U.S. Army Materiel Command

Lessons Learned from the Installation and Monitoring of a Permeable Reactive Barrier at the Lake City Army Ammunition Plant, Independence, MO

Presented by

Kevin Keller, PG, CGWP - Shaw E&I, Inc.

Thomas Graff, PE – US Army Corps of Engineers

Thomas Buechler, PE – US Army, LCAAP

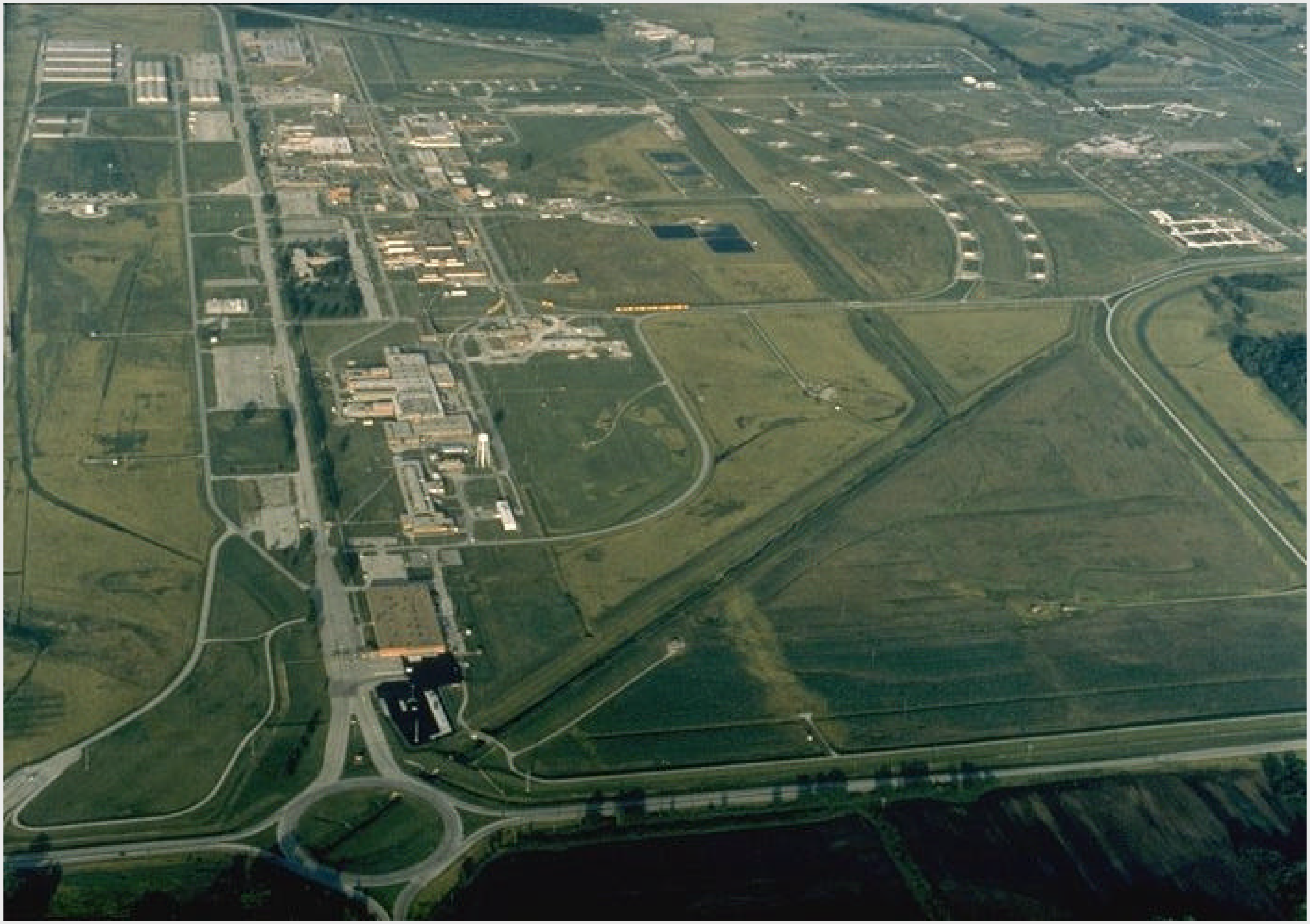
February 28, 2003

Shaw

Shaw Environmental & Infrastructure, Inc.

U.S. Army Materiel Command

Lake City Army Ammunition Plant (LCAAP)
Independence, MO



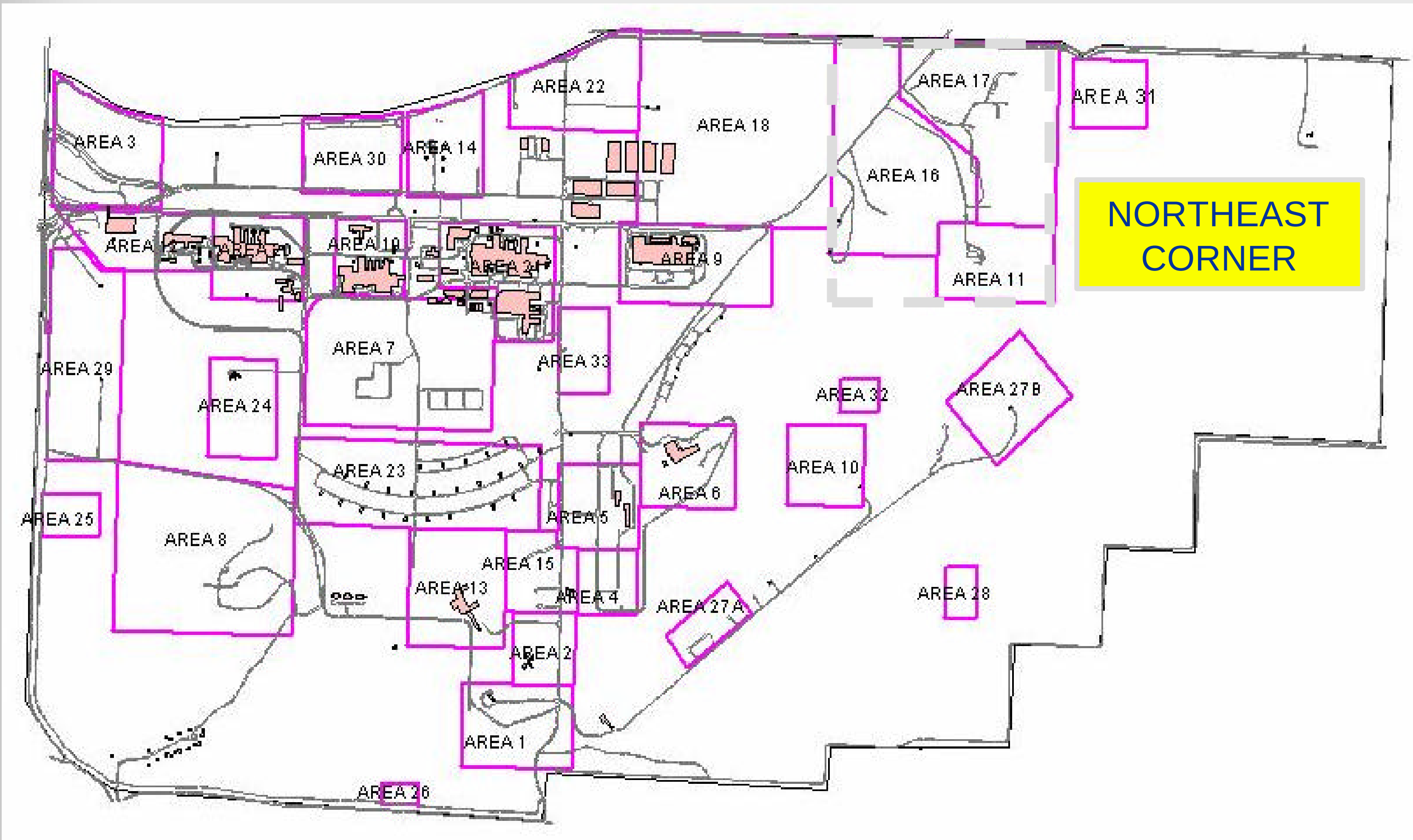
Shaw Environmental & Infrastructure, Inc.

LCAAP Description

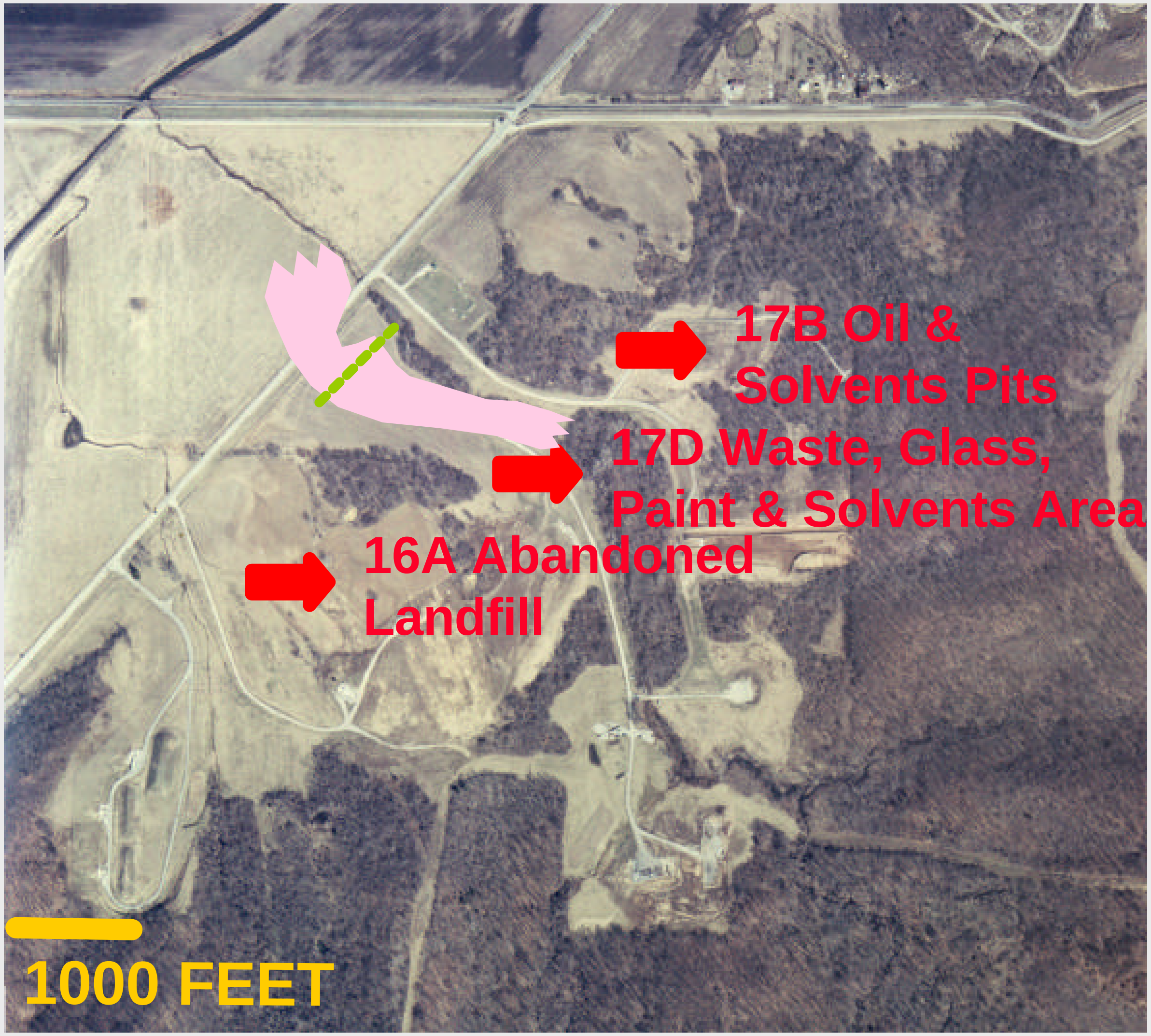
- Located in Independence, MO
- Just under 4,000 acres
- US ARMY - Joint Munitions Command Installation
- Built in early 1940's
- Government-Owned, Contractor-Operated
- Only operational DOD facility manufacturing small caliber ammunition for US Armed Forces and NATO
- NPL Site
- FFA – EPA Region VII, MDNR. Army
- CERCLA and RCRA Programs
- Three Operable Units (OUs)

Shaw Environmental & Infrastructure, Inc.

