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, Sevenson 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

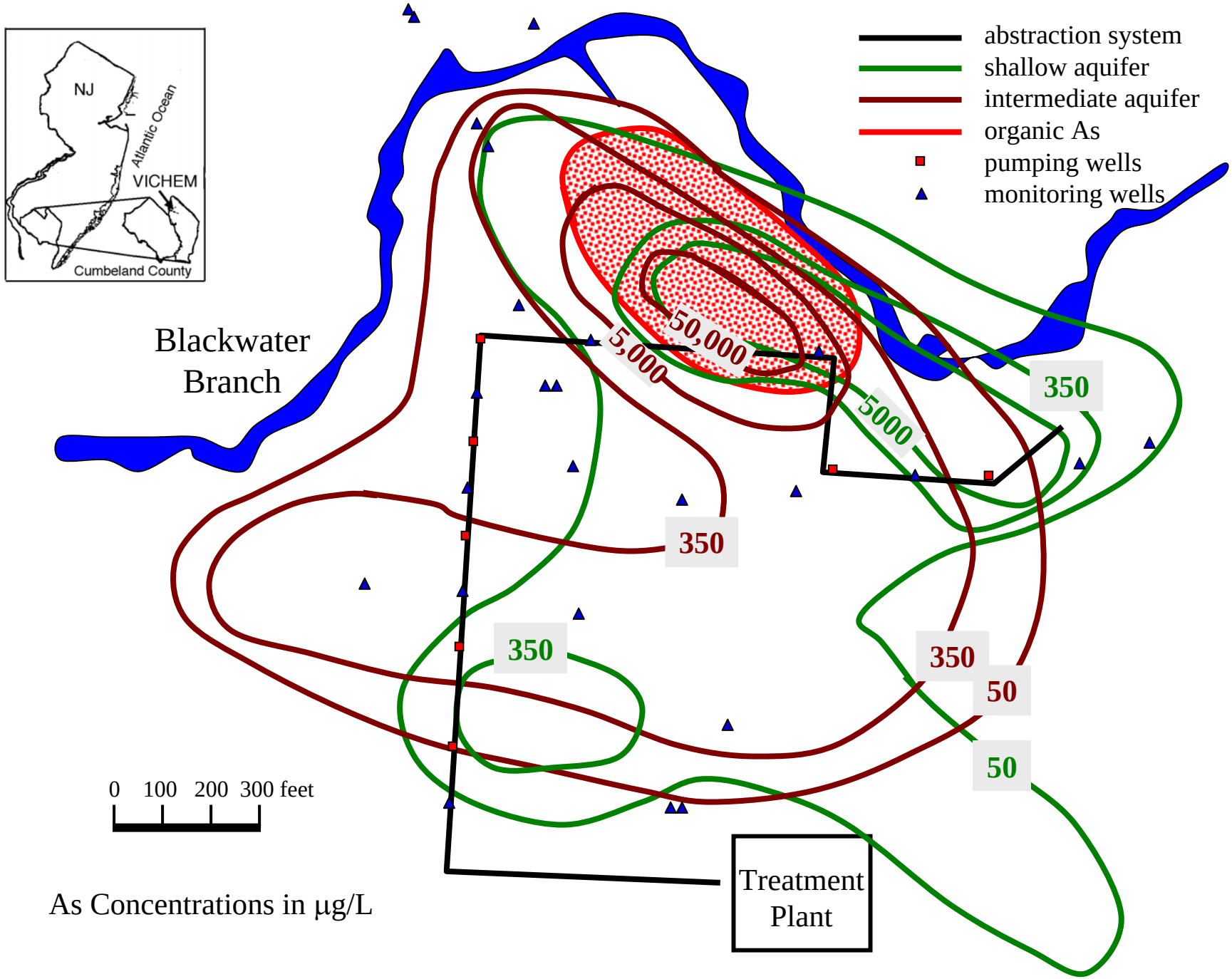
EPA, 2001, 2003

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: ~$1.6*10^6$ gal/day
  - GW residence time changed from decades to 200 days
- soil washing operation began in 2003
- Overall expect to spend ~$100M


NJ
Atlantic Ocean
VICHEM
Cumbeland County
abstraction system
shallow aquifer
intermediate aquifer
organic As
pumping wells
monitoring wells
Blackwater Branch
50,000
5,000
5000
350
350
350
350
50
50
0 100 200 300 feet
Treatment Plant
As Concentrations in µg/L

