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Arsenic Removal from Groundwater using a PRB of BOF Slag at the DuPont East Chicago (IN) Site

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CCER
CORPORATE CENTER FOR ENGINEERING RESEARCH

Overview

Site Background

Laboratory Scouting

Field Demonstration

PRB Installation

Post-Installation Monitoring & Joint Research

East Chicago Site

Site History

- DuPont purchased from Grasselli Corp. in 1928
  - Diversified chemical manufacturing facility
  - 440 acres, some undeveloped
- DuPont sold plant in 2000
  - Retained land & environmental responsibility

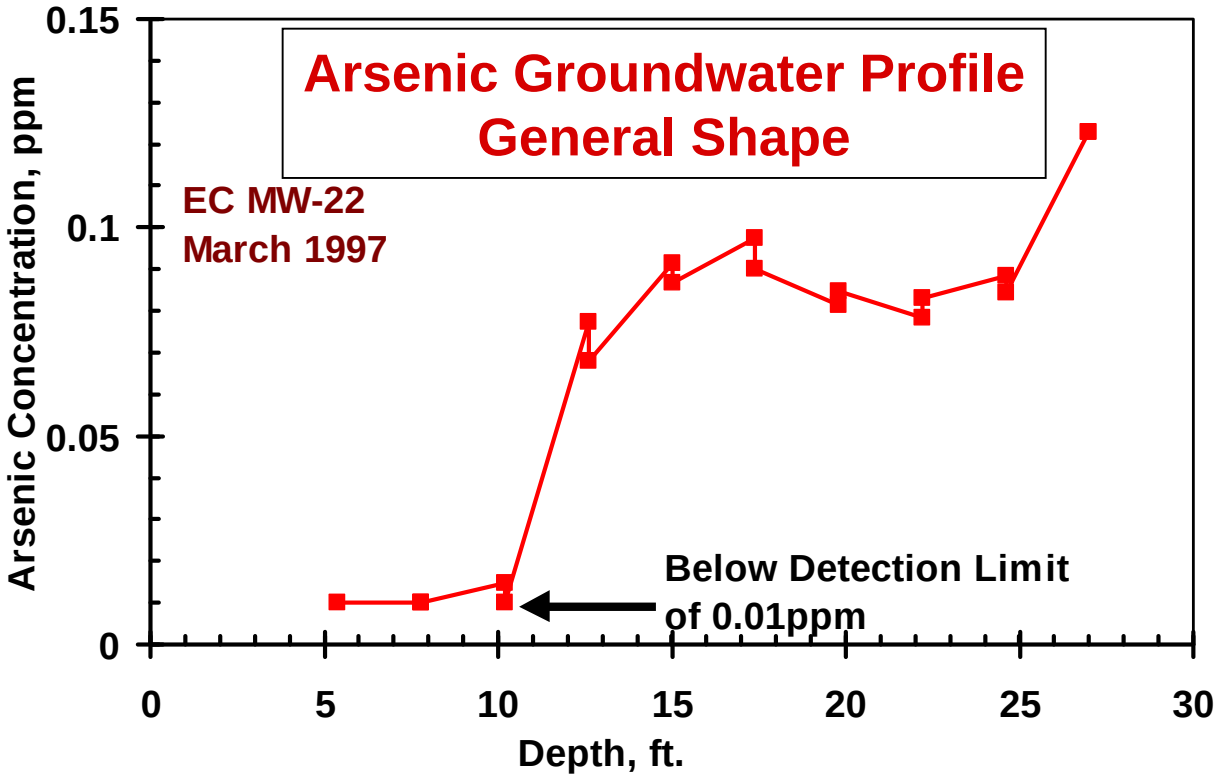
PRB Driving Force

- Achieve “YES” status for EI-750 metric as a GPRA baseline facility
  - Demonstrate adequate groundwater migration control