LCAAP Areas

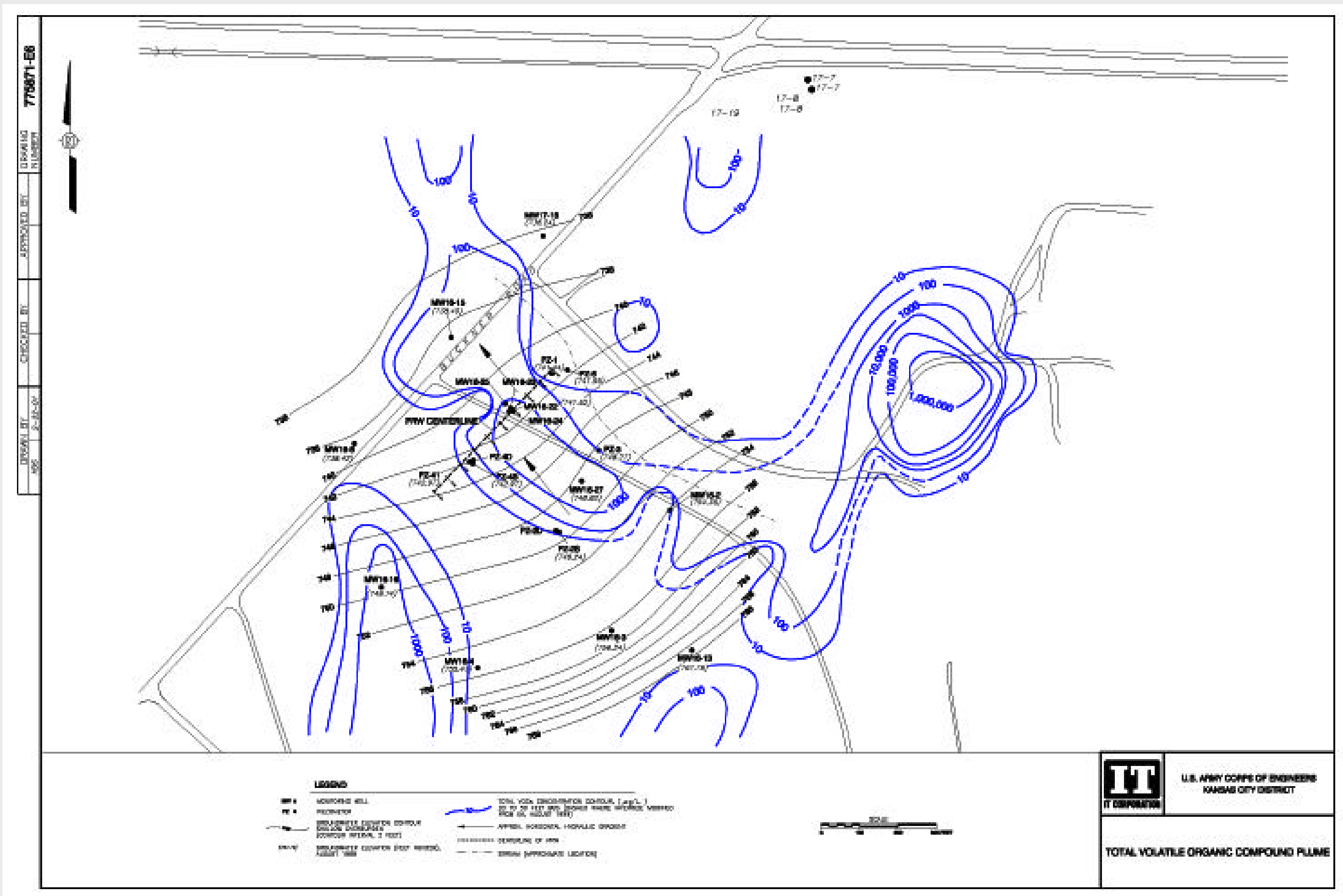

AREA 22
AREA 18
AREA 17
AREA 31
AREA 3
AREA 30
AREA 14
AREA 16
NORTHEAST CORNER
AREA 19
AREA 9
AREA 11
AREA 7
AREA 33
AREA 29
AREA 24
AREA 32
AREA 27 B
AREA 10
AREA 23
AREA 6
AREA 25
AREA 5
AREA 8
AREA 15
AREA 13
AREA 4
AREA 27 A
AREA 28
AREA 2
AREA 1
AREA 26

Release History, May 1982



Shaw Environmental & Infrastructure, Inc.

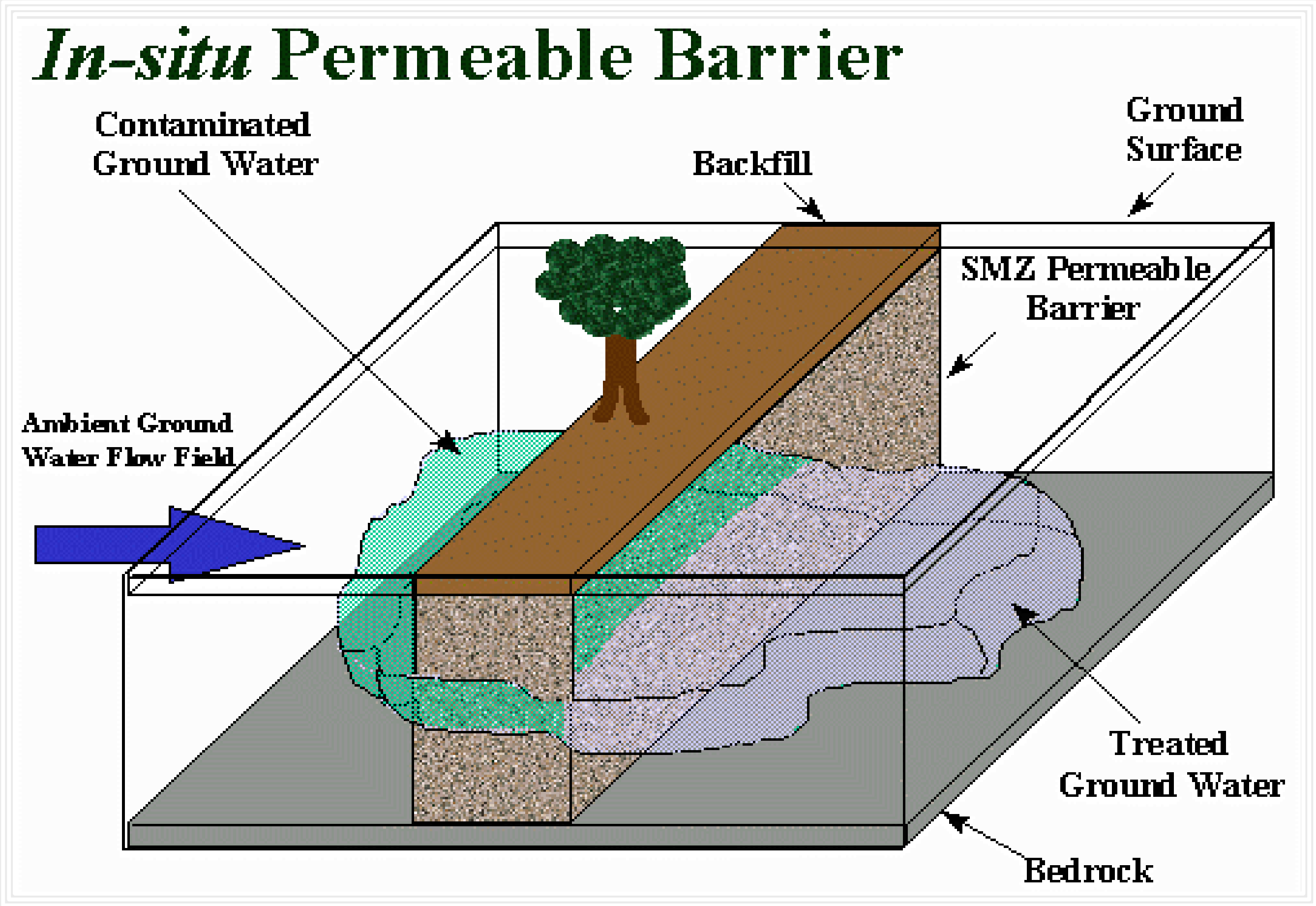
Total VOC Plume



ROD Remedial Action Objectives

- Reduce further migration of groundwater containing COCs at concentrations above cleanup goals (MCLs) from the NECOU to the Lake City Aquifer
- Installation of a subsurface permeable reactive barrier (PRB) to treat contaminated groundwater inplace (in-situ)
- Point of compliance immediately downgradient of the PRB

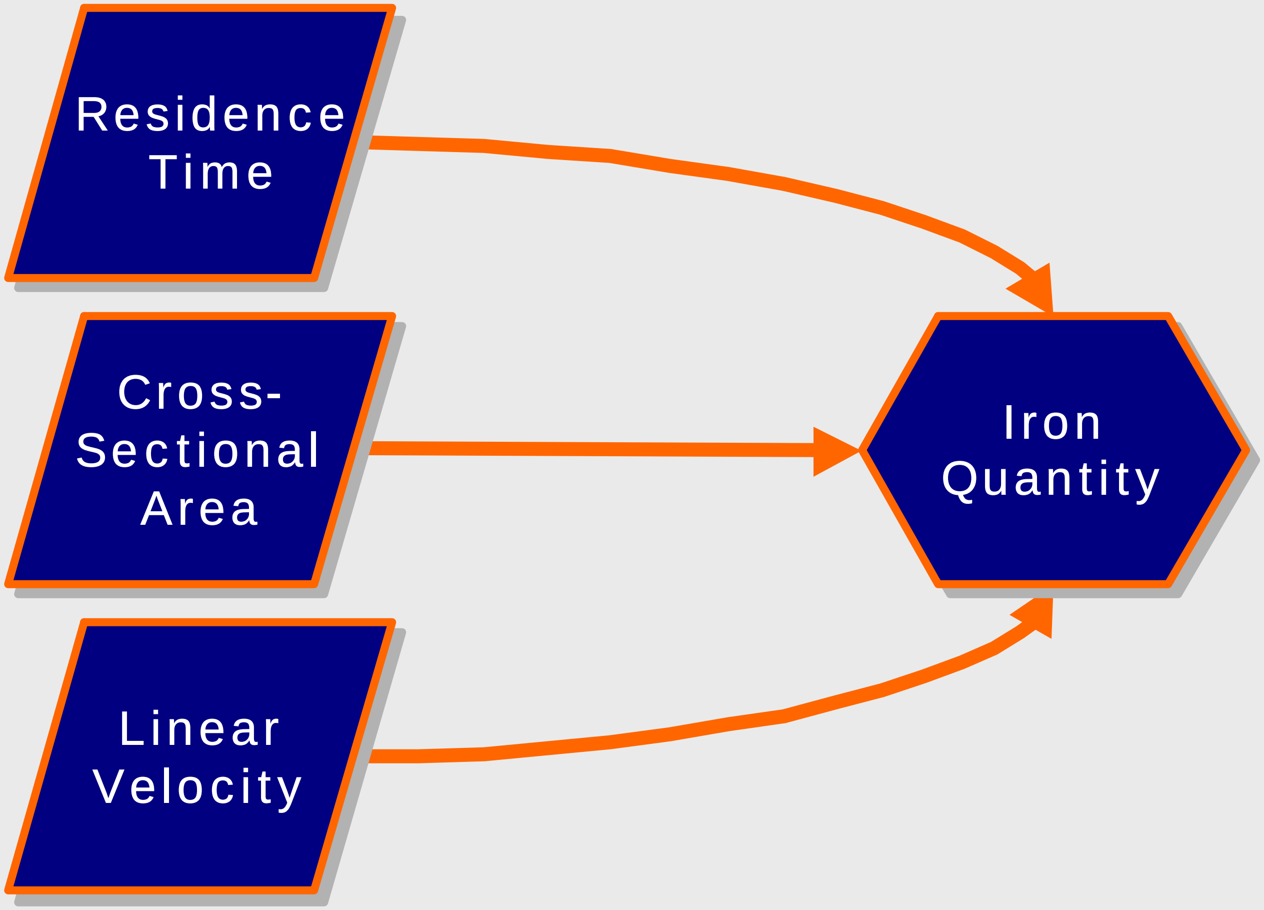
PRB Schematic



Reactive Media Selection Guidance

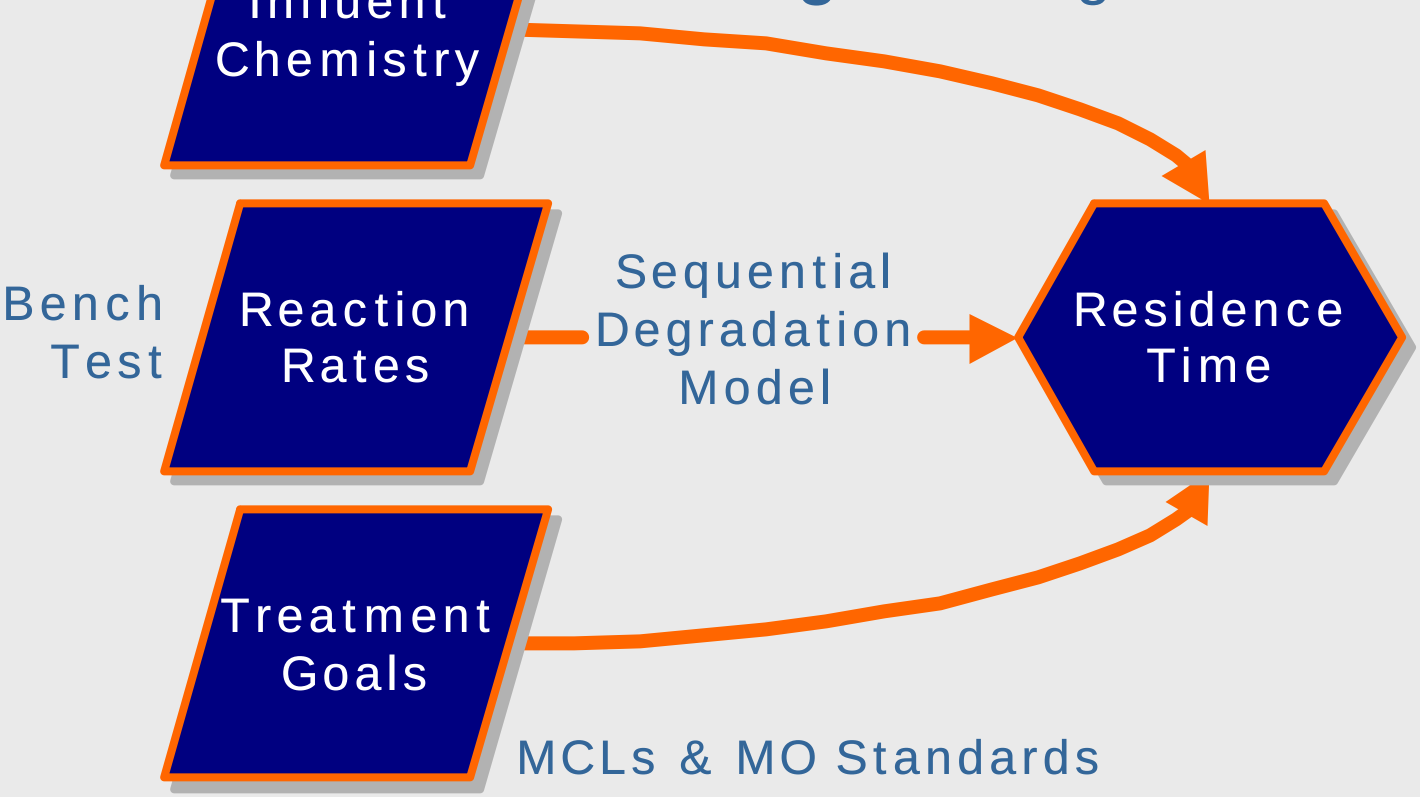
Treatment Material and Treatable Contaminants		
Treatment Material	**Target Contaminants**	**Status**
Zero-Valent Iron	Halocarbons, Reducible metals	In Practice
Reduced Metals	Halocarbons, Reducible Metals	Field Demonstration
Metals Couples	Halocarbons	Field Demonstration
Limestone	Metals, Acid Water	In Practice
Soptive Agents	Metals, Organics	Field Demonstration, In Practice
Reducing Agents	Reducible Metals, Organics	Field Demonstration, In Practice
Biological Electron Acceptors	Petroleum Hydrocarbons	In Practice, Field Demo

