

Hydrogeological Investigations at Pump & Treat Superfund Sites

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Columbia University SFBRP ('Health Effects of and geochemistry of Arsenic and lead')

**EPA Region II, ACE, Severson
Staff at Vineland (NJ) plant**

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Pump and Treat systems (P&T) at Superfund sites

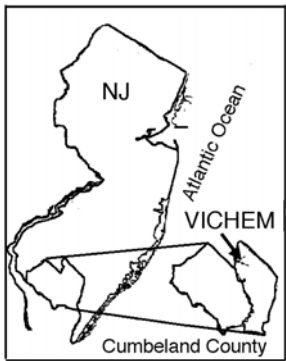
- 700 groundwater pump-and-treat (P&T) systems are operating at NPL sites
- 88 of those are Superfund financed at a an average cost per site ~570,000/year
- Chlorinated solvents are at 56 sites, and metals (As, Cd, Cr, or other) at 22 sites the primary contaminants of concern

Effectiveness of P&T operations is often limited by:

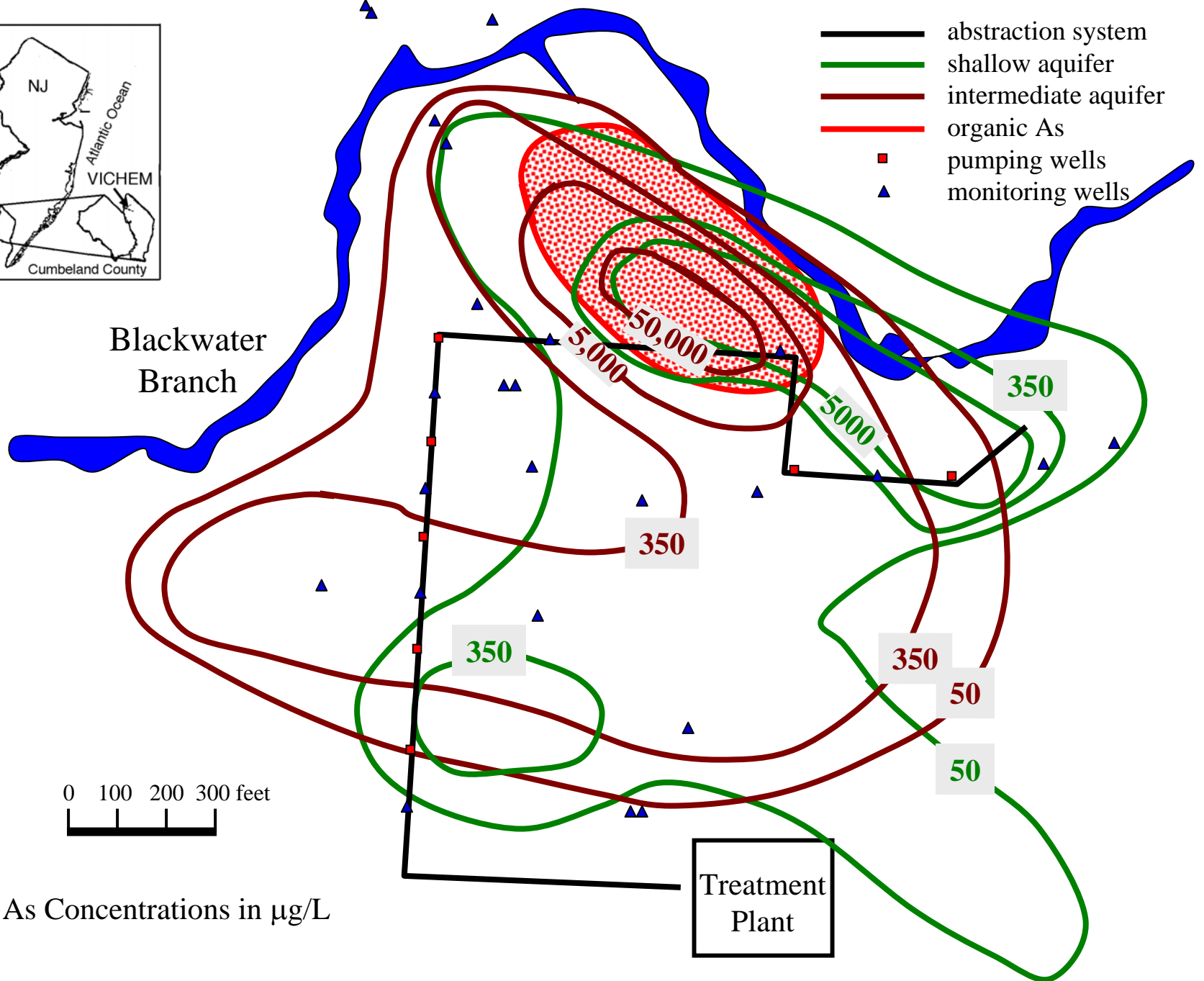
1. incomplete capture of the plumes
2. well 'fouling'
3. slow removal rate relative to large inventory of the contaminant relative to mobilization rate
4. heterogeneity of the aquifer

Vineland Chemical Timeline

- production of arsenic-based herbicides and fungicides since 1949
- management by EPA since 1989
- pump and treat operation since 2000
 - Target 2×10^6 gal/day, actually: $\sim 1.6 \times 10^6$ gal/day
 - GW residence time changed from decades to 200 days
- soil washing operation began in 2003
- Overall expect to spend $\sim \$100\text{M}$



- abstraction system
- shallow aquifer
- intermediate aquifer
- organic As
- pumping wells
- ▲ monitoring wells



Extraction well



Treatment plant



Monitoring well



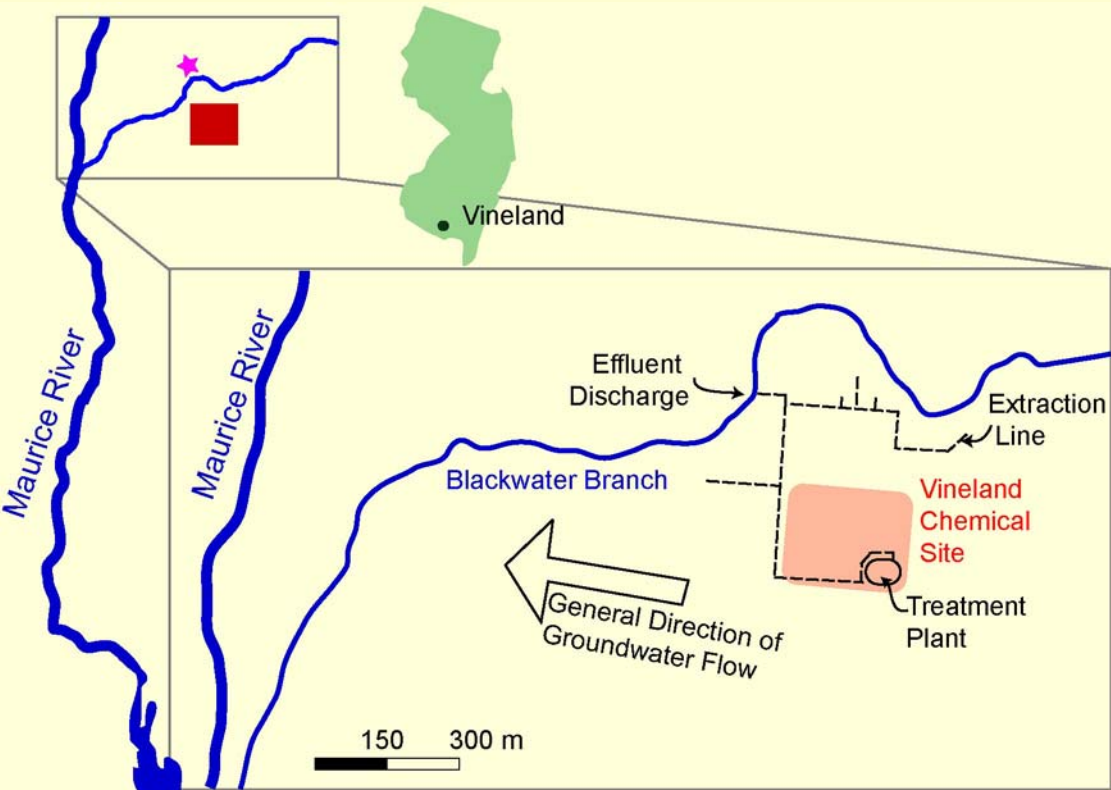
Effluent discharge



Issues at Vineland Chemical site:

1. Incomplete capture of the plume
2. 20% reduced pumping efficiency due to well fouling
3. Slow decrease of As concentrations in pumping wells

