Remediation Innovations

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REMEDIATION INNOVATIONS

Outline

- Innovations in Site Characterization
- Traditional Remedial Approaches
- Innovations in Remedial Technologies
  - Surfactant Flushing
  - In Situ Chemical Oxidation (ISCO)
  - Enhanced Bioremediation
  - In Situ Injection Technologies
  - In Situ Thermal Desorption
  - In Situ Heating

REMEDIATION INNOVATIONS

Innovations in Site Characterization

- Triad Approach
- MIP, LIF, HPT
- Field Labs (GC/MS, Immunoassays)
- Geophysics
- Vapor Intrusion Issues (VI)

Remediation Innovations

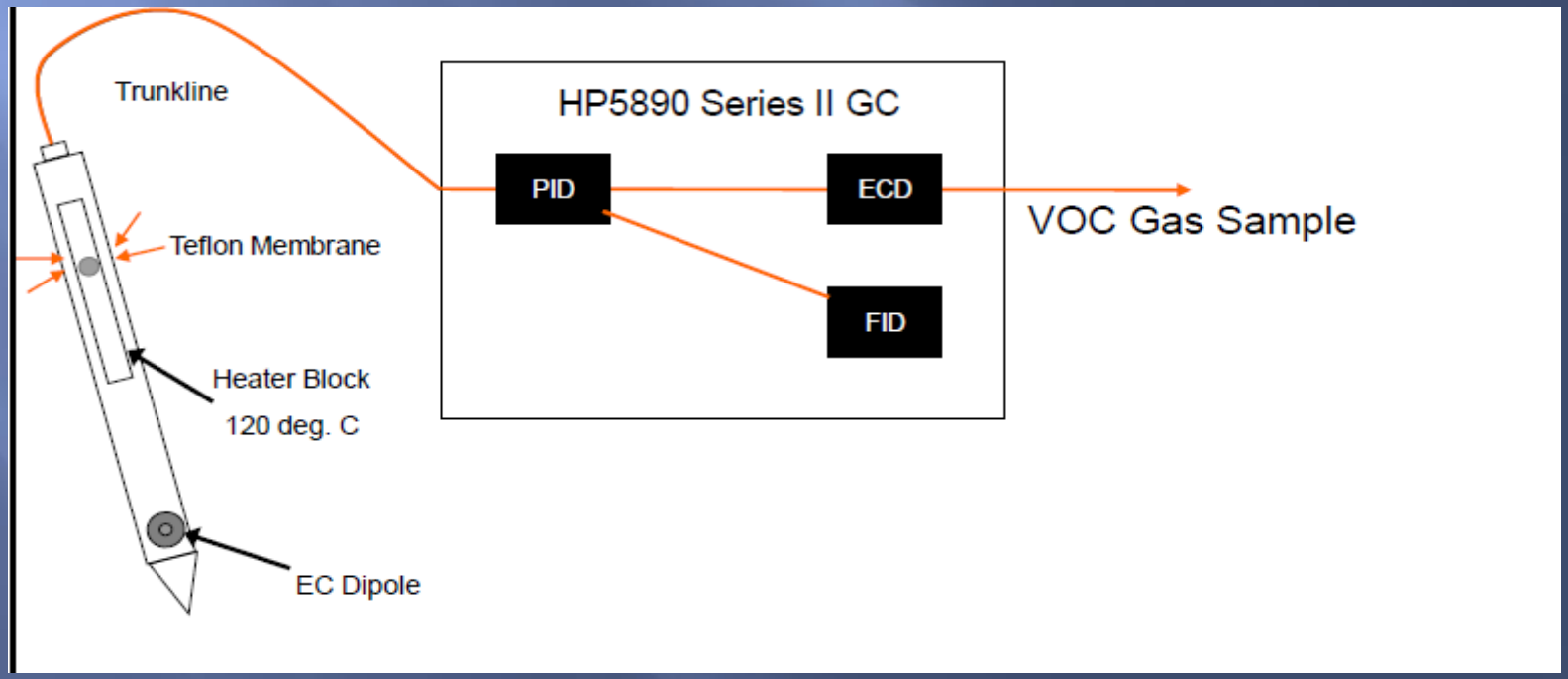
Triad Approach

REMEDIATION INNOVATIONS

Innovations in Site Characterization

MIP

- Membrane Interface Probe (MIP) Screening Tool



REMEDIATION INNOVATIONS

Innovations in Site Characterization
MIP (cont.)

- Strengths
  - Vertically continuous, real-time data
  - Can typically complete 150 to 250 linear feet of exploration per day
  - Ideal for locating source areas and plume cores
- Limitations
  - Limited depth penetration
  - Units (volts) not the same as with soil or water concentration
  - Correlations with soil/water concentrations problematic
  - Generally does not distinguish between analytes
  - Apparent "dragdown" of contamination
  - No particular NAPL signature
  - Once in NAPL the tool is highly contaminated and needs to be cleaned before continuing

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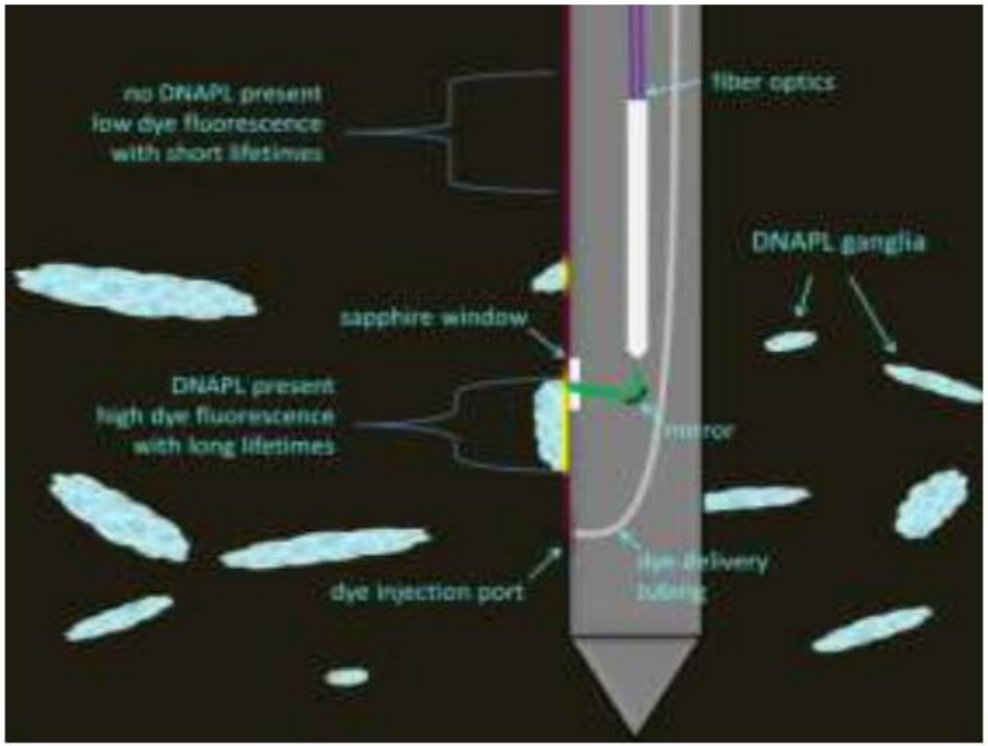
Innovations in Site Characterization

