

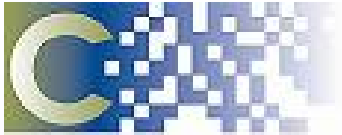
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SOLUTIONS AND ENVIRONMENTAL PRODUCTS
WATER - SOIL - AIR

**Tools and Methods to Reduce and Control
Uncertainties Associated
with the Use of In Situ Remediation Techniques
(Chemical Oxidation)
for Organic Contaminants in Soil and
Groundwater**

**Remtech 2010
Banff, Alberta**

**Prepared by Jean Paré, P. Eng.
Chemco Inc.**



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The Chemistry works but the geology screw it up ...

**Remtech 2010
Banff, Alberta**

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Presentation Agenda

- Chemical Oxidation – Technology Review and Limitations
- Field application challenges and contact issue
- Tools, testing and tricks
 - Before you get to the field
 - When you're in the field
 - Follow up After injection events
- Case Study Presentation



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Chemical Oxidation – Technology Review

- Oxidants are introduced or mixed into the soil and groundwater to attack the organic contaminants
- Chemical oxidation treatments are commonly used in potable and wastewater applications
- Oxidants are non-specific and will react with the targeted contaminants AND with the soil organic content (SOD).
- Chemical oxidation reactions involve the transfer of electrons and the breaking of chemical bonds
- Water is the carrier for the oxidants used in chemical oxidation (except for ozone)
- If you have enough oxidant present and sufficient time you will push reaction to FULL mineralization (CO_2 , H_2O , Cl^-) of the contaminant of concern



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Chemical Oxidation – Technology Review (2)

Common Chemical Oxidants

- Potassium or sodium permanganate
- Hydrogen Peroxide alone
- Catalyzed Hydrogen Peroxide
 - Hydrogen Peroxide with iron (regular Fenton reagent reaction)
 - Need to establish acidic conditions (ideal pH between 4 and 6)
 - Modified Fenton Reagent with chelated species (neutral pH)
- Ozone
 - Ozone is a gas and must be produced on site
 - The gas must be injected into the soil
- Persulfate
 - Requires activation to generate free sulphate radicals.
 - Heat, chelated metal, high pH or hydrogen peroxide can be used to activate the persulphate. Activation method can be adapted to site conditions.
- Percarbonate
 - Requires activation to generate free radicals



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Chemical Oxidation – Limitations

- All chemical oxidation reactions occur in the WATER or moisture phase (except for ozone)
- Kinetics of the chemical oxidation reaction is thus influence by the contaminant of concern solubility and availability in the groundwater or moisture phase
- Sorbed phase contamination might be challenging to remediate (less available)
- In NAPL containing sites, contamination can persist because of the highly hydrophobic properties of the chemicals that make up the NAPLs
- Injection technique must induce proper contact between the contaminant and the oxidant for a proper duration for the required reaction to occurs (kinetics)



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Field application challenges and contact issue

- Good treatment require good contact
- Application challenges
 - Geology (Silts and Clays, Sands, gravel and other)
 - Heterogeneity
 - Low GW Velocity
 - < Fracture Pressures
 - High Volumes to inject
 - Reagent Kinetics
 - Depth
 - Shallow environment
 - Deep environment



Field application challenges and contact issue

14 Subsurface Compartments Potentially Containing Chlorinated Solvents

	Source		Plume	
	Transmissive	Low Permeability	Transmissive	Low Permeability
DNAPL	Low Pressure Injection	Mixing or Heating	Absent	Absent
Aqueous	Low Pressure Injection	Fracturing	Low Pressure Injection	High Pressure Injection
Sorbed	Low Pressure Injection	Fracturing	Low Pressure Injection	High Pressure Injection
Vapor	x	x	x	x

Source – *Management of Chlorinated Solvents in Soils and Groundwater, August 2009 -ESTCP*



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Tools, testing and tricks

Before you get to the field

- Validating the qualification and quantification of the selected oxidant or amendment with bench scale lab study

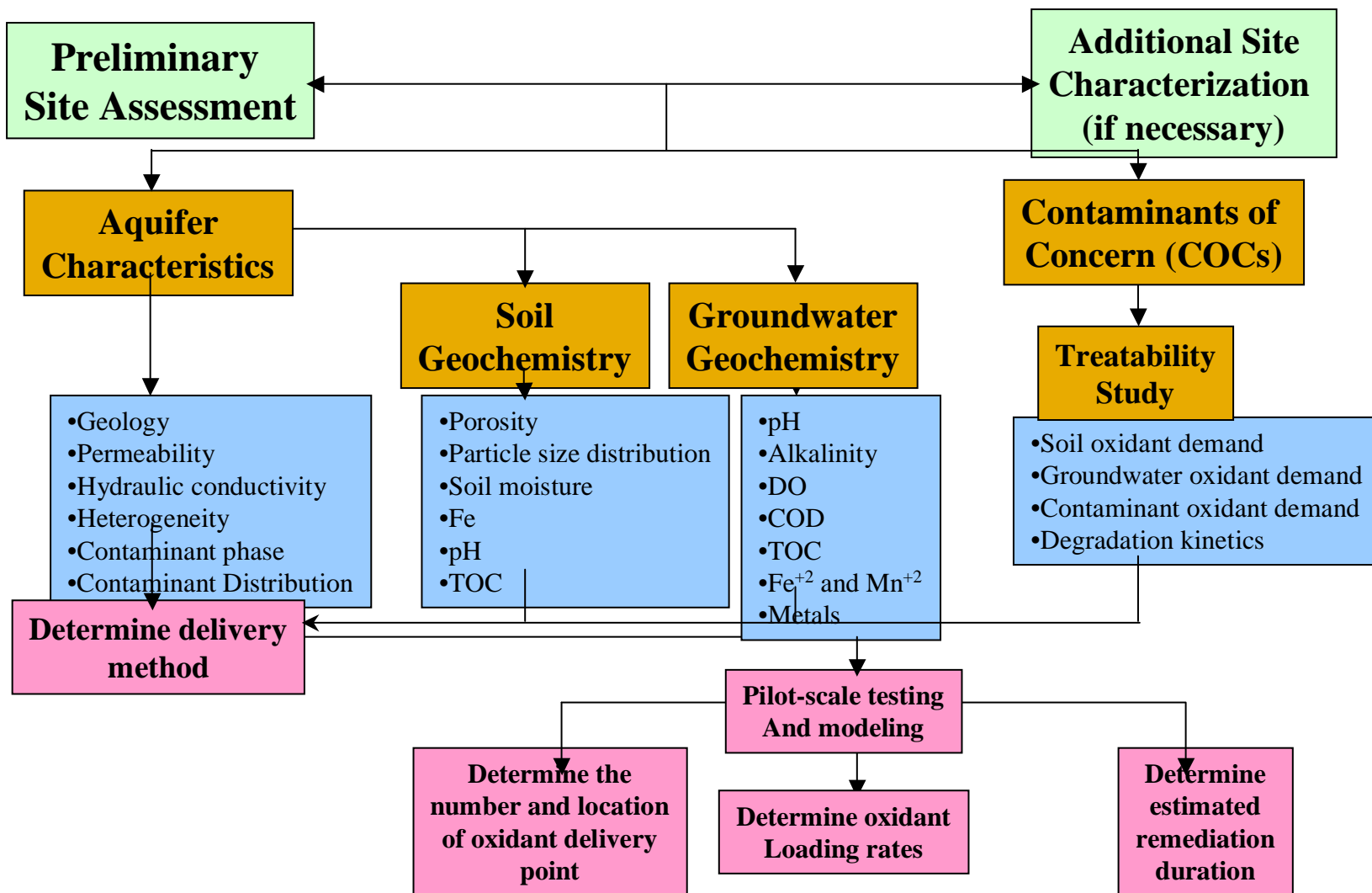
Soil and Groundwater Oxidant Demand validation and treatability study are ALWAYS recommended

