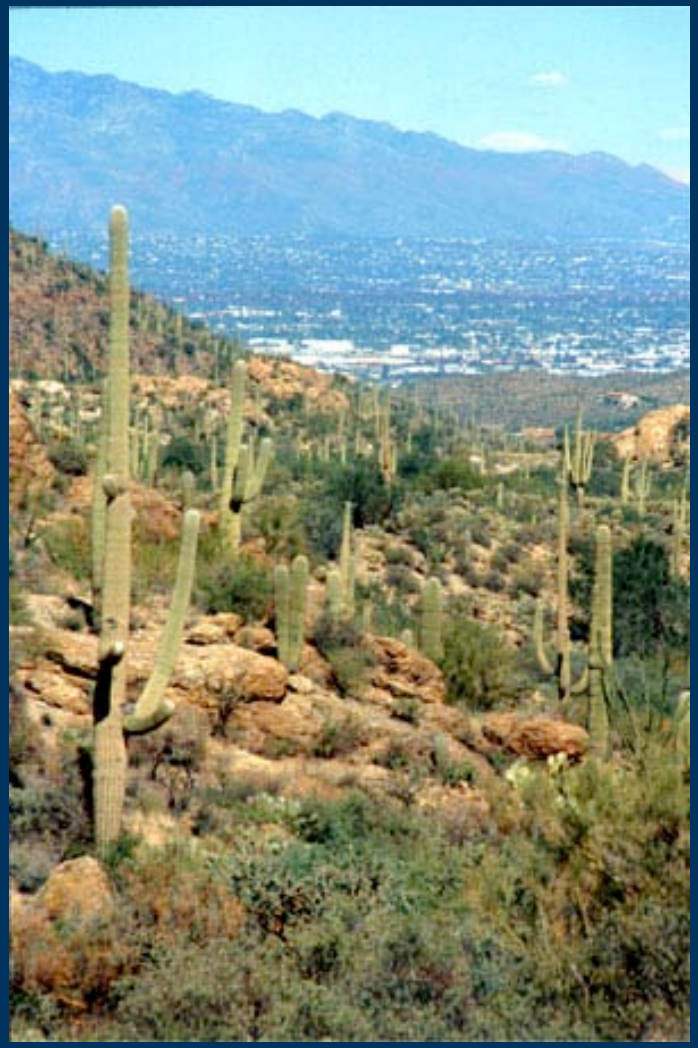
Fate of Organics during Soil Aquifer Treatment



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Transatlantic Water Symposium

Louisiana State University
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Pima County Wastewater Management Department

Talk Outline

1. Reclaimed water program in Tucson, AZ
2. Sweetwater Recharge Facilities
3. Research at the SRF:
   - Organics/EfOM
   - Estrogens, PBDEs

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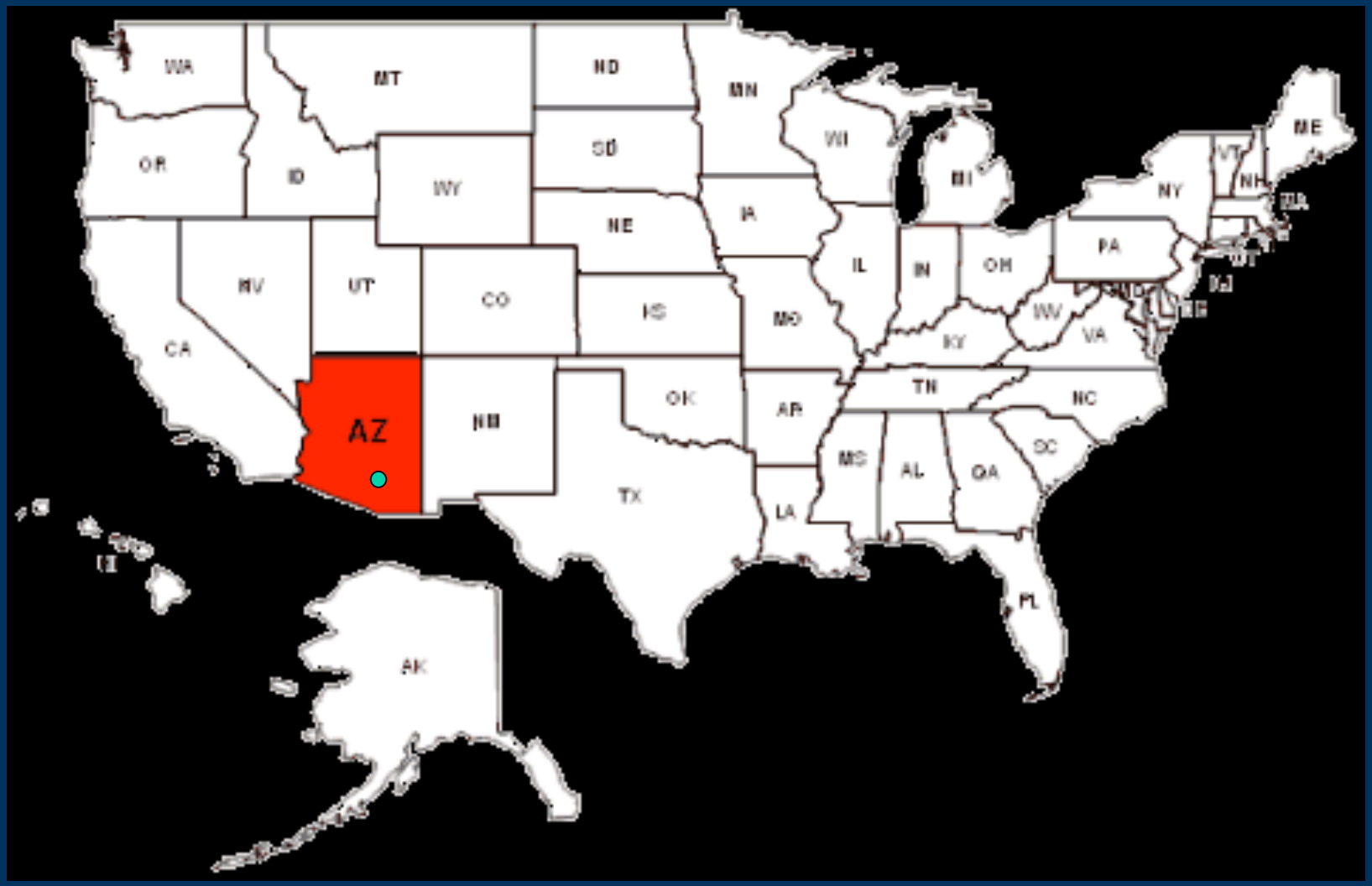
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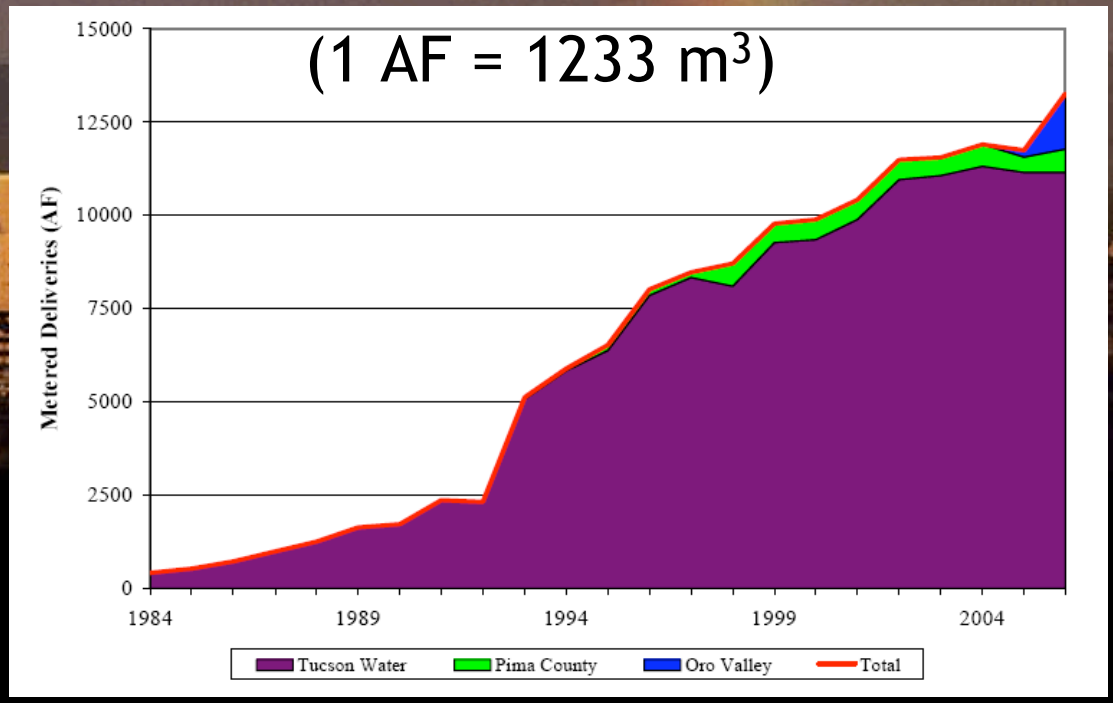
Reclaimed water in Tucson, AZ