PRW Design Basis



Residence Time

Maximum concentrations assumed **throughout** alignment

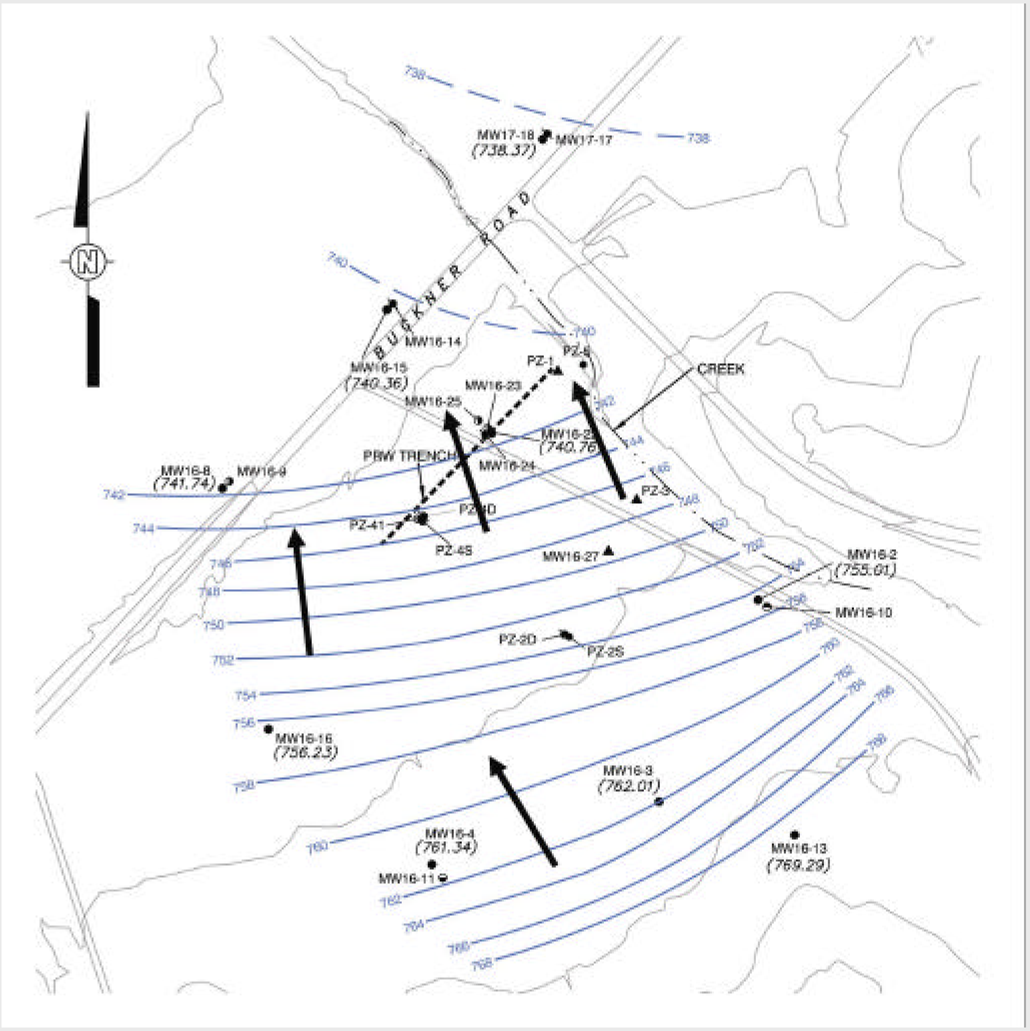


Residence Time-Iron/Guar

- Expected concentrations
  - Maximum values at alignment, TCE 1,000 ug/L
  - 1,869 ug/L Total VOCs at STA 2+40
  - t_r = 12 hours
- Low concentrations
  - At fringe of plume (PZ-4S), TCE 22 ug/L
  - 29.7 ug/L Total VOCs at STA 0+66
  - t_r = 2 hours
- Upgradient concentrations
  - SC17-57, TCE = 8,600 µg/L
  - 9,510 ug/L Total VOCs
  - t_r = 18 hours

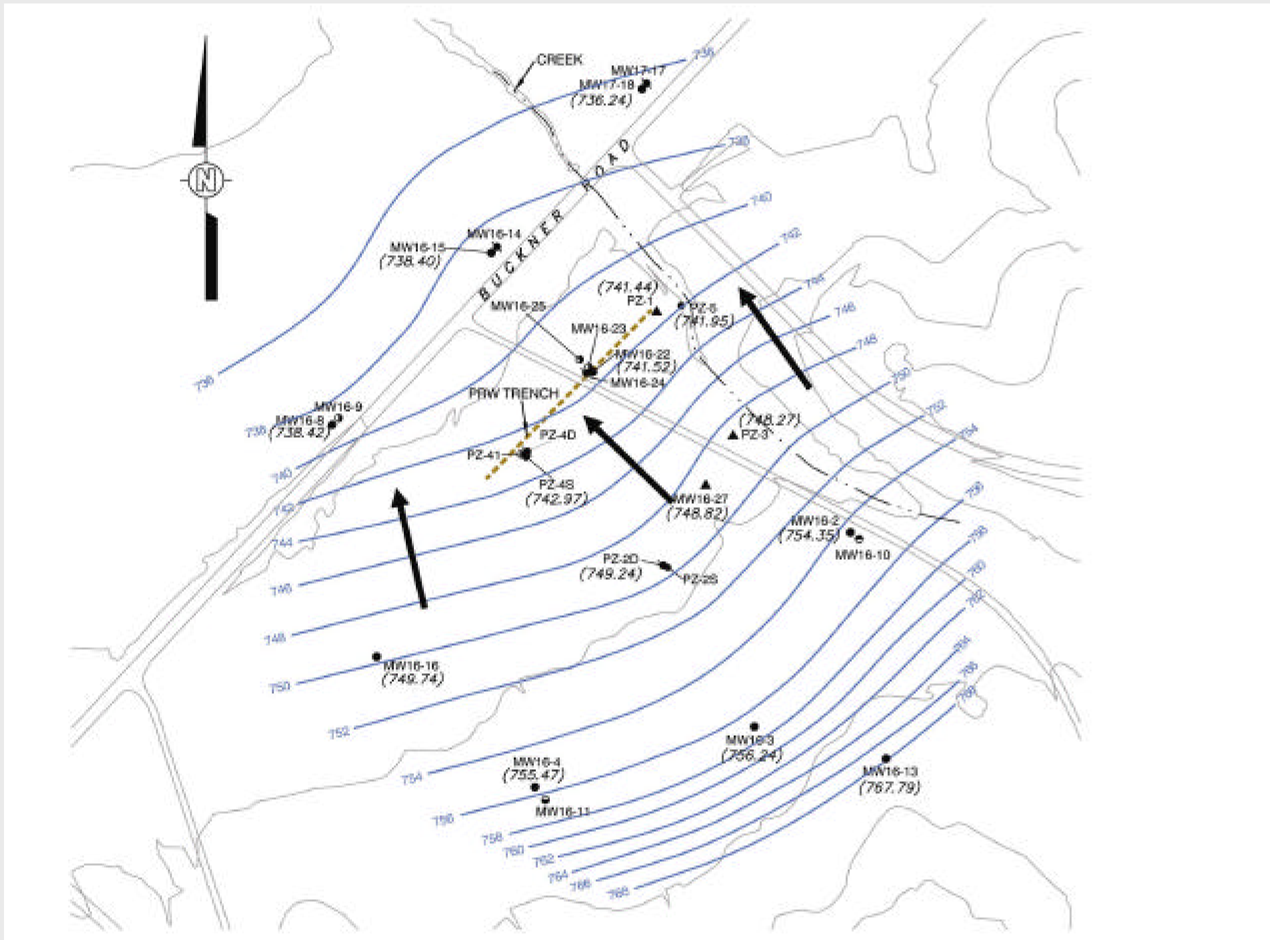
Shaw Environmental & Infrastructure, Inc.

April 1999
Predesign Shallow Groundwater Elevations



Shaw Environmental & Infrastructure, Inc.

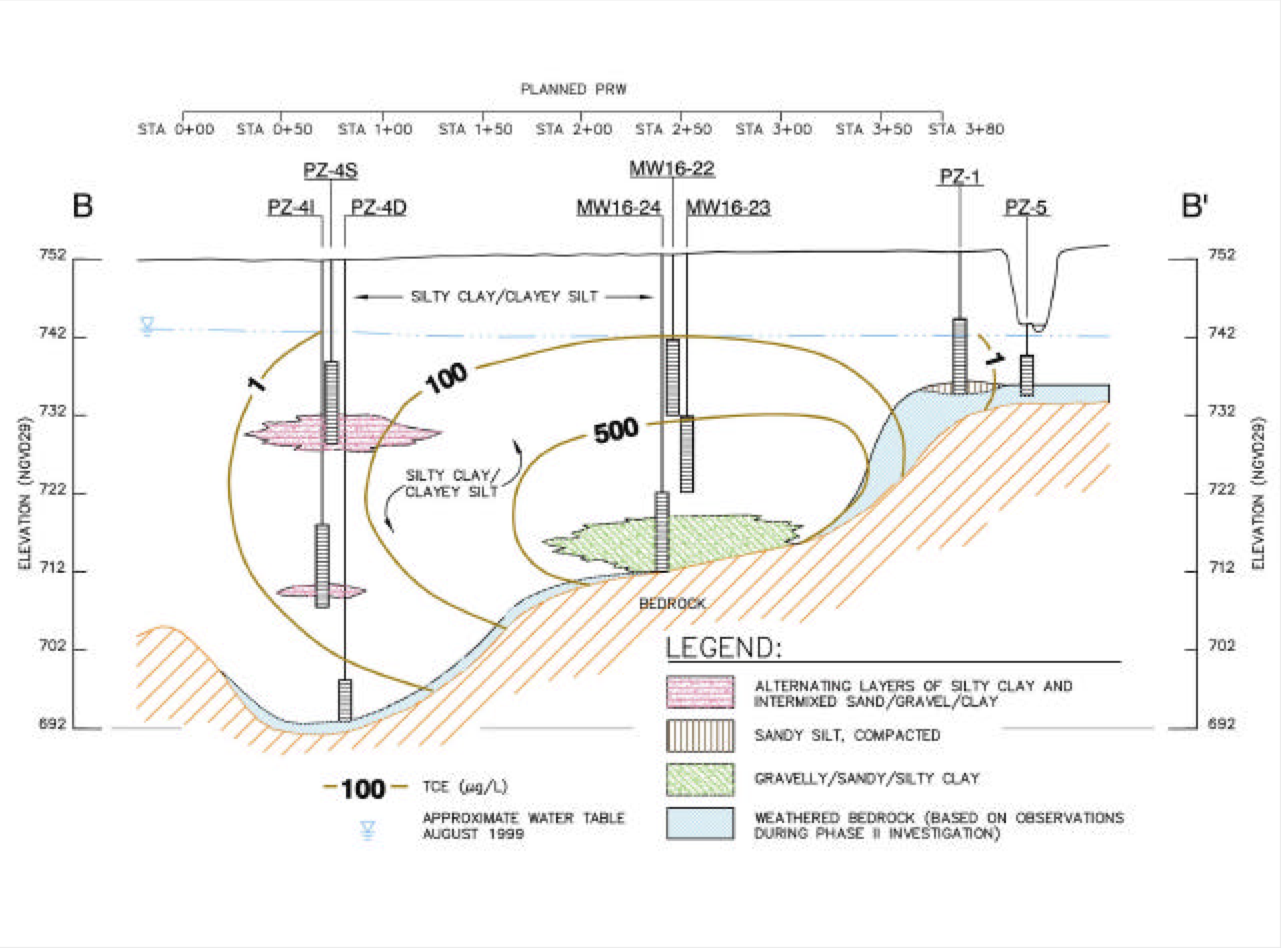
August 1999
Predesign Shallow Groundwater Elevations



Shaw Environmental & Infrastructure, Inc.

