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IN-SITU THERMAL REMEDIATION BENEATH A HISTORIC HOME

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In-Situ or Ex-Situ Treatment?

+ In-Situ Thermal Remediation

- No excavation / land filling required
- Effective above or below the water table
- >99.99% hydrocarbon removal efficiencies possible
- Compare to: in-situ soil mixing, bioremediation

+ Ex-Situ Thermal Remediation

- Onsite or consolidated treatment is the norm
- >99.99% hydrocarbon removal efficiencies possible
- Eliminates truck travel on public roads; soil reused onsite
- Compare to: portable rotating kiln, bioremediation

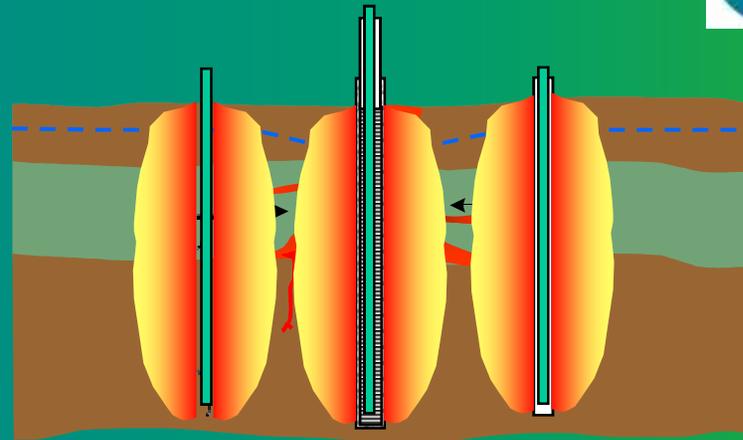


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Gas Thermal Remediation (GTR) and GTR+Fuel (GTR+F)

In Situ Thermal Desorption (ISTD) – Thermal Conduction Heating (TCH)

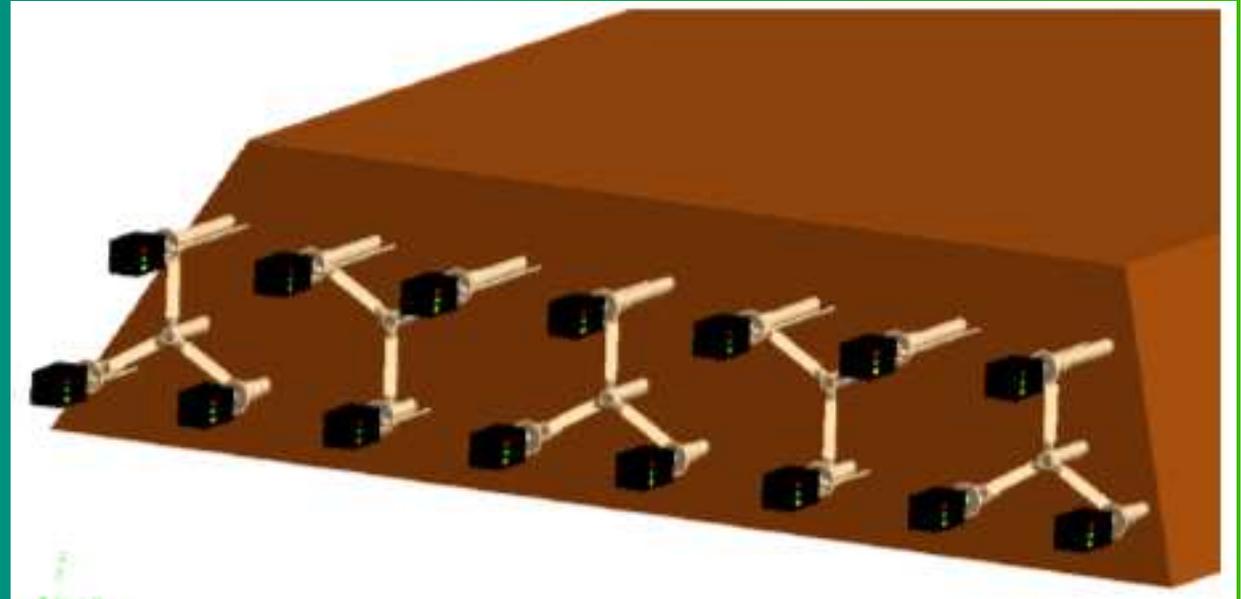
Ex Situ Thermal Desorption (ESTD) – Thermal Conduction Heating (TCH)



