

Green remediation of petroleum-impacted groundwater & soil: innovative technologies with low carbon footprints

Réhabilitation verte du pétrole-Impacté eaux souterraines et des sols: des technologies novatrices à faible émission de carbone footprints

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Today's presentation

- **Green Remediation Technologies Overviews**

- ✓ **Sulfate-Enhanced Biodegradation (SEB) Process**

- *Utilizes sulfate-reduction biodegradation (SRB) natural attenuation processes and microbial populations to remediate petroleum hydrocarbons*
- *Increases the in-situ concentration of the sulfate (SO_4) terminal electron acceptor through amendments of magnesium sulfate ($Mg SO_4$)*

- ✓ **Enhanced Concentrating Oxygen Soil Vapor Extraction (ECO-SVE)**

- *A remediation system which eliminates air emissions*
- *Enhances in-situ bioremediation and extraction of volatile organic compounds (VOCs) from subsurface soils and groundwater*

- ✓ **Carbon Footprints**

Carbon Footprint Calculators

http://www.hmvt.nl/sites/hmvt.nl/files/CO2_v0.5.swf

LEAKING UST Footprint Calculator BETA

February 8, 2013

BACKGROUND ASSUMPTIONS TECH SCENARIOS PARAMETERS CALCULATIONS


Welcome to the Leaking UST Footprint Calculator

The Leaking UST Footprint Calculator estimates and compares the greenhouse gas emissions for the five most common remediation technologies used at contaminated underground storage tank sites in California. Results are normalized to short-tons of CO₂ emissions. One short-ton is equal to 2,000 pounds. The calculator is pre-populated with average values collected from real leaking UST sites across California. You can use these average values, select a design scenario, or customize inputs to fit the conditions at your site.


The calculator is meant to help cleanup professionals and stakeholders better understand the greenhouse gas emissions of common technologies. It provides a breakdown of where emissions come from and where they can be reduced for remedy optimization.

Sullivan International Group, Inc. designed and built this website with input and funding from the U.S. EPA and the California State Water Resources Control Board. It is a BETA release. Input is welcome. Please submit your comments and suggestions about the Calculator methodology via the "Contact Us" link. If something is not working on the website, use the "Report a Bug" link.


Remediation Technologies




Excavation




SVE



P&T



MPE



MNA

Soil Excavation Soil Vapor Extraction Pump and Treat Multi-Phase Extraction Monitored Natural Attenuation

Start Calculator

<http://www.ustcalc.org/>

Calculate your own Carbon Footprint

hmvt

Name of site: LUST Site #1
Location: Denver, CO

Consumption of electricity, water & gas

Electricity production diesel aggregate ☐

Electricity usage project [kWh]

Water usage project [m³]

Natural gas usage project [m³]

Consumption of chemicals

26 Hydrogen peroxide (50%) usage [m³]

0 Phosphoric acid (75%) usage [m³]

0 Iron Sulfate usage [kg]

5 N-source injection [tonnes*]

1 P-source injection [tonnes*]

0 Permanganate injection [tonnes*]

0 Molasses usage [m³]

0 Sodium Hydroxide usage [m³]

0 Hydrochloric Acid usage [m³]

Consumption of fuel [diesel]

Distance driving cars [km]

Distance driving vans [km]

Transport equipment 15t lorry [km]

Excavator active on site [days]

Soil drilling machine forecast [days]

Transport exc. soil 50t lorry [km]

Excavated soil treatment [tonnes*]

Biologically

Thermally

Physical/chemically

Other items

500 Reactivated carbon usage [kg]

100 Activated carbon usage [kg]


150 HDPE piping usage (avg diameter) [m¹]

More info? **Load / Save**

CO₂ produced [tonnes*]

Matching households

Relation between CO₂-sources



Electricity, water & gas
Fuel [diesel]
Chemicals
Soil treatment
Other items

CO₂ produced: 137,9
Matching households: 27,6

Leaking Underground Storage Tank (LUST) Remediation Carbon Footprint Calculator

Leaking UST Footprint Calculator (source: US-EPA Region 9)

- Estimates and compares the greenhouse gas emissions for the five most common LUST remediation technologies

Remediation Technologies



Soil Excavation



Soil Vapor Extraction



Pump and Treat



Multi-Phase Extraction



Monitored Natural
Attenuation

- Default, pre-populated average values collected from actual remediation experiences of California LUST sites.
- Results are normalized to short-tons of CO2 emissions.


Leaking UST Footprint Calculator

- Considers emissions that result from direct cleanup work, such as electricity generation, transportation to the site, and energy consumed treating water.
- ✓ Does not quantify the carbon footprint of processes associated with the manufacture of materials used in the remediation technology, such as the manufacture of heavy equipment and PVC piping for monitoring wells.

HMVT Carbon Footprint Model

http://www.hmvt.nl/sites/hmvt.nl/files/CO2_v0.5.swf

- ✓ More completely quantifies the carbon footprint of materials used in the remediation technology and their manufacturing processes, such as PVC piping for monitoring wells, periodic GAC replacement, and chemical reagents.

Calculate your own Carbon Footprint 

Name of site: LUST Site #1
Location: Denver, CO

Consumption of electricity, water & gas

Electricity production diesel aggregate ☐
Electricity usage project [kWh] 10000
Water usage project [m³] 5000
Natural gas usage project [m³] 250

Consumption of chemicals

26 Hydrogen peroxide (50%) usage [m³]
0 Phosphoric acid (75%) usage [m³]
0 Iron Sulfate usage [kg]
5 N-source injection [tonnes*]
1 P-source injection [tonnes*]
0 Permanganate injection [tonnes*]
0 Molasses usage [m³]
0 Sodium Hydroxide usage [m³]
0 Hydrochloric Acid usage [m³]

Consumption of fuel [diesel]

Distance driving cars [km] 1000
Distance driving vans [km] 5000
Transport equipment 15t lorry [km] 250
Excavator active on site [days] 5
Soil drilling machine forecast [days] 5
Transport exc. soil 50t lorry [km] 50

Excavated soil treatment [tonnes*]

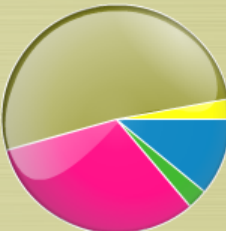
Biologically 1000
Thermally 250
Physical/chemically 1250