PRB Development

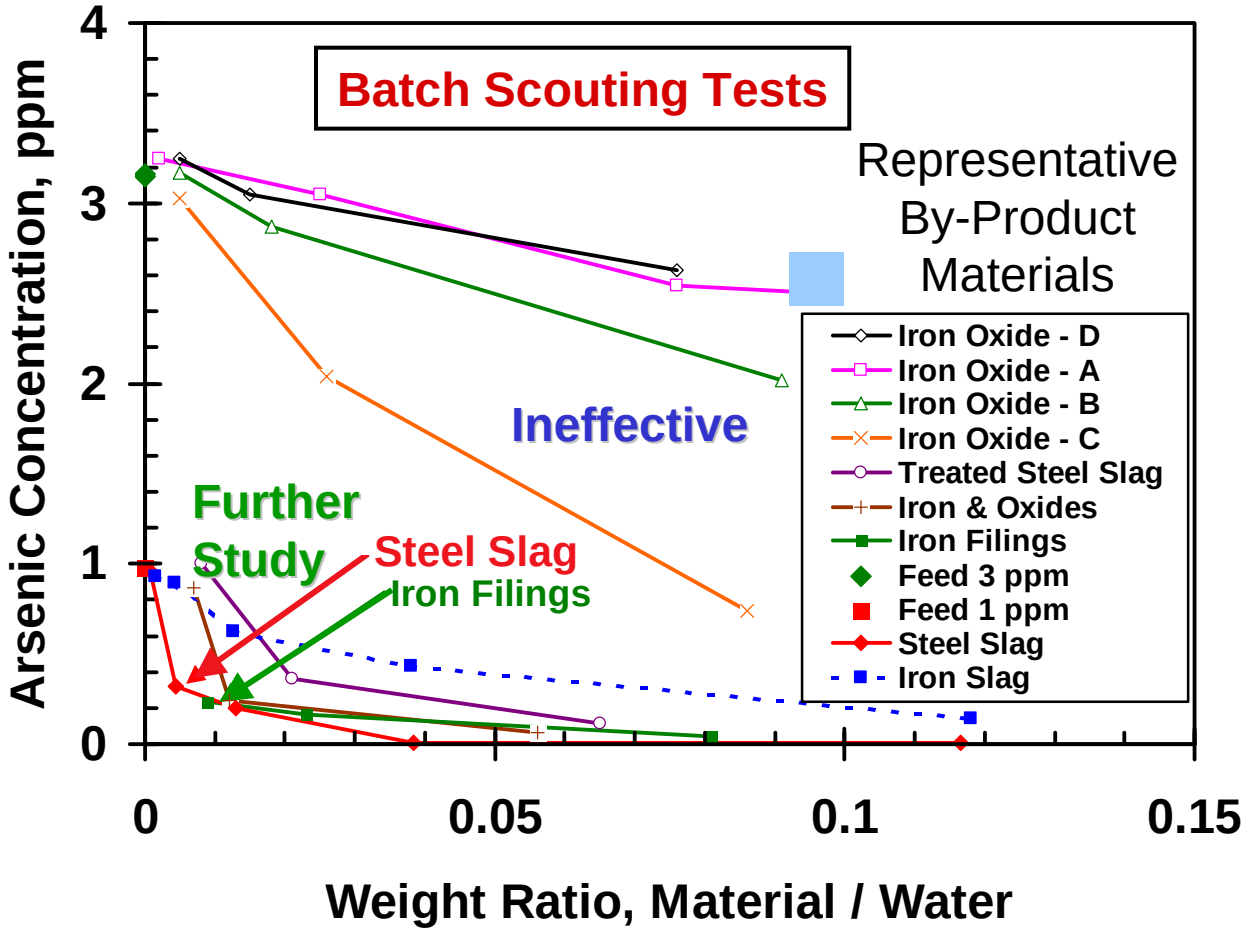
- Program initiated in late 1990s

Arsenic in Groundwater - EC North Side



DMLS Sampler

PRB for Arsenic Removal: Material Scouting



Scouting

- **Focus: iron by-products**
- **EC water**
  - **As spiked**
- **Batch tests**
  - **screening**
- **Kinetic runs**
- **Best materials reduced As to < 10 ppb**

