GROUNDWATER RESTORATION AND LONG-TERM STEWARDSHIP AT A FORMER SMELTER

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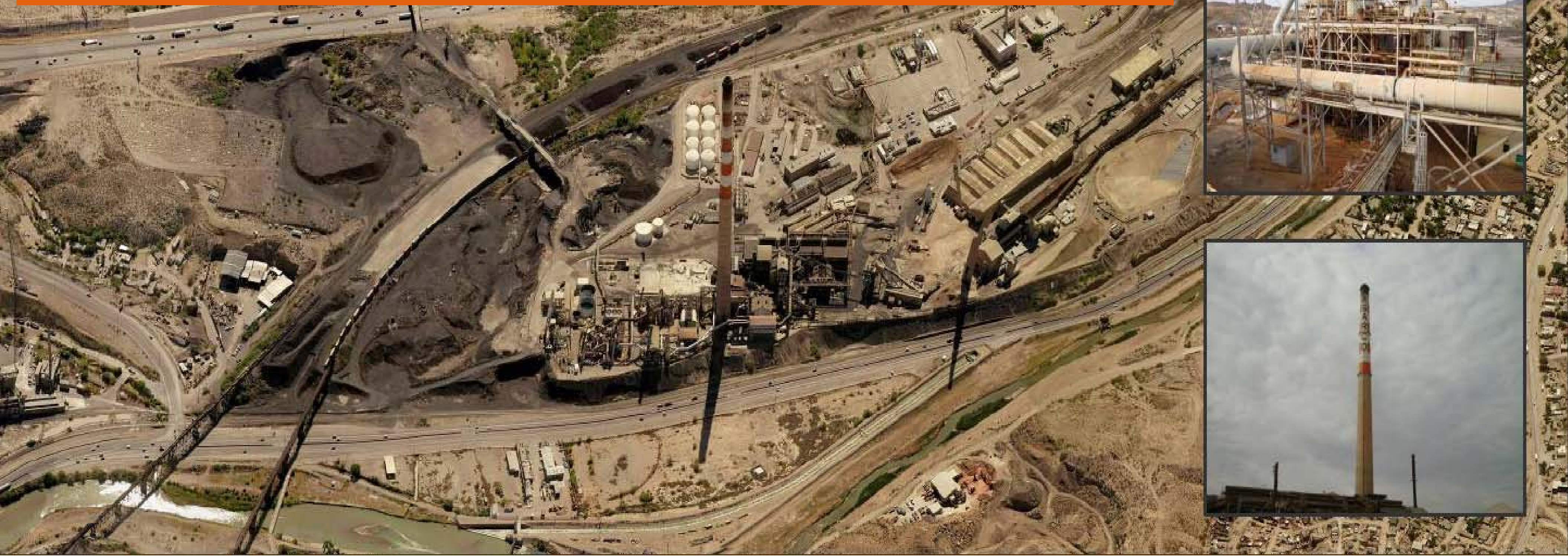


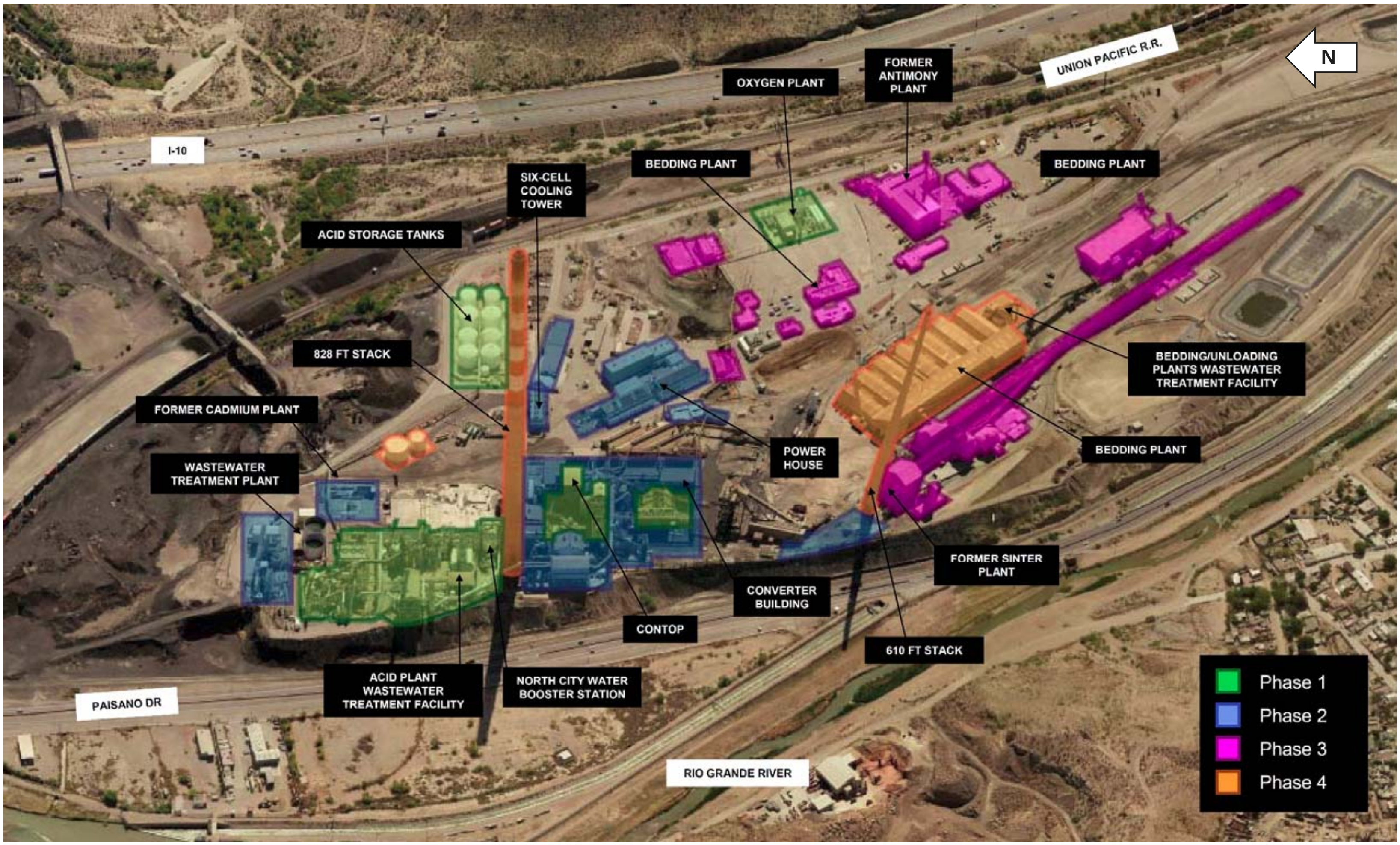
Outline

- Site Overview and History
- Conceptual Site Model and Remedial Strategy
  - Movement from Pump & Treat → Source Removal and Passive Options
- Groundwater Strategies: Arsenic
  - Zerovalent iron permeable reactive barriers
  - Mass flux-based approaches
- Current Status