Thermal Conductivity
Low to High T
Low To High k

$$\nabla \cdot (\lambda \nabla T)$$

Conduction

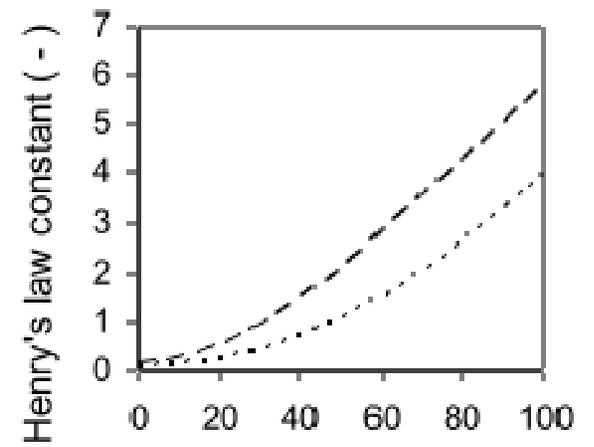
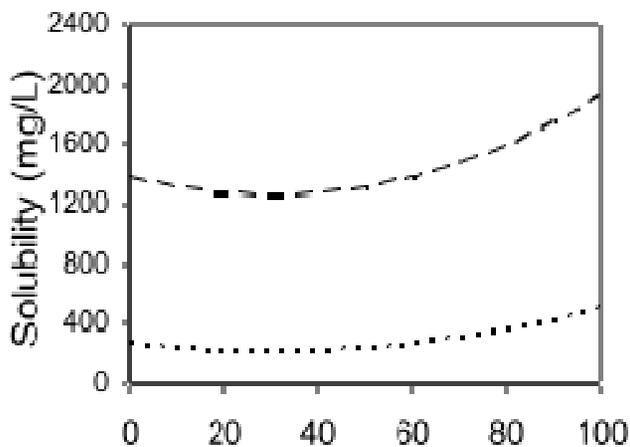
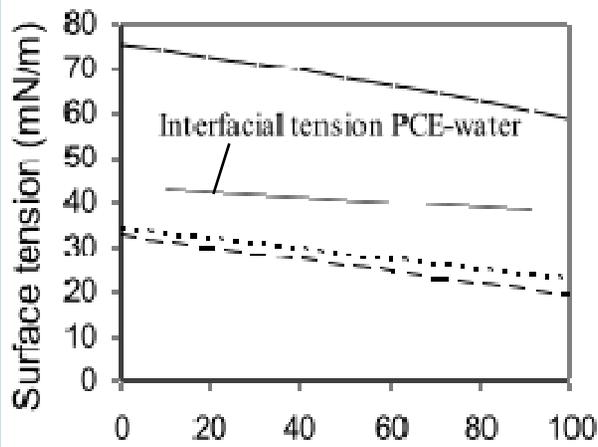
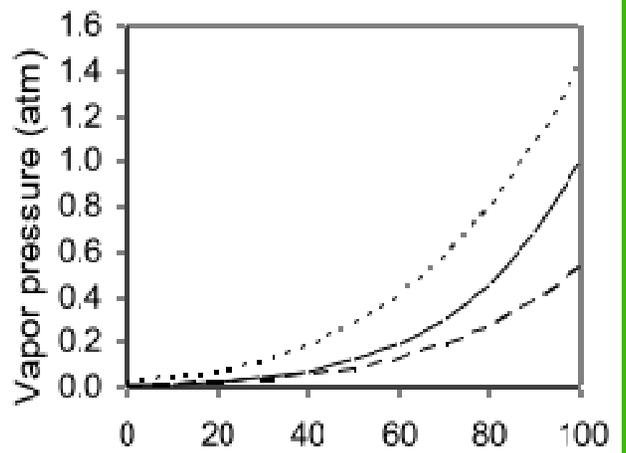
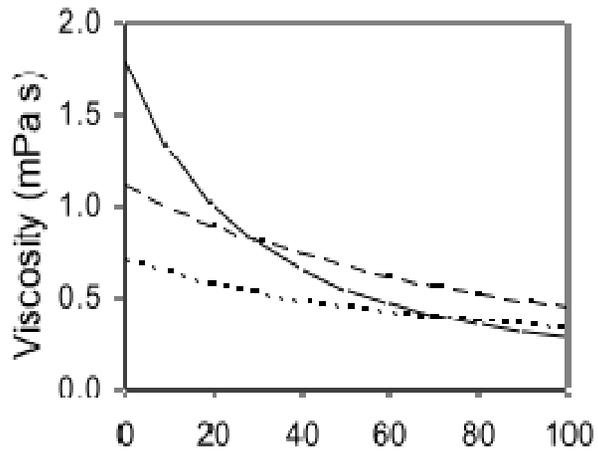
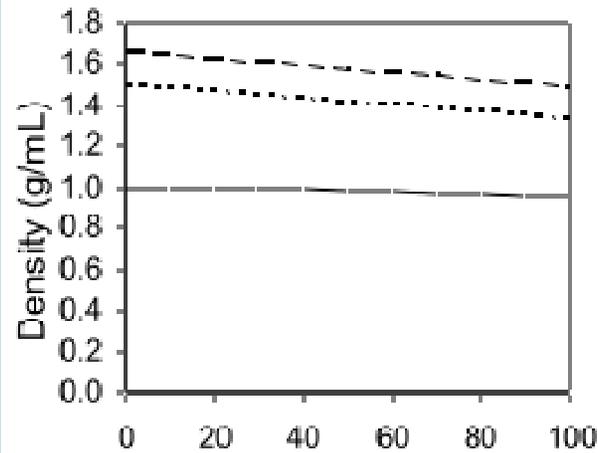