Field Demonstration

Best materials from lab chosen

- **Zero-valent iron (Peerless) -- 5 wt. % in pure silica sand**
- **Basic Oxygen Furnace (BOF) slag -- 30 and 100 wt. %**
- **Iron oxide -- 5 and 20 wt. %**
- **Control -- pure silica sand**

Laboratory Experiments -- limitations

- **Arsenic content**
- **Dissolved oxygen**
- **Redox potential**

Reactive Test Wells

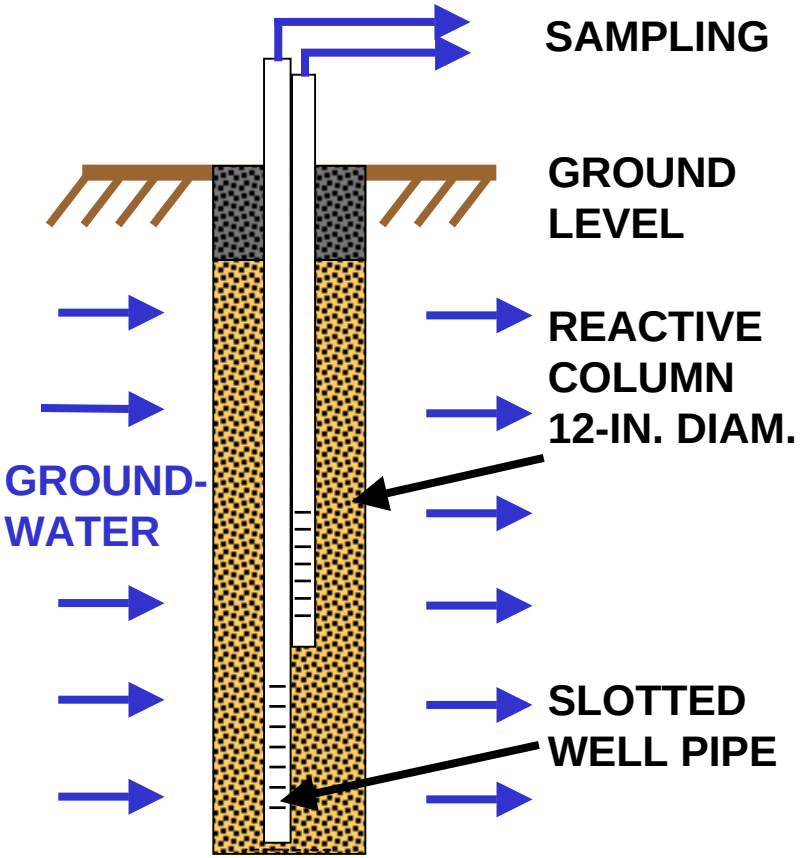
Field Demonstration -- Reactive Test Wells

- **Potential for high data quality, technical certainty**
- **Actual groundwater chemistry**
- **Simulate “real-time” PRB**
- **No contaminant losses**
- **Ease of operation -- passive**
- **Long-term monitoring**

Application

- **Installed in high-arsenic area of potential PRB**

Reactive Test Wells at EC



IN-GROUND TEST COLUMNS

- Columns filled with reactive material mixtures
- Passive flow of groundwater through columns
- 12-in diameter, 35 feet deep, keyed into clay
- Two, One-inch sampling wells
  - Two-foot slotted sections

SAMPLING

- Low-flow
- Bi-level: shallow, deep

Reactive Test Wells -- Installation

Rotasonic drilling

Centralized sampling pipe

RTW Results:
Arsenic Concentrations @ 7 Months

Material	Shallow		Deep	
Sand -- Control	42	%	1000	%
Iron - 5%	ND	=	3,100	%
Iron by-product - 5%*	30	=	3000	%
Iron by-product - 20%	400	&	1,100	=
BOF Slag - 30%	ND	=	ND	=
BOF Slag - 100%	~ND	=	~ND	=