(If it doesn't work in the lab in ideal contact condition it WON'T work in the field)

- Make sure you have all the necessary data and you injection plan is set properly



Carus Haz Rem Assessment Process



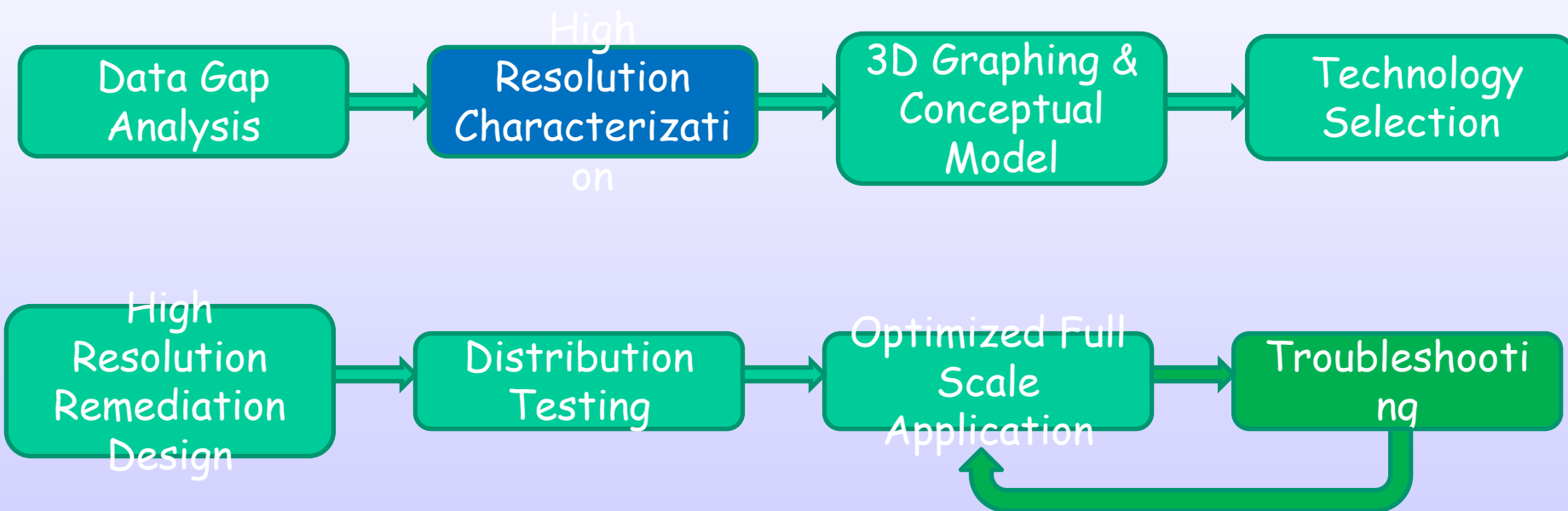


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Tools, testing and tricks

Search and Destroy™ Methodology Targeted Distribution





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Tools, testing and tricks

When you're in the field

- Making sure you are injecting in the adequate zone
CHARACTERIZE, CHARACTERIZE, CHARATERIZE
- Validating the distribution and dilution of the oxidant or amendment in the subsurface aquifer through the use of an INERT tracer PRIOR moving with you're expensive oxidant or amendment.
- Evaluate the pro and cons of the various equipments and techniques to induce proper contact