- City of Tucson began deliveries in 1984
- Reclaimed water users:
  - 19 golf courses
  - 30 parks
  - 40 schools (incl. Univ of AZ)
  - more than 700 single family homes



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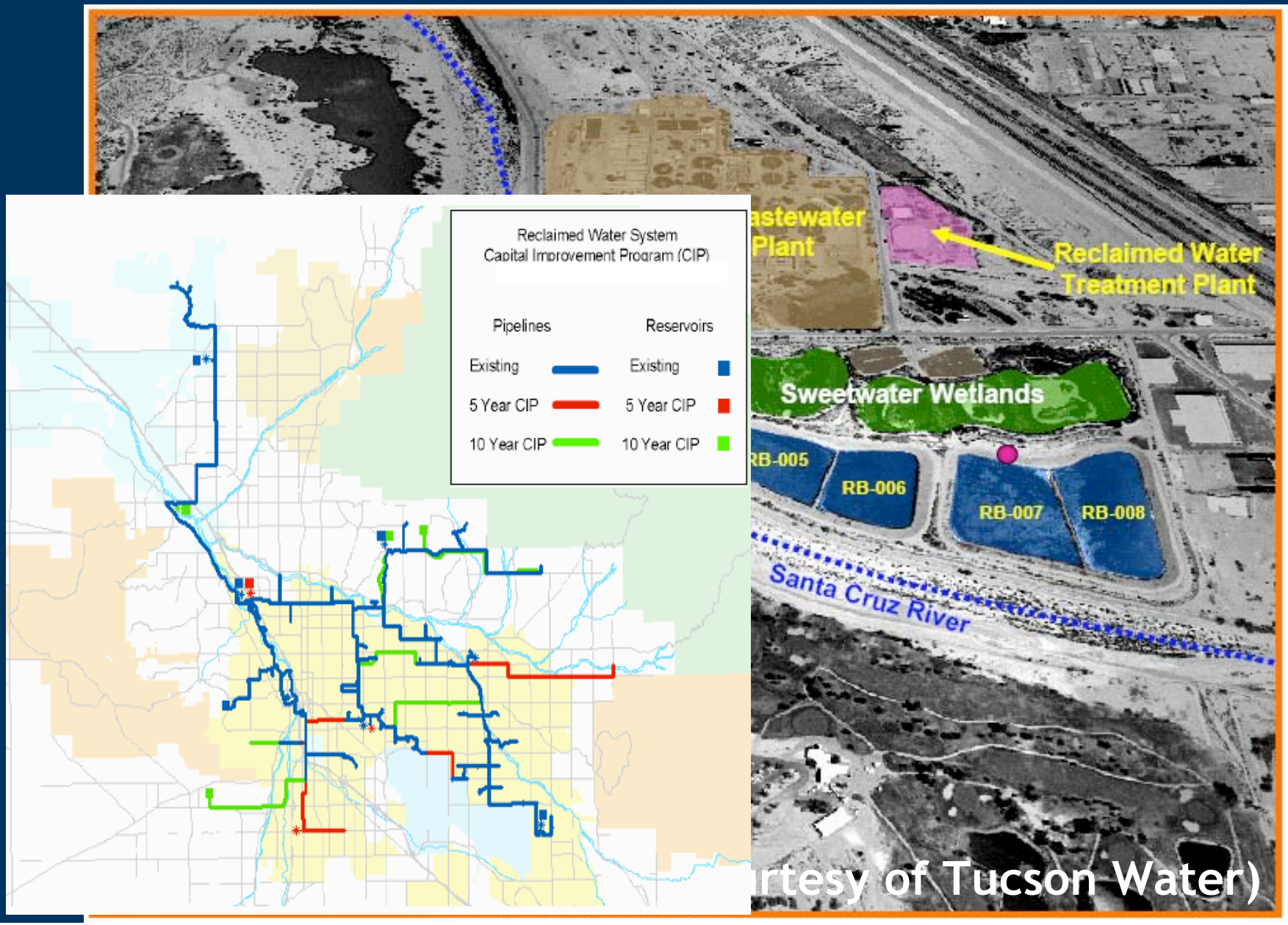
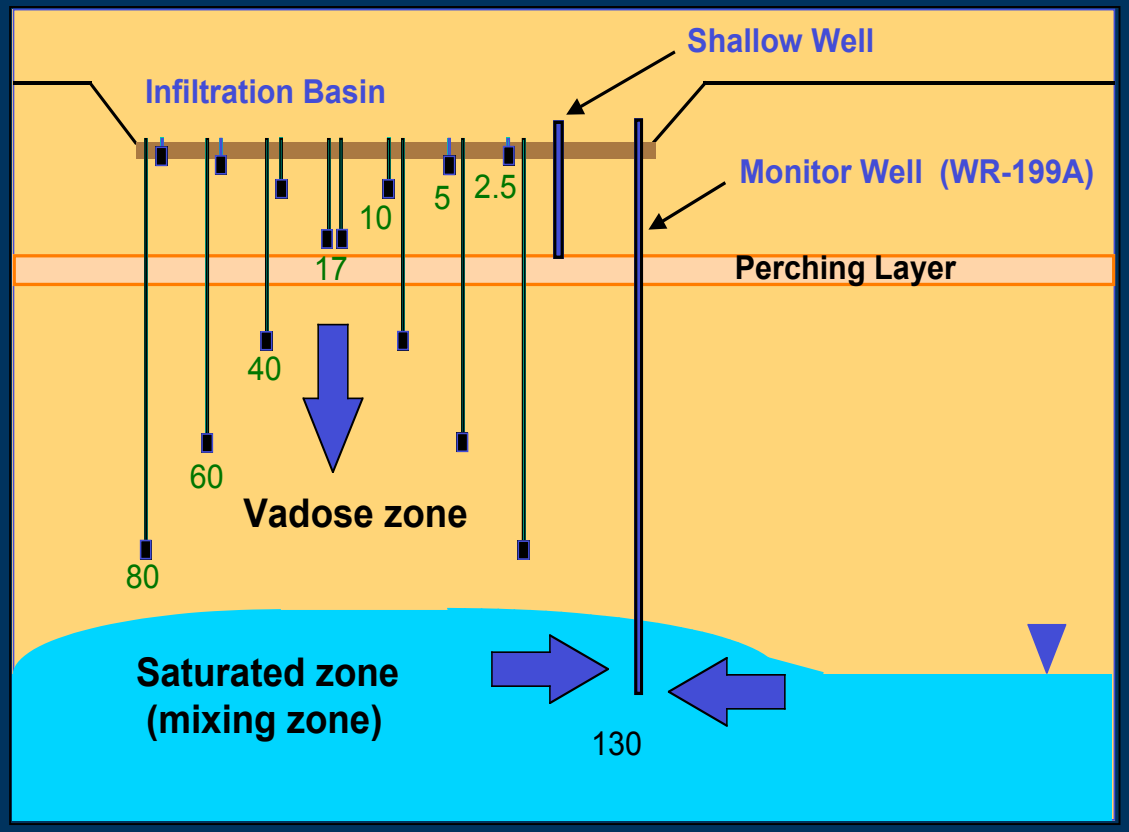
Sweetwater Recharge Facilities (Tucson, AZ)



