Remediation Technologies 101

EBC Ascending Professionals &
Site Remediation and Redevelopment Webinar

EBC

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Introduction to In-Situ Remedies

Jason McNew

Vice President Client Programs

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Remediation Technologies 101
Introduction to Site Remedies

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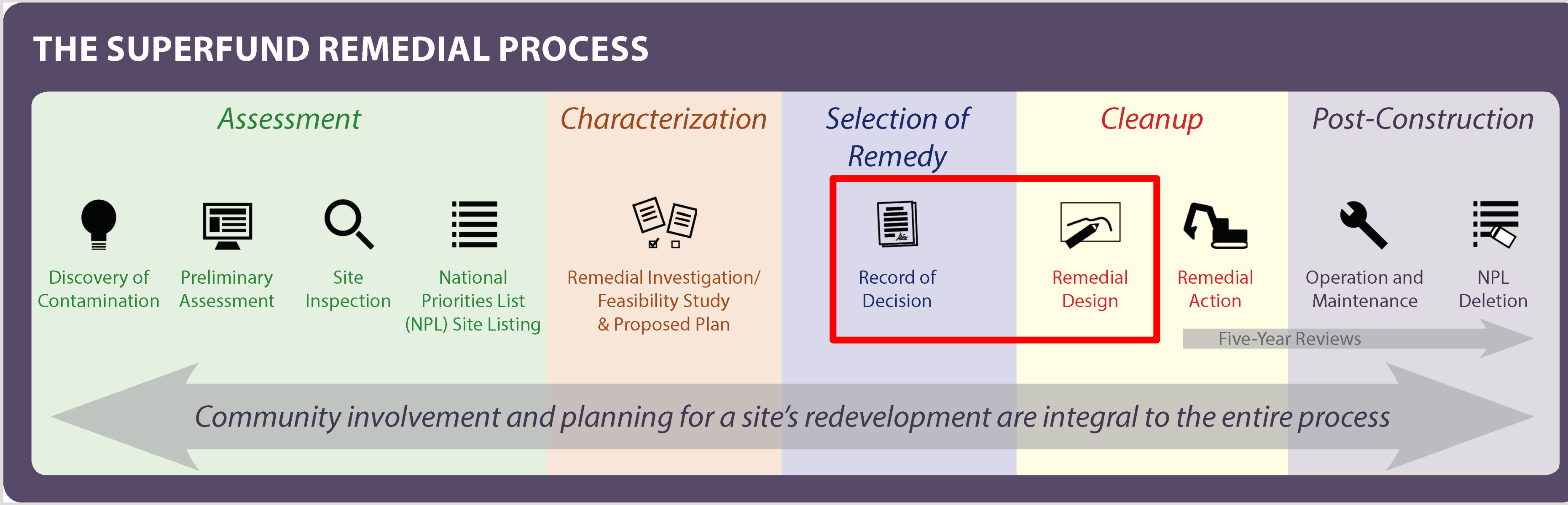
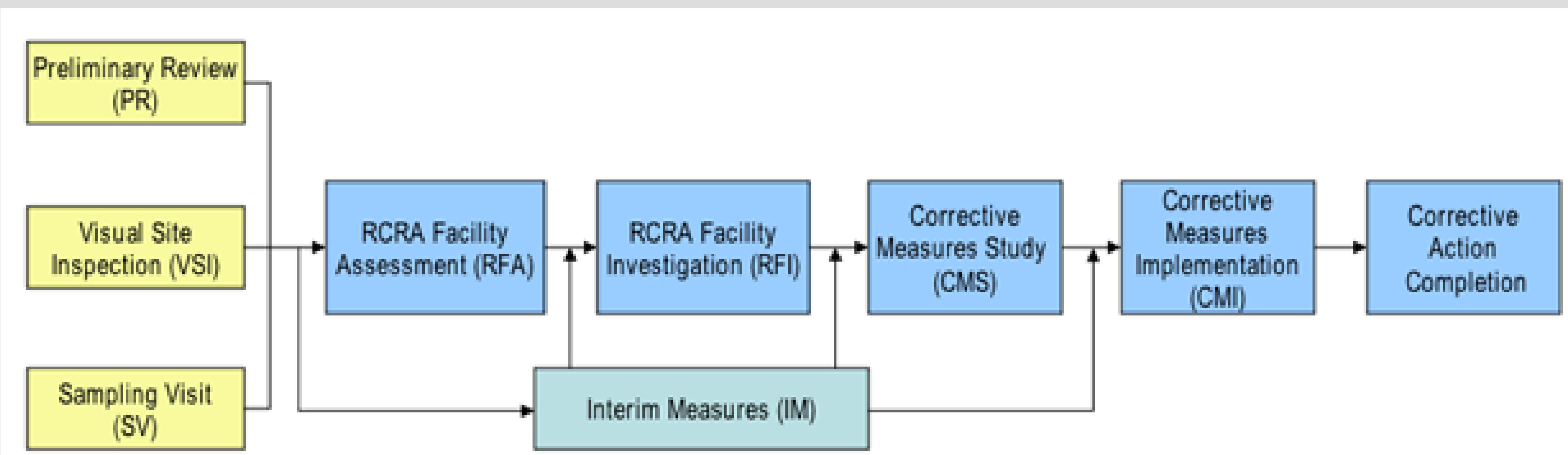
May 14, 2024

Project Life Cycle





Remedy Evaluation and Design Phases

- Feasibility Study
  - Screen technologies, then develop and evaluate potential remedies (remedial alternatives)
  - Compare against 9 criteria (usually) – cost, implementability, short and long term effectiveness, meeting ARAs, protects human health/environment, etc.
  - Conclusion: Proposes a remedy → Proposed Plan - public review/comment
  - States may have their own process/guidance
- Decision Document – selects remedy
  - In EPA world – Record of Decision (ROD)
  - Again, states have their own process/document
- Remedial Design
  - Basis of design, design itself, performance objectives, etc.

Remedy Evaluation

- Typically completed as Feasibility Study (FS)
  - Identify and evaluate potential remedies (remedial alternatives)
  - Compare against 9 criteria (usually):
    - Overall Protection of Human Health and Environment
    - Compliance with ARARs (laws and regulations)

      } Threshold Criteria
    - Long-term effectiveness
    - Short-term effectiveness
    - Reduction of toxicity, mobility, or volume through treatment
    - Implementability
    - Cost

      } Balancing Criteria
    - Regulatory acceptance
    - Community acceptance

      } Modifying Criteria
  - "Score" the alternatives on these criteria, then rank

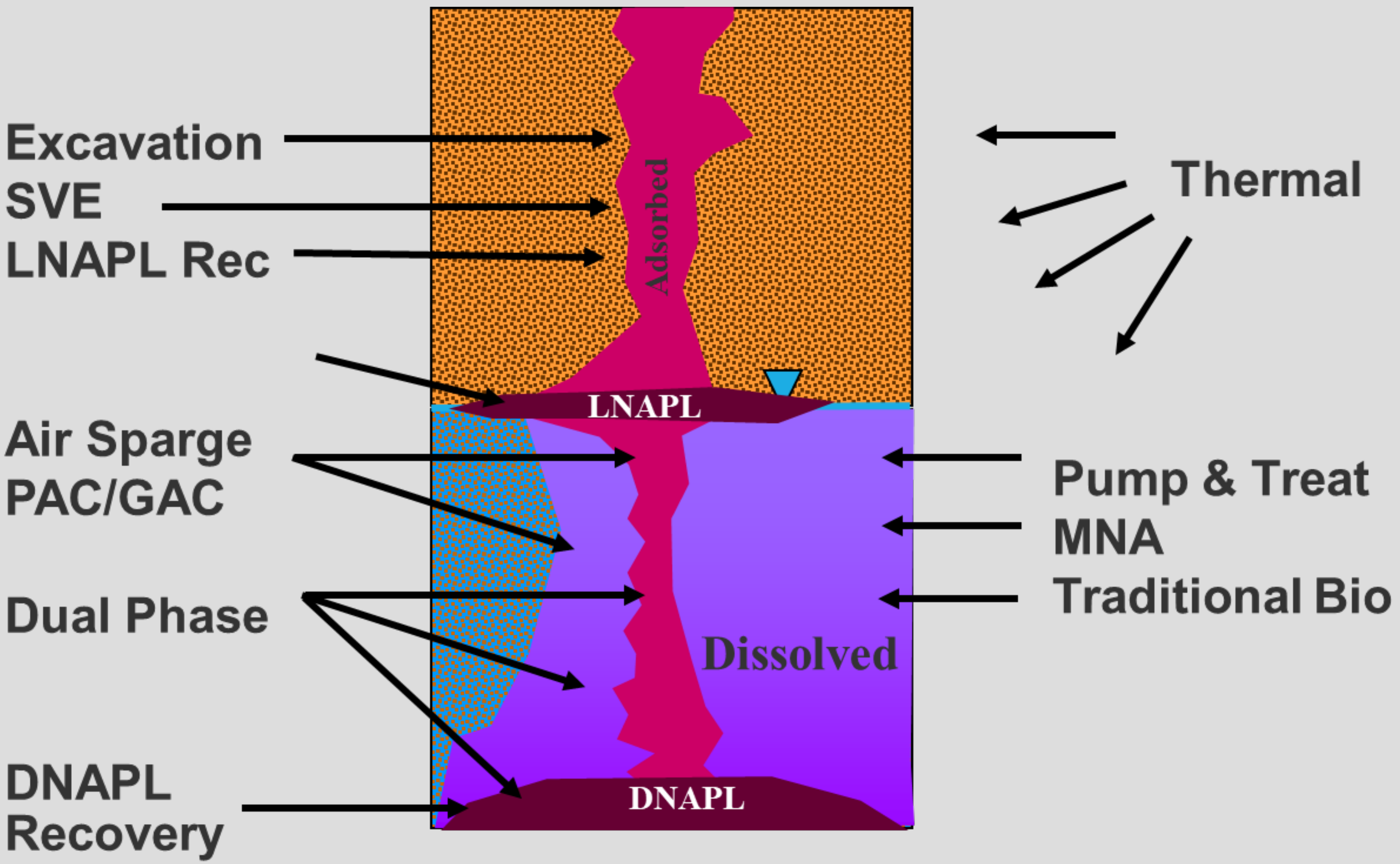
Source Area vs. Non-Source Area Treatment

- Magnitude of remedy is driven by magnitude of contamination
- Contamination is sometimes broken up into 2 “areas”: source area and non-source area
- Source Area
  - Highest area of contaminant mass, primary source of risk, primary source of contaminant migration
  - Typically requires more aggressive remediation
  - Examples: Large contaminant mass in soil, NAPL in groundwater, etc.
- Non-Source Area
  - Lower concentration areas, typically secondary source of risk, typically the “receiver” of contamination migrating from the source area
  - Typically requires less aggressive remediation, but sometimes the hardest to remediate
  - Examples: Downgradient groundwater plumes