Other items

500 Reactivated carbon usage [kg]
100 Activated carbon usage [kg]
150 HDPE piping usage (avg diameter) [m¹]

CO2 produced [tonnes*] 137,9
Matching households 27,6

Relation between CO2-sources



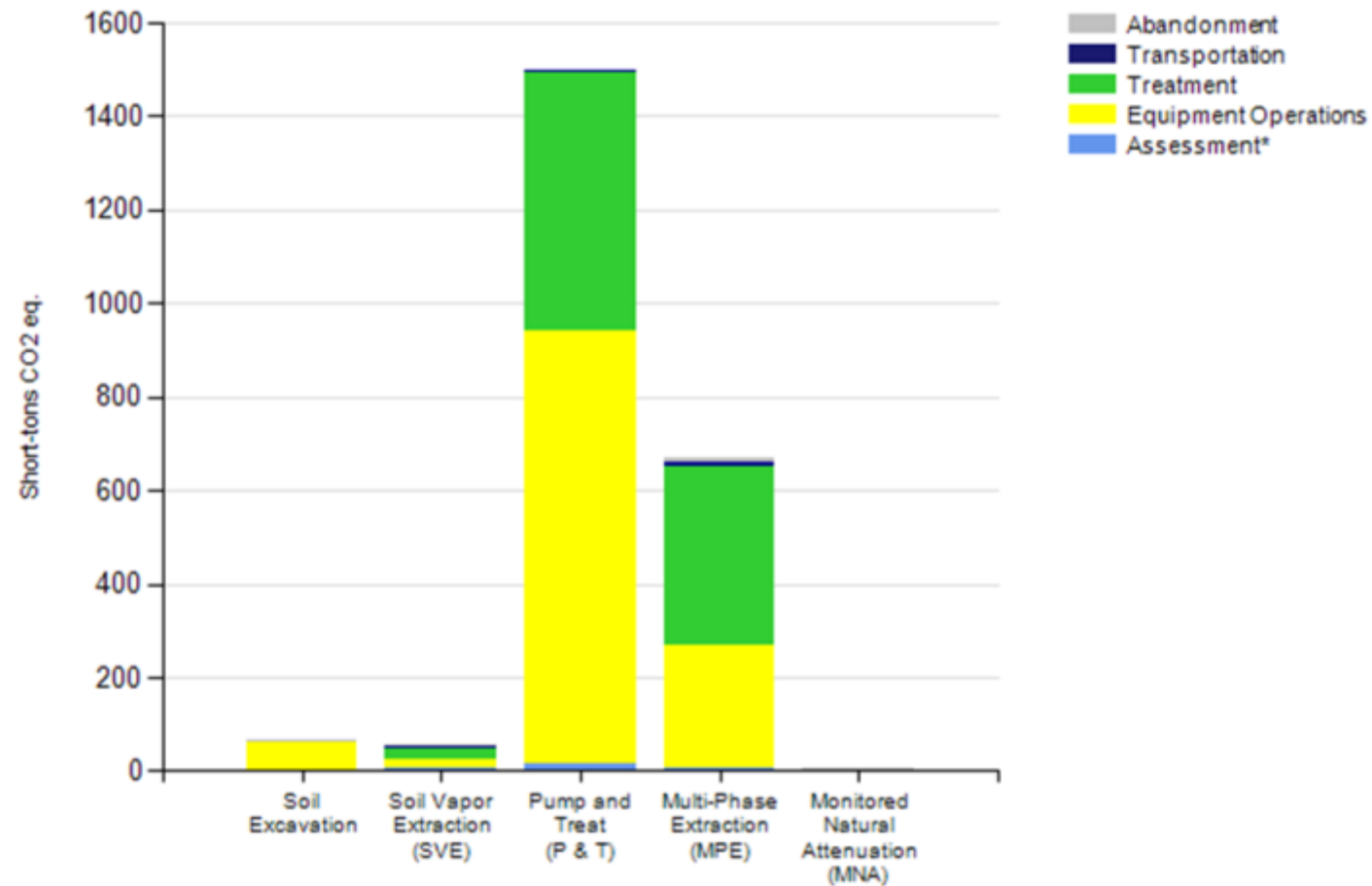
- Electricity, water & gas
- Fuel [diesel]
- Chemicals
- Soil treatment
- Other items

Carbon Footprint Estimations for Technologies

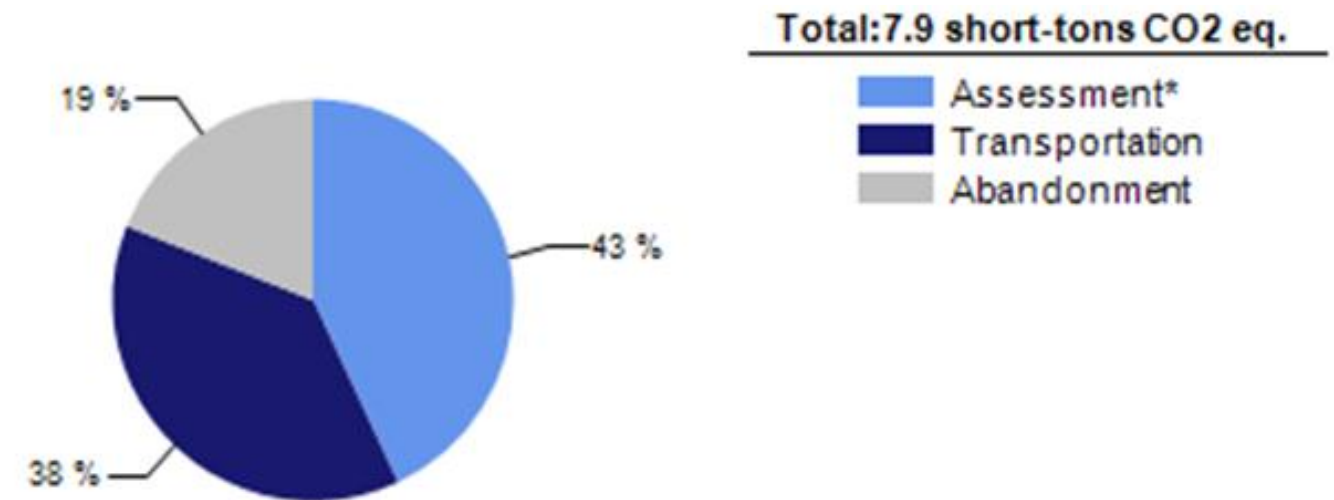
Technology	Duration	Short-tons CO2 eq.	Metric tons CO2 eq.	<u>Cars on the road for one year</u>	<u>Acres of forest needed to sequester carbon</u>
Excavation	19.4 days	70.5	64.0	12.2	0.6
ECO-SVE	1.0 years	57.8	52.4	10.0	0.5
P & T	6.0 years	1504.0	1364.4	260.9	12.9
MPE	3.0 years	667.7	605.7	115.8	5.7
SEB-MNA	6.0 years	7.9	7.2	1.4	0.1

<http://www.epa.gov/cleanenergy/energy-resources/calculator.html>

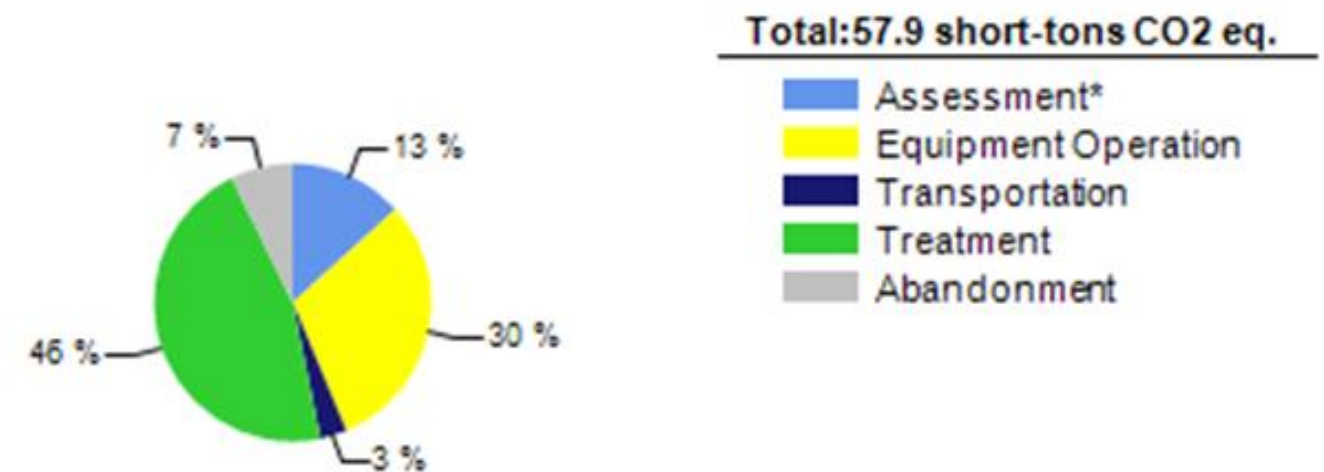
Carbon Footprint Estimations for Technologies