Why Thermal Works

Heat causes the following to happen:

- + **Vapor pressure** of organic materials increase
- + **Viscosity** of separate phase liquids decrease
- + Sorption coefficients of dissolved phase compounds decrease
- + Diffusion rates increase
- + Solubility increases
- + Rates of abiotic degradation increase
- + Rates of **Hydrolysis** increase
- + **Pyrolysis** also takes place
- + **Oxidation** occurs at superheating temperatures

Why Thermal Works



In-Situ Thermal Desorption

Three Levels of Treatment



Level of Heating & Contaminant	Target Treatment Temperature (°C)	Heating Well Spacing (m)	Desiccation of Zone?	Range of Costs (all inclusive) (\$/m ³)
1. VOCs: Gentle Heating (BTEX, CVOCs)	<100	4 – 8	No	40-200
2. VOCs (CVOCs, PAHs)	>100	3 – 6	Depends	60-300
3. SVOCs (PCBs, dioxins)	>200	1.5 – 3	Yes	150-500

In-Situ Thermal Desorption Applications

+ Contaminants Treated:

- All VOCs and SVOCs
- LNAPL and DNAPL
- PAHs
- Long chain Hydrocarbons
- Tar
- Mercury
- Dioxins
- Pesticides, Fertilizers and POPs
- PCBs

How It Works

Closed-loop in-situ thermal conduction heating system;

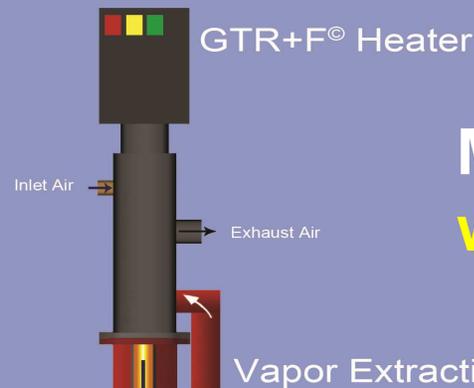
Co-located vapor extraction and heating wells;