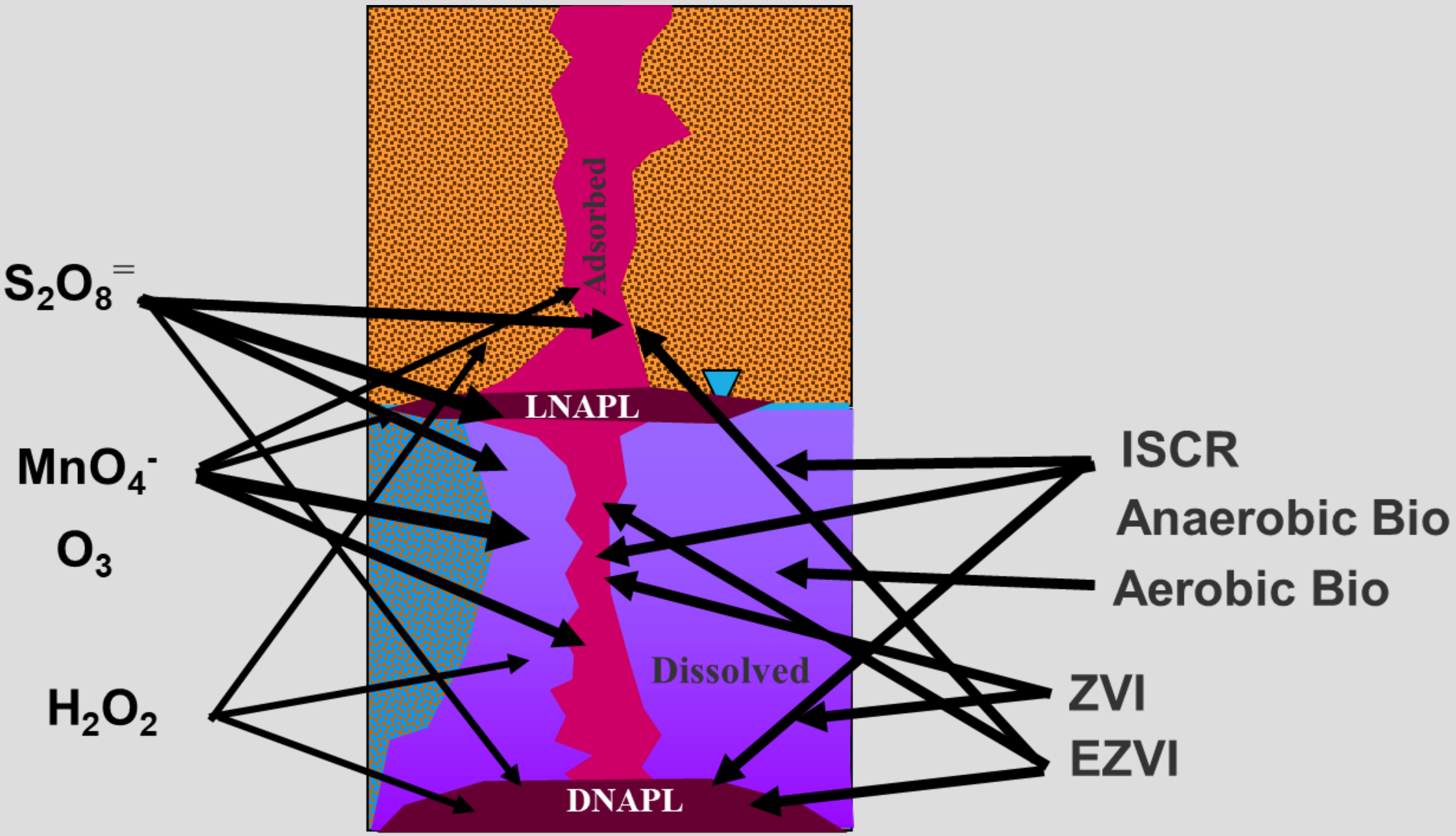
Remedy Selection Drivers

- Identified Risk
  - What risks are present? What contaminant(s) is driving it? How can you mitigate exposure?
- Remedial Goals can be developed to:
  - Remove all contaminant mass to directly address risk(s)
  - Remove enough contaminant mass to address direct risk(s) and address secondary contamination (e.g., soil leaching to groundwater, soil/groundwater contamination vaporizing, etc.)
- Timeline
  - Is the risk imminent? Do you need to address the contamination quickly?
  - Can you establish a barrier to prevent exposure and let than operate for years?
- Treatment can consist of:
  - Addressing unsaturated zone, saturated zone, or both
  - Addressing only one media or multiple media
  - Multiple technologies to address multiple media
- Need to understand extent of contamination, what media is impacted, and how each media/COC type can be addressed
- Also need to consider how multiple remedies may help or hurt each other

Technology Overview



Technology Overview – Chem/Bio



Unsaturated Zone Treatment (Soil)

- Also known as vadose zone (surface to top of groundwater table)
  - Excavation and Off-Site Disposal
  - Solidification/Stabilization
    - Mixing in reagent with soil to “bind” contaminants, prevent leaching
  - Capping
    - Physical barrier to prevent access/volatilization
  - Soil Vapor Extraction
    - Applying a vacuum to subsurface to collect/treat vapors
  - Bioventing
    - Low flow injection of oxygen to promote biodegradation
  - Thermal Treatment
    - Heating subsurface to promote volatilization
  - Land Use Controls
    - Administrative controls to prevent exposure (access restrictions, land use restrictions)

Saturated Zone Treatment (Soil/Groundwater)

- Top of groundwater to your target depth (confining layer, extent of contamination, etc.)
  - Excavation and Off-Site Disposal
    - Need to consider dewatering and limits to how deep you can feasibly go
  - Air Sparging / Vapor Extraction
    - Injecting air into groundwater to promote volatilization and then collect/treat vapors
  - Thermal Treatment
    - Heating subsurface to promote volatilization
  - In Situ Injections
    - Chemical oxidation (e.g., persulfate, permanganate, hydrogen peroxide)
    - Chemical reduction (e.g., zero valent iron)
    - Enhanced bioremediation (e.g., carbon source, microbes, nutrients)
  - Pump and Treat
    - Extraction and treatment of groundwater
  - Monitored Natural Attenuation
    - Not active - utilizing natural degradation processes, and monitoring to ensure meeting goals
  - Land Use Controls
    - Administrative controls to prevent exposure (don't drink the water)

Groundwater Extraction and Treatment

- Commonly called Pump and Treat
- Extraction of groundwater using wells/trenches
- Treatment of extracted groundwater
  - Air stripper: VOCs
  - Granular activated carbon (GAC): VOCs, SVOCs, metals, PFAS, etc.
  - Advanced oxidation: VOCs, SVOCs, PFAS??
  - Biological: Various COCs
- Discharge to surface water body, sewer, surface, or re-injection
- Components
  - Wells
  - Pumps
  - Plumbing
  - Treatment components
  - Building?
  - Control systems (SCADA), Variable Frequency Drives (VFDs)

Groundwater Extraction and Treatment

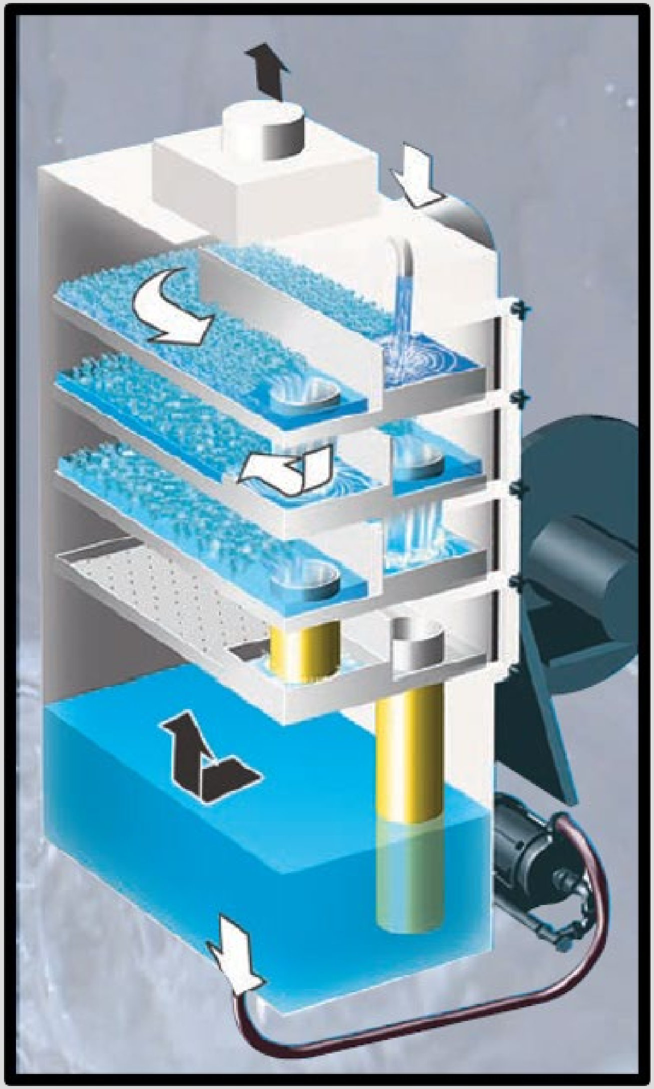
Groundwater Pumping Wells

Groundwater Treatment Building

Indoor Treatment Facility

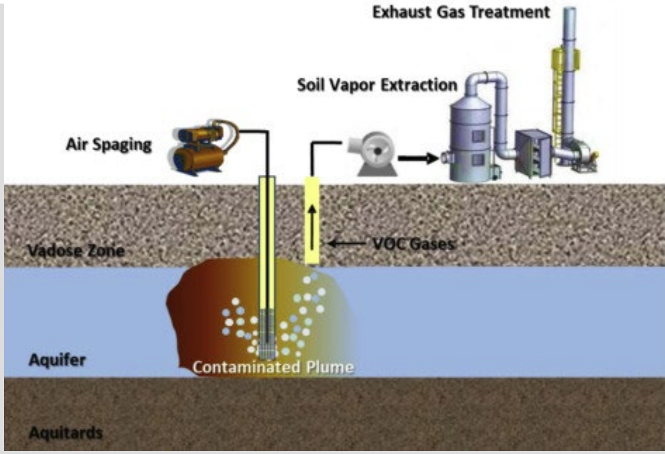
Outdoor Treatment Facility

Groundwater Extraction and Treatment



Air Sparging/Soil Vapor Extraction

- Promote volatilization and capture of vapors
- Typically AS with SVE, or SVE alone
- Each uses blowers (either positive pressure or vacuum)
- Injected air into groundwater "bubbles" out contaminants
- Vapors captured through series of extraction wells in vadose zone
- Captured vapors (and condensate) typically treated with activated carbon
- Key item is to ensure vapor capture



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EBC Environmental Business Council of

Monitored Natural Attenuation (MNA)

- Do Nothing?? Not really…
- Contaminants will naturally degrade in environment
- This remedy consists of monitoring to document and ensure that contaminants are attenuating (i.e., cleaning up as expected
- Usually has triggers where active remedy becomes required
- Applies when no current risk is present, but potential/hypothetical future risk
- Requires fair amount of up front investigation and data evaluation to prove attenuation is occurring

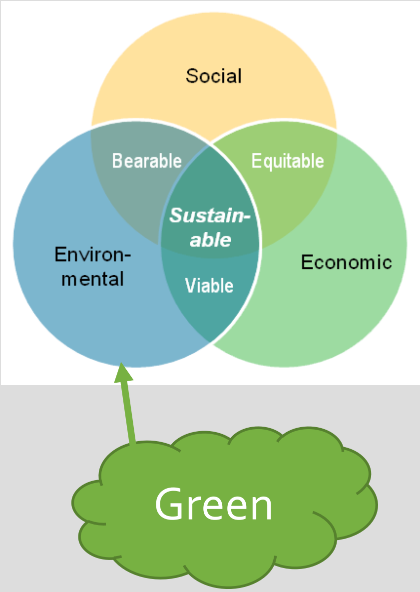
Land Use Controls (LUCs)

- Controls set in place to prevent/limit exposure
- Can be:
  - Administrative
  - Legal
  - Engineered
- For groundwater, common LUCs are:
  - Groundwater use restrictions (deed restrictions)
  - Government classifications to prevent new wells
- For soil, common LUCs are:
  - Land use/build/dig restrictions (deed restrictions)
  - Access restrictions (fencing, security, etc.)
- Also known as institutional controls, environmental covenants
- Common when cleaning up soil/groundwater is not practical/feasible and there are no current exposures
- Can be used in conjunction with connecting people to municipal water (abandoning private water wells)
- Typical for sites with active remedies until cleanup is completed