Sulfate-Enhanced Biodegradation - MNA



ECO - SVE

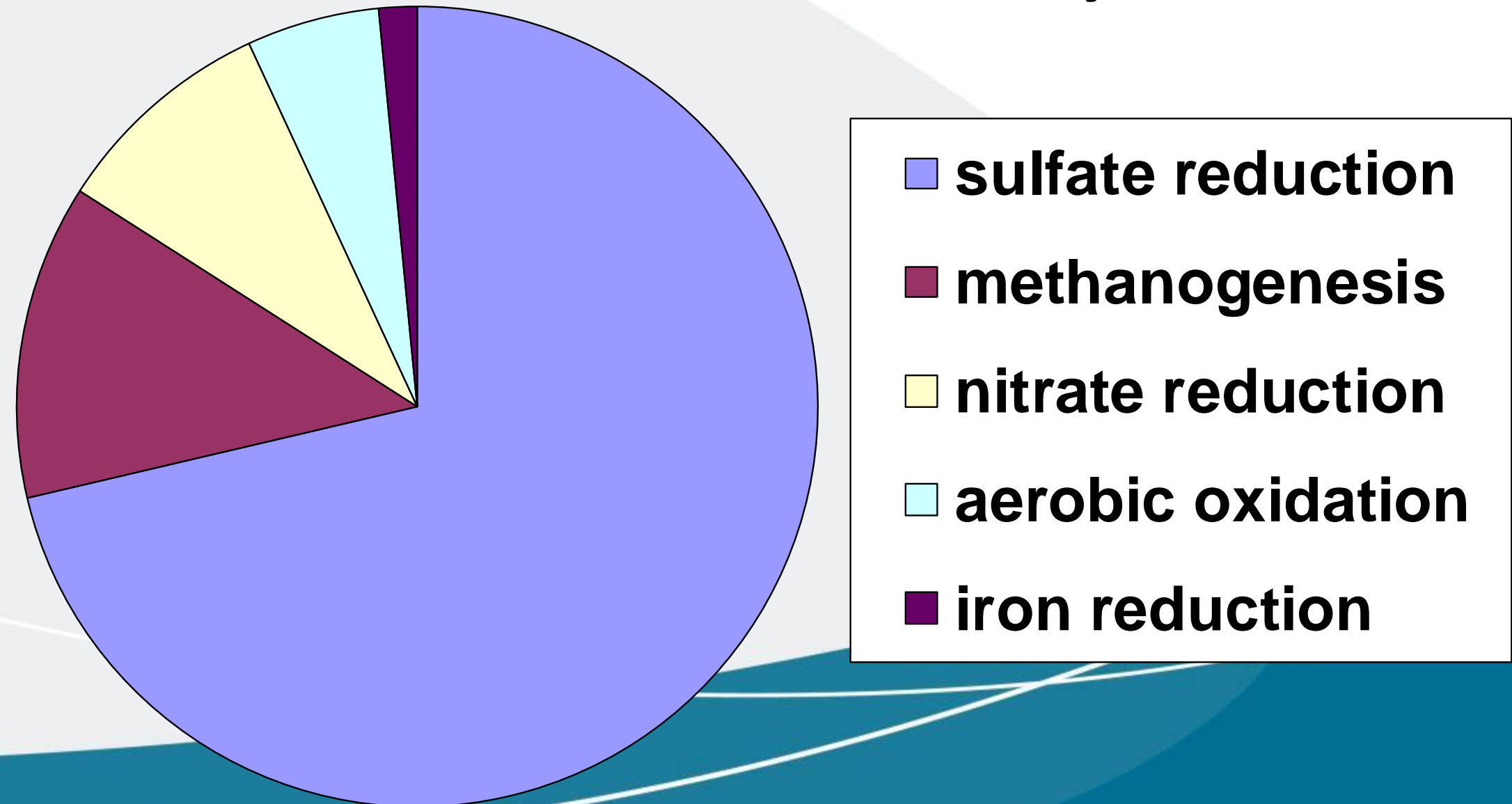


Sulfate-Enhanced Biodegradation (SEB)

- **Petroleum Hydrocarbon + MgSO_4 + Dissolved Iron \rightarrow Iron Sulfide + H_2O + MgCO_3 + CO_2**
 - ✓ Iron Sulfide and Magnesium Carbonate are insoluble and immobile
 - ✓ 4.7 grams of Sulfate utilized per gram of BTEX degradation
- **US Patent 7,138,060 issued in November 2006**

Significance of Sulfate in MNA

Sulfate Reduction is the predominant electron-accepting process for monitored natural attenuation of hydrocarbons



What's really happening during MNA?

- Anaerobic processes dominate hydrocarbon natural attenuation
- Terminal electron acceptors control *in-situ* biodegradation rates
- Sulfate provides many advantages
 - ✓ High solubility
 - ✓ Low health risk
 - ✓ Economical

Process Overview

- Nearly saturated aqueous MgSO_4 solution utilized
 - ✓ ~15-25% w/v
- Periodic amendments (3 to 6 month intervals)
- Applied by gravity flow
 - ✓ Ground surface applications
 - ✓ Application wells or trenches
 - ✓ Via infiltration galleries
 - ✓ Fed into former SVE wells



Sulfate Application



- Easy to apply
- Minimal health and safety risk
- Minimal site disruption

Site Selection Criteria

- Conditions inside GW plume vs. background
 - Depleted **Dissolved Oxygen (DO)**
 - Decreased **Nitrate (NO_3)**
 - Elevated **Dissolved Iron (Fe^{2+})**
 - Decreased **Sulfate (SO_4)**
- Confirm presence of Sulfate-Reducing bacteria
 - *Optional line of MNA evidence*

Site Selection Criteria

- Potentially useful for product sheens
- Effective within saturated zone
- Effective for petroleum hydrocarbons including BTEX, MTBE, and TBA

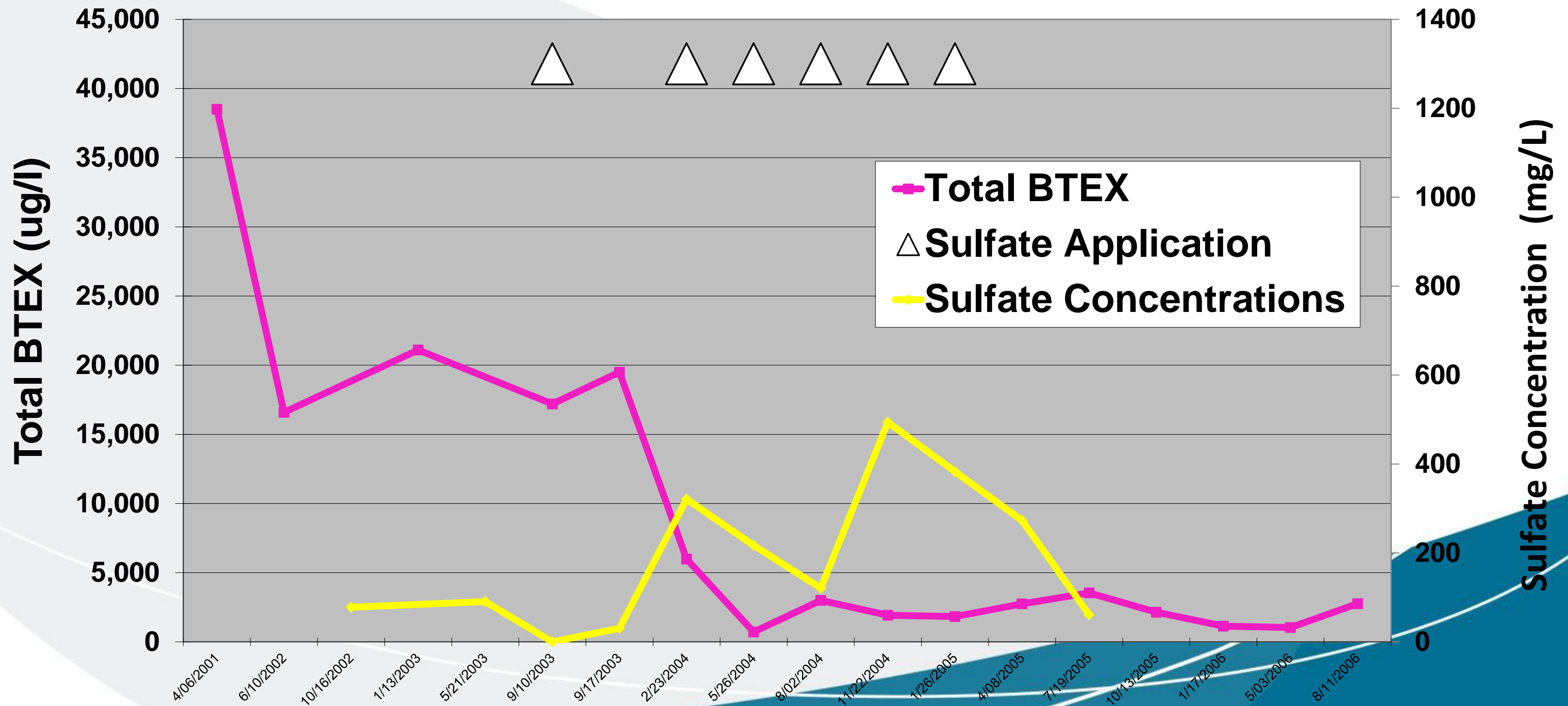
Petroleum Hydrocarbon Case Study

- Former gas station releases in 1992 and 2001
- Geology: silty clay with sand fill
- Groundwater 1 to 2 feet bgs (0,5 meter)
- LPH was last encountered in March 2003

