

**Natural tracers as tools to address
management issues related to
groundwater – surface water interactions**

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**Two water management issues
related to sustainability**

- **Siting of new high capacity wells – potential impacts of groundwater use on surface water resources**
- **Aquifer storage recovery to facilitate surface water use for municipal supplies – potential impacts of surface water on groundwater quality**

**I. Regulating high capacity wells
(>100,000 gpd)**

- **WI regulations from the 1940s designed to avoid “interference” impacts on public supply wells**
- **No consideration for potential impacts on streams, springs or wetlands**

Waterkeepers of Wisconsin

Waterkeepers of Wisconsin (WOW) opposes any taking of spring water or any other ground water reserves that feed Wisconsin headwaters, lakes, rivers and streams.

2003 Wisconsin Act 310

Gov Signs Ground Water Protection Bill

The Capital Times, Friday, April 23, 2004

Gov. Jim Doyle signed legislation Thursday that would give the Department of Natural Resources the authority to deny high-capacity wells, with the intention of protecting ground water.

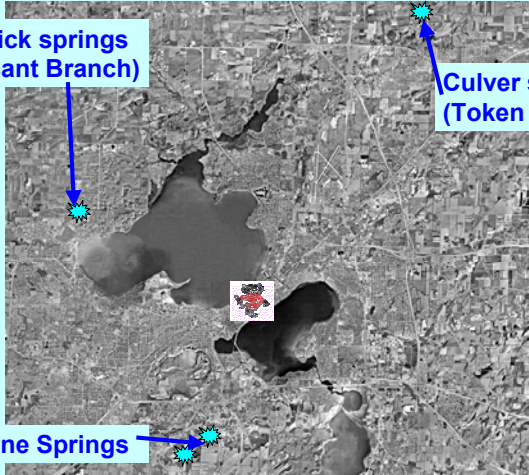
- **Permit can be denied on basis of significant impacts on high flow springs (>1 cubic foot per second)**
- **Requires knowledge of contributing aquifers and of hydraulic connections between pumped aquifers and springs**
- **Two examples: Madison area springs, Mukwonago River watershed**

Major Springs Near Madison WI

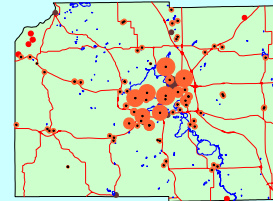
Frederick springs
(Pheasant Branch)

Culver springs
(Token Creek)

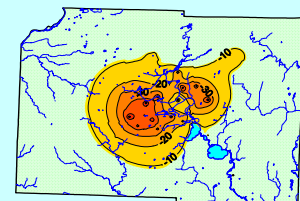
Nine Springs



Impacts of groundwater development



Pumping centers in Dane County
(Circles proportional to pumping)



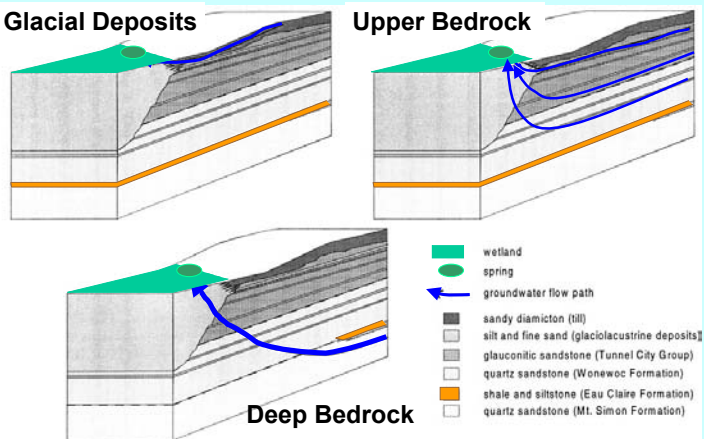
Drawdown in the deep Sandstone Aquifer
(Contours in feet)

