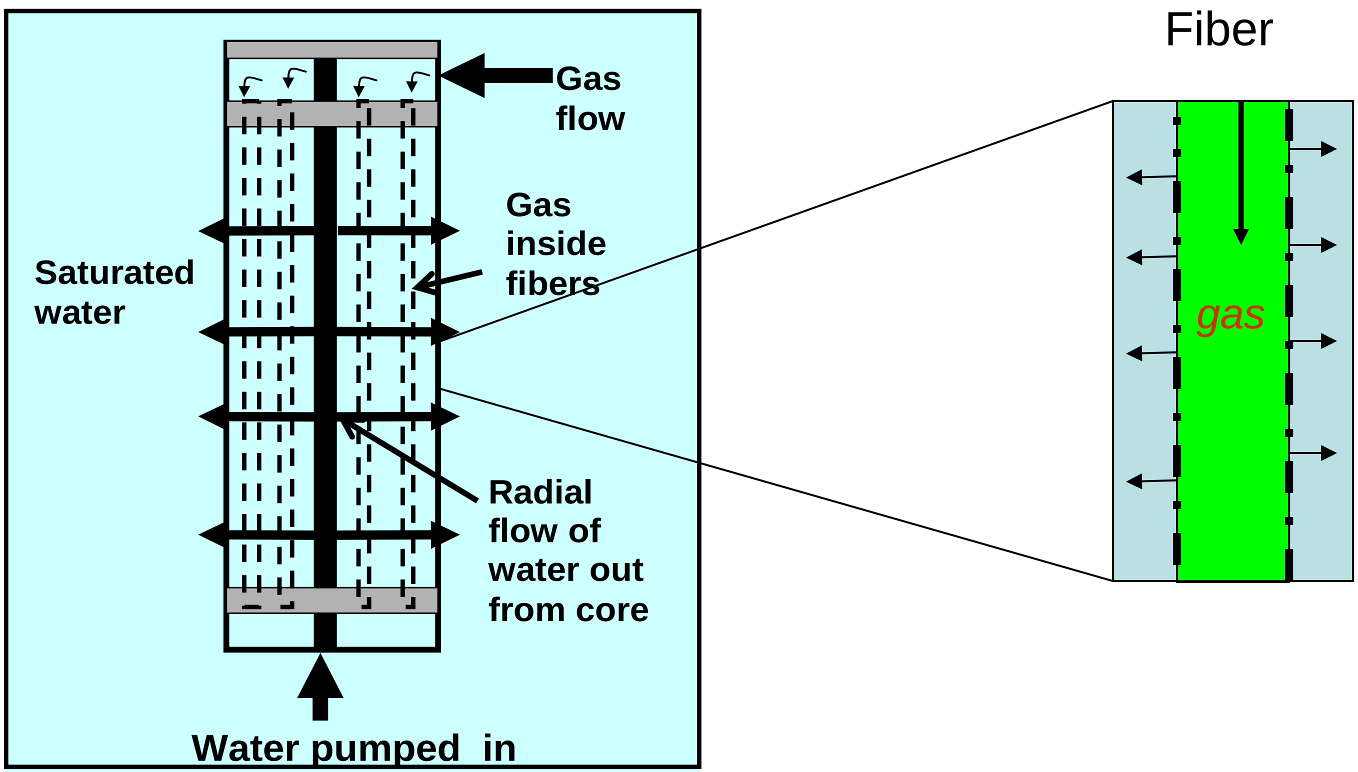
- **Biological treatment**
  - Aerobic oxidation (oxygen)
  - Cometabolic oxidation (oxygen and alkane gas)
  - Cosubstrate oxidation (oxygen and ethene or other co-substrates)
  - Anaerobic reductive dechlorination (hydrogen)

- **Physical treatment**
  - LNAPL and DNAPL recovery enhancement (carbon dioxide)

gPRO Market Applications

- **Chemical treatment**
  - pH adjustment (sulfur dioxide, carbon dioxide, ammonia)
  - geochemical fixation of metals (hydrogen and sulfur dioxide)
  - oxidation of metals (oxygen)
- Any miscible gas (hydrogen, carbon dioxide, propane, methane, sulfur dioxide, etc.) can be applied depending upon the remediation required

gPRO Module for Active Gas inFusion



How gPRO HP Works

gPRO Production

- Delivered gas fills the hollow fibers
- Pressurized water flows past the hollow fibers
- Mass transfer occurs transferring gas into the high pressured water
- For a gas such as oxygen 25-150 mg/l of dissolved oxygen can be produced
- Dissolved gas levels can be adjusted to suit specific conditions

gPRO Delivery

- gPRO HP distribution header and any number of lines are deployed to groundwater inFusion wells
- Pressure is regulated to guarantee bubble-less injection
- gPRO HP delivery process ensures dissolved gas does not come out of solution