Extraction well

Treatment plant

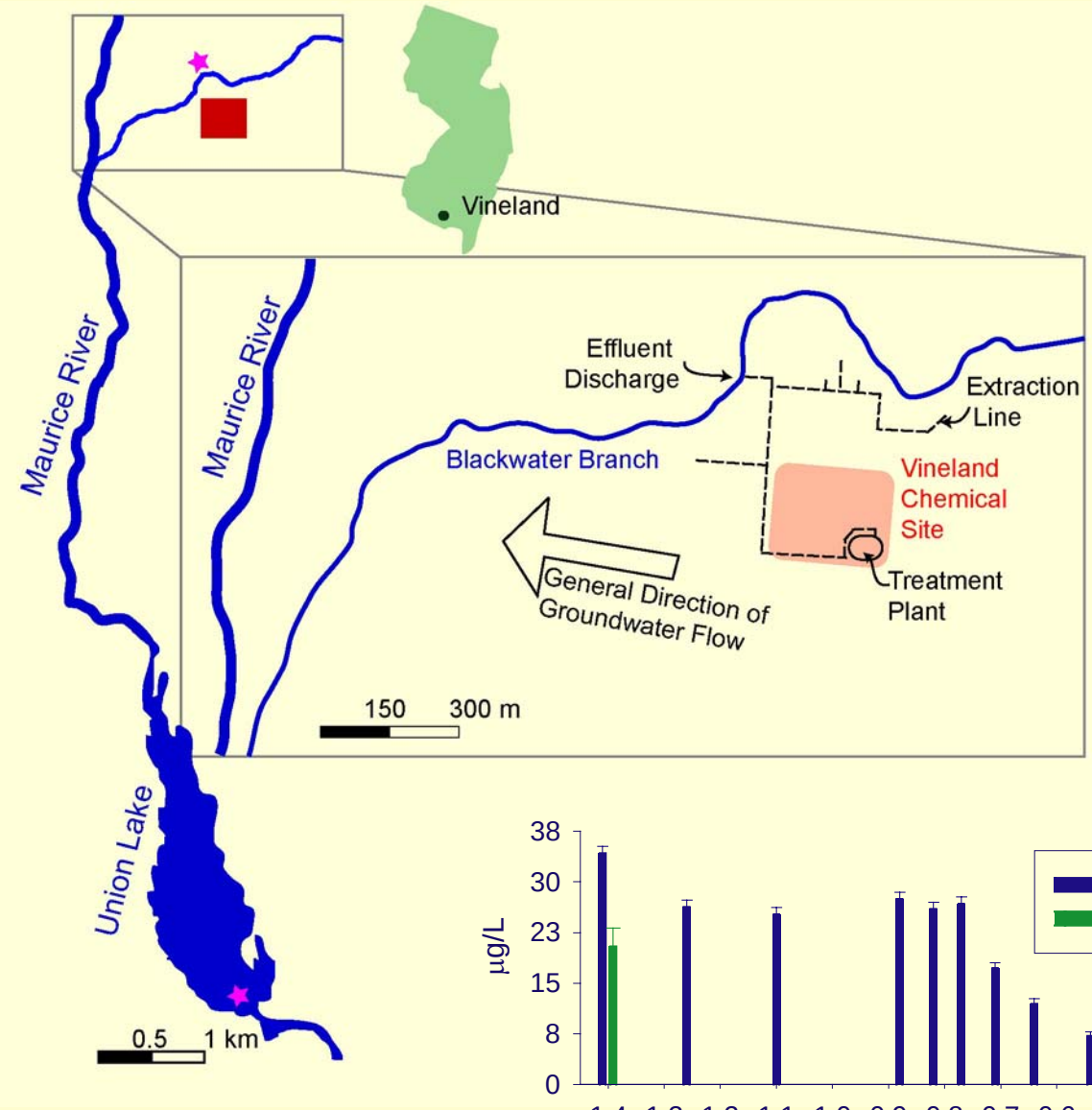
Monitoring well

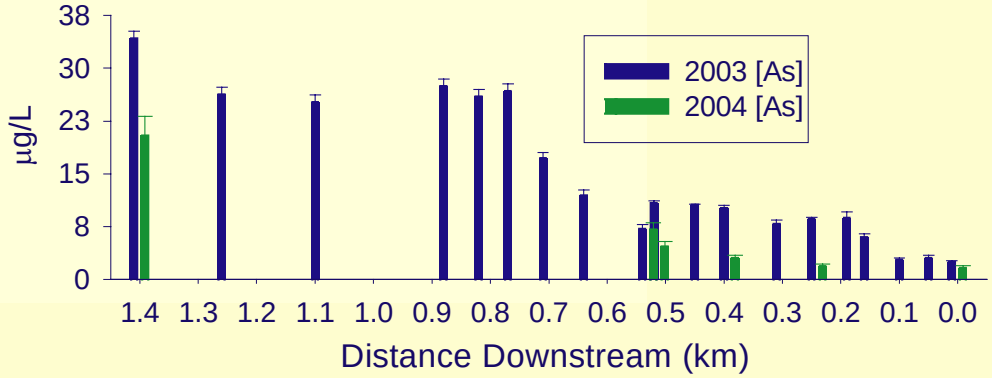
Effluent discharge

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





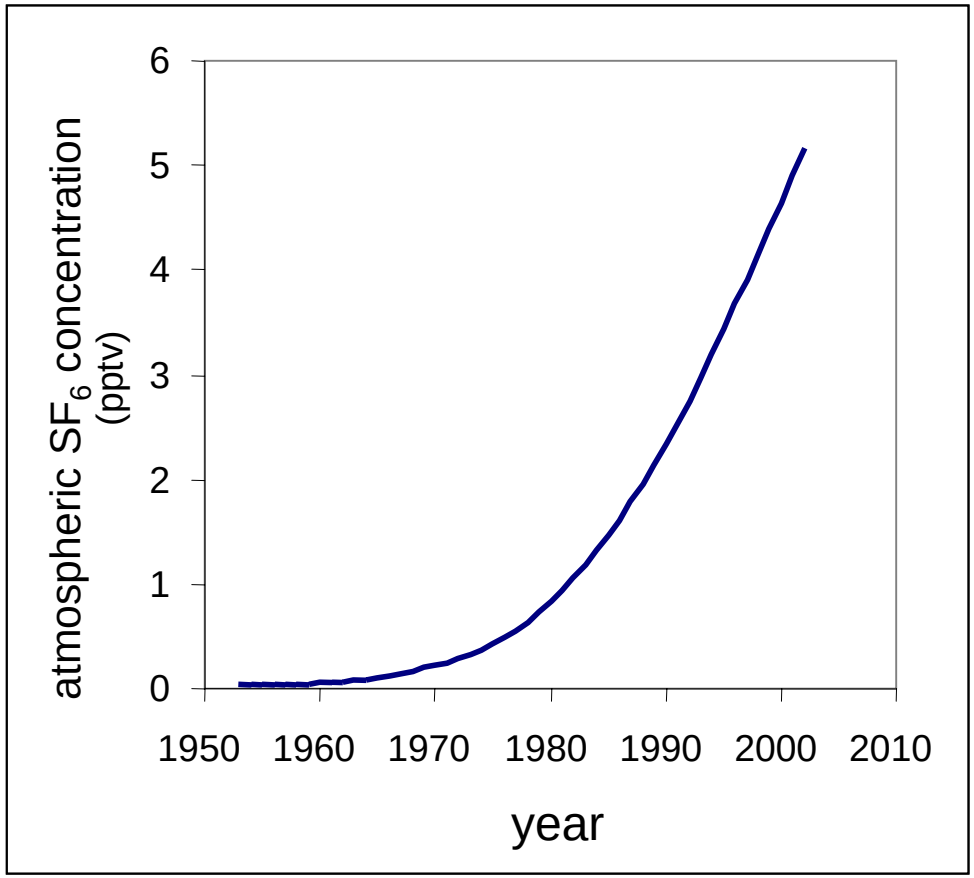
Daily As fluxes off site:

2003: 2.3 kg/day

2004: 1.6 kg/day

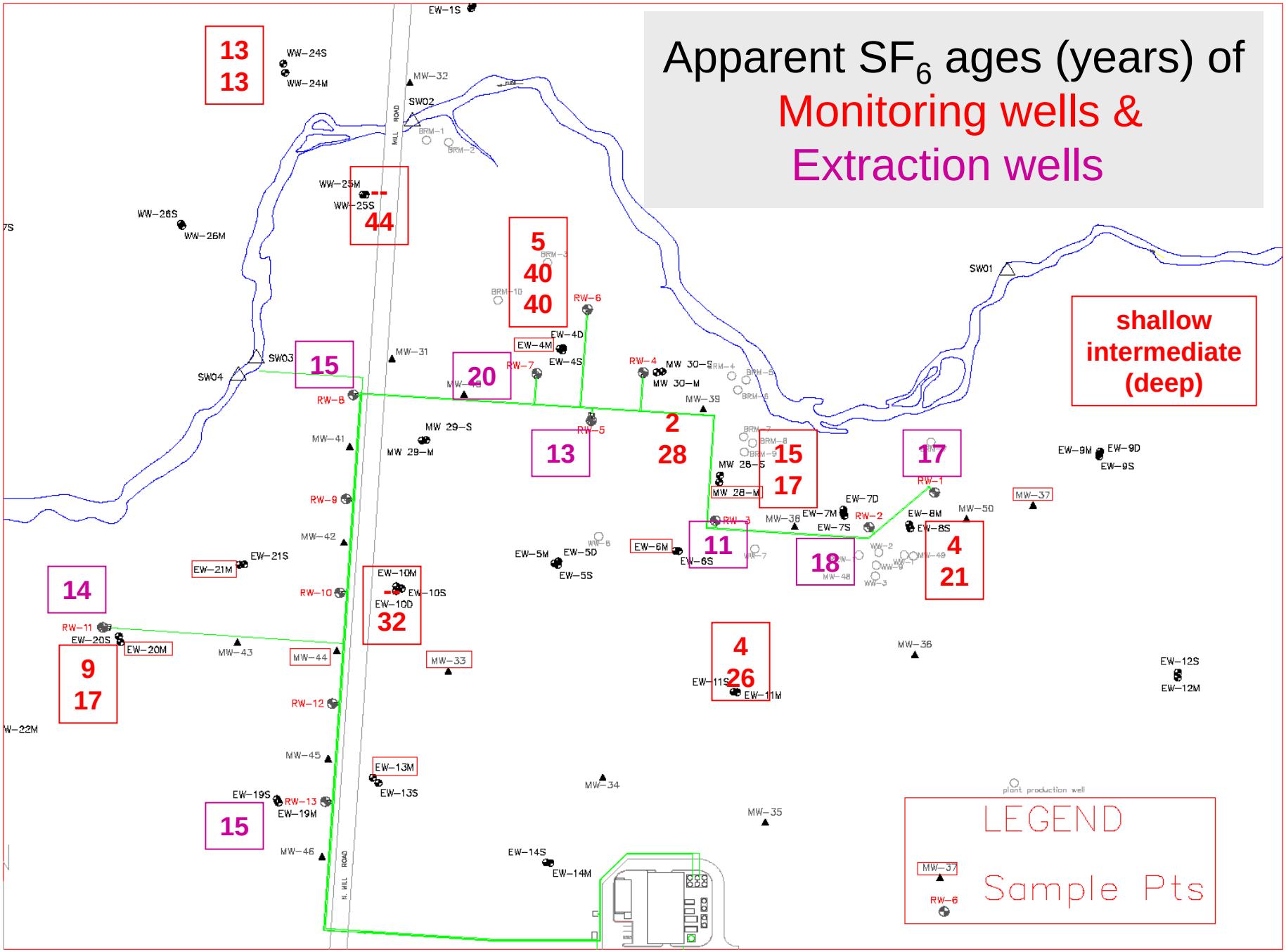
Same order of magnitude as P&T removal rate

Sulfurhexafluoride (SF_6)

