Stormwater to baseflow?

Investigating surface-groundwater interactions in Minnehaha Creek for stormwater management and ecosystem enhancement

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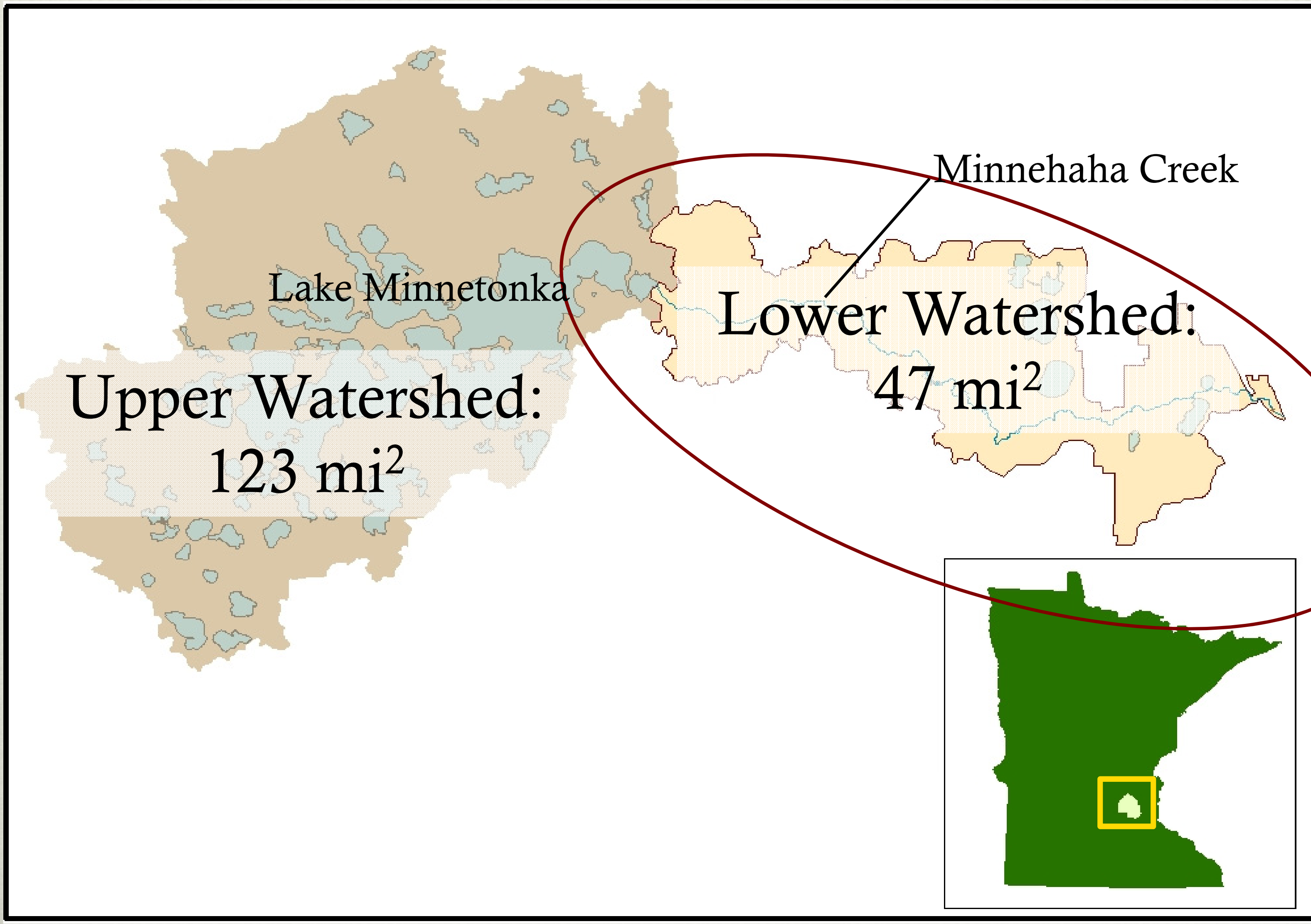
Midwest Groundwater Association Conference 10.01.12