Soil aquifer treatment (SAT)—the sum of water quality benefits accompanying percolation of effluent through unsaturated sediments and subsequent mixing with ground water



Vadose zone instrumentation in basin no. 1 at the Sweetwater Recharge Facilities

Vadose zone suction sampler

Installation of vadose zone liquid samplers at the Sweetwater Recharge Facilities, Aug 1997

Talk Outline

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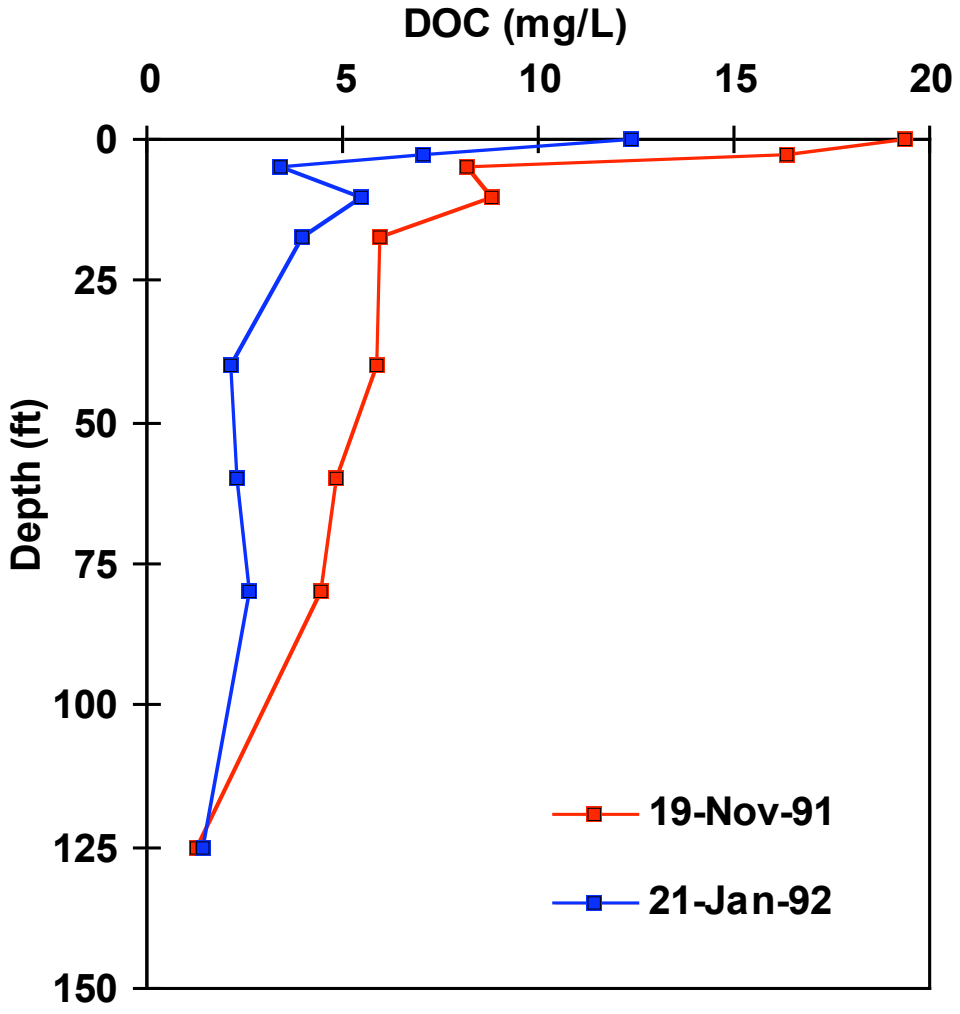
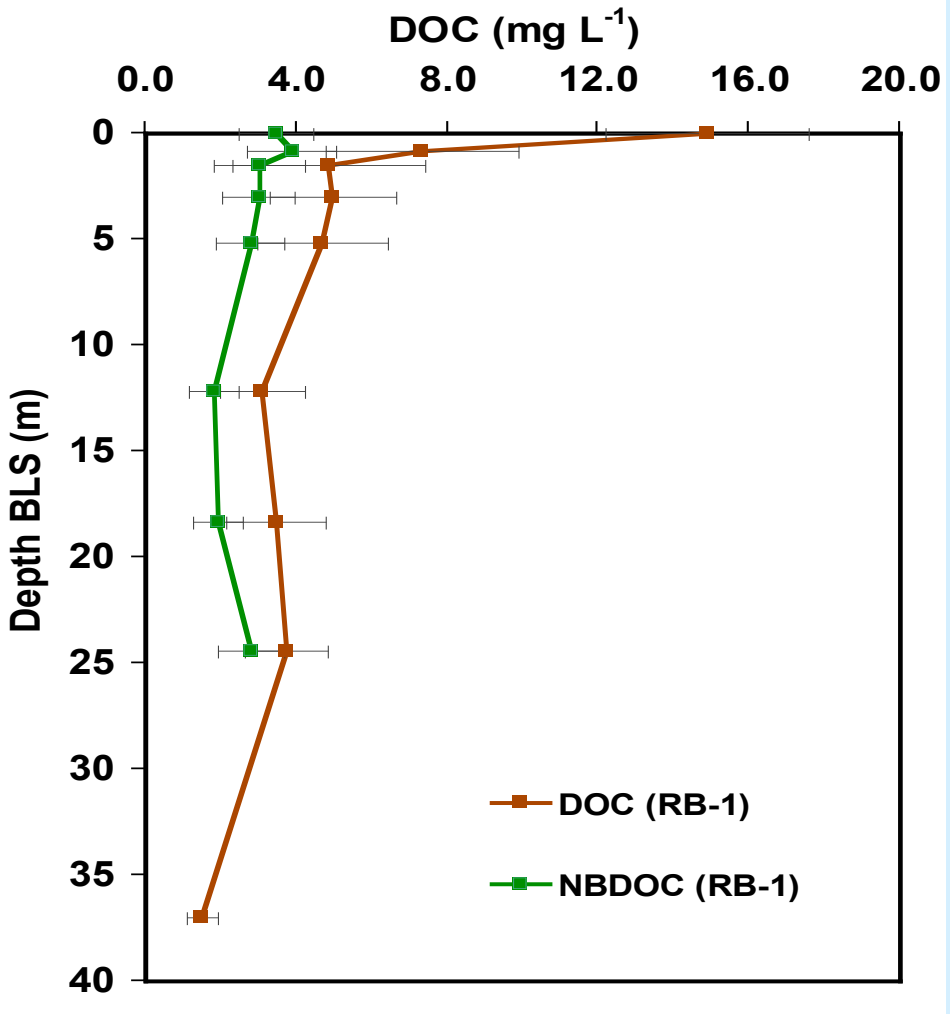
Sustainability of SAT?
--fate of dissolved organic carbon--