LIF

- Laser Induced Fluorescence is a powerful, high resolution, direct sensing tool for locating NAPLs consisting of aromatic compounds (e.g., fuels, coal tar etc)
- However, chlorinated solvents do not fluoresce – so LIF does not work for chlorinated solvent DNAPLS
- Dye LIF developed to overcome this limitation



Courtesy of Dakota Technologies

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Hydraulic Profiling Tool (HPT)

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GeoProbe

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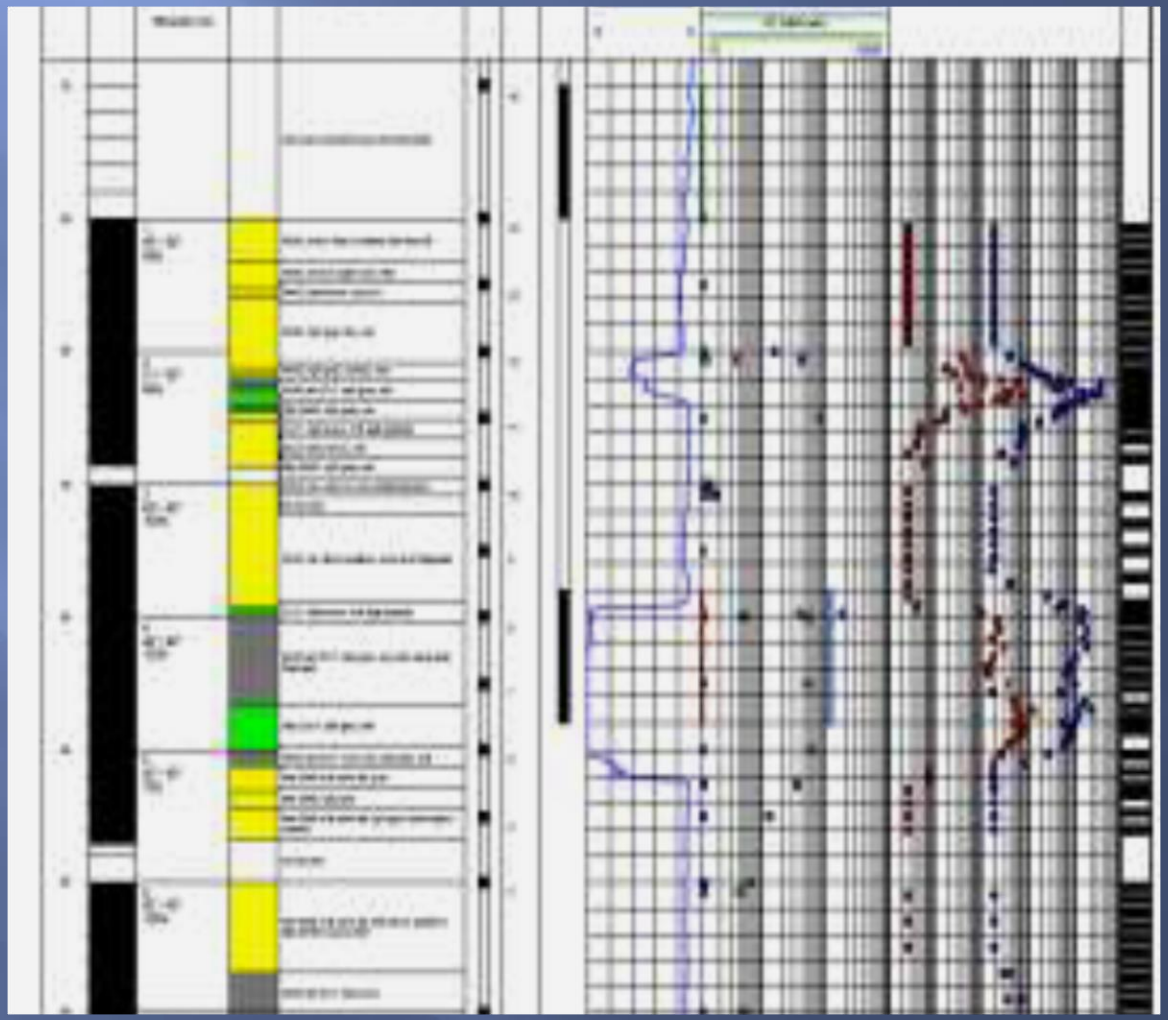
MIP/LIF/HPT Log



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Field Labs

- **Advantages**
  - Real Time Physical/Chemical Site Data
  - Real Time Data
  - Concentration Data