Treatment temperatures from **~100°C** to **400°C**

Some off-gases may be used as supplemental fuel (PAHs and BTEXs), others treated with C3 Technology condenser



In-Situ Thermal Desorption by



More information at:
www.tpsthermal.com

How GTR[®] Works

- + Propane or natural gas is used to heat the air circulating within the pipes
- + Soil is heated indirectly through conduction
- + Vaporized contaminants are collected from extraction wells and routed to heaters as a supplemental fuel source (contaminants can also be routed to a vapor treatment system)

Vertical, Slant, Horizontal or Directional Wells?



1. **Vertical** – Deep, shallow or vertically-extensive volumes. Drilling is readily available. Inside or outside structures.
2. **Slant** – Hot spot treatment, or when obstructions or rejections occur.
3. **Horizontal** – Shallow, deep or vertically-narrow volumes. Trenching or excavation may be required. Drilling is readily available.
4. **Directional** – Vertically-limited volumes (deep or shallow), underneath buildings, streets, or in open environs. Requires “set back” and only two vendors exist in the United States; however, the quality of their work is very high.

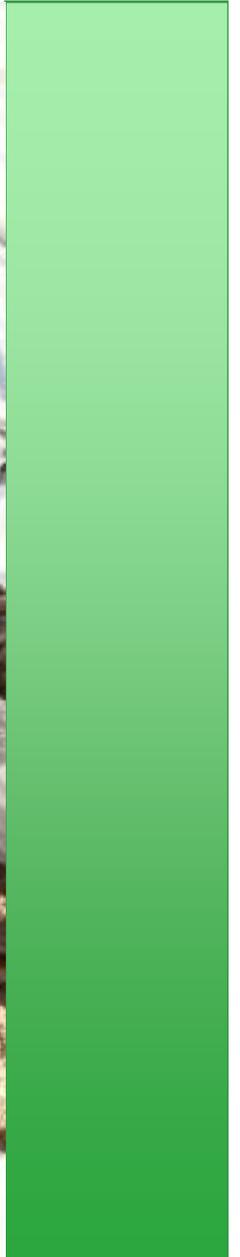
TPS TECH Saves Historic Homes?