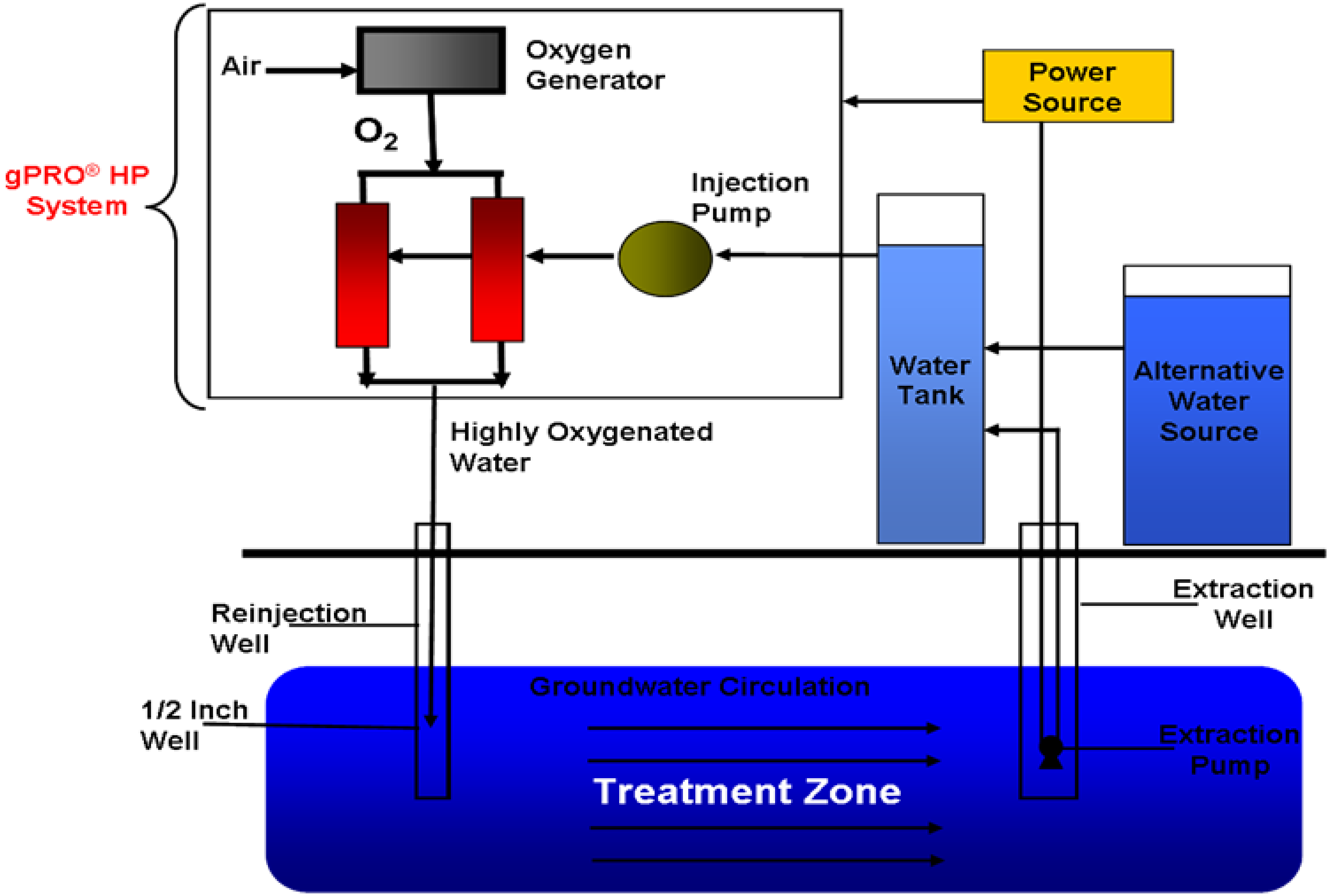
gPRO HP System

gPRO Module
Easy Change-Out
Containers

gPRO Gas
inFusion Module

gPRO HP4 Unit

gPRO HP System



gPRO HP Oxygen Delivery Rate

Water Flow gpm	Water Flow lpm	O_2 Transfer lb/day	O_2 Transfer kg/day	Dissolved O_2 mg/l
8	31	7.7	3.5	77
11	40	7.9	3.6	63
13	48	7.9	3.6	52
15	55	7.5	3.4	43
16	61	7.1	3.2	36

