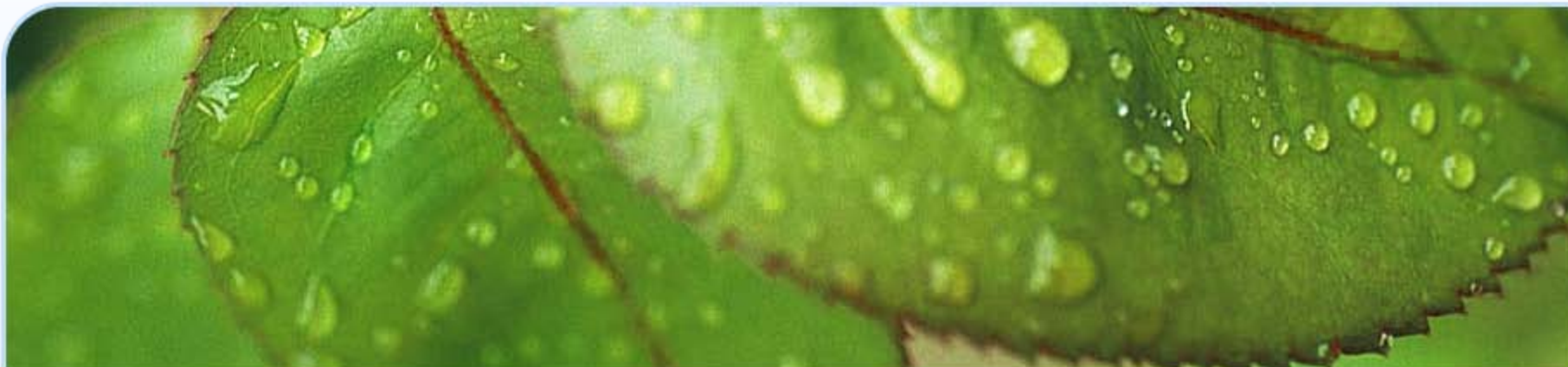


# EHC-M® *In Situ* Chemical Reduction (ISCR) Technology for Removal of Heavy Metals (and persistent organic compounds)

Jim Mueller, Andrzej Przepiora, Josephine  
Molin, John Vogan and Alan Seech  
Adventus Europe - Austria

INTERSOL 2010 – 9<sup>th</sup> Conference on  
Polluted Sites & Soils  
Paris-Sud March 16-19, 2010



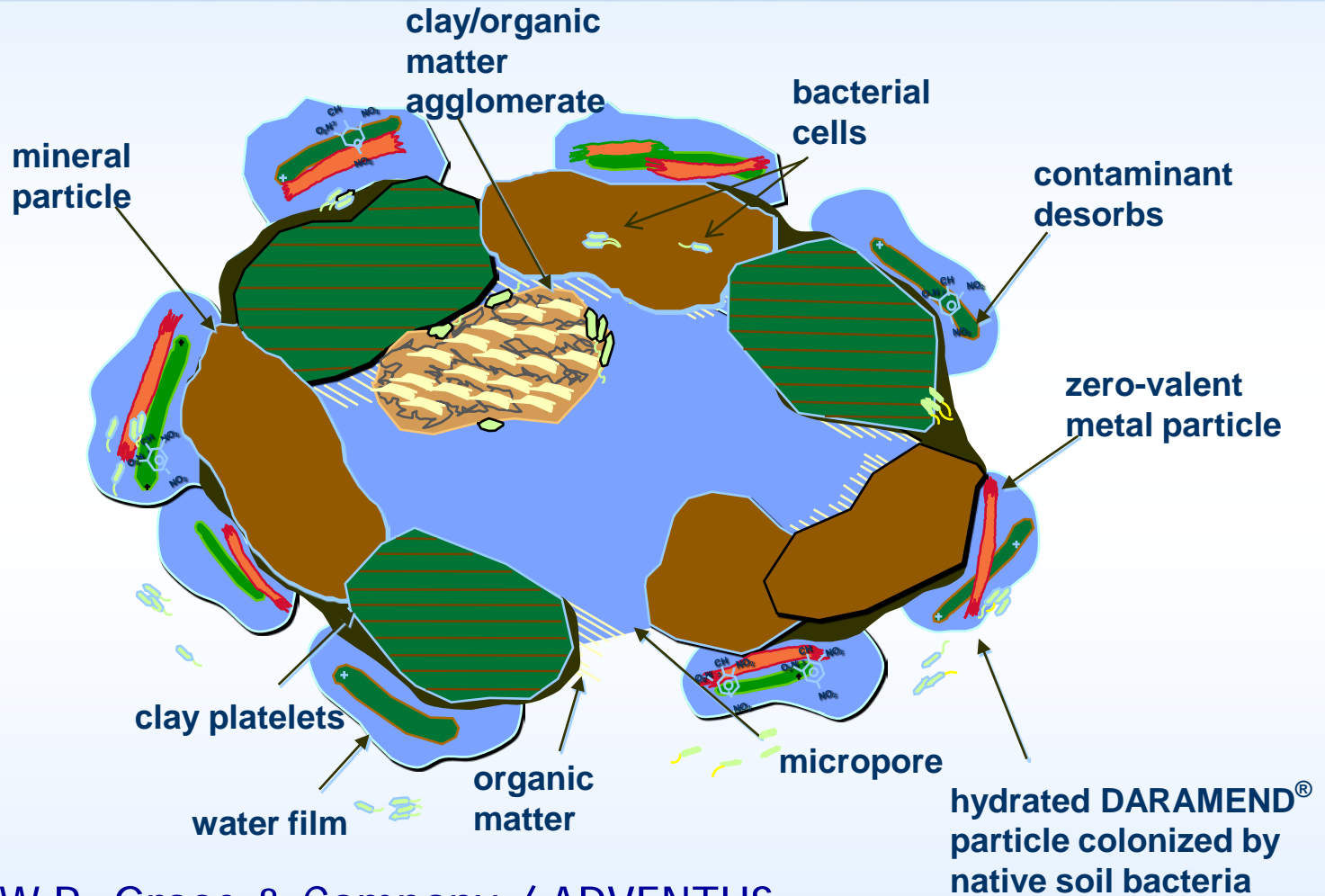


# Presentation Overview

- EHC-M Technology background
- Laboratory results
- Field Applications (Successes and lessons learned)
- Conclusions



# *In Situ* Chemical Reduction (ISCR™)



US Patents W.R. Grace & Company / ADVENTUS



# What is EHC-M?

EHC-M is an injectable remediation product composed of:

- Controlled-release, food grade, complex carbon
- Micro-scale zero valent iron (5 - 10  $\mu\text{m}$ )
- Major, minor, and micronutrients
- Food grade organic binding agent
- (Sulfate)





## EHC-M Treatment Efficiencies Observed in Laboratory Batch Tests

Compound	Influent Concentration Range (ug/L)	Observed Removal Efficiency (%)
<b>Antimony</b>	<b>24,500</b>	<b>&gt;99</b>
<b>Arsenic</b>	<b>500</b>	<b>98</b>
<b>Cadmium</b>	<b>11</b>	<b>&gt;99</b>
<b>Chromium</b>	<b>200</b>	<b>&gt;99</b>
<b>Cobalt</b>	<b>210</b>	<b>&gt;99</b>
<b>Copper</b>	<b>86</b>	<b>&gt;99</b>
<b>Lead</b>	<b>64,000</b>	<b>&gt;99</b>
<b>Mercury</b>	<b>1,020</b>	<b>97</b>
<b>Nickel</b>	<b>350</b>	<b>&gt;99</b>
<b>Zinc</b>	<b>50,400</b>	<b>92</b>



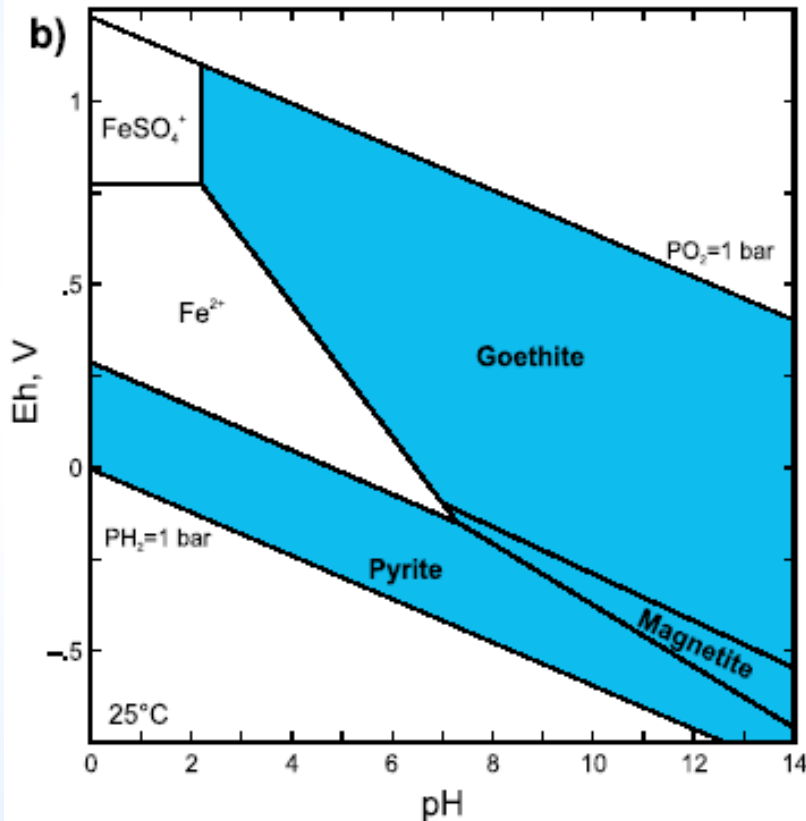
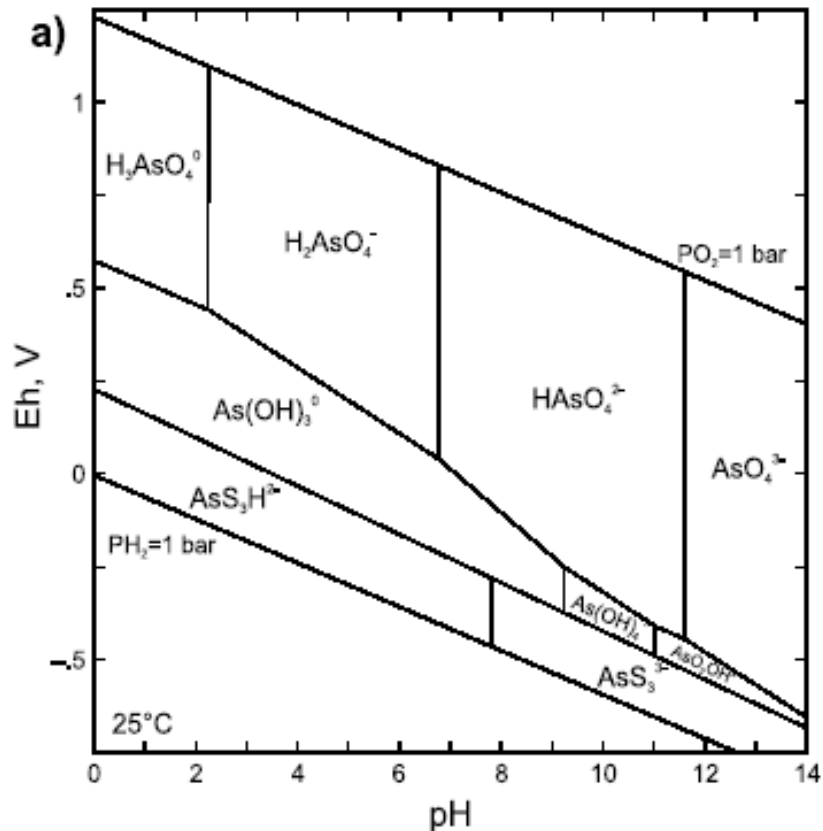
# Metals Treated and Mechanisms