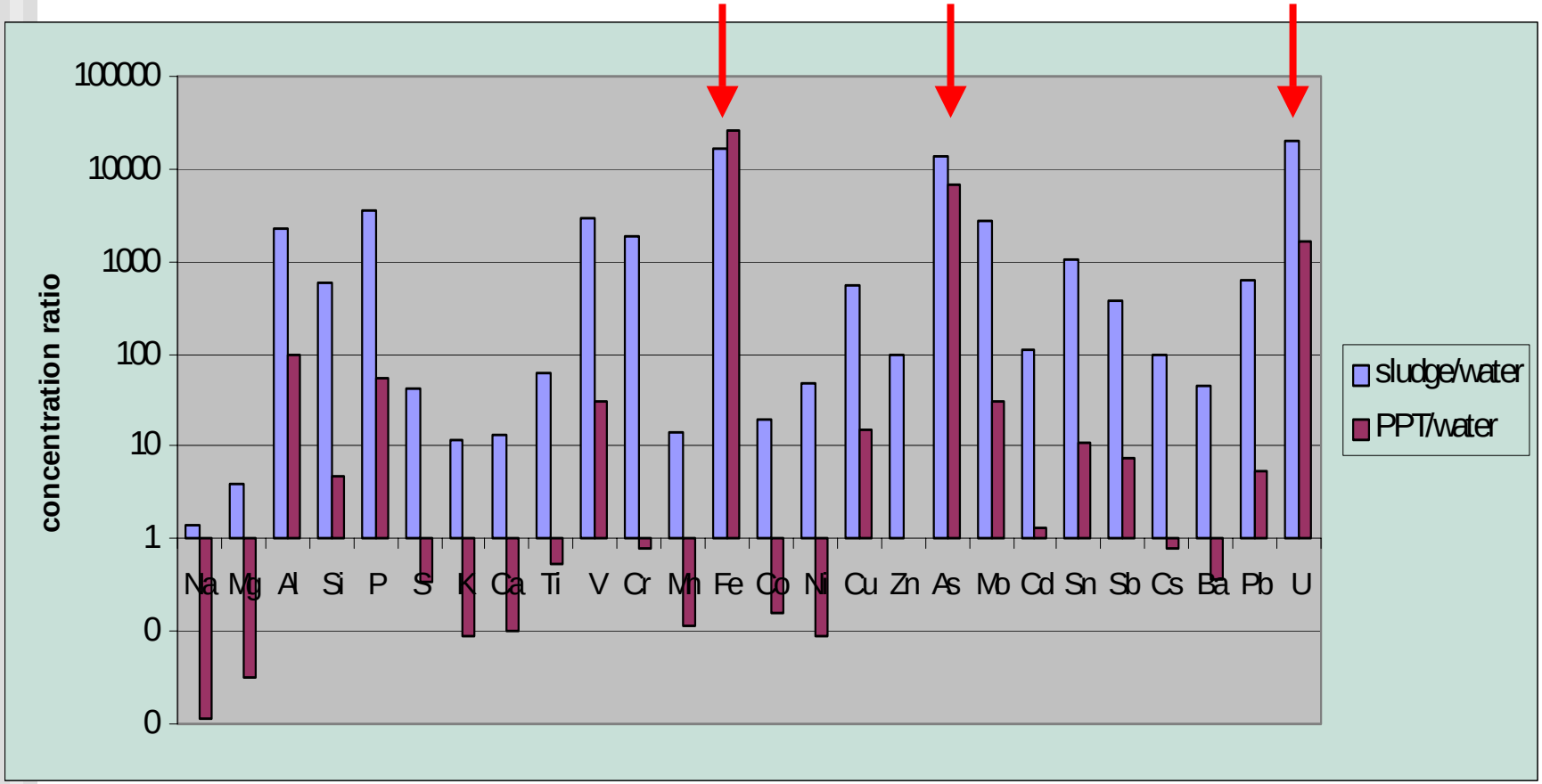


- Used as electrical insulator in switches and transformers
- Strong greenhouse gas
- Can be measured in the fm/L range by ECD GC
- Used as environmental tracer and purposefully injected tracer

Apparent SF_6 ages (years) of Monitoring wells & Extraction wells



2.) Reduced pumping efficiency due to well fouling

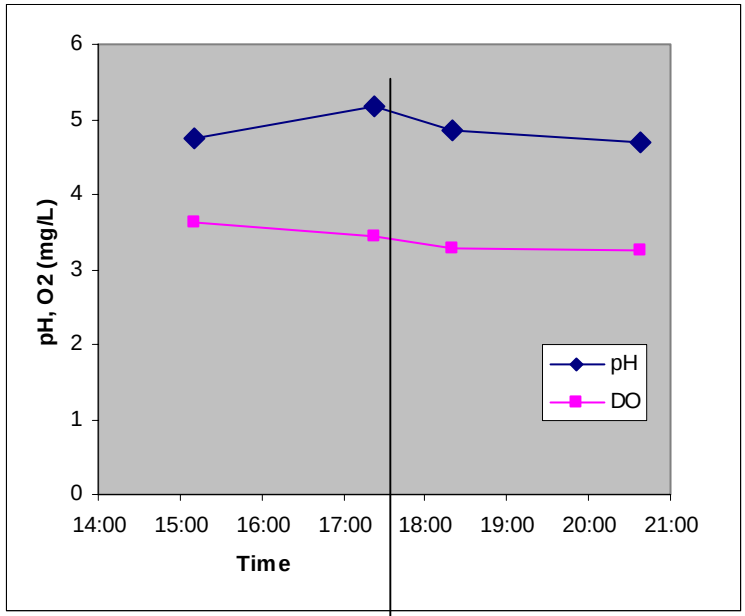


Sludge and Precipitated GW -very similar in Fe, As and U enrichments

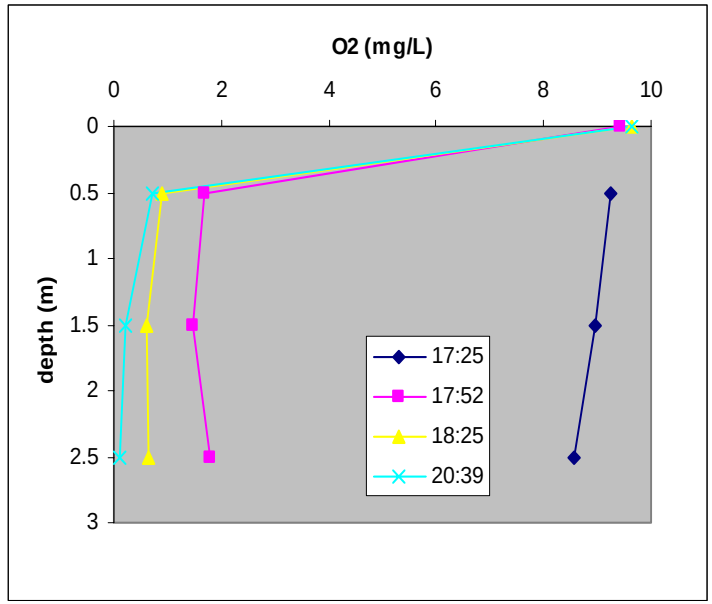
Microbe driven or simple inorganic chemistry

Oxygen entrainment in wells?

water:



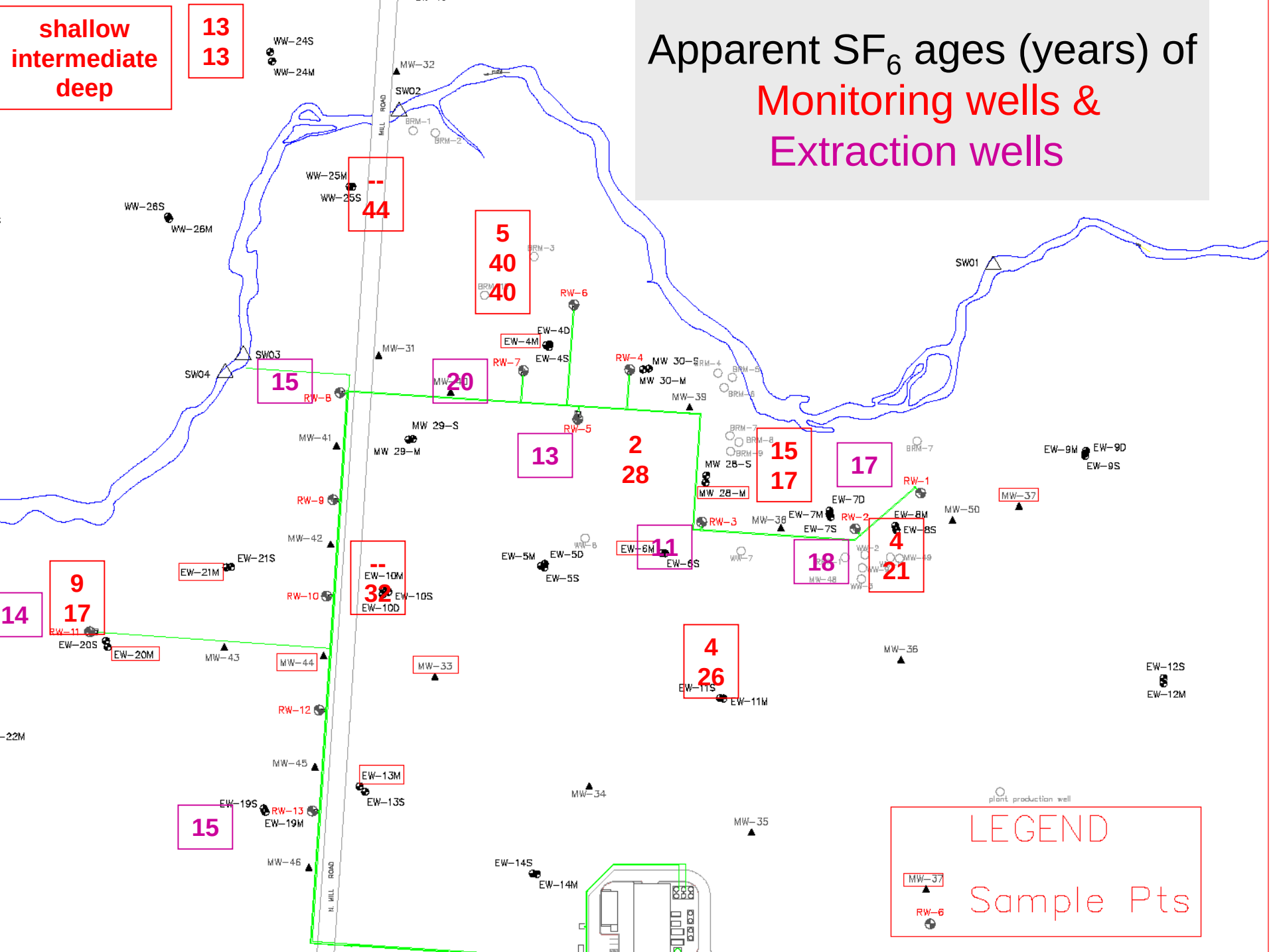
air in well:



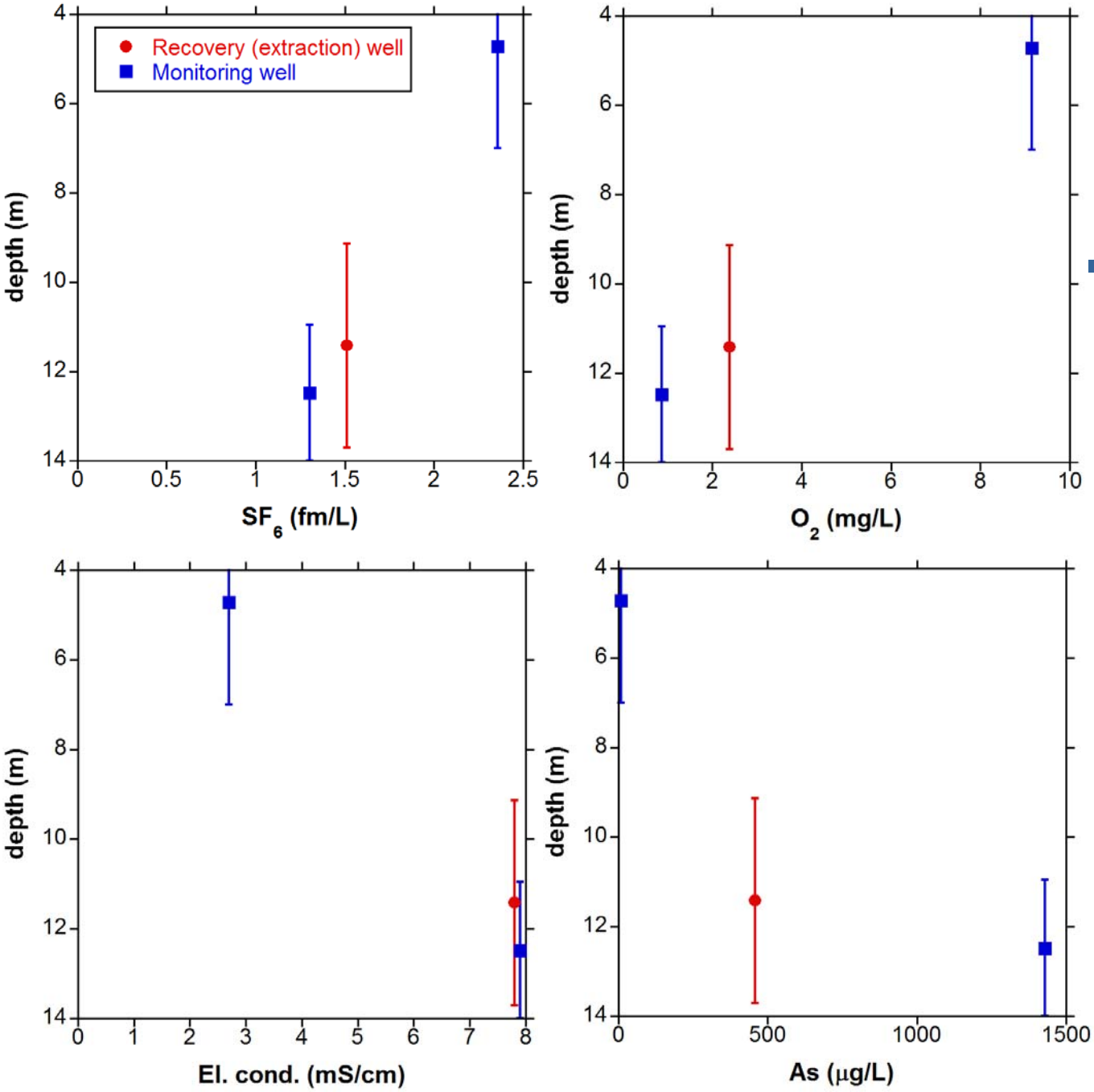
Flushing of well RW13 with CO_2 started at 17:35