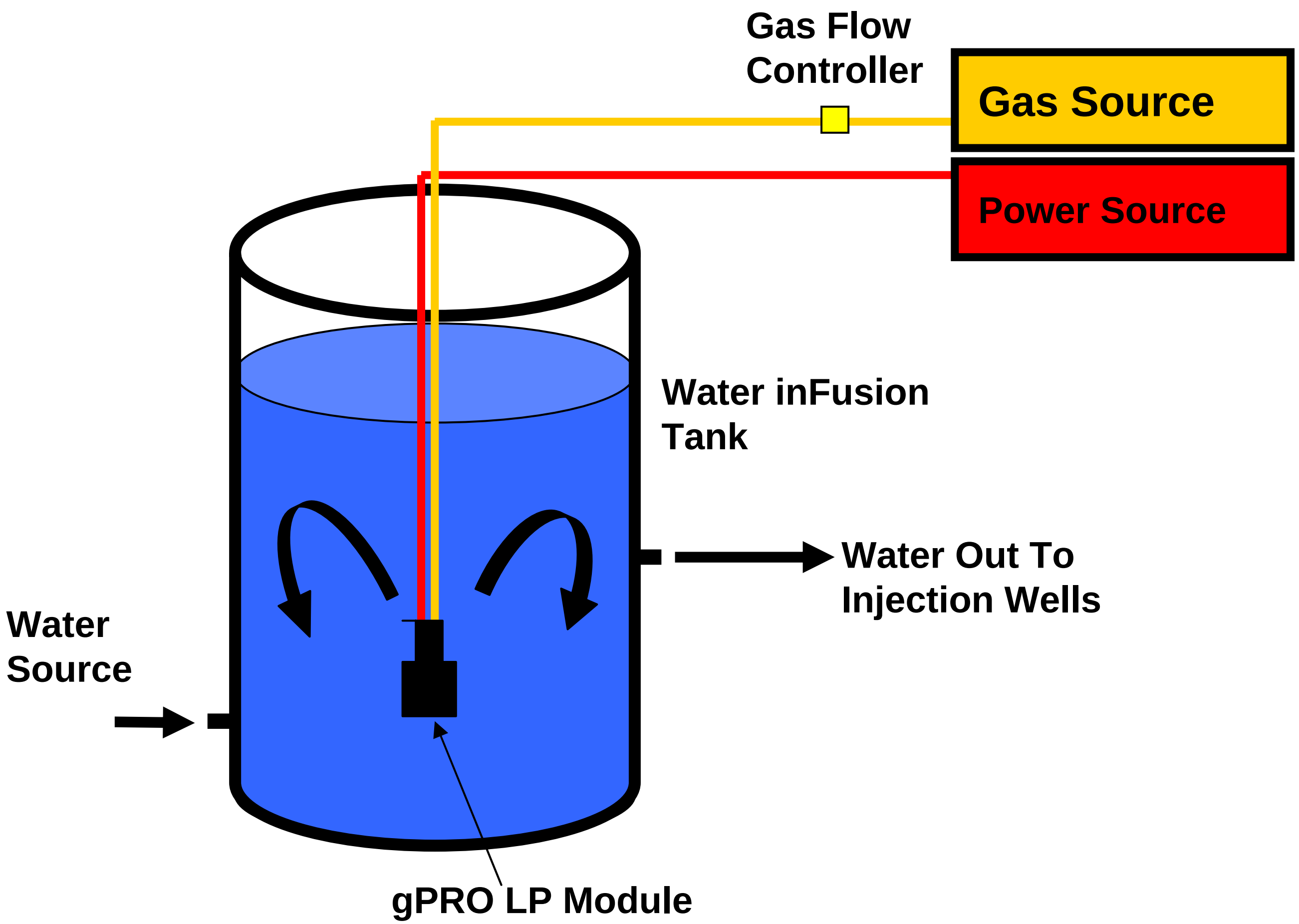
gPRO HP4 with all 4 Modules Engaged

gPRO LP System

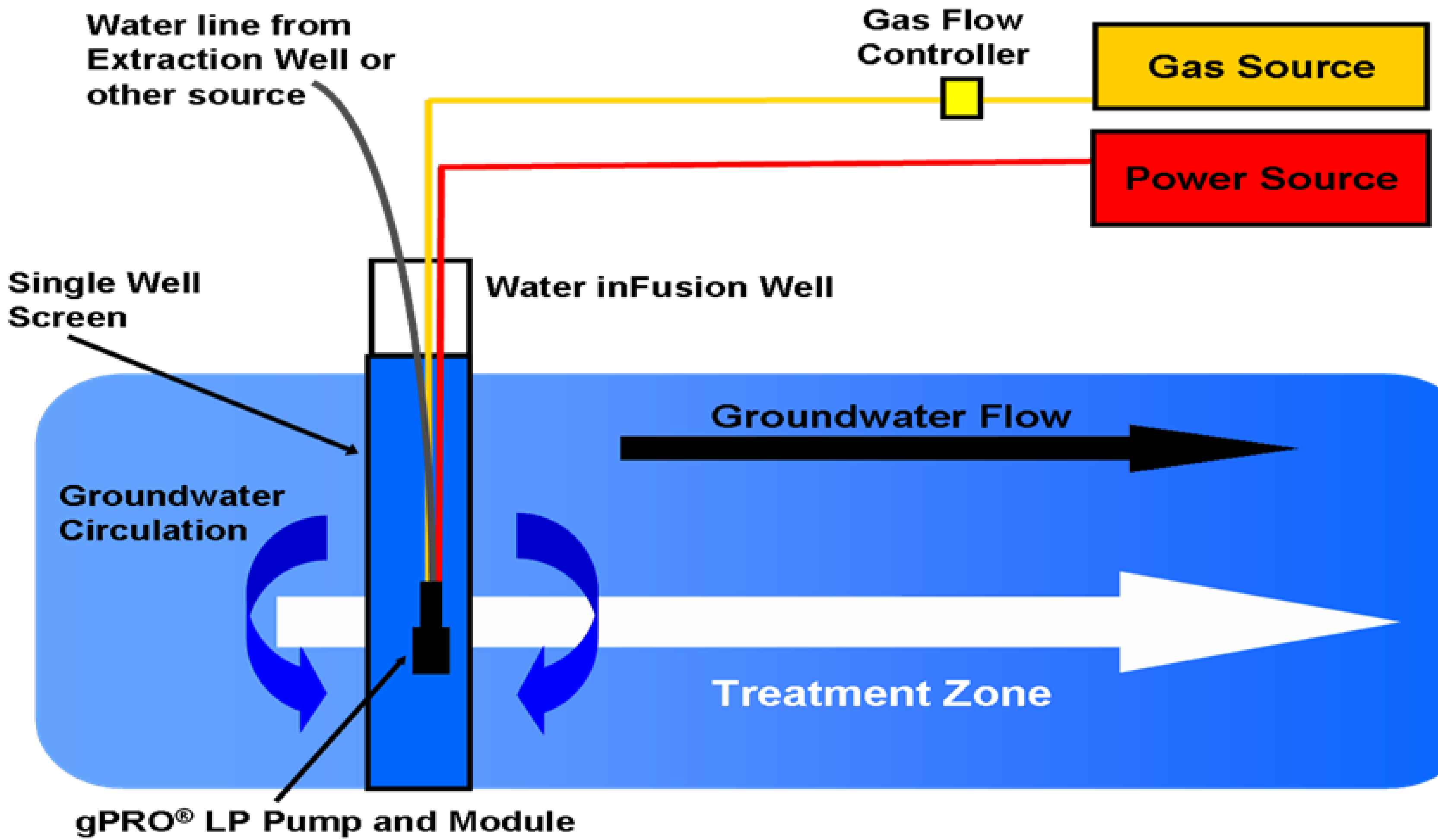
How gPRO LP Works

- 25 -125mg/l of dissolved oxygen can be attained (based upon depths up to 70 feet)
- gPRO LP system will provide aerobic / anaerobic / cometabolic treatment depending on gas infused
- The gPRO LP system is submerged directly into the body of water
- Water is pumped through an internal core and passes over the gPRO LP fiber modules
- The enormous surface area allows for high amounts of dissolved gas to transfer into the water