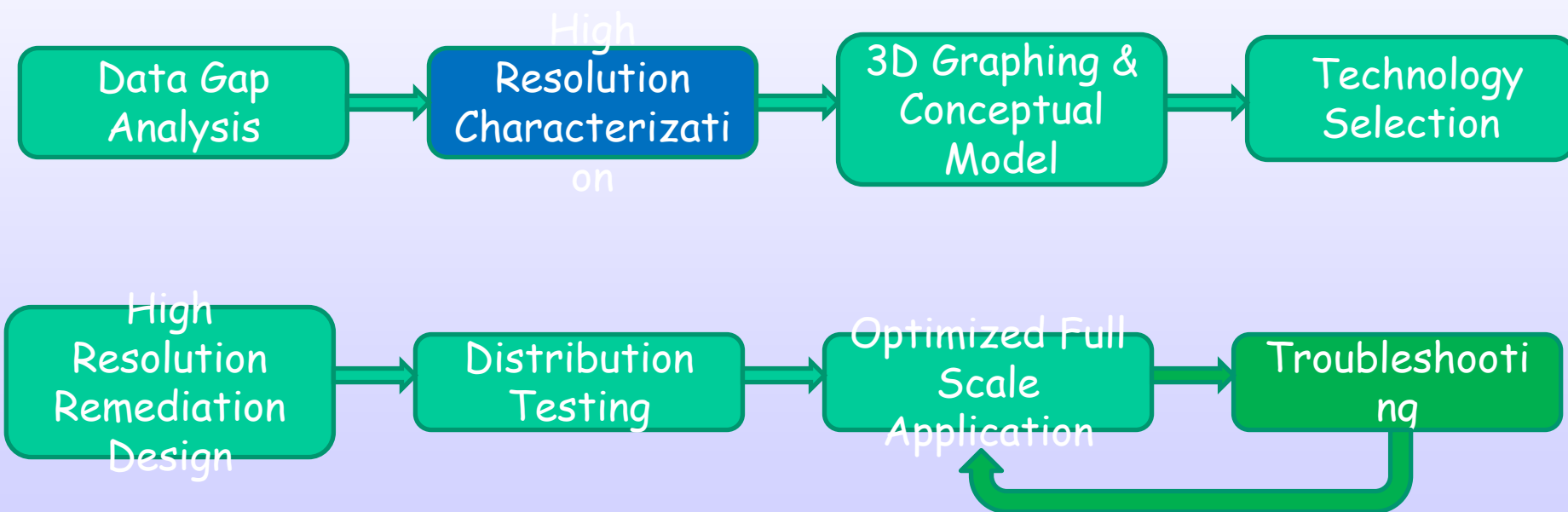


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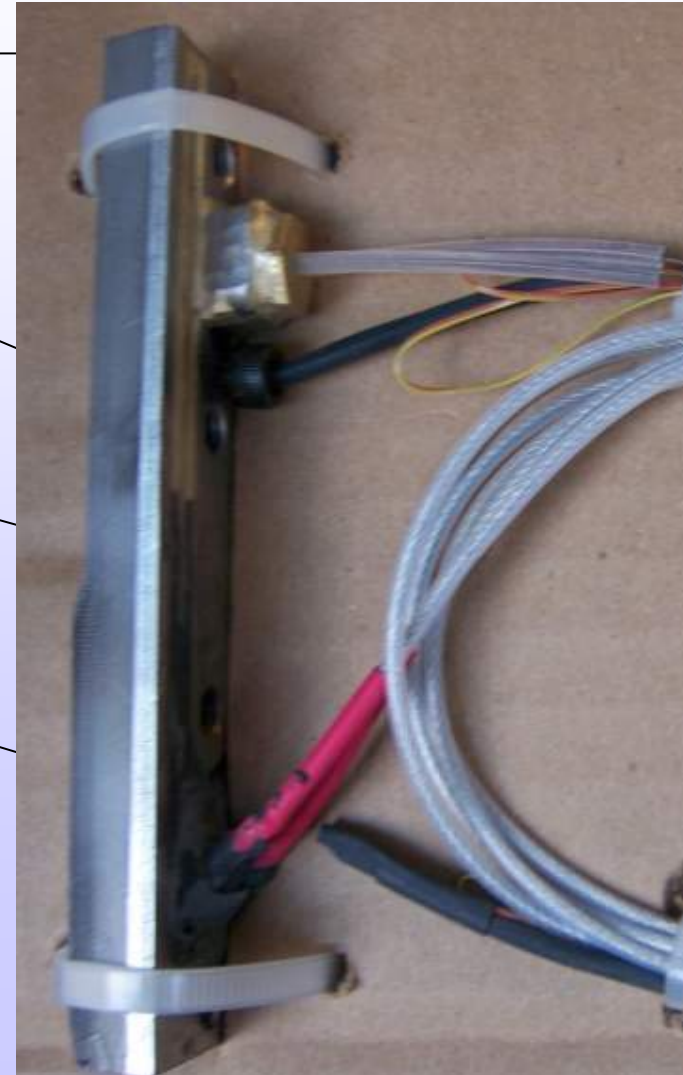
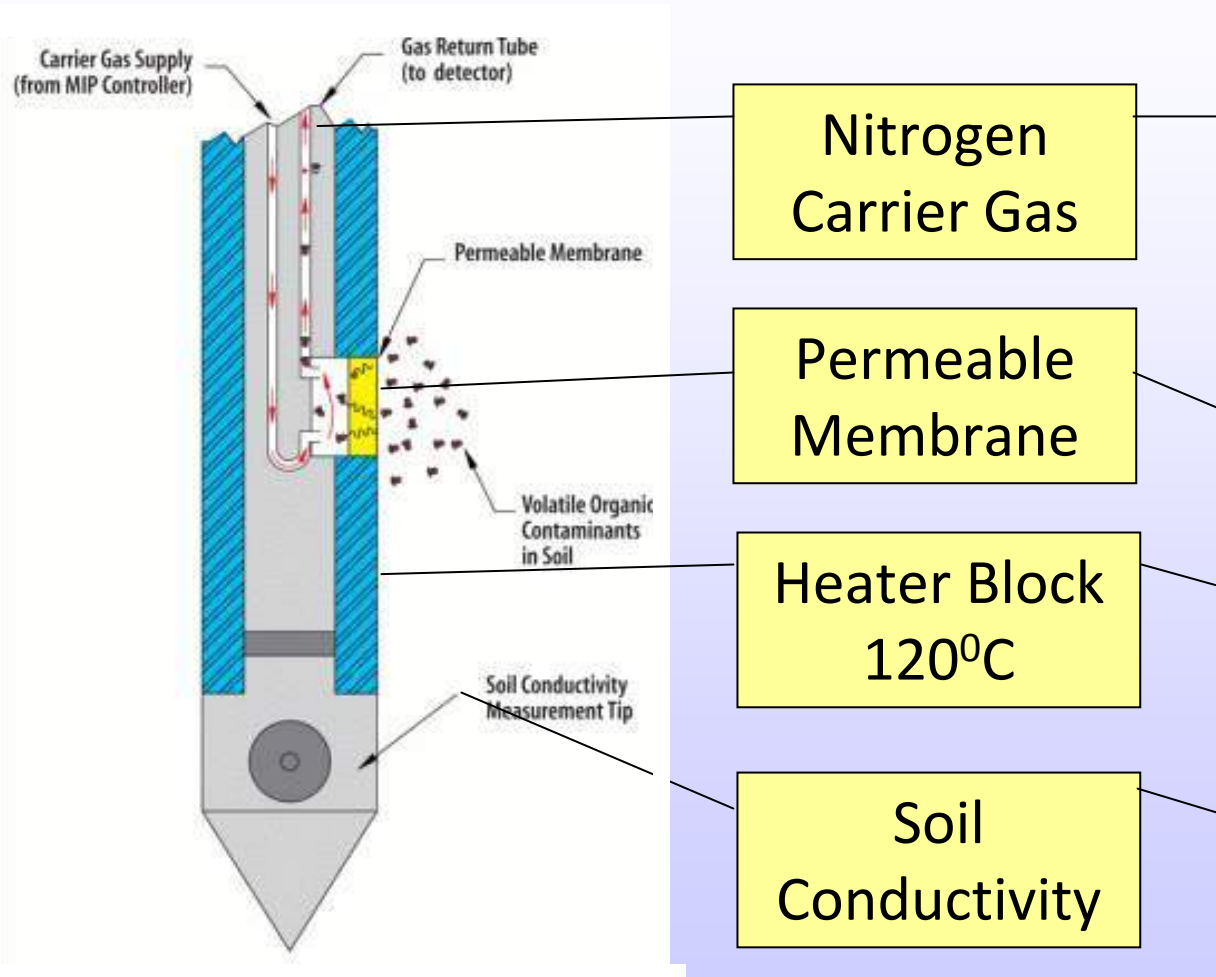
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Search - How The MIP Works





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 Santa Ana, CA 92705
 P:(714) 847-8290
 F:(714) 847-8221
 www.vironex.com