Contaminant	Treatment Mechanisms in the ZVI-Carbon zone
As (III, V)	Reductive precipitation with oxidized iron minerals. Precipitation as As sulfide and mixed Fe-As sulfide
Cr(VI), Mo(VI), Se(IV,VI), U(VI)	Reductive precipitation with oxidized iron minerals and adsorption to iron oxides.
Me <sup>2+</sup> (Cu, Zn, Pb, Cd, Ni)	Metal cations precipitate as sulfides, following stimulated heterotrophic microbial sulfate reduction to sulfide. Adsorption to iron corrosion products (e.g.; iron oxides and oxyhydroxides).





# Co-precipitation/Sorption of Arsenic in the presence of dissolved Fe and S

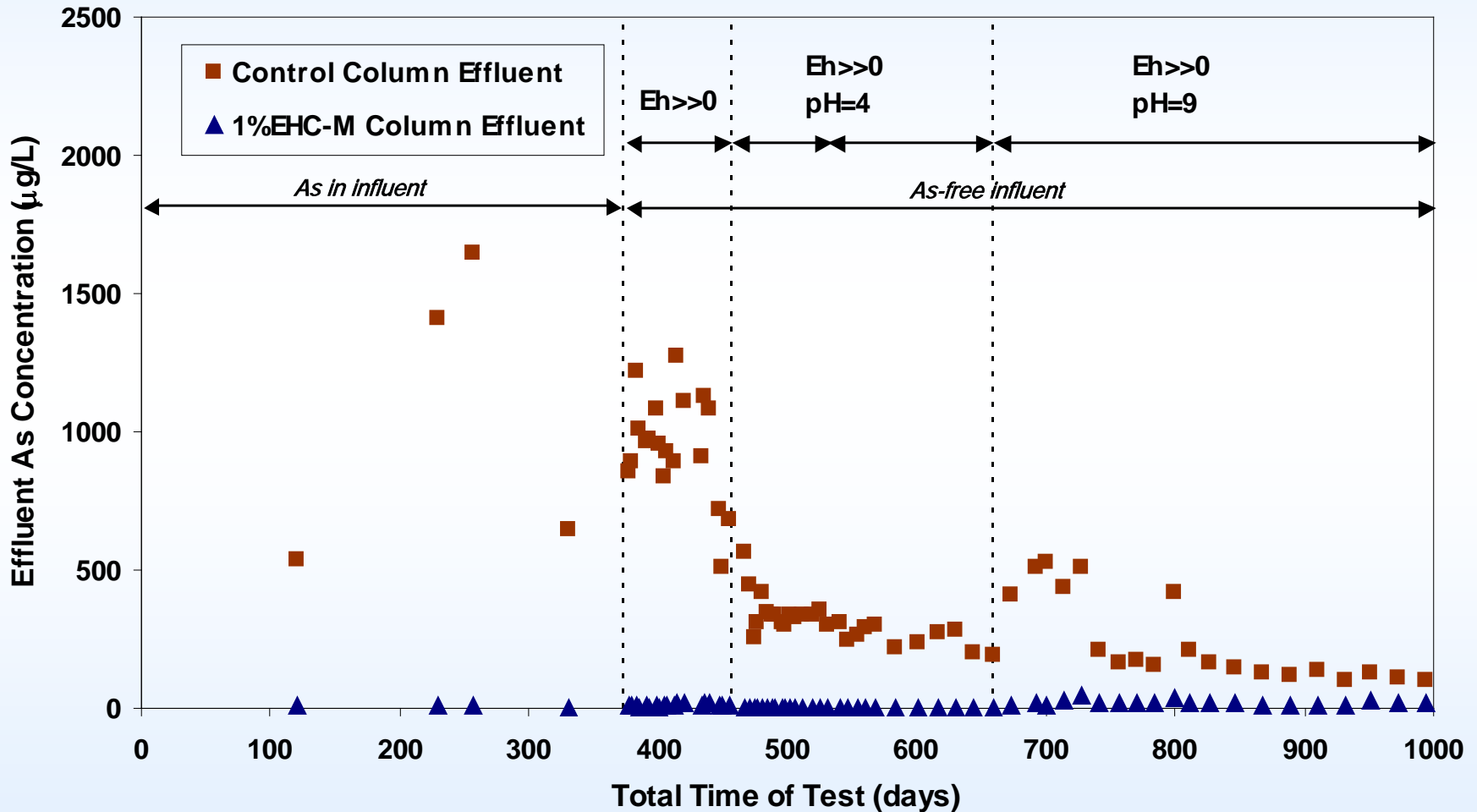


From EPA/600/R-07/140



# Influence of Changing DO and pH on Precipitated Arsenic

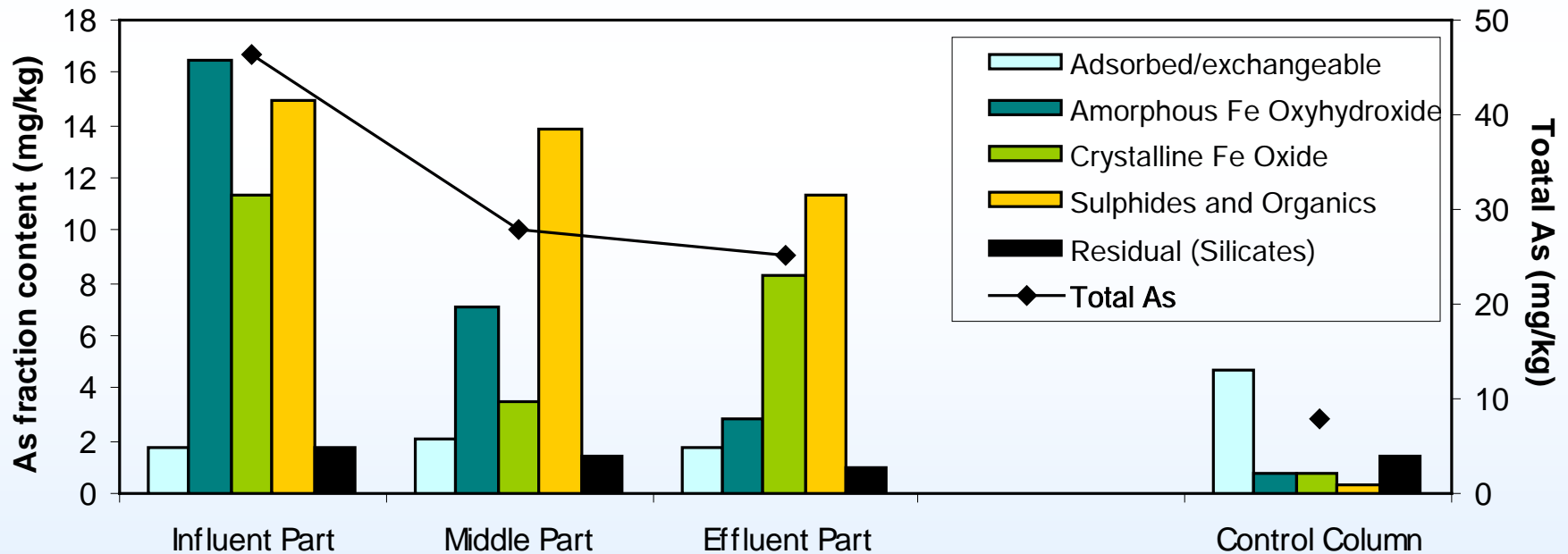
Column: 13 cm long and 5 cm Ø, Flow rate = 50 mL/d, Residence time = 2 days