Site History

- ASARCO El Paso Smelter, El Paso, TX
- Adjacent to Rio Grande
- 1887: Began operations as lead smelter
- 1910: Copper production
- 1980s: Operations downsizing
- 1999: Consent Decree directs ASARCO to complete corrective actions, temporary cessation of plant
- 2009: Custodial trust established to support remedial activities

Former Site Features and Demolition

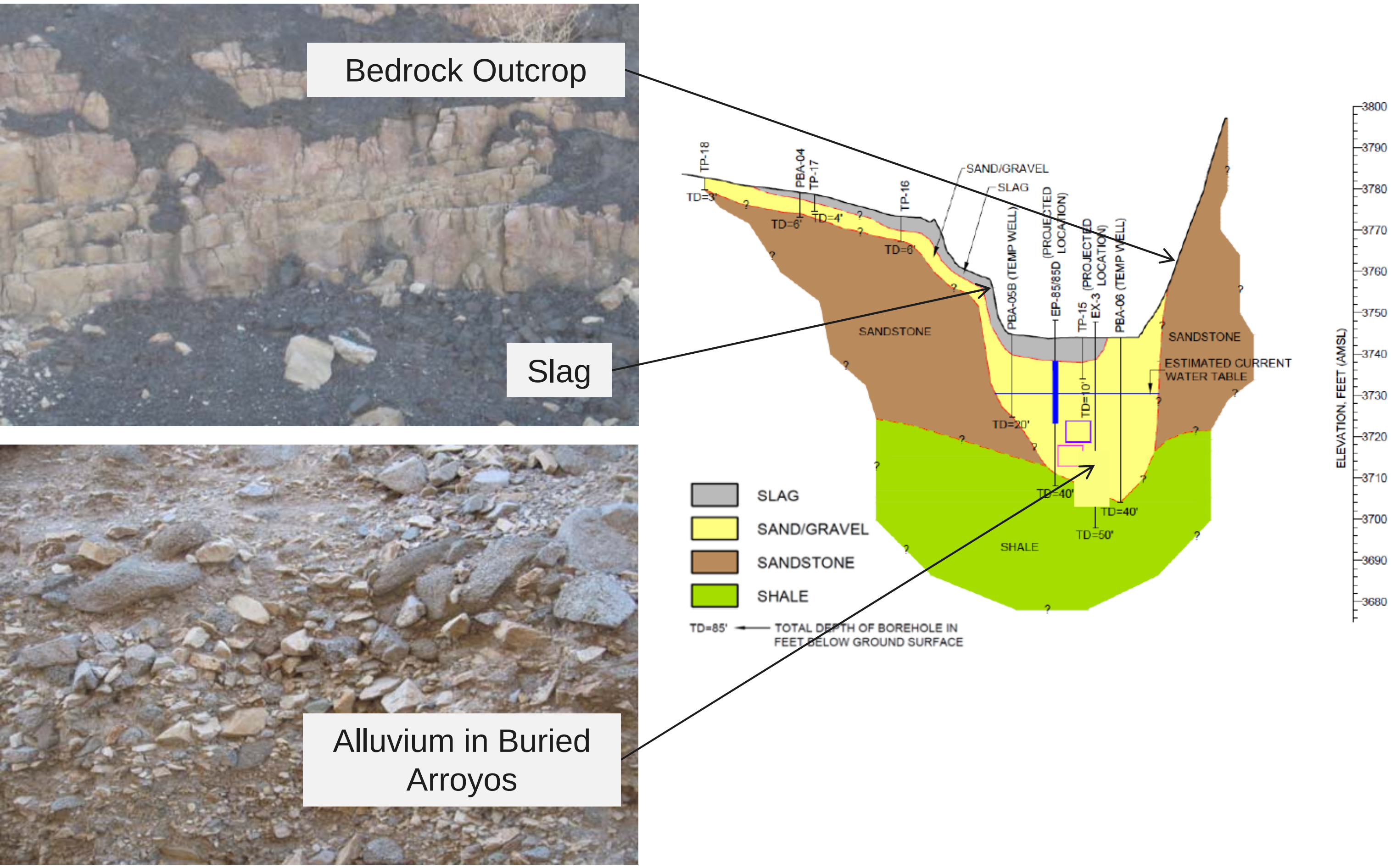


- Demolition ~2012
- Completed in four phases

Groundwater Flow CSM

- Groundwater flow through backfilled arroyos
- East to west toward Rio Grande floodplain
- Parker Brothers Arroyo:
  - Drainage area ~ 2,000 ac
  - Majority of groundwater flow
  - Largest control on mass flux