Wilson et al., 1995



Quanrud et al., 2003

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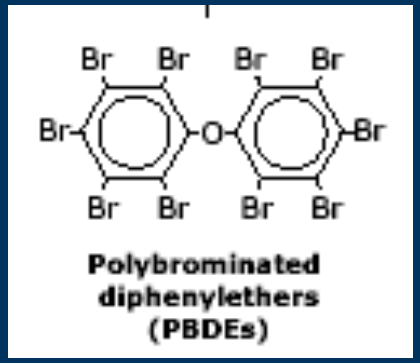
Research question

Do hydrophobic EDCs accumulate in surface soil during rapid infiltration/soil aquifer treatment?

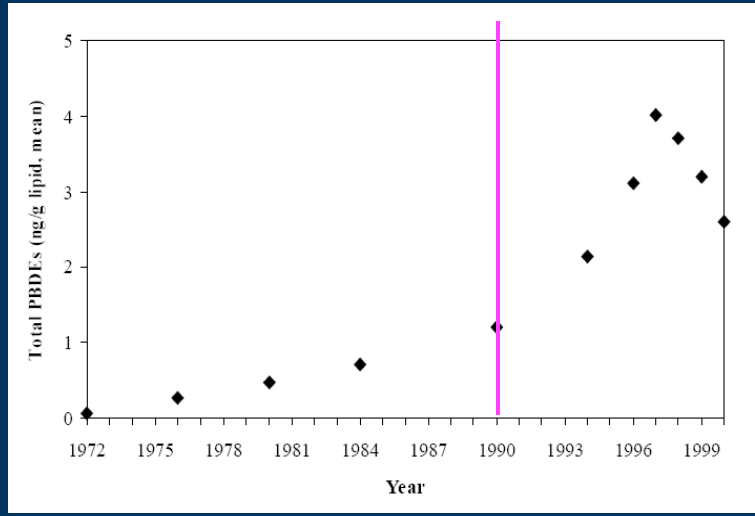
- Estrogenic activity
- Nonylphenol
- Polybrominated diphenyl ethers (PBDEs)

PBDEs

- Most widely used flame retardant in North America
- Polyurethane foam, fabrics, clothing, electronics, & building mtrls
- Similar in structure to PCBs; three commercial mixtures
  - Penta, Octa, Deca



- Thyroid hormone mimic
- Lab animal studies on PBDEs:
  - Impairment of brain development
  - sensory motor development
  - Permanent learning/memory impairment
- Sweden: PBDE levels doubled every 5 years from 1972 to 1997; phase out began in 1990

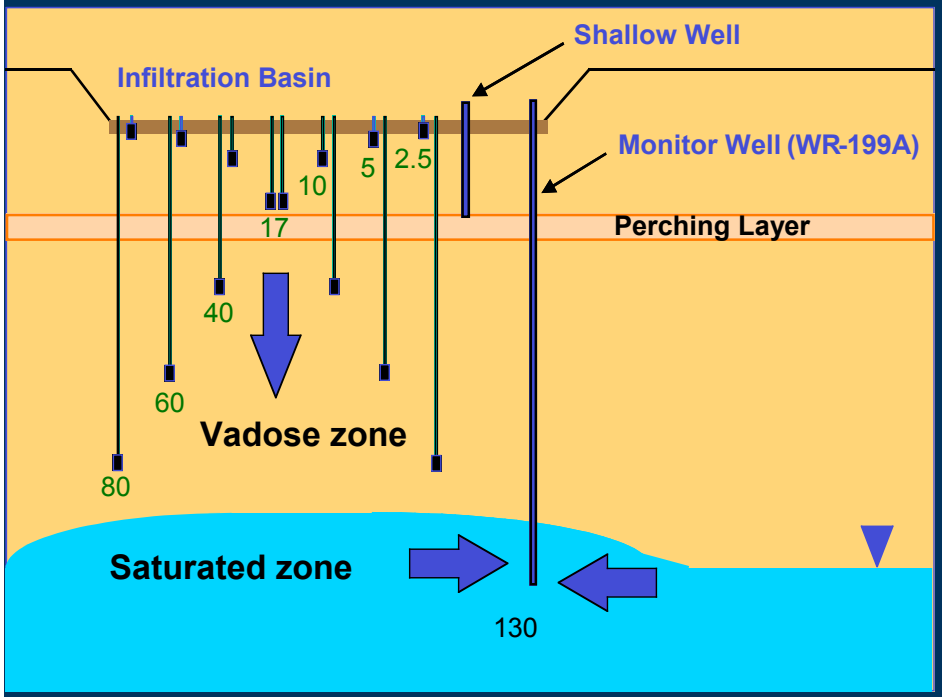


Properties of selected organic contaminants

Chemical Name	Molecular Weight	Log K_{ow}
Bisphenol A	228	3.40
17β-estradiol (E2)	272	3.94
Octylphenol (OP)	206	4.12
17α-ethinylestradiol (EE2)	296	4.15
Nonylphenol monoethoxylate	264	4.17
Nonylphenol (NP)	220	4.48
BDE-47	469	6.81
BDE-99	627	7.32
BDE-209	943	>8

Approach

Measure liquid-phase and solid-phase concentrations of EDCs to evaluate their long-term fate during SAT



- Depthwise water sampling
- 0 to 37m (120 ft)