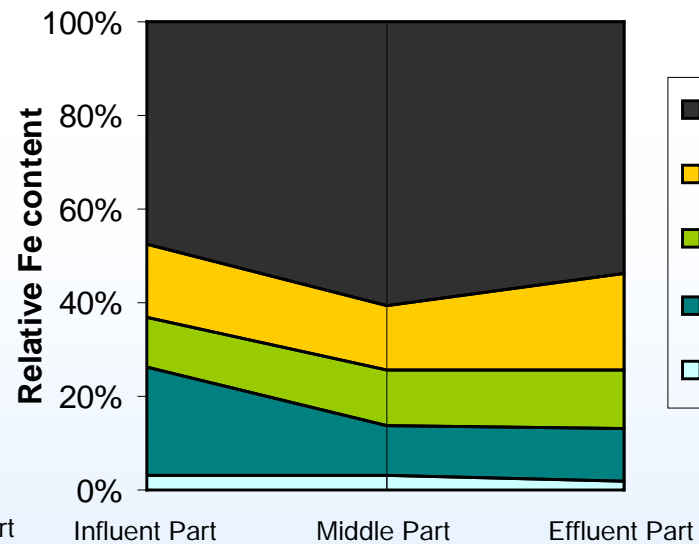
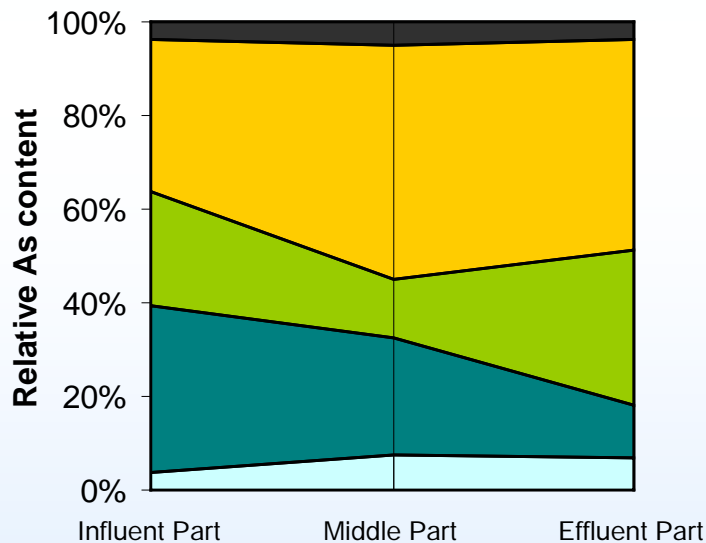


# Long-Term Column Test for As Treatment Solid As Speciation





# Progressive Digestions - Correlation of As and Fe fractions



- Residual (Silicates)
- Sulphides and Organics
- Crystalline Fe Oxide
- Amorphous Fe Oxyhydroxide
- Adsorbed/exchangeable

*Mass of As: Fe(II+III) = 1:100*



## Field Applications of EHC-M

- 💧 Over 30 world-wide (pilot and full-scale)
- 💧 Target concentrations met for various metals including  $\text{Cr}^{+6}$ , divalent metals, arsenic
- 💧 VOCs present also treated
- 💧 Five Case studies
  - ➡ Washington (TCE,  $\text{Cr}^{+6}$ )
  - ➡ Ontario (Cu, Ni, Zn)
  - ➡ Brazil ( $\text{Pb}^{+2}$ )
  - ➡ Florida (Toxaphene, Arsenic)
  - ➡ Florida (Arsenic)

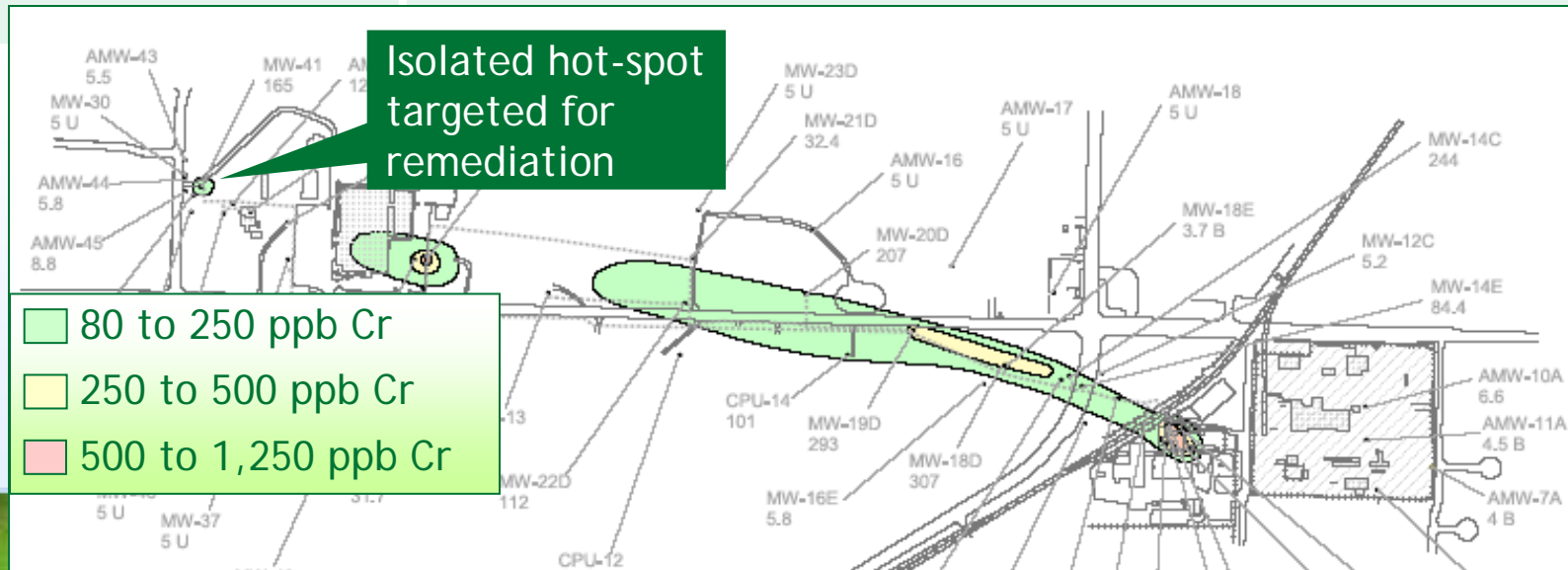


# EHC-M Case Study #1

## Cr(VI) and TCE in Groundwater Plume

### Case Description

Location	Northwestern US
Type of Site	Industrial facility
Description of Impacts	Cr(VI) 165 ug/l and TCE 6 ug/l in groundwater; 75 to 85 ft bgs. Isolated area experienced rebound
Objective and Approach	Injection of EHC-M for treatment of isolated hot-spot.





# EHC-M Injection Layout

## Treatment Area Dimensions:

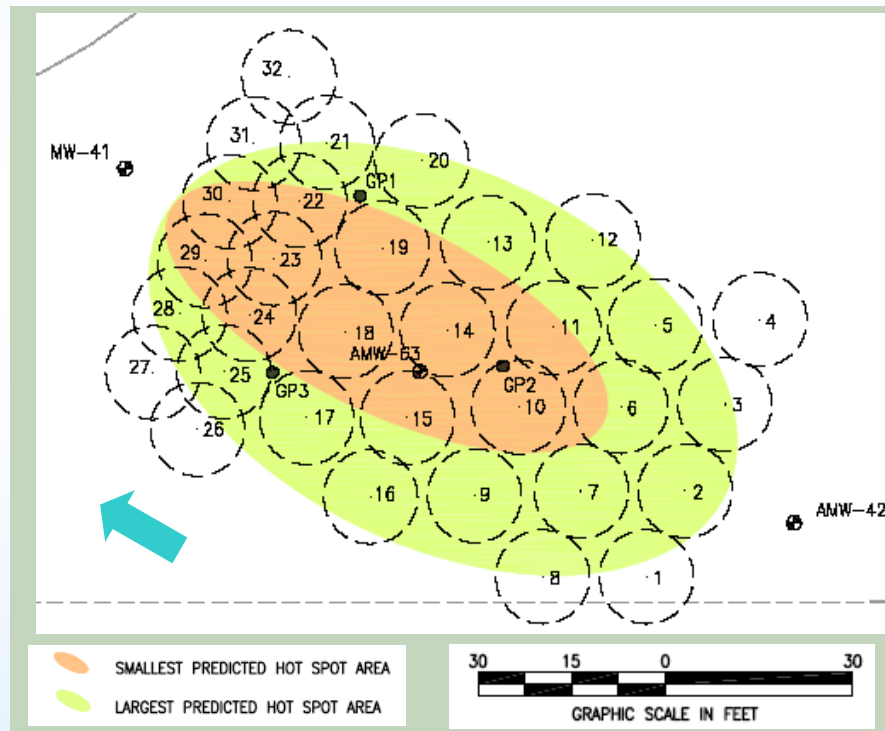
- 100 ft long x 60 ft wide x 10 ft deep (from 75 to 85 ft.