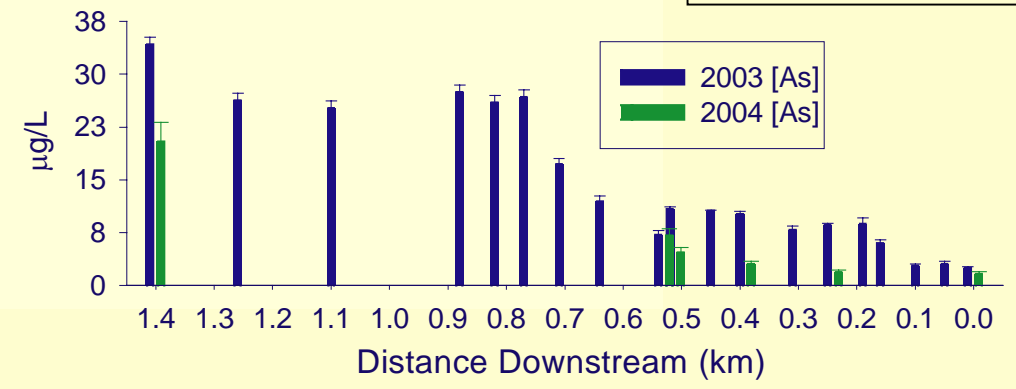
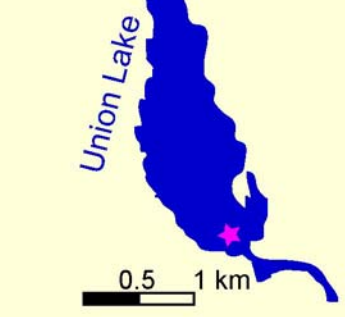
1.) Incomplete capture of the plume



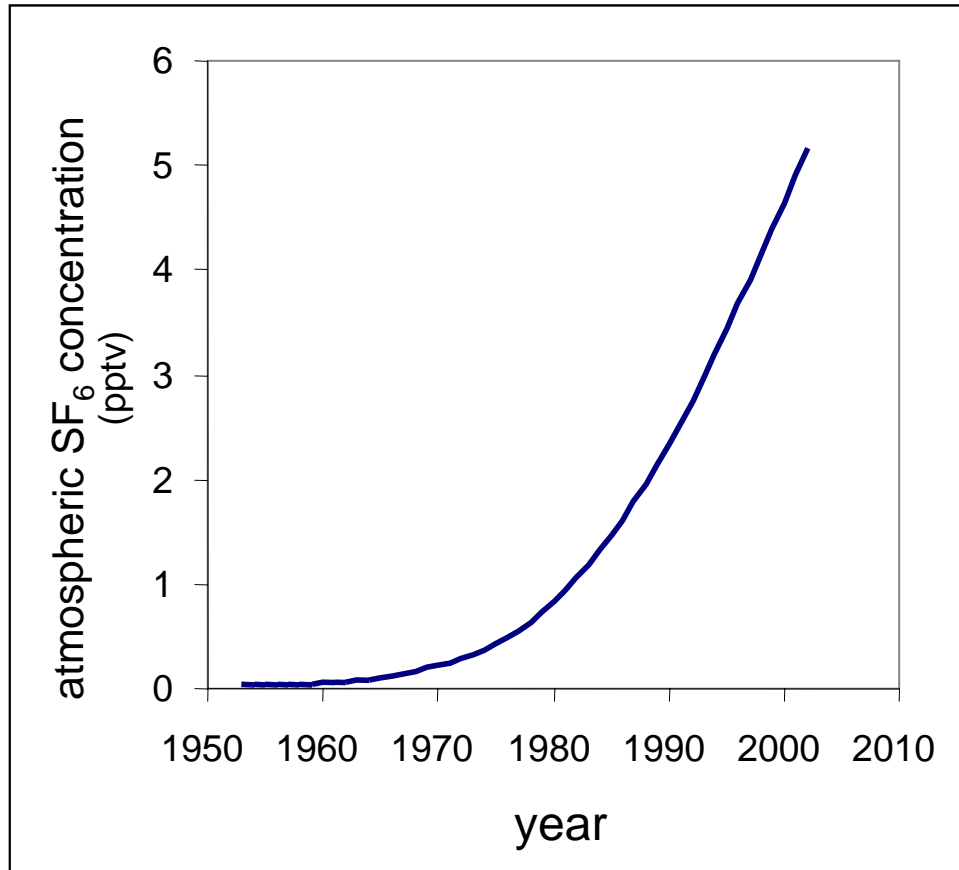
Daily As fluxes off site:

2003: 2.3 kg/day
2004: 1.6 kg/day

Same order of magnitude as P&T removal rate

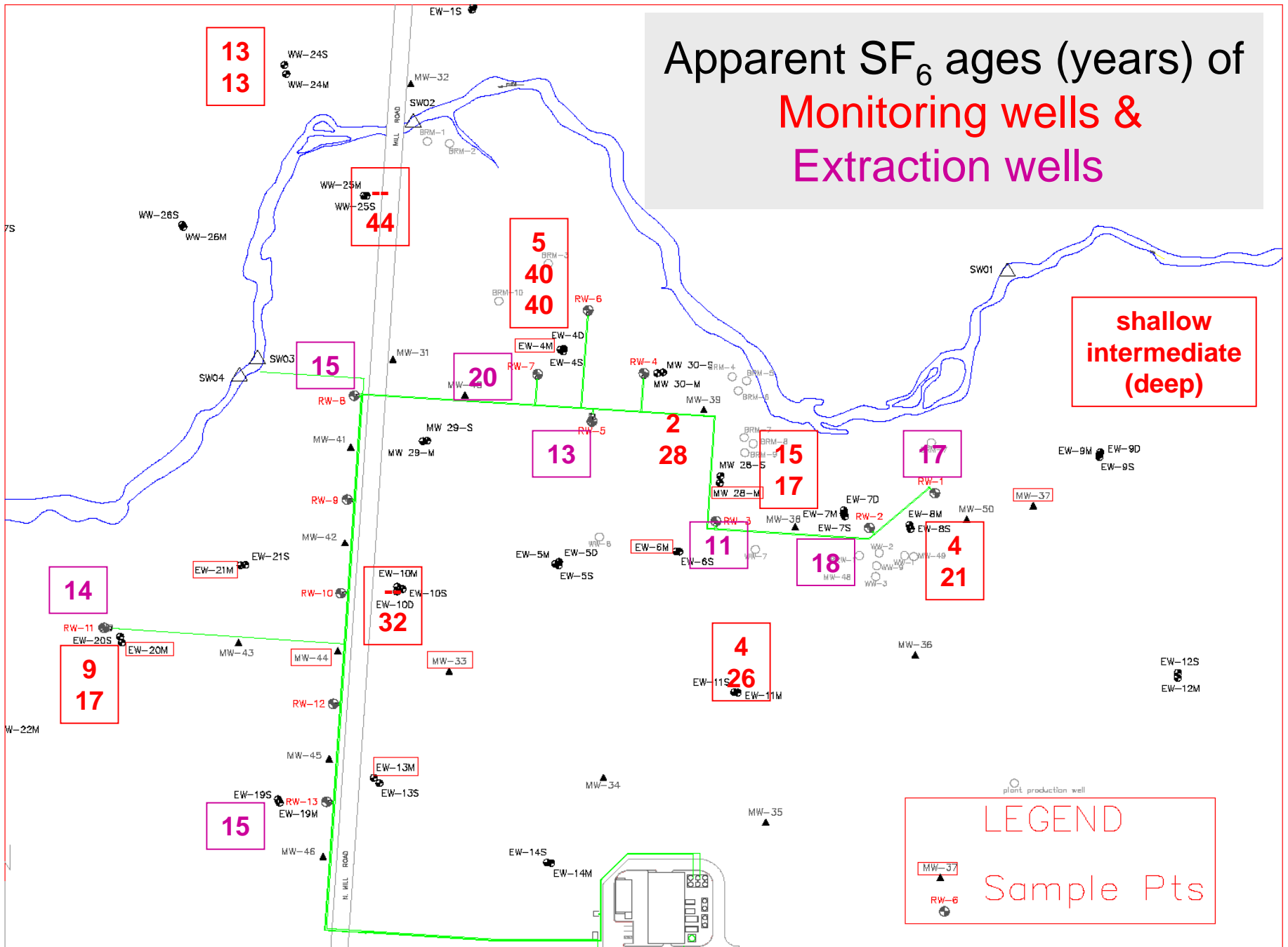


Sulfurhexafluoride (SF₆)