Three possible sources for spring flow

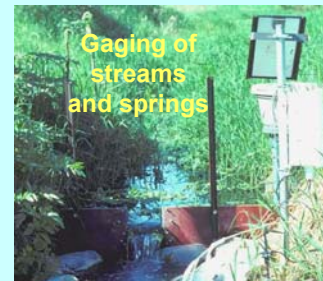
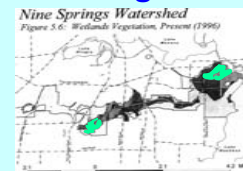
Glacial Deposits

Upper Bedrock

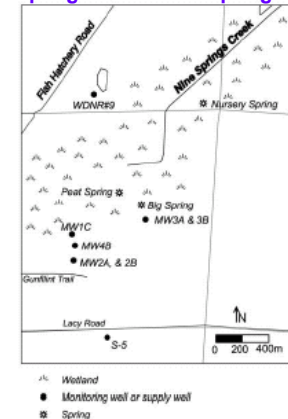
Deep Bedrock



Testing conceptual models of spring flow



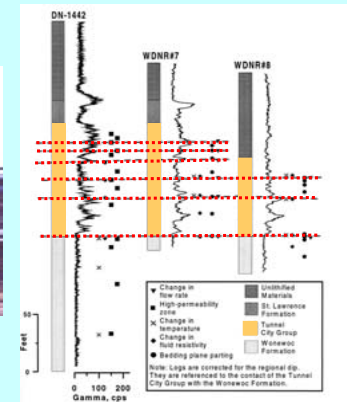
Sampling of wells and springs



Major ions and tritium-helium dating (Swanson et al. 2001, Chemical Geology)

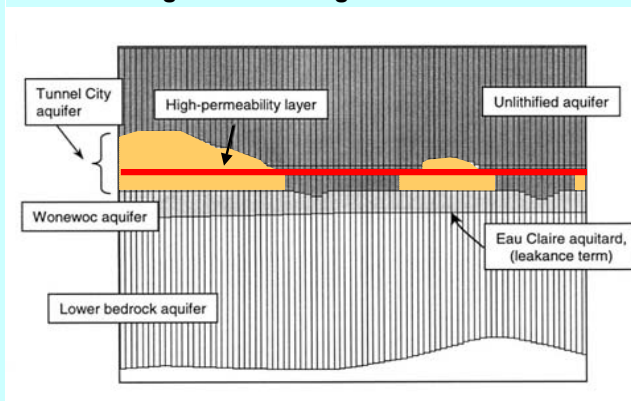
Group	I	II (springs)	III
Major ions	Variable NO ₃ and Cl	Elevated and stable NO ₃	Low NO ₃
	Low but variable Na	Elevated and stable Cl	Low Cl
	Variable alkalinity	Elevated and stable Na	Lower conductivity
³H/He age	3 – 9 yrs	10-15 yrs	> 40 yrs
Inferred Aquifer Source	Glacial Deposits	Upper Bedrock	Lower Bedrock