## EHC-M Application Rate:

- 0.15% wt/wt
- 9,600 lbs injected

## Direct Injection:

- 32 direct push points
- 10 to 15 ft spacing







## Field Results – Washington State

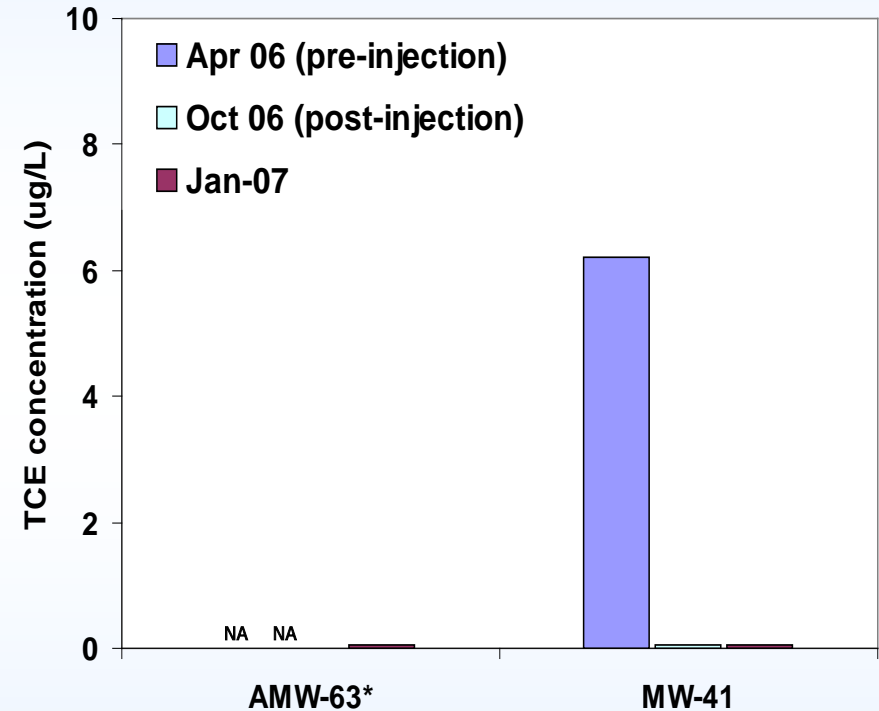
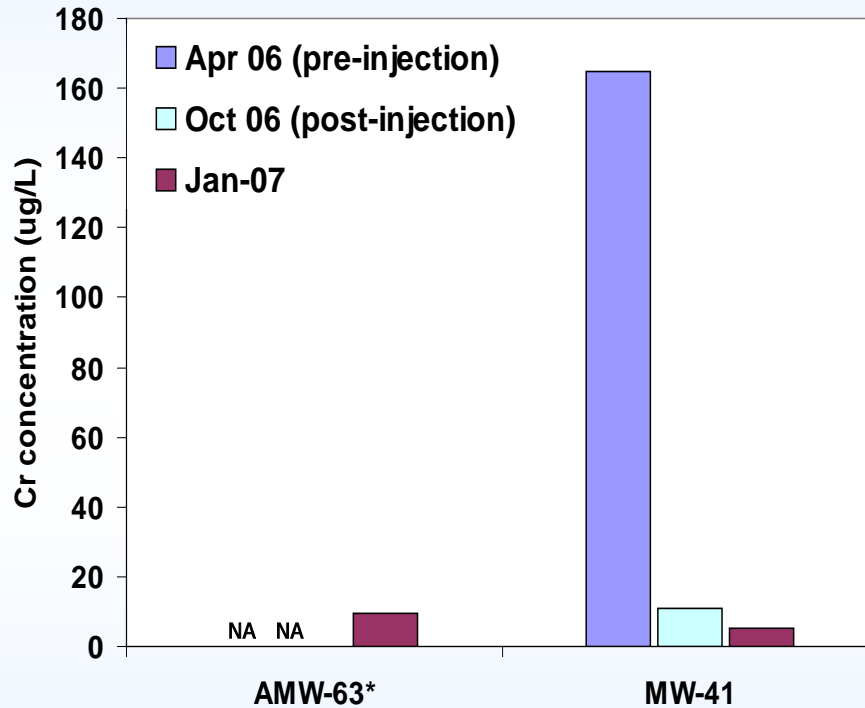
A total of 9,600 lbs of EHC-M was injected into the area, resulting in an average application rate of 0.15% to soil mass.







# Field Results - Washington State



*AMW-63 - New well installed in November 2006*

*(Courtesy of EA Engineering, Science and Technology, Inc.)*



# Case Study #2

## Trace metal groundwater plume

### Case Description

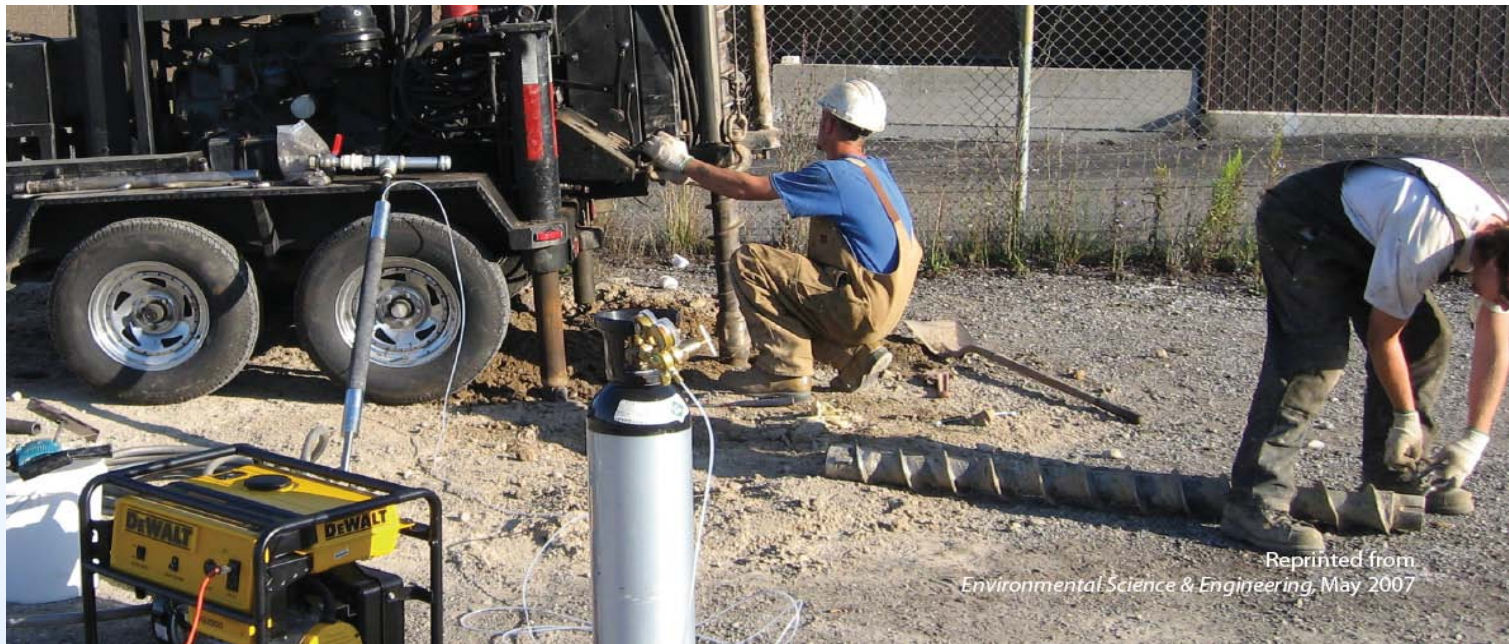
Location	Ontario Canada
Type of Site	Industrial
Description of Impacts	Copper, Cobalt and Nickel
Objective and Approach	EHC-M injected along site boundary for plume cut-off.





## Installation Method

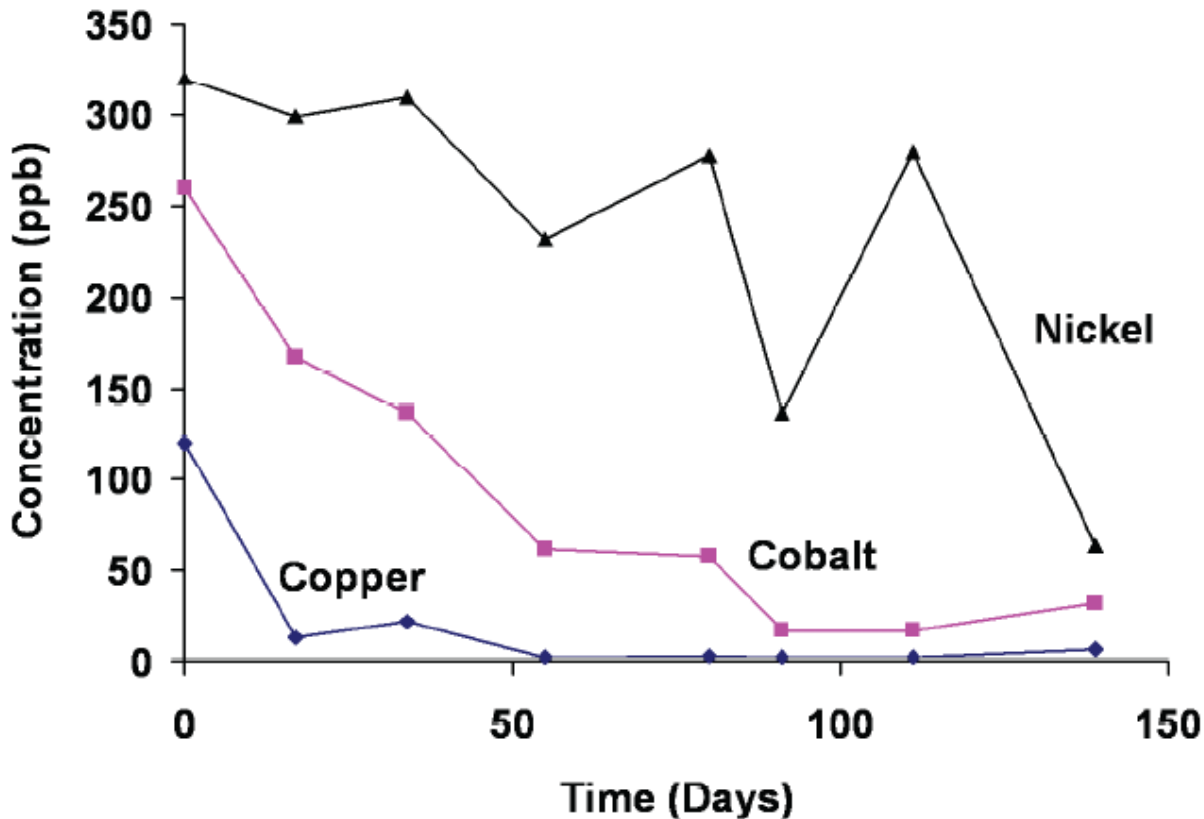
- Total of 600 kg EHC-M injected into area measuring 9 m L x 7 m wide x 7 m deep (0.08% to soil mass).
- EHC-M slurry injected via open bore holes using packers - total of 12 locations.
- Nitrogen gas also added to facilitate anaerobic conditions







## Field Results- Ontario site



- Sulfate reducing conditions ( $E_h < -250$  mV) achieved in days
- Remediation objectives were met for all metals
- Regulatory approval was obtained.