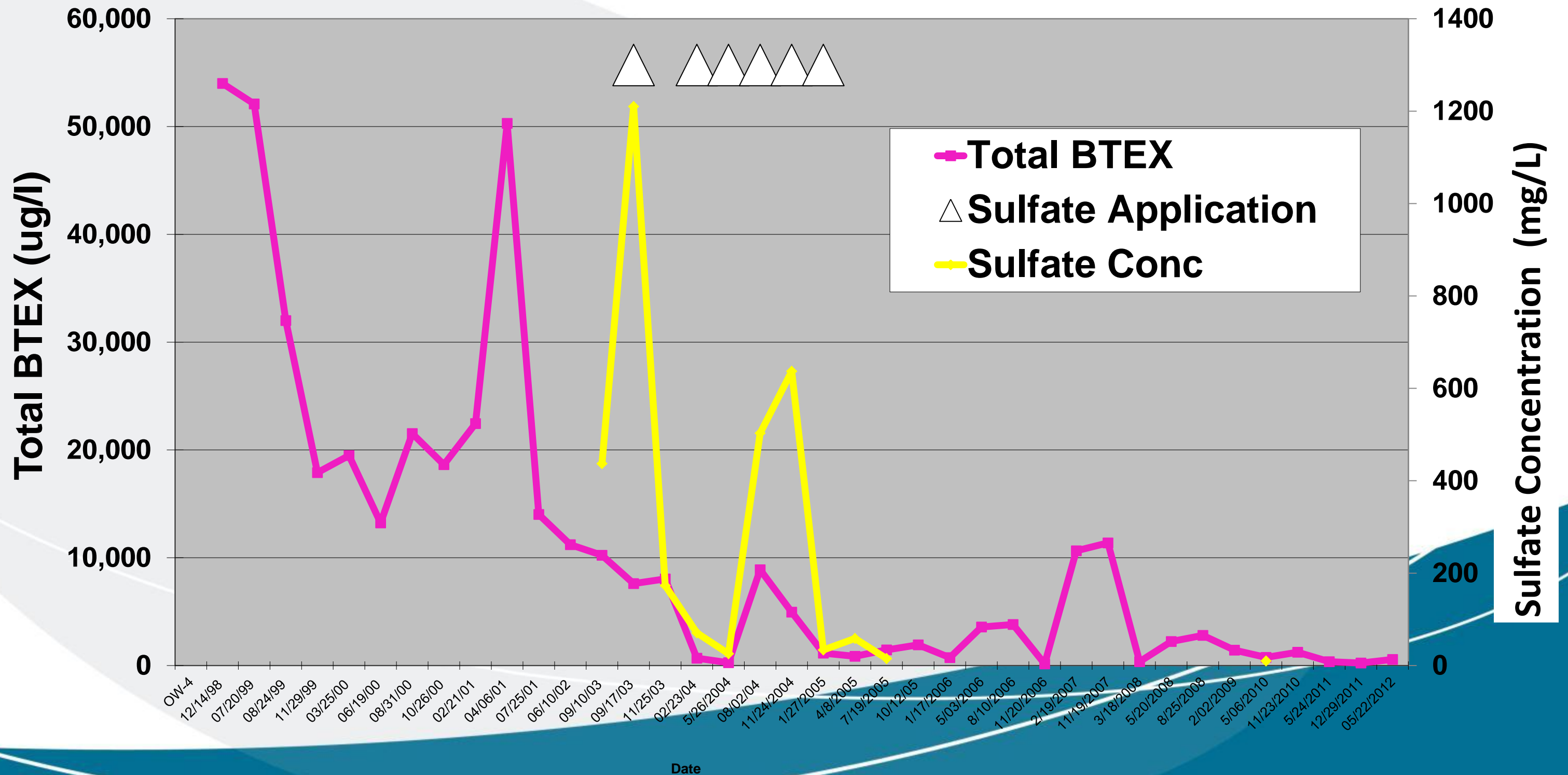
Petroleum Hydrocarbon Case Study

- Prior remediation attempts were unsuccessful
 - *high vacuum total fluids extraction*
 - *oxygen bio-sparging*
 - *bioaugmentation*
 - *monitored natural attenuation*
- Six (6) Sulfate amendments were surface-applied over a two year period

Source Area Well



Down Gradient Well



Common Misconceptions

- Biodegradation requires aerobic conditions
- Anaerobic Biodegradation is too slow
- Hydrogen Sulfide gas will be generated
- Sulfate solution amendments increase plume migration
- SEB produces a Sulfate 'contaminant plume'

Advantages - Sulfate-Enhanced Biodegradation

- Naturally occurring
- High solubility
- Easily applied as an aqueous solution
- Results are surprisingly rapid
- Minimizes site disturbance
- No long term operation and maintenance

Another Green Remediation Alternative

ECO- SVE

Enhanced Concentrating Oxygen Soil Vapor Extraction

- Remediation system which eliminates air emissions
 - ✓ no air permits needed
- Enhances extraction of VOC's from the subsurface soils and groundwater
- Stimulates *in-situ* bioremediation of subsurface groundwater and vadose soils

ECO- SVE

- Creates a slight net vacuum between the subsurface and the atmosphere by extracting more air than is injected
 - ✓ Causes atmospheric air to be drawn into the subsurface
 - ✓ Eliminates the potential for fugitive emissions
- Utilizes pressure swing adsorption to separate VOCs, Nitrogen, Oxygen and Carbon Dioxide into separate vapor streams
 - ✓ Re-injected oxygen enhances the bioremediation process

ECO- SVE

- O₂ is injected into the impacted areas (GW or vadose) to enhance aerobic bioremediation
 - ✓ Air stripping (volatilization) benefit, but not a primary driver
- N₂ and CO₂ can be injected to create anaerobic conditions
- Goal is not to extract, the goal is to make a gentle circulatory system that primarily destroys contaminants *in-situ*
 - ✓ Mass removal by SVE occurs, but adds cost