Arsenic concentrations in ppb

MDL = 5 ppb; PQL = 10 ppb

Arrows indicate trends since 4-month sampling

*** sampling terminated at 4-months**

BOF Slag

Component	Wt. Pct.
Fe forms Σ	27
Fe^0 (est)	3
FeO (est)	21
Fe_2O_3 (est)	3
CaO	41
SiO_2	12
MgO	9
MnO	5
Al_2O_3	5
P_2O_5	1
TiO_2	0.5
K_2O	0.05
Zn forms	0.02

Slag source:
Bethlehem Steel, Burns Harbor, IN
via **The Levy Company,** Portage, IN

PRB Specifications

Performance

- **Treat 1-3 ppm arsenic to below 10 ppb**
- **20 year life**

Material

- **100% Basic Oxygen Furnace (BOF) slag**
  - **Bethlehem Steel, provided by The Levy Company**

Dimensions

- **2000 ft. long**
- **30 in. wide minimum**
- **37+/- ft. deep**
- **Begin below waste/ash at 5-ft. below ground surface**

PRB Installation

Site Challenges

- Sandy material restricts open, unsupported trench
- PRB to be located beneath waste layer
- Relatively high groundwater table

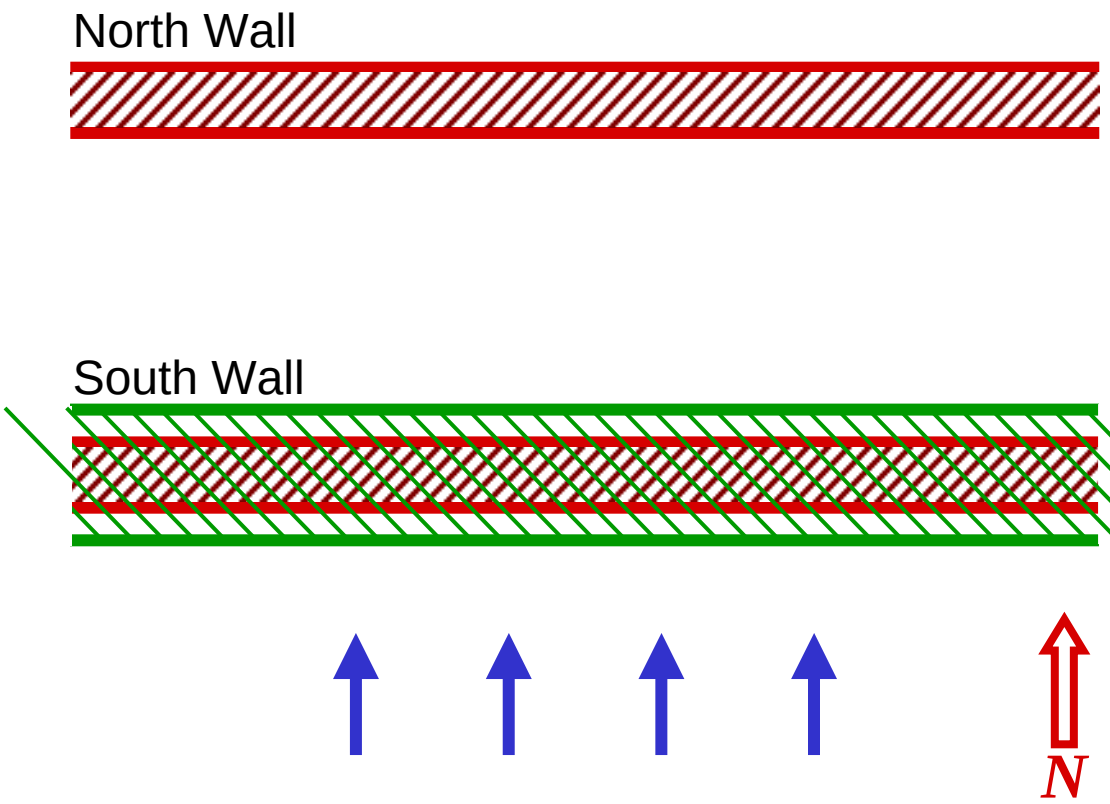
Bioslurry -- not feasible

- High pH of BOF slag reduces guar gum bioslurry viscosity
- Enzyme breaker less effective at high pH
- Overall: significant uncertainty