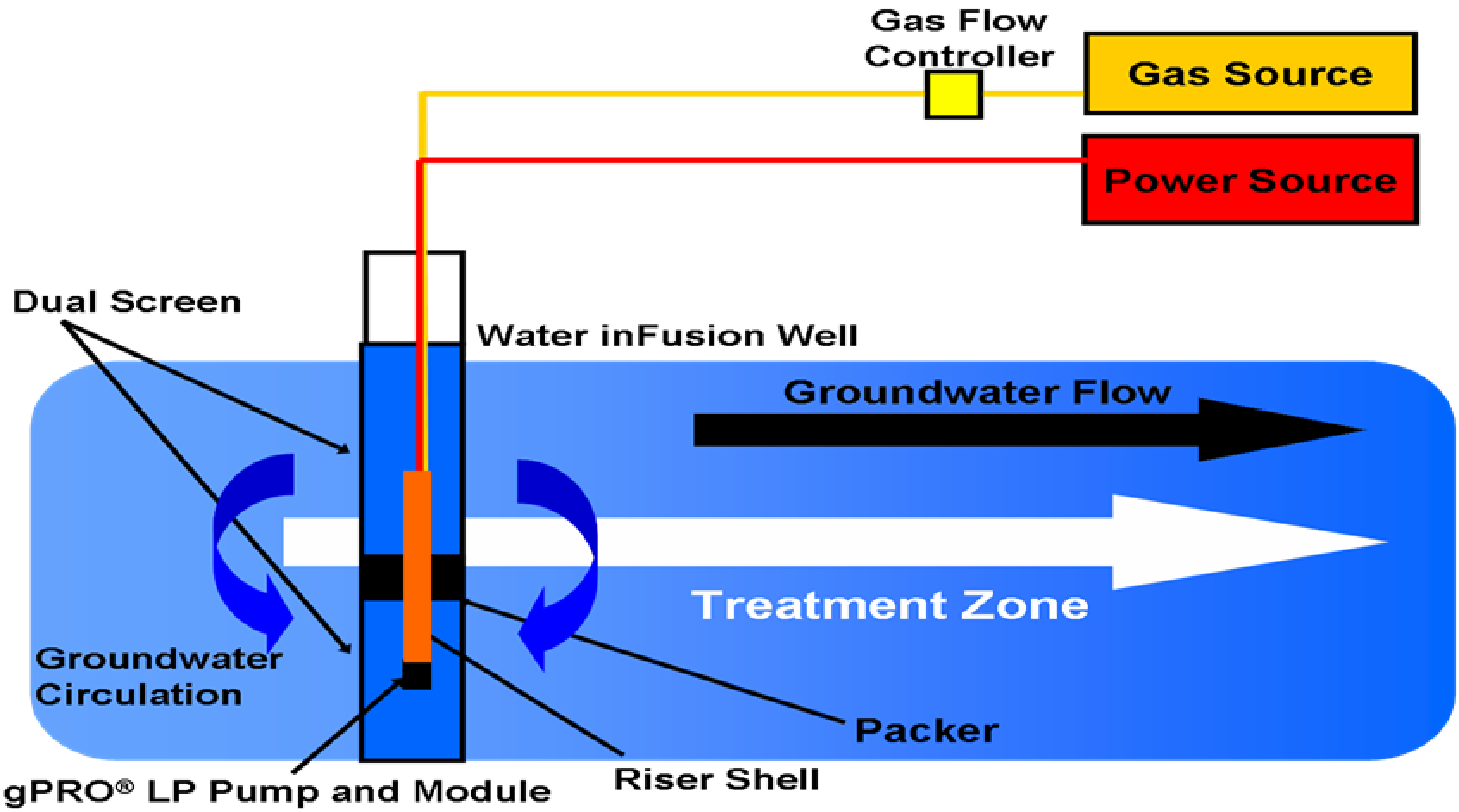
gPRO LP Tank System



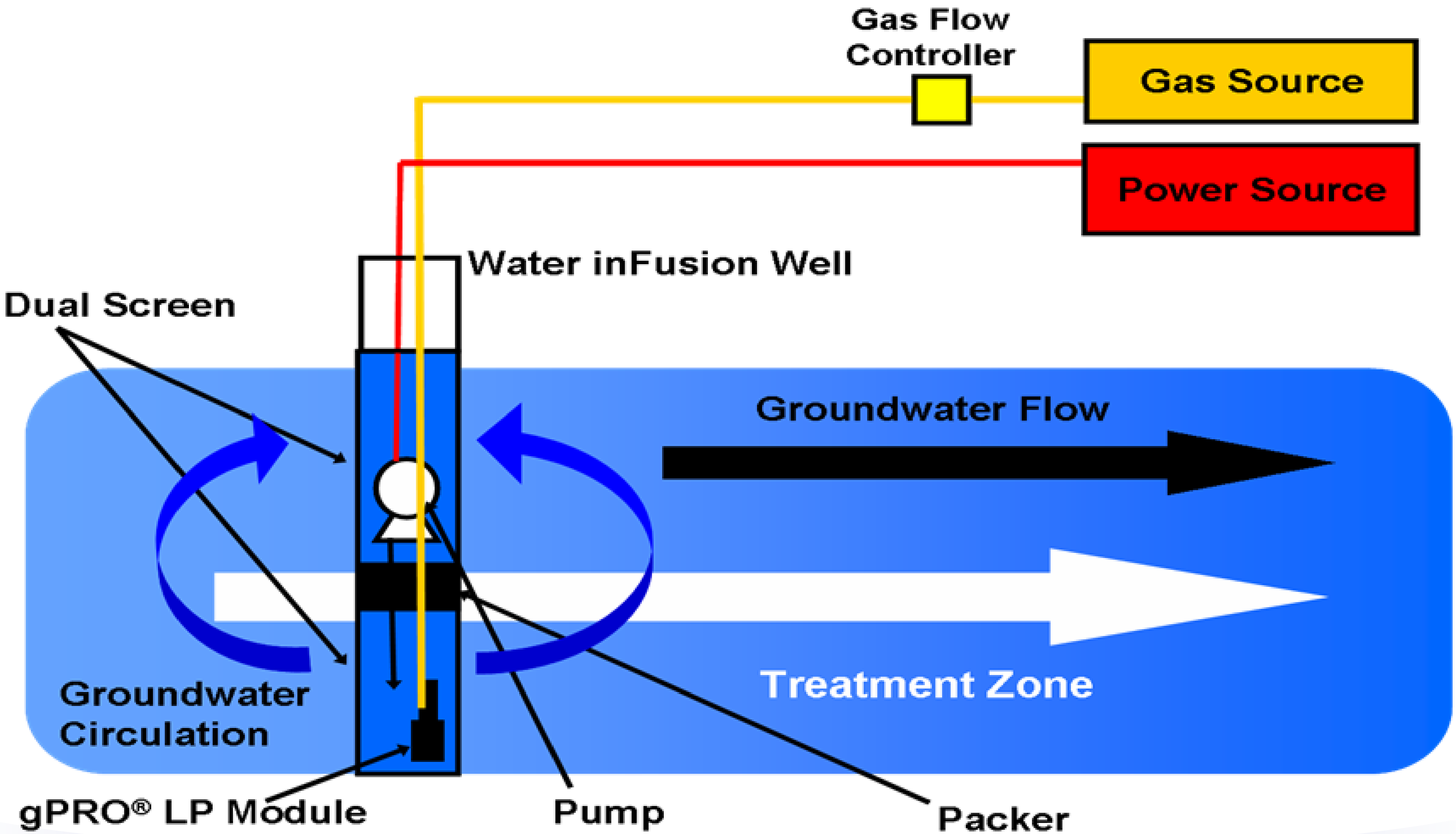
gPRO LP In-Well Amended Groundwater Recharge System



gPRO LP Dual Screen in-Well System (Shallow to Deep)



gPRO LP Dual Screen in-Well System



gPRO Case Studies

The following five case studies establish that gPRO can effectively transfer dissolved gases in groundwater aquifers

The use of the gases transferred by gPRO for bioremediation have been proven at thousands of sites

Indiana Chlorinated Solvent Site

gPRO HP Oxygen inFusion

and

CL-Solutions - CL-Out

Case Study 1

Background

- IWM is the consultant
- Former electronics manufacturing facility with release of VOCs primarily PCE, TCE and TCA
- Highly calcified subsurface environment

inVentures Strategy

- To prove that the gPRO HP system can deliver high concentrations of dissolved oxygen in the treatment zone

- Determine if CL-Out would break down PCE in an aerobic environment as it would be an excellent way to help drive gPRO into the market