- Depthwise sediment sampling
- Top 0.85m

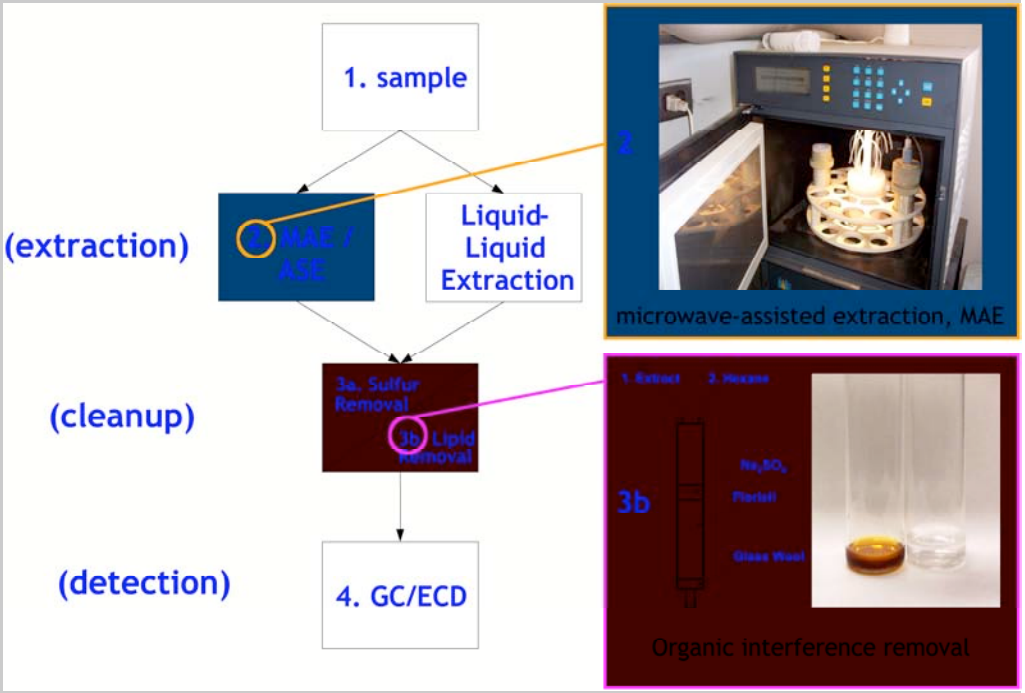
Sample preparation steps

Liquid samples

- Concentration (500-1000x) step: C18 disk (3M Empore)
- Elution step: 0.2., 0.8 MeOH

- PBDEs: liquid/liquid extraction using hexane

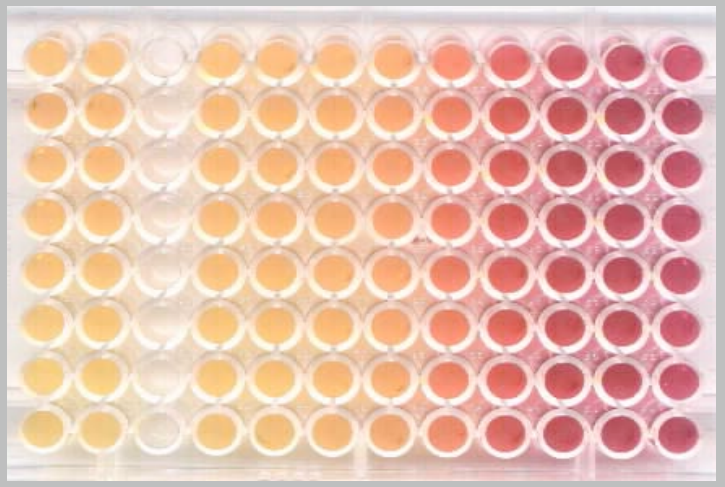
Solid extraction/cleanup (PBDEs)

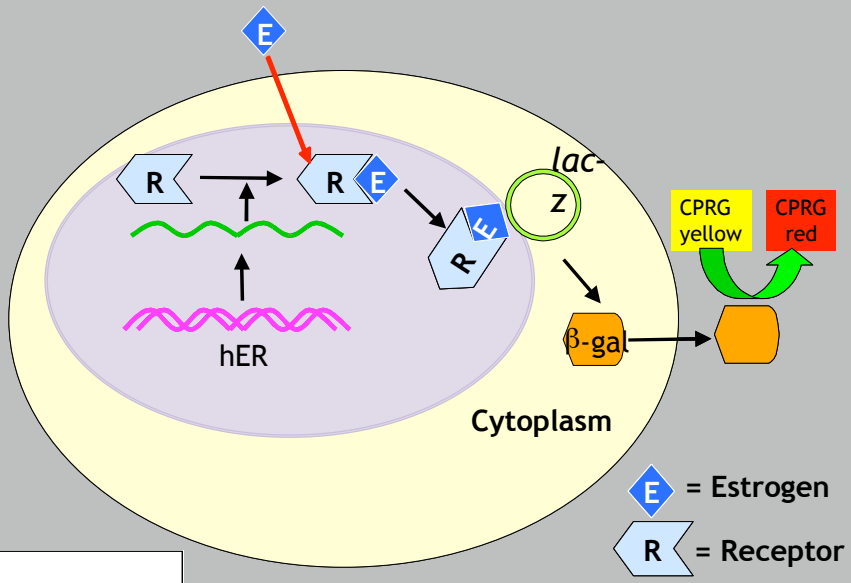


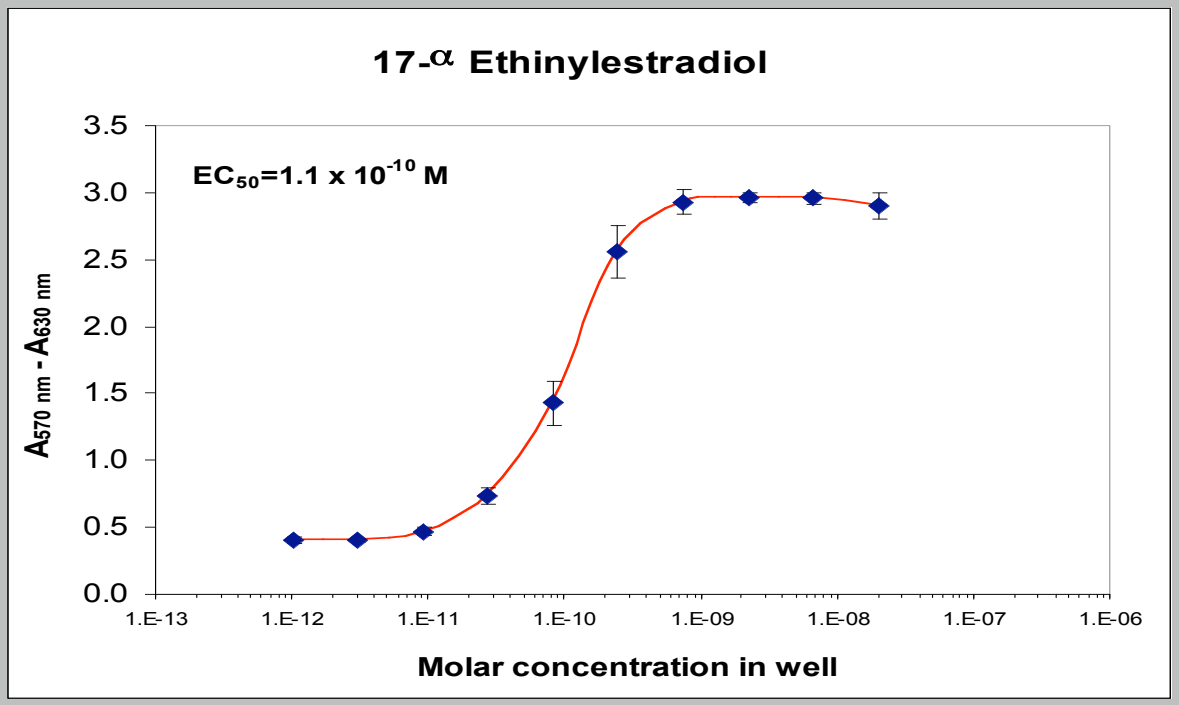
Recoveries:

EA: 1.01
NP: 0.7-1.04
PBDEs: 0.95

Procedure: YES assay



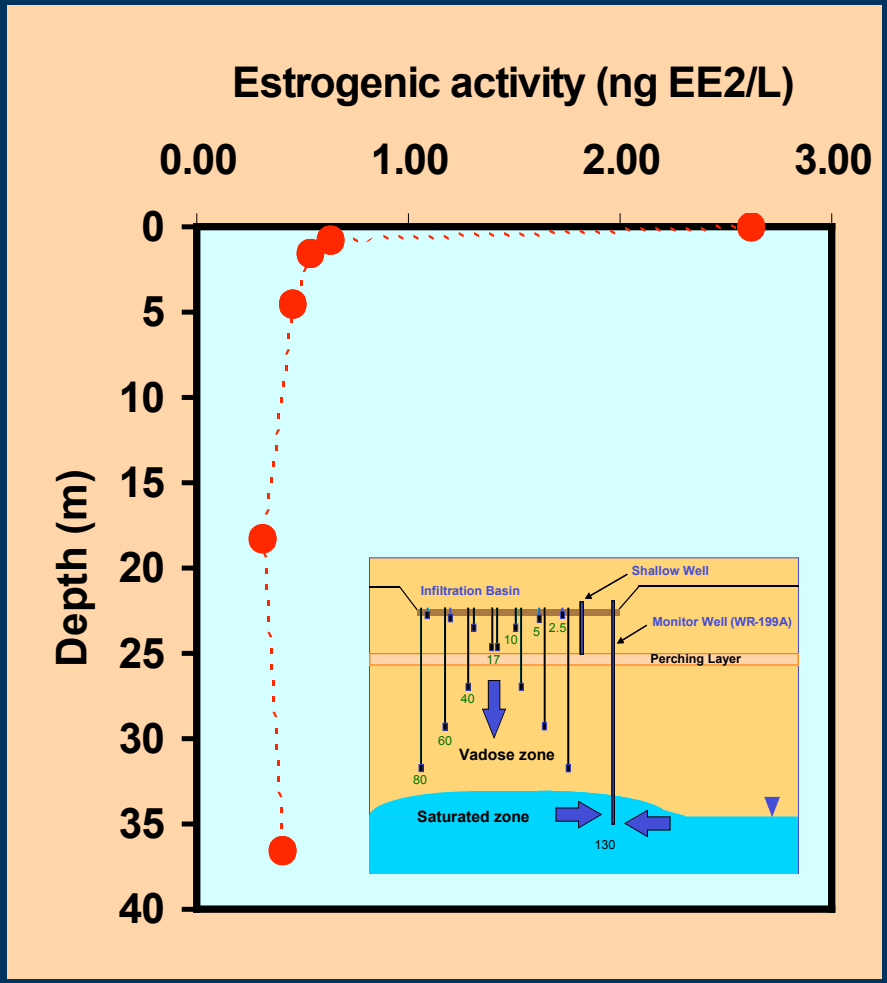




$$\text{EE2 Eq} = \frac{EC_{50}(EE2)}{EC_{50}(\text{sample}) \times CF}$$

Results (liquid phase)

percolation of secondary effluent



Top 0.85m:

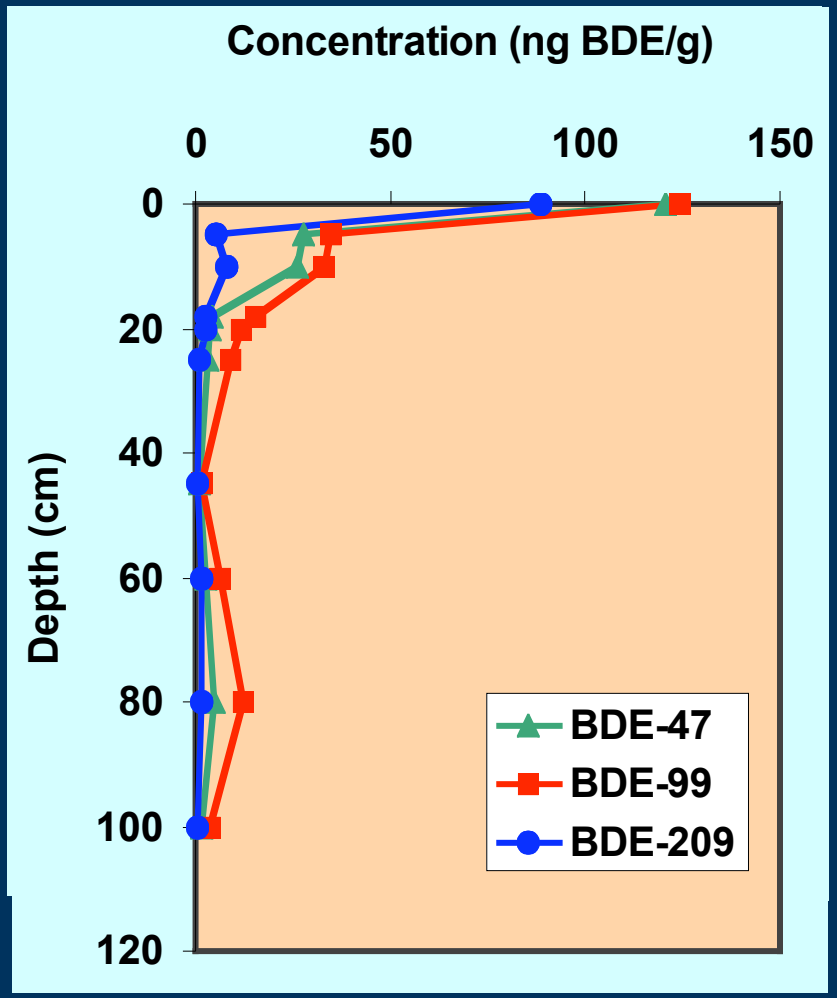
EA: 2.6 ng/L to 0.41 ng/L
(84% reduction)

NP: 79 µg/L to 9.0 µg/L
(88% reduction)

PBDEs: 87 ng/L to 26 ng/L
(70% reduction)

Results (solid phase)