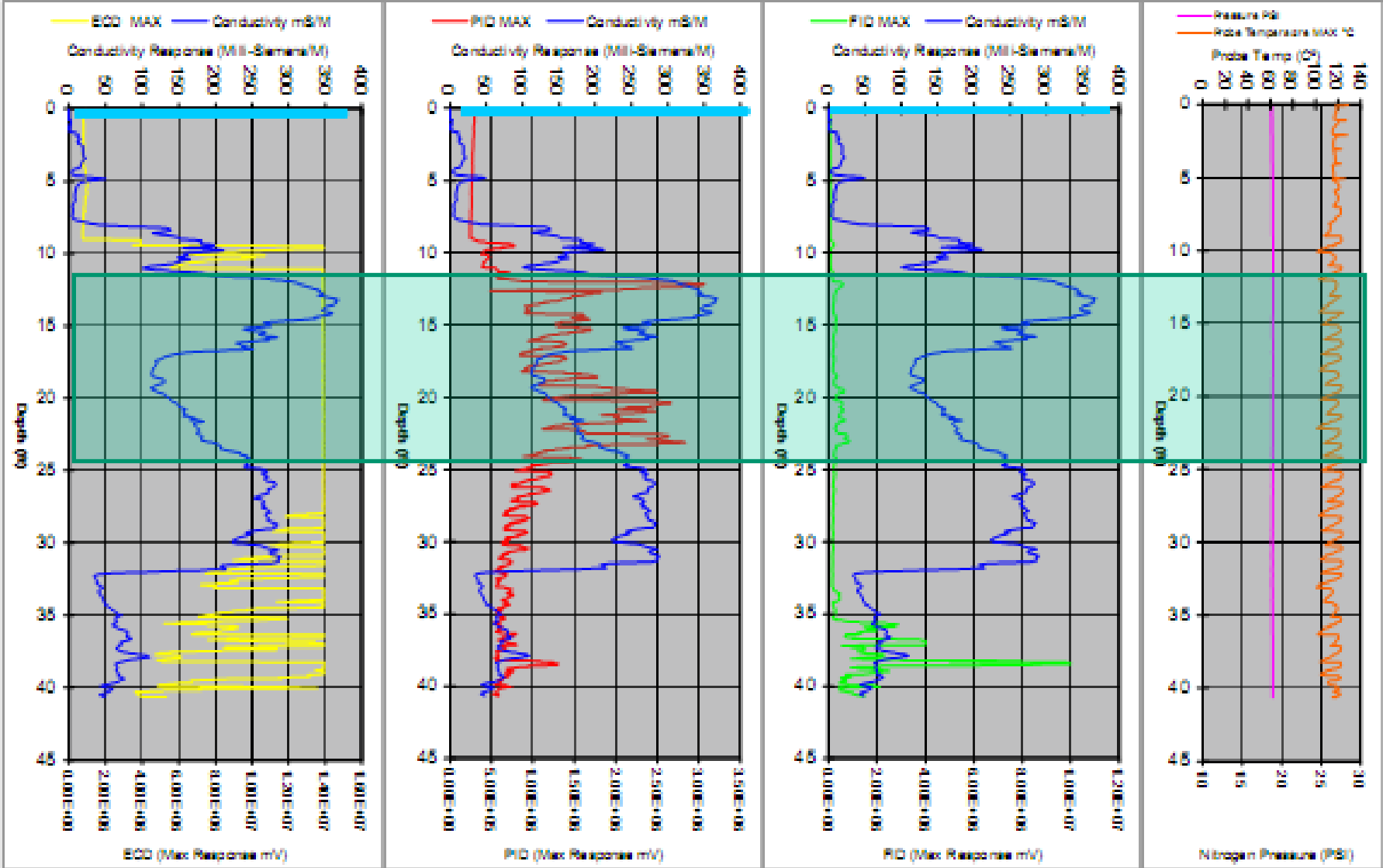
Boring Name: 3-MIP-10

Total Depth (ft): 40.65

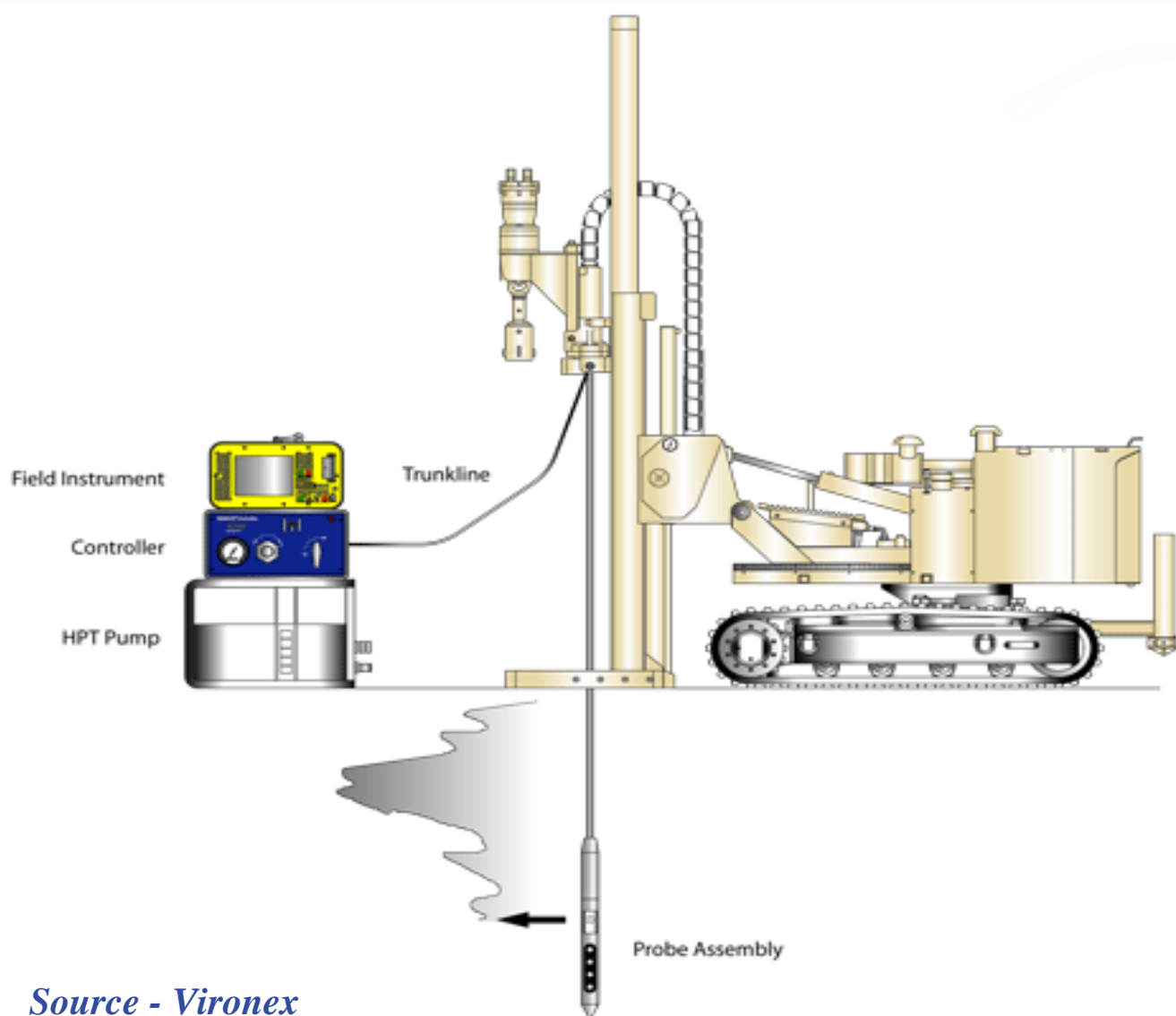
Notes:

GW Depth (ft):
 Day 1st GW Provided by Client

Job Information		MIP Sampling Information	
Client Company:	Tetra Tech	Trunkline Length:	150'
Project Name:	Vandenberg AFB MIP	Probe Type:	BS 10
Site Address:	Vandenberg AFB	Rig Type:	Geoprobe 8600
		Start Boring Time:	Fri Apr 25 2008 13:17
		End Boring Time:	Fri Apr 25 2008 14:02
		MIP Specialist:	Kyle Ervin



Search - How The HPT Works



Source - Vironex

Search - Why MIP/HPT before injecting ?