Trenching -- chosen option

- Simple, no additional chemicals
- Trenching through homogenous sands, devoid of obstructions
- 25 ft depth limitation overcome by phased construction

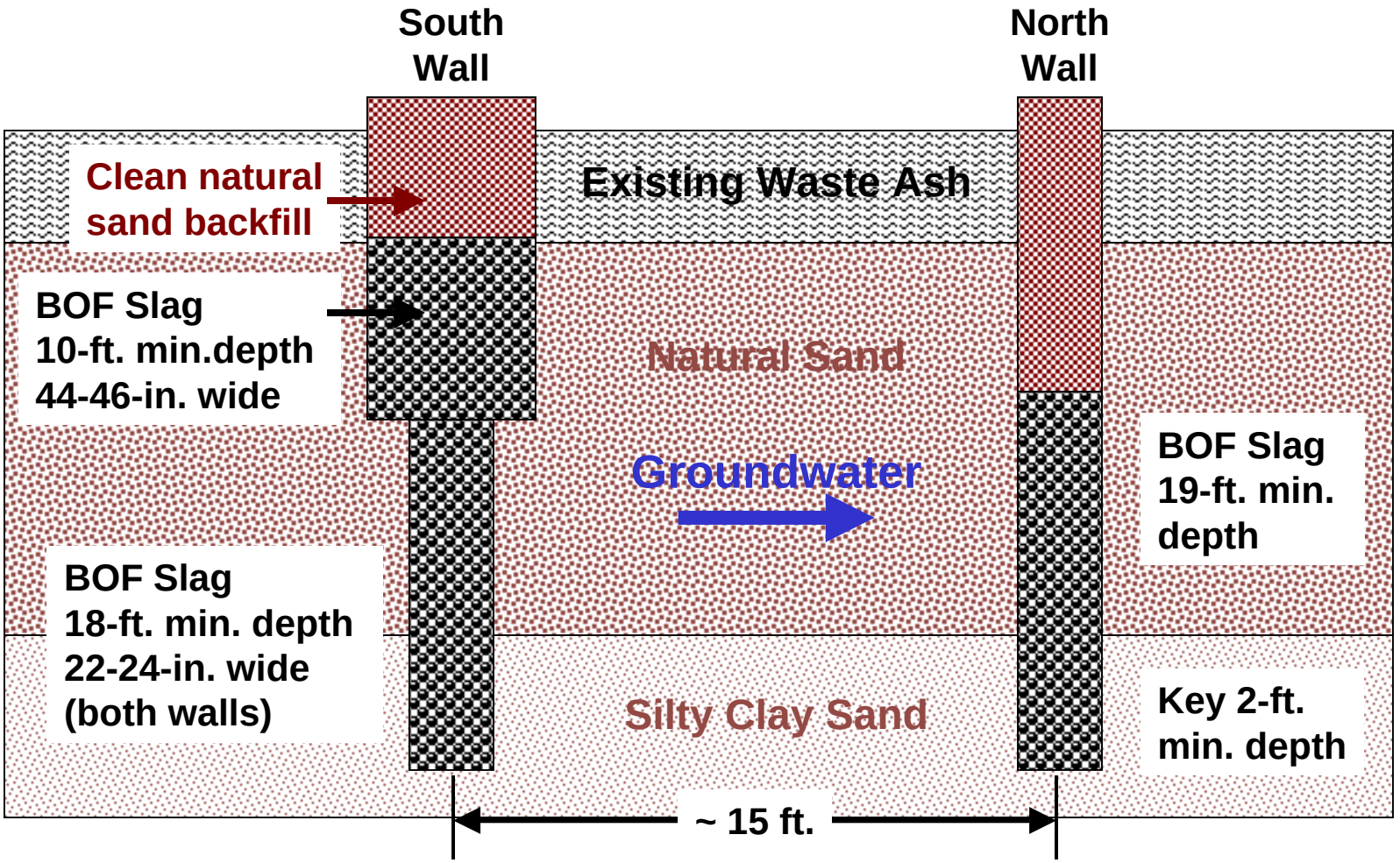
PRB Layout



Two parallel PRBs
- **2000 ft. long**
- **~ 15 ft. centers separation**
- **To ~ 37 ft. depth**