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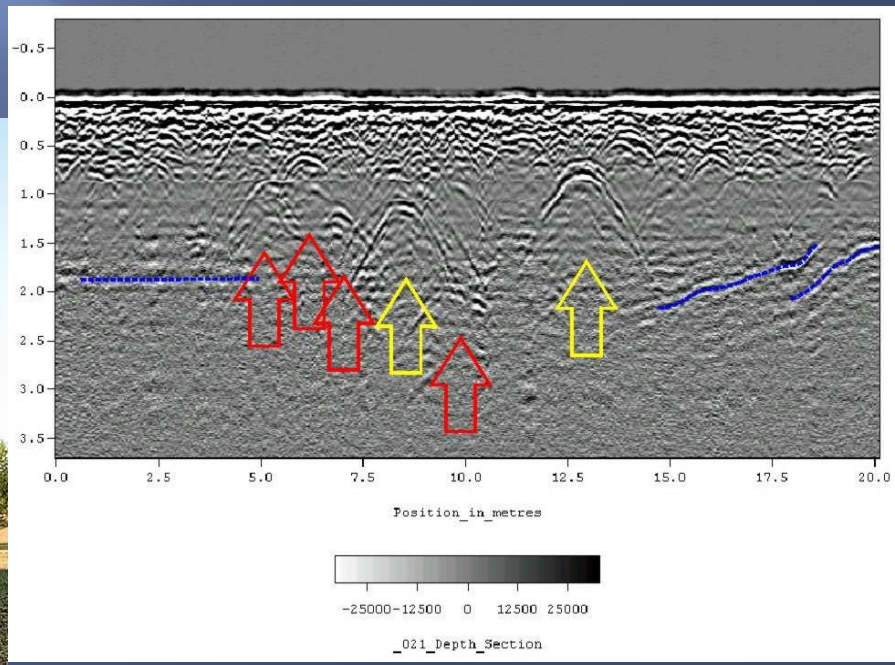
Geophysics

- Ground Penetrating Radar (GPR)
- Electromagnetic Induction (EM)
- Precision Utility Location (PUL)
- Seismic Refraction



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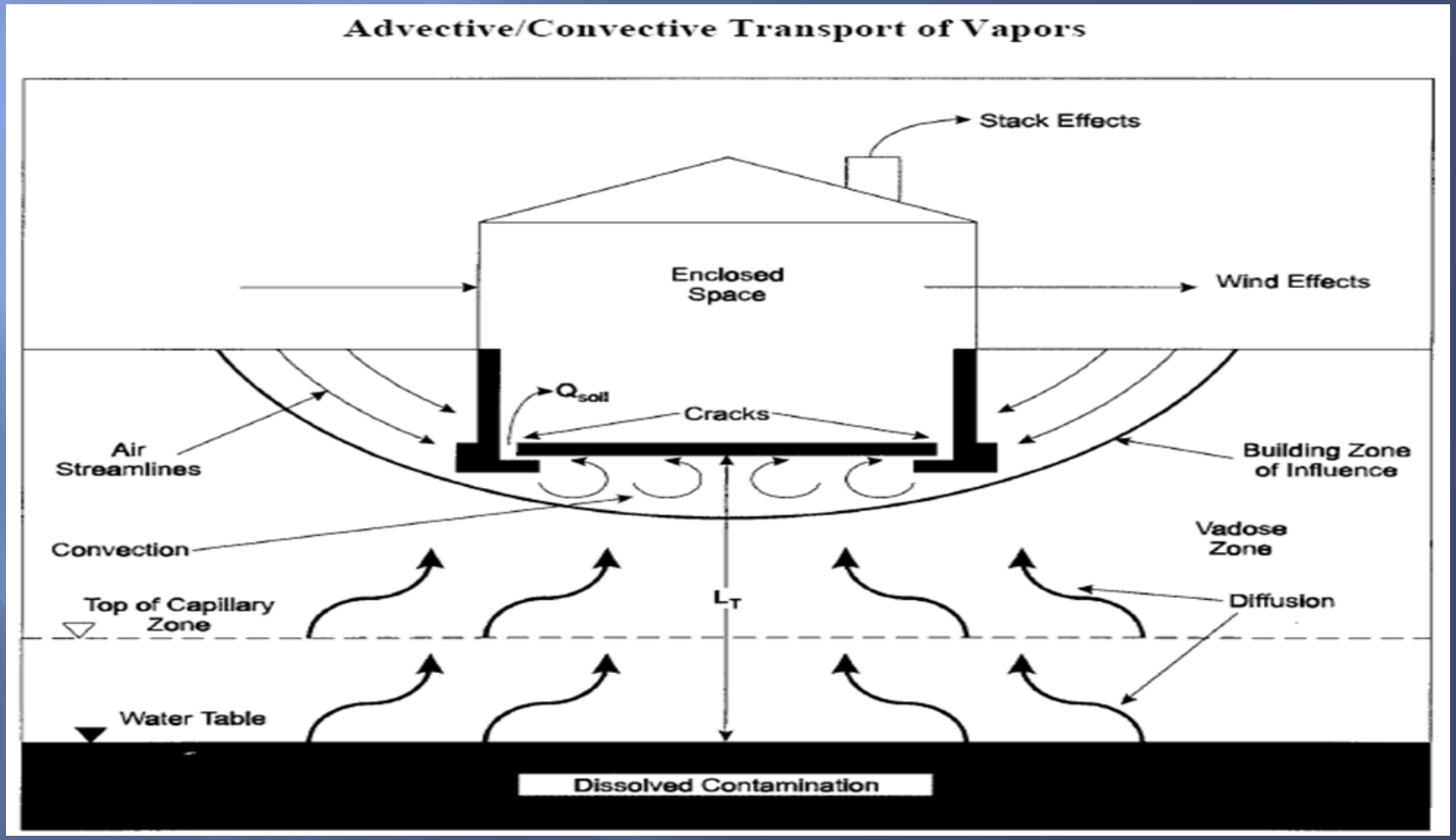
Petroleum Vapor Intrusion



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Vermont Vapor Intrusion Guidance
Petroleum Sites (or other biodegradable COCs)

- TPH w/i 5' structure, use VI Screening Values Table
  - TPH soils >100mg/kg or PID >10 ppm &/or GW above VI Screening Value, or
- TPH soils >5' from structure, use UT empirical data studies
  - TPH Soils 5-10' use TPH >100 mg/kg or PID >10 ppm &/or GW exceeds 1000 ug/l benzene or 10,000 TPH, or
- NAPL on water table within 30' of structure, or
- Residual NAPL in soils adjacent to structure foundation