Sustainability and Resilience

- Sustainable Remediation
  - Maximize benefits and minimize unintended impacts of remediation ("green")
  - Consider energy use, emissions, water/resource use, land impacts, waste, etc.
  - Also consider the economic and social impacts of the remedy
- Remedy Resilience
  - Ensure remedy is resilient to changing climate
  - Consider increased flooding, drought, storm frequency/intensity, sea levels, wildfires, etc.
  - Typically perform vulnerability study, then incorporate resilient features into the remedy design

Lots of opportunity for young professionals in this realm…



Elevated electrical controls for full-scale groundwater extraction

Introduction to Bioremediation

Will Caldicott

Director of Remediation Technologies

ISOTEC

INTRODUCTION TO BIOREMEDIATION

Will Caldicott

Remediation Technologies 101
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May 14, 2024

ISOTEC REMEDIATION TECHNOLOGIES

WILL CALDICOTT

- ISOTEC Director of Remediation Technologies
- MS from Yale School of the Environment

ENHANCED BIOREMEDIATION

ISOTEC REMEDIATION TECHNOLOGIES

- Modification of site subsurface conditions to stimulate activity of bacteria in order to biodegrade organic contaminants

- Biostimulation: addition of nutrients, carbon source(s), electron acceptors (oxygen, nitrate, sulfate), and/or pH buffers to increase the metabolic rate of native soil microbes

- Bioaugmentation: addition of target beneficial microorganisms that are absent or not uniformly distributed

ENHANCED BIOREMEDIATION

ISOTEC REMEDIATION TECHNOLOGIES

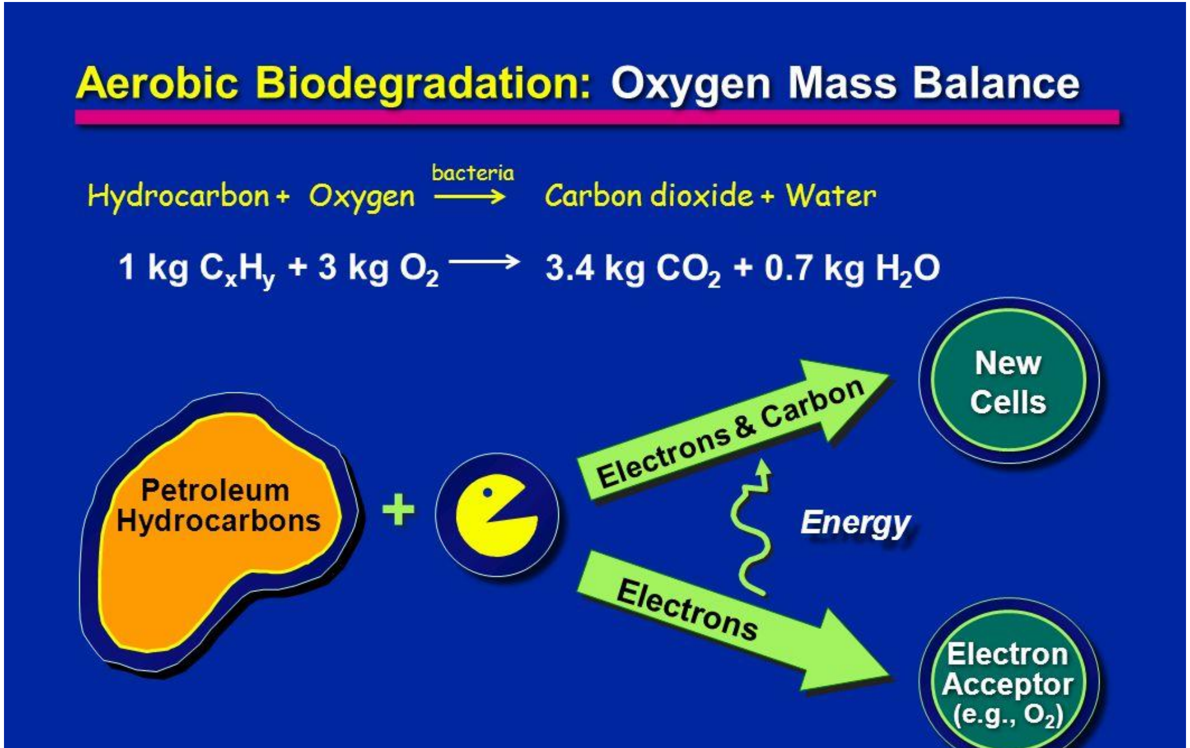
- Bioremediation occurs by numerous pathways
- <u>Aerobic Biodegradation:</u> biodegradation performed by bacteria that use oxygen
- <u>Anaerobic Biodegradation:</u> biodegradation performed by bacteria when oxygen is not present
- Cometabolism: energy is not gained from fortuitous reaction with contaminant as another compound is being metabolized

AEROBIC BIOREMEDIATION

- Biodegradation of organic contaminants occurs more rapidly under aerobic conditions
- Most commonly applied to stimulate biodegradation of petroleum hydrocarbons
  - wide range of naturally-occurring bacteria can degrade petroleum hydrocarbons
  - dissolved oxygen concentrations of 1 milligram per liter (mg/L) or greater
- Oxygen is quickly consumed in groundwater due to rapid aerobic biodegradation and relatively low solubility of oxygen in water

Aerobic Bioremediation = apply oxygen

AEROBIC BIOREMEDIATION

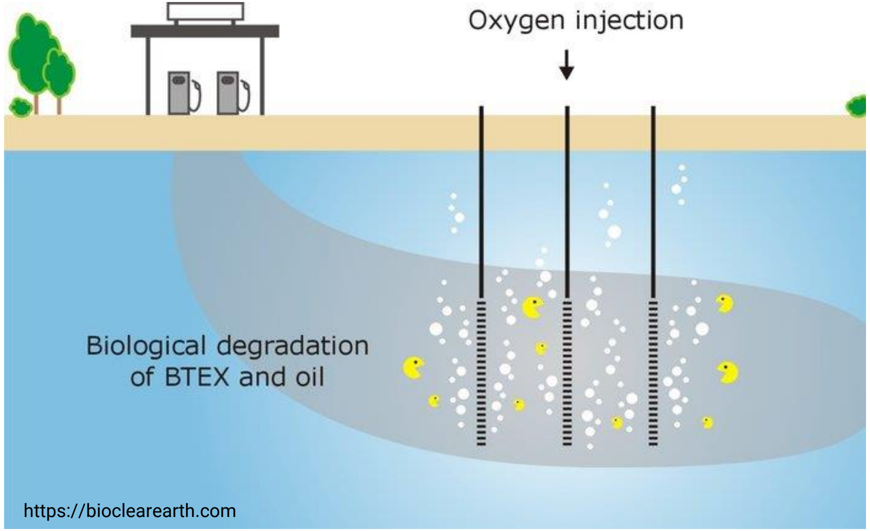


Source BioVapor

AEROBIC BIOREMEDIATION – HOW?

Aerobic Bioremediation = apply oxygen

- Inject air / oxygen (biosparging)
- Inject hydrogen peroxide (reaction product is oxygen)
- Apply oxygen releasing compounds (calcium peroxide)



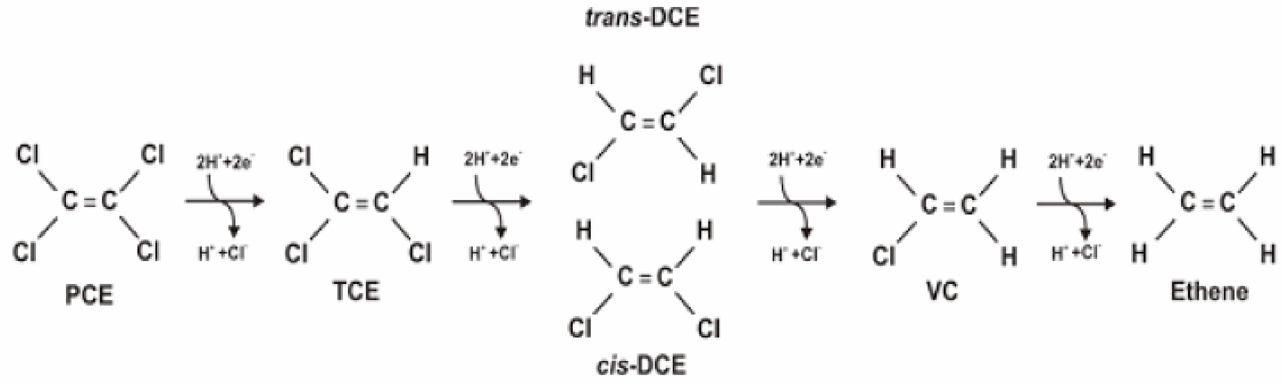
ENHANCED ANAEROBIC BIOREMEDIATION

- Addition of an electron donor to soil to increase the activity of anaerobic bacteria to biodegrade anaerobically degradable contaminant
  - Most commonly treat chlorinated solvents
    - Tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), vinyl chloride (VC), 1,1,1-trichloroethane (1,1,1-TCA), dichloroethane (DCA)

- Other contaminants that can be anaerobically degraded:
  - certain pesticides/herbicides, pentachlorophenol (PCP), perchlorate, nitrate, nitroaromatic explosives (TNT, RDX), dyes, chlorofluorocarbons (CFCs), benzene/toluene/ethylbenzene/xylene (BTEX)

ENHANCED REDUCTIVE DECHLORINATION

ISOTEC REMEDIATION TECHNOLOGIES



- Sequential reactions where each step replaces 1 chlorine with 1 hydrogen
- Eventual product is non-toxic ethene

ANAEROBIC BIOREMEDIATION – HOW?

ISOTEC REMEDIATION TECHNOLOGIES

- Provide carbon source / electron donor
- Soluble/Quick Release
  - Lactate, methanol, molasses, high fructose corn syrup
- Slow-Release
  - Emulsified vegetable oil, whey powder
- Solid products
  - Mulch, compost, shells
- Bioaugmentation

EVO stock solution diluted to selected dosage

Bacteria Culture Keg

Flow meter on each leg (pressure gauge at well points)

CAPE COD CASE STUDY

ISOTEC REMEDIATION TECHNOLOGIES

- Septic systems: ~85% of wastewater on Cape Cod
  - Large dilute nitrate plumes in groundwater flow into coastal waters
  - Eutrophication – Poor Water Quality, Loss of Habitat, Aesthetic & Economic Impacts

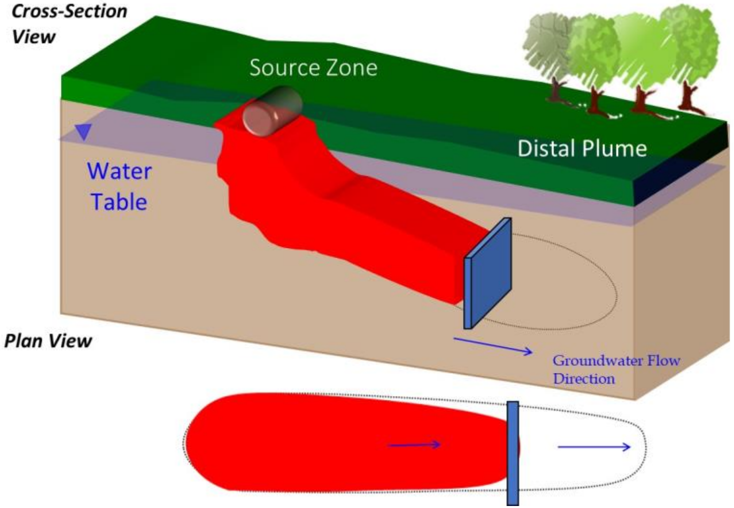
(Boston Globe, 2011)

- USEPA has issued orders to reduce nitrogen discharge into coastal water bodies under the Clean Water Act

CAPE COD CASE STUDY

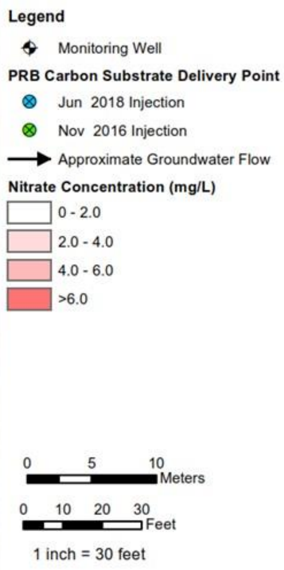
ISOTEC REMEDIATION TECHNOLOGIES

- Apply emulsified vegetable oil into injection points to establish a reactive barrier to intercept nitrate in groundwater
  - On-going treatment observed more than 7 years after EVO injection



CAPE COD CASE STUDY

NOVEMBER 2016
(Pre-Injection)



SUMMARY

- In-situ treatment with limited site disturbance
- Low costs compared with other remediation technologies
- Demonstrated to degrade wide range of contaminants
- Low carbon footprint

    Sustainable Remediation

THANK YOU

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Bioremediation

Chemical Oxidation / Chemical Reduction

Surfactant Remediation

Bedrock Injections

Treatability Laboratory

Activated Carbon Injectates (BOS 100® & BOS 200®)

Soil Mixing

Locations Nationwide
Lawrenceville, NJ (Headquarters)
Denver Area
Boston Area
Atlanta Area
San Diego
Connecticut

Introduction of In Situ Thermal Remediation

John LaChance

Vice President – Development

TerraTherm, Inc.