=> No evidence for external entrainment of O_2 in well

Apparent SF_6 ages (years) of Monitoring wells & Extraction wells

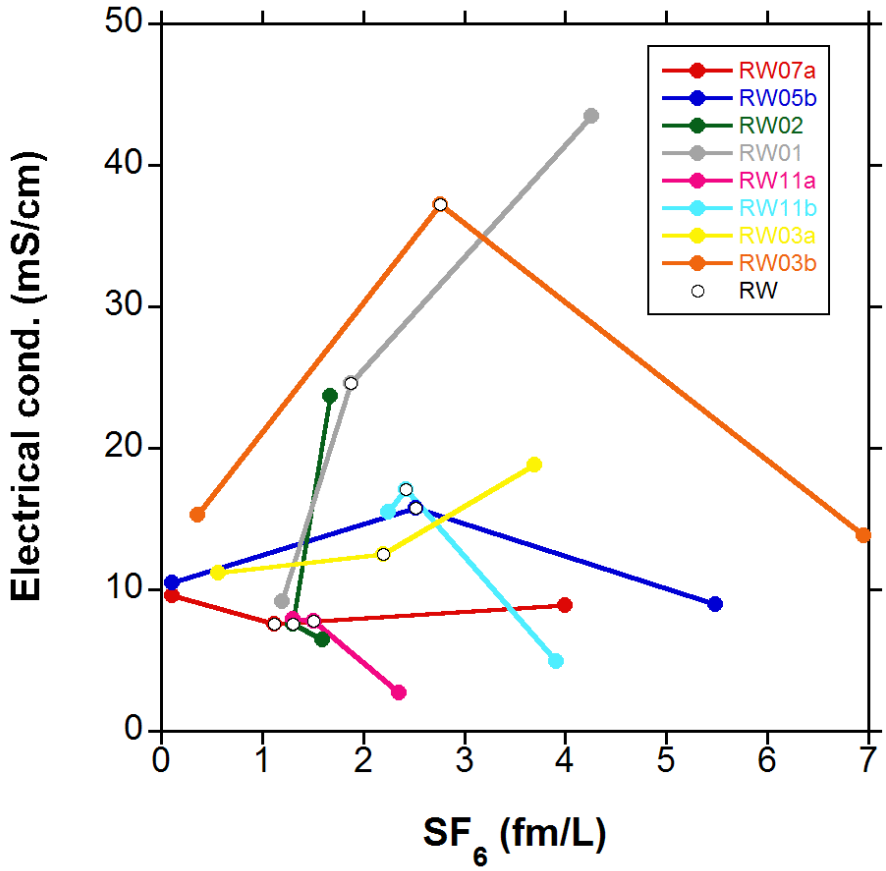


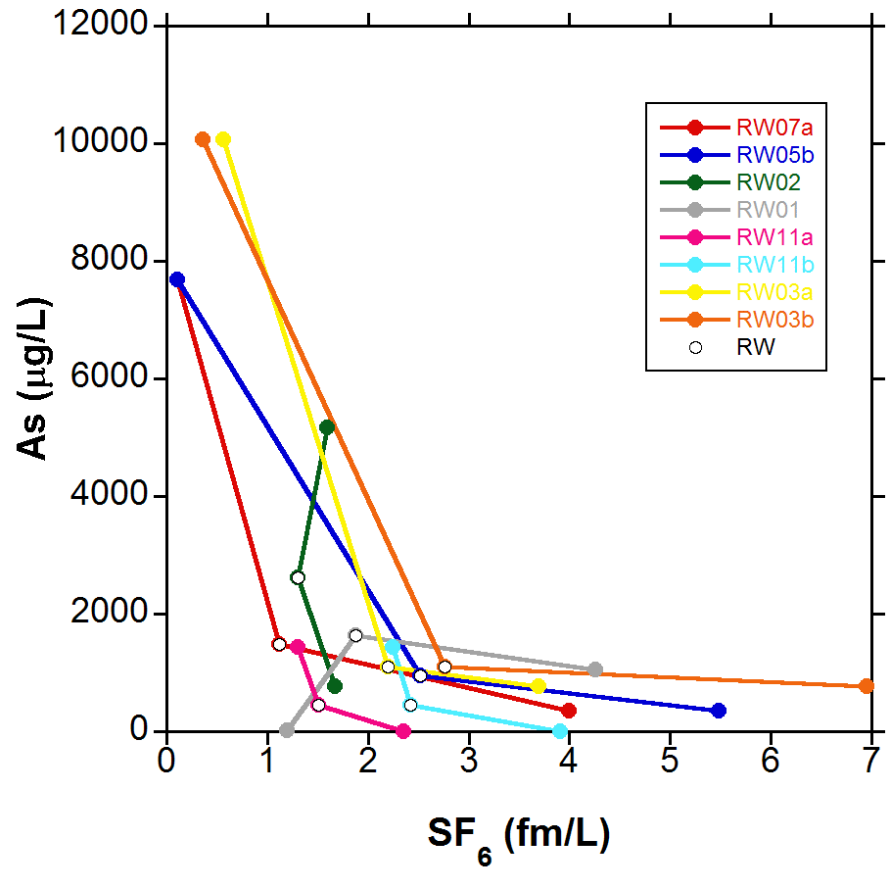
RW 11

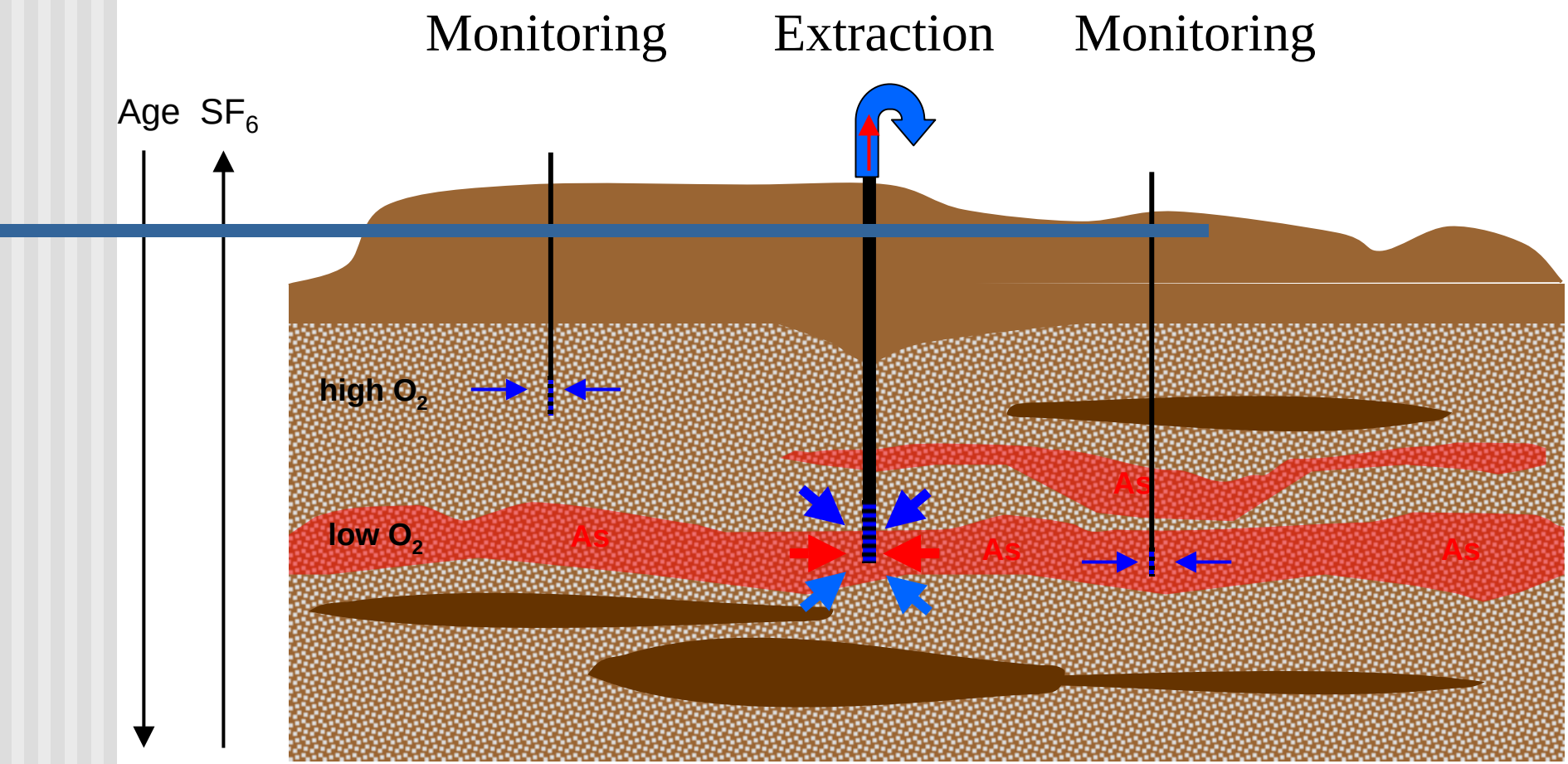


⇒Evidence for mixing in aquifer

Precipitation of As in/near pumping wells?