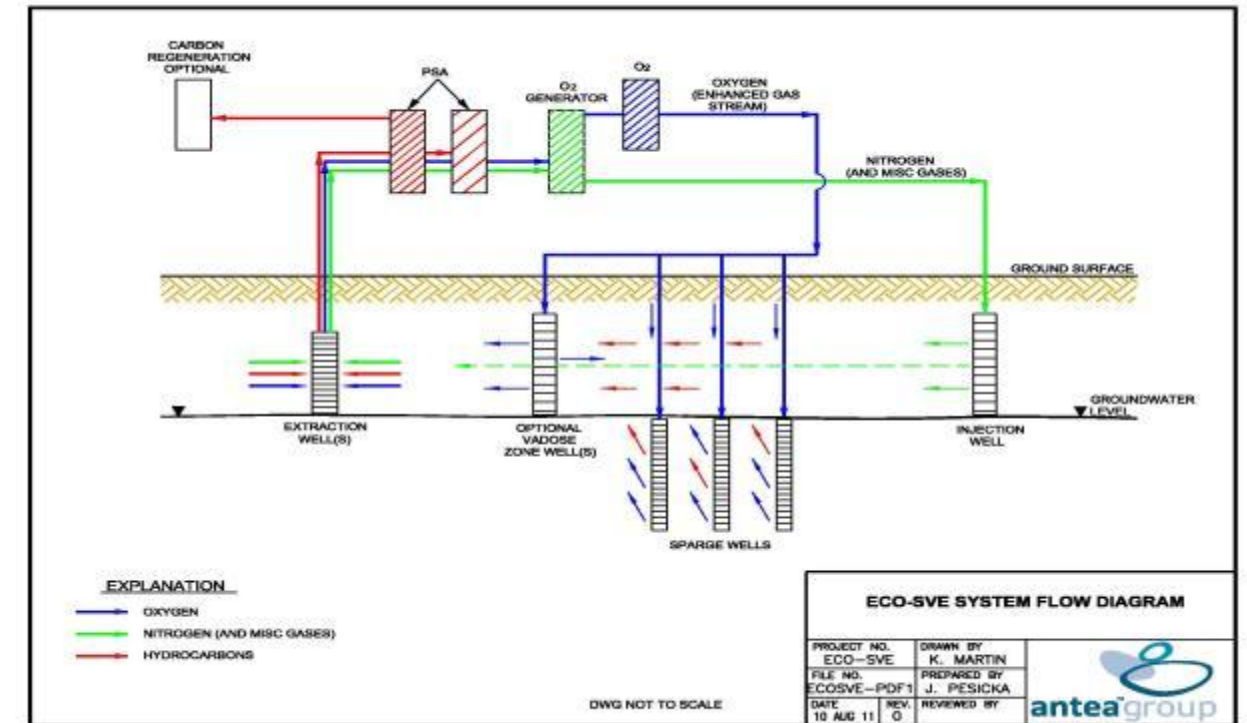
Key Components

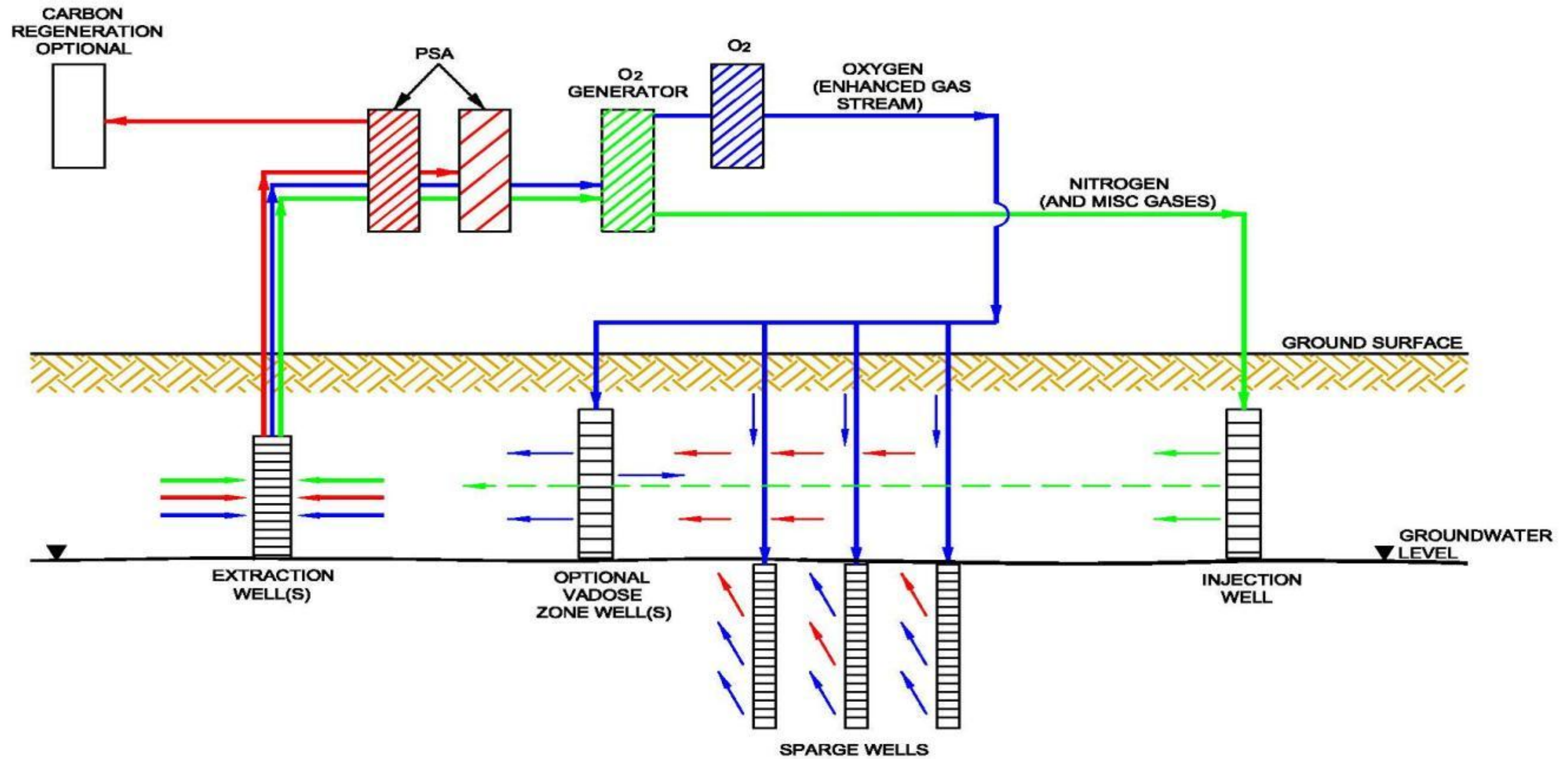
- Vapor Extraction Pump
- Injection Pump (may be same as above)
- Pressure Swing Adsorbers (may be more than one adsorbent type)
- Optional - VOC and Water Condenser
- Water and liquid transfer pumps as necessary
- Extraction and Injection wells



Process Description

- VOC's/Gases extracted from subsurface
- All Vapors enter pressure swing absorber (PSA)
- VOC's, N_2 , CO_2 , O_2 adsorbed in or passed through each PSA, based on desired configuration
- VOC's, desorbed and condensed along with water (additional equipment required)
- Other gases re-injected
- **US Patent 8,210,772 issued July 2012**