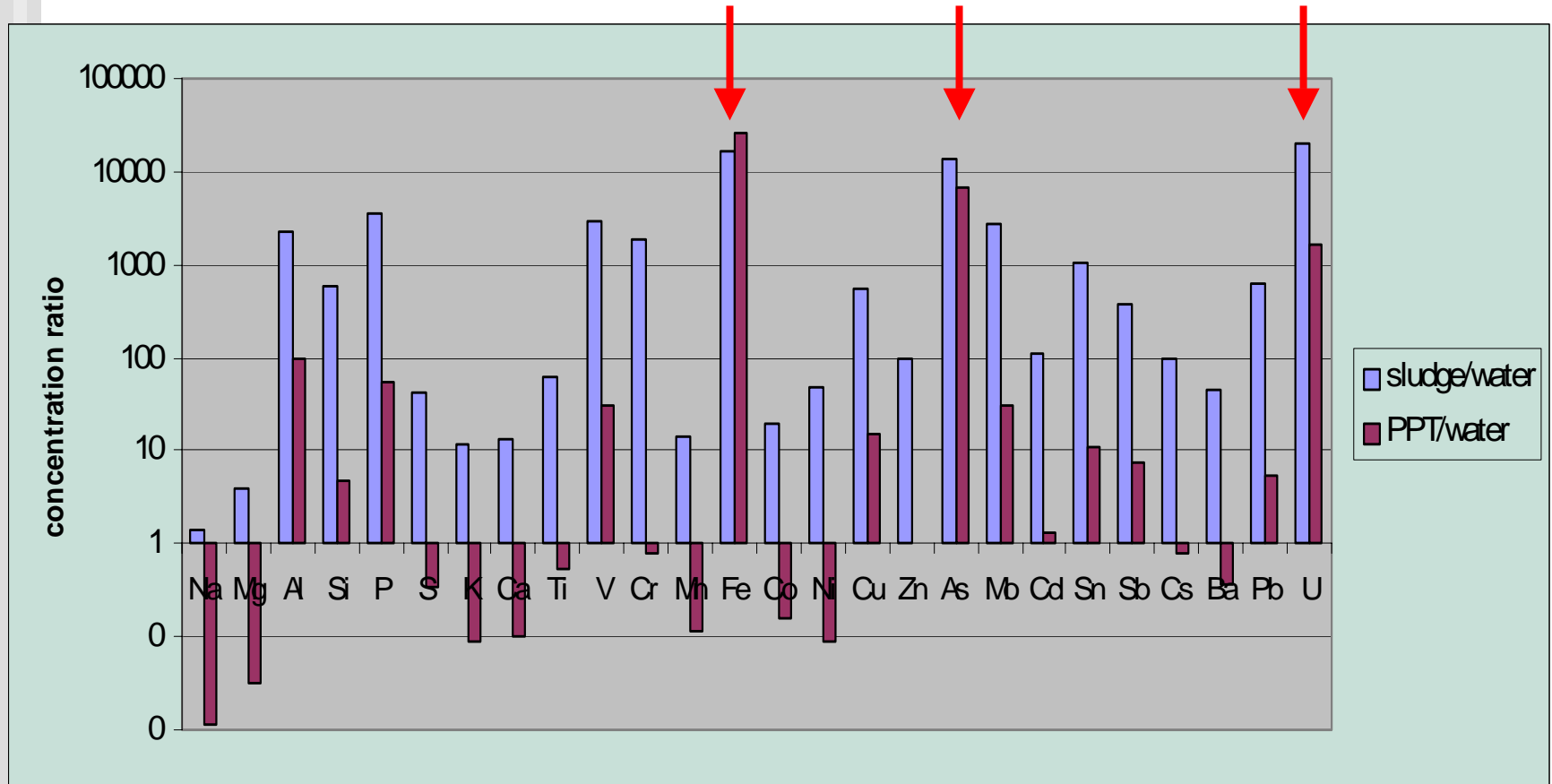


- Used as electrical insulator in switches and transformers
- Strong greenhouse gas
- Can be measured in the fm/L range by ECD GC
- Used as environmental tracer and purposefully injected tracer

Apparent SF₆ ages (years) of Monitoring wells & Extraction wells



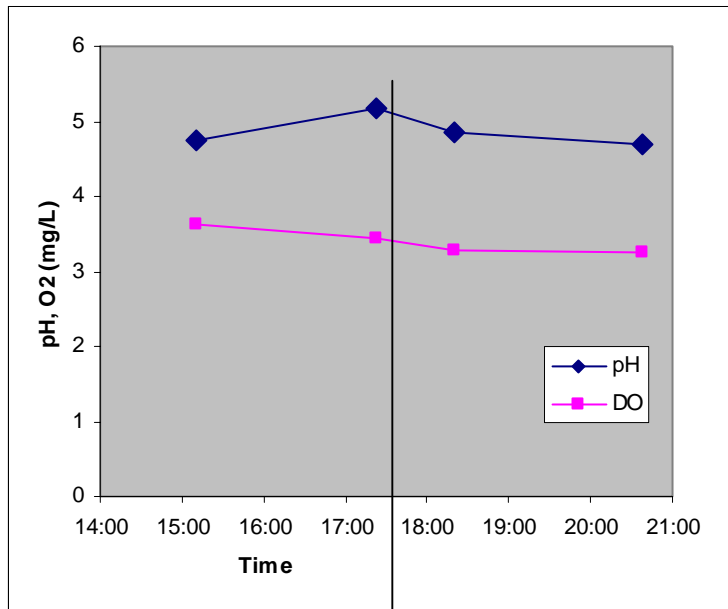
2.) Reduced pumping efficiency due to well fouling



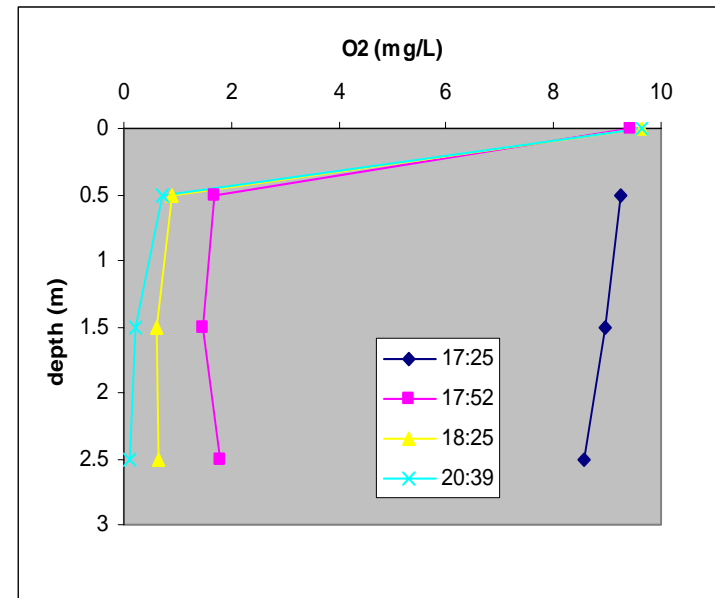
Sludge and Precipitated GW -very similar in Fe, As and U enrichments
Microbe driven or simple inorganic chemistry

Oxygen entrainment in wells?

water:



air in well:



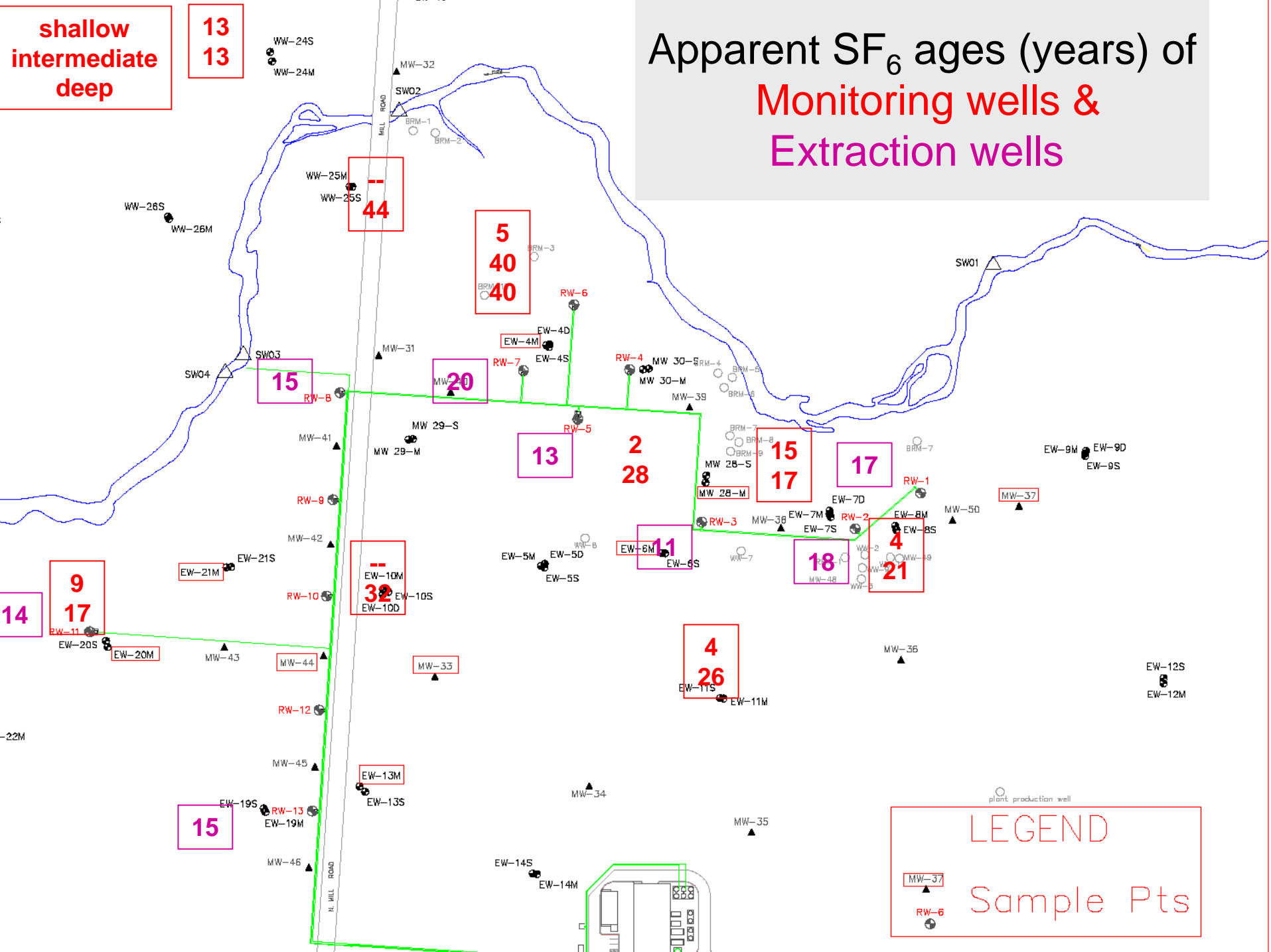
Flushing of well RW13 with CO₂ started at 17:35