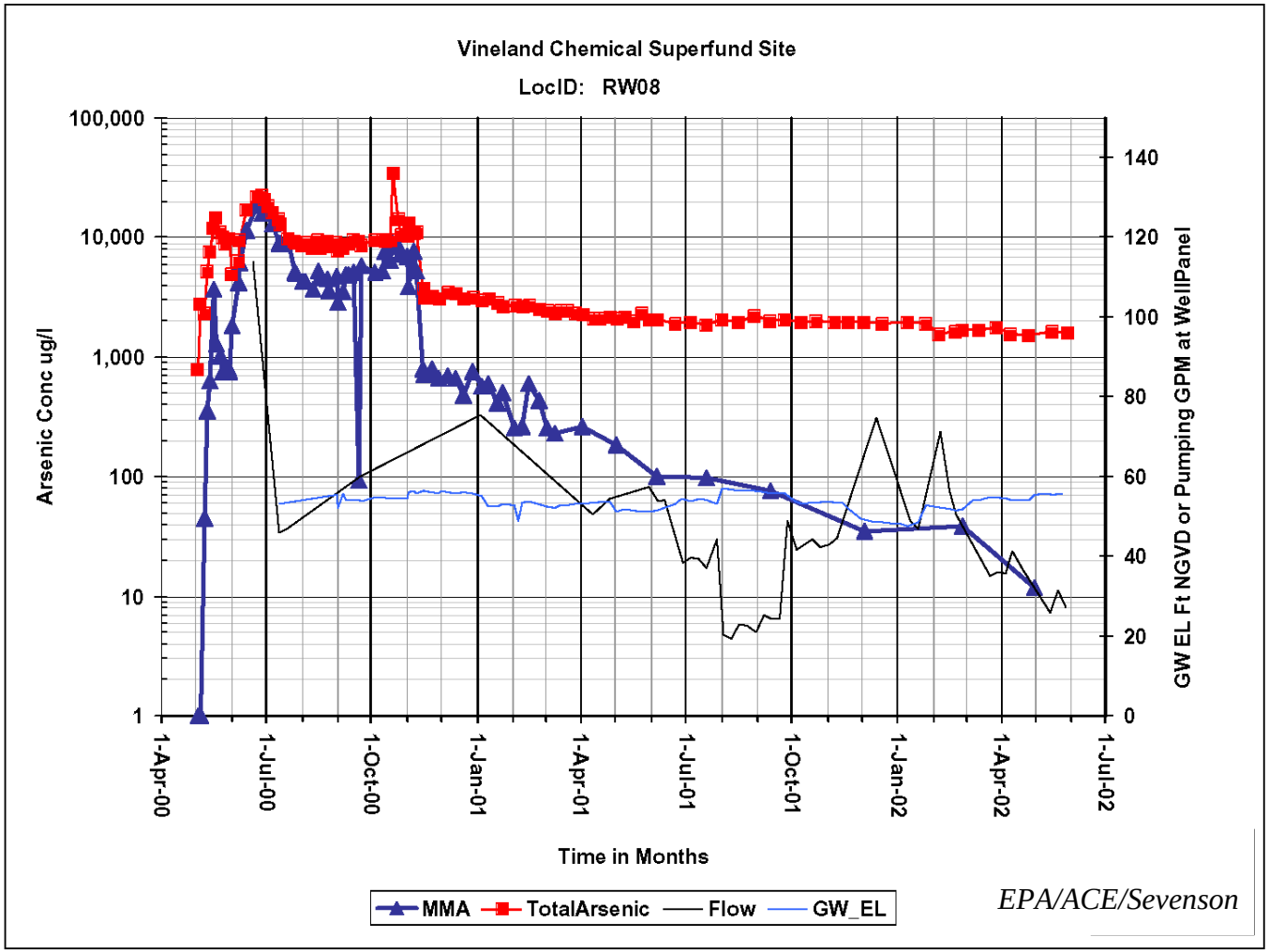






=> Mixing induced by pumping may cause As/Fe precipitation in well

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

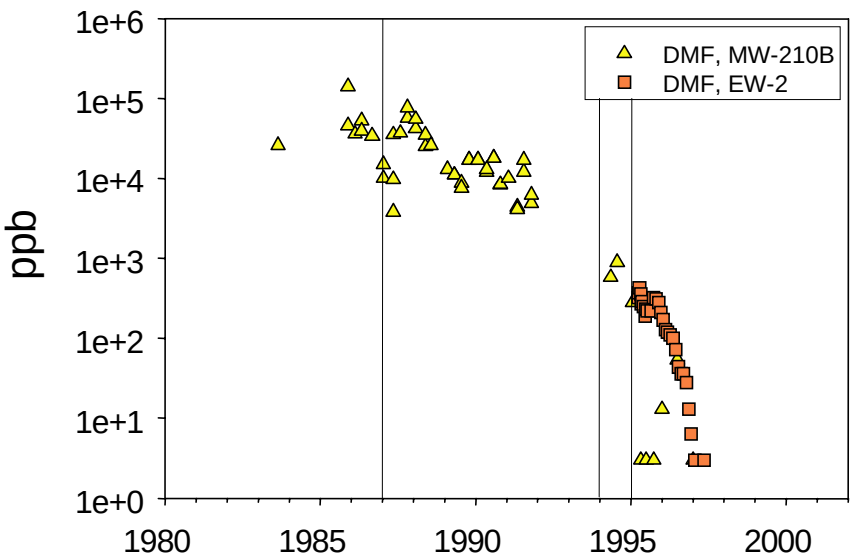
↓

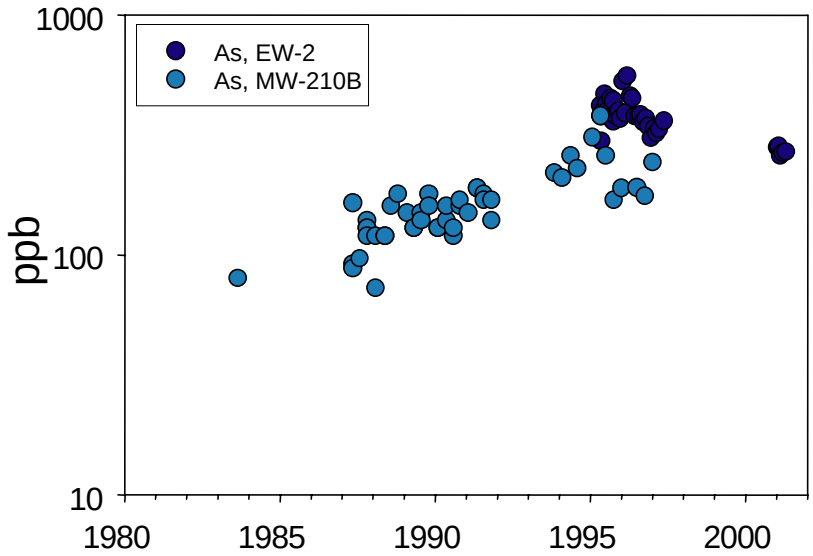
treatment

↓

re-injection

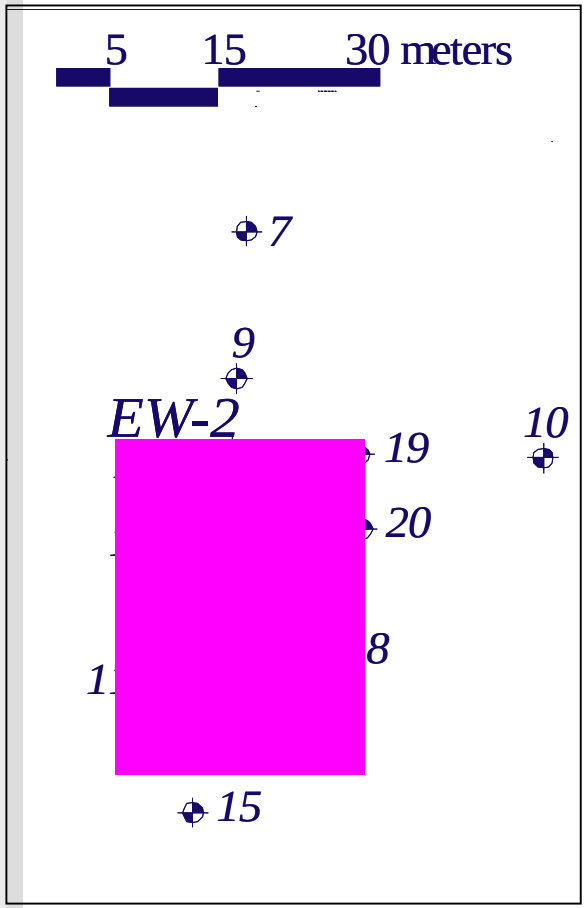
Issues: organics & As



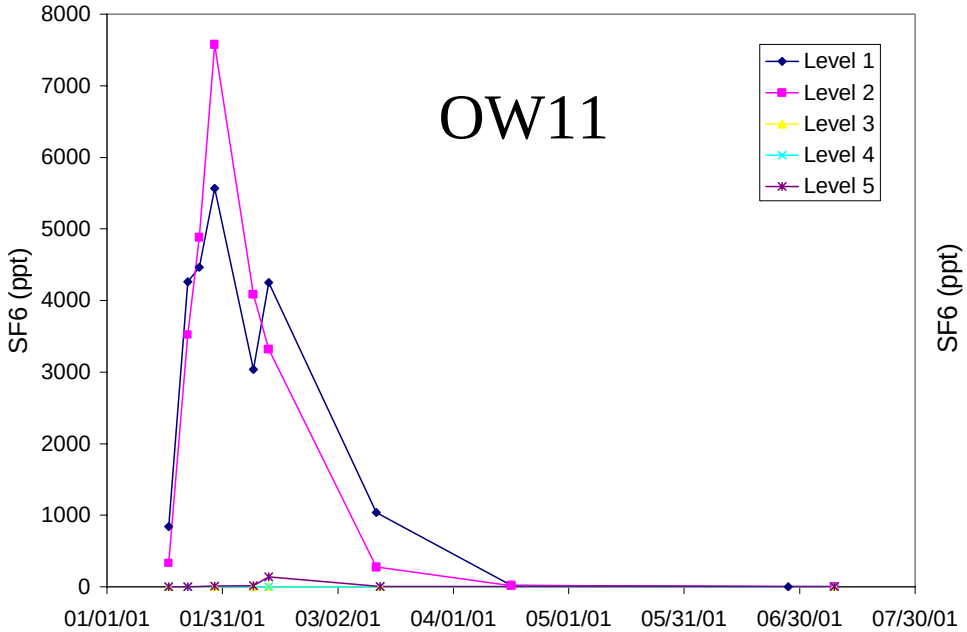