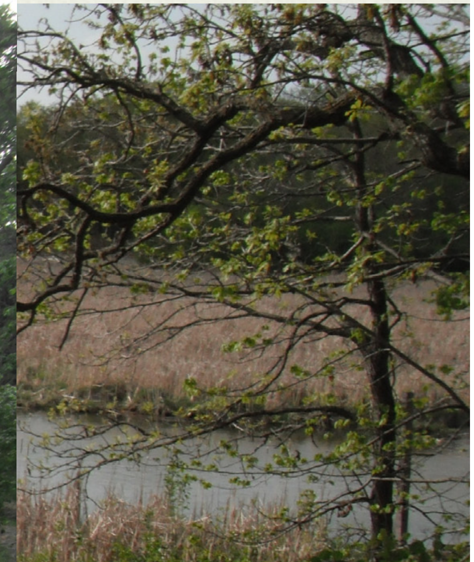
Stormwater to baseflow?

- John Gulliver (Civil Eng./SAFL), John Nieber (Bioproducts and Biosystems Eng.) and Joe Magner (Bioproducts and Biosystems Eng.)
- Minnehaha Creek Watershed District
- Mississippi Watershed Management Organization

Minnehaha Creek Watershed

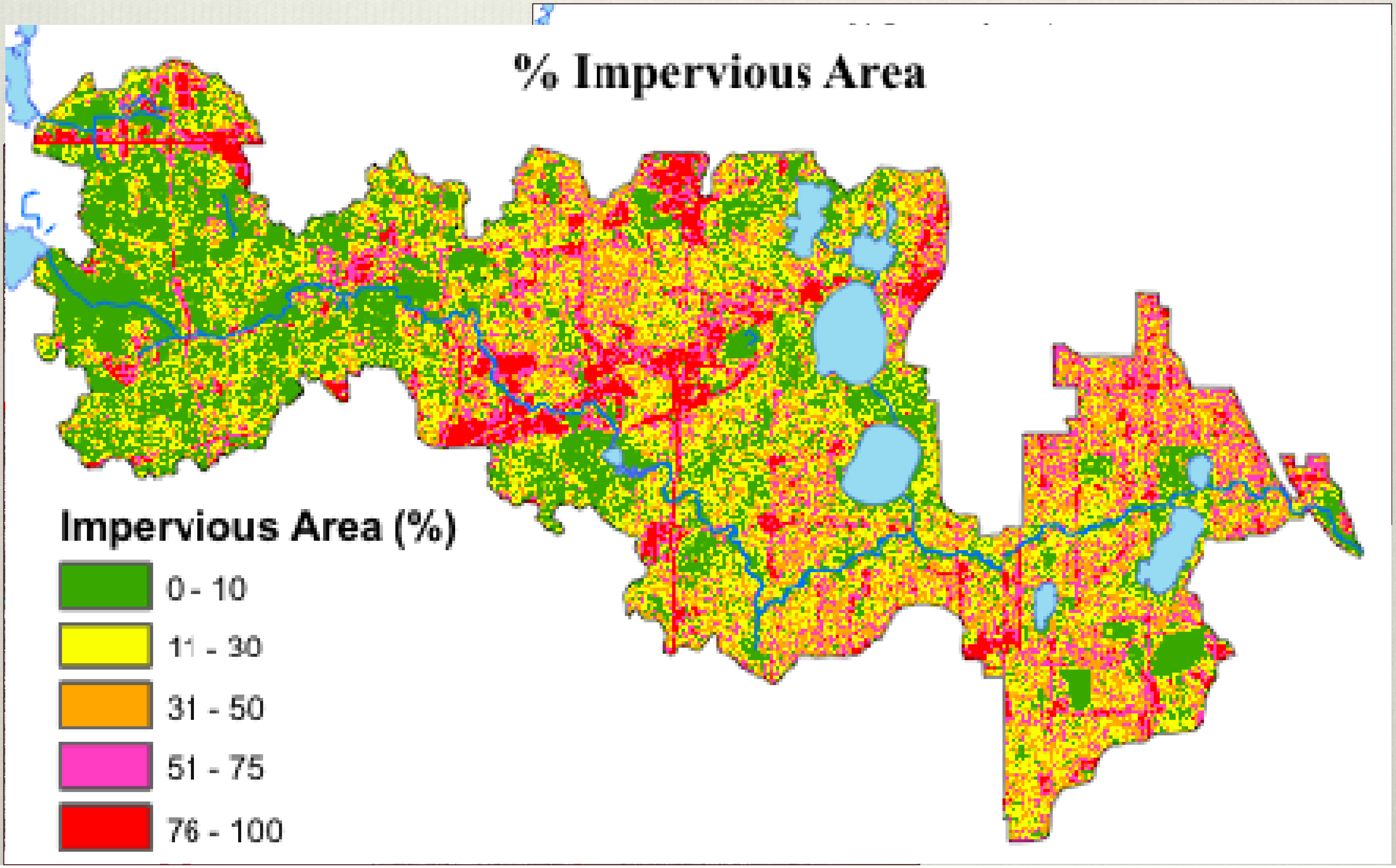





Hydrologic alterations:

Urban runoff management

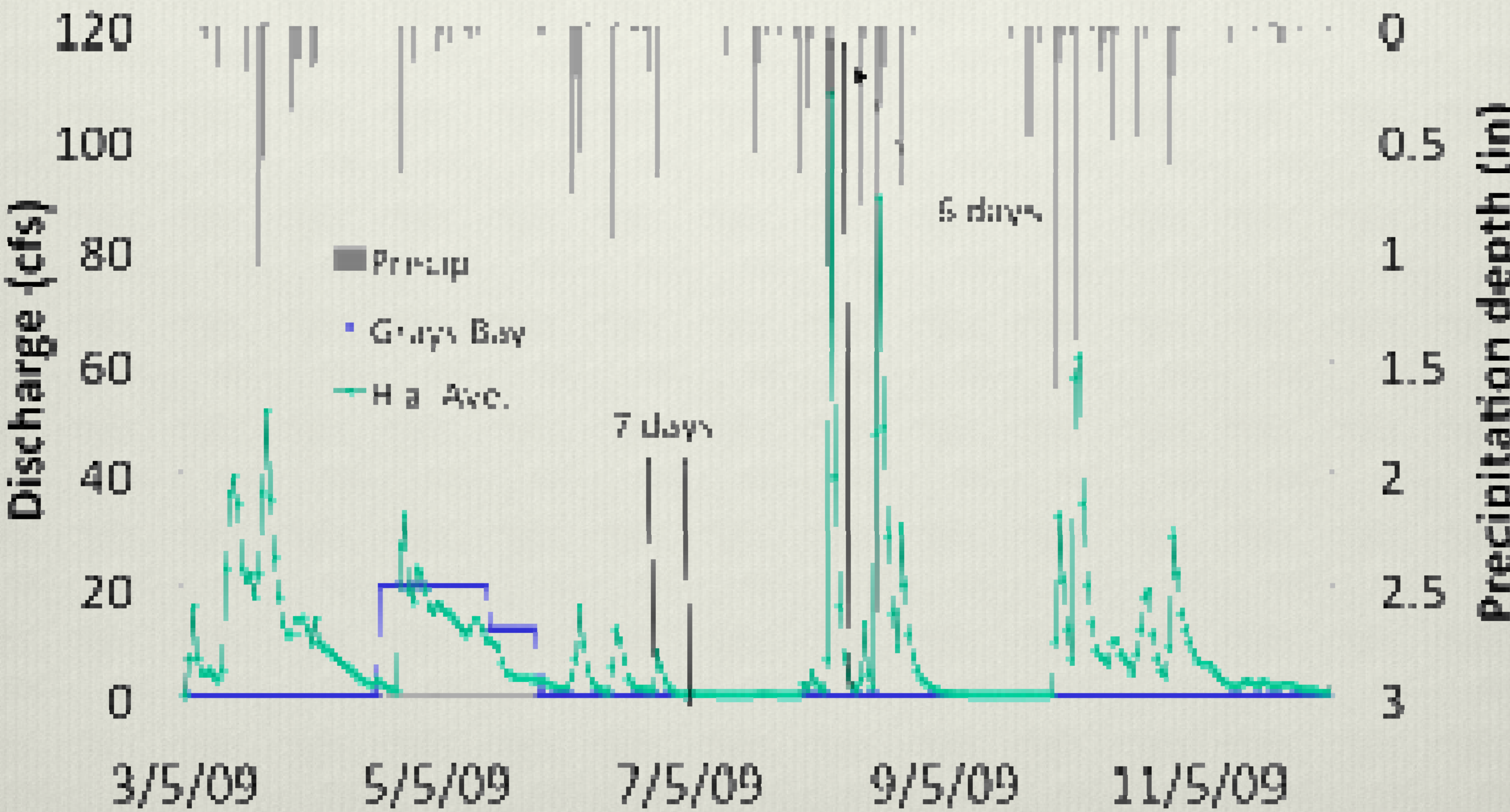


Hydrologic alterations:

Headwaters Regulation

Hydrologic alterations:

Resulting flashy hydrology



A waterfall with no flow?