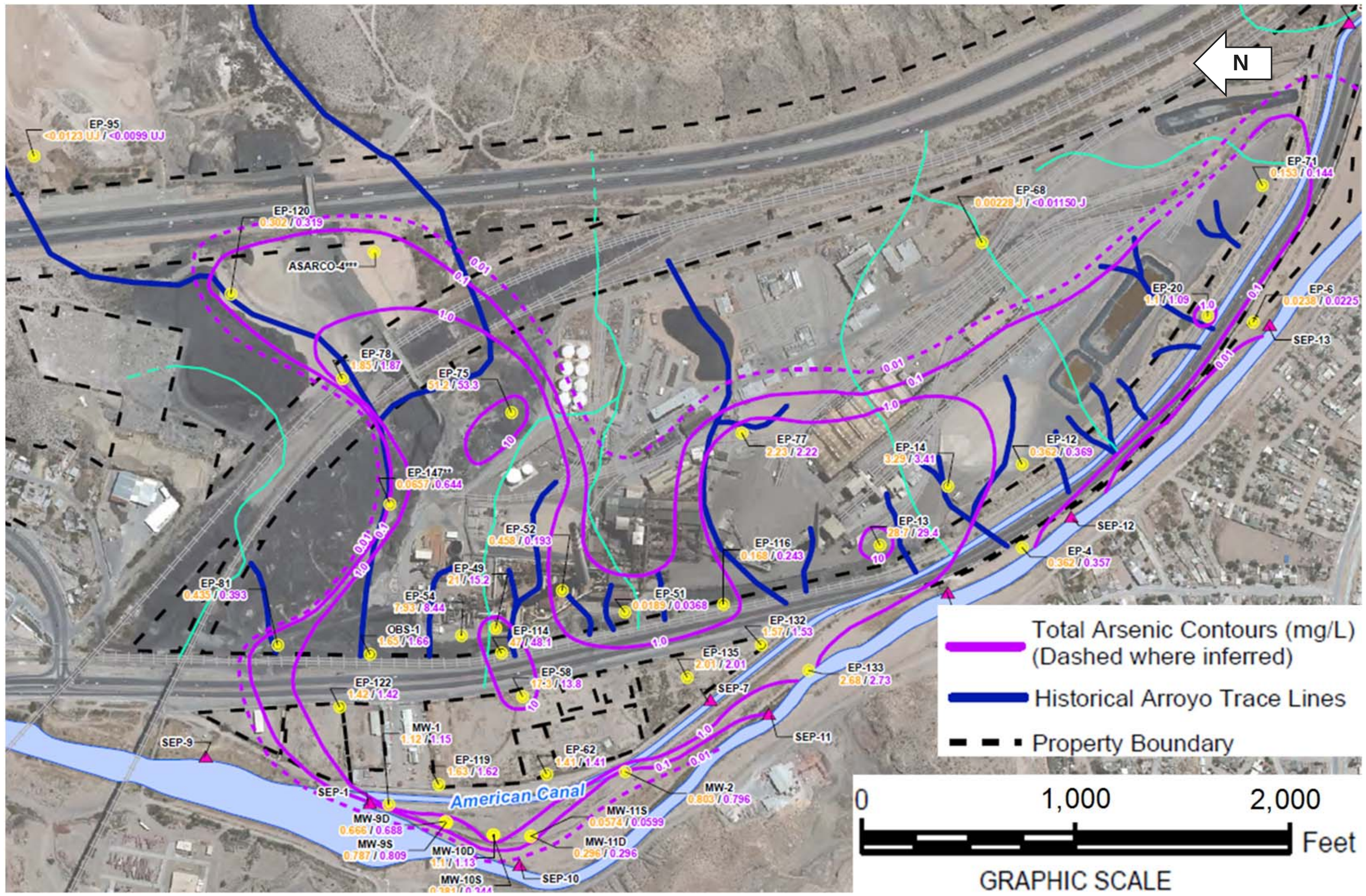
Parker Brothers Arroyo



- Arroyos mapped using surface geophysics and soil borings
- Groundwater flow focused along sand and gravel alluvium
- Groundwater remedy makes use of natural drainage features to focus remediation

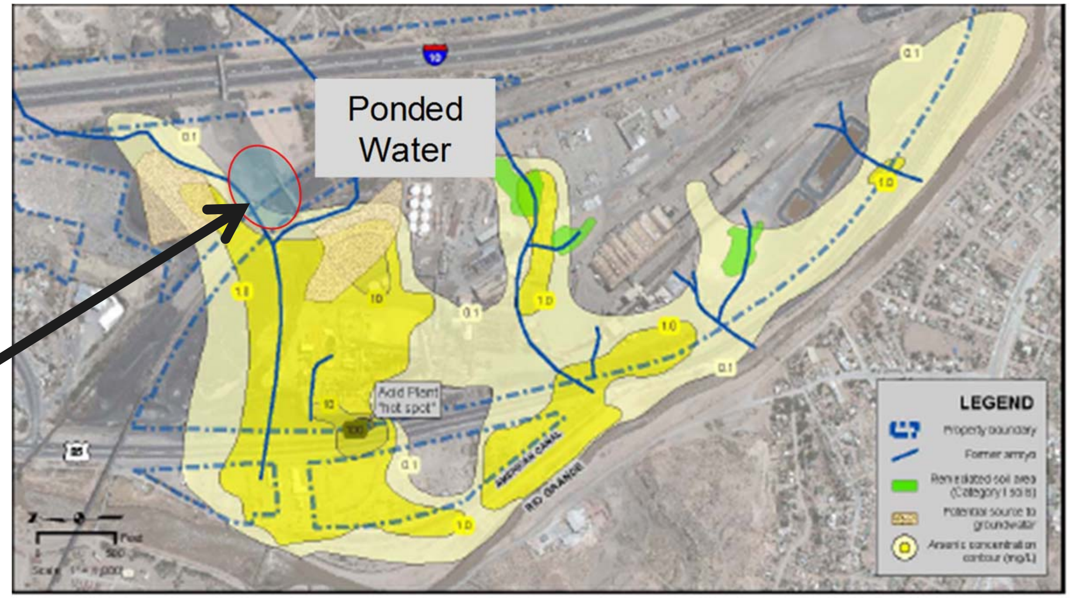
Groundwater Quality CSM

- Groundwater impacts from 100+ years of plant operation
- Arsenic is remedial driver
- > 10 mg/L arsenic historically