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Vapor Intrusion Tools

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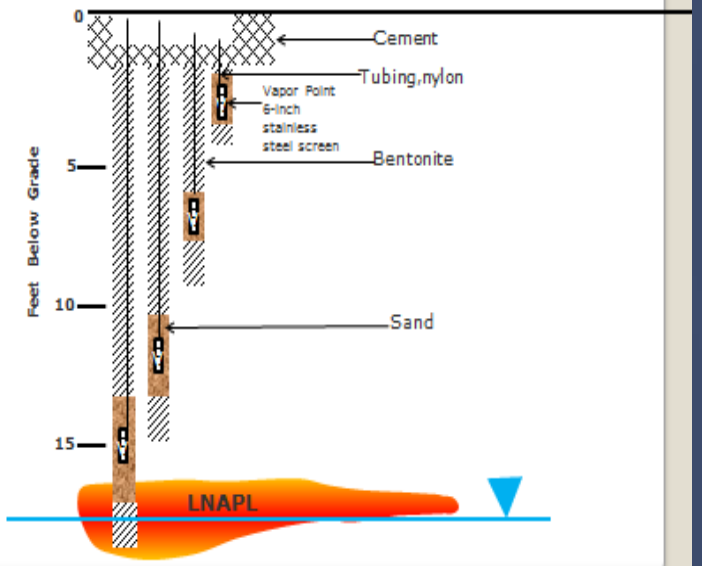
Sub-Slab Vapor Monitoring Point

Multi-Depth Vapor Monitoring Well
1x2-inch Boring for Each Completion Depth



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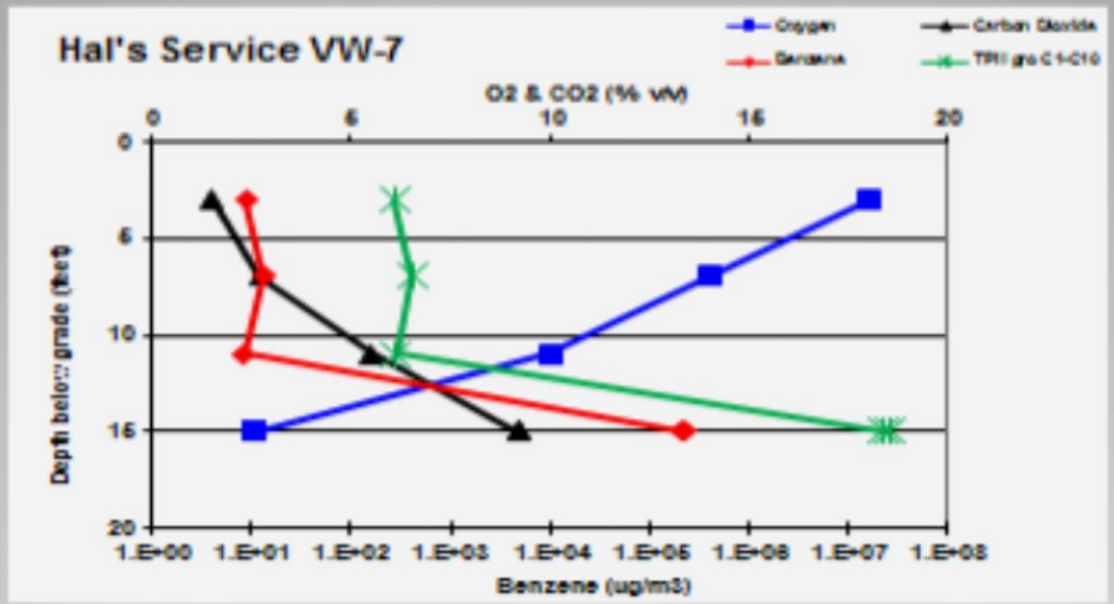
Vapor Profile Graph



- Vapor-phase petroleum hydrocarbons aerobically biodegrade with a few feet of clean overlying soil
- No vapor data for lead scavengers

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Traditional Remedial Approaches

- Soil Removal
- Groundwater/Product Pump and Treat
- Soil Vapor Extraction/Air Sparging
- Multi-phase Extraction
- Monitored Natural Attenuation

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Innovative Remedial Approaches

- Surfactant Flushing
- In-Situ Chemical Oxidation
- Enhanced Biological Degradation
  - Oxygen Additives
  - Injecting Air/Pure O2
- In-Situ Injection Technologies
  - Trap & Treat (BOS 200 with AST & RPI/KY)
  - GeoGac
  - Plume Stop (Regenesis)
- In-Situ Heating

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Surfactant Flushing

- Adding Surfactant (Soap) to scrub contaminants from soils and recover
- May need permits for UIC, POTW, NPDES, and Air
- May be Health and Safety Issues (flammability)
- Can greatly increase the recoverability of LNAPL
- Can help reduce residual phase contamination; thereby greatly improve groundwater quality

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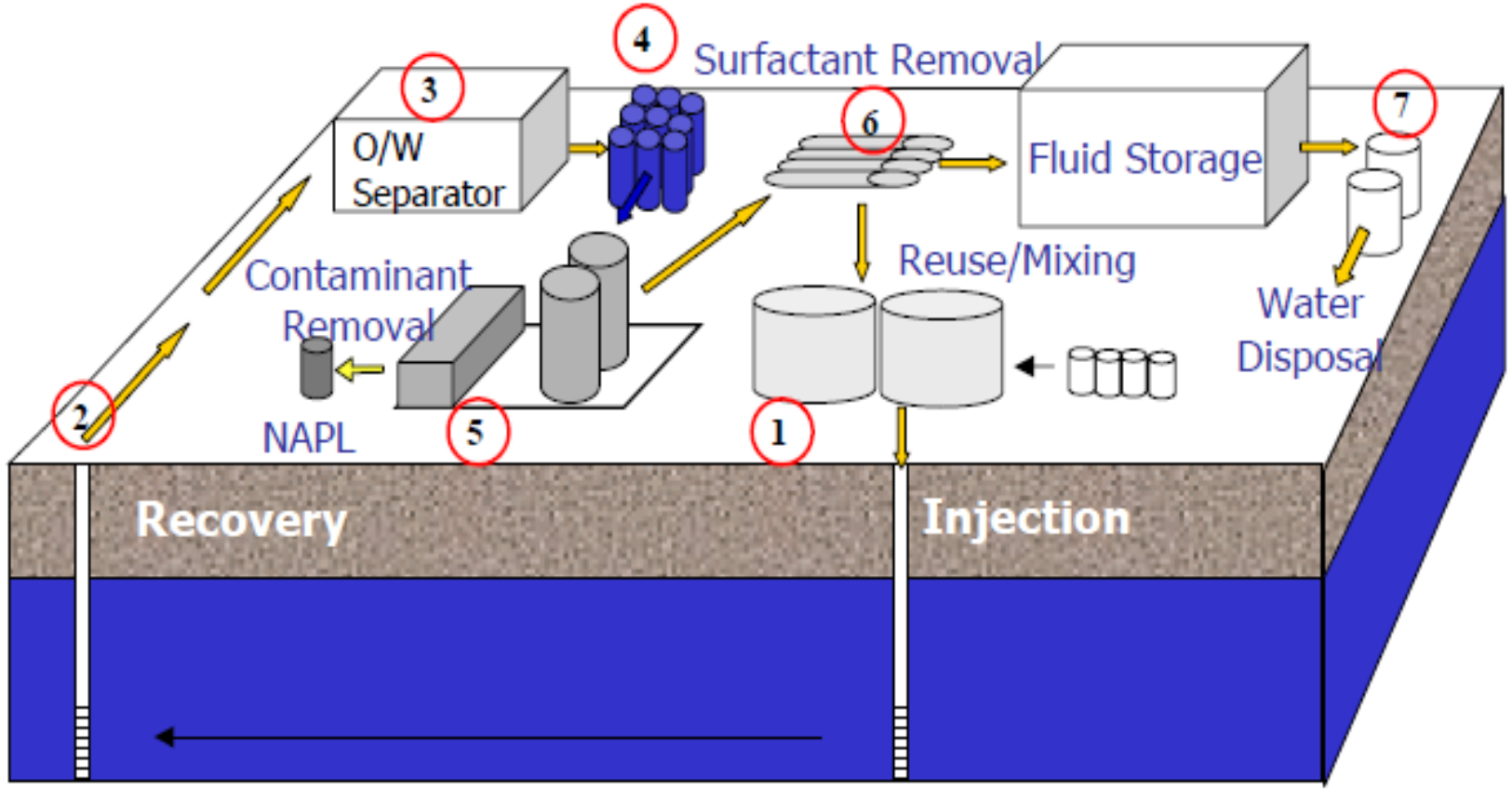
Schematic of Surfactant Flushing System