EXPLANATION

- OXYGEN
- NITROGEN (AND MISC GASES)
- HYDROCARBONS

DWG NOT TO SCALE

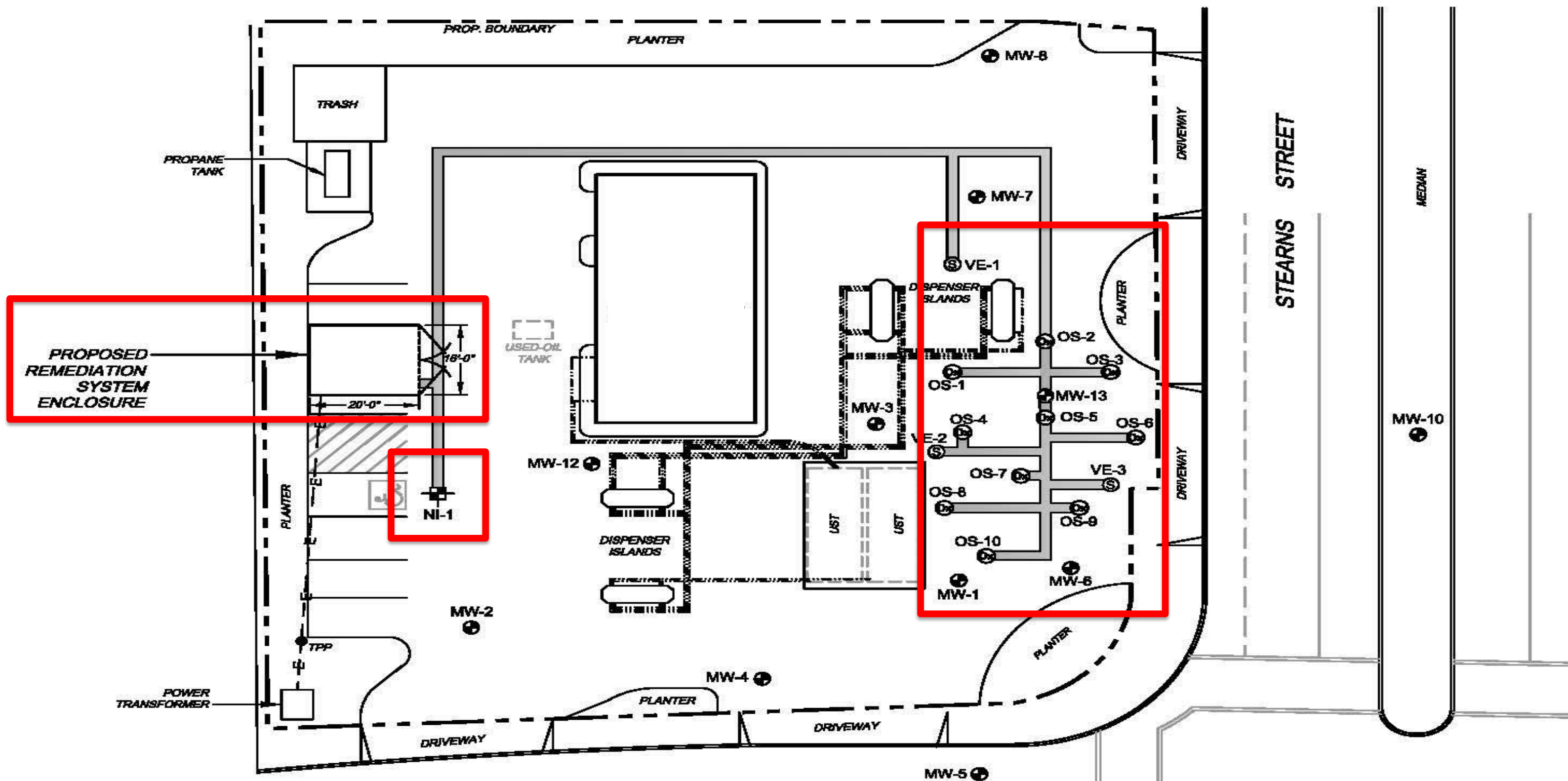
ECO-SVE SYSTEM FLOW DIAGRAM

PROJECT NO. ECO-SVE	DRAWN BY K. MARTIN
FILE NO. ECOSVE-PDF1	PREPARED BY J. PESICKA
DATE 10 AUG 11	REV. 0
	REVIEWED BY

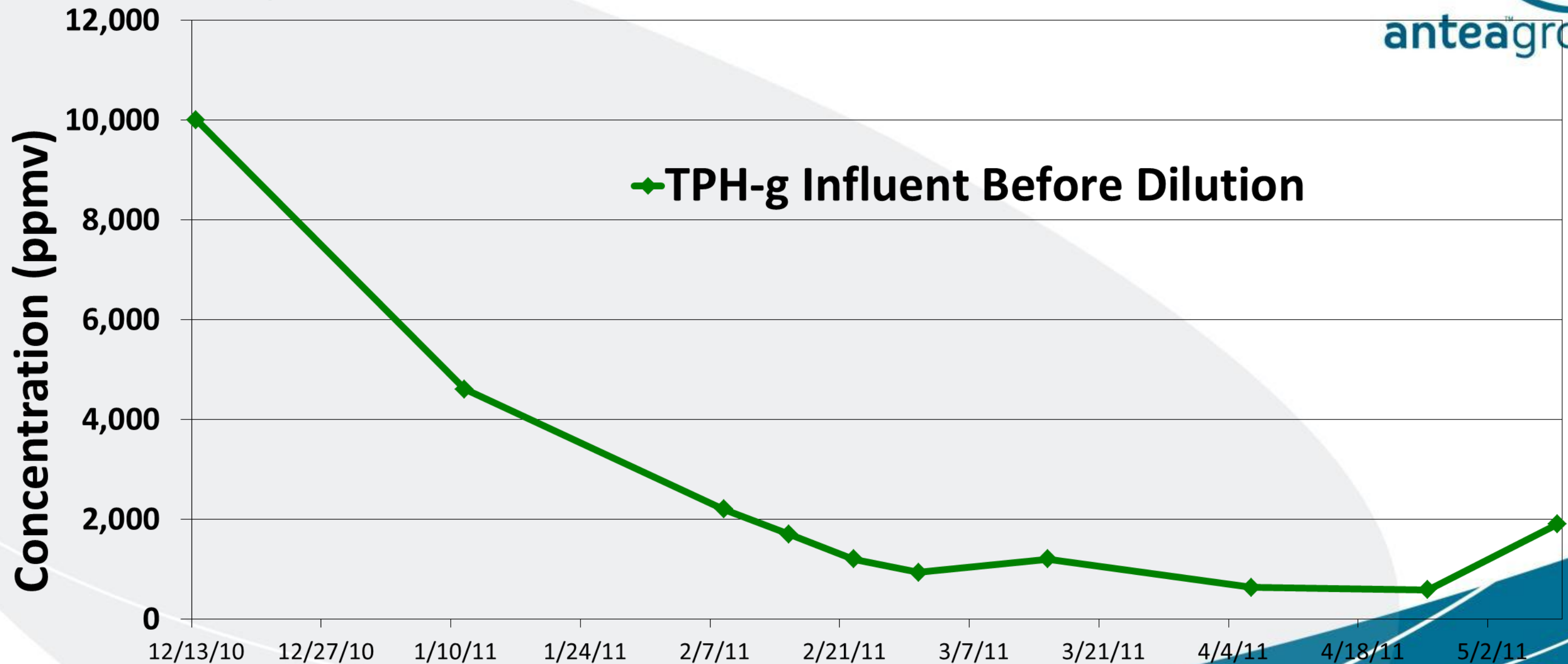


Case Study

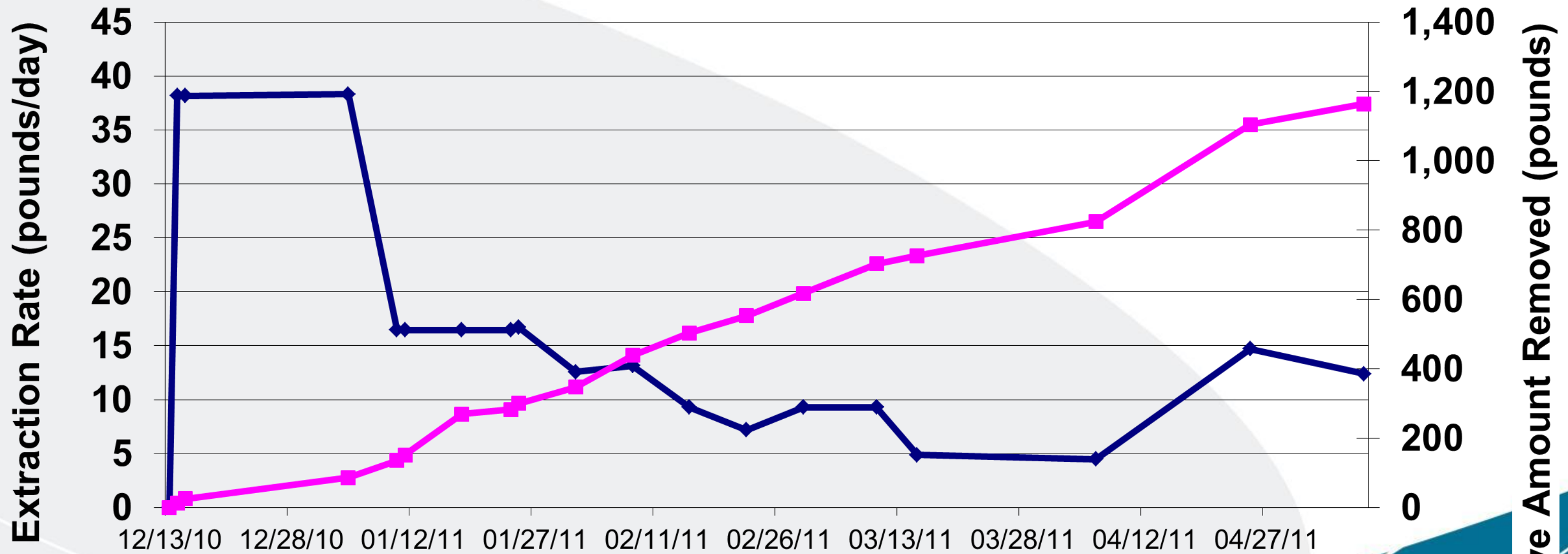
- Hydrocarbon (gasoline range) impacted site
 - ✓ discovered 1989
- Southern California
- Impacted soil and groundwater
- Depth to water 45 feet (13 m)
- Geology – silty sand/sand
- Impacts on site