=> No evidence for external entrainment of O₂ in well

Apparent SF₆ ages (years) of Monitoring wells & Extraction wells

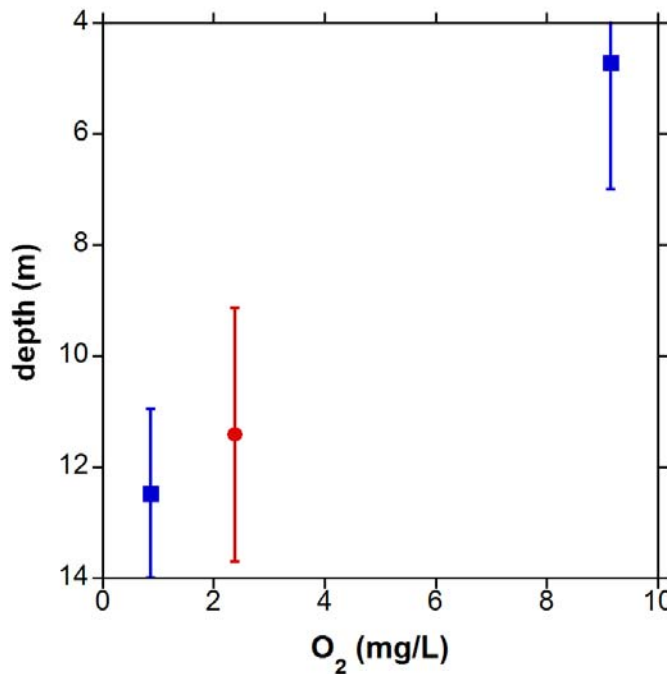
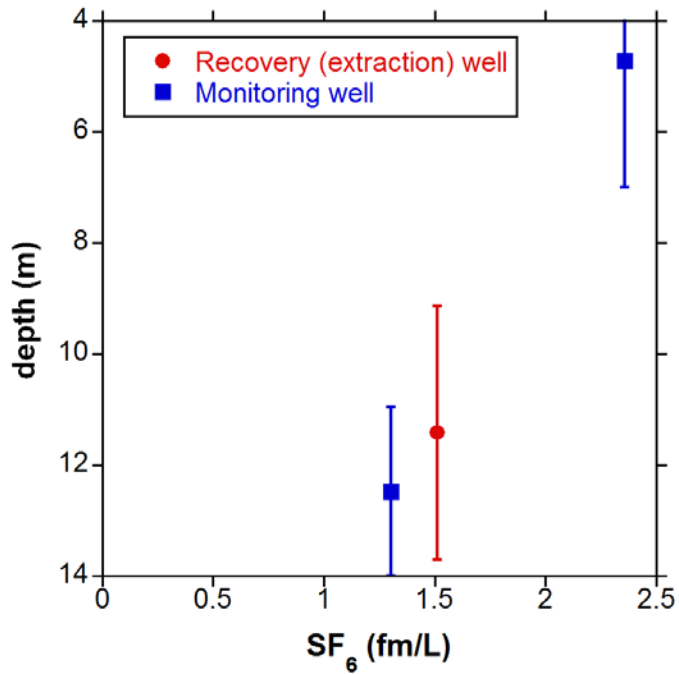
shallow
intermediate
deep

13
13

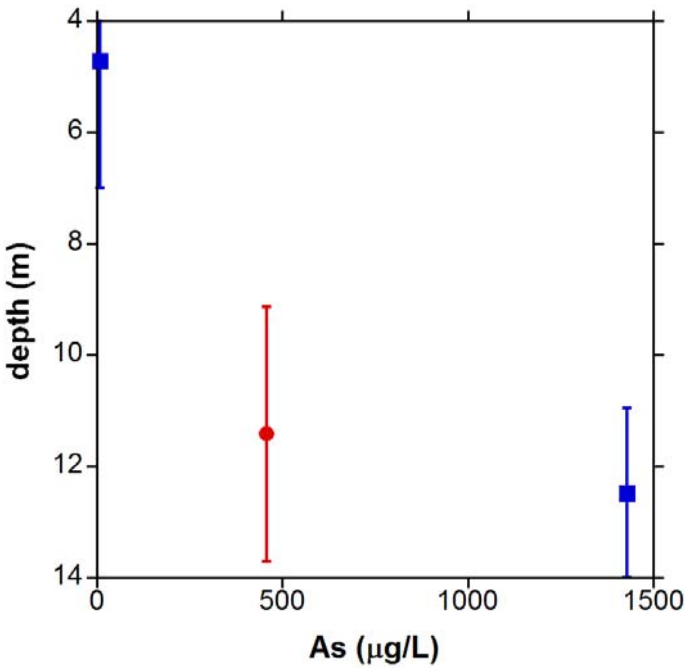
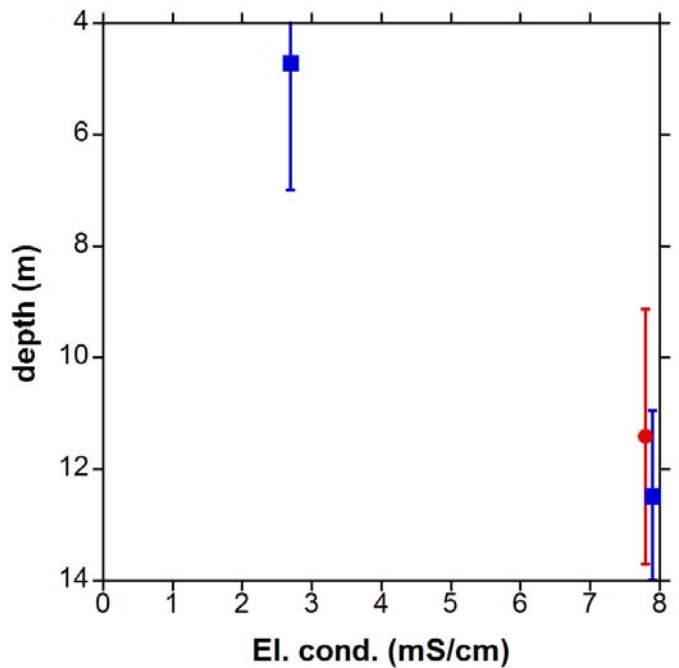