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In-Situ Chemical Oxidation (ISCO)

Technology Basis

Geosyntec consultants

- Addition of an oxidant to promote direct oxidative destruction of organic contaminants to acceptable end products (e.g., CO_2, H_2O, chloride)
- Various oxidants are in common use:
  - Catalyzed hydrogen peroxide
  - Ozone
  - Permanganates
  - Persulfate
  - Solid phase peroxygens

Potassium Permanganate Delivery System

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Technology Basis

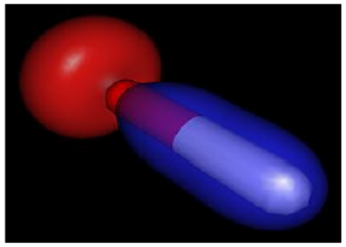
Geosyntec consultants

- Oxidation is accomplished by the direct contact of a reactive chemical species with the contaminant(s) of concern
- Example: Hydrogen peroxide mixed with ferrous iron at low pH results in formation of a hydroxyl radical which acts as the reactive species:

1. $Fe^{+2} + H_2O_2 \rightarrow Fe^{+3} + OH\cdot + OH^-$
2. $Fe^{+3} + H_2O_2 \rightarrow Fe^{+2} + OOH\cdot + H^+$

Hydroxyl Radical

- The radical then reacts with the contaminant, resulting in non-regulated by-products and CO_2
- Direct oxidation also occurs
  - Ozone, permanganate, peroxide and persulfate anion



Hydroxyl Radical

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Conceptual Design

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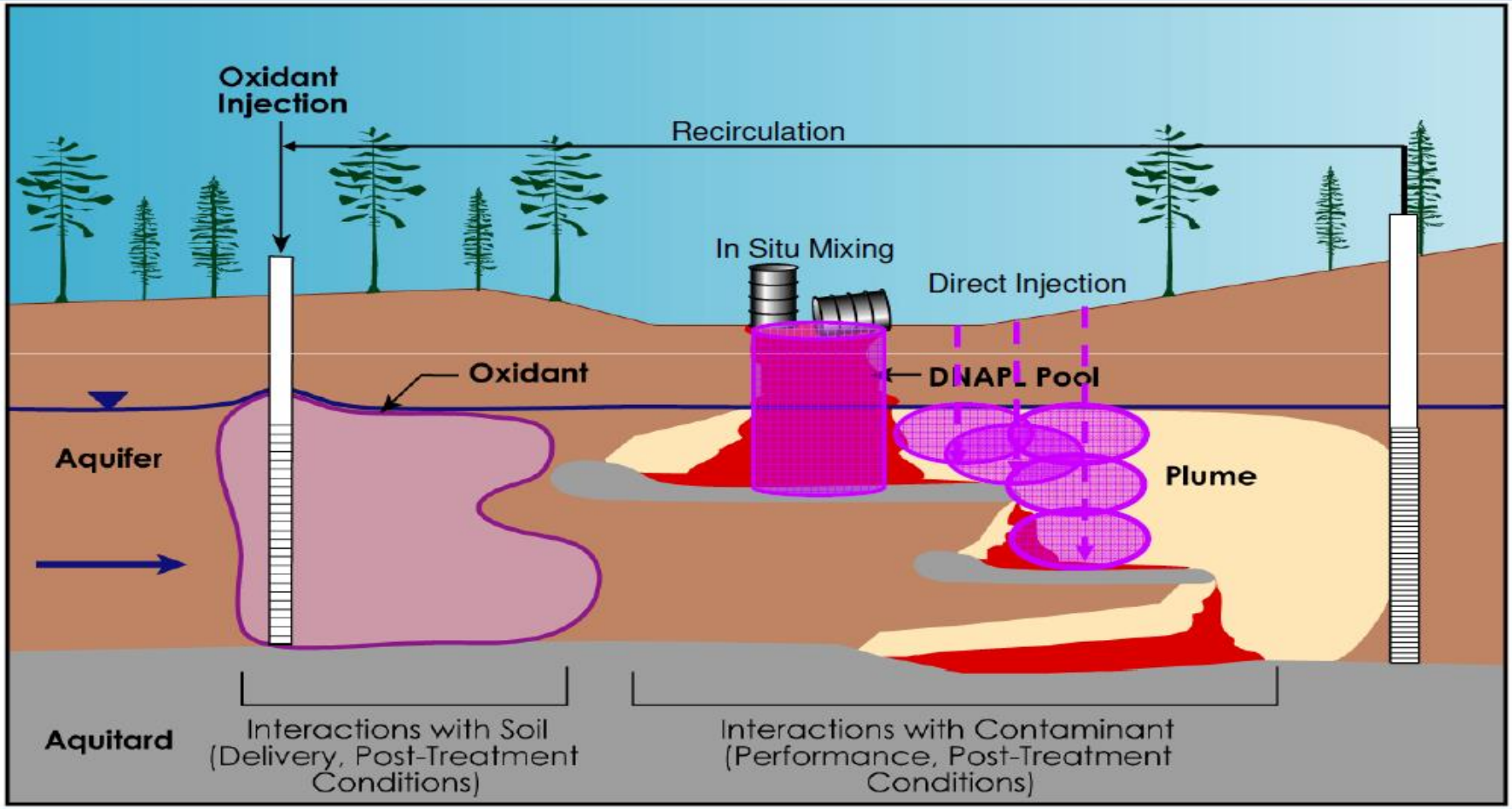