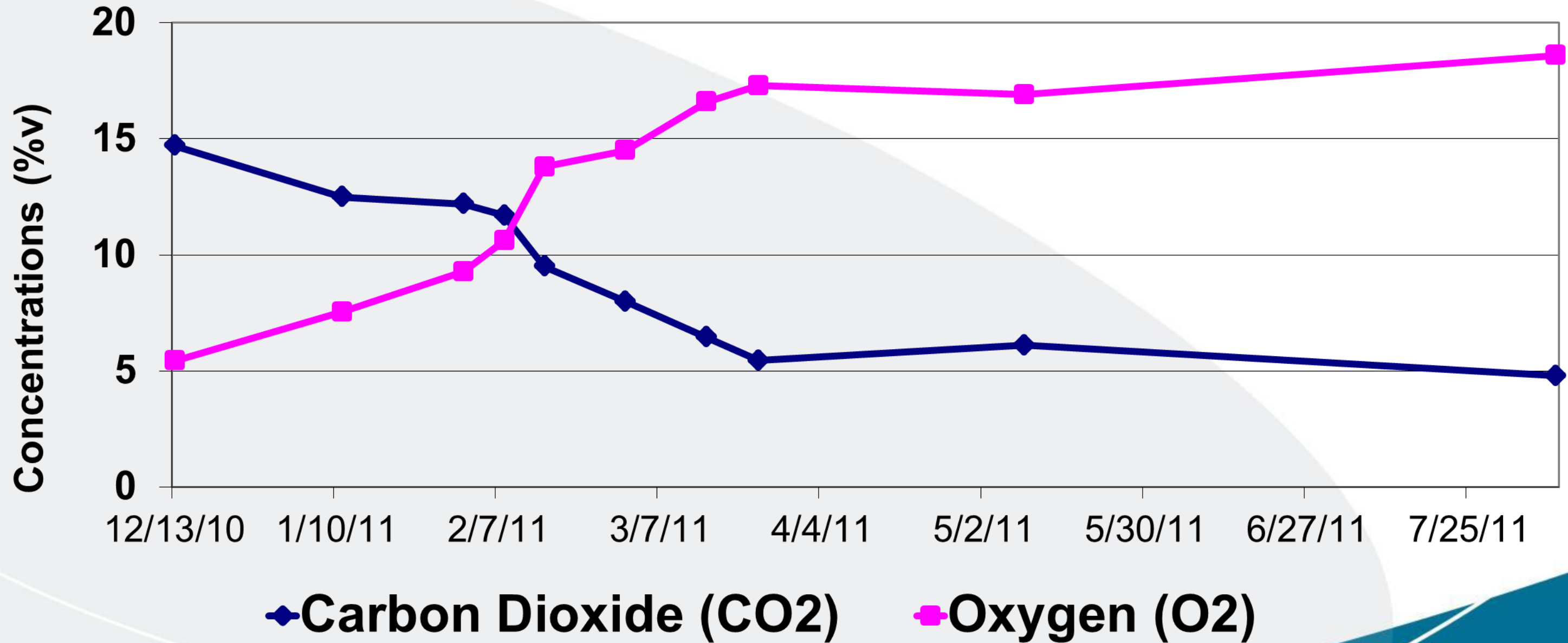
Vapor Concentration - Extraction



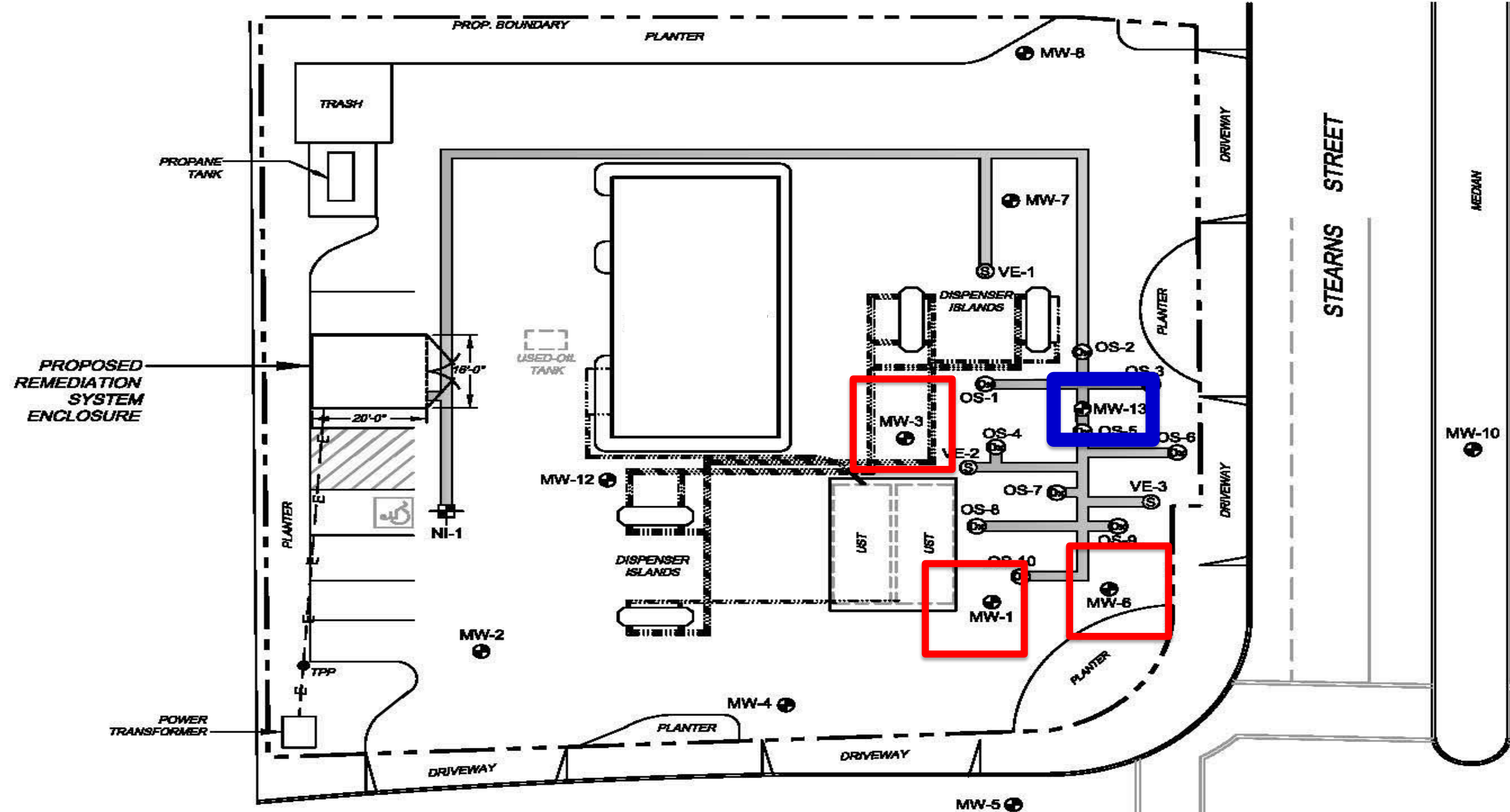
Mass Removal – Extraction Only



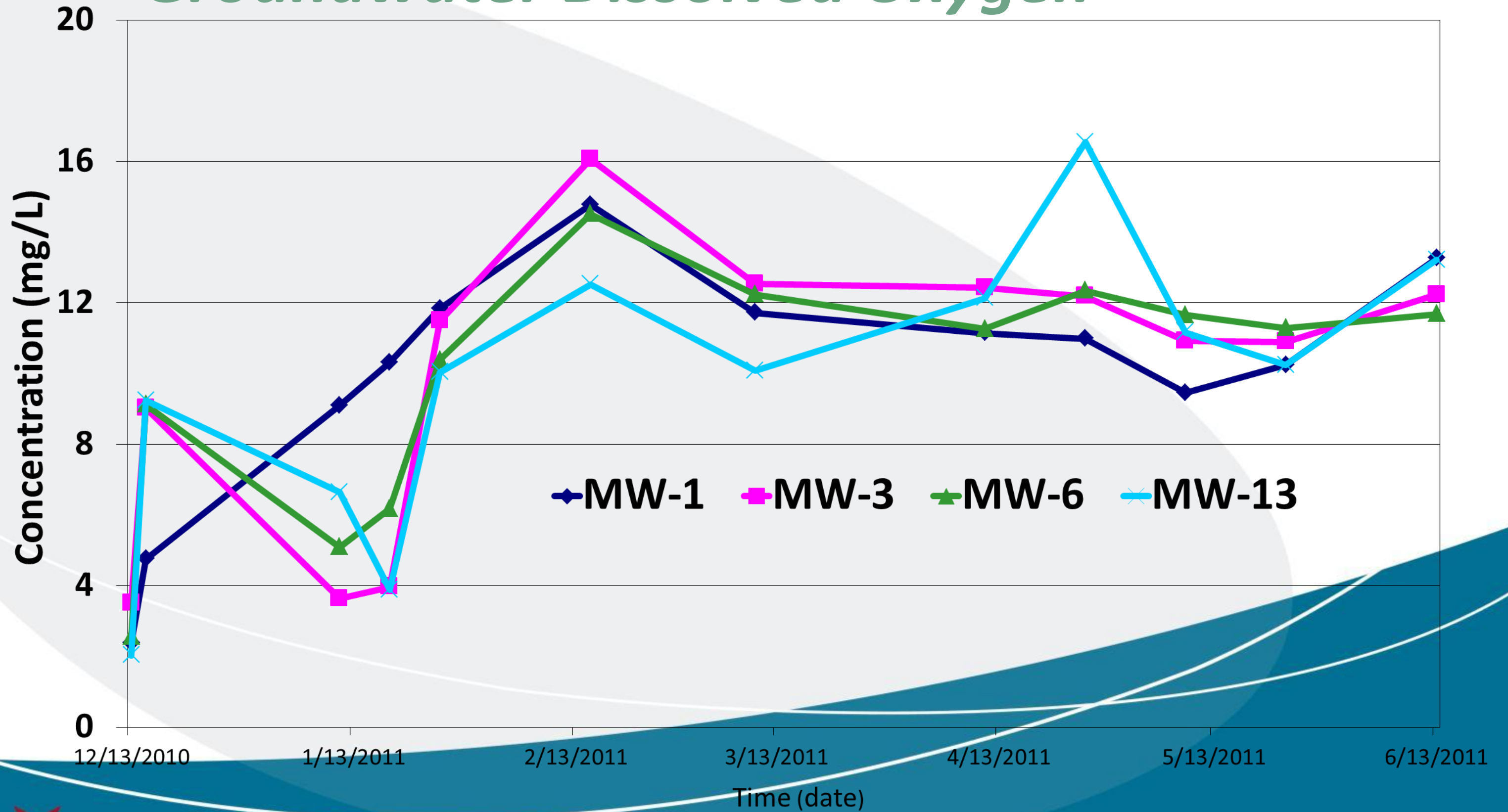
Influent Fixed Gases



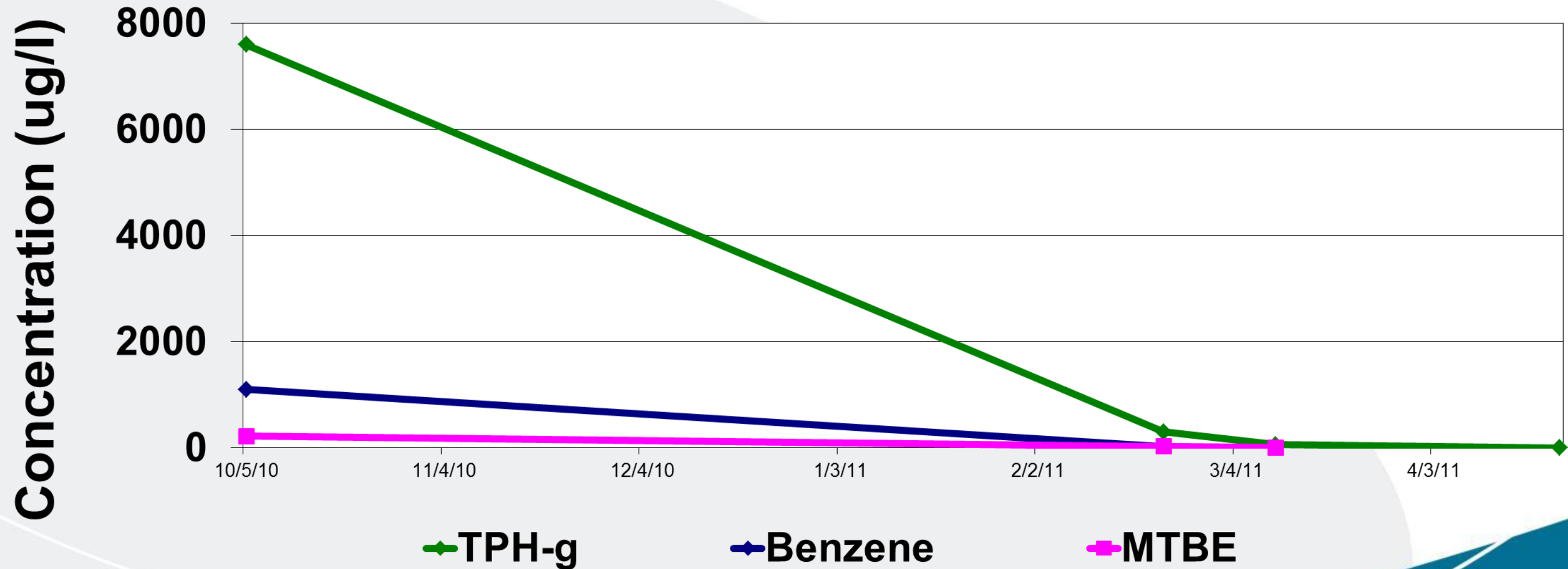
Groundwater Dissolved Oxygen & Concentrations



Groundwater Dissolved Oxygen



Groundwater Concentrations



System Advantages

- Enhanced bioremediation
- Reduction in energy costs
- Recycling of VOC's rather than destruction
 - ✓ optional equipment required
- Unaffected by the level of VOC's in extracted gas stream
- Relatively low carbon foot print w/o emissions



System Advantages

No Combustion – No Off-Gas

- No catalytic or thermal combustion
- No high temperature processes
- No supplemental fuel
- No air exhaust or emissions

- Cost Savings

- ✓ Lower electrical & fuel costs
- ✓ Lower flow rates / lower energy cost