What is Thermal Remediation?

TerraTherm Think Thermal Webinar Series

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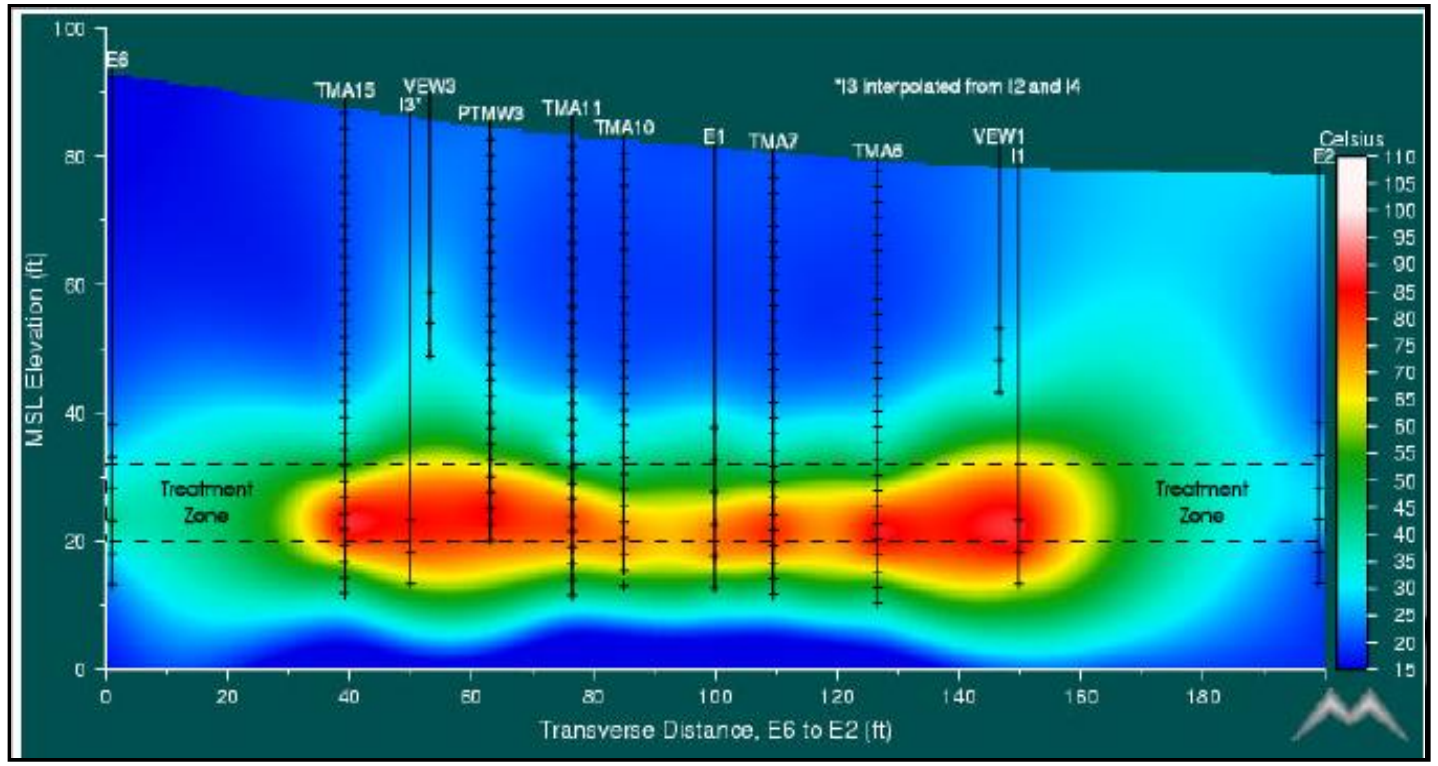
John LaChance

VP of Development

What is Thermal Remediation?



Traditional Thermal Remediation is *Fast!*

- Source zone technology – sweet spot
- Employs heat to volatize organic chemicals
- Chemical and water vapors are:
  - Captured by vacuum
  - Brought to the surface
  - Treated before discharge
- Multiple Heating Methods:
  - Thermal Conduction Heating (TCH)
  - Electrical Resistance Heating (ERH)
  - Steam Enhanced Extraction (SEE)

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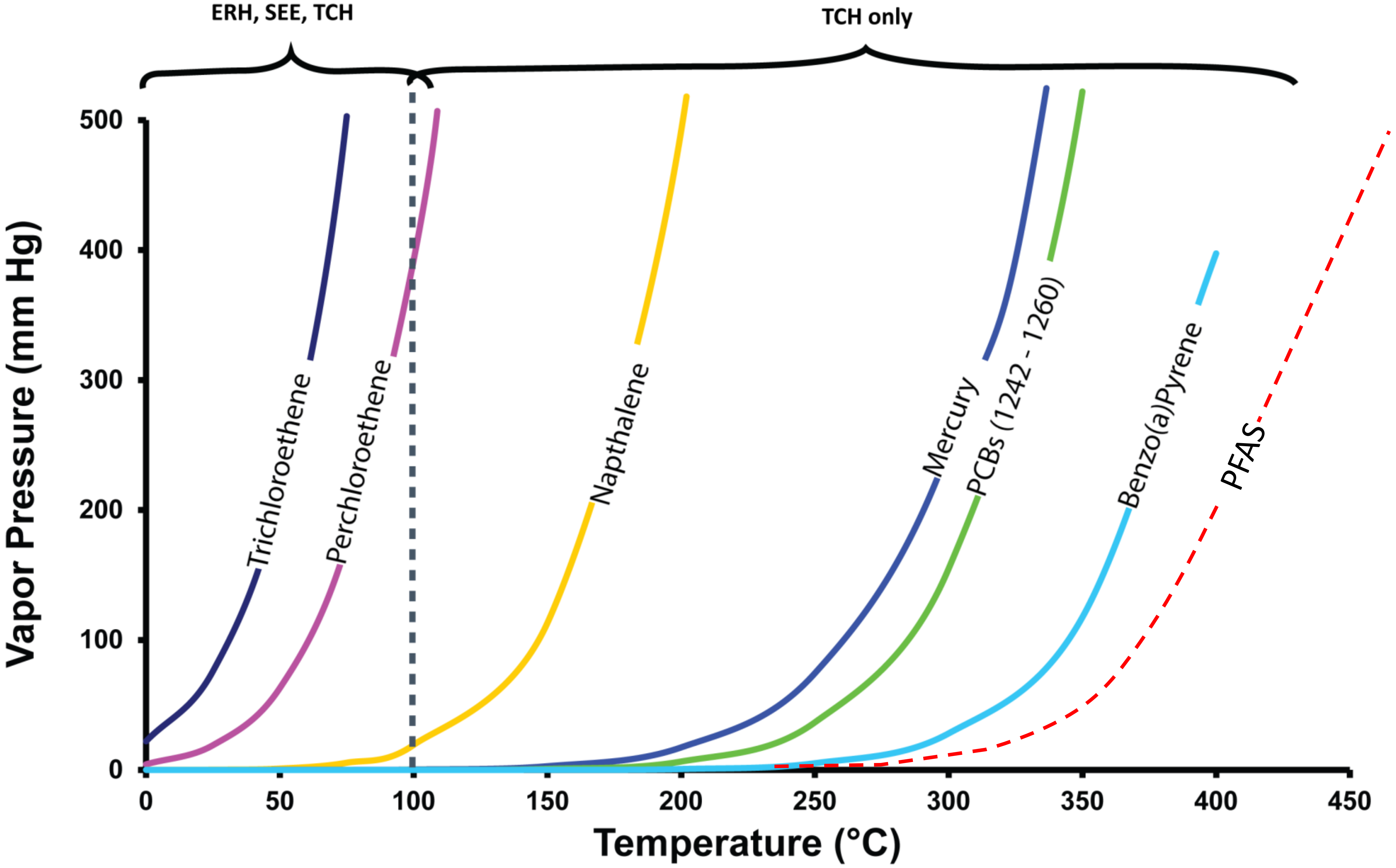
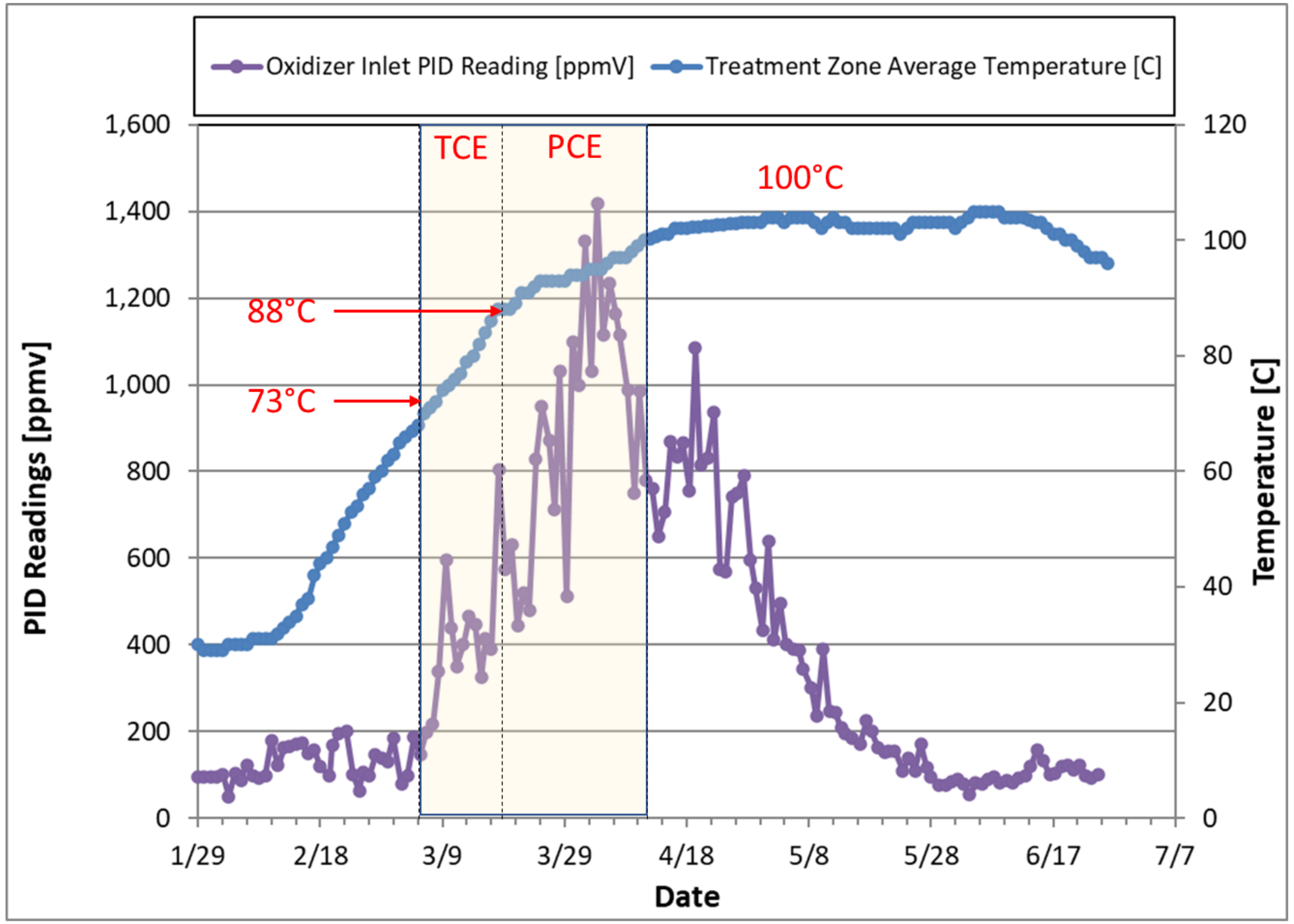
Removal Mechanism - Volatilization