- Locate contaminant mass through high vertical resolution
- Define injection flows and pressures
- Don't get fooled by tight sands or clays with low conductivity

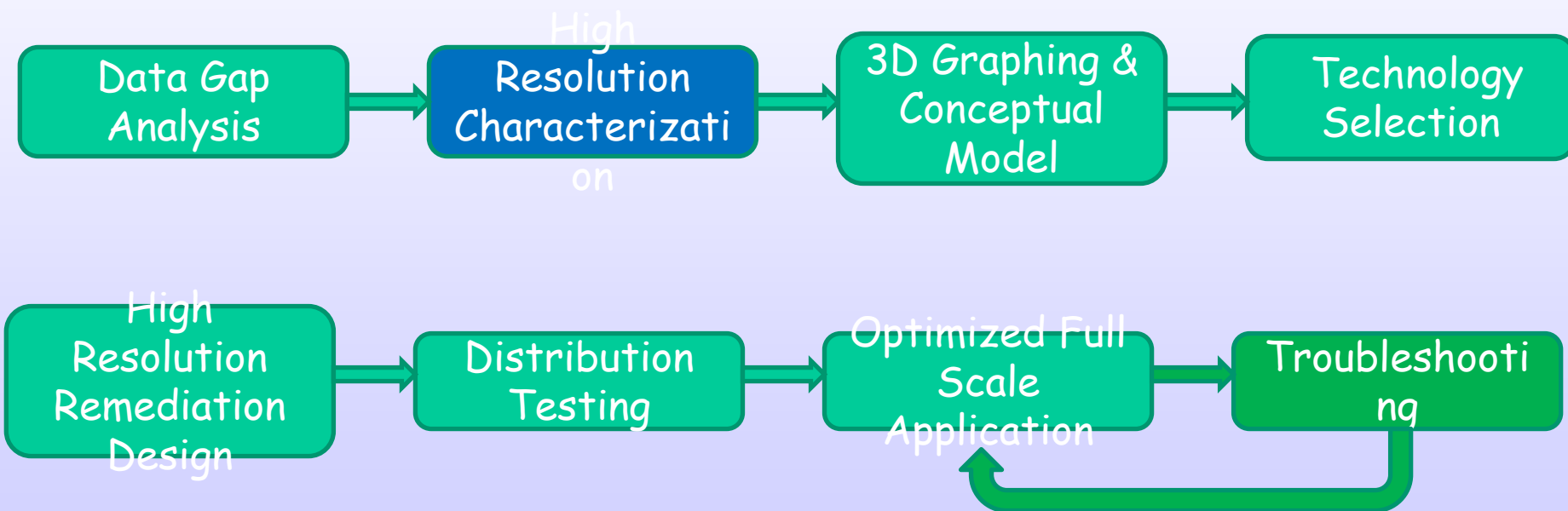


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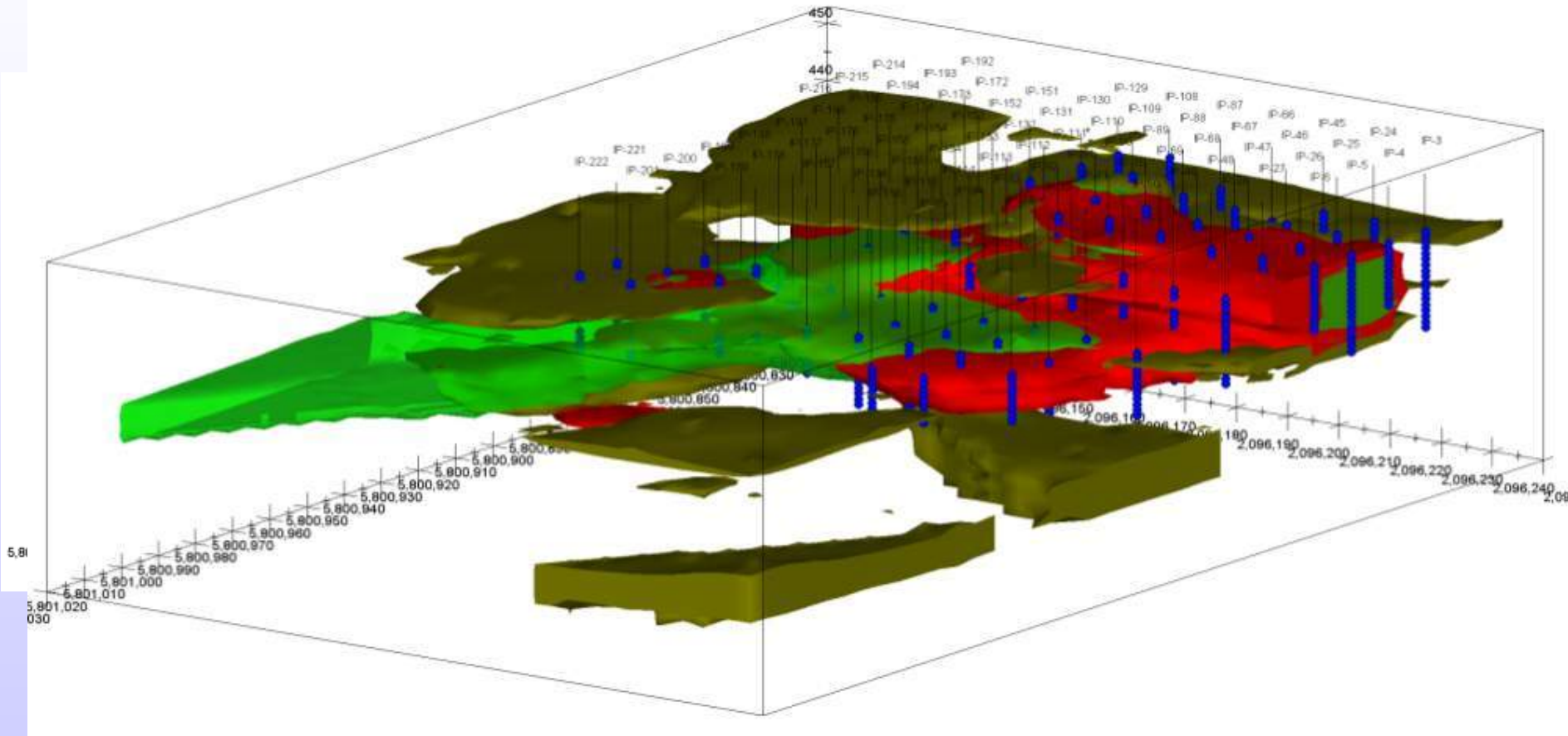
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Tools, testing and tricks

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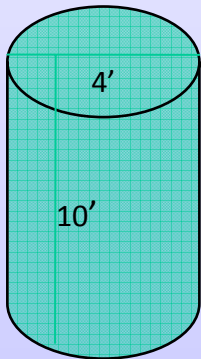


MIP 3D Imaging / Injection Locations



Radius of Influence (ROI)

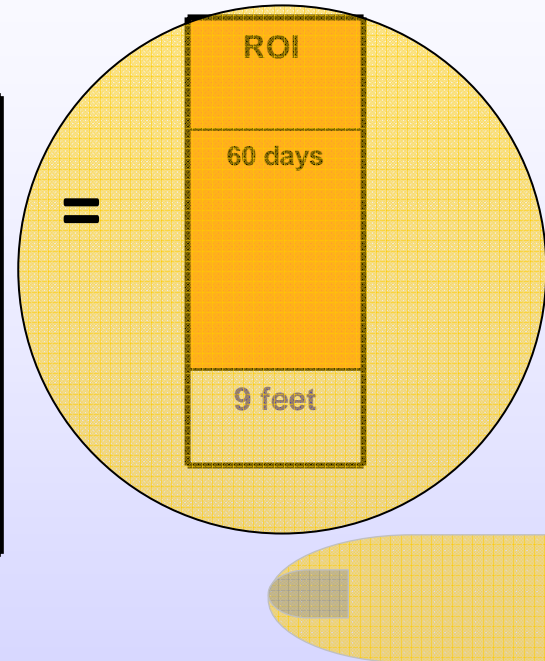
Pore Volume ROI		
Reagent Per Location	Injection Volume as a % of Effective Pore Volume	Pore Volume ROI
500 gals	100%	2 feet