Extent of Previously Excavated Volume

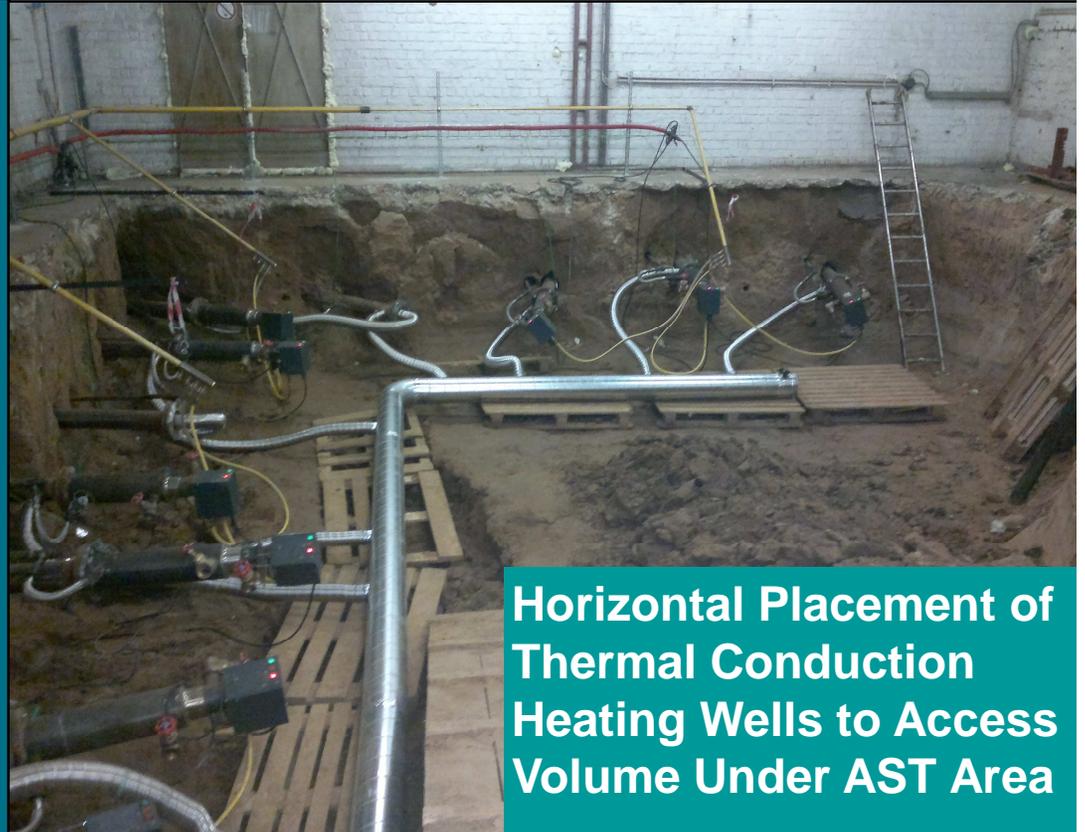


No. 2 Fuel Oil Impacts Beneath Historic Home



Diesel: In Situ Thermal Remediation Using Horizontal Heating Wells at a Fuel Depot

Summary: An above ground storage tank was the source of previous diesel and fuel oil leaks. Elevated concentrations of these COCs in the vadose and shallow groundwater zones were addressed. Vertical wells could not be installed through the AST pad. Horizontal heating wells were installed from an adjacent access area. The horizontal wells reached the affected volumes underneath the AST pad. The system operated on propane. Extracted hydrocarbon off gases were utilized as supplemental fuel for the ISTT system (GTR+F units). All project goals were met, on time and on budget.



Horizontal Placement of Thermal Conduction Heating Wells to Access Volume Under AST Area