Clean Up Strategy

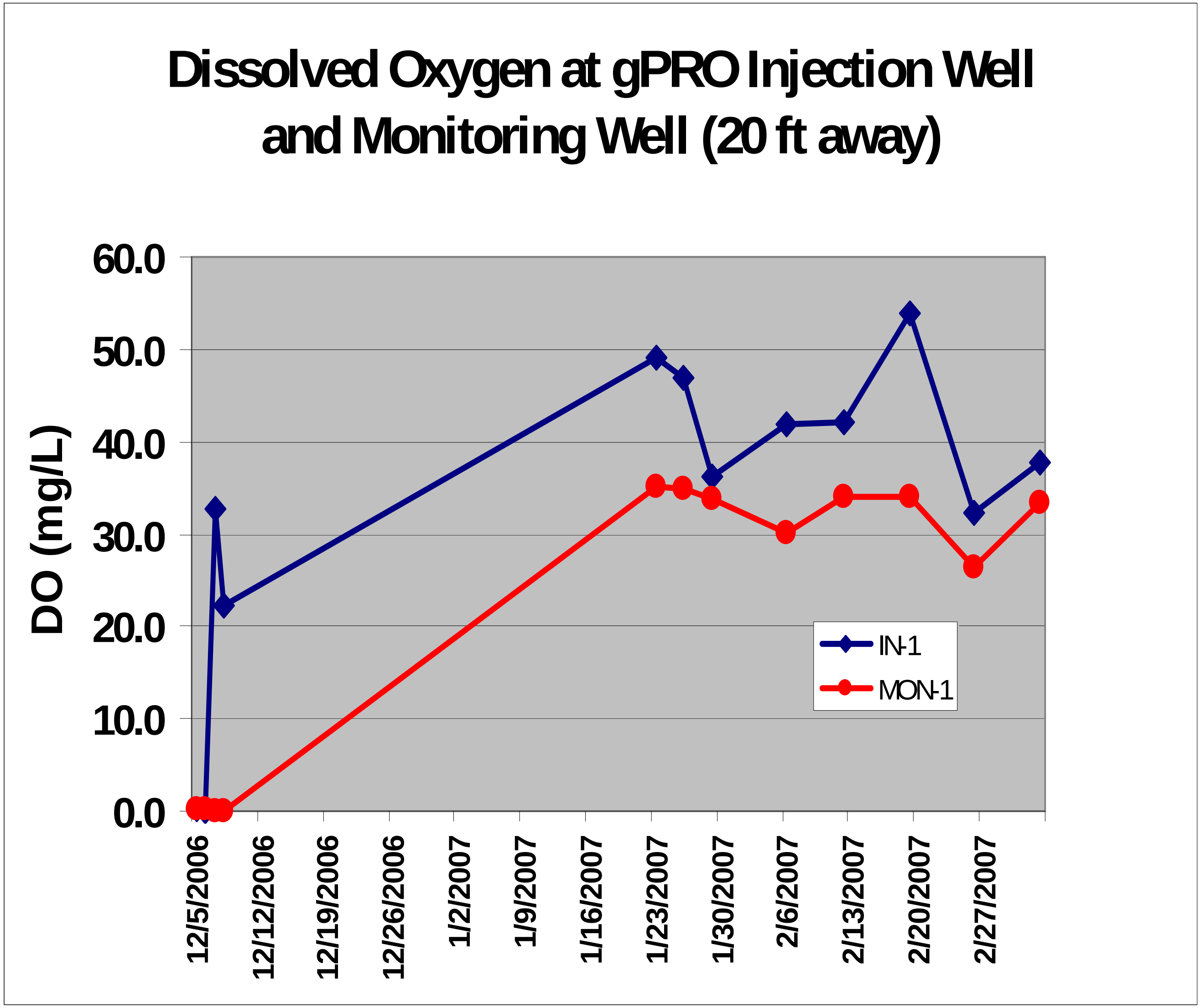
- IWM has been using a pump and treat system to contain the spill for the past 12 years
- Bioremediation of chlorinated solvents utilizing a gPRO HP system and CL-Out could assist clean up of the site
- gPRO HP will supply oxygenated water (between 30-50 ppm) into the subsurface

Case Study 1

Preliminary Results

- DO has risen from a basically anoxic background to very high levels (30 to 50 ppm) over 40 feet away

- Positive indications that CL-Out in combination with highly oxygenated water supplied by the gPRO HP is degrading the PCE aerobically



Dissolved Oxygen at gPRO Injection Well and Monitoring Well (20 ft away)
DO (mg/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
12/5/2006
12/12/2006
12/19/2006
12/26/2006
1/2/2007
1/9/2007
1/16/2007
1/23/2007
1/30/2007
2/6/2007
2/13/2007
2/20/2007
2/27/2007
IN-1
MON-1

Case Study 1

gPRO HP with O_2 Generator

Case Study 1

gPRO HP to Injection Well Manifold

Case Study 1

Water Lines to Injection Wells

Case Study 1

New Mexico TCE Site

gPRO LP Hydrogen inFusion System

Case Study 2

Background

- AMEC Earth & Environmental Inc. is the current consultant
- Estimated mass of PCE DNAPL in the source zone: 300 pounds, Dissolved-phase plume: approximately 275 pounds of PCE and its breakdown products
- Major Concern: Contaminated ground water plume is in a sole-source drinking water aquifer

inVentures Strategy

- Demonstrate that gPRO LP as an effective tool for transferring hydrogen gas (H_2) into groundwater

- H_2 is an effective gas for the bioremediation of PCE

Clean Up Strategy

- A design reaction concentration of H_2 addition 1,000 ug/l planned
- gPRO LP in a tank set up attains the desired concentration of H_2 and then the water is injected into the aquifer
- Emulsified vegetable oil will promote a slow fermentation process

Preliminary Results

- Initial system trials demonstrated the gPRO LP system achieved the target concentration of 1 mg/l of H_2 in water flowing through the infusion tank at 2.5 GPM

Hydrogen Gas Supply

Case Study 2

Gas inFusion Tank

Case Study 2

gPRO LP Module

Case Study 2

Gas Regulator and Flow Controller

Case Study 2

Carp, Ontario Leaking Underground Storage Tank Site

gPRO HP Oxygen inFusion System

Case Study 3

Background

- Water and Earth Science Associates (WESA) began remedial investigation in 2004
- Underground storage tank leakage in an airplane maintenance hangar
- Leaking F1, F2 Hydrocarbons and BTEX into the soil matrix
- Low permeability fine and silty sands

inVentures Strategy

- To introduce gPRO HP and determine radius of influence in low permeability soils
- Water has very high iron content, we wanted to ascertain what the affects would be on the mass transfer modules and what we needed to do as pretreatment to keep the unit running
- gPRO HP system installed Jan. 2006