Volatilization - Vapor Pressures Increase Exponentially During Heating



Example Mass Removal from an ISTR Site



For this DNAPL Site with PCE and TCE, the peak in mass removal began as the average temperature approached the co-boiling point of TCE.

Co-Boiling Points with Water

- TCE = 73°C
- PCE = 88°C

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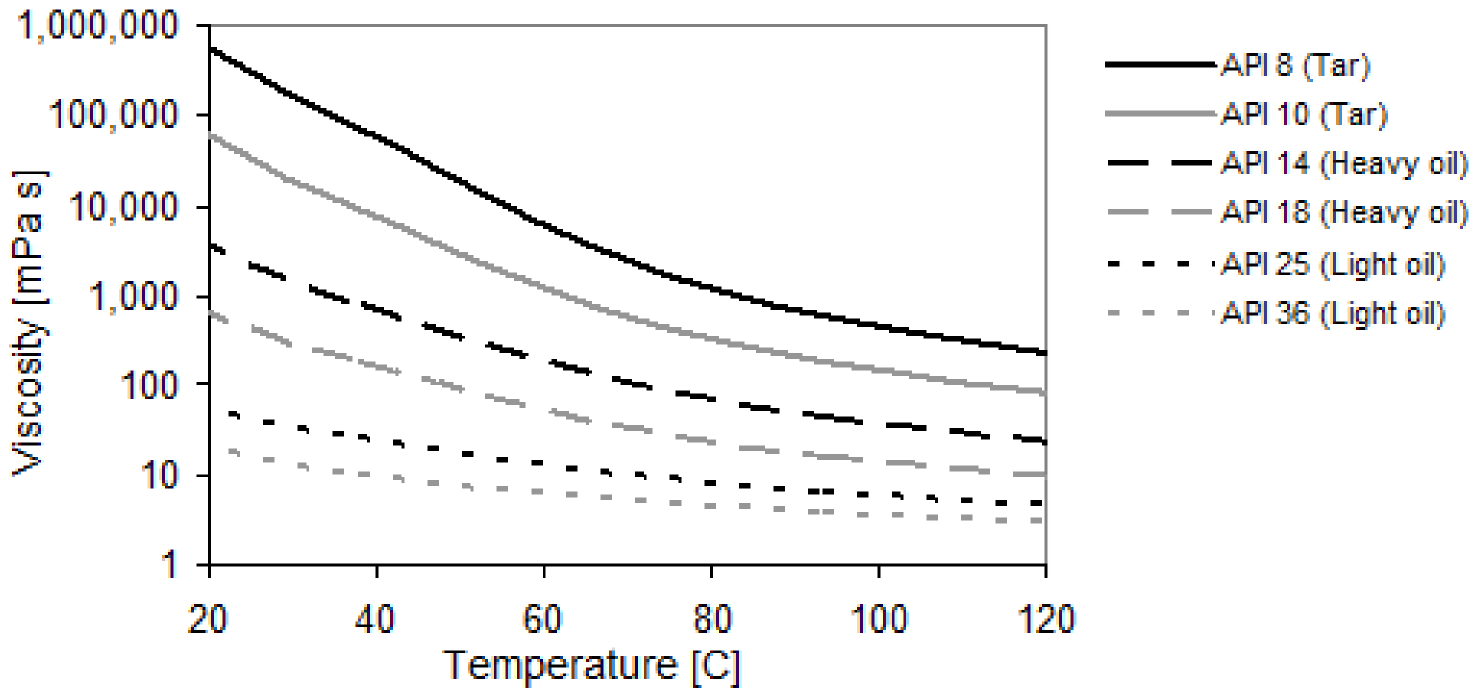
Viscosity Reduction

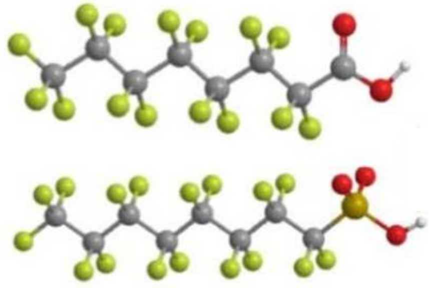


- 1,000-3,000 times for tar
- 10 times for light oils

Removal Mechanism - In Situ Degradation

- Oxidation (requires oxygen)
- Pyrolysis (no oxygen)
- Hydrolysis (in aqueous phase)
- Biodegradation (aerobic and anerobic)
- Defluorination and Mineralization

30 to 90°C
Low Temperature
Thermal Remediation



PFAS

400 °C

Complete Mineralization

HF
Metal Fluorides (CaF, FeF)
CO
CO_2

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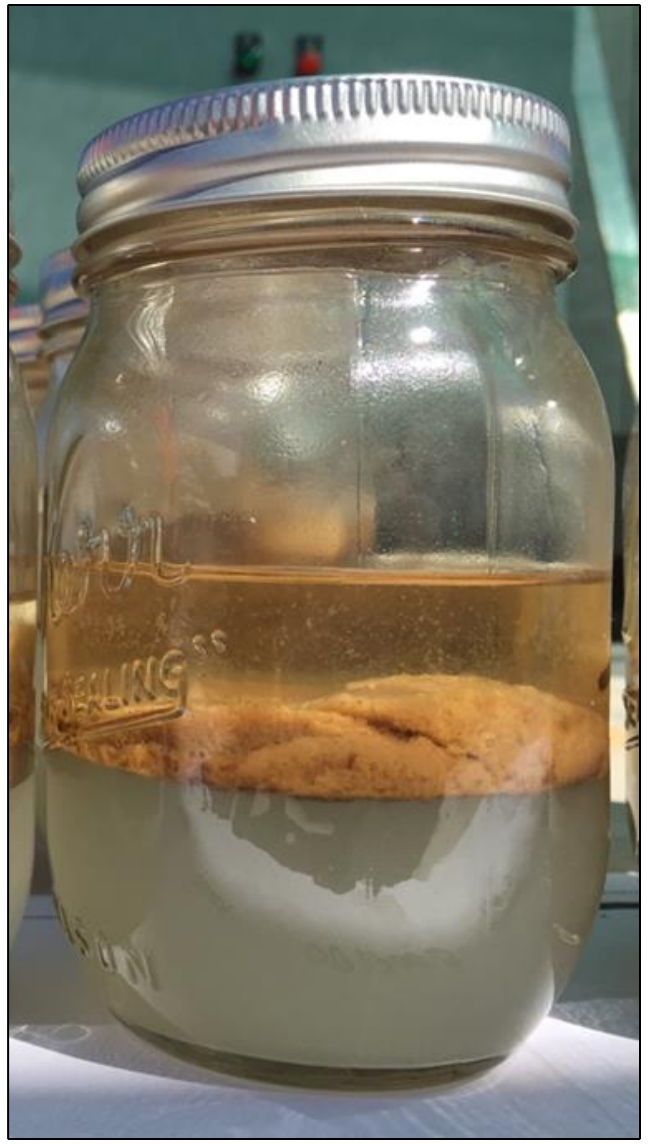
What Contaminants Can Be Targeted?

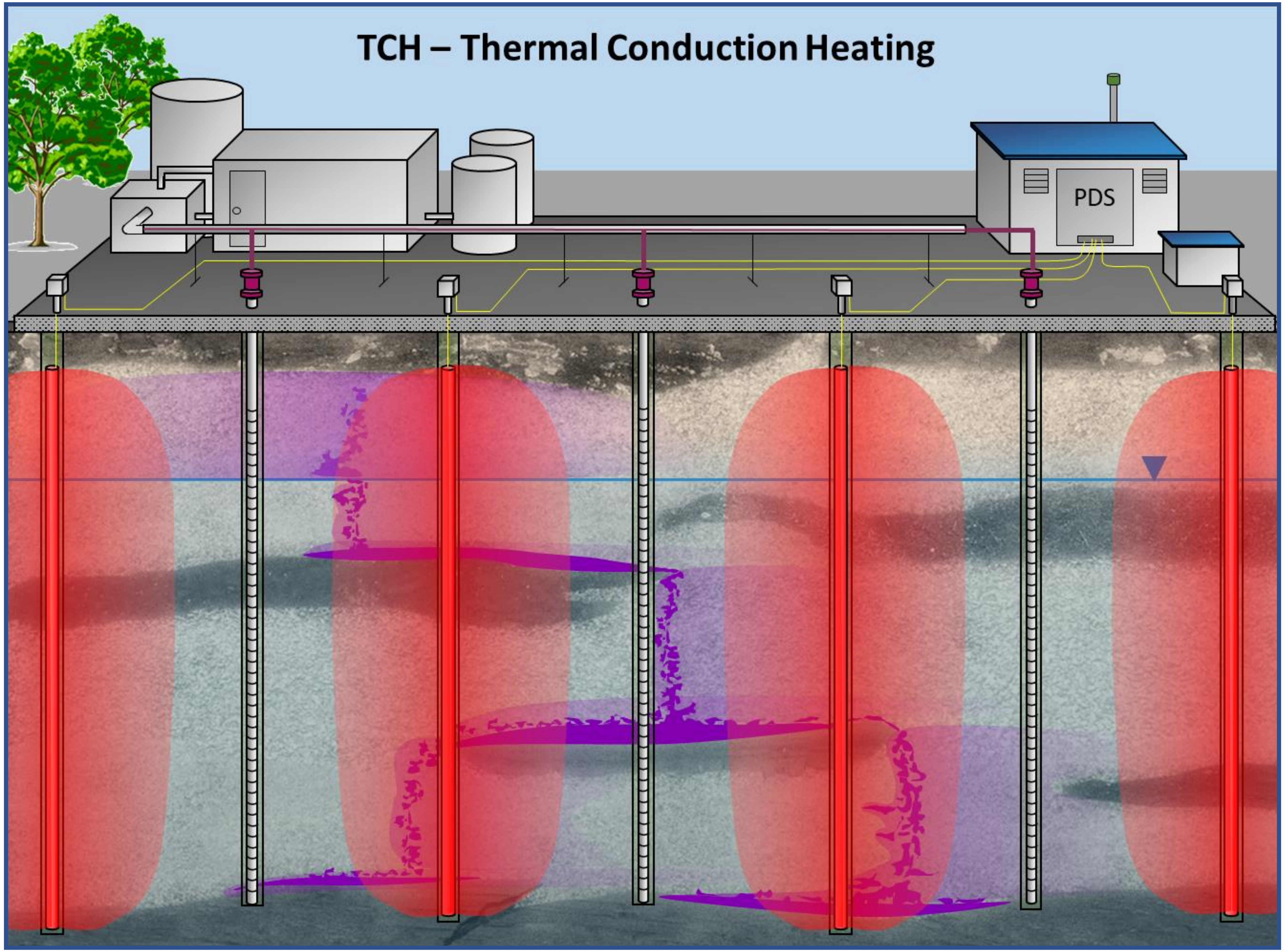
- VOCs
- CVOCs
- SVOCs
- PAHs, PCBs, Dioxins
- Miscible VOCs (1,4-Dioxane, MIBK, MEK, Acetone)
- TPH/Creosote/Coal tar
- Oils/LNAPL
- Mercury
- PFAS