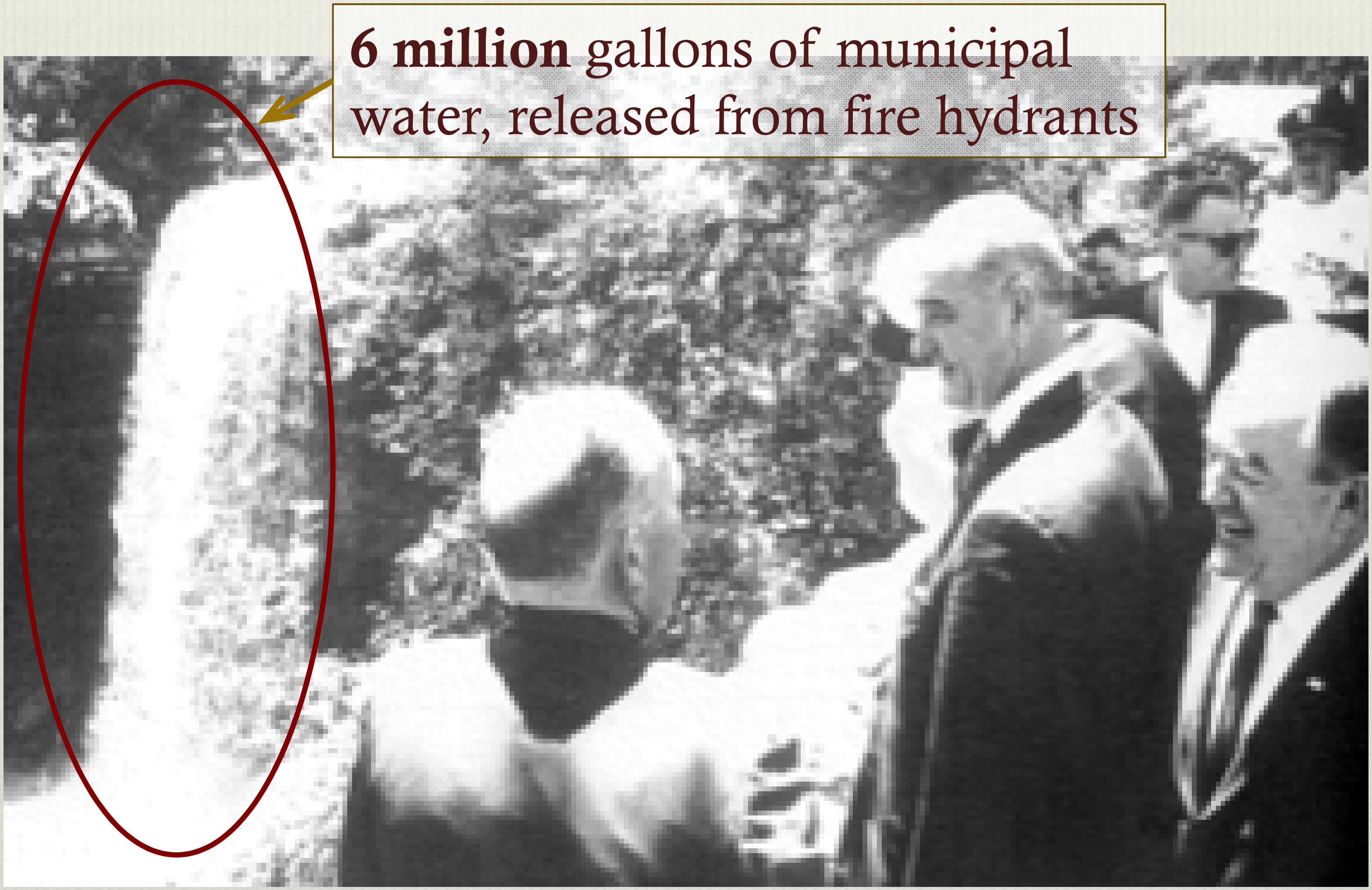


Photo credit: Star Tribune, 1964

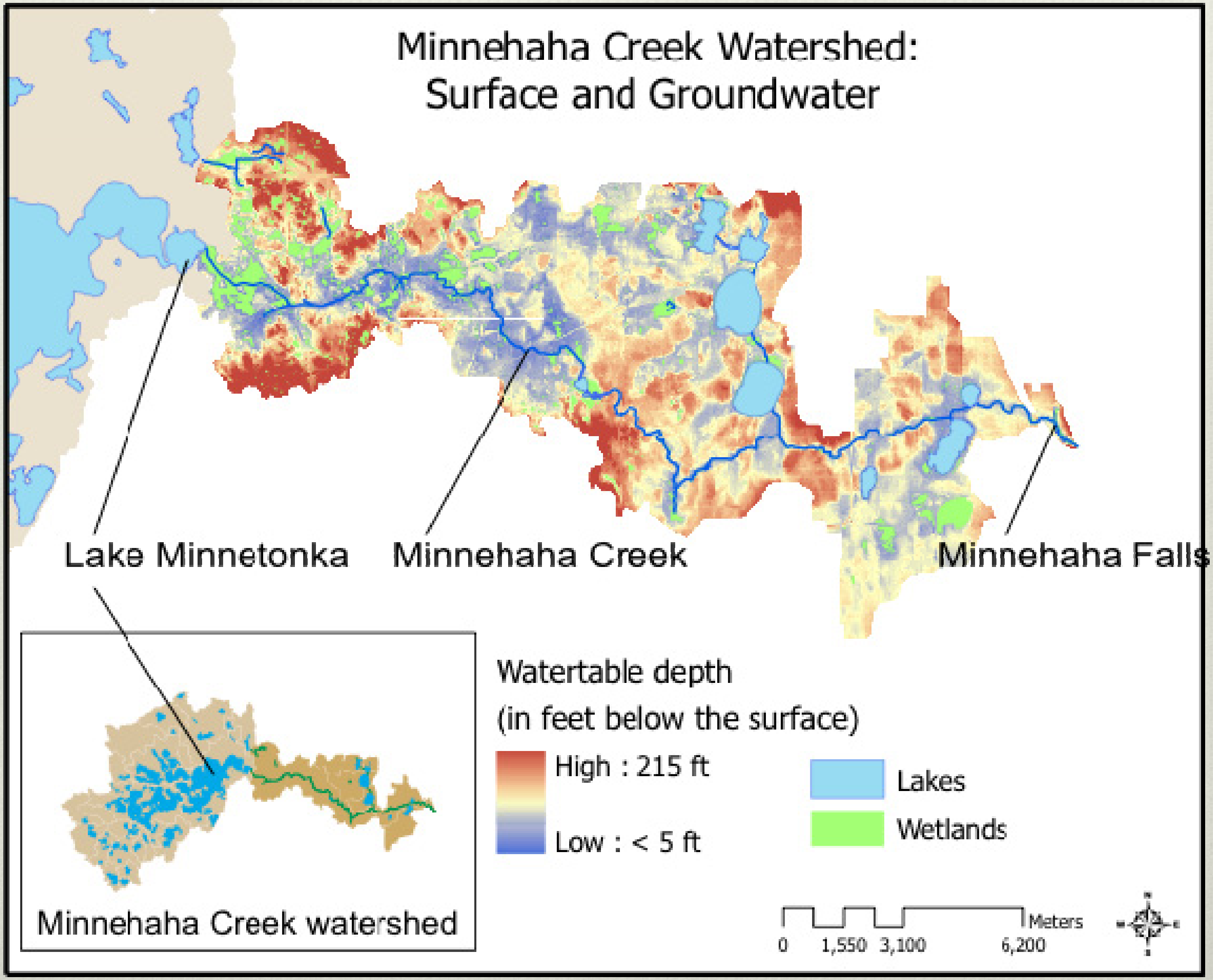
Can stormwater runoff be infiltrated to augment baseflow?

- What are the sources of flow in Minnehaha Creek? What is the relative contribution of each?
- What is the direction of groundwater flow in the vicinity of the creek?
- What is the potential to capture, store, and redistribute stormwater runoff to contribute to baseflow?