Client: Imperbel

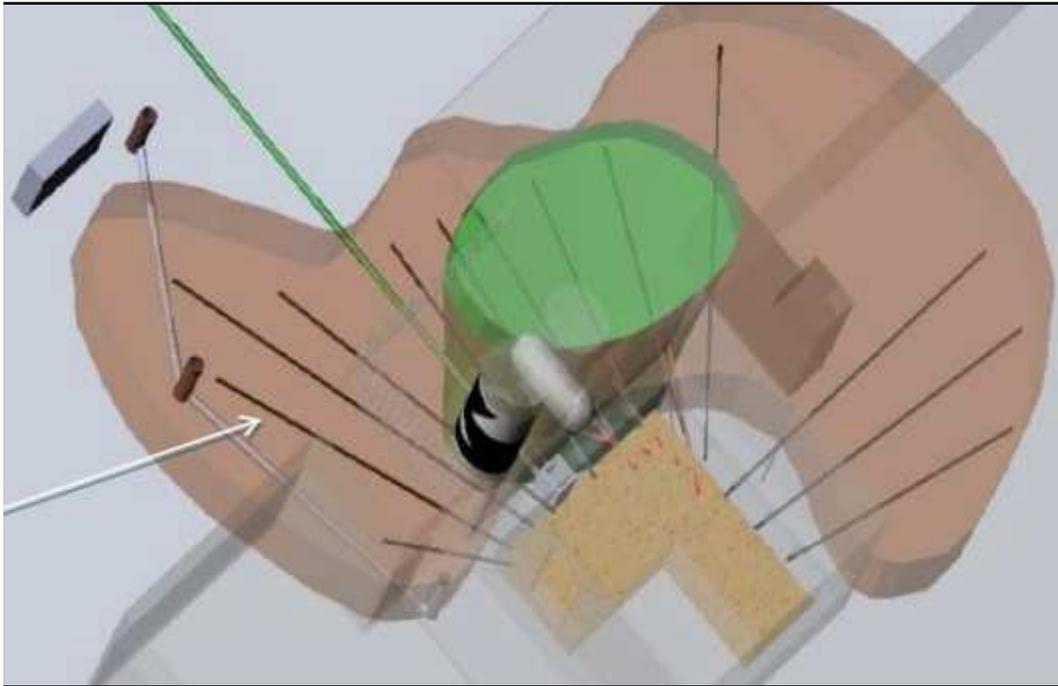
Consultant: Ibeve

Location: Belgium

Soil Type: Sandy silt, sand

LNAPL present?: Yes

In Situ Thermal Desorption Using Slant, Horizontal and Semi-Directional Heating Wells at a Fuel Depot



Contaminants: Diesel and Fuel Oil (C10-C40) , PCE, TCE

Maximum Concentration: 14,000 mg/kg

Remediation Goal: < 500 mg/kg

Treatment Volume: 800 cubic yards

Number of Horizontal Heating Wells: 13

Target Treatment Temperature: 200°C (24 hours) or 100°C (336 hours)

Project Duration: 45 - 60 days (depending on zone)

Post-Treatment Concentrations: < 200 mg/kg

Project Goals Met?: Yes



BTEX: In Situ Thermal Remediation Using Horizontal Heating Wells at a Fuel Depot



Installation:

Simple trenching with Class C PPE; zero soil waste offsite, as excavated soils are refilled over TCH wells

Mobilization Timeframe:

4,000 cu yds mobilized and installed in less than two weeks.

Fuel Source for Heating:

Natural Gas

Energy Source for Extraction System:

220v 3ph

Vapor Treatment:

Combination of condenser + VGAC and GTR+F supplemental fuel

Water Treatment:

Offsite disposal

Permitting:

Similar to SVE / DPE project

Highly Urbanized Environment



BTEX: In Situ Thermal Remediation Using Horizontal Heating Wells at a Fuel Depot



Contaminants:

BTEX

Maximum Concentration:

11,000 mg/kg

Remediation Goal:

< 700 mg/kg

Treatment Volume:

4,000 cubic yards

of Horizontal Heating Trenches:

19 (effective depth 6 ft.)

Target Treatment Temperature:

120°C (168 hours)

Project Duration:

41 days (active heating)