August 1999 Total VOC Plume

Design Hydrogeologic Cross-Section Along PRB Axis

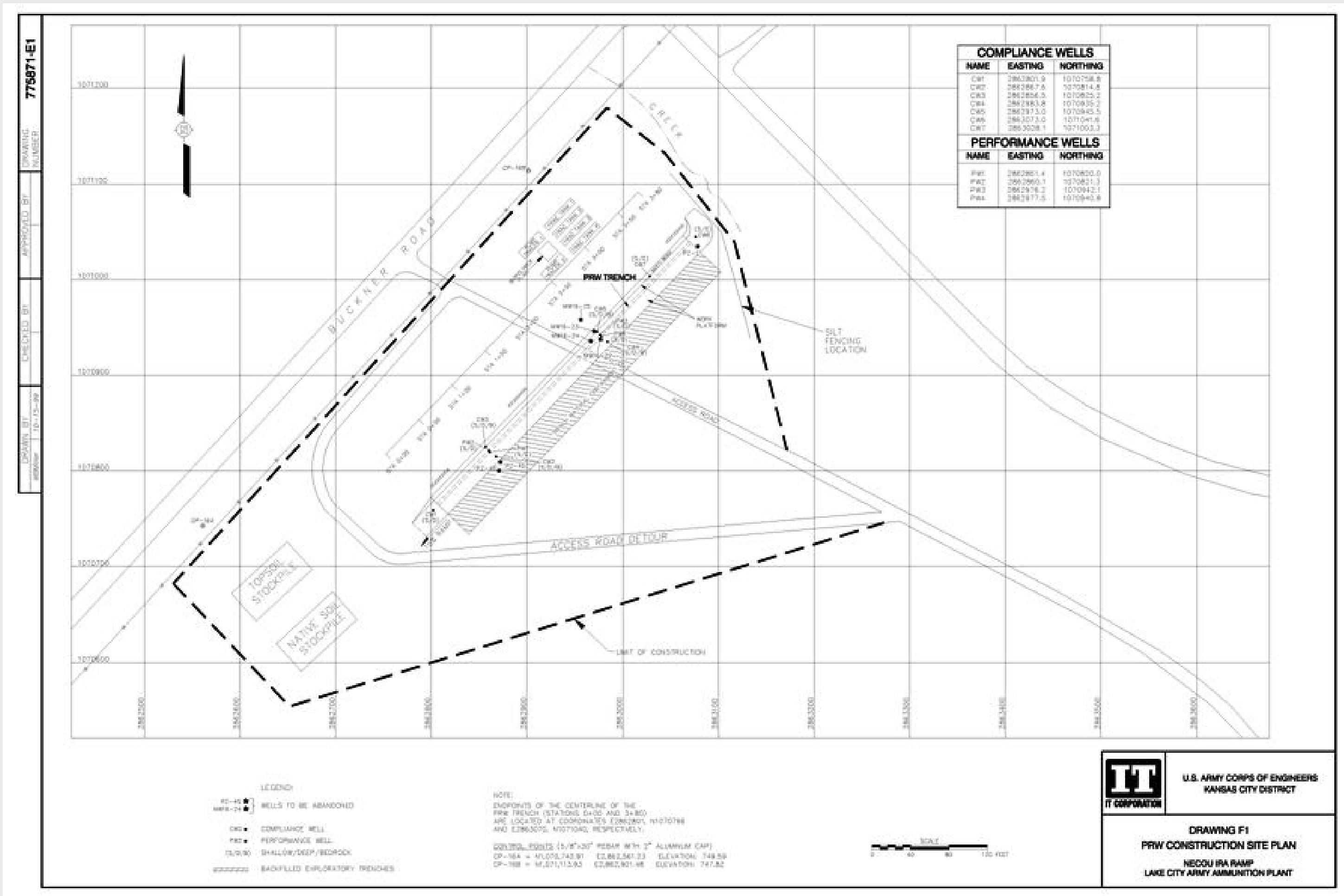


Shaw Environmental & Infrastructure, Inc.

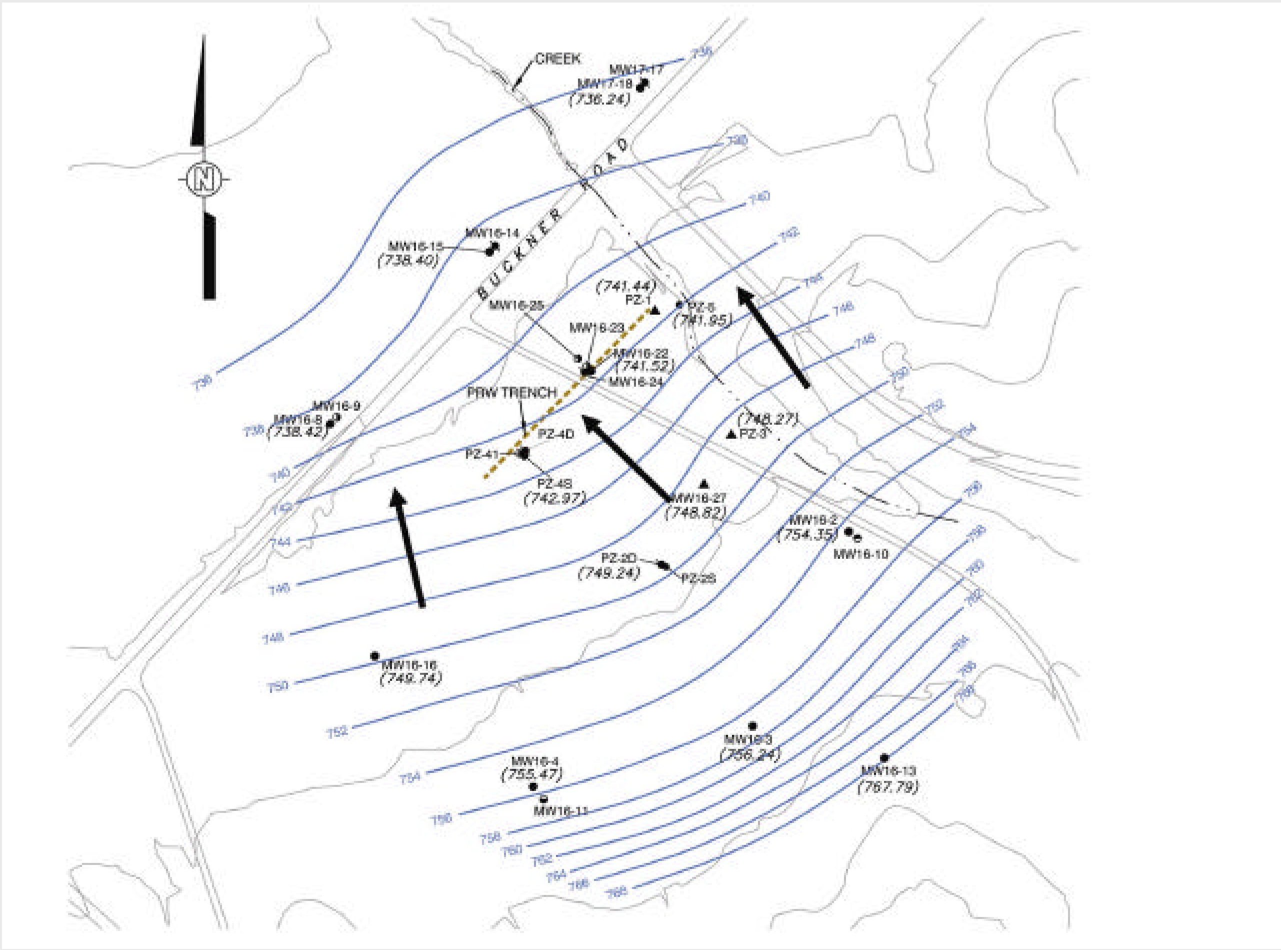
PRB Design Cross-Sectional Area

- IROD requirement - keyed to bedrock
- Bedrock depths based on boring logs/CPT logs
- PRB length = 380 ft
- Total cross-sectional area = 15,150 sq ft

PRB Work Area

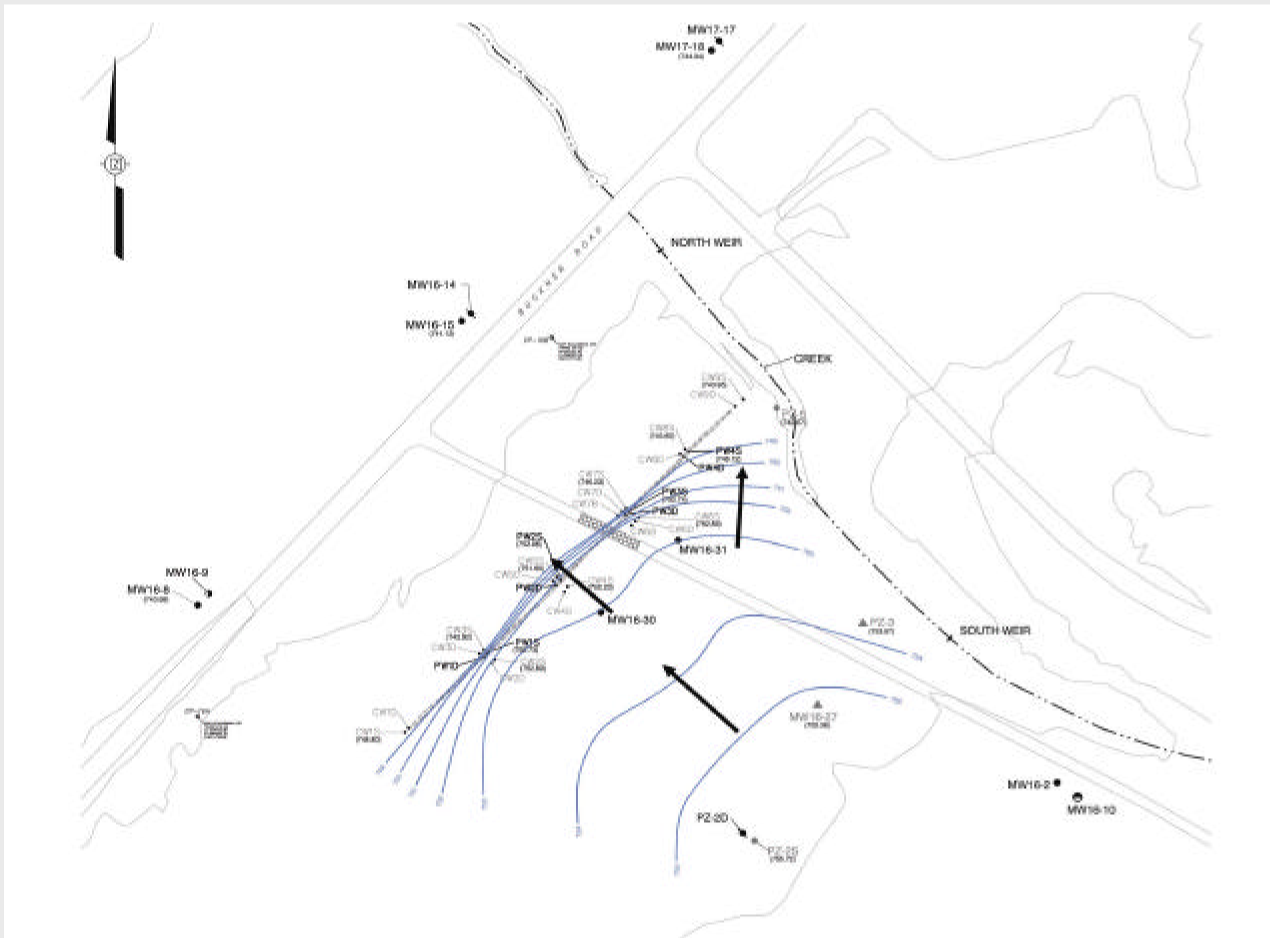


August 1999
Predesign Shallow Groundwater Elevations

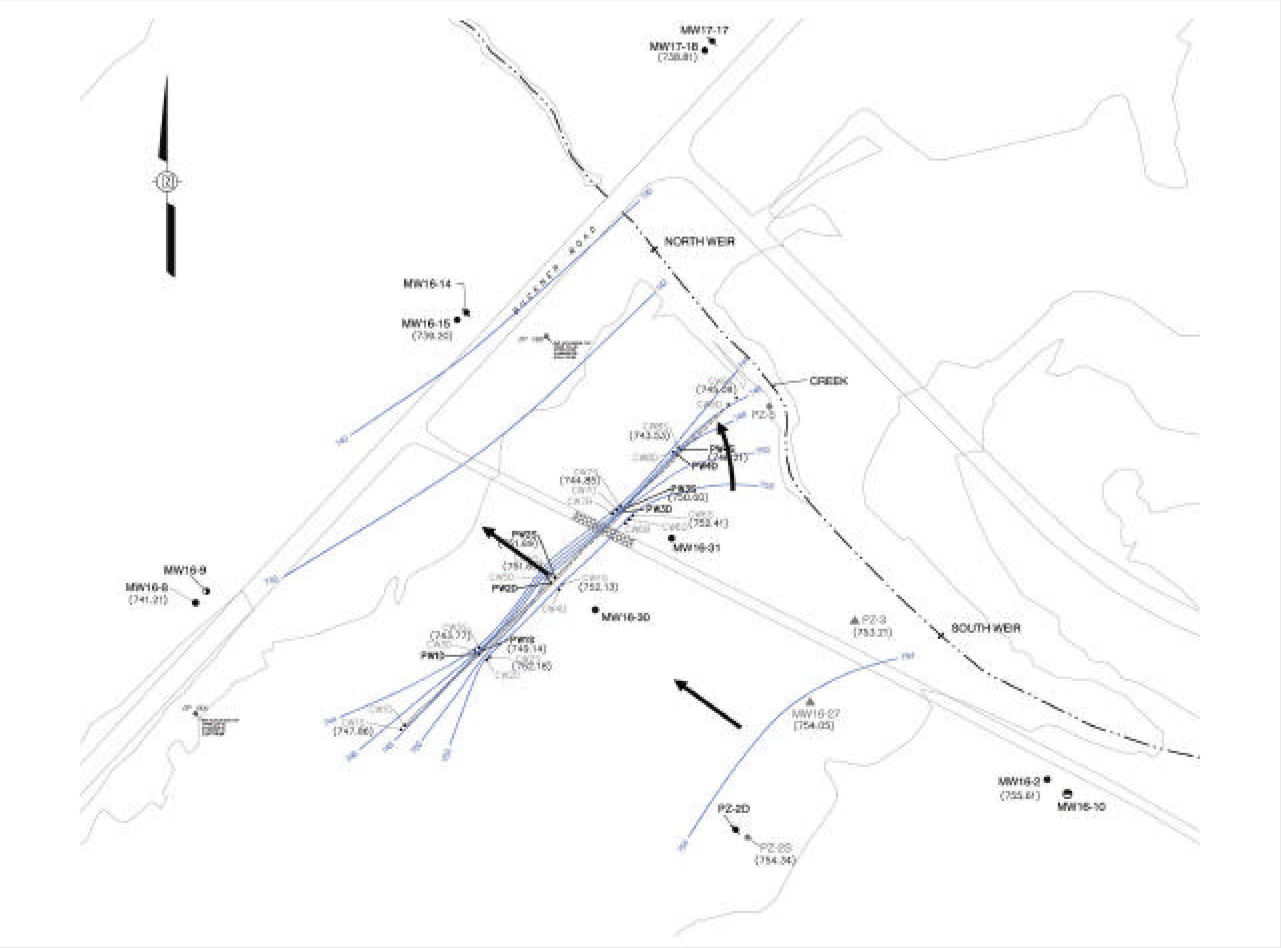


Shaw Environmental & Infrastructure, Inc.