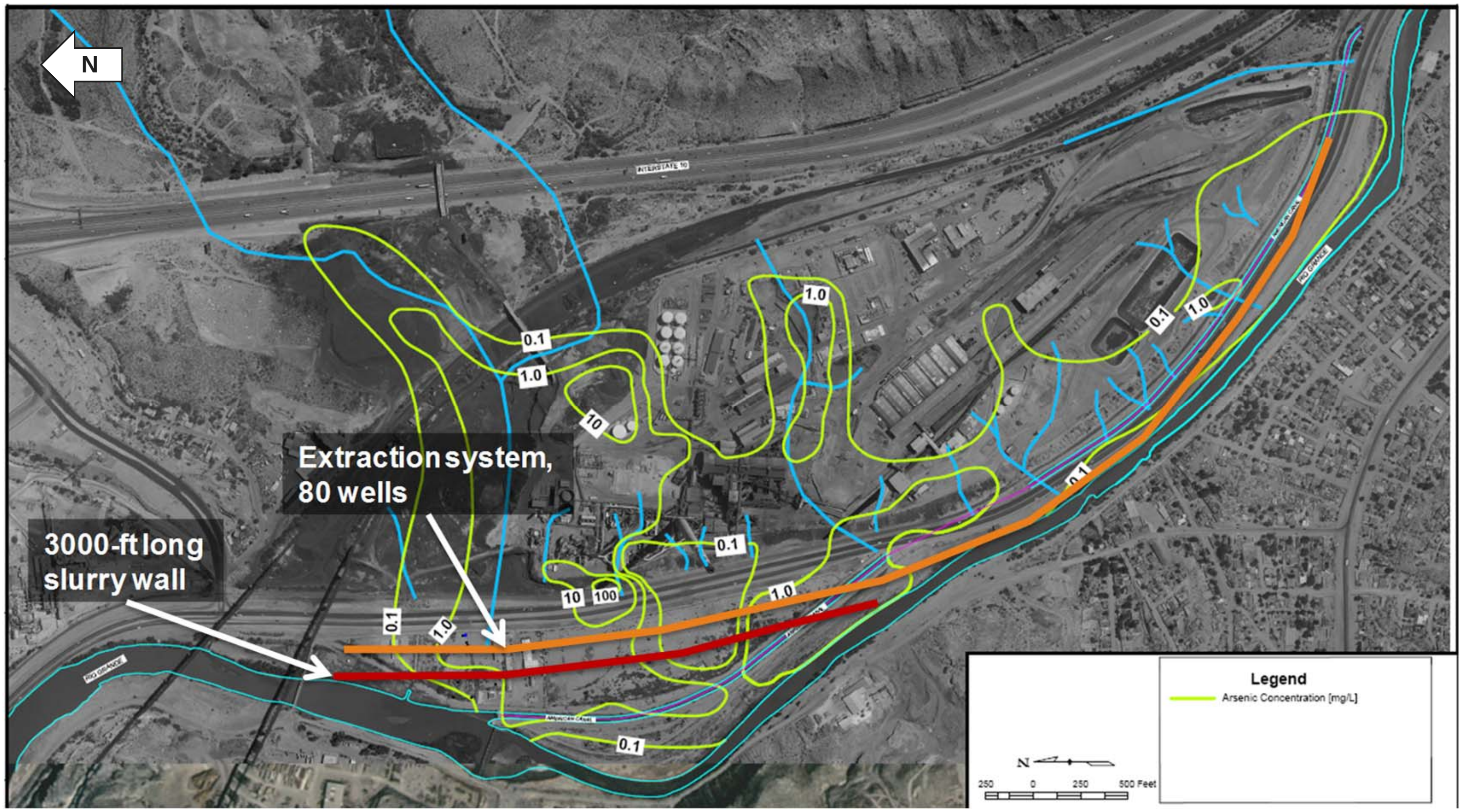


Groundwater Quality CSM

- Stormwater accumulation in ponds underlain by slag
- Significant source of groundwater impacts