South wall
- **Upper & lower sections**

PRB Cross Section



Dewatering

- **Stabilized flowing sands**
- **Enabled trenching**
  - **Avoided “lake”**

1,000,000 gallons/day

Benching

Enable 25-ft. trencher to reach 40-ft. depth

- **Benching**
- **Phased construction**

Shallow: 5 ft. bgs

Deep: 18-20 ft. bgs

105,000 cubic yards excavated

Trencher

Custom trencher

- **DeWind Environmental**
- **25-ft. working depth**

Trenching

Continuous trenching
- **Ongoing refill**

BOF Slag Installed
- **26,500 cubic yards**
- **43,000 tons**

Trenchbox to “Top” South Wall

Trenchbox

- **Add section to top of wall**
- **10 ft. deep x 44-46-in. wide**

Procedure efficient

- **Fill bench to base of ash**
- **Dig new trench for box**

And at Completion...

Restored site

Completion

- **Three month process**
- **One week early**

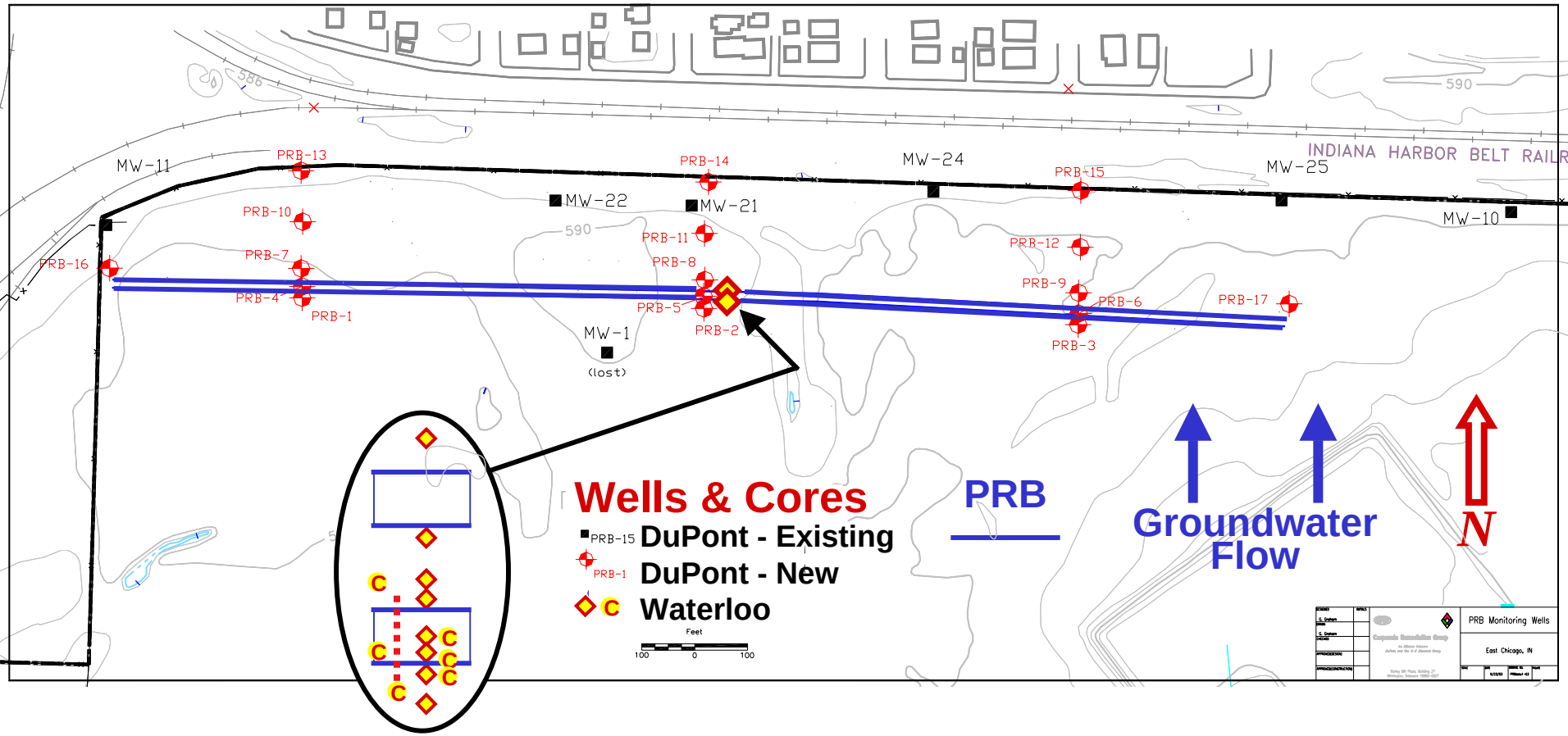
SAFETY prevailed:
5,000 safe contractor work hours