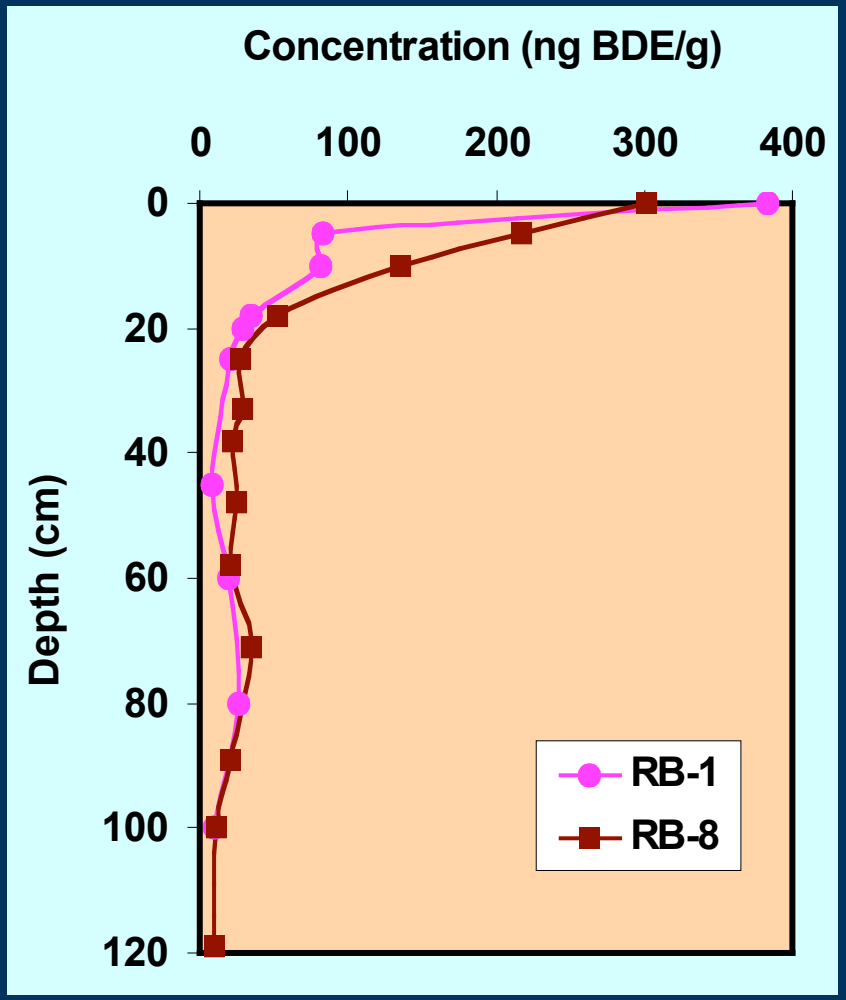
Extractable estrogenic activity and NP in basin sediments (top 0.85m)



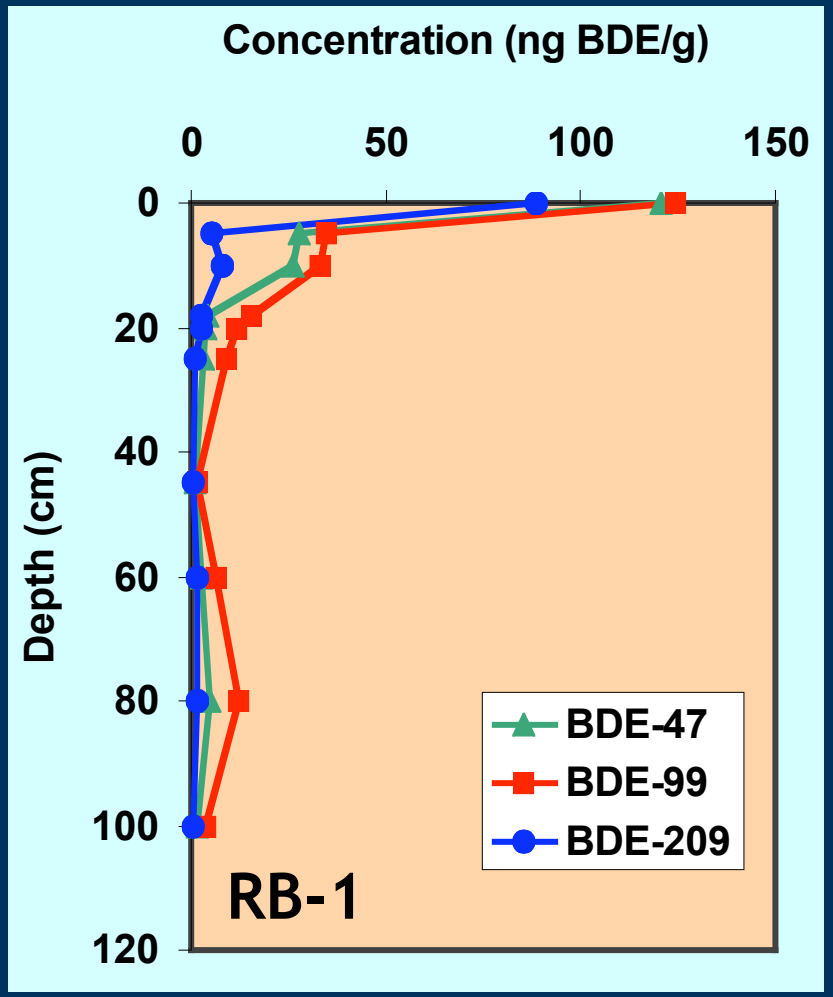
Results (solid phase)

Extractable PBDEs in basin sediments

(Total PBDEs)