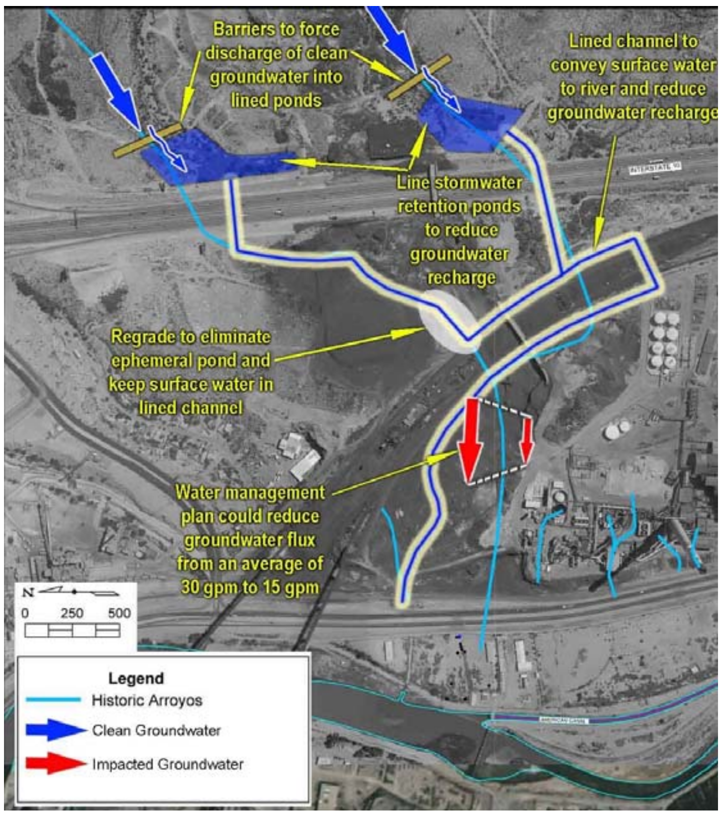
Original Remedial Strategy

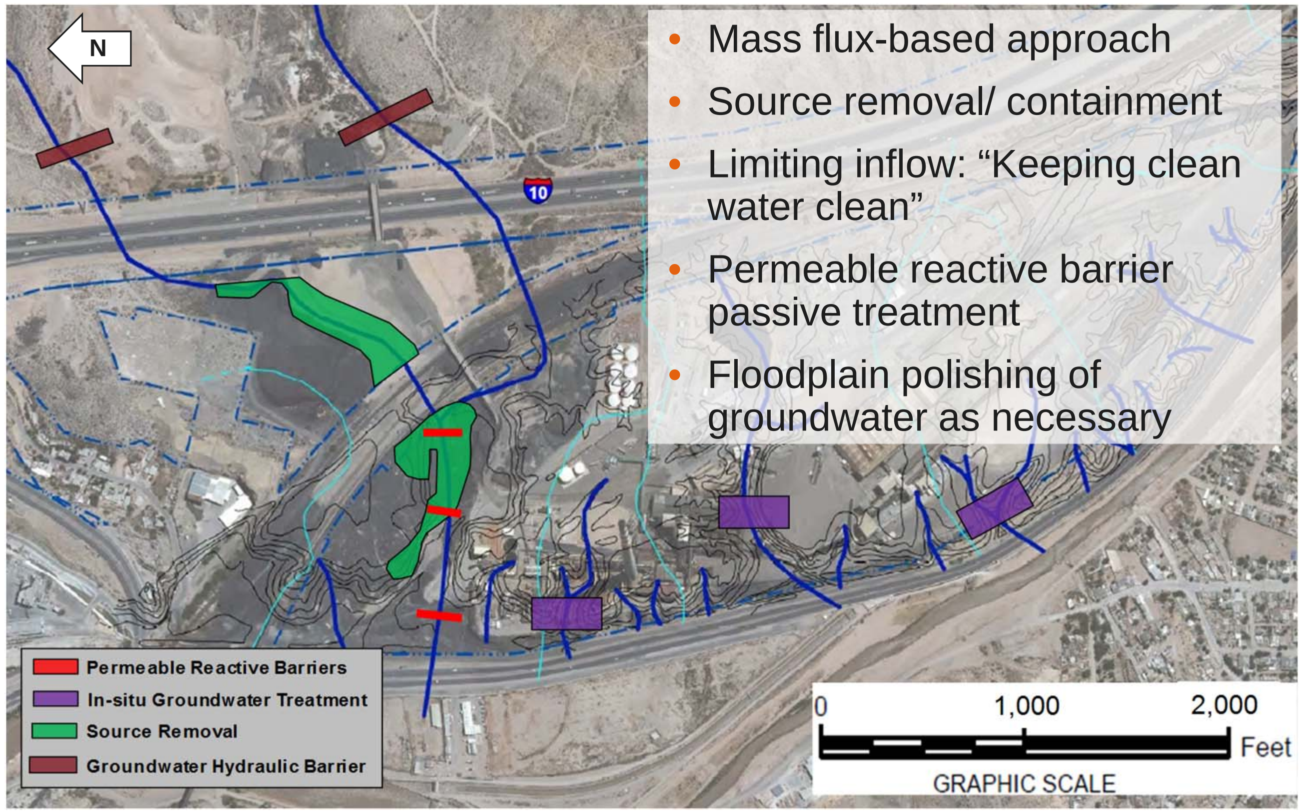


- Slurry wall to limit off-site discharge
- Extraction wells for removal and aboveground groundwater treatment
- Remedy based on:
  - Insufficient understanding of discrete COC sources and drivers
  - Controls on mass flux leading to largest risk

Revised Remedial Strategy

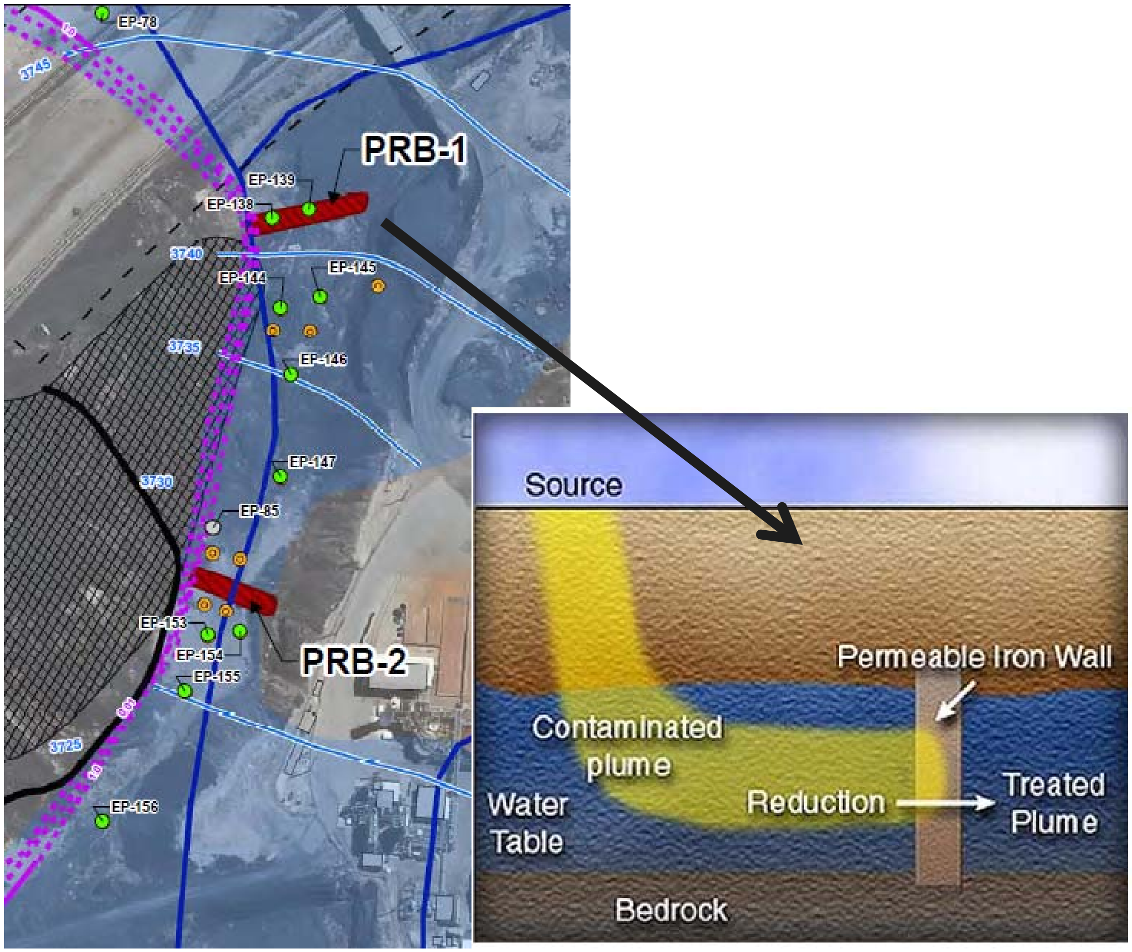
- Water Management Plan: Reduce arsenic flux to Rio Grande





- Mass flux-based approach
- Source removal/ containment
- Limiting inflow: “Keeping clean water clean”
- Permeable reactive barrier passive treatment
- Floodplain polishing of groundwater as necessary

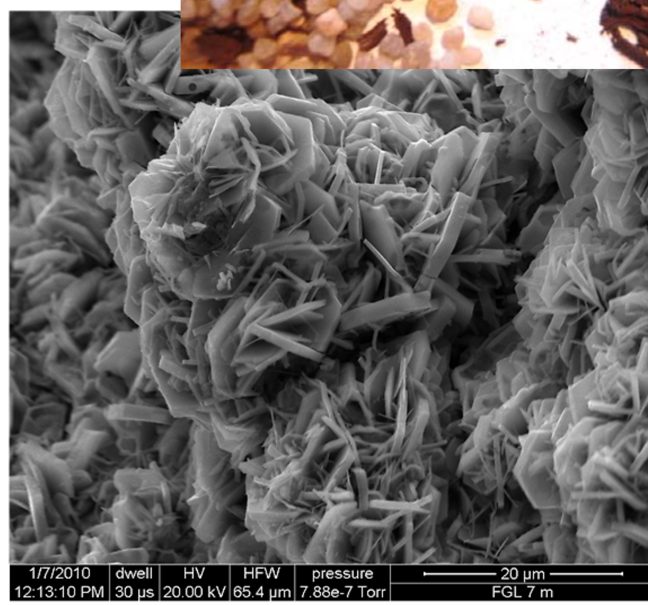
Permeable Reactive Barriers



- Two PRBs installed in 2012
- PRB-1: Source area
  - Placed downgradient of Stormwater Pond
  - Main source area in Parker Bros Arroyo
- PRB-2: Flow bottleneck
  - Narrowest portion of channel
  - Sandstone outcrops confine flow
- Strategy: Arsenic removal using zerovalent iron