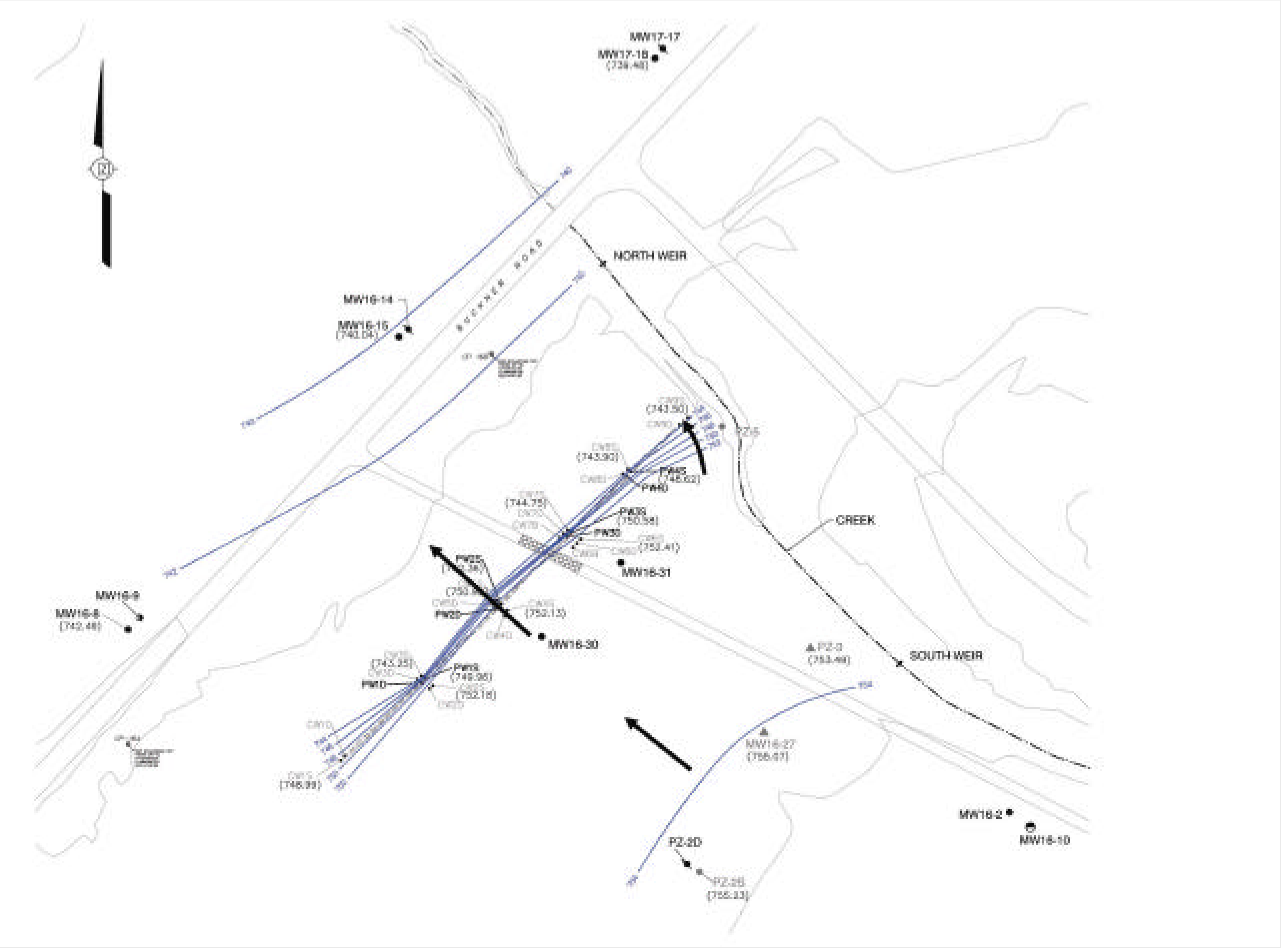
April 2001
Shallow Overburden Potentiometric Surface Map



July 2001
Shallow Overburden Potentiometric Surface Map

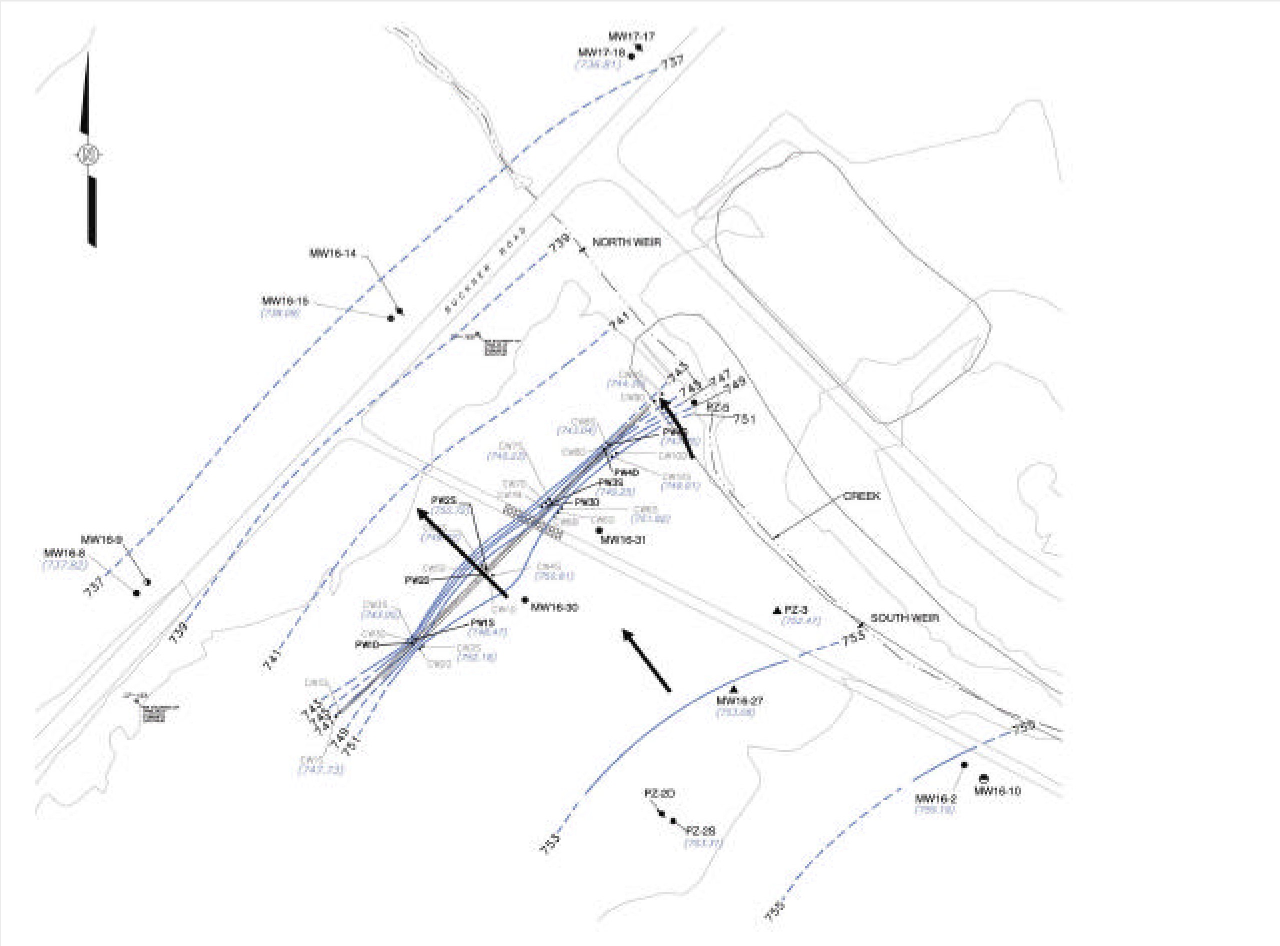


October 2001
Shallow Overburden Potentiometric Surface Map

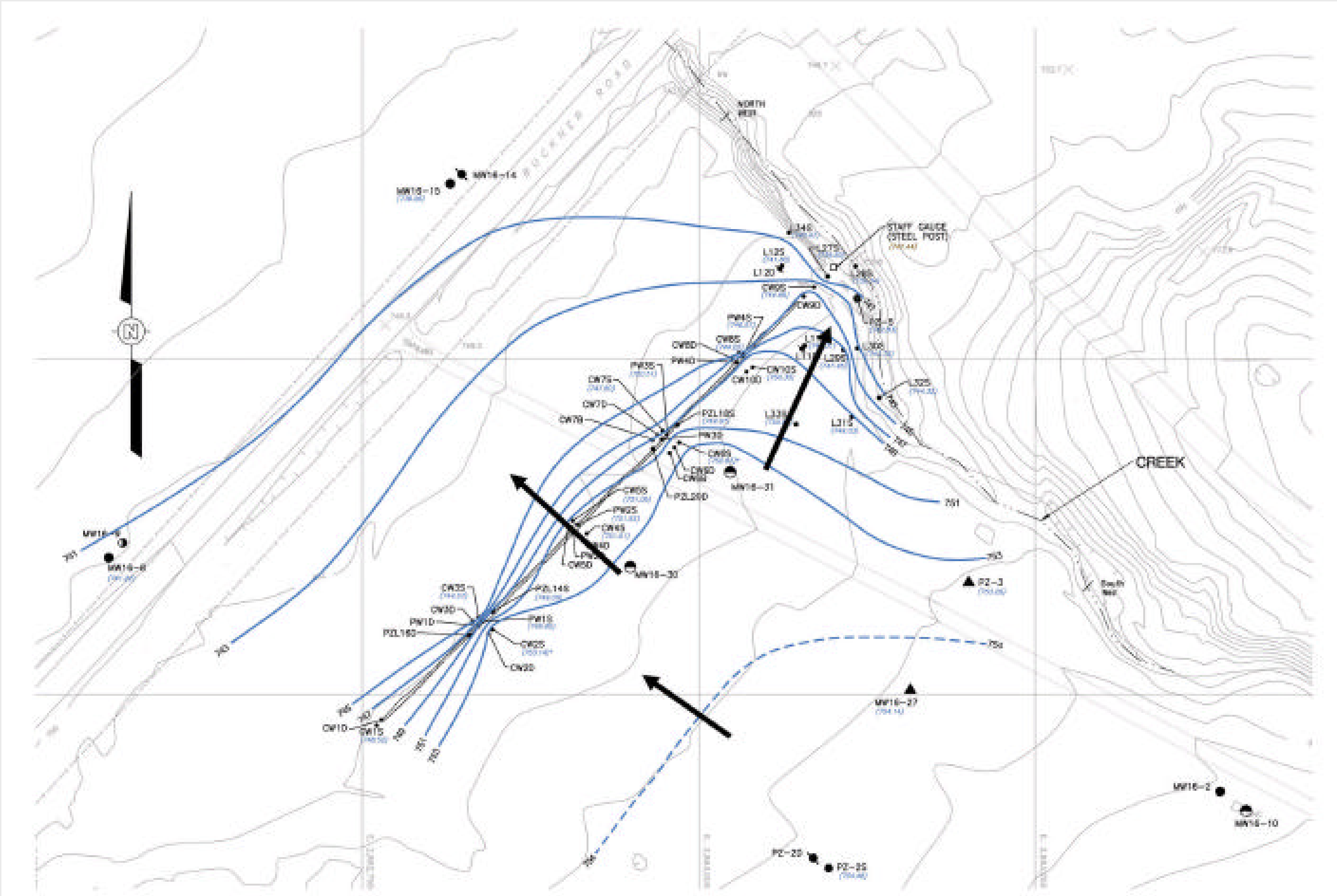


Shaw Environmental & Infrastructure, Inc.

December 2001
Shallow Overburden Potentiometric Surface Map



April 2002
Shallow Overburden Potentiometric Surface Map



Shaw Environmental & Infrastructure, Inc.