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ISCO - Pros and Cons

Geosyntec consultants

Pros

- Rapid treatment with mass destruction, in-situ
- Selection of proper oxidant allows of treatment of wide spectrum of chemicals
- Applicable in overburden and bedrock
- Appropriate for source zones or "hot spots"
- Generally innocuous end products
- Accepted by most regulatory agencies

Cons

- Natural oxidant demand (NOD) consumes oxidant
- Delivery limited by heterogeneity or low permeability
- Post-treatment rebound
- Can mobilize certain metals
- Health and safety concerns
- Often not cost effective for dispersed or dilute plumes
- Injection and storage permit requirements

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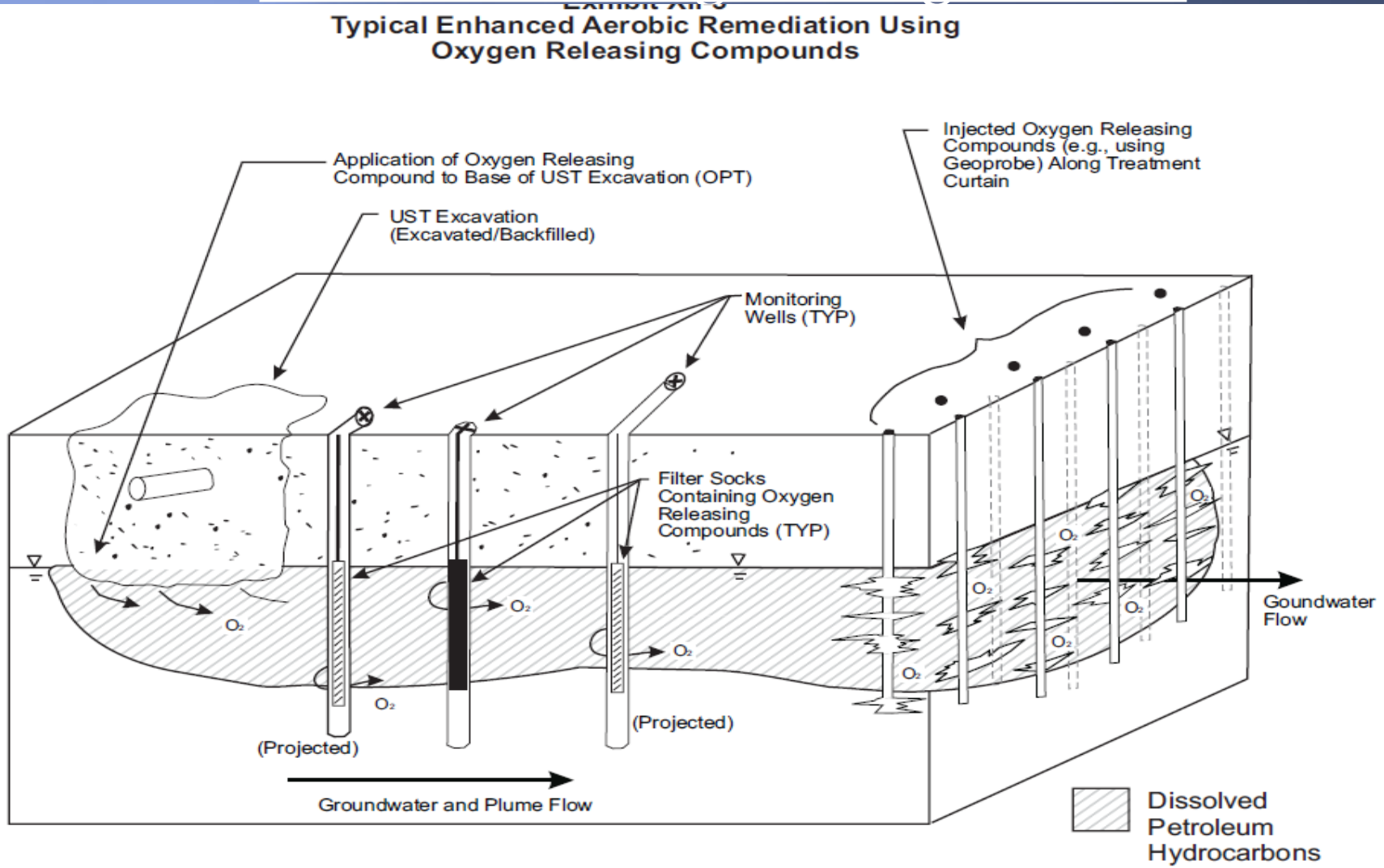
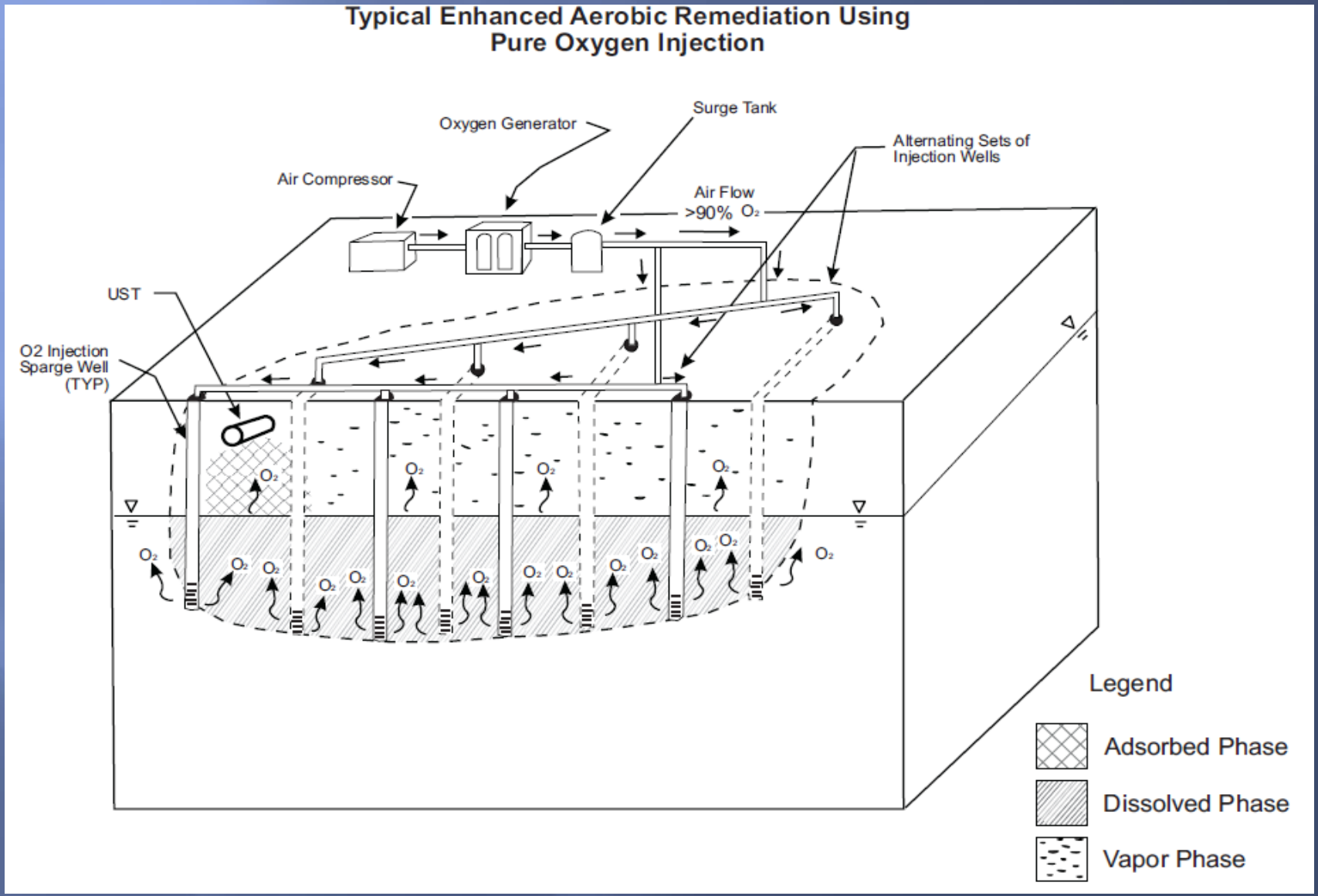
- **Enhanced Biological Degradation**