Cost Advantages

- Other Cost Savings
 - ✓ No permit application fees
 - ✓ No annual permit fee
 - ✓ No emission monitoring labor costs
 - ✓ No emission analytical costs
 - ✓ Reduced O&M site visit costs
 - ✓ Expedited site clean up times



Ideal sites for ECO-SVE

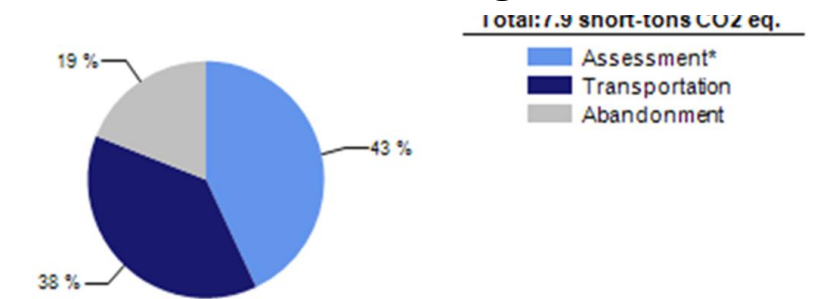
- Locations with stringent air permit & discharge issues
 - ✓ Cost to air discharge
 - ✓ Exhaust or nuisance issues
 - ✓ Monitoring requirements
 - ✓ Stakeholder issues
- Anywhere Air Sparge/Soil Vapor Extraction is applicable
- No Liquid Phase Hydrocarbons (LPH)

Summary: Green Remediation Options

Unique technological approaches:

- Sulfate-Enhanced Biodegradation (SEB)
 - ✓ Very low carbon footprint
- ECO-SVE
 - ✓ Eliminates key air emissions stream
 - ✓ Promotes *in-situ* destruction of contaminants
 - ✓ Relatively low carbon footprint

Sulfate-Enhanced Biodegradation - MNA



ECO - SVE