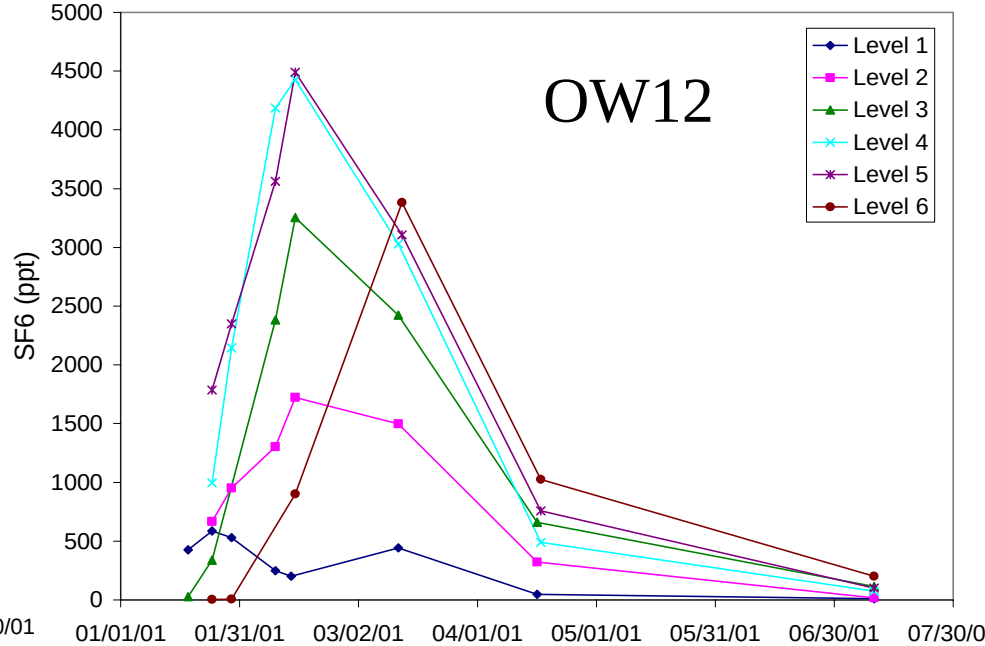
N. Nikolaidis, Personal Communication

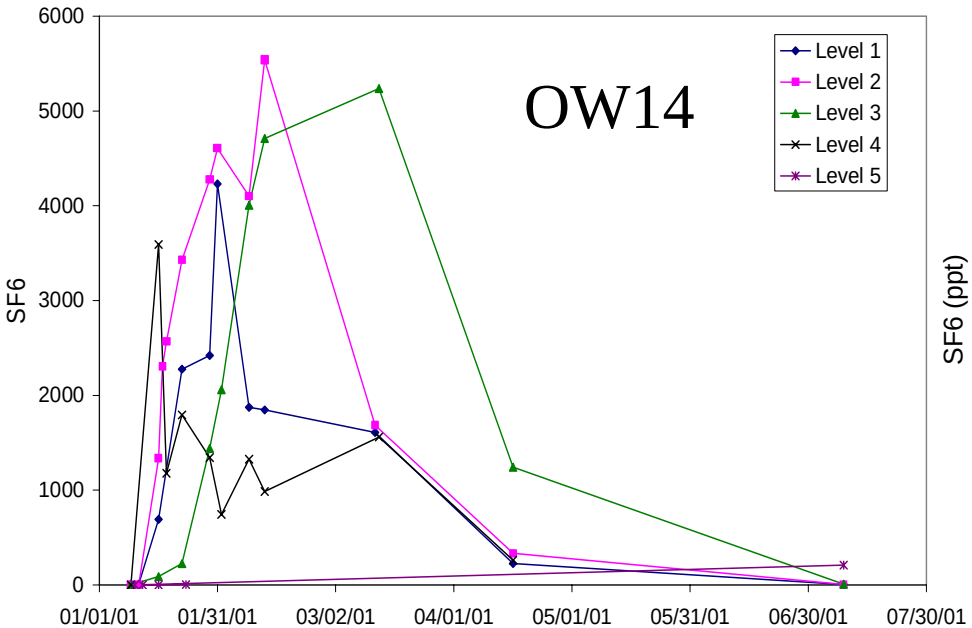
4.) Aquifer heterogeneity

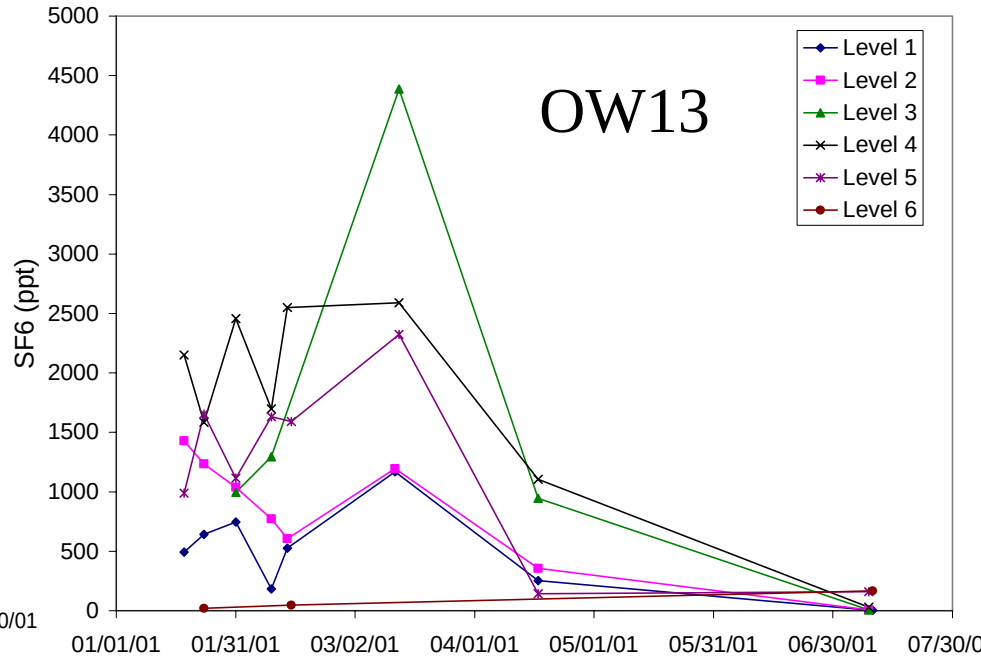


- injected
  - 1370 kg of ORC
  - 12 kg of NaBr
  - 2.4 ml of SF_6
- 10 Geoprobe holes, injection equally over entire thickness of the aquifer
- followed tracer for 250 days
- heterogeneous glacial deposits