LEGEND
MW-37
RW-6
Sample Pts

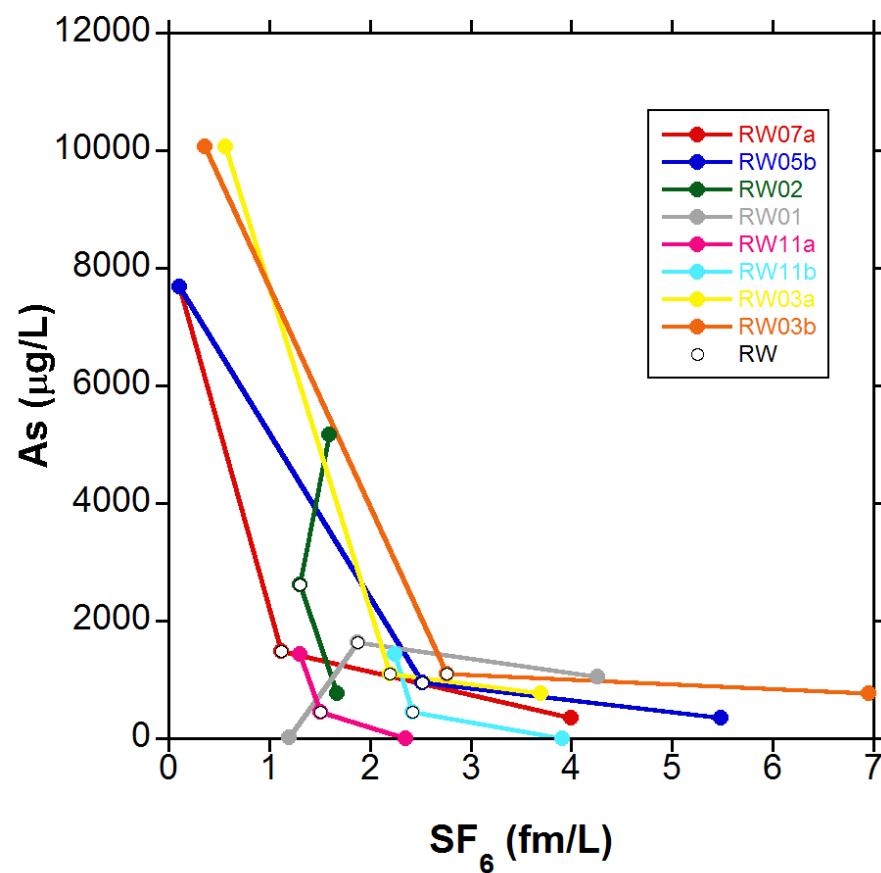
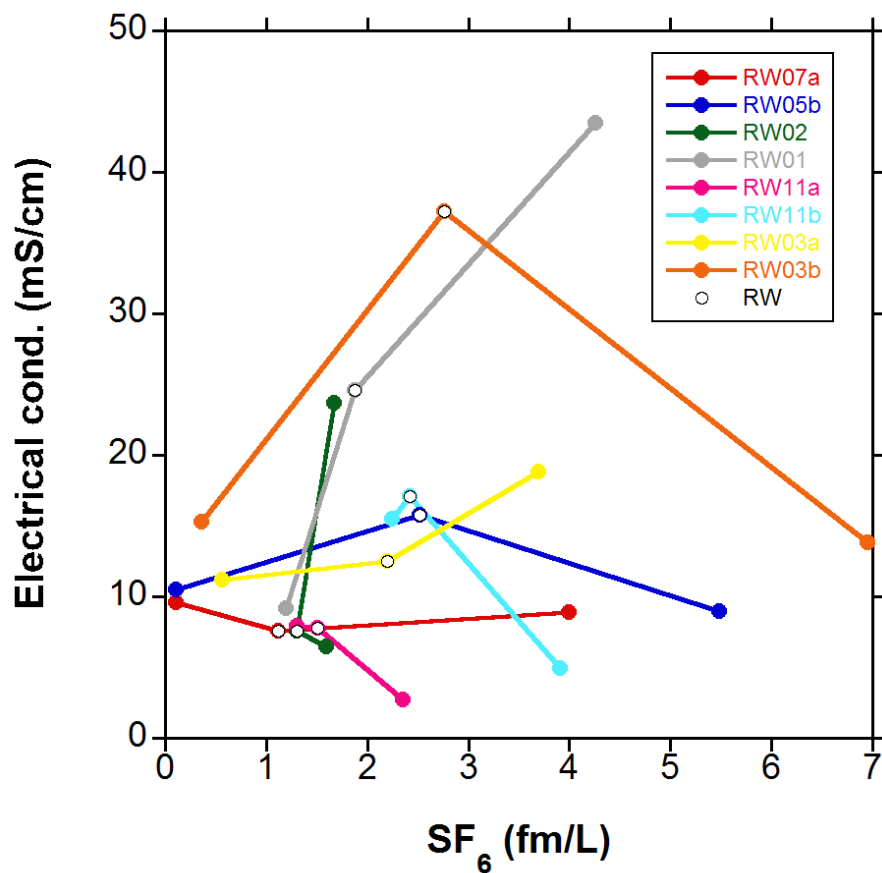
RW 11

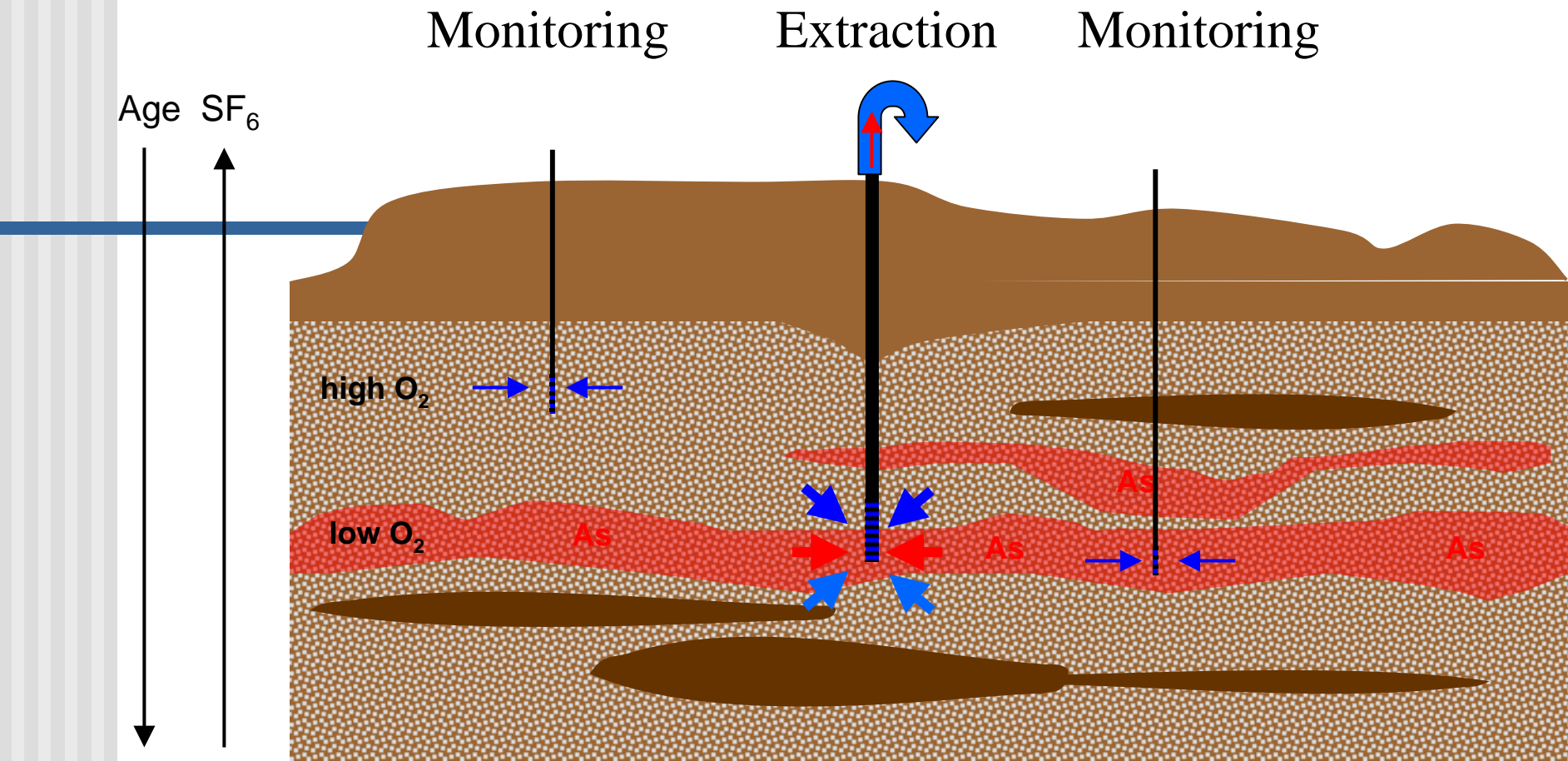


⇒ Evidence for mixing in aquifer



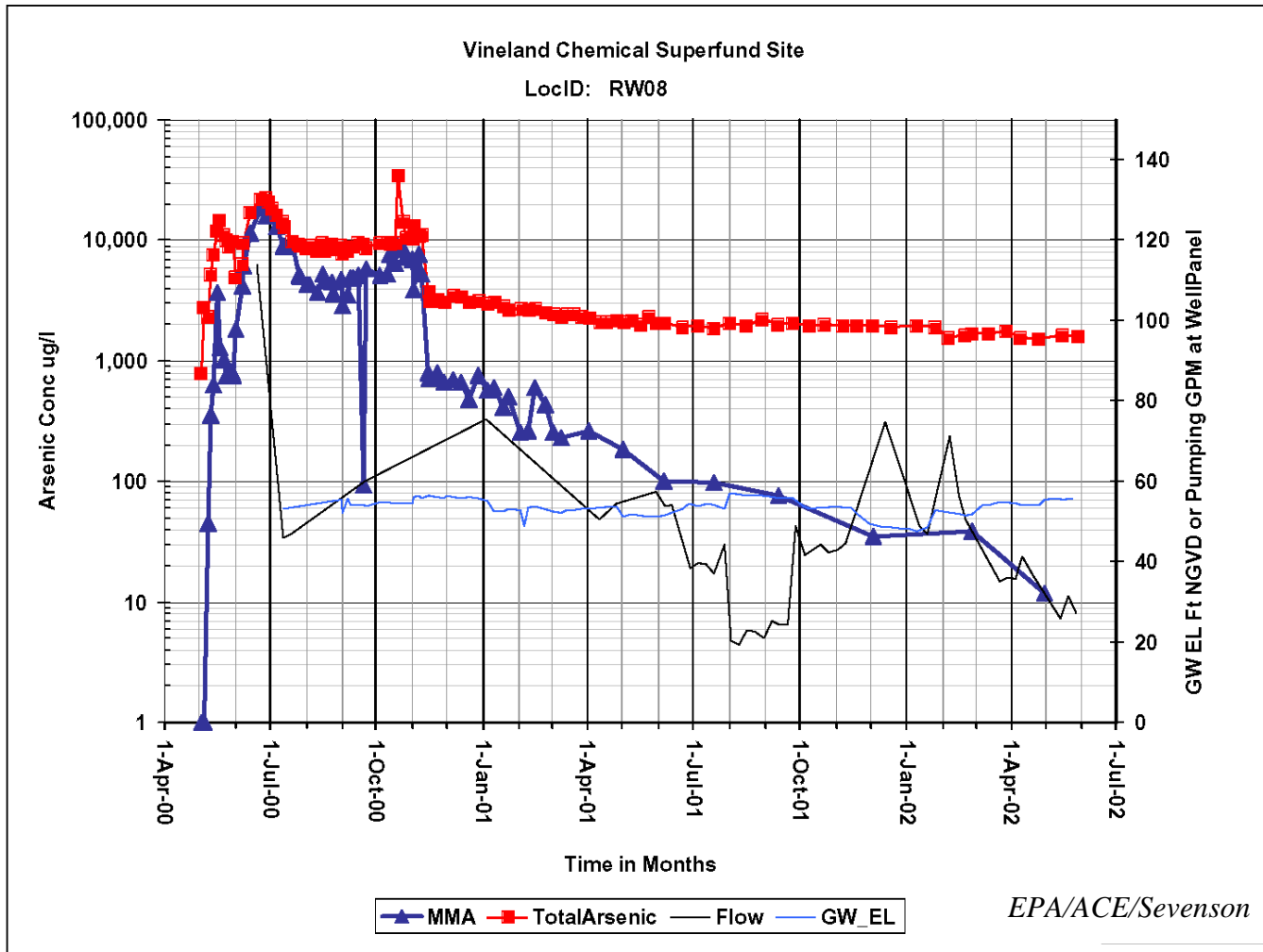
Precipitation of As in/near pumping wells?