# Case Study #3

## EHC-M and pH Control for Pb Immobilization

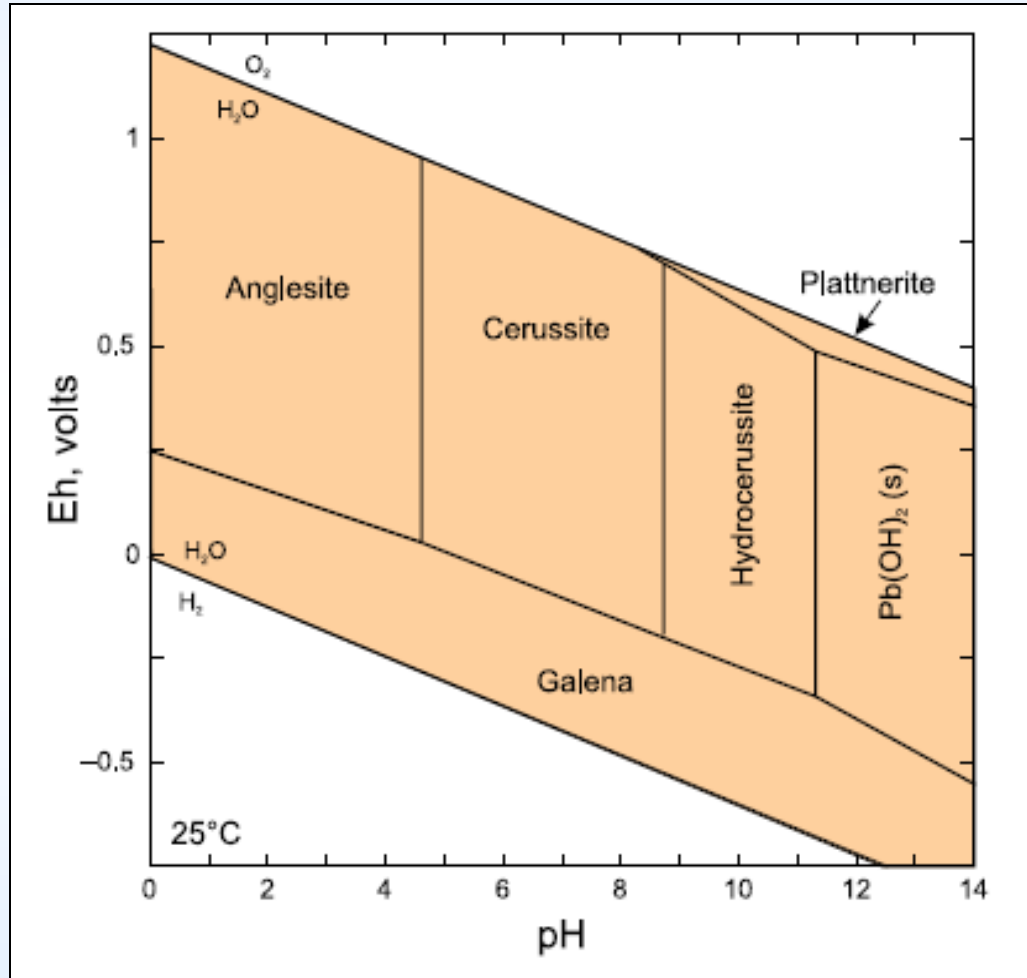
### Case Description

Location	Sao Paulo, Brazil
Type of Site	Former battery recycling facility
Description of Impacts	Dissolved lead plume measuring 250 m long x 150 m wide x 15 m deep (from 15 to 30 m bgs); pH of 4 to 5.
Objective and Approach	Pilot study injection of EHC-M. Treatment included pH adjustment using dolomite.





# Potential solid phase Pb precipitates



## Input values:

total Pb =  $10^{-5}$  molal, total C =  $10^{-3}$  molal, total S =  $10^{-3}$  molal;  
all organic Pb complexes are suppressed; activity coeff. for all species are set equal to 1.

Source: EPA, 2007. Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 2 Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium. EPA/600/R-07/140.

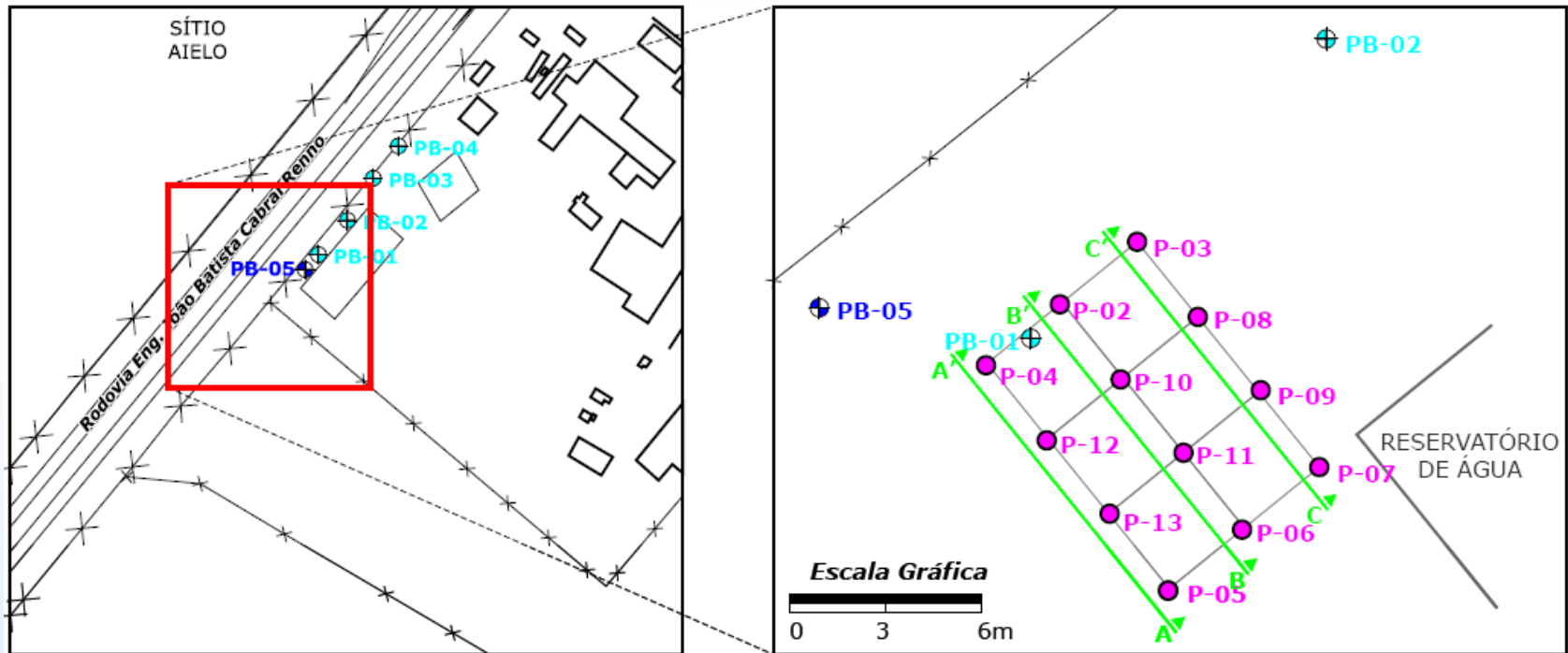
anglesite ( $\text{PbSO}_4$ ),  
cerussite ( $\text{PbCO}_3$ ),  
hydrocerussite ( $\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$ ),  
galena ( $\text{PbS}$ )