Technologies

Overview of Heating Technologies

TCH



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TCH Wellfield

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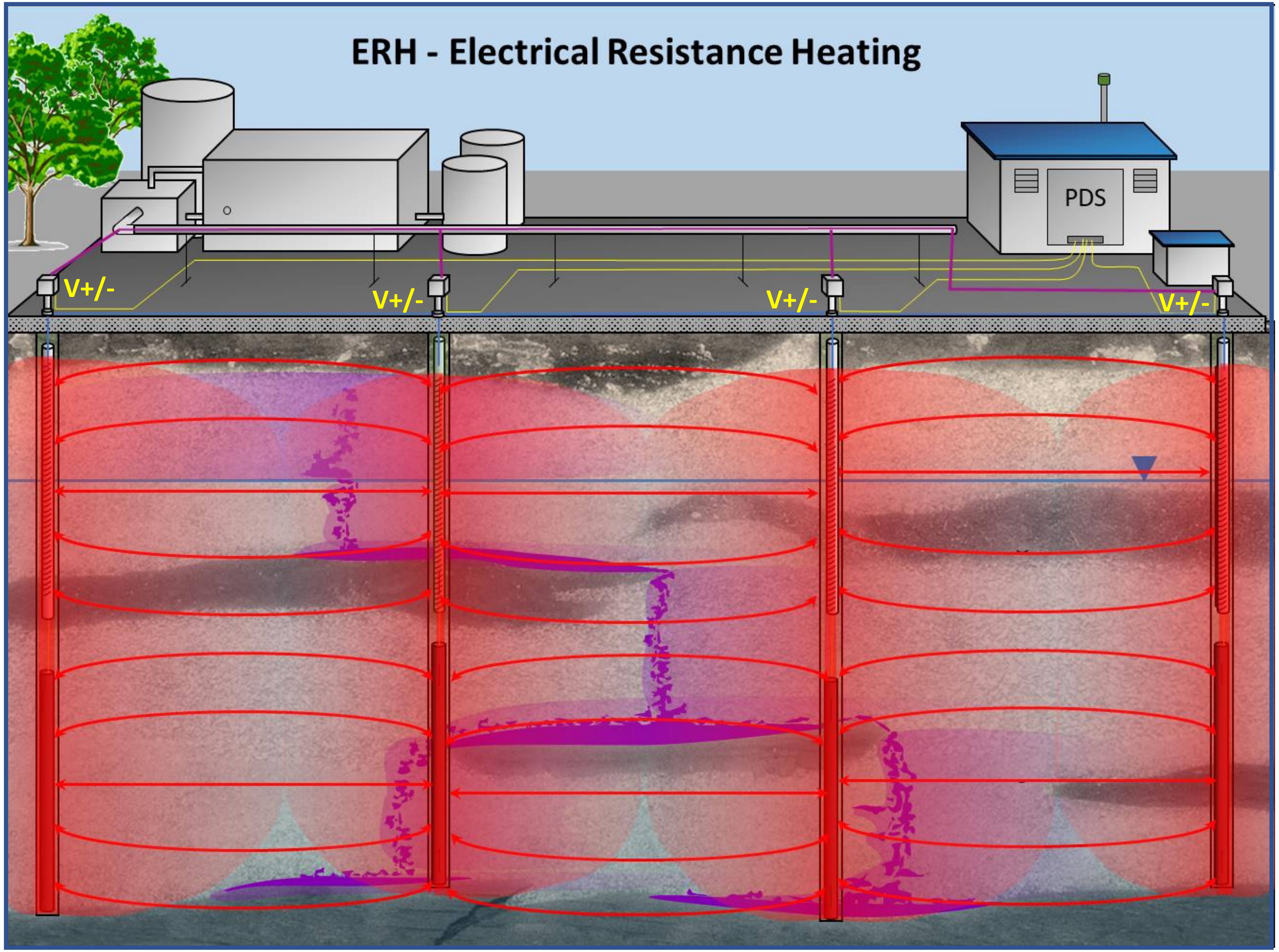
Overview of Heating Technologies

ERH



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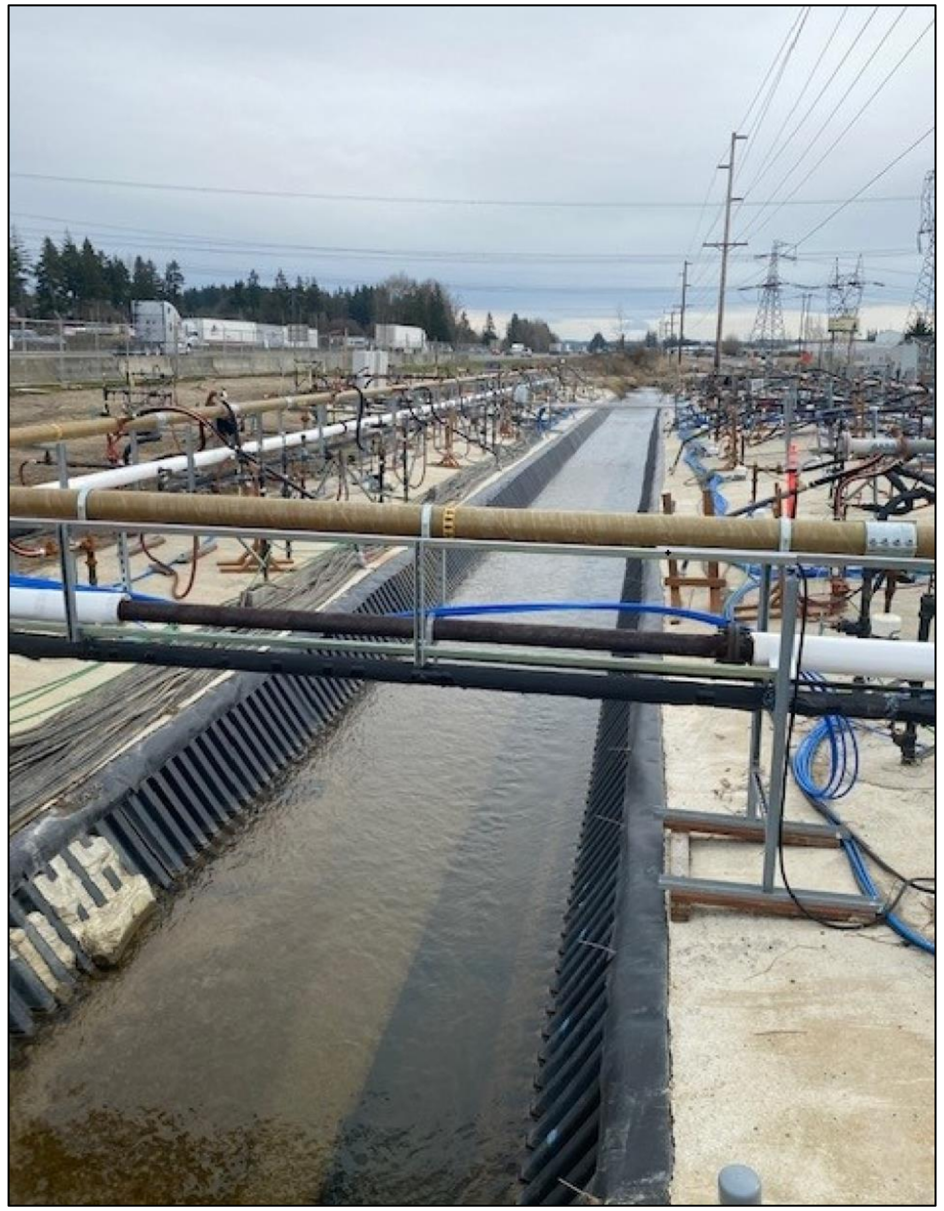
ERH Wellfield



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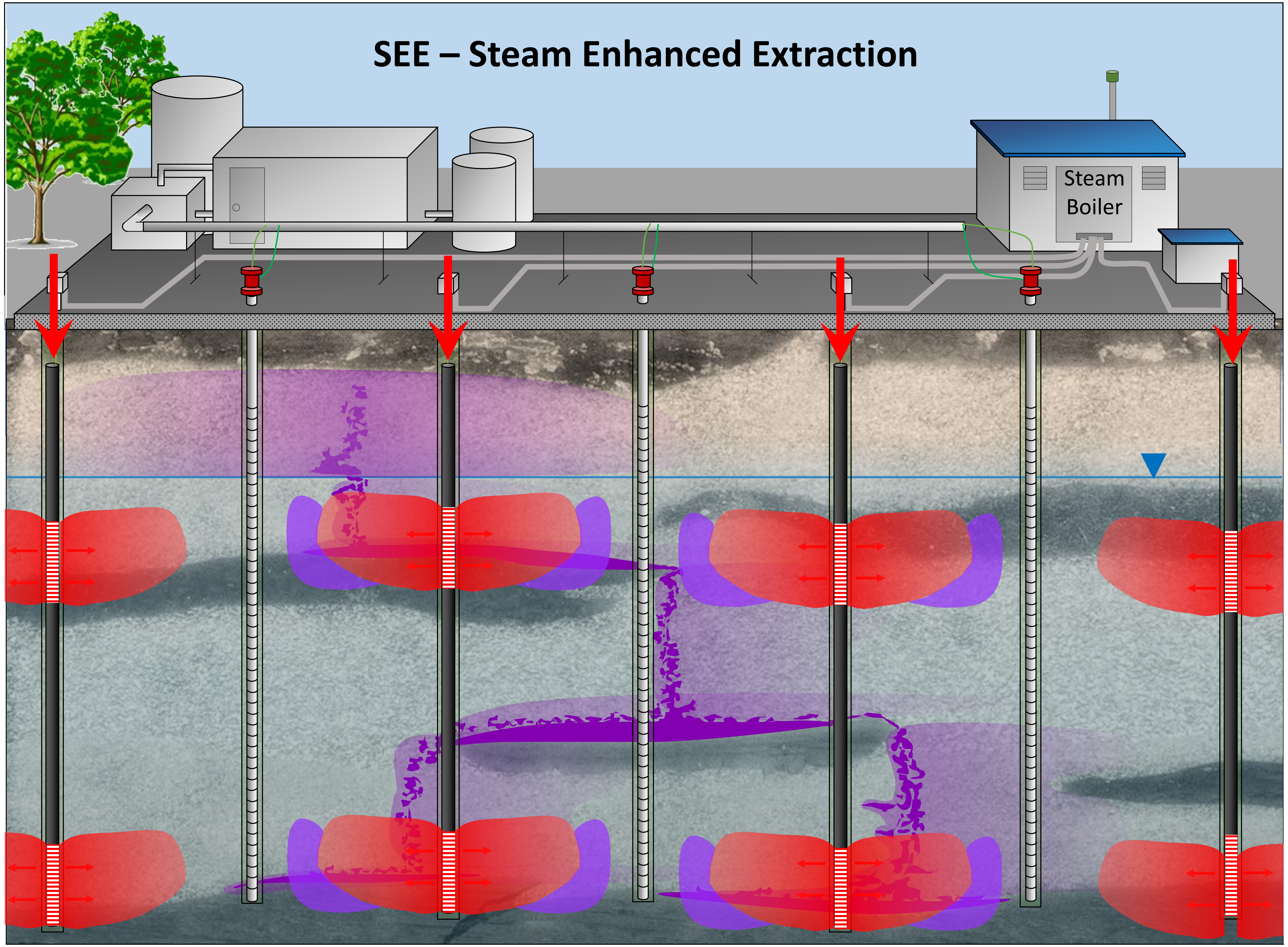
Overview of Heating Technologies