+

Advection / Dispersion ROI	
Additional ROI from Advection / Dispersion (Feet)	Time Frame To Achieve Advection / Dispersion ROI (Days)
7 feet	60 Days

=



$$ROI = P_{ROI} + A/D_{ROI}$$

ROI = pore volume ROI (ft) + advection/dispersion ROI (ft)

9 feet = 2 feet + 7 feet @ 60 days

Kinetics > ROI_T

ROI Realities

Pore Volume ROI		
Reagent Per Location	Injection Volume as a % of Effective Pore Volume	Pore Volume ROI
500 gals	50%	2 feet

Advection / Dispersion ROI	
Additional ROI from Advection / Dispersion (Feet)	Time Frame To Achieve Advection / Dispersion ROI (Days)
7 feet	60 Days

ROI
60 days
9 feet

Tight Soils

- Low Injection Pore Volumes
- Tighter Spacing
- Higher Reagent Concentrations

- Reagent Persistence
- Exceed Fracture Pressure

Permeable Soils / Flat Gradient

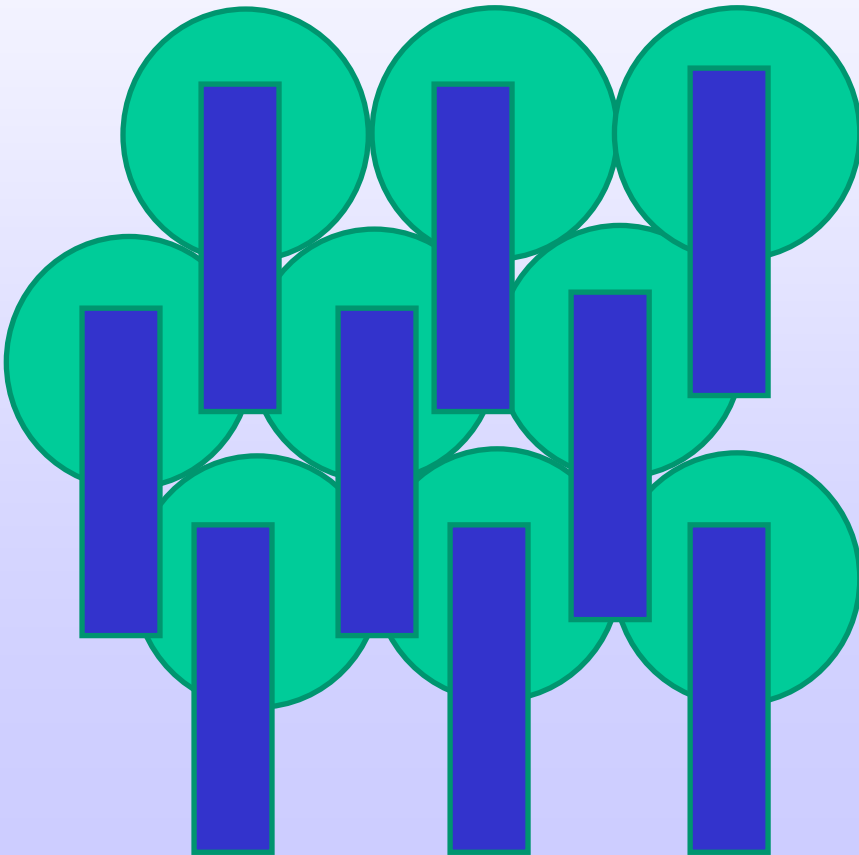
- Requires High Injection Pore Volume
- Stay Below Fracture Pressure

Permeable Soils / Steep Gradient

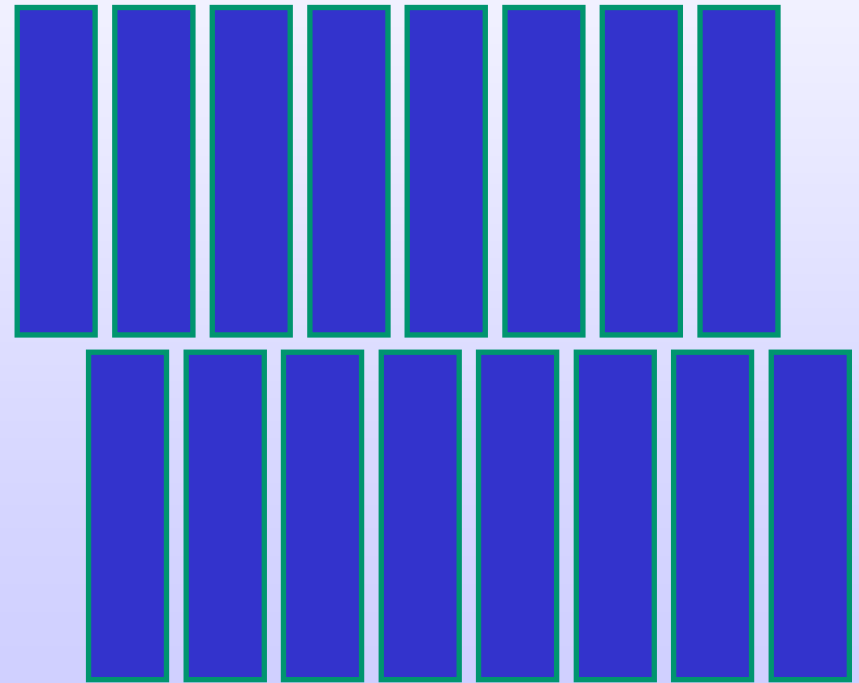
- Lower Residence Time

Distribution Primarily Advection Driven 10' ROI @ 30% pore Volume

• Advection & Dispersion



Advection Only



Injection < Fracture Pressure

$$P_{I_{max}} < [(d_{dry} g h_{dry} + d_{sat} g h_{sat}) - d_{water} g h_{sat}] \text{ psi}$$

$P_{I_{max}}$ = Maximum injection pressure to prevent structural failure (fracturing)