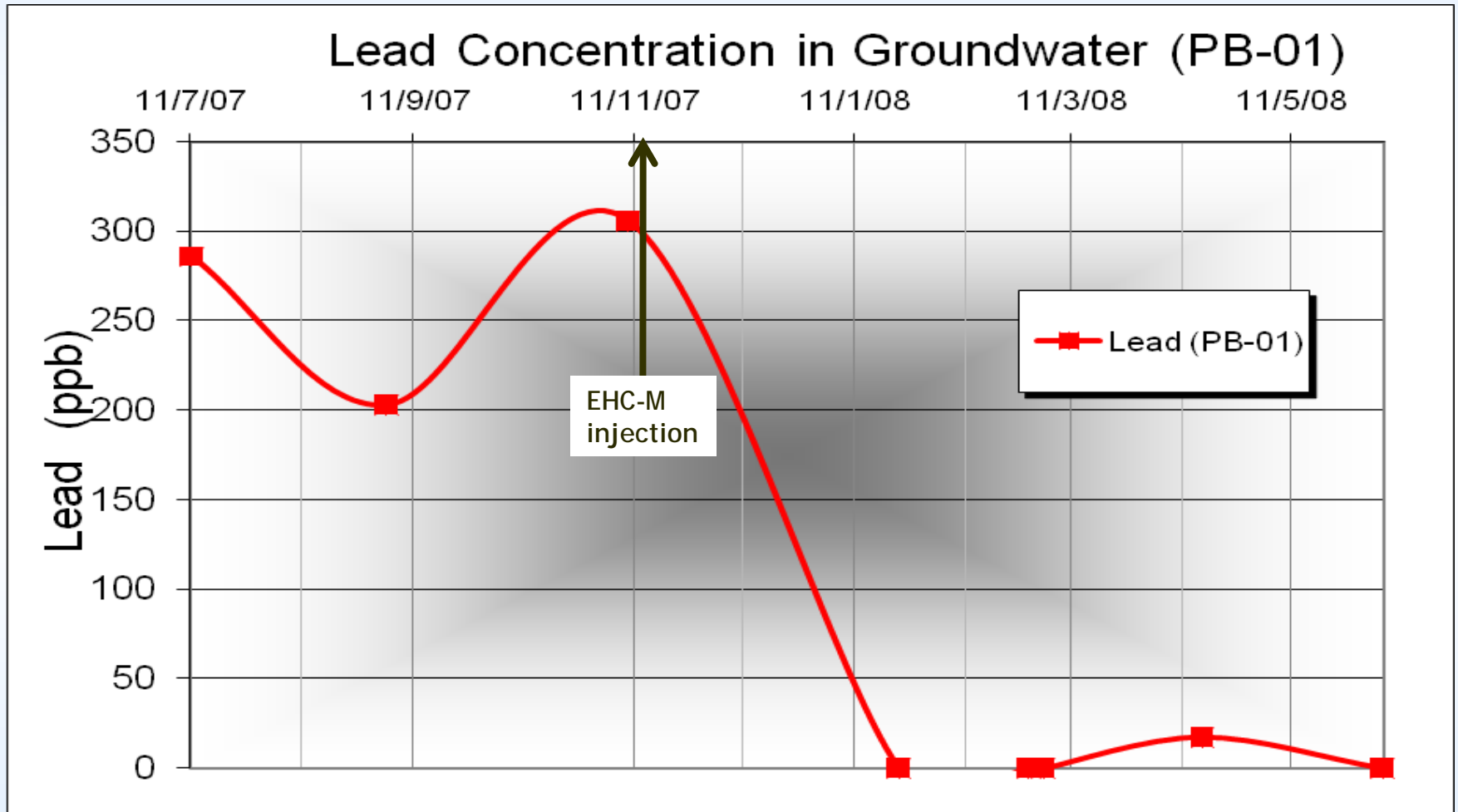
# Injection Design

- 1,000 kg of EHC-M was injected from ca 17 to 27 m bgs (0.05% to soil mass).
- 5,000 kg dolomite injected to upper 5 ft of treatment zone (0.5% to soil mass based on pH titration testing ).