SEE



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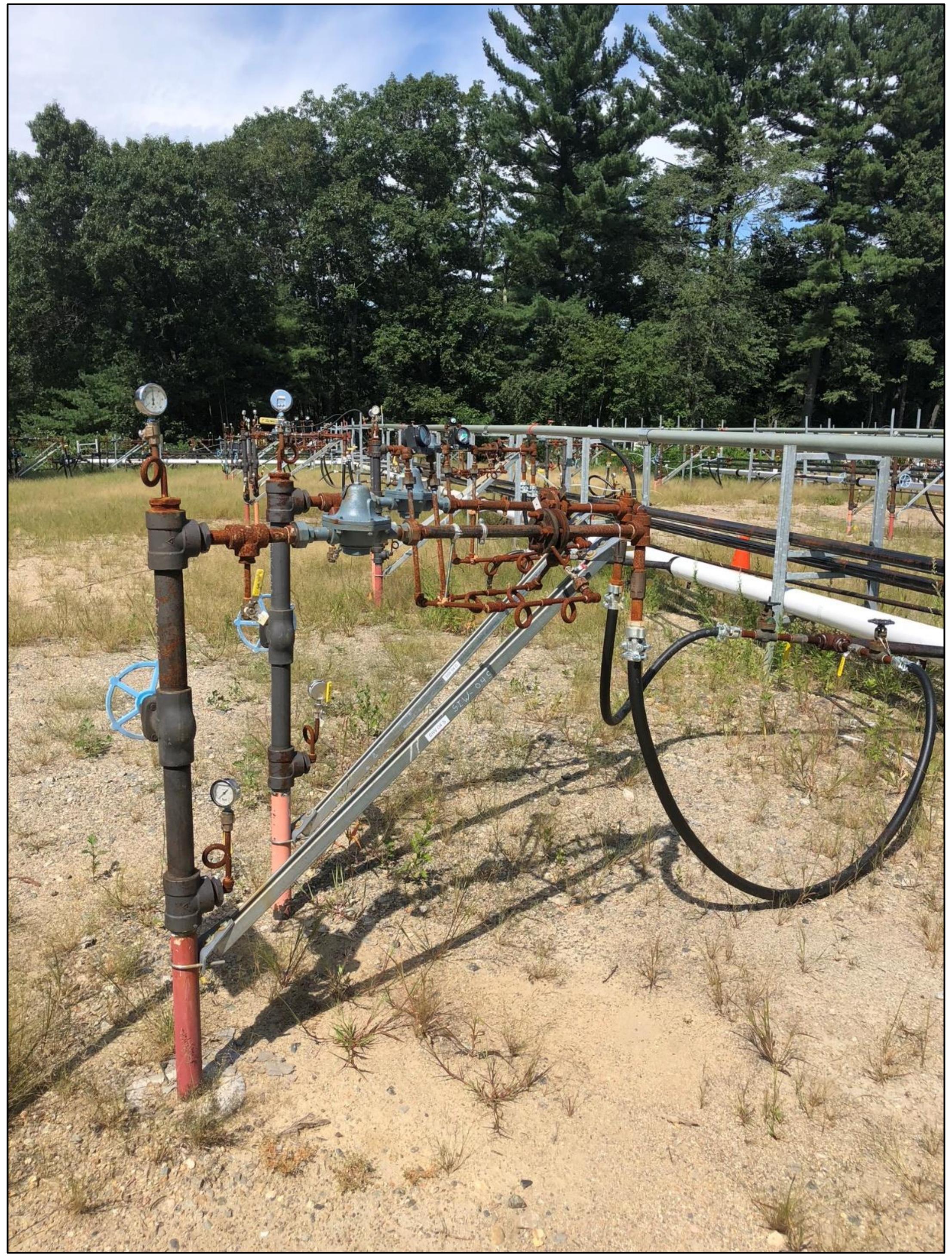
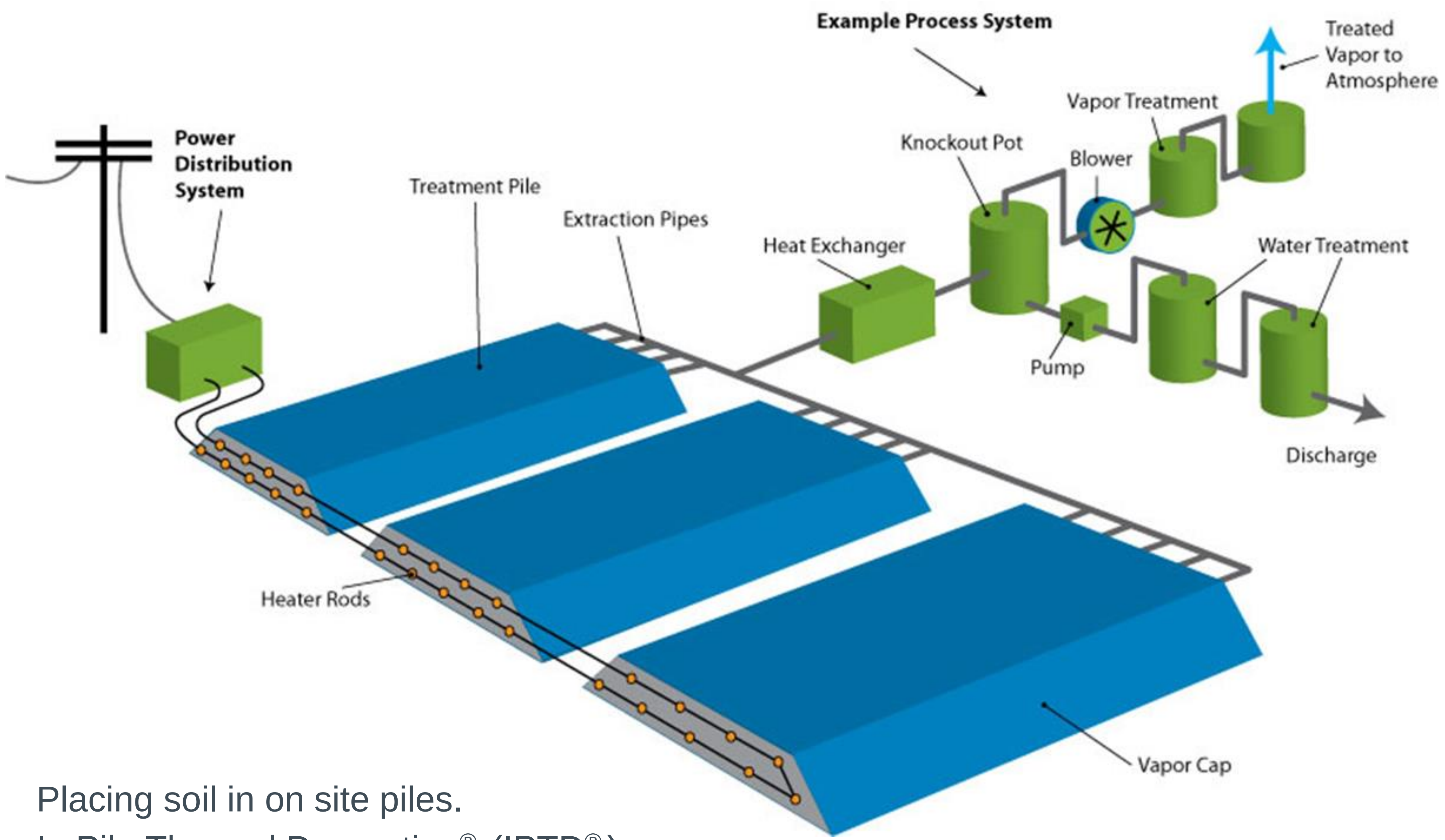
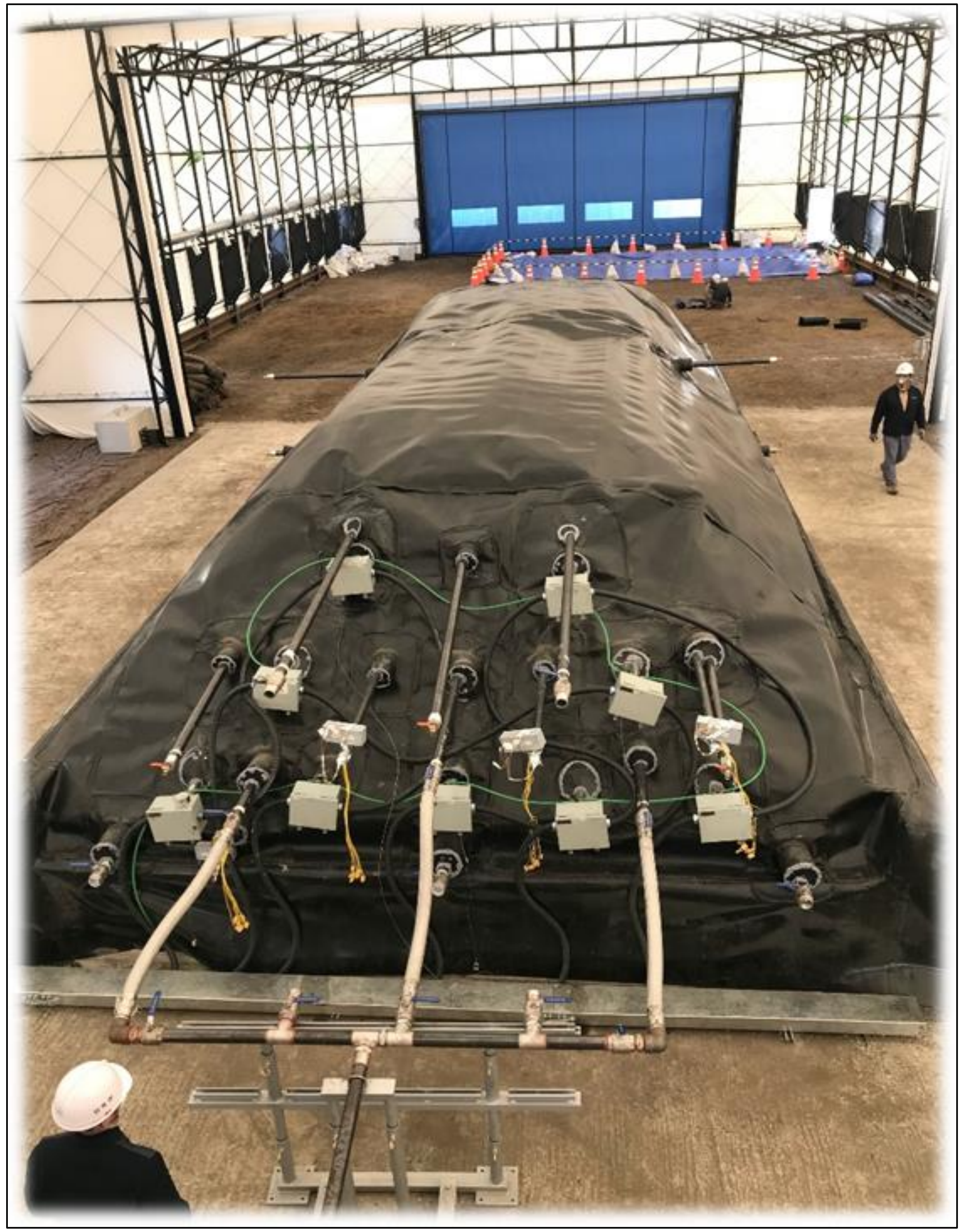
SEE Wellfield