Post-Installation Monitoring

Collaboration with Waterloo University

- **Prof. David Blowes**
  - **Jeff Bain, graduate student**
  - **David Smyth**
- **Joint monitoring and analysis**
  - **Monitoring by both groups**
  - **Cores by Waterloo**

Monitoring Wells & Cores



Path Forward

Monitoring

- **Performance measurement**

Analysis

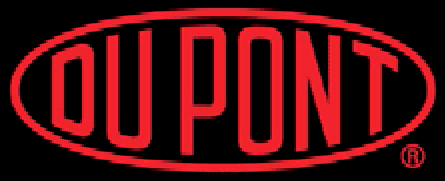
- **Performance assessment**
- **Geochemical and reactive transport modeling**
- **Mechanism elucidation**
- **Recommendations**

Program

- **Monitoring in progress**
- **First public report spring 2004**

At the End of the Rainbow… a PRB

Double rainbow over East Chicago, IN following PRB field test - September 2001



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Abstract

A DuPont site in East Chicago, Indiana is the first full-scale application of basic oxygen furnace (BOF) slag to remove arsenic from groundwater. To remediate a 1 to 2 mg/L arsenic plume, a 2000-ft. long by 35-ft. deep permeable reactive barrier (PRB) was installed in 2002.

Development began with laboratory scouting of materials for a PRB using site groundwater. Performance under actual site conditions was considered critical because of the difficulties in simulating site groundwater conditions in the laboratory, particularly such parameters as arsenic content, redox potential and dissolved oxygen. To test the best materials under actual site conditions, several reactive test wells (RTW) were installed. The RTWs incorporated proposed PRB materials as packing in 12-inch diameter, uncased wells with internal sampling points. Data were collected regularly over a nine-month period, and significant differences in material performance were observed.

Based on the RTW results and hydrological modeling, a full-scale PRB was installed, 2000-feet long and 35-ft. deep, consisting of 100% BOF slag. To achieve the desired wall thickness, the PRB comprised two parallel, two-foot-wide trenches plus a unique two-level design. The hydrogeologic conditions at the site include a 35-ft. deep fine sand aquifer overlying thick clay aquitard, with groundwater velocity in the sand of 0.25 ft. per day. The installation was particularly challenging due to flowing sands and the presence of a high water table. Deep benching and extensive dewatering allowed a trenching machine to install the PRB in two passes followed by trench-box installation of an upper level of reactive material.

DuPont and the University of Waterloo are collaborating on field monitoring and analysis of the PRB performance. Eight multilevel bundle piezometers were installed, crossing the two PRB sections along the centerline. Measurements indicate that the hydraulic conductivity of the PRB material is higher than that of the surrounding materials, favoring groundwater flow through the PRB.