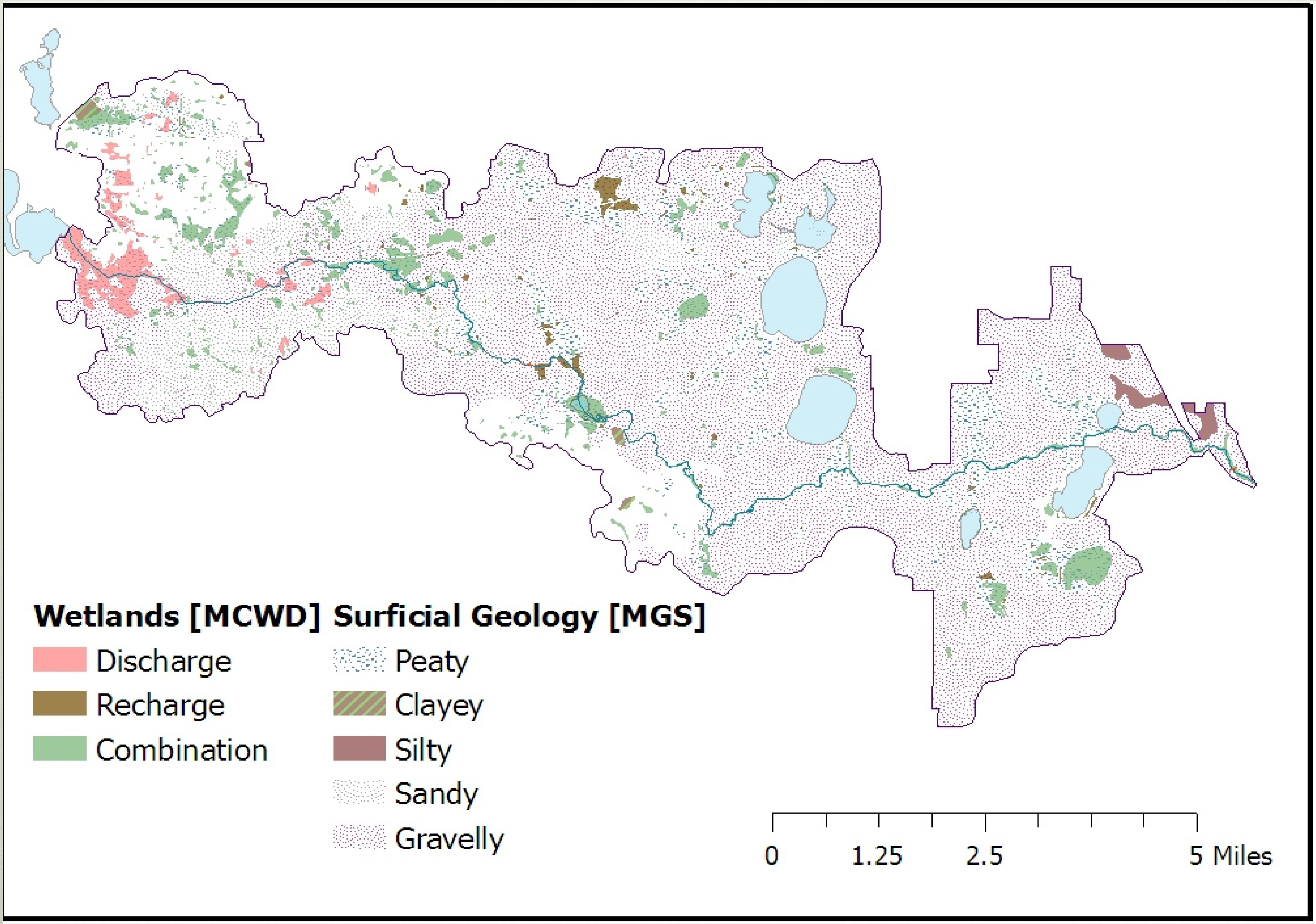
Presentation outline

- Survey of potential baseflow sources to creek
- Overview of watershed geology and hydraulic characteristics
- Preliminary field results to quantify surface-groundwater interactions in stream
  - Isotope analysis – identify flow sources
  - Seepage meters – measure groundwater fluxes
  - Piezometers – establish hydraulic gradients
  - Temperature – thermal profiles as groundwater tracer