In-Pile Thermal Desorption®

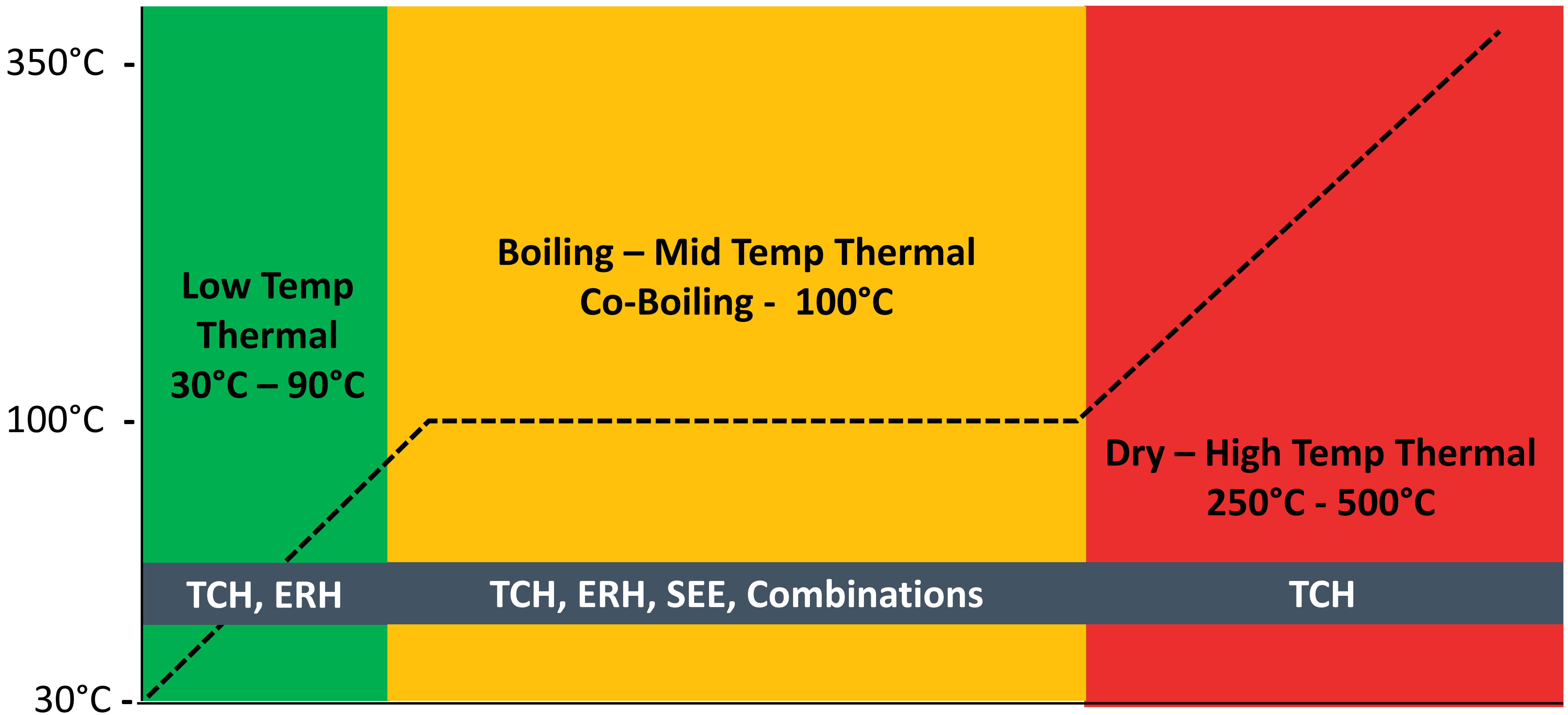


Placing soil in on site piles.
In Pile Thermal Desorption® (IPTD®)



IPTD application, Asia (Dioxin)

Target Temperatures & Applicable Technologies



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Geologies/Hydrogeologies

What type of sites can be targeted?

- Sand and gravel
- Silt and clay
- Heterogeneous mixtures
- Interbedded/layered systems
- Saprolite
- Sedimentary rock
- Fractured rock
- Competent rock

- **Key parameters:**
- Thermal conductivity
- Electrical resistance
- Permeability

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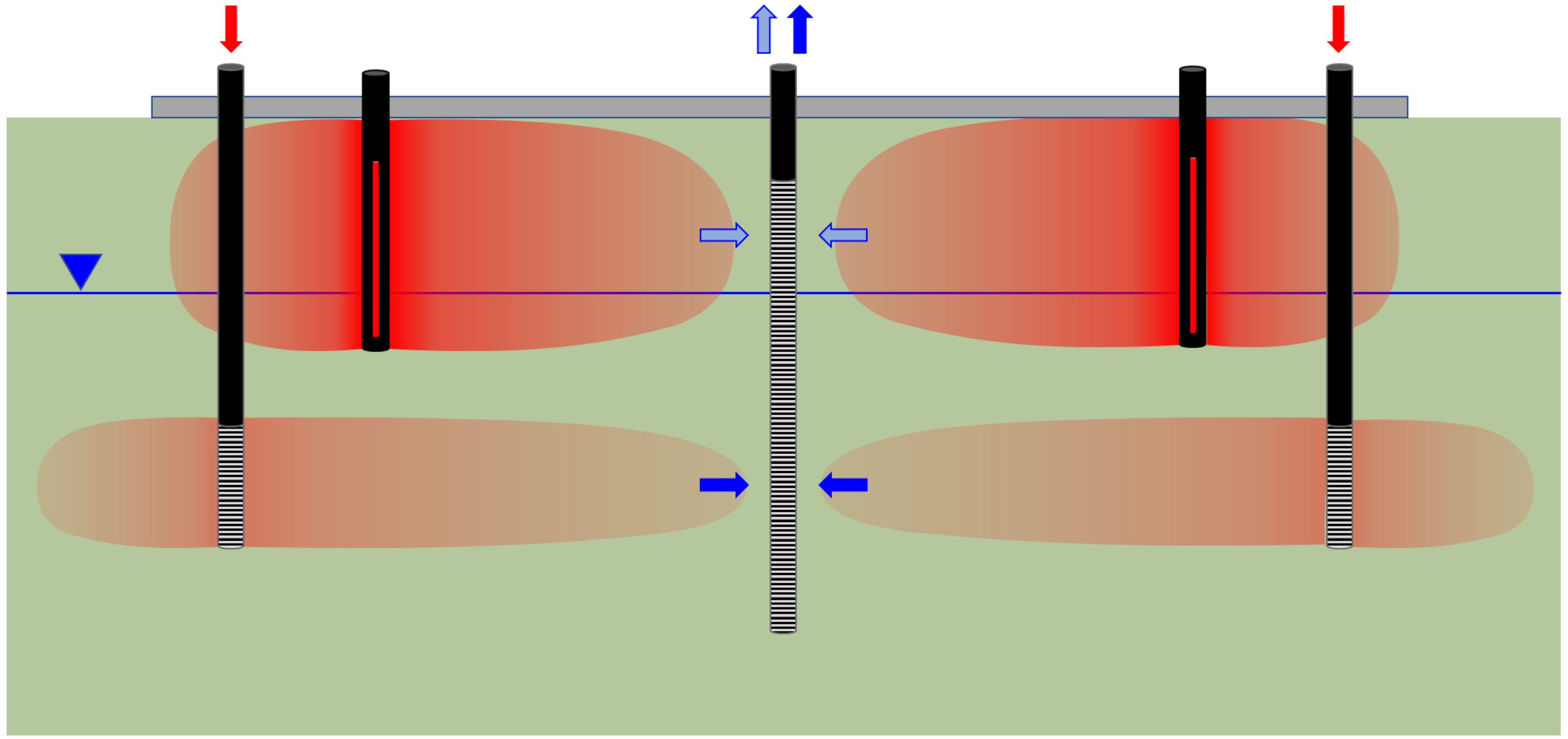
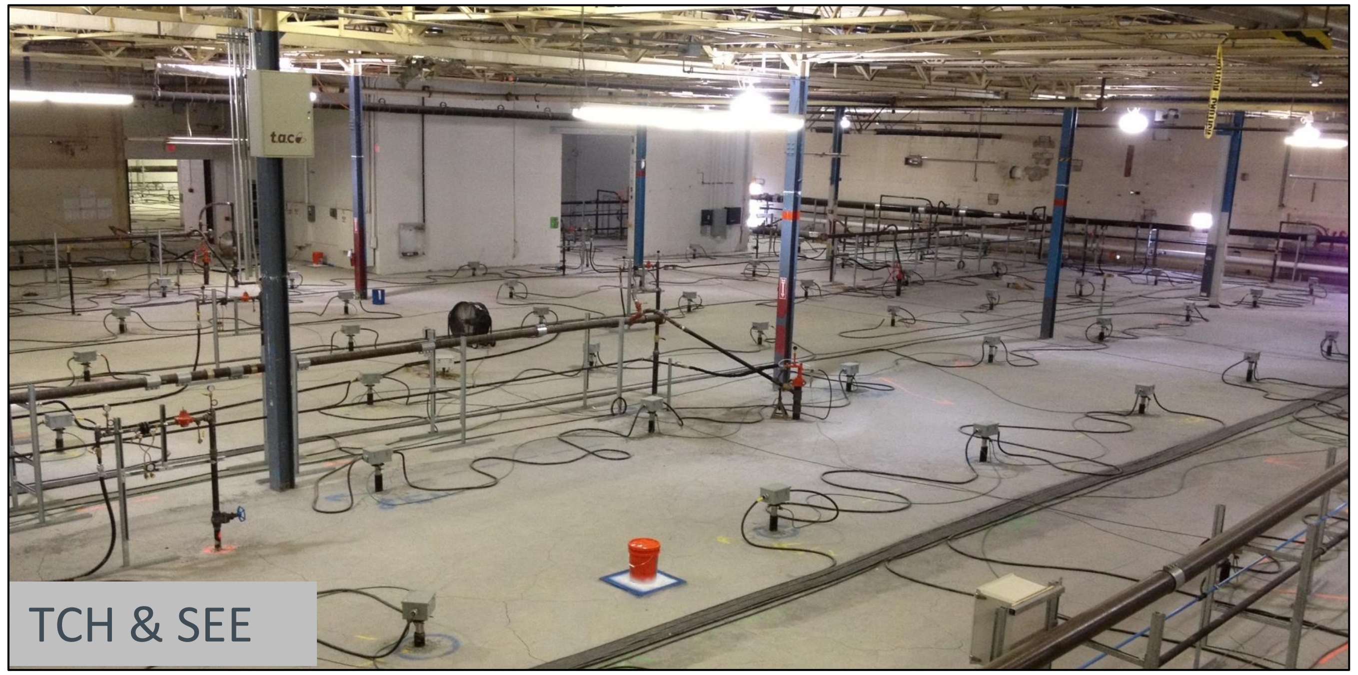
Combinations of Technologies



ERH & SEE



TCH & SEE

Applications and Key Points

- Dry Cleaners
- Chemical Spills
- Redevelopment Sites
- MGP Sites
- Chemical Facilities

- In-situ
- No excavation
- No landfilling

- Deep
- Beneath Buildings
- Bedrock

Before - Syracuse, NY

After - Syracuse, NY (1 year later)

Questions?

John LaChacne

VP of Development

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