-----Rule Of Thumb-----

$$P_{I_{max}} = DPT_p + (DTI * 0.5PSI) \text{ (includes safety factor)}$$

DTI = Depth To Target Interval

DPT_p = Direct Push Compaction Factor



Source: Remediation Hydraulics – Payne, Quinnan, Potter - CRC Press

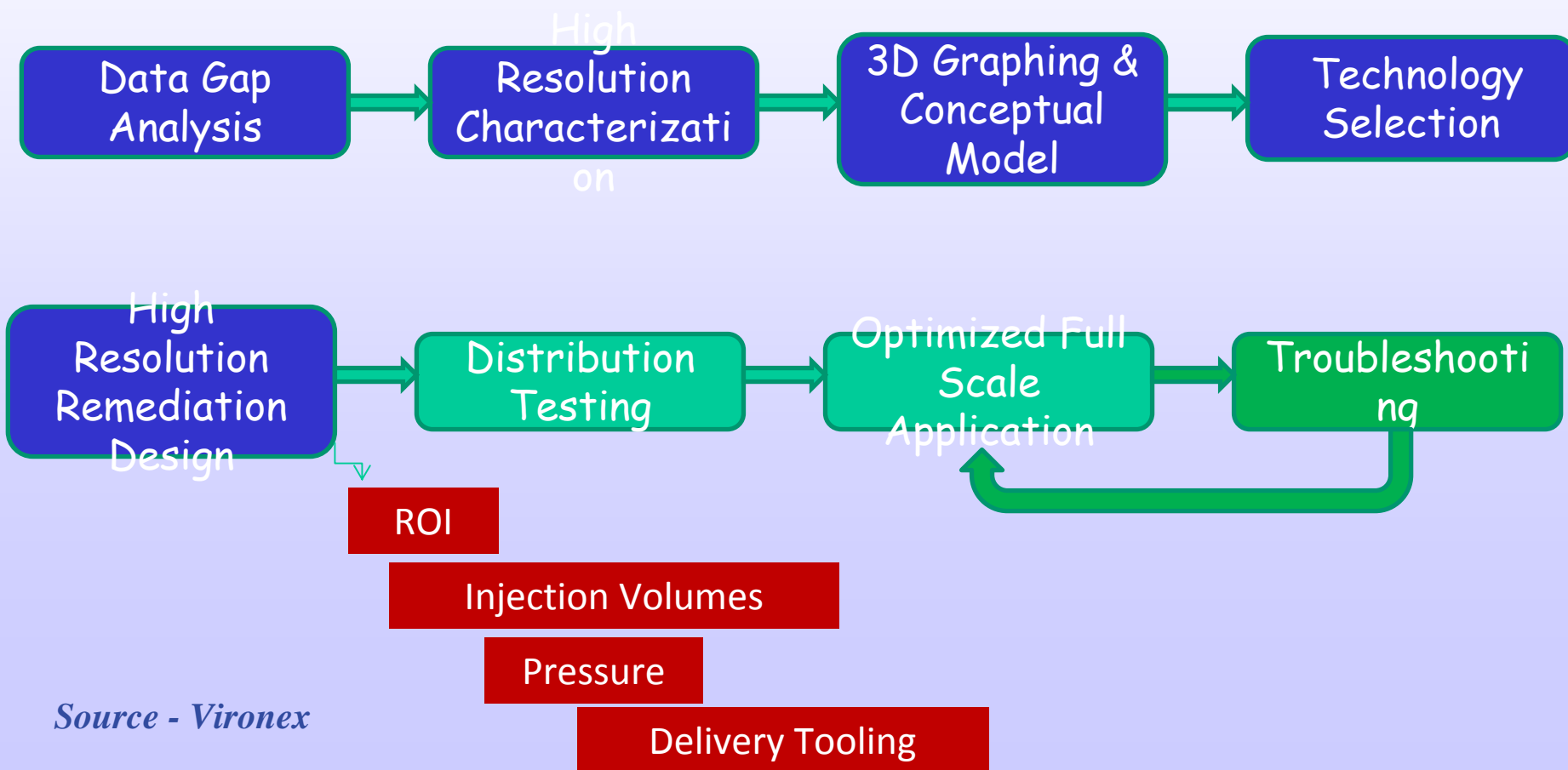


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Tools, testing and tricks

Search and Destroy™ Methodology Targeted Distribution



Source - Vironex



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Source - Vironex

Delivery Systems

Direct Push

- ❑ Bottom-Up or Top-Down tools (screens 1 to 5 feet) targeting of discrete lithologies

Injection Wells

- ❑ Injection wells
- ❑ Packer isolation of open bore holes

Fracturing

- ❑ DPT fracturing of tight formations
- ❑ Pneumatic and Hydraulic

Extraction / Injection

Electrokinetic

Injection Pressure

- Low to Moderate

- Low

- Low to High

- Moderate to High

- Low

Destroy - Why Distribution Testing



Avoid Major Design Changes During Full-Scale

- Confirm Injection Pressure and Flow Assumptions
- Confirm Formation Acceptance of Design Volume
- Confirm Vertical and Horizontal Distribution of Reagents Over Time



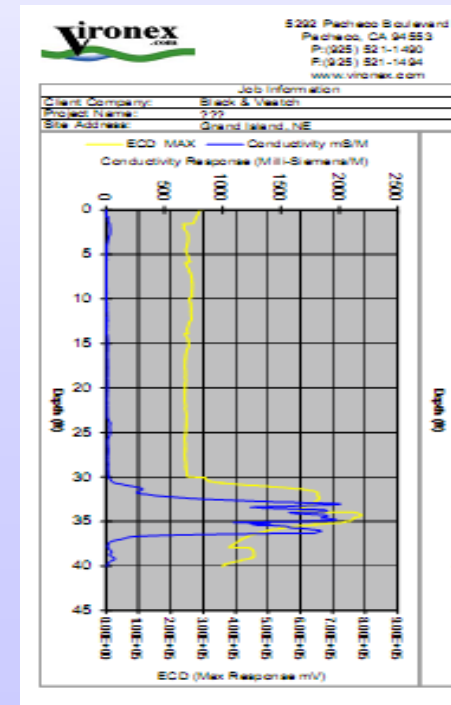
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Tools, testing and tricks

Follow up After injection events

- Validate oxidant/amendment distribution (may integrate inert tracer to evaluate dilution factor) with :
 - Core samples
 - Hydropunch sampling
 - Electrical Conductivity
 - Groundwater sampling through monitoring well