Zerovalent Iron

- Fe metal, sourced from recycled scrap iron
- Iron oxidation
  - Fe(0) → Fe(II) → Fe(III)
- Coupled to:
  - O_2 consumption
  - H_2 gas generation
  - Sulfate reduction
- Effective for organics:
  - Reductive dechlorination
- Effective for metals/inorganics:
  - Reductive precipitation (e.g., U, Se)
  - Adsorption/coprecipitation with iron oxyhydroxides

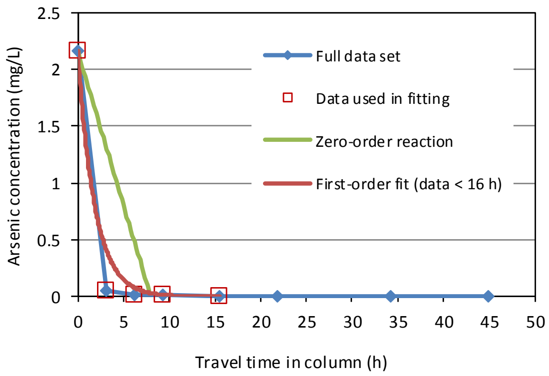


PRB Design

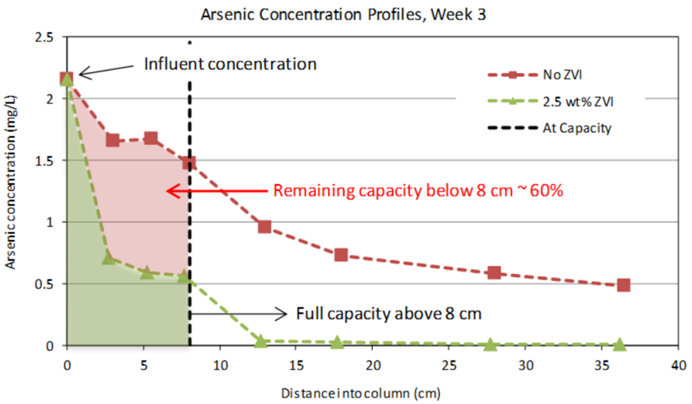
- Uptake capacity and residence time estimated from column testing (D. Blowes lab, University Waterloo)
  - Uptake capacity: 1.3 mg As/g ZVI
  - $t_{1/2}$ = 1.3 hours

15 wt% ZVI column

First-order rate constant: 12.8 d^{-1}
First-order half life: 1.3 h



2.5 wt% ZVI column



PRB Design

- Key Design Parameters:

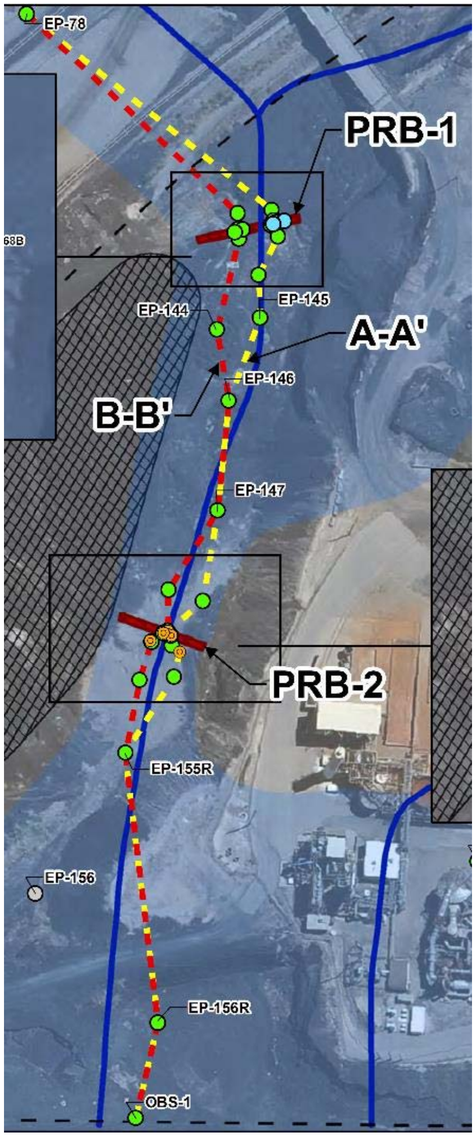
Parameter	PRB-1	PRB-2
K (ft/day)	18	116
Seepage Velocity (ft/day)	2.7	7.5
Arsenic influent concentration (mg/L)	1.0	0.5
Arsenic loading (lbs/day)	0.10	0.15
Design lifetime (years)	20	20
ZVI Demand (tons)	365	550

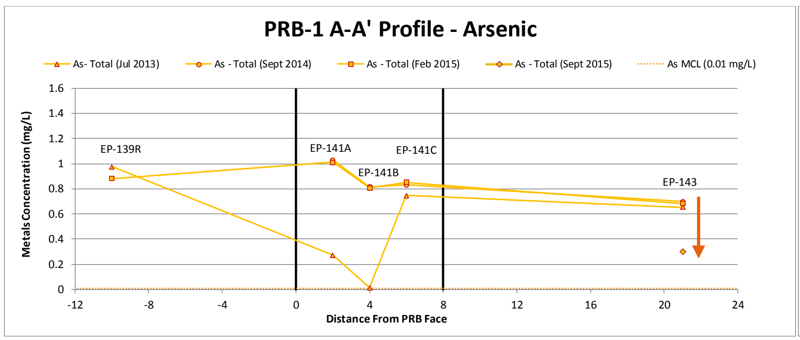
PRB Construction

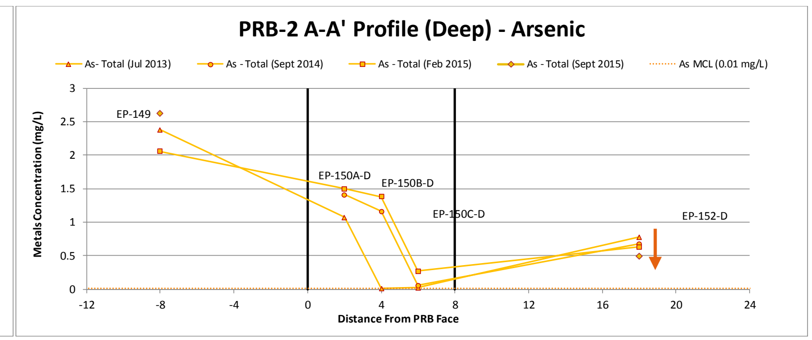
- Slide rail system install
  - 20 ft × 8 ft cells
- Wall thickness = 8 ft
  - Minimum required thickness = 4.3 ft based on required residence time
- Maximum depth: 25 ft
- Total length: 260 ft
- ZVI content = 30%
- Sand backfill (local sand pit)