## Pilot Study Results





# Case Study #4

## EHC-M for Toxaphene and As Immobilization

### Case Description

**Location**

Jacksonville, Florida

**Type of Site**

Cattle Dipping Vat

**Description of Impacts**

Toxaphene and Arsenic impacts.  
Source zone treatment and plume control

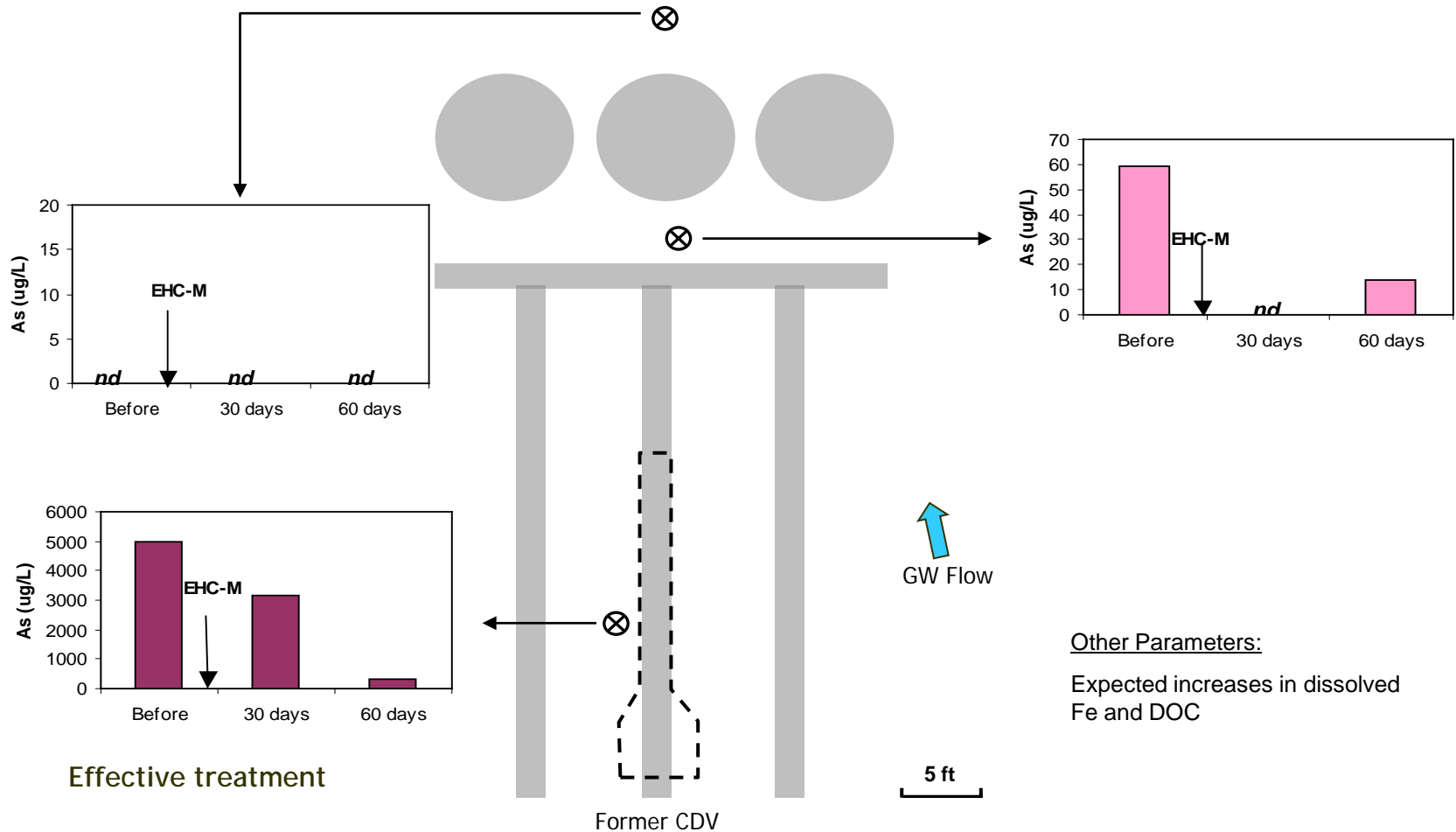
**Objective and Approach**

Full scale application of EHC-M to destroy pesticide and immobilize arsenic





# Florida Application (3 to 13 ft bgs)





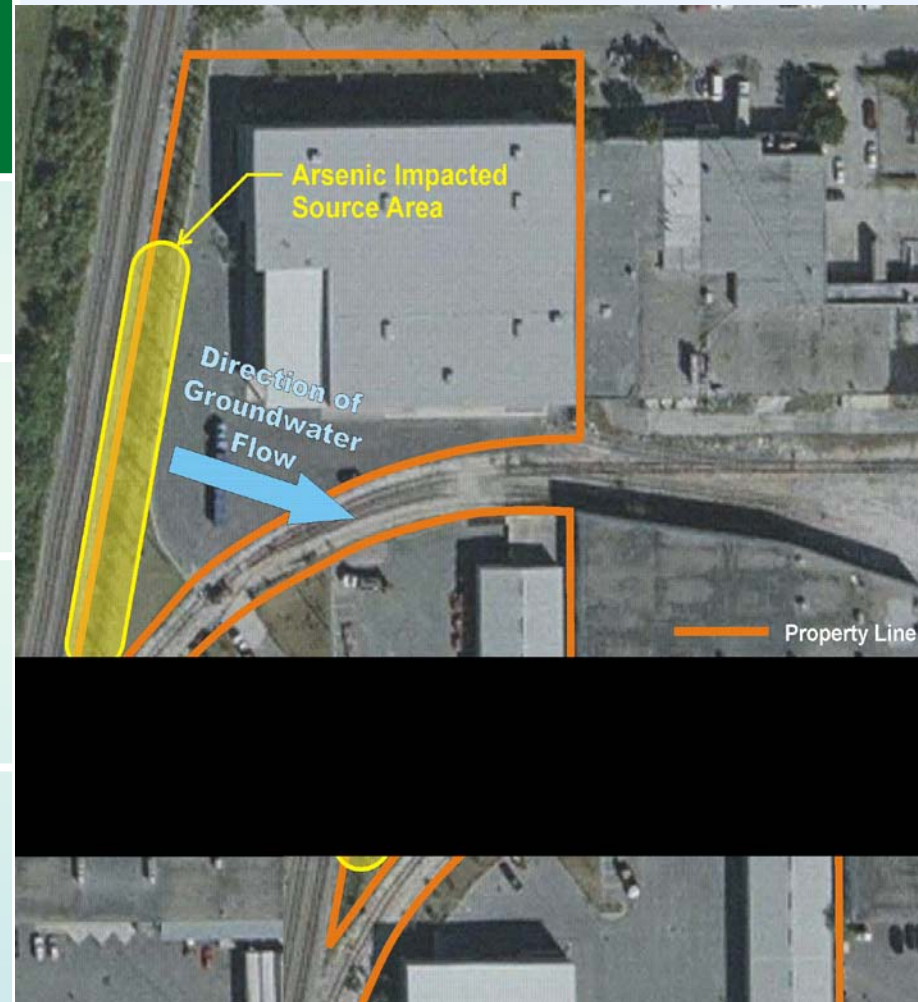


# Case Study #5

## EHC-M for Arsenic Immobilization

### Case Description

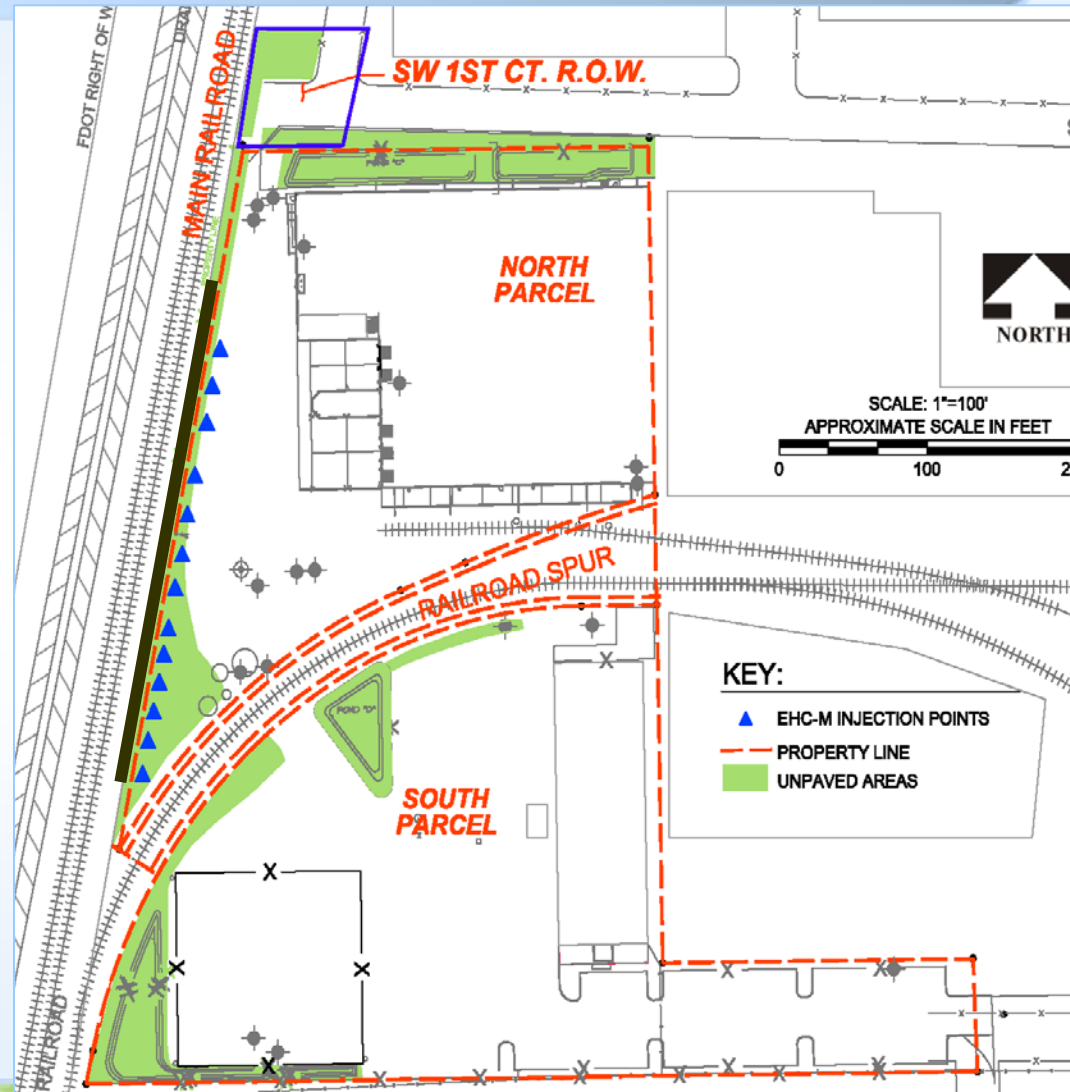
Location	Pompano Beach, Florida
Type of Site	Industrial (wood treating)
Description of Impacts	Arsenic impacts from rail road. Source zone treatment and plume control. Rail line and fiber optics limit remedial options
Objective and Approach	Full scale application of EHC-M to immobilize arsenic.





# On-Site Engineering Design

- Treatment consisted of 13 "Chimneys" located within the As source area
- Chimneys contained 50% EHC-M + sand to a depth of 0 to 5 ft bgs
- EHC-M was also added in a shallow trench from 0 to 6 inches bgs
- Delivered EHC-M targeted the unsaturated soil and capillary fringe (ca. 3 to 5 ft bgs)







ATLANTIC BUSINESS  
PARK

12/2/08	3280
6/17/09	3040

12/2/08	14000
6/17/09	1340

RETENTION  
POND

DRAINAGE DITCH

FOOT HIGH

TMW-6B

SW 1ST CT.

MW-15A

MW-4A

EXISTING ONE  
STORY BUILDING

STALLS

24.0  
(TYP OF 11)

MW-14A

MW-14B

FORMER  
PROCESS  
AREA

PN-1

MW-16A

MW-18D

TMW-1

TMW-3

MW-5B

MW-5A

MW-5BR

MW-5C

MW-13C

MW-13A

TMW-4C

TMW-4A

EXISTING ONE  
STORY BUILDING

MW-2A

MW-2B

GRASSY AREA (TYP)

FORMER  
AST AREA

MW-6B

MW-6A

MW-6C

ASPHALT

MW-1A

APPROXIMATE SCALE IN FEET



KEY:

- ⊕ EXISTING MONITORING WELL
- \* DESTROYED MONITORING WELL
- ABANDONED

**URS**

FILE

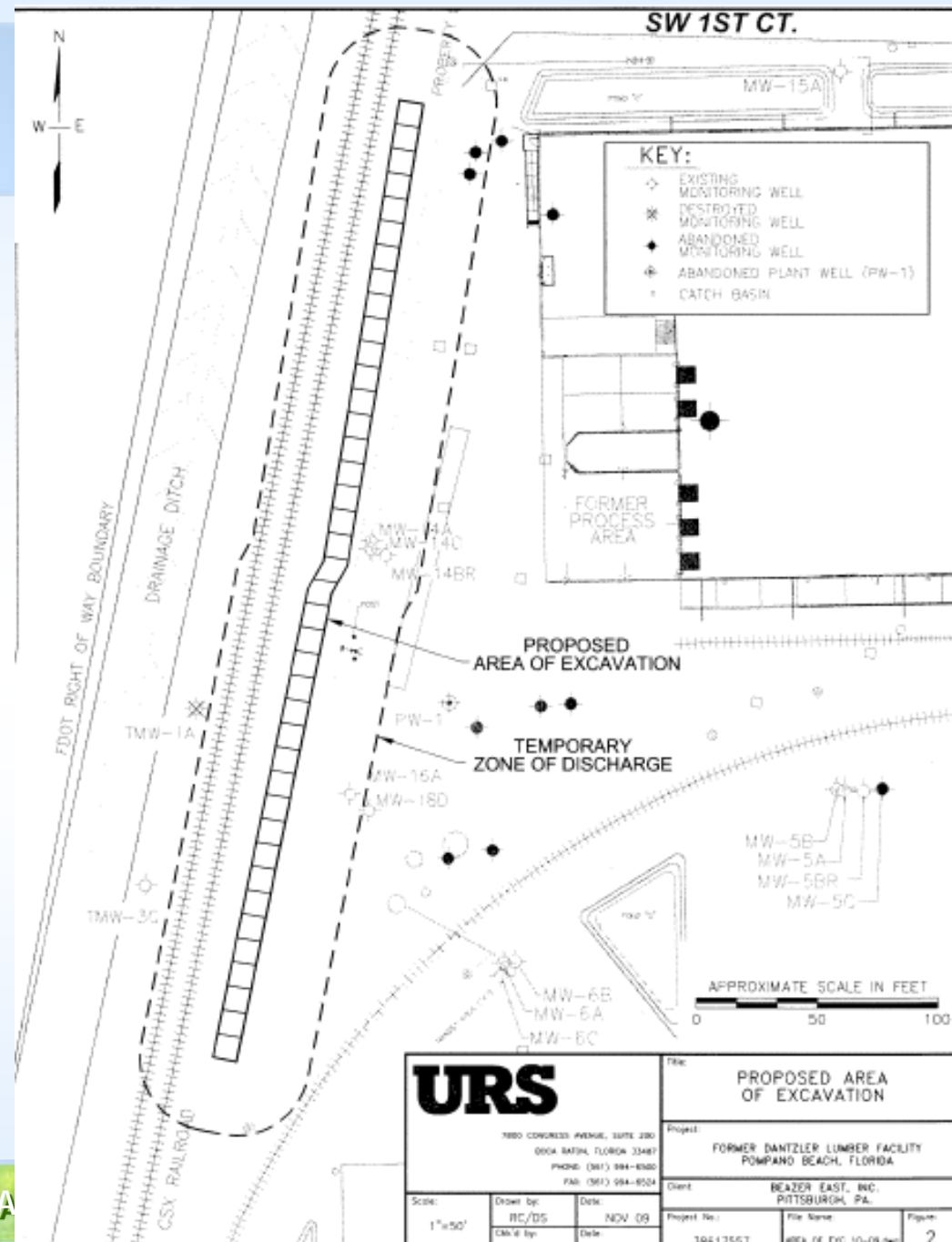
GROUNDWATER  
QUALITY MAP





## Phase II

- ca. 300 ft trench
- 10 ft long x 10 ft wide x 3 ft deep
- EHC-M + backfill (50%) mix placed into bottom 1 ft
- Return non-visually impacted soil to trench
- 5,800 lbs EHC-M





## Summary of Treatment Performance

Location	Compounds Treated	Baseline Conc. (µg/L)	Post Treatment Conc. (µg/L)	Removal Efficiency
Washington, USA	Chromium(VI)	165	<5	>97%
	TCE	6.1	<0.5	>92%
Ontario, Canada	Copper	120	10	92%
	Cobalt	260	40	85%
	Nickel	320	70	78%
Sao Paulo, Brazil	Lead	306	<10	>97%
Florida Sites	Arsenic	>14,000 > 5,000	<1,000 <50	>99%