Clean Up Strategy

- Storage tank excavated Fall 2004
- Back filled with gravel and perforated piping was added
- gPRO HP system installed January 2006

Results

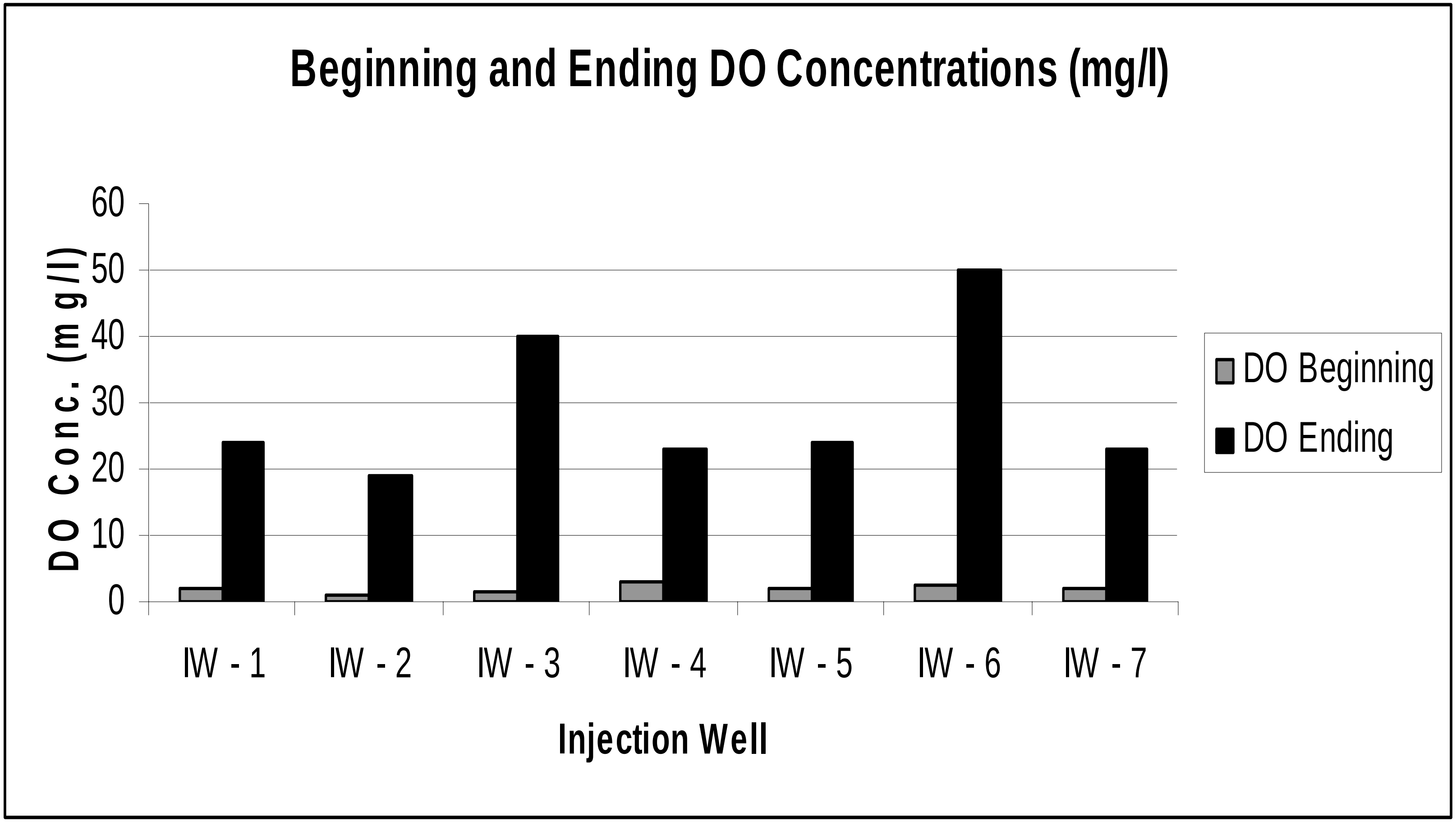
- gPRO HP performed well, providing high levels of oxygen
- The CoC levels dropped sufficiently for consultant to close the site
- A small iron removal system (zeolite) was installed ahead of the gPRO HP and removed enough iron such that modules and lines were not fouled

Site Analysis

Well	Distance from injection well (Meters/Feet)	Beginning DO Mg/l	Ending DO Mg/l
IW-1	4 / 13	1.8	24.2
IW-2	7 / 23	1.2	18.9
IW-3	6.7 / 22	1.6	40.0
IW-4	10 / 33	3.0	23.0
IW-5	2.7 / 9	1.9	24.2
IW-6	0 / 0	2.4	50.0
IW-7	2.7 / 9	2.0	22.9