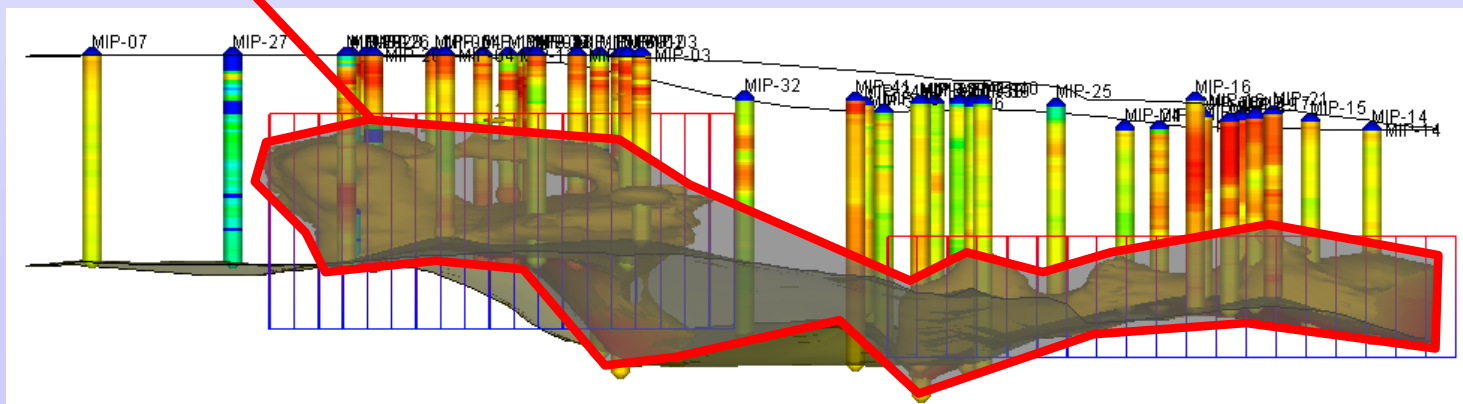
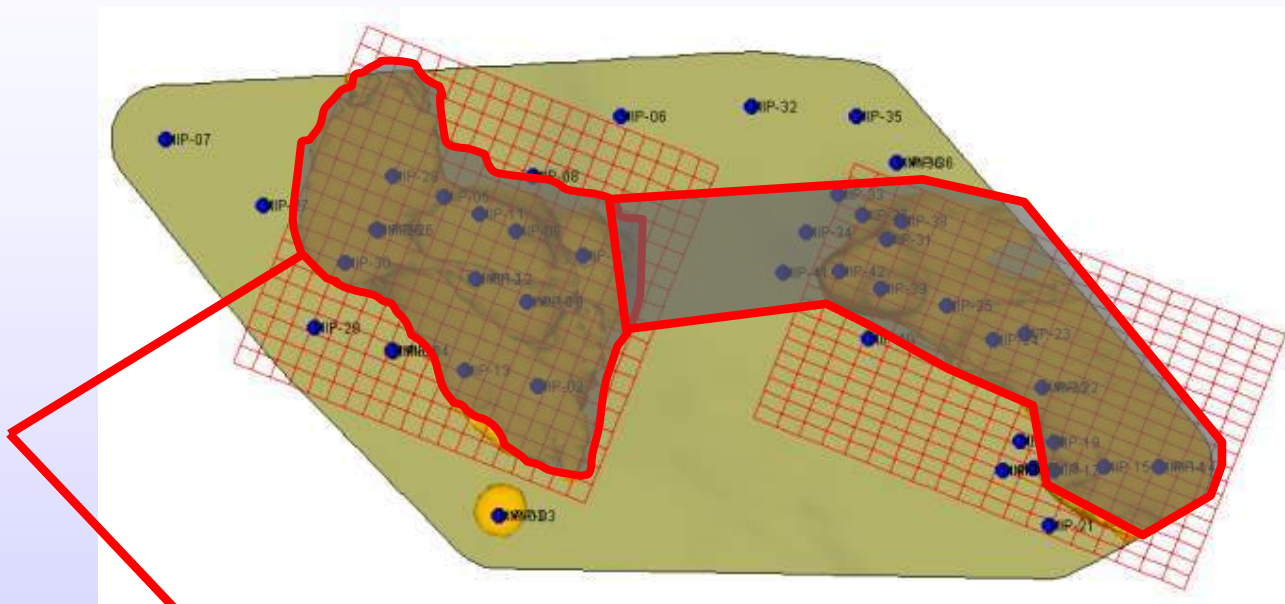
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Outputs Visual Data Dry Cleaner Case Study

Injection

Strategic
Injection
Strategy



Source: Vironex



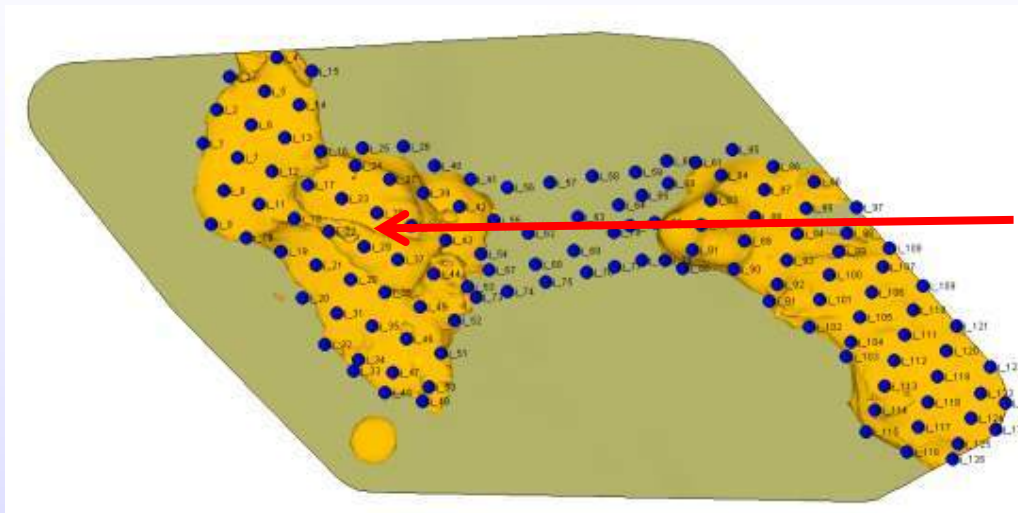
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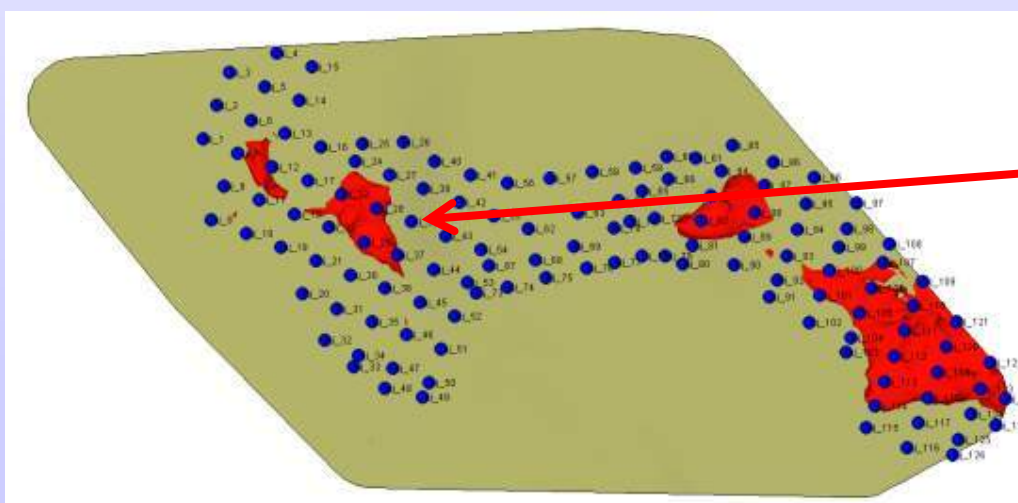
Outputs Visual Data MIP Post Injection

Injection

Strategic Injection
Strategy



Pre-Injection
MIP



Post-Injection
MIP



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Who we are

- Canadian Company founded in 1988
- Production and warehouse facilities in Quebec, Ontario and in Western Canada with Quadra Chemicals
- **Sectors of activity**
 - Industrial and Municipal Waste Water
 - Contaminated Soil and Groundwater
 - Air, Odours and Atmospheric Emissions
 - Process Water
- **Products:** coagulants, flocculants, nutrients, bacterial preparations strains, oxidants, catalysts, oxygen and hydrogen release compounds, odour control agents
- **Services:** technical support, product selection, product supply and sourcing, logistics, laboratories (SOD and treatability testing), design and staff training.



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Acknowledgements

- Carus Chemical
- FMC Corporation
- Progressive Engineering & Construction
- Vironex

**Thank you for your attention !
Have a good day !!!**

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