=> Mixing induced by pumping may cause As/Fe precipitation in well

3.) Slow decrease of As concentrations in pumping wells



If aquifer contains
10 ppm
mobilizable As

⇒ 70 years of
pumping needed!

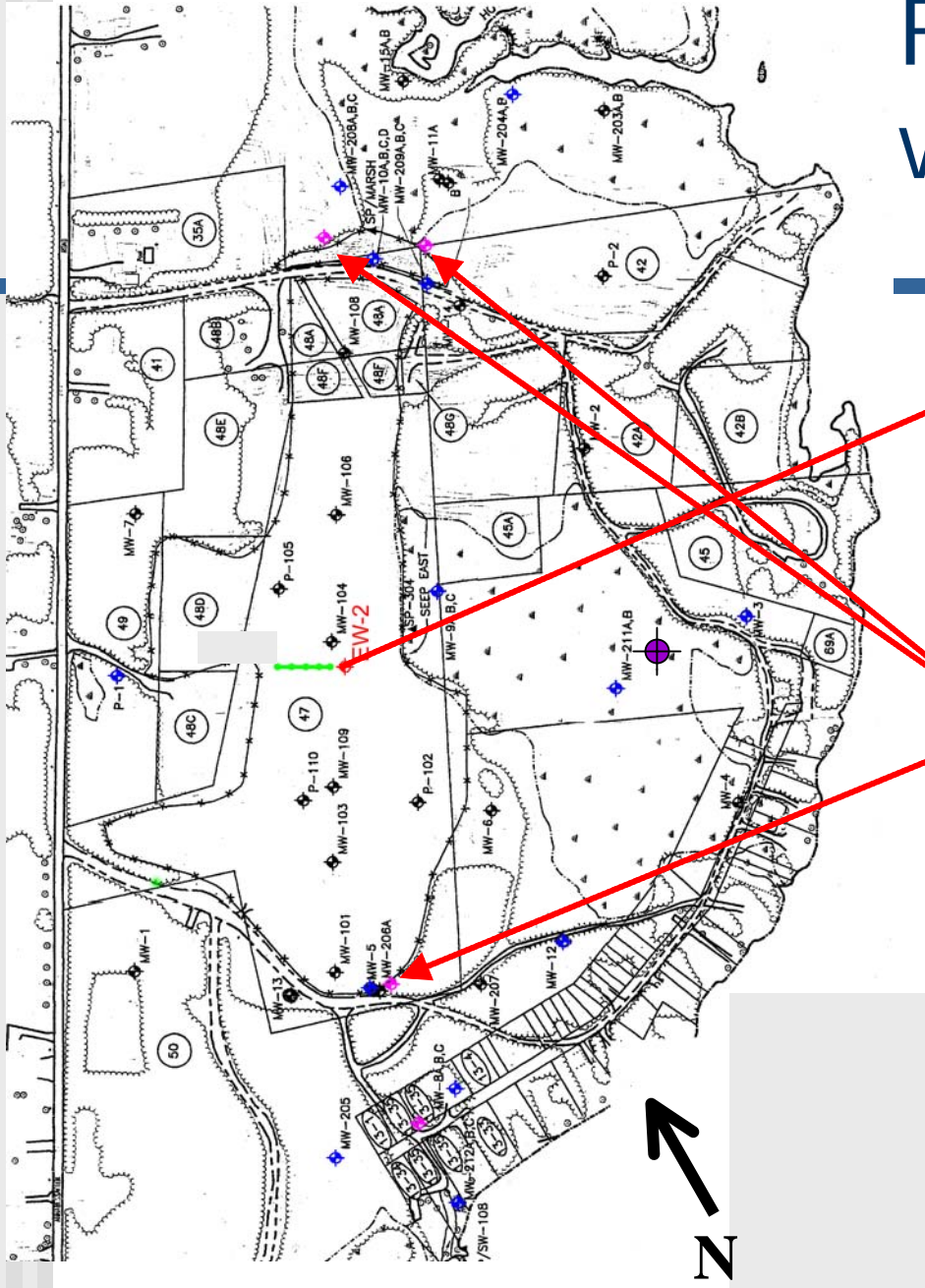
(assuming uniform
distribution of As
& flushing)

See poster by
Karen Wovkulich

Effectiveness of P&T operations is often limited by:

1. incomplete capture of the plumes
2. well 'fouling'
3. slow removal rate relative to large inventory of the contaminant relative to mobilization rate
4. heterogeneity of the aquifer

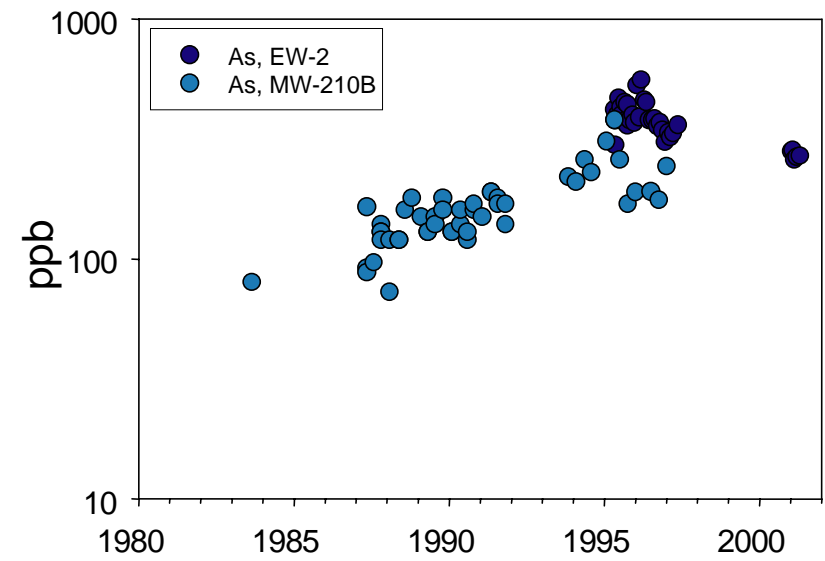
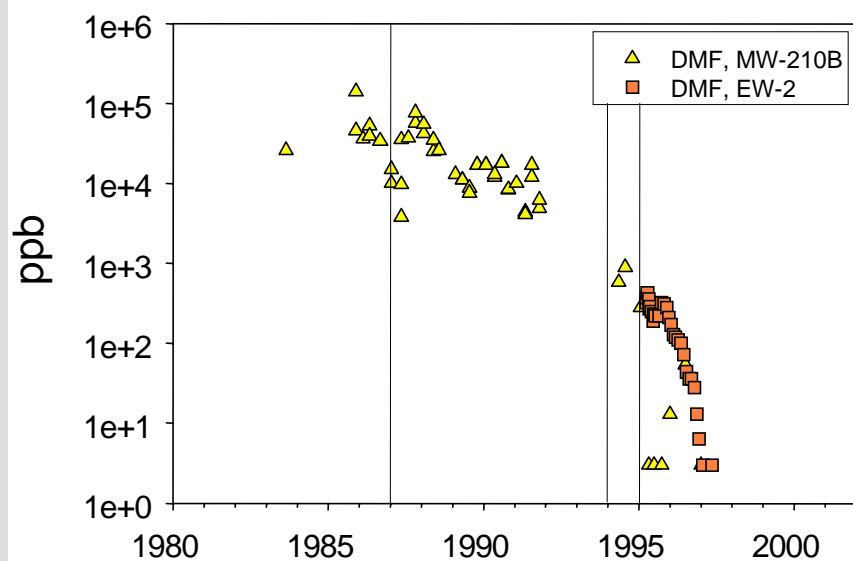
Former landfill site with P&T system