DO – Dissolved Oxygen

DO Concentrations Before and After gPRO HP Installation



Case Study 3

Borden, Ontario SWI NAPL Recovery Demonstration

gPRO HP NAPL Recovery with CO_2 Saturated Water

Case Study 4

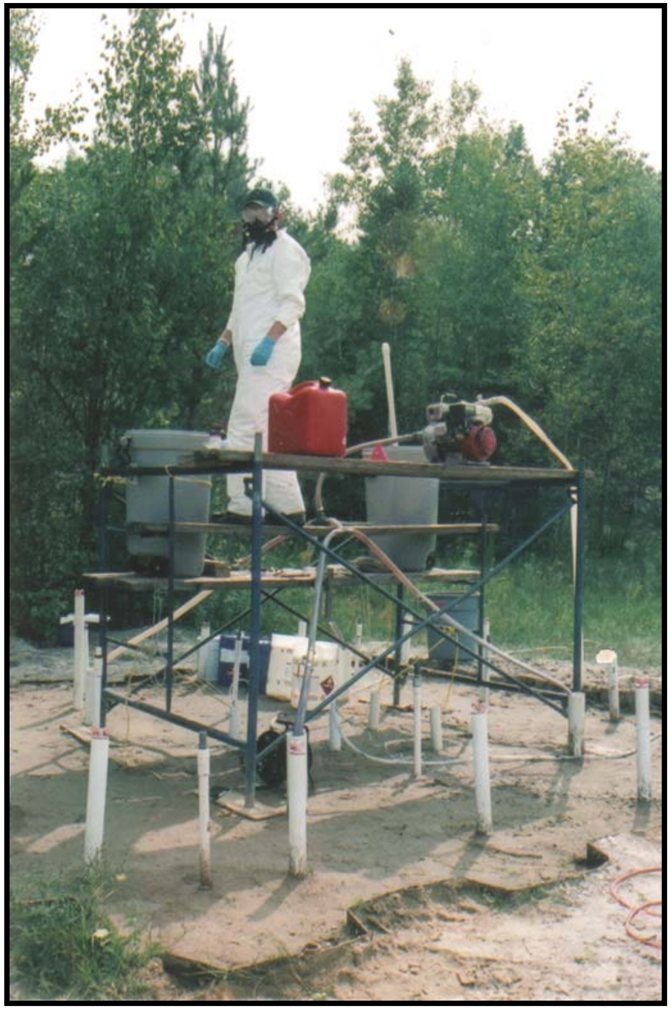
Background

- This was an experimental pilot project conducted by inVentures and the University of Waterloo at Base Borden. The project was carried out in 3 phases:

1. The lab experiments to verify the theory of NAPL Recovery using CO_2 saturated water through volatilization and mobilization.
2. Field experiments to see the extent of CO_2 laden water transport in porous media under non-recovery pumping conditions (i.e. no extraction)
3. The actual NAPL Recovery

Proof of concept in the field

- 200 L of hydrocarbon (mixture of pentane, hexane and Soltrol) existing as residual NAPL in the saturated zone (enclosed cell in the sand pit at Borden)



Case Study 4

inVentures Strategy

- **To determine the radius of influence of carbonated water at a single injection point under non-recovery pumping conditions and demonstrate gPRO HP capability**

Clean Up Strategy

- gPRO HP will be utilized to inject CO_2 supersaturated water into the porous medium
- The in-situ evolution of carbon dioxide in the gas phase will be determined by total gas pressure analysis
- Hydraulic monitoring will be performed to determine if mounding occurs during injection of the carbonated water
- The saturated water is extracted along with the volatile hydrocarbons and non volatiles using duel phase extraction

Results

- CO_2 was measured 6 meters (19.7 feet) in all directions from a single injection point with no mounding – total diameter of 39.4 feet.

- The experiment revealed that the water flow path of CO_2 laden water is very important for maximizing NAPL recovery.

Kinston, North Carolina Leaking Underground Storage Tank Site

gPRO HP Oxygen inFusion System

Case Study 5

Background

- Pyramid Environmental and Engineering is the current consultant.
- Petroleum release from underground storage tanks at a former Kwik Mart facility.
- The site has been accepted for the Performance Based Clean Up program by NC DENR
- The upper 15 to 18 feet below land surface is characterized by gray to brown sand, sandy clay, and silty sand.

Background - Cont

- Dark gray silty to clayey sand was encountered from approximately 18 to 43 feet below land surface.
- For purposes of the site remediation the uppermost 20 feet of the saturated aquifer is the target zone for treatment.
- Depth to ground water is about 6 feet, and the surficial aquifer thickness is about 40 feet.
- iSOC was the technology of choice for the remediation

inVentures Strategy

- inVentures wants to showcase the gPRO and have it demonstrated at as many sites as possible.
- A gPRO HP unit was deployed for a short period of time dramatically to boost oxygen levels in the aquifer.

Clean Up Strategy

- There are very high concentrations of BTEX and MTBE in a very localized area of the site
- The periphery areas are being handled by the original six iSOC used
- In the high concentration areas a vacuum truck was used to pull vapors and contaminated water from the site
- The gPRO was used to replace the water removed with clean highly oxygenated water (~ 60 to 70 ppm)

Results

- The work was carried out very recently and there are no sampling events allowed for 90 days after this removal and reinjection process.
- gPRO proved easy to move around the site and worked well in the vacuum / reinjection of highly oxygenated water remediation scenario.
- The vaccum / reinjection method is another way in which gPRO can be used.

gPRO HP Setup

Case Study 5

gPRO vs. Sparging Technologies

gPRO Systems

- No gas transfer to unsaturated zone or vapor intrusion
- Works in layered stratigraphy
- Allows for addition of nutrients and bioaugmentation

Sparging (Air, O_2 or O_3)

- Typically requires SVE to control vapors
- Relies on bubble rise - low permeability lenses result in treatment gaps and uncontrolled gas migration
- Possible vapor intrusion

gPRO inFusion

Sparging