Testing of bedrock wells revealed high K zones in the Tunnel City Group

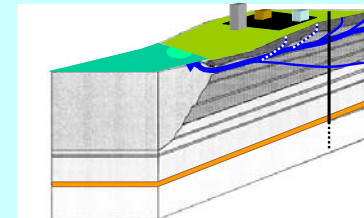


Groundwater model with high K layer

Good match to water levels, spring flow and groundwater age estimates

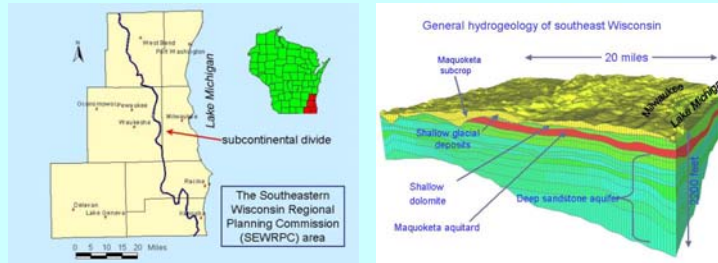


Implications for siting of deep wells



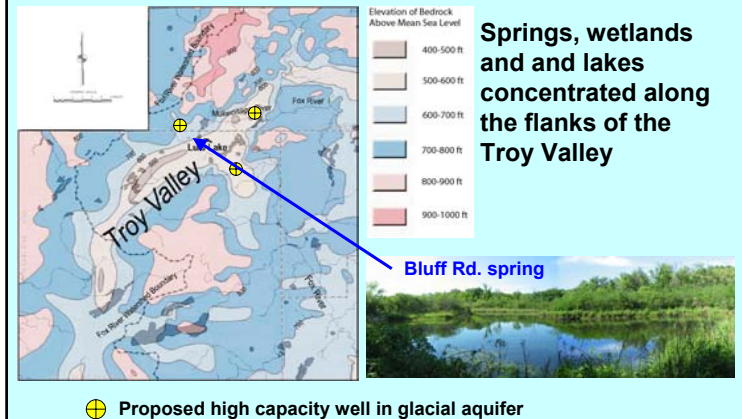
- Limited *localized* effects of municipal pumping
- Critical to maintain recharge in nearby areas

Mukwonago River Watershed, southeastern WI



- Rapid suburban expansion near Milwaukee
- Lake water cannot be transferred across subcontinental divide
- Deep wells produce water with high concentrations of radium
- Many new wells proposed in glacial deposits

Bedrock topography reveals buried valley

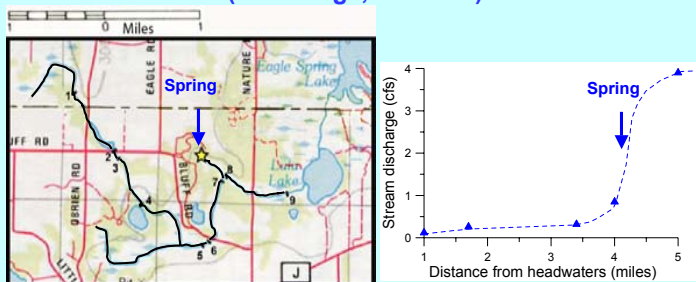


Springs, wetlands and lakes concentrated along the flanks of the Troy Valley

Bluff Rd. spring

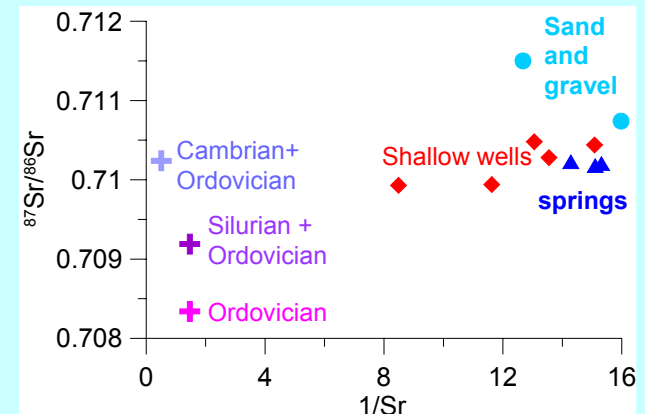
⊕ Proposed high capacity well in glacial aquifer

Evidence suggesting preferential flow (H. Gittings, MS 2005)