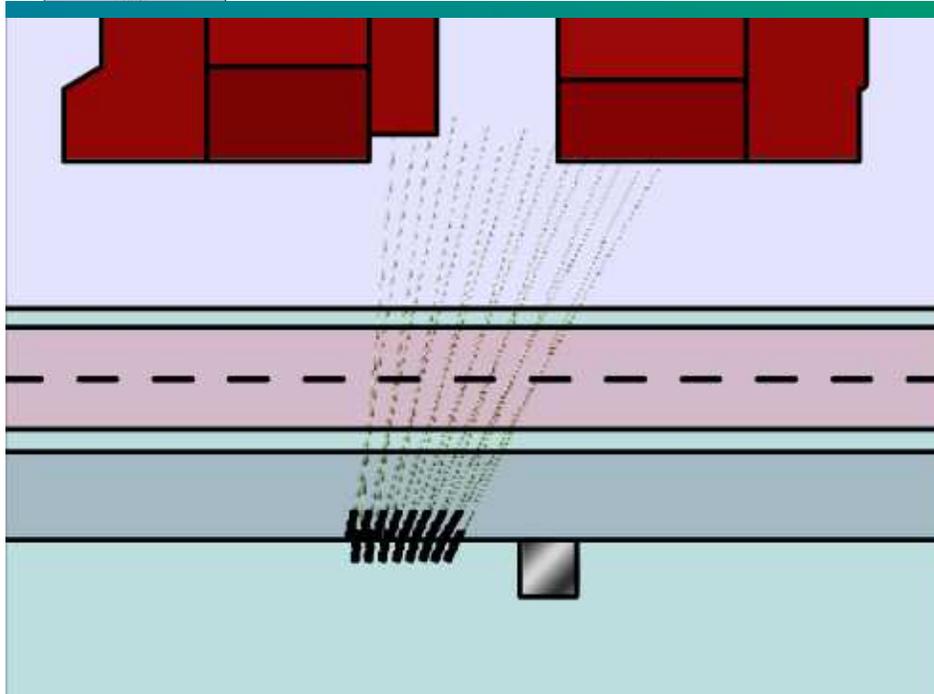
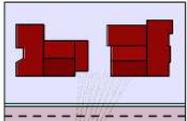
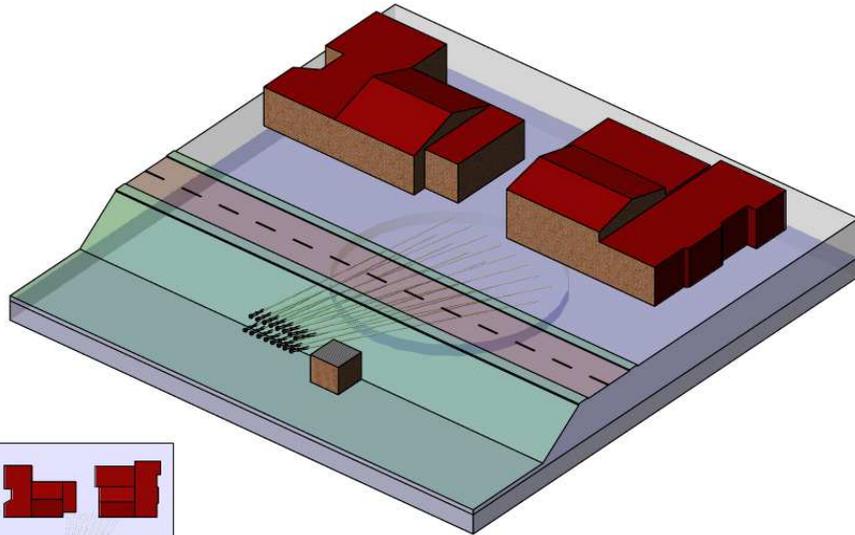
Post-Treatment Concentrations:

< 200 mg/kg

Project Goals Met?:

Yes

Naphthalene : In Situ Thermal Remediation Using Horizontal and Slant Heating Wells Under Road and Residence



Installation:

Horizontal and slant wells in limited access area down a slope

Mobilization Timeframe:

Drilling and well installation lasted approximately one month

Fuel Source for Heating:

Propane

Energy Source for Extraction System:

Diesel Generator

Vapor Treatment:

GTR+F supplemental fuel

Water Treatment:

Limited Dewatering

Permitting:

Similar to SVE / DPE project, but with stringent off-gas treatment metrics

Installation Underneath Road and Near Active Utility Lines



Horizontal ISTR Beneath a Bed & Breakfast and Road



Contaminants:

Naptha-, Fuel Oils

Maximum Concentration:

11,000 mg/kg

Remediation Goal:

Residential Goals

Treatment Volume:

2,000 cubic yards

of Horizontal Heating Wells:

16

Target Treatment Temperature:

200°C (72 hours)

Project Duration:

74 days (active heating)

Project Goals Met?:

Yes; >99% reduction in hydrocarbon concentrations (vadoze and saturated zones)

Lessons Learned: “Horizontal” ISTR Applications

- + Proper characterization is KEY...
- + Regulatory approval may require some extra effort
- + Shallow trench-type ISTR applications require insulating cap
- + Convective heat loss can be moderate, but using horizontal well types can reduce drilling-derived wastes (vs. vertical wells)
- + It may still make sense to install temperature and pressure monitoring points vertically
- + Directional drilling may be more difficult to find outside the U.S.



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Conclusions: “Horizontal” ISTR Applications

- + TCH, SEE, ERH and ISTD options are available
- + Four types of ISTR installations proven:
 - Vertical
 - Slant
 - Horizontal
 - Directional
- + CONSULT technology provider and drilling contractor
- + All ISTR installations have been proven beneath active facilities, roads/highways, homes, apartments and near subsurface utilities
- + ~~Assumptions.~~ Contact TPS TECH for site specific inquiries



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