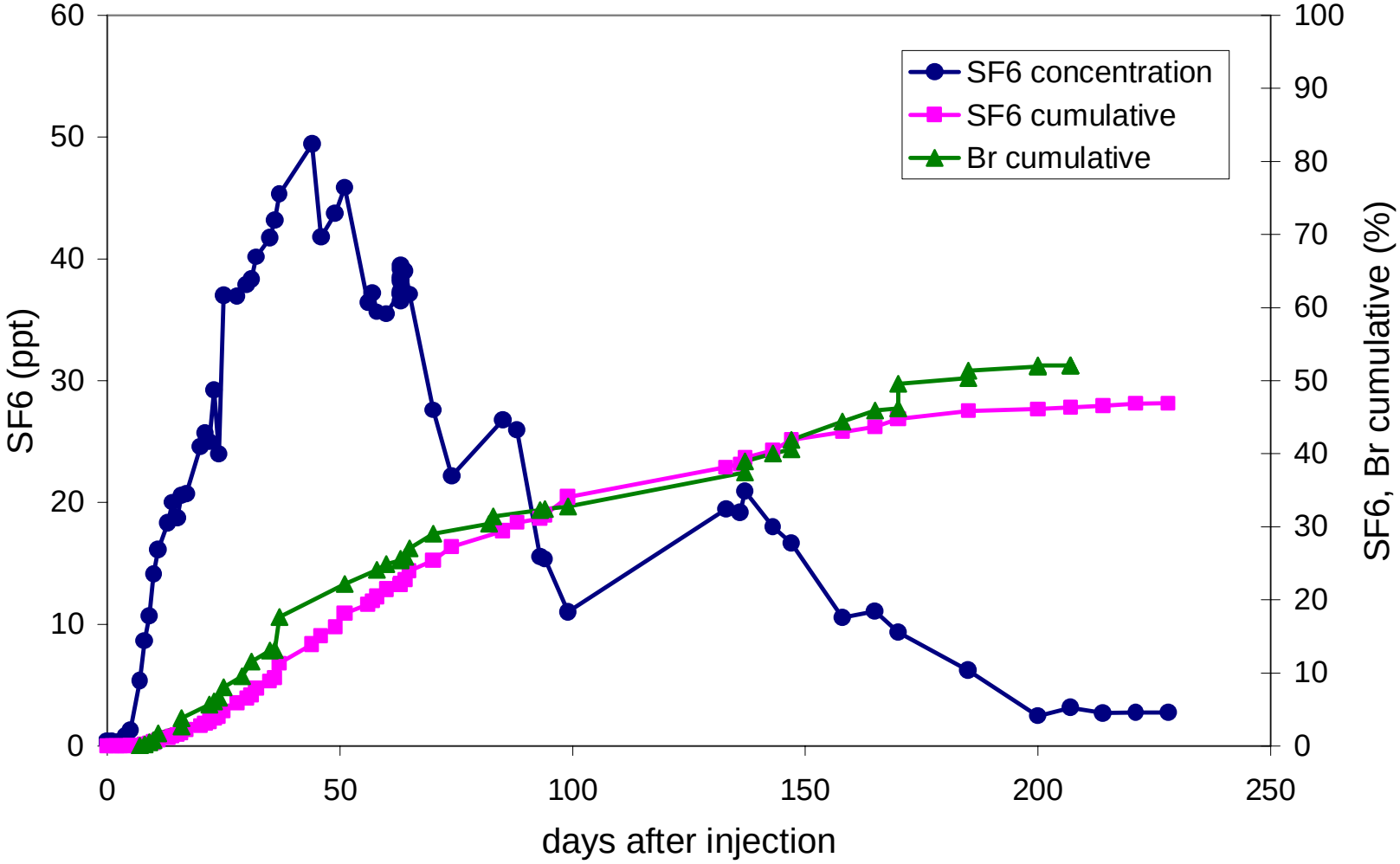

OW11
SF6 (ppt)
8000
7000
6000
5000
4000
3000
2000
1000
0
01/01/01
01/31/01
03/02/01
04/01/01
05/01/01
05/31/01
06/30/01
07/30/01
Level 1
Level 2
Level 3
Level 4
Level 5


OW12
SF6 (ppt)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/01/01
01/31/01
03/02/01
04/01/01
05/01/01
05/31/01
06/30/01
Level 1
Level 2
Level 3
Level 4
Level 5
Level 6


OW14
SF6
6000
5000
4000
3000
2000
1000
0
01/01/01
01/31/01
03/02/01
04/01/01
05/01/01
05/31/01
06/30/01
07/30/01
Level 1
Level 2
Level 3
Level 4
Level 5


OW13
SF6 (ppt)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/01/01
01/31/01
03/02/01
04/01/01
05/01/01
05/31/01
06/30/01
Level 1
Level 2
Level 3
Level 4
Level 5
Level 6

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

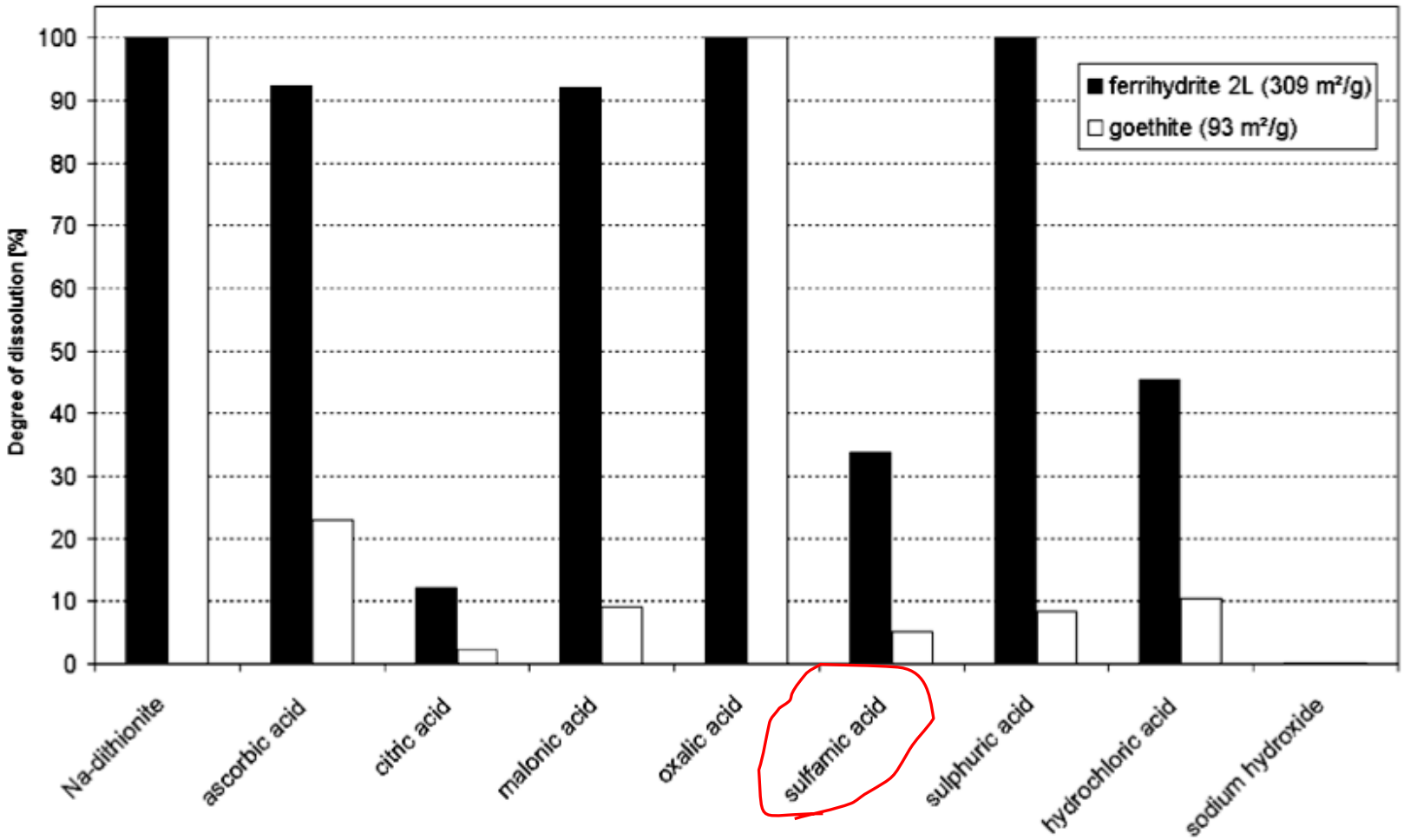


Fig. 14. Comparison of the efficiency of the chemicals used (after 7 h).