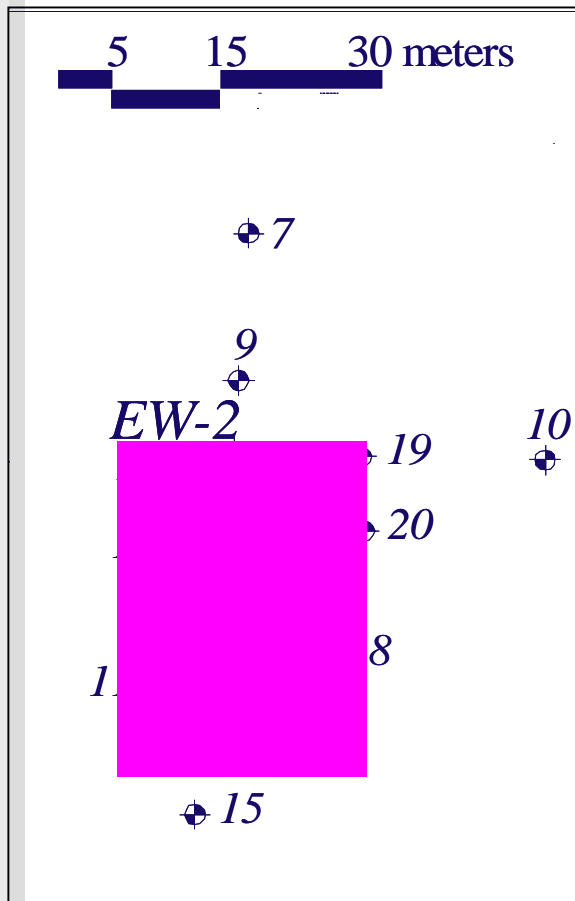
pumping
↓
treatment
↓
re-injection



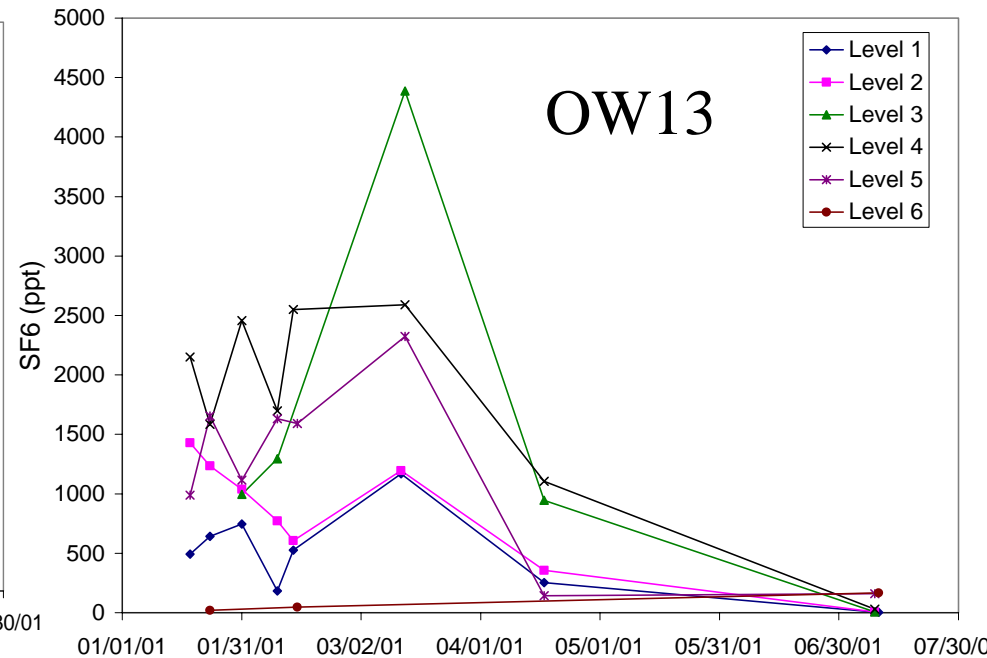
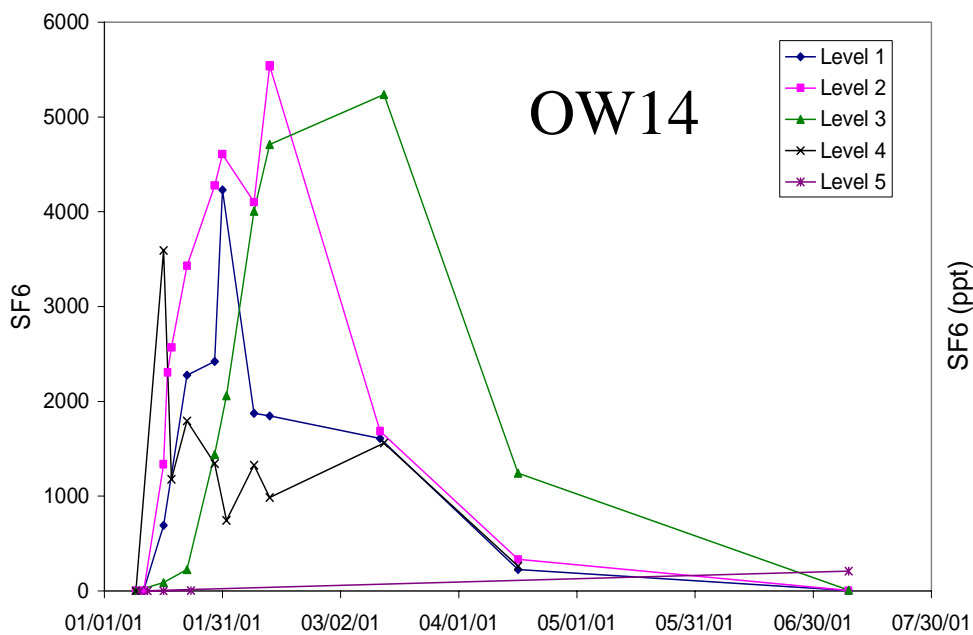
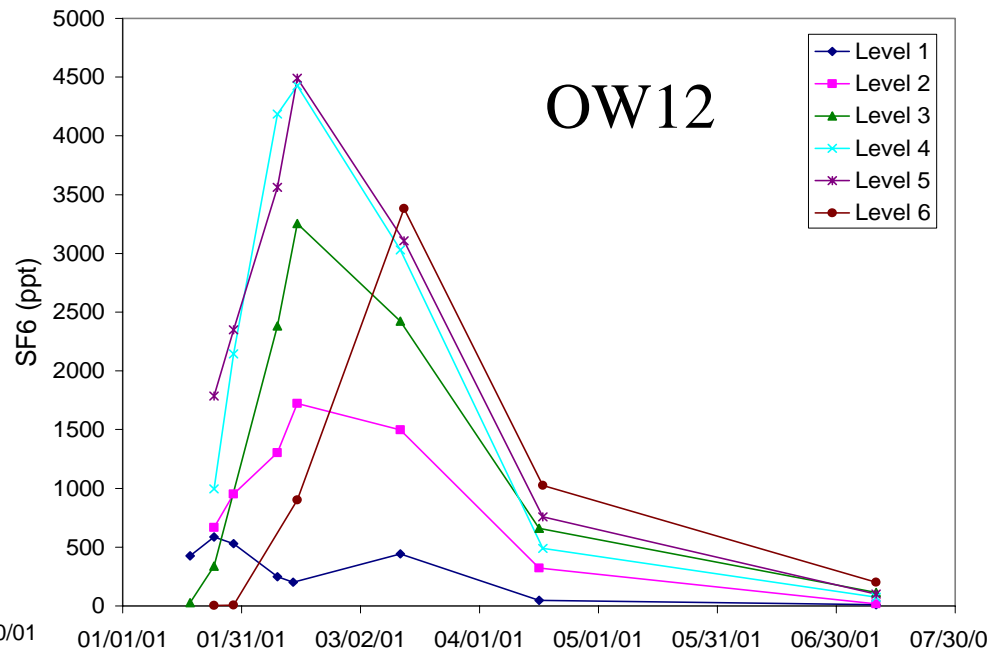
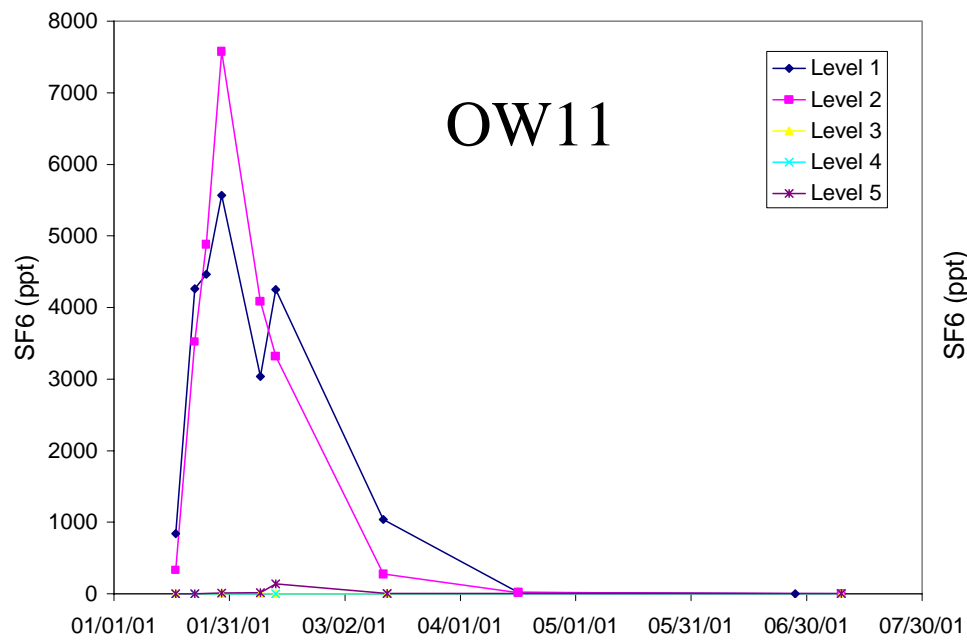
Issues: organics & As