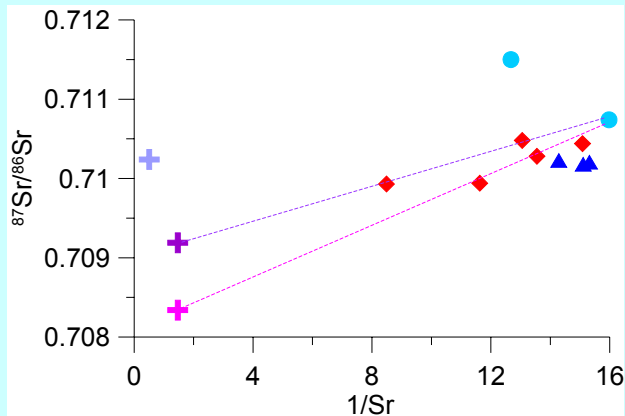


Abrupt increase in baseflow near edge of buried valley

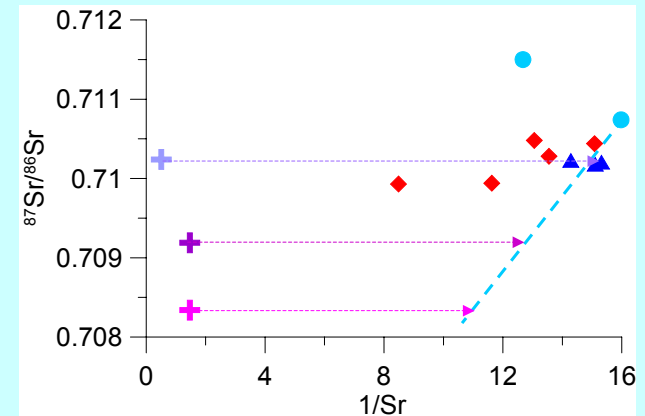
Sr isotopes to identify aquifers



Simple mixing models with bedrock



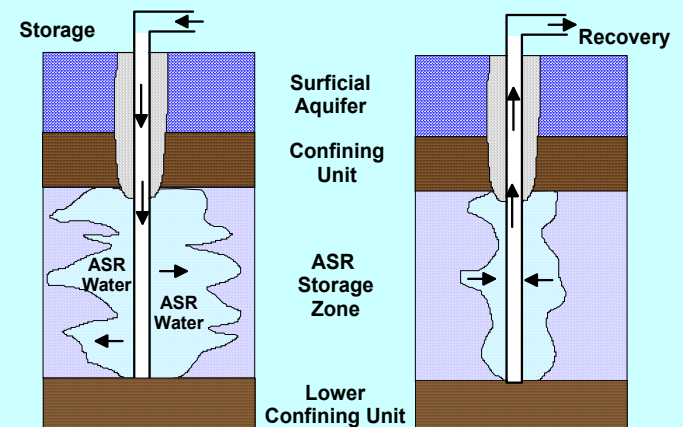
Mixing with water from fast flow zones



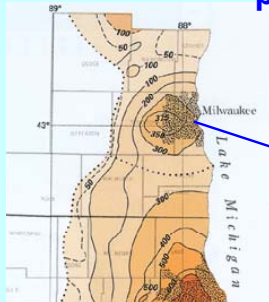
Conclusions and implications

- 15% - 75% of stream baseflow comes from bedrock aquifers and remainder is discharge from the sand and gravel aquifer
- New high capacity wells in sand and gravel have potential to decrease baseflow but effects may be partially buffered by discharge from bedrock aquifers

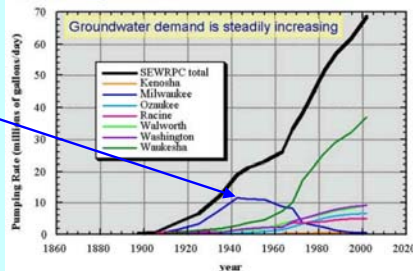
II. Aquifer Storage Recovery



Lake water replacing groundwater for public supply



Trends in groundwater use



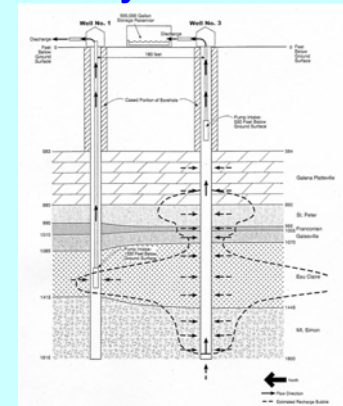
- East of the subcontinental divide in Milwaukee area to
- limit continued expansion of cone of depression
 - meet increasing demands
 - avoid treatment for radium

First ASR proposal in WI by Oak Creek

Treatment plant for lake water near limit to meet peak summer demand

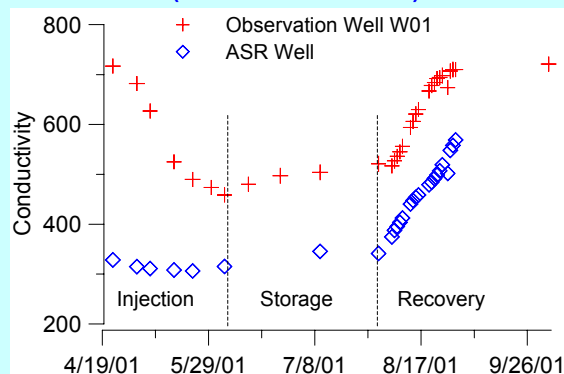
Existing wells no longer used for production because of high radium proposed for conversion to ASR wells