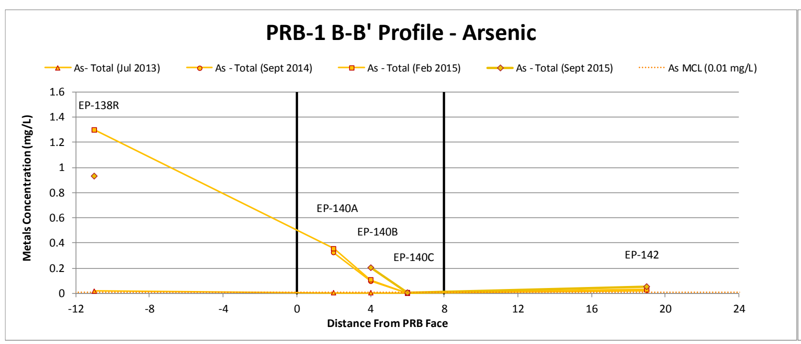
PRB Performance

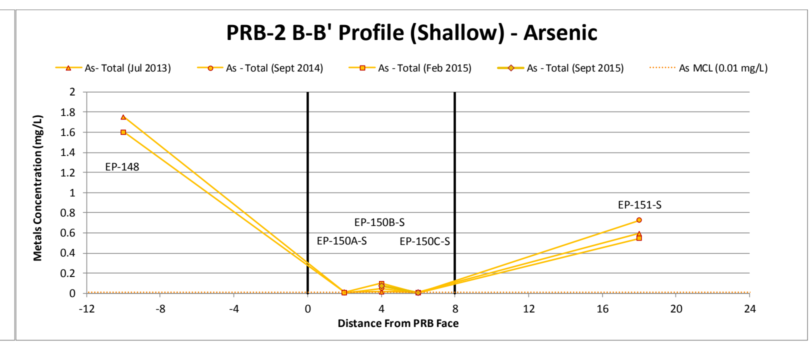
- Overall effective for arsenic removal
- Some channeling exhibited
- Downgradient re-equilibration with adsorbed As, but mass reduction evident



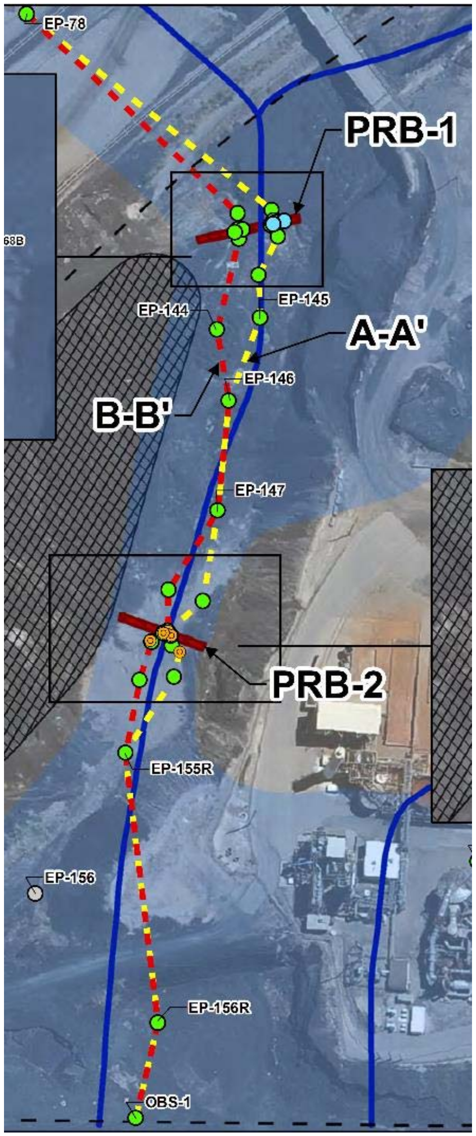




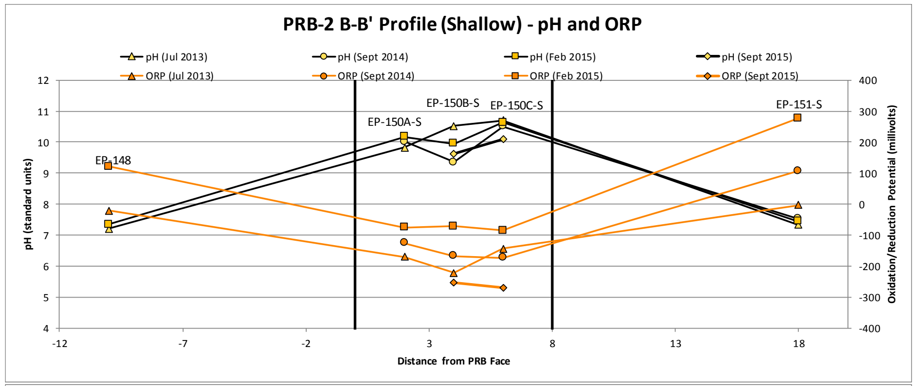


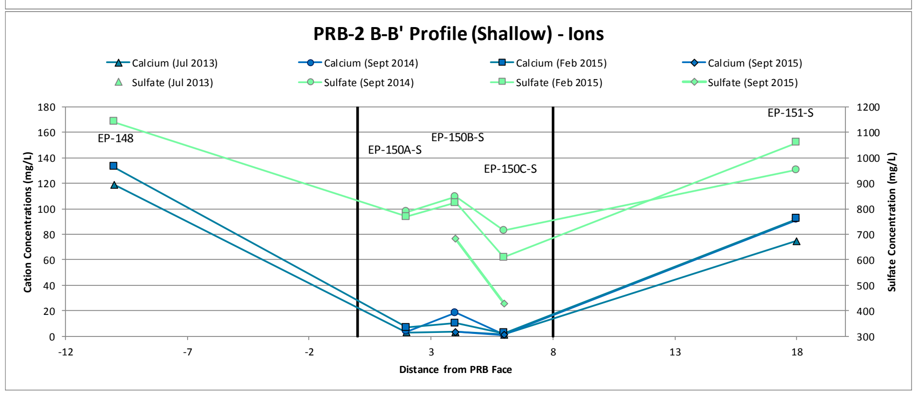


ARCADIS Design & Consultancy for natural and built assets



PRB Performance





- Increase in pH resulted in precipitation of calcite
- Significant driver in affecting media lifetime

Mass Flux as Driver

- Determination of:
  - Protective Concentration Levels (PCL) for surface water, sediment, soil, groundwater
  - Attenuation Action Levels (AALs) for individual monitoring wells
- Based on mass flux and mixing; ensuring concentrations are protective of receptors
- Prediction of when target GW/SW concentrations will be attained

