

Assessment of Reactive Iron Barrier Performance at a Complex Site in Australia

***RTDF PRB Meeting
Washington DC, November 6 & 7, 2002***

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***(acknowledgements to James Stening, John Vogan &
Joe Duran)***

Subject Site - Location

- **Sandy unconfined aquifer**
 - peat lenses
 - sandstone bedrock at ~30m (~100 ft)
- **Hydraulically downgradient of a large petrochemical complex**
 - former solvents and plastics manufacturing

Subject Site - Organics

- **Chlorinated hydrocarbons (up to 220 mg/L)**
 - **carbon tetrachloride (CTC)**
 - **tetrachloroethene (PCE)**
 - **vinyl chloride monomer (VCM)**
 - **1,2-dichloroethane (ethylene dichloride, EDC)**
 - **trichloroethene (TCE)**
 - **1,1,2,2-tetrachloroethane (PCA)**

Subject Site - Inorganics

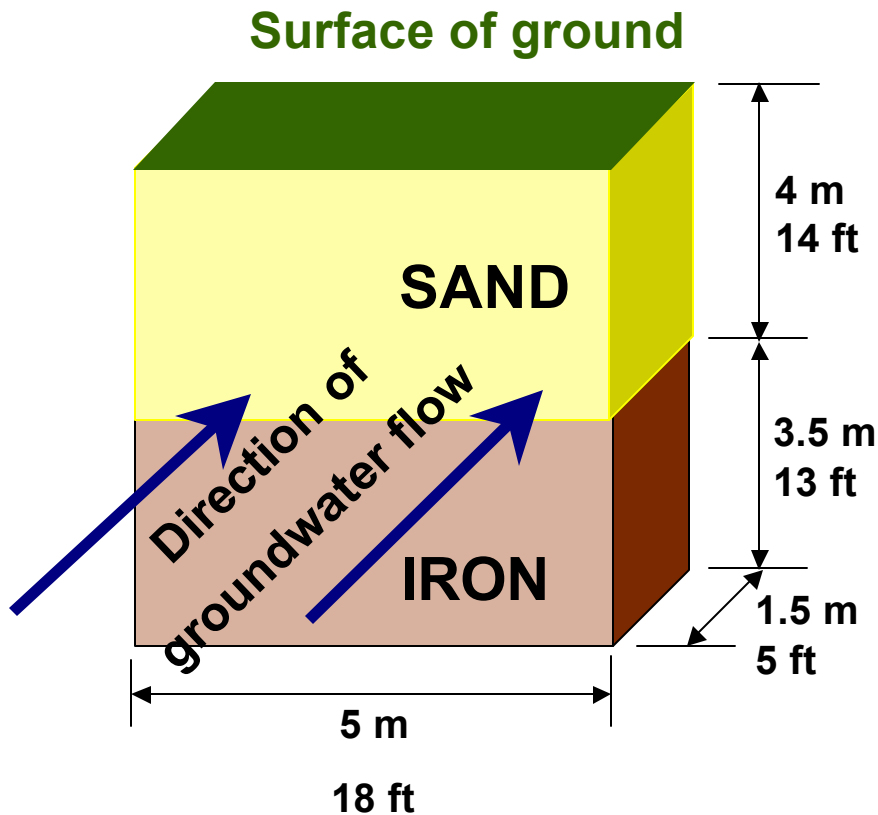
- **Reduced conditions**
- **Acidic (pH < 5)**
- **High TOC (> 500 mg/L)**
- **Sulphide > 30 mg/L**
- **Range of volatile fatty acids**

Laboratory Column Trials

- **Results (Uni of Waterloo, August 1998):**

- ✓ CTC and PCE degraded
- ✗ reaction half lives higher than for other sites' groundwater and other iron sources
- ✗ very high dissolved organic carbon blamed by coating the iron surface or by entraining PCE in solution, preventing reaction
- ✓ typical Eh values, but lower pH
- ✓ no sign of biological fouling or precipitation
- ✓ Australian iron source validated

Pilot Scale Field Installation



- **Design:**
 - 5 m wide
 - 1.5 m thick (° 10 days)
 - 3.5 m tall
- **Position:**
 - 4 m below surface
 - perpendicular to flow
 - in path of CTC & PCE

Pilot Scale Field Installation

- **Construction:**
 - sheet piled to 11 m (39 ft)
 - excavated to 7.5 m (27 ft)
 - filled with water
 - installed monitoring wells and bundle piezometers on a frame
 - poured in 72 one ton bags of iron
 - filled to surface with clean sand
 - capped with concrete

Pilot Scale Field Installation



Sheet piling

Pilot Scale Field Installation



Installing frame to support wells and piezometers

Pilot Scale Field Installation



Installing iron

Pilot Scale Field Installation



Back- filling with clean sand

Pilot Scale Field Installation

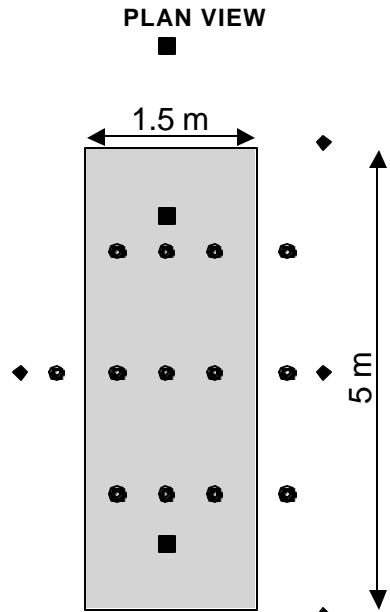


Wells and piezometers

Pilot Scale Field Installation

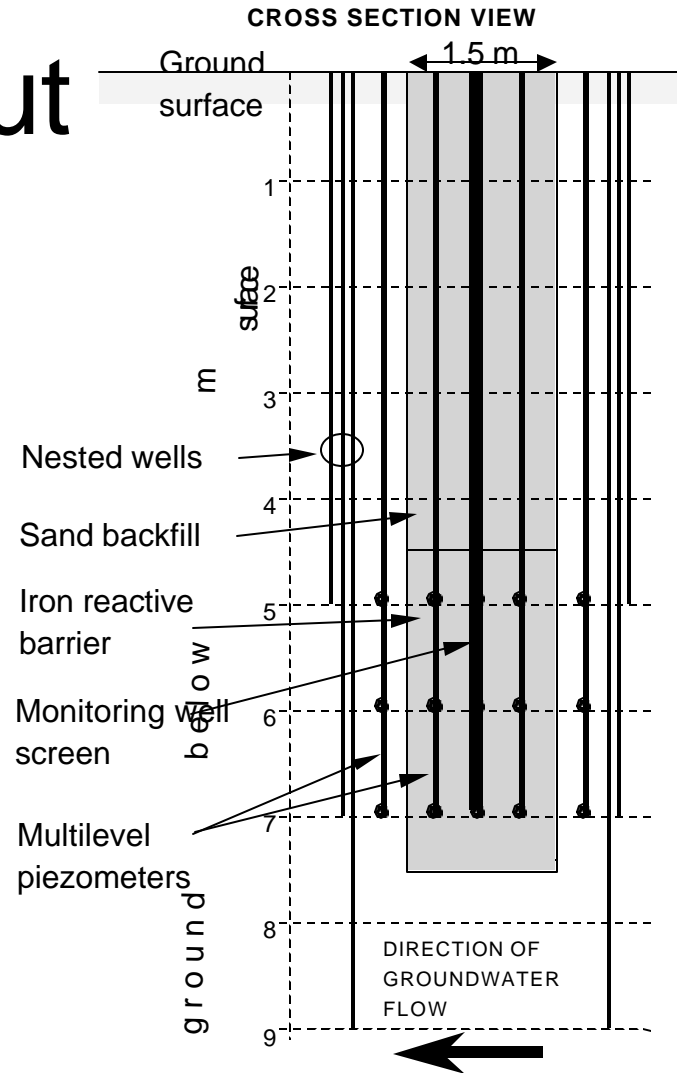
- **Groundwater sampling design:**
 - wells to measure velocities
 - bundle piezometers to collect discrete samples
 - upstream and downstream of barrier
 - 3x3x3 array of sample points in barrier
 - in October 2000 added two piezometers 0.2 m (8 in.) from front face to measure CTC

Pilot Scale Layout



LEGEND

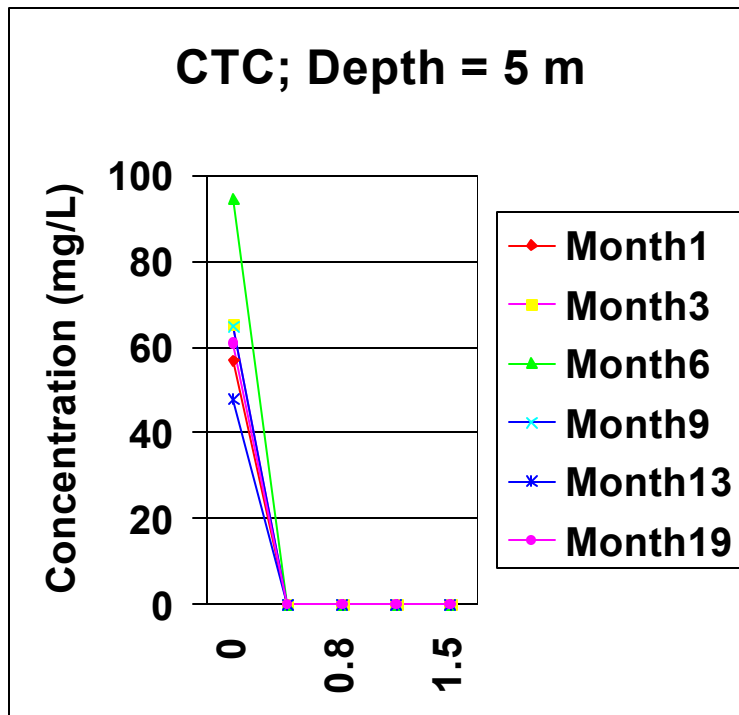
- Multilevel piezometers
- Monitoring well screen
- ◆ Nested wells



Pilot Scale Field Installation

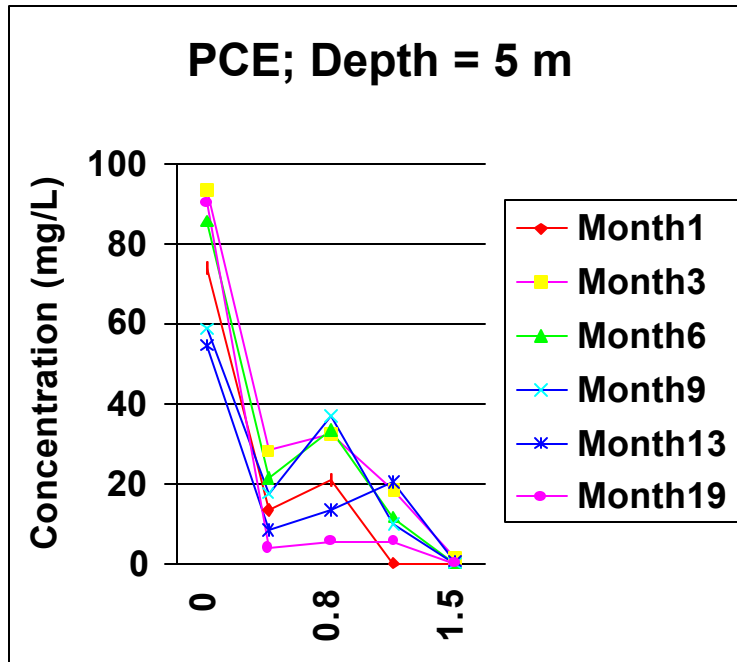
- **Sampling parameters:**
 - chlorinated hydrocarbons
 - organics (DOC, TOC, COD, BOD)
 - inorganics (Fe, S²⁻, SO₄²⁺, alkalinity, TDS)
 - Eh, pH
- **Sampling programme:**
 - initially months 1, 3 and 6
 - added months 9, 12, 19 and 39
 - two iron cores at month 19

Pilot Scale Results



- **Carbon tetrachloride**
 - ✓ **complete destruction in first 0.4 m (16 in.)**
 - ✓ **> 90% destroyed in first 0.2 m (8 in.)**
 - ✓ **consistent at all depths, transects and over time**

Pilot Scale Results



- **Tetrachloroethylene**
 - ✓ complete destruction through the barrier
 - ✓ consistent at 5 & 6 m below grade
 - ✗ at 7 m concentration appears to increase at end of barrier, possibly due to up-welling through base

Pilot Scale Results

Mass Reduction of Total Chlorinated Hydrocarbons									
Month	5 m (18 ft)			6 m (22 ft)			7 m (25 ft)		
	0 m	1.2 m	%MR	0 m	1.2 m	%MR	0 m	1.2 m	%MR
1	150	24	85	81	25	69	69	10	86
3	193	46	76	111	38	66	87	11	88
6	202	35	83	99	29	72	72	14	81
9	140	42	70	140	36	75	89	18	79
13	114	38	67	149	36	75	60	19	69
19	167	19	88	143	19	87	51	18	64
39				117	12	90			

Pilot Scale Results

- **Mass reduction results:**
 - vary with depth
 - vary with time
 - vary with influent concentration
 - vary with total organic carbon
- **But ... no clear trends**

Pilot Scale Results

Reaction Half Lives – Tetrachloroethylene (PCE)

Month	5 m	6 m	7 m
1	6.3	10	1.7
3	23	27*	3.3
6	20	21*	6.7*
9	23*	12*	15
13	45*	11	21
19	13*	10*	12*
39		1.5	

Laboratory column trial: 45 hours

* regression coefficient $r^2 < 0.7$

Pilot Scale Results

- **Reaction half life results:**
 - ✓ **variable for PCE, but significantly less than column trial results**
 - ✓ **very fast for CTC (all < 2.5 hours), similar to column trial results**
 - ✓ **very difficult to calculate for degradation products, but appear to be generally comparable with other sites**

Pilot Scale Results

- **Other results - longevity indicators:**

- ✓ **no evidence of biological fouling**
- ✓ **some evidence of sulphide precipitation, but no indications of plugging**
- ✓ **Eh results similar to other sites**
- ✓ **pH lower, reducing iron hydroxide precipitation**

Full Scale Pre-design

- Results of pilot scale test favour full scale installation
 - Pre-design parameters:
 - continuous barrier
 - ~270 m (970 ft) long
 - 0.4 m (16 in.) thick (100% ZVI)
 - up to 10 m (36 ft) deep
- } • 2800 t of iron
- Biopolymer slurry trench installation