Pilot cycle testing approved by WI DNR

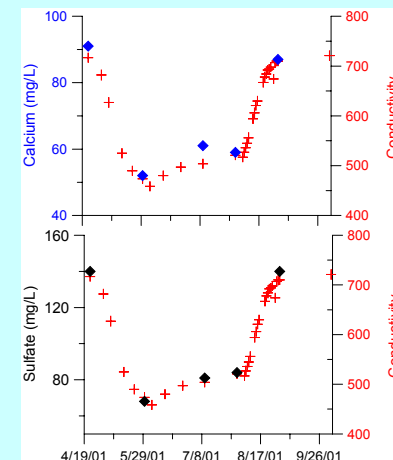


Consultant prediction of flow patterns at Oak Creek ASR

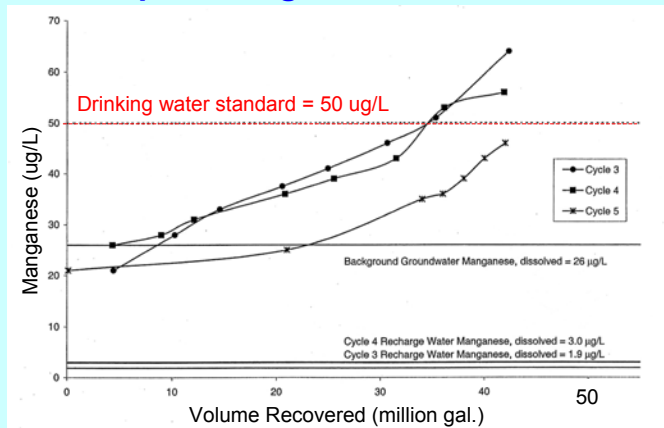
Mixing of ambient and injected water inferred from conductivity record (Data from CH2MHill)



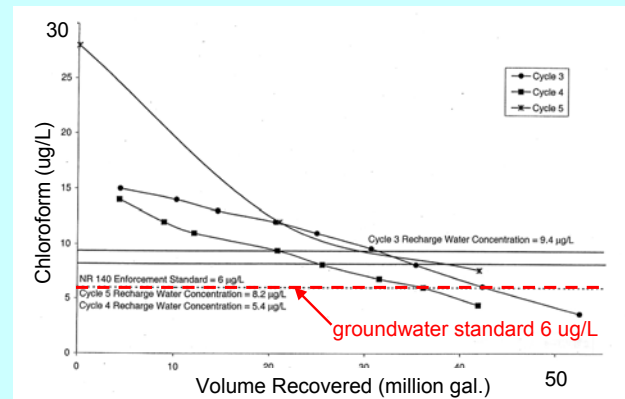
Calcium and sulfate parallel conductivity



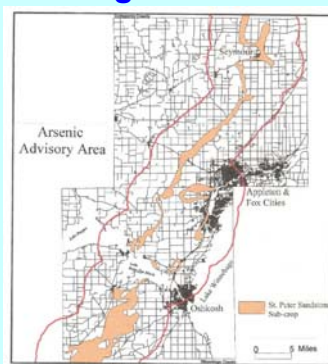
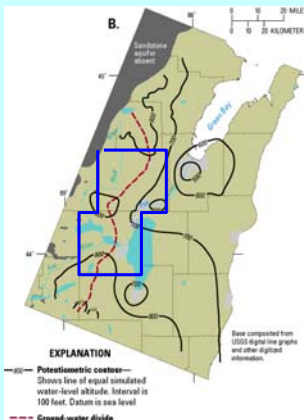
Quantification of mixing required to interpret manganese mobilization