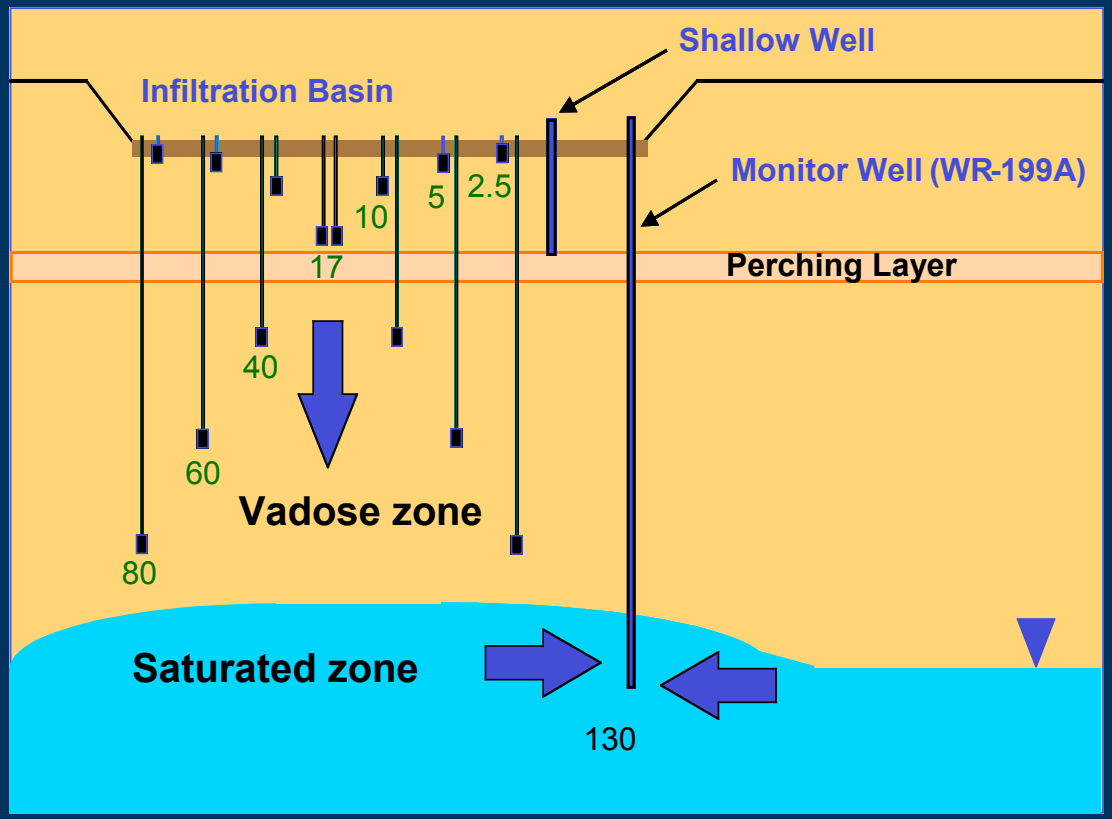


(Main PBDE Congeners)



Mass Balance Analysis

Determine mass fluxes and “storage” of EDCs to evaluate their long-term fate during SAT



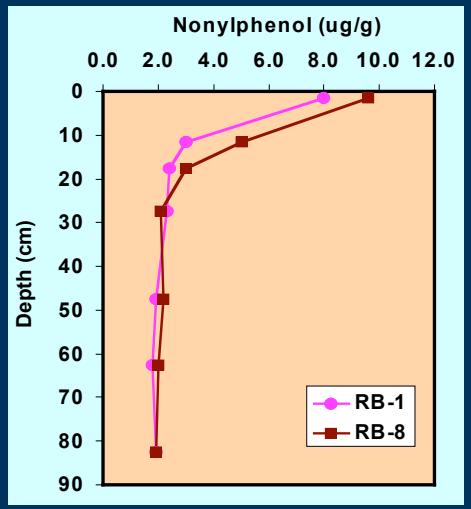
Mass Balance Analysis: NP in RB-1

Expected NP accumulation (if no degradation)

(control volume: 0.01m × 0.01m × 0.85m)
(bulk density 1.7 g/cm^3)
(hydraulic loading : 71m per yr)
(NP removed: 70 μg/L)

Expected annual accumulation: 3.4 μg

After 15 yrs, total NP mass = **7,370 μg**



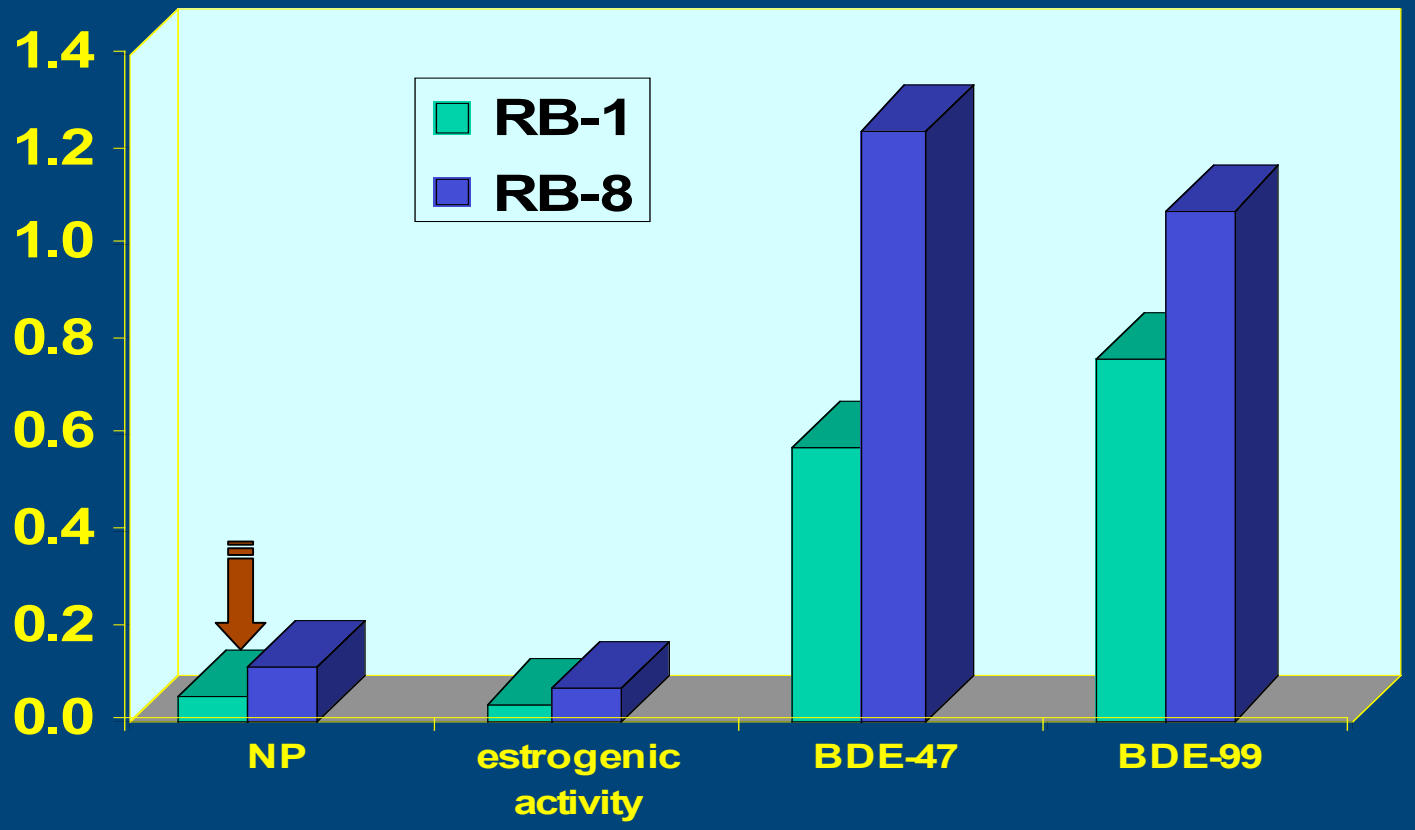
Actual NP accumulation

recovered NP mass = 370 μg

fractional recovery = 370μg/7,370μg

= 0.050

Fractional recovery of EDCs
(top 0.85m of sediment)



Summary

1. Bulk effluent organic matter is efficiently removed during SAT
2. EfOM removal is sustainable in the long term
3. Estrogenic activity and nonylphenol do not accumulate in surface sediments over time
4. PBDEs accumulate over time in surface sediments and may be a contaminant of concern in the long term

Analytical Methods

	Method detection limits (Liquid)	(solid)
Estrogenic activity (YES assay)	0.1 ng/L	0.03 ng/g
Nonylphenol (HPLC)	2.0 µg/L	0.1 µg/g
Polybrominated diphenyl ethers (GC-ECD, EPA 1614)	0.1 ng/L	0.1-1.0 ng/g