Problem Statement

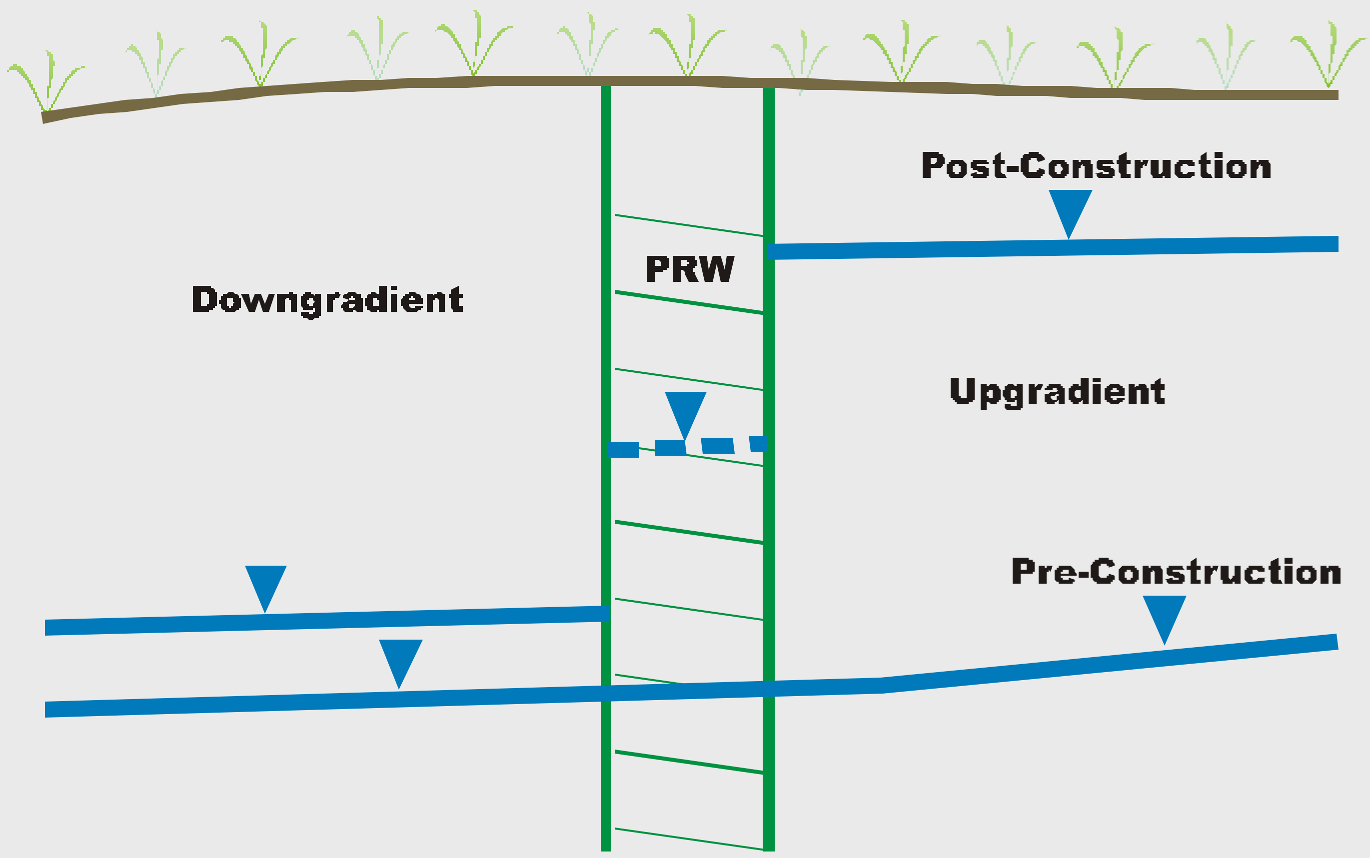
- Is the PRB working hydraulically?
- The groundwater levels upgradient of the PRB have been observed to be elevated in comparison to pre-construction design levels. This mounding may result in groundwater bypassing the PRB, possibly resulting in:
  - Flow to the creek
  - Changes in plume shape and flow direction
  - Effects on the treatment process

Construction Variances

Trench Excavation (CSR)

- Media Placement Method
- Guar Viscosity in Tank
- Endstops
- Side Wall Sloughing (STA 1+20 to 1+60)
- Endstop at STA 1+60 and Clay Sliver
- Sand Backfill (STA 1+20 to 1+60)
- Elevated Work Platform (755 ft)
- Injection/Extraction Well
- Well Optimization - Revised Well Placement
- Performance Well Design/Installation
- Trench Vertical Alignment

Groundwater Gradients (Conceptual)



Groundwater Gradients

	Upgradient of PRW		Across PRW		Downgradient of PRW	
	Shallow Overburden (ft/ft)	Deep Overburden (ft/ft)	Shallow Overburden (ft/ft)	Deep Overburden (ft/ft)	Shallow Overburden (ft/ft)	Deep Overburden (ft/ft)
Pre-construction (August 1999)	0.025	0.028	NA	NA	0.014	0.037
4th Quarter Average (2001)	0.010	0.017	0.331	0.266	0.015	0.050

Hydrologic Assessment

- Slug tests
  - Conducted slug tests at 21 compliance wells and 8 performance wells

Monitoring Well and Piezometer Locations

Shaw Environmental & Infrastructure, Inc.

Hydraulic Conductivity Values

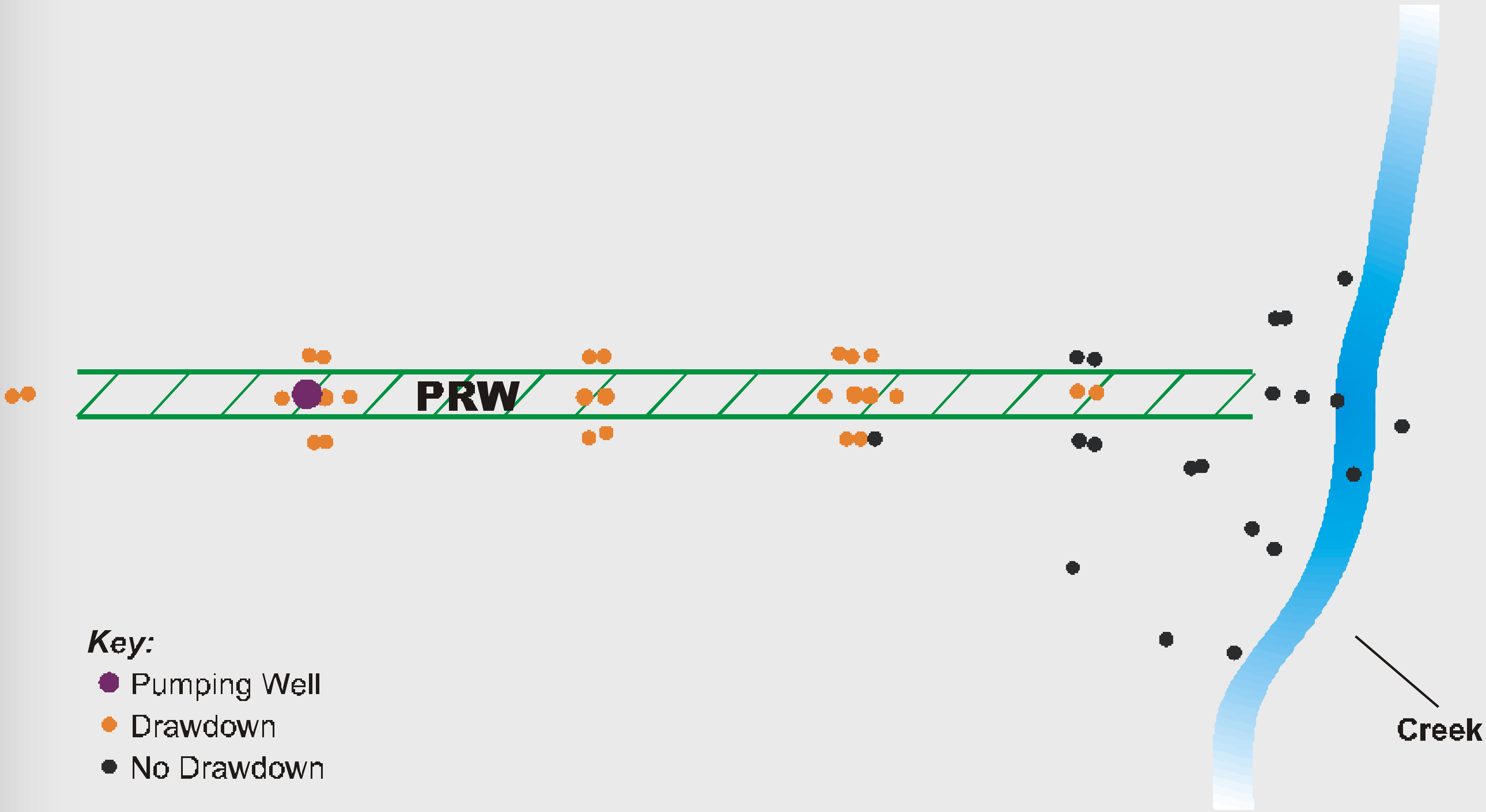
- PreDesign Estimates
  - Shallow Wells
    - 5.7×10^{-5} cm/sec
  - Intermediate Wells
    - 2.8×10^{-5} cm/sec
  - Deep Wells
    - 2.0×10^{-4} cm/sec
- Slug Test Results
  - Shallow Wells (CW)
    - 3.1×10^{-4} cm/sec
  - Shallow Wells (PW)
    - 3.9×10^{-3} cm/sec
  - Deep Wells (CW)
    - 2.6×10^{-4} cm/sec
  - Deep Wells (PW)
    - 1.3×10^{-3} cm/sec
  - Bedrock Wells
    - 9.5×10^{-6} cm/sec

Shaw Environmental & Infrastructure, Inc.

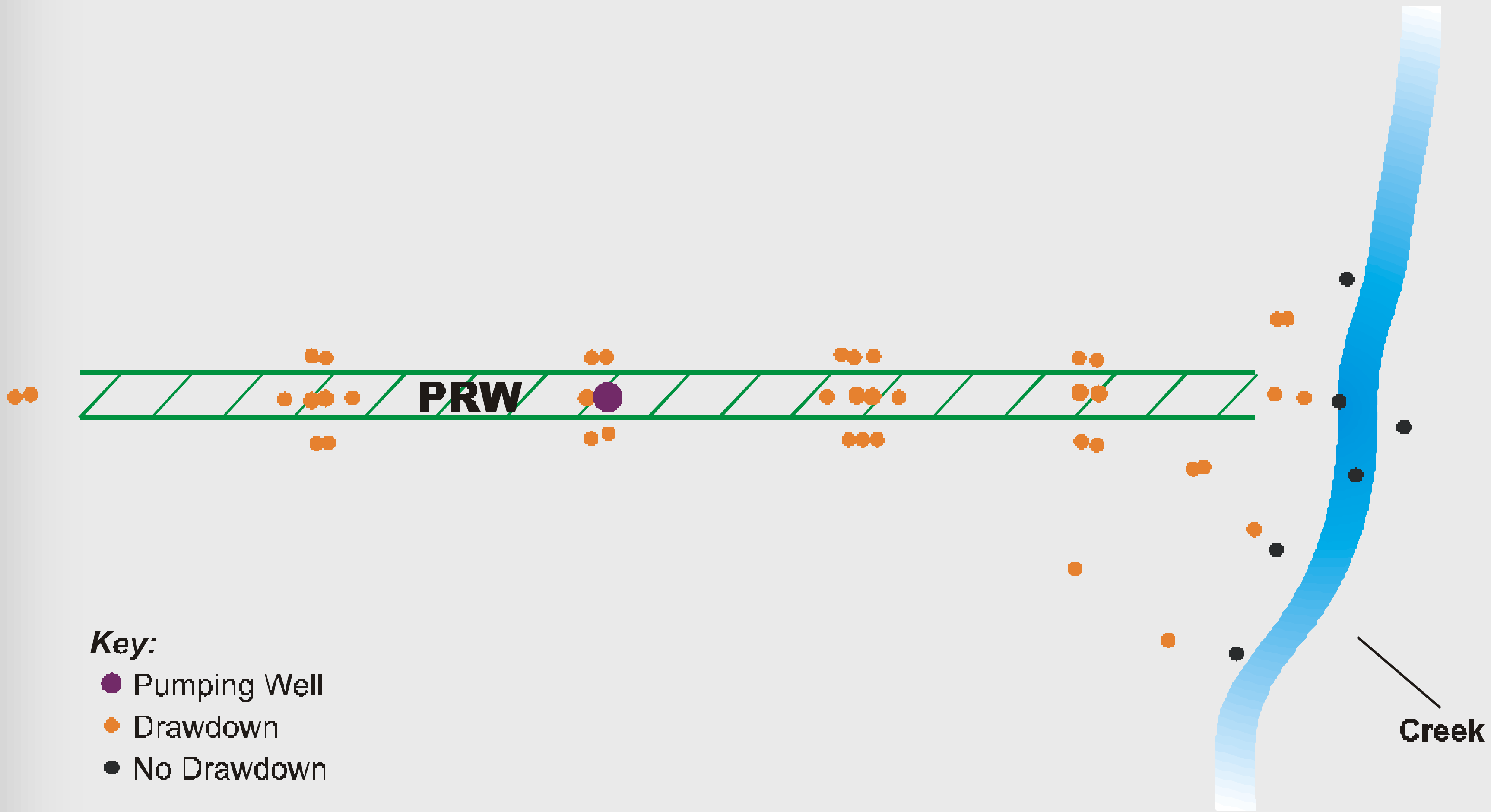
Pumping Tests

- Twelve piezometers installed in creek bank and adjacent to creek
- Four in wall piezometers
- Five step drawdown tests
- Four 72-hour pumping tests
- Deep PRB well pumped at PW-1D, PW-3D, PW-4D, and shallow at PW-2S
- Pumping rates 1 to 3 gpm
- Creek response monitored
- Qualitative data analyses

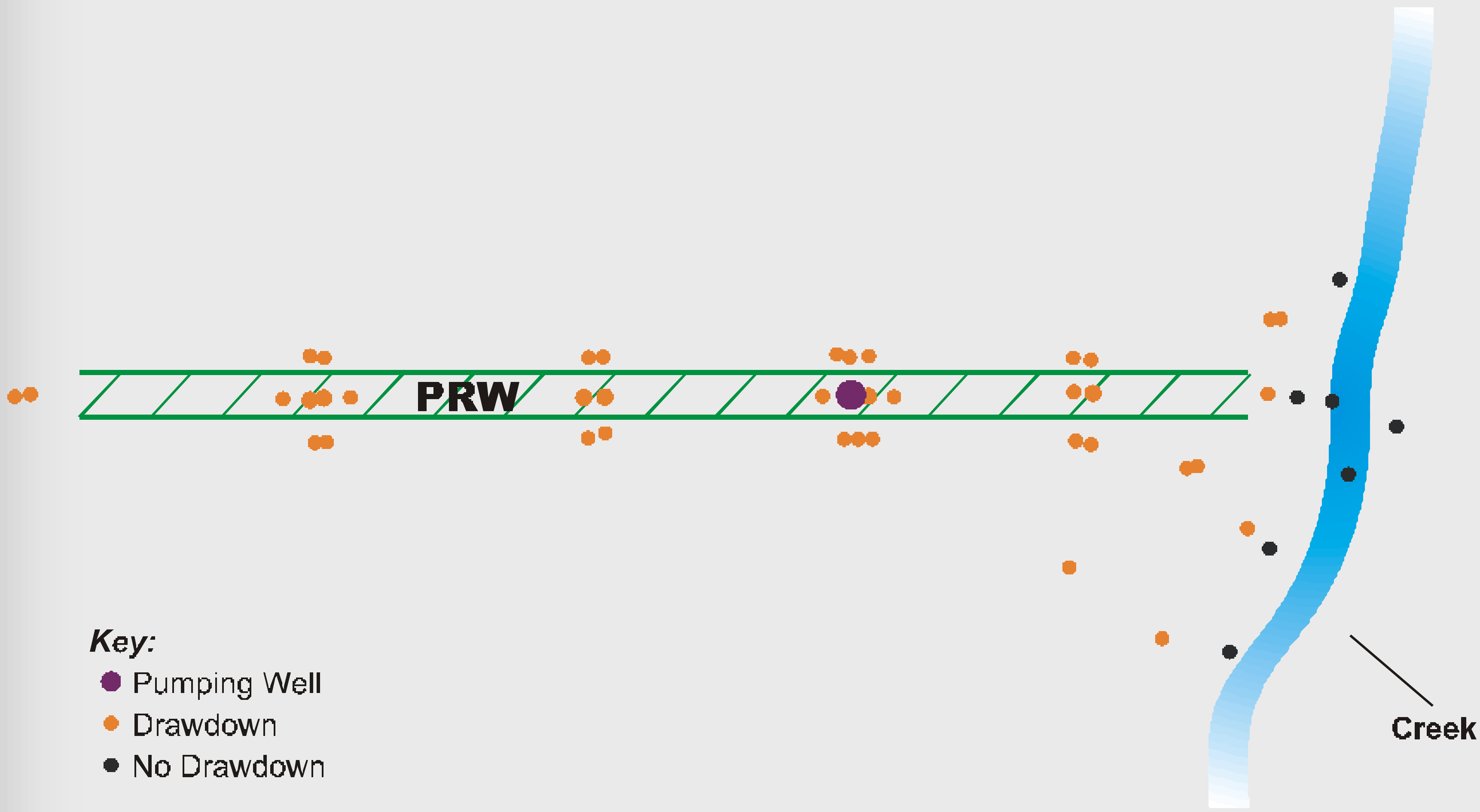
PW-1D Pumping Test Results



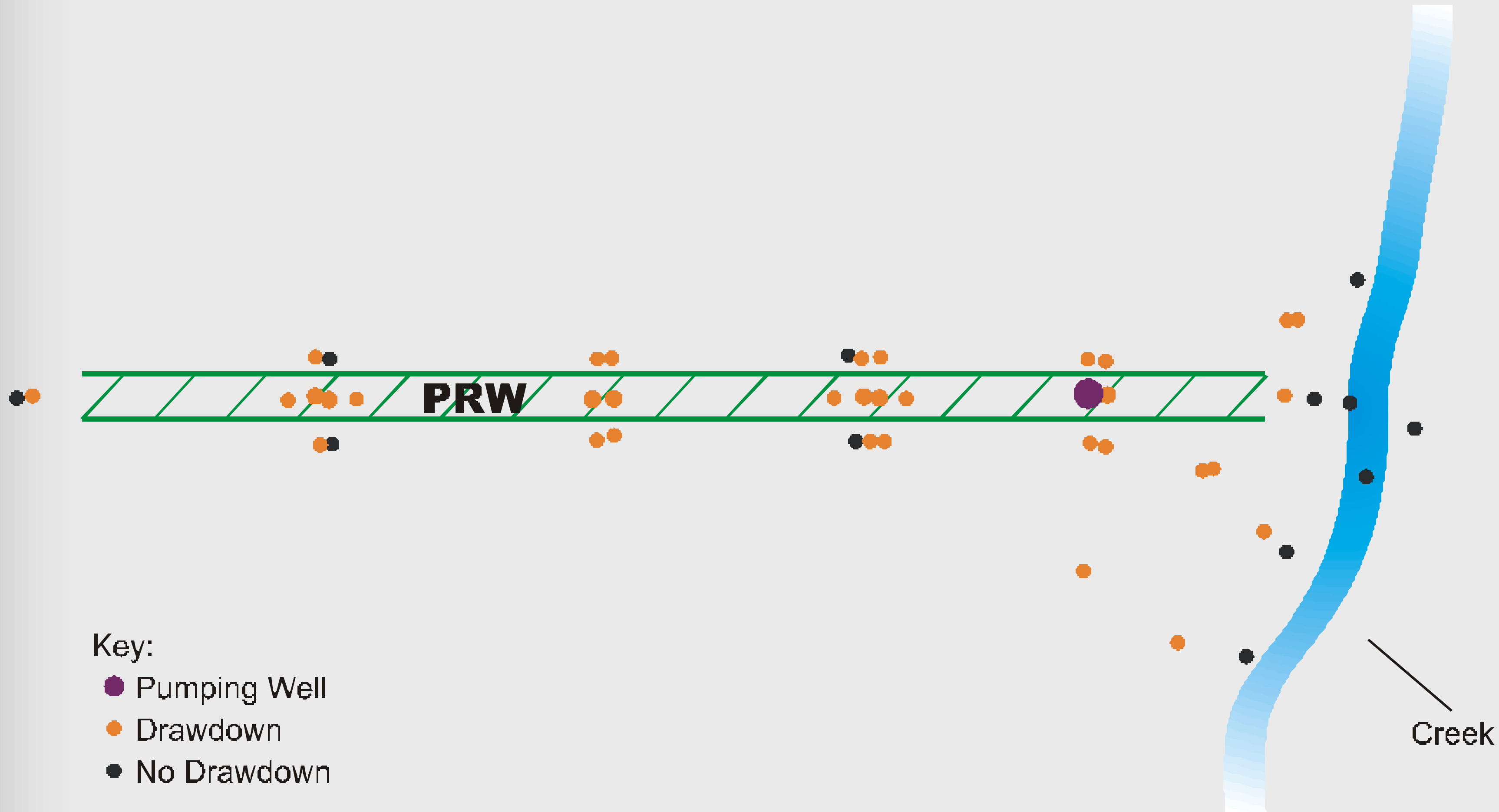
PW-2S Pumping Test Results



PW-3D Pumping Test Results



PW-4D Pumping Test Results



Creek Flow Response to Pumping

- Two monitoring methods used
  - Weir flow measurements
  - Stream elevation measurement (steel post)
- Variability in stream flow and head appears unrelated to pumping
- Supported by lack of response in piezometers L27S and L34S

Pumping Test Conclusions

- Groundwater pumping (1 to 3 gpm) during each of the four pumping tests resulted in drawdowns along the entire length of the PRB
- The PRB media appears to be generally homogeneous with the exception of a deep section around PW-2D (STA 1+50)
- The effect of pumping within the PRB is transmitted throughout the wall, and to materials surrounding the wall, without evidence of impediment to flow

Shaw Environmental & Infrastructure, Inc.

Pumping Test Conclusions

- Groundwater pumping in the PRB did not result in changes in the creek water levels
- Groundwater pumping effects were not observed in piezometers installed adjacent to the creek
- The PRB is in hydraulic communication with the surrounding media based on drawdowns observed in compliance wells both up and down gradient
- The effects of smearing (or a decreased permeability zone) at the interface between the PRB and the overburden were not observed during the pumping test

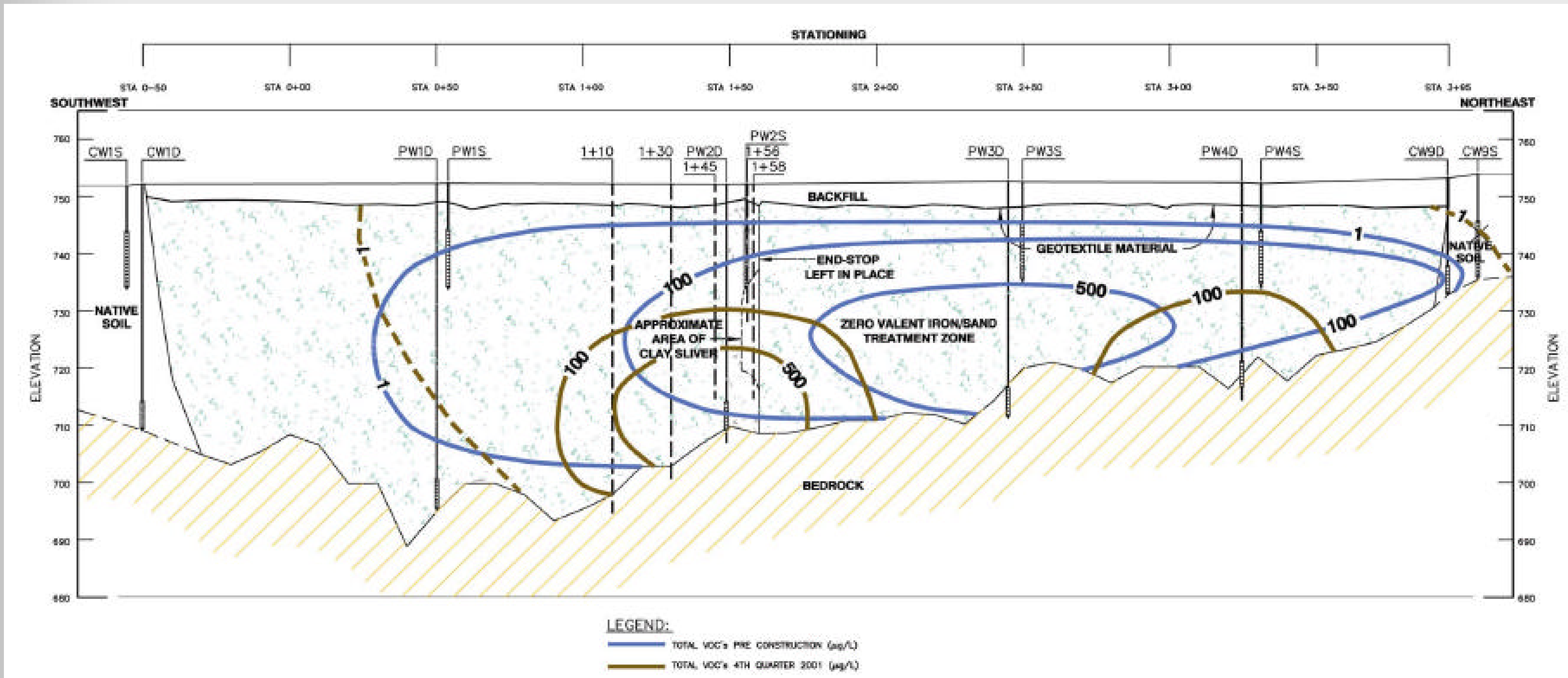
PRB Design Criteria vs Post Construction Values (In Wall)

		Design	Post Construction
Cross-sectional area		15,150 sq ft	16,800 sq ft
Hydraulic gradient		0.065 ft/ft	0.299 ft/ft (CW wells)
Media hydraulic conductivity		1.1×10^{-3} cm/sec	2.3×10^{-3} cm/sec
Specific discharge		0.16 ft/day	1.95 ft/day
Average linear velocity		0.40 ft/day	4.88 ft/day*
Influent plume chemistry (Maximum)	PCE	53 µg/l	7.17 µg/l (CW-2S)
	TCE	1000 µg/l	694 µg/l (CW-4D)
	cis-12 DCE	740 µg/l	227 µg/l (CW-4D)
	1,1 DCE	15 µg/l	6.48 µg/l (CW-4D
	VC	0.28 µg/l	0.65 µg/l (CW-6S)
	1,1,2 TCA	0.87 µg/l	0.56 µg/l (CW-4D)
	1,1 DCA	60 µg/l	13.9 µg/l (CW-4D)
Residence time		8 hrs Iron	9.8 hrs
		12 hrs Iron/Guar	

*Not accounting for potential smear zone

Shaw Environmental & Infrastructure, Inc.

As-built Hydrogeologic Cross-Section Along PRB Axis



CW MONITORING WELLS JUST UPGRADIENT OF THE WALL

Shaw Environmental & Infrastructure, Inc.

General Conclusions

- The PRB appears to be working hydraulically based on the data collected to date.
- A significant portion of the VOC plume is bypassing the PRB. The GW flow pattern that has developed since the PRB was installed is complex.
- Limited pre-design investigation and delayed implementation of the performance monitoring program have hindered timely recognition of the performance problems.
- Monitoring wells are not located along flow lines due to flow redistribution.
- GW contamination in the portion of the plume that is currently passing through the PRB appears to be degrading to below MCLs.

General Conclusions

- There are three major causes of the plume bypass:
  - The PRB is not aligned parallel to the pre-construction equipotential contours.
  - The hydraulic conductivity of the PRB backfill is low and varies laterally.
  - There is a low conductivity skin at the PRB trench walls.

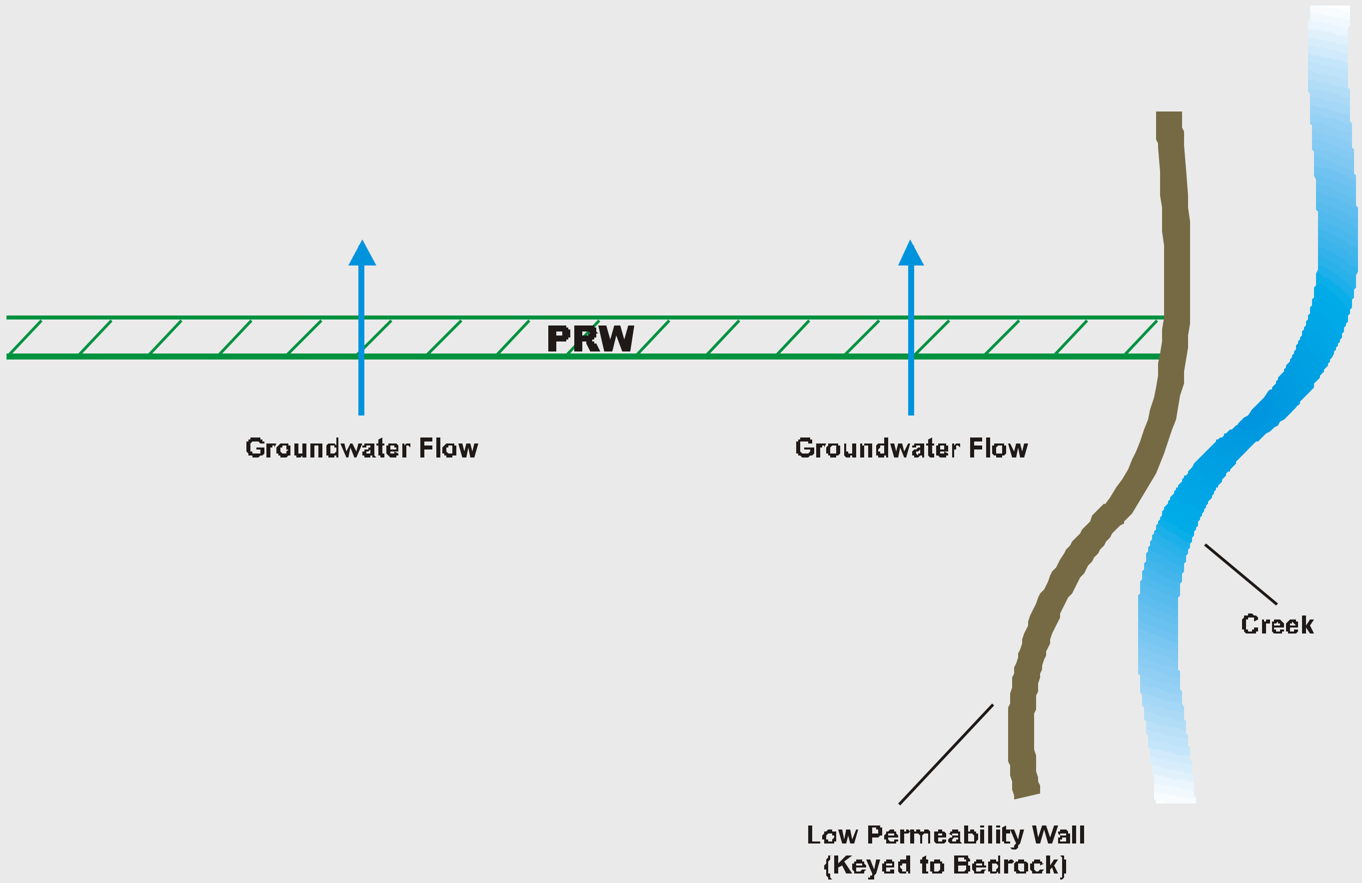
Possible PRB Augmentation/Data Gaps

- No immediate wall augmentation
  - Map seep locations and elevations along the creek
  - Sample the seeps
  - Install and sample the Phase II wells
  - Install and sample additional temporary piezometers on east side of creek and establish broader network
  - Perform groundwater modeling
  - Survey creek bottom profile (elevations) between weirs
  - Add passive diffusion samplers to creek bottom
  - Quarterly monitoring

Possible PRB Augmentation/Data Gaps

- Add sheetpiling/slurry wall along creek
  - Map seep locations and elevations along the creek
  - Sample the seeps
  - Install and sample the Phase II wells
  - Install and sample additional temporary piezometers on east side of creek and establish broader network
  - Perform groundwater modeling
  - Survey creek bottom profile (elevations) between weirs
  - Add passive diffusion samplers to creek bottom
  - Quarterly monitoring

Sheetpiling/Slurry Wall Along Creek

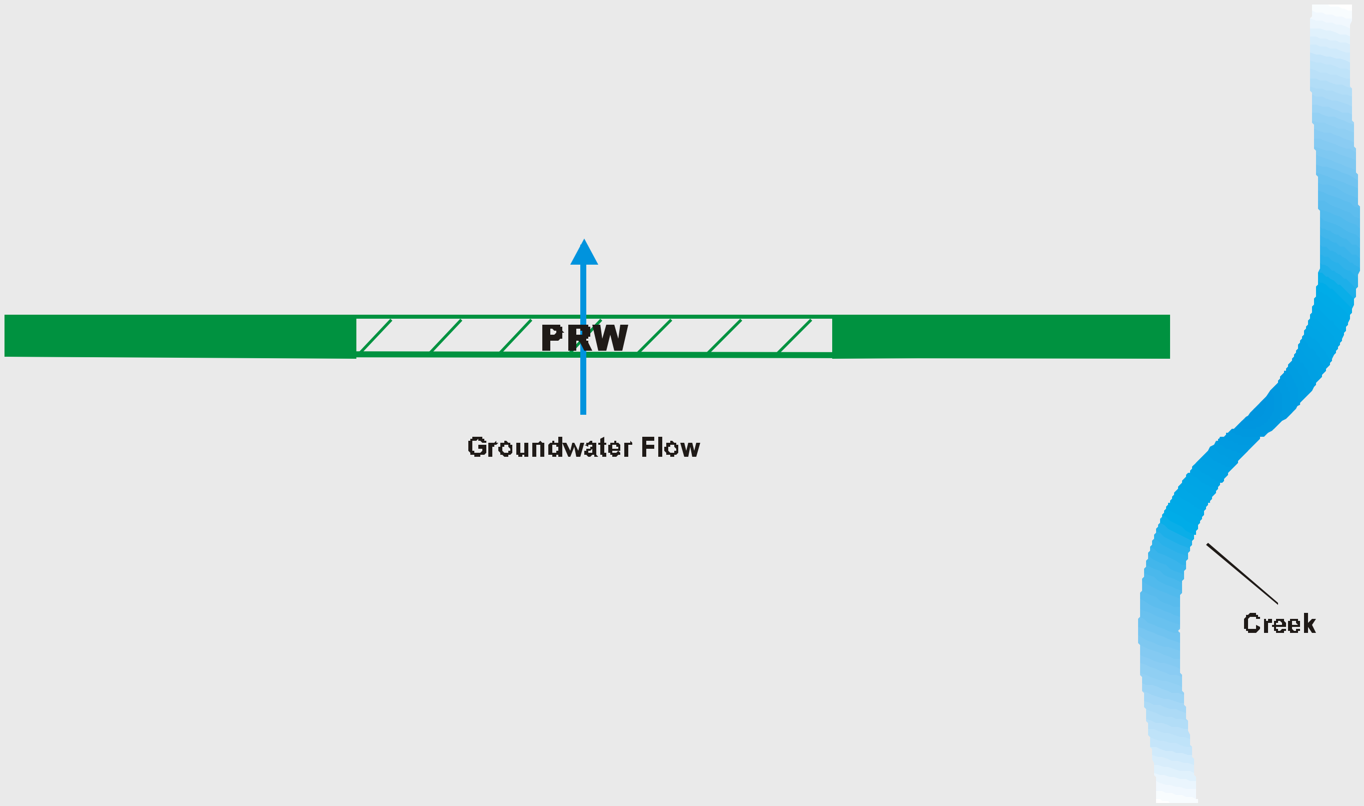


Shaw Environmental & Infrastructure, Inc.

Possible PRB Augmentation/Data Gaps

- Develop wall into funnel and gate system
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Perform groundwater modeling
  - Perform tracer tests from wells in wall for velocity measurements
  - Evaluate use of flow meters in wells
  - Collect samples for bio and mineral precipitation
  - Quarterly monitoring

PRB to Funnel and Gate System



Possible PRB Augmentation/Data Gaps

- Clear potential smear zone along wall interfaces - Pressure Pulse Technology and/or chemical cleaning (Surfactants)
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Perform tracer tests from wells in wall for velocity measurements
  - Evaluate use of flow meters in wells
  - Collect samples for biological activity, mineral precipitation, and interfacial overburden soil smearing
  - Quarterly monitoring

Possible PRB Augmentation/Data Gaps

- Inject iron into wall
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Quarterly monitoring

Possible PRB Augmentation/Data Gaps

- Add phyto evapotranspiration system upgradient of wall
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Quarterly monitoring

Shaw Environmental & Infrastructure, Inc.

Possible PRB Augmentation/Data Gaps

- Perform chemical oxidation (potassium permanganate or Fe nanoparticles) in areas upgradient and downgradient of wall
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Quarterly monitoring

Shaw Environmental & Infrastructure, Inc.

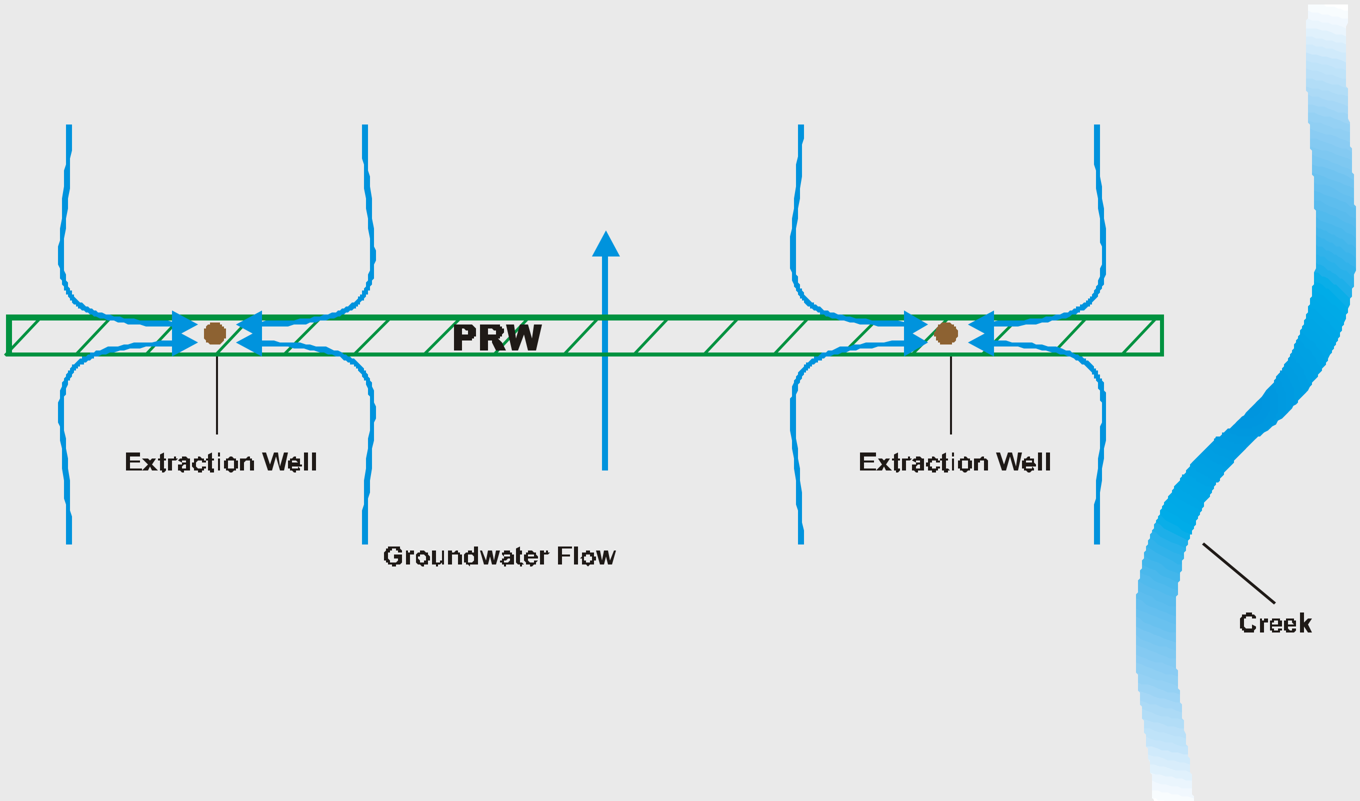
Possible PRB Augmentation/Data Gaps

- Install upgradient extraction wells - pipe or truck water to building 163 or local discharge (containment and sampling system to be established)
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Perform groundwater modeling
  - Quarterly monitoring

Possible PRB Augmentation/Data Gaps

- Install extraction wells in the PRB - pipe or truck water to building 163 or local discharge (containment and sampling system to be established)
  - Install and sample additional piezometers for broader network
  - Install and sample the Phase II wells
  - Perform groundwater modeling
  - Quarterly monitoring

Install Extraction Wells in PRB



Shaw Environmental & Infrastructure, Inc.

Path Forward

- Fill data gaps
- Perform mini FS
- Perform PRW augmentation

Shaw Environmental & Infrastructure, Inc.