Mixing effects also required to assess fate of disinfection products



Green Bay WI also proposed ASR to store treated Lake Michigan Water

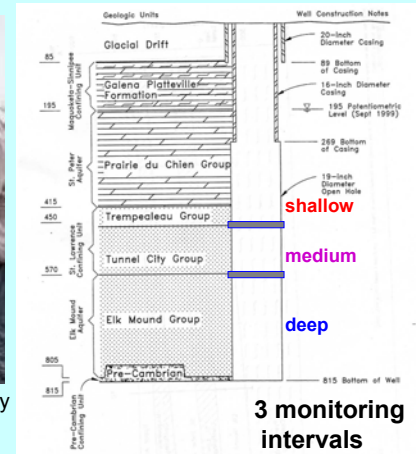


Arsenic mobilization by introduction of oxygen

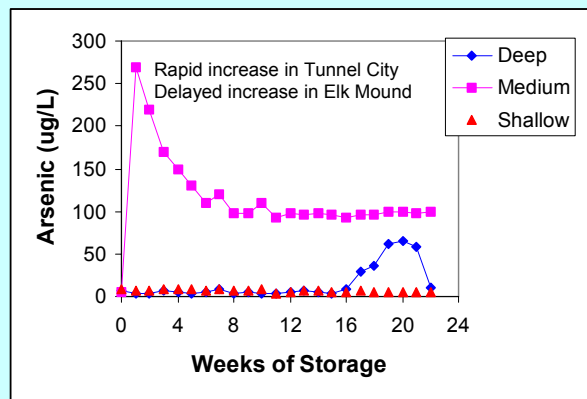
Green Bay Well 10



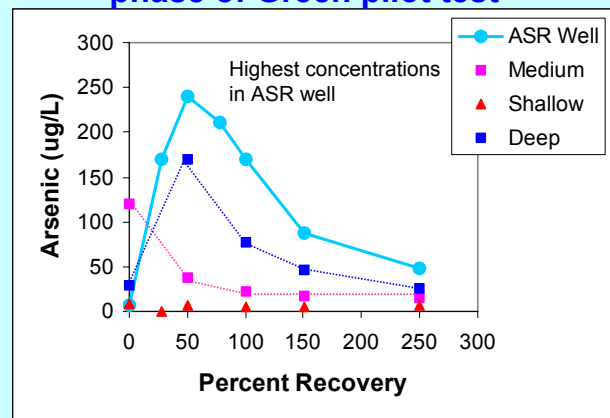
Borehole flowmeter logging by WGNHS to identify possible preferential flow zones



Arsenic concentrations during storage phase of Green Bay pilot test

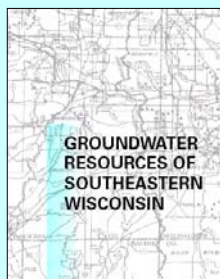


Arsenic concentrations during recovery phase of Green pilot test

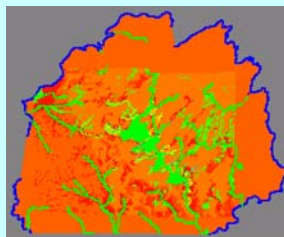


Scientific studies, data, and tools needed to evaluate sustainability

- Regional hydrostratigraphy



- Regional scale flow models



Dane County Model

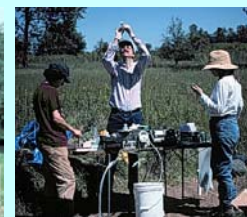
- Collection of site specific data



Flow and water level measurements

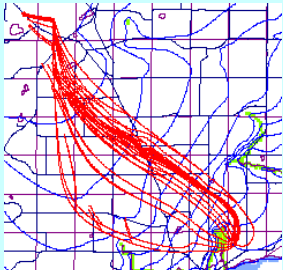


Drilling, monitoring well installation and testing

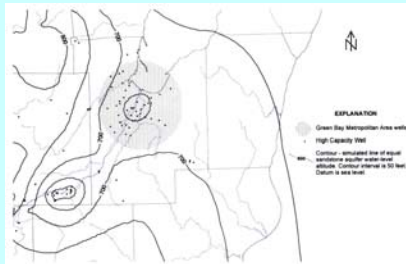


Chemical and isotopic analyses

- Local scale modeling to test conceptual models and predict impacts



Capture zone of proposed well near springs



Simulated water levels near Green Bay with ASR system