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Table 2E-5
Summary of Groundwater-to-Surface Water PCL (^{SW}GW) Development
Former ASARCO Smelter Site

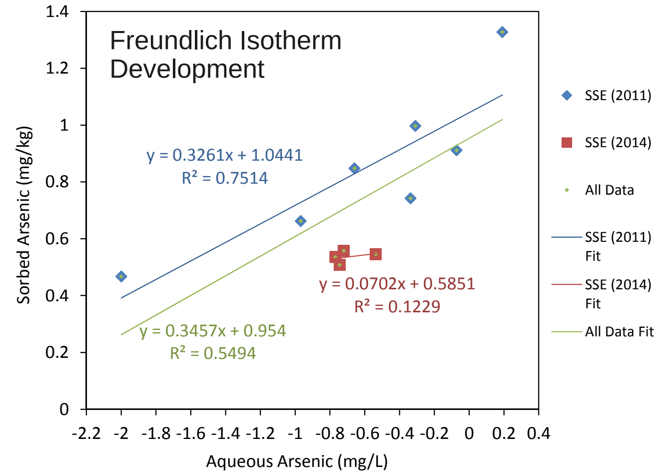
	^{SW}SW PCL[1]	Dilution Factor[2]	^{SW}GW PCL[1]	Background 95% UPL[1]	Selected ^{SW}GW PCL[1]
Antimony	0.006	0.01179	0.509	NA	0.509
Arsenic	0.01	0.01179	0.848	0.02	0.848
Barium	2	0.01179	170	0.037	170
Cadmium	0.0016	0.03404	0.047	NA	0.047
Chloride	340	0.01179	28,826	425	28,826
Chromium	0.1	0.01179	8.5	0.016	8.5
Cobalt	0.24	0.03404	7.1	NA	7.05
Copper	0.07	0.03404	2.06	0.06	2.06
Iron	NE	0.03404	NE	0.704	NE
Lead	0.0073	0.01179	0.619	NA	0.619
Mercury	0.000012	0.01179	0.00102	NA	0.00102
Molybdenum	0.122	0.01179	10.3	0.069	10.3
Nickel	0.32	0.03404	9.4	NA	9.4
Selenium	0.005	0.03404	0.147	0.035	0.147
Silver	0.0007	0.03404	0.022	NA	0.022
Sulfate	600	0.01179	50,870	974	50,870
Thallium	0.00012	0.01179	0.010	NA	0.010
Zinc	1.05	0.03404	31	0.084	31
Fluoride	4	0.01179	339	8.3	339
Nitrate	10	0.01179	848	NA	848
Nitrite	1	0.01179	85	NA	85

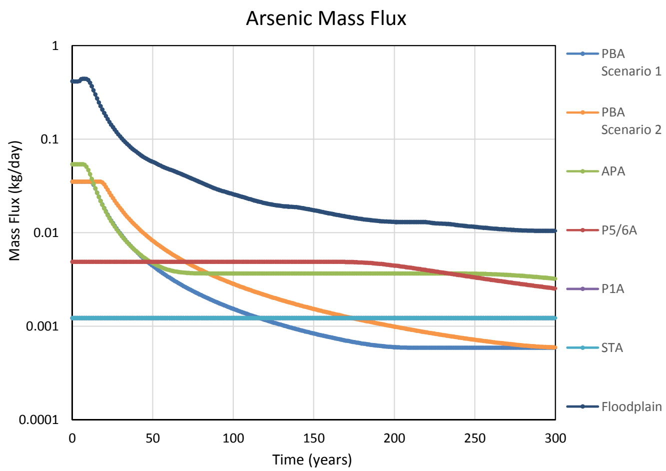
Notes:
1. Results are shown in milligrams per liter (mg/L).
2. Human health-based SWSW PCLs use Harmonic Mean flow of 6.2 cfs for dilution factor, ecological-based SWSW PCLs use 7Q2 Flow of 2.1 cfs for dilution factor. Human health PCLS are used for antimony, arsenic, barium, chloride, chromium, lead, mercury, molybdenum, sulfate, thallium, fluoride, Nitrate, and Nitrite.

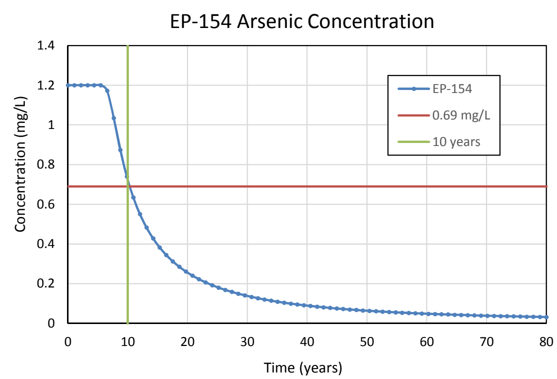
$^{GW}GW_{Ing}$ = Groundwater ingestion PCL
NA = Not applicable
NE = Not established
PCL = Protective Concentration Level
^{SW}GW = groundwater-to-surface water PCL
^{SW}SW = surface water PCL
UPL = upper predicted limit

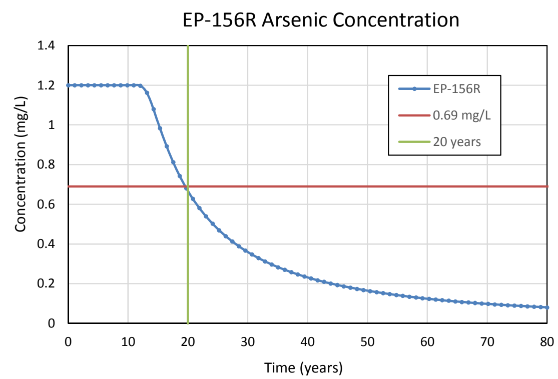
Mass Flux as Driver

- Estimation of arsenic adsorption coefficients from site-specific groundwater and alluvium extractions
- Flushing timeframes predicted for arroyos and AAL wells
  - 30 year timeframe given source area mass removal/treatment
- Verification with continued groundwater monitoring









Current Status

- Source removal, surface water management complete
- Land sale in progress
  - Board of Regents, University of Texas System
  - ~464 acre land purchase

Summary

- Revised remedial approach
  - Better use of site-specific characteristics
  - Passive options, keeping clean water clean
  - Mass flux approach: Target largest impacts
- Permeable Reactive Barriers
  - Effective removal of arsenic from groundwater
  - Adequate treatment in spite of water quality challenges
- Effective regulatory strategy is key to meeting end-goal

Better Outcome with Reduction in Long-Term Site Stewardship

Thank you!