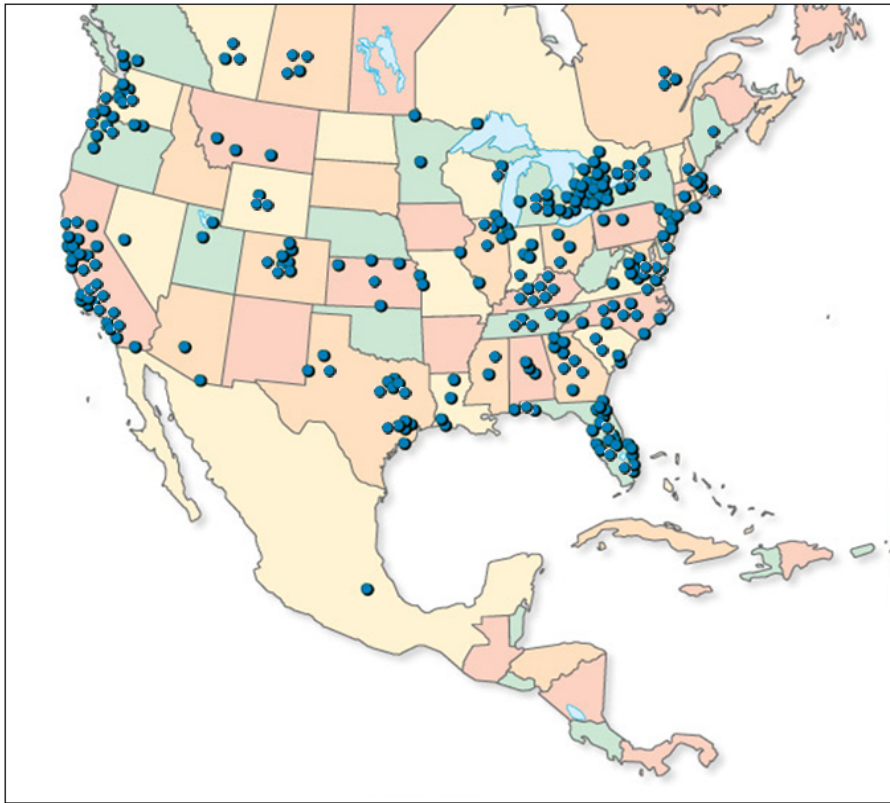
# Conclusions

- 💧 Numerous successful applications
- 💧 Reaction chemistry is well-understood
- 💧 Some 'mixed successes' related to
  - ➡ lack of knowledge of oxidant flux (consumption of EHC-M ), especially shallow water table sites with recharging oxygenated groundwater
  - ➡ inadequate distribution
- 💧 Arsenic sites among the toughest- Eh/pH conditions more complex relative to those for Cr, metal sulfides?
- 💧 More consideration to other amendments added with EHC-M which may facilitate removal?

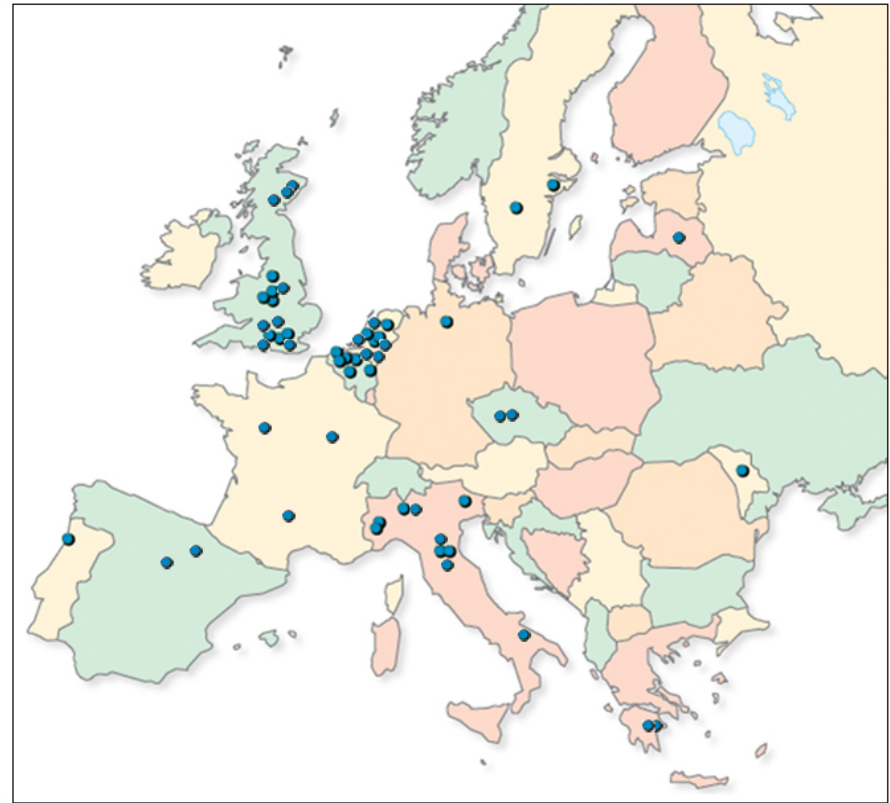


# Adventus Field Projects 2003 - 2009

**Figure 1a:** Adventus Field-Scale ISCR Projects in North America  
41 States > 400 Sites  
November 2009



**Figure 1b:** Adventus Field-Scale ISCR Projects in Europe  
14 Countries > 50 Sites  
November 2009







# QUESTIONS ARE ALWAYS WELCOMED...

## Adventus Americas, Inc.

### *Illinois - Corporate HQ*

2871 W. Forest Rd, Ste 2

Freeport, IL 61032

tel: 815.235.3503

toll-free: 888.295.8661

fax: 815.235.3506

[Info@AdventusGroup.com](mailto:Info@AdventusGroup.com)

[www.AdventusGroup.com](http://www.AdventusGroup.com)

### *California*

3334 E. Coast HWY, Ste 114

Corona Del Mar, CA 92625

tel: 949.788.1269

fax: 815.235.3506

### *Florida*

55 East Broad St.

Titusville, FL 32796

tel: 866.965.1777

fax: 321.747.0316

## Adventus Canada

### *Ontario*

1345 Fewster Drive

Mississauga, Ontario

Canada L4W 2A5

tel: 905.273.5374

fax: 905.273.4367

### *British Columbia*

#113-437 Martin Street

Suite # 376

Penticton, BC V2A 5L1

tel: 416.917.0099

fax: 905.273.4367

### *Quebec*

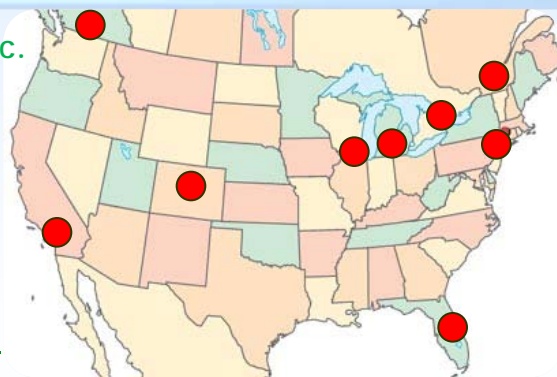
55 Charbonneau

Sorel-Tracy, QC

J3P 6Z2

tel: 450.517.5315

email: benoit.laplante  
@adventusgroup.com



### *Colorado*

11560 Penney Rd.

Conifer, CO 80433

tel: 303.838.3823

fax: 303.838.3823

### *Michigan*

1493 West Pratt Rd.

DeWitt, MI 48820

tel: 517.669.5400

fax: 517.669.5455

### *New Jersey*

1435 Morris Ave.

Union, NJ 07083

tel: 908.688.8543

fax: 908.688.8563

## Adventus Europe

### • *Austria*

Franz-Plattner Str. 28F

6170 Zirl, Tirol, Austria

tel: (+43) 5238.53262

fax: (+43) 512.219.100333

[Info@dventusGroup.com](mailto:Info@dventusGroup.com)

[www.Adventus.eu](http://www.Adventus.eu)

### • *United Kingdom*

Packwood Forge,

Vicarage Road,

Hockley Heath,

West Midlands B94 6PS

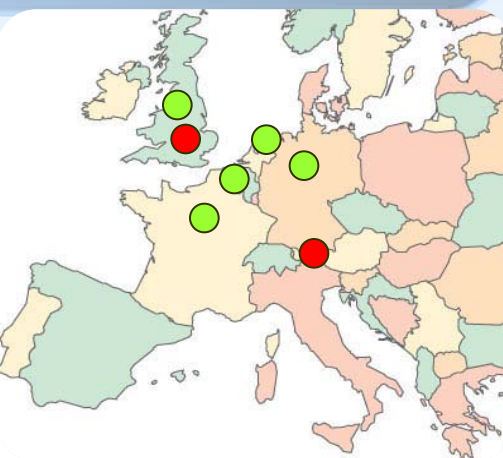
tel: (+44) (0) 7872.080353

fax: (+43) 512.219.100333

ADVENTUS technologies manufactured and warehoused in Europe.

Quick and cost-efficient intra-EU shipping of inventory to your site from our network of facilities located in:

- *Belgium*
- *France*
- *Germany*
- *Netherlands*
- *UK*



### Adventus • *Brazil*

Avenida Paulista,

nº 37 — 4º andar

Ed. Parque Cultural Paulista

CEP: 01311-902

São Paulo



# Santé!



*As an environmental industry professional,  
Join Eco-Applications / ADVENTUS  
for our annual Cocktail Reception  
on Thursday, 18 March  
from 18h30 to 20h00*

*Please be our guest for a complimentary  
afterhours gathering in the Exhibition Hall*



*Abordable Technologies de Biorestauration pour Sols,  
Sédiments, et Eaux Souterraines*