Remediation Innovations



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In-Situ Injection Technologies

"Trap and Treat®"

- Overcomes Site Constraints
- Safe Solution
    - Predictable Results
    - Longevity
    - Cost Effective
    - Rapidly Achieves Objectives

Specialty Engineered and Manufactured In-situ Remediation Products by Remediation Products, Inc. (RPI)

Remediation Innovations

BOS 200

A Carbon/Biological Based Product consisting of:

Activated Carbon — Time Release TEAs (Nitrate, Sulfate)
Micro and Macro Nutrients — Nitrogen for Cell Growth

Blend of Over 27 Species of Microorganisms

Two primary treatment mechanisms take place with BOS 200®:

The first mechanism is the "Trap": BOS 200® uses activated carbon to adsorb petroleum hydrocarbons.

Biodegradation, the "Treatment", is the second mechanism of BOS 200® remediation.

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More on BOS 200®…

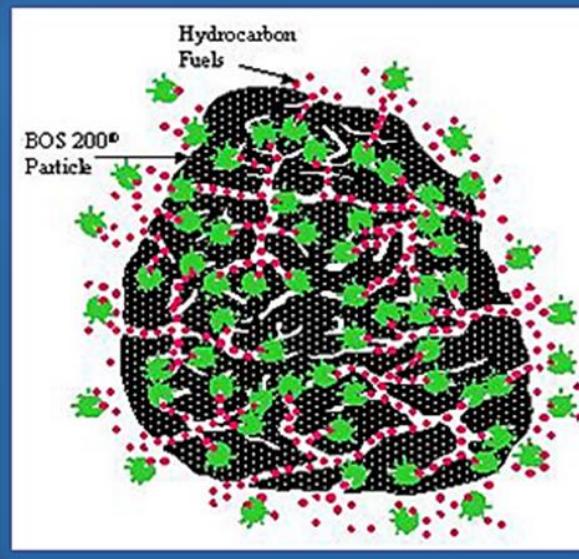
- An ideal environment for the biological process, where hydrocarbons are adsorbed on to BOS 200® particles made up of:

  -Electron Acceptors: oxygen, nitrate, and sulfate

  - Nutrients – phosphorus, nitrogen, etc.

  -Aerobic and Anaerobic Blend of Microbes

- Initially, Aerobic but then Anaerobic (Oxidation to Sulfate Reduction)



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BOS 200® - Versatility

- Treatment for a Wide Range of Hydrocarbons
- LNAPL to Dissolved Plume Remediation
- Overburden and Bedrock Applications
- Plume Wide Treatment and Barrier Applications
- Achieve Remedial Goals with a Single Installation
- Passive System - Long Term Treatment
- Control Back Diffusion

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Remediation Innovations

Keys for Successful In-situ Remediation Using Injection

- High Resolution Sampling to Determine Total Mass and Distribution of Mass in Formation
- Implementation Techniques “Distribution”
- Longevity of Product – BOS 200®
- Safe, Effective, and Predictable

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GeoGac

Chemically Oxygenated Granular Activated Carbon

Designed to provide

- Chemical oxidation
- Aerobic bacterial growth
- Carbon Adsorption

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1 pound of Activated Carbon can have as much as 3 million square feet of surface area for adsorption.

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- Sodium persulfate activated by calcium peroxide.

- Using calcium peroxide instead of hydrogen peroxide slows the reaction time.

- Leaves groundwater with elevated DO and also provides sulfate as electron acceptor and nutrient

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Plume Stop (Regenesis)

- Wide dispersion of sorptive medium in aqueous state
- Sorbs contaminants (removes from aqueous state)
- High surface area for microbial growth
- Diffuses throughout the soil matrix

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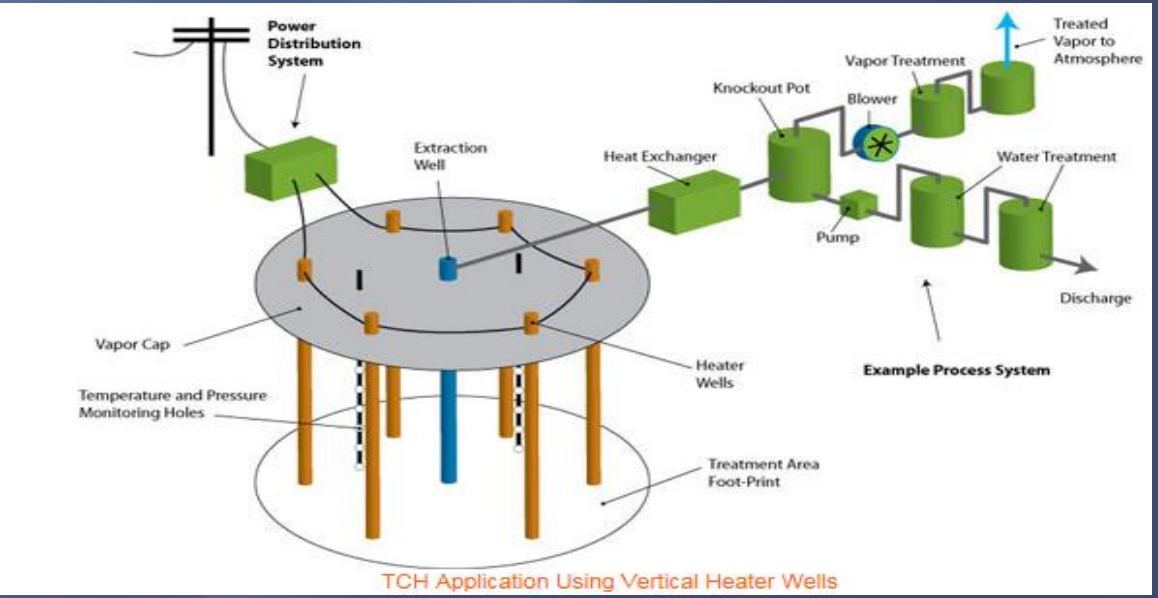
In-Situ Thermal Desorption

- Heat and vacuum applied volatilizing contaminants to be recovered by vacuum
- Temperatures up to 1300 ° F
- 90-95% of contaminant mass destroyed in situ
- Uses large amounts of Electricity



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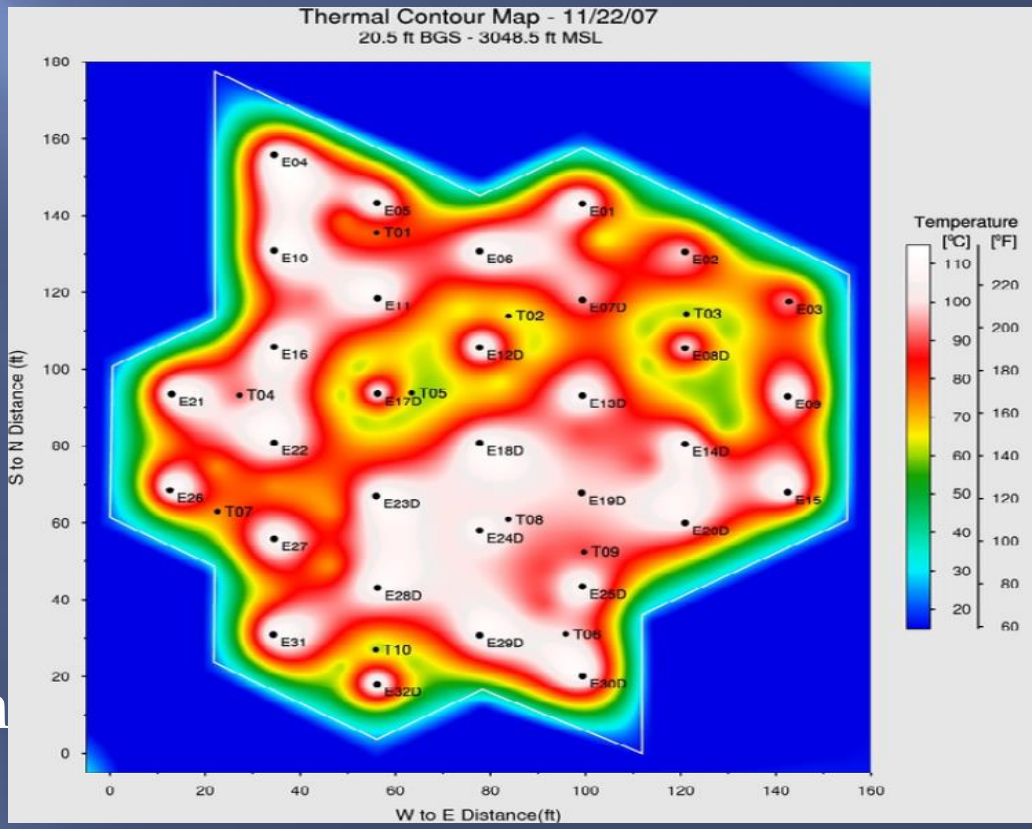
In Situ Heating

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- A variety of soil types are present, causing the ground to heat unevenly.
- The soil has a lot of organic matter, which causes chemicals to stick to the soil and not evapora



Remediation Innovations

ERH system cleans up contaminated soil and groundwater.

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Conclusions

- Innovative Site Characterization Approaches can improve Innovative Remedial Approaches Chance of Success
- Traditional Remedial Approaches May Still Be Appropriate for Remediating LUST Sites, but may be more expensive and less environmentally friendly
- Innovative Remedial Approaches like Surfactant Flushing, ISCO, Enhanced Biological Degradation, and In-Situ Injection Technologies may be more cost effective and environmentally friendly to implement than traditional methods; BUT, you must know and trust the consultant proposing these technologies