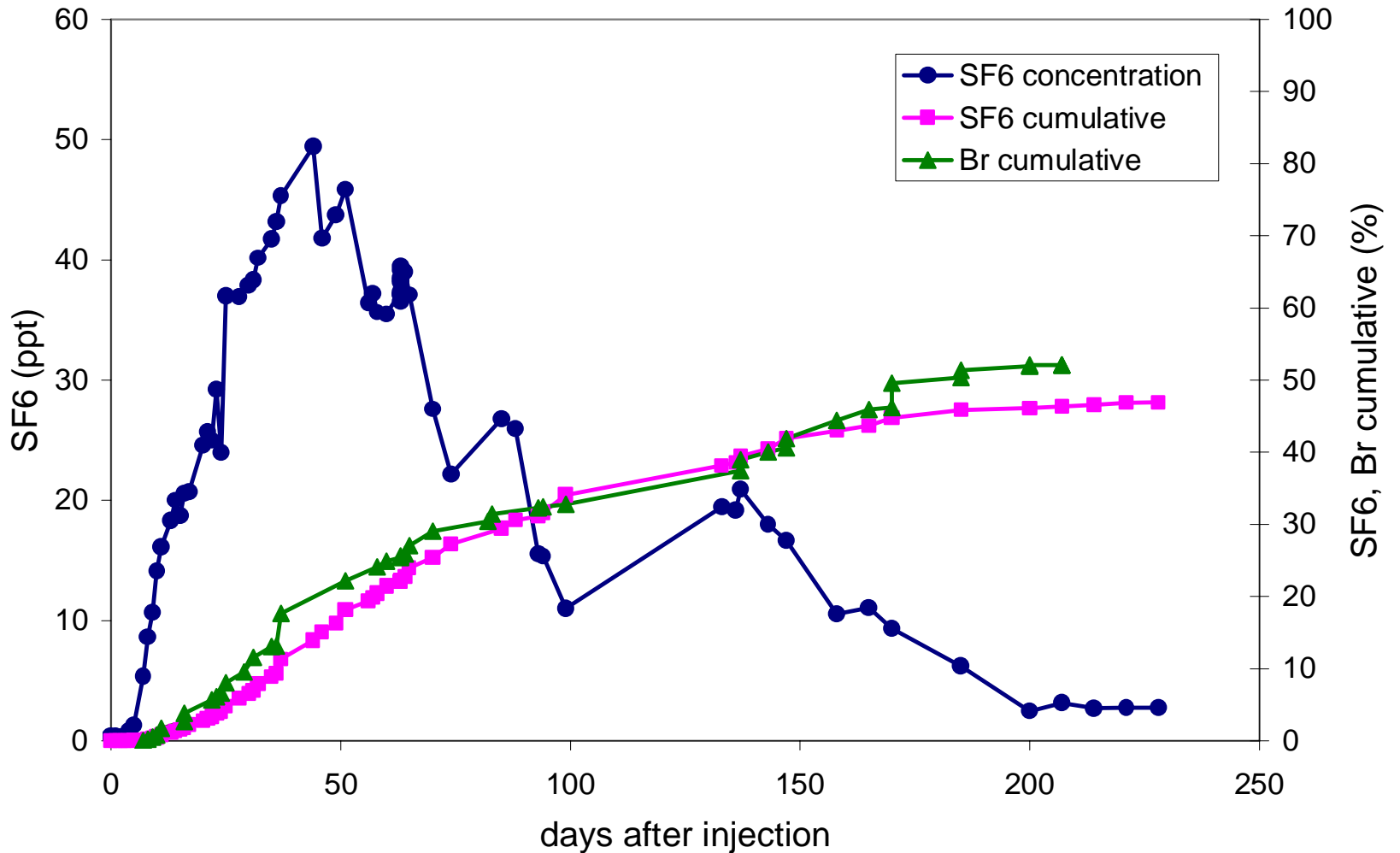
4.) Aquifer heterogeneity



- injected
 - 1370 kg of ORC
 - 12 kg of NaBr
 - 2.4 ml of SF₆
- 10 Geoprobe holes, injection equally over entire thickness of the aquifer
- followed tracer for 250 days
- heterogeneous glacial deposits



Pumping well



Conclusions

- Significant quantities of As escape the P&T system (=> tracer data as calibration target for models?)
- Well fouling related to pumping induced mixing
- Large inventory and slow removal can prolong remediation (=> enhanced mobilization? Soil washing)
- Aquifer heterogeneity will further prolong P&T operation

Recommendations for cleaning

G.J. Houben / *Applied Geochemistry* 18 (2003) 941–954

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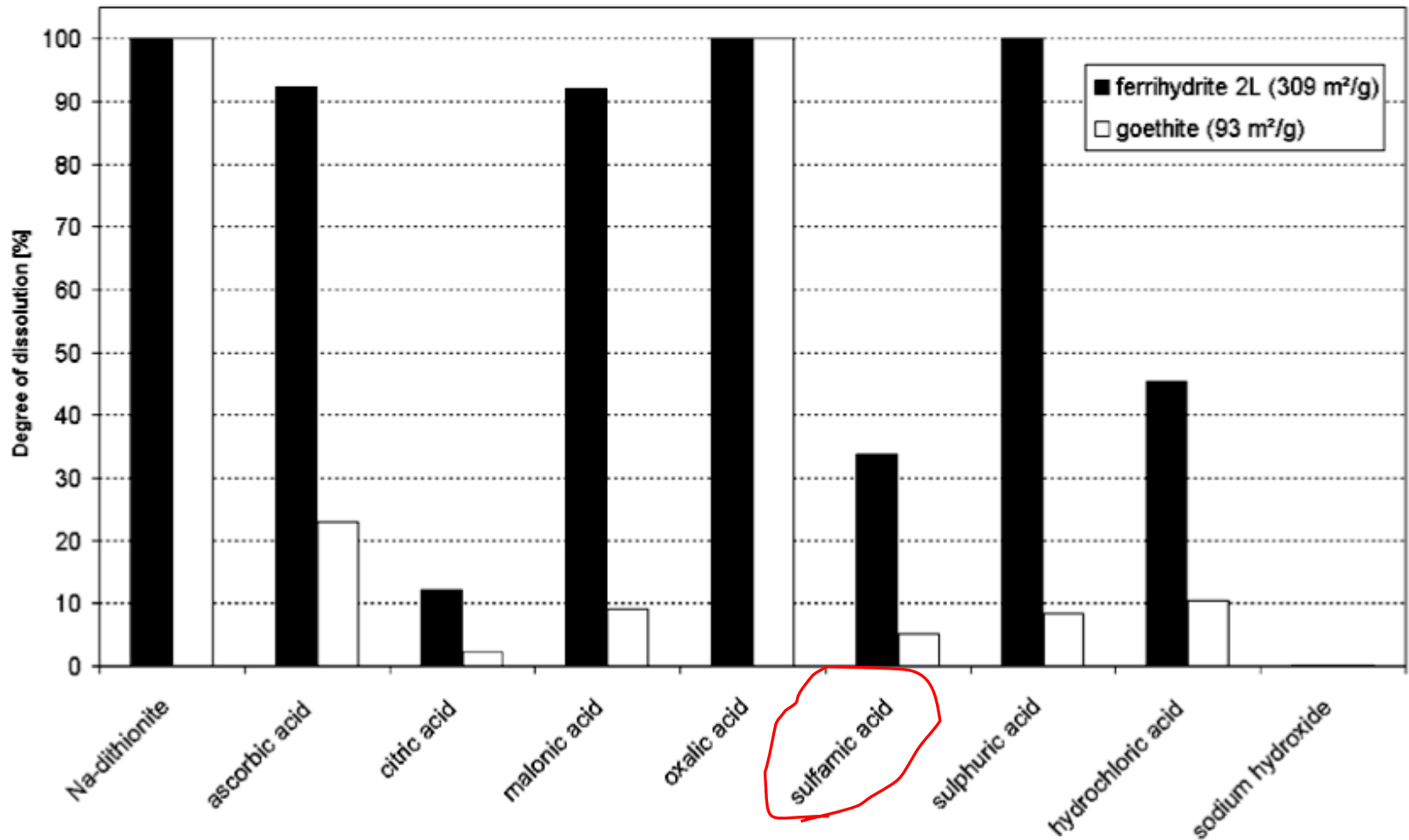


Fig. 14. Comparison of the efficiency of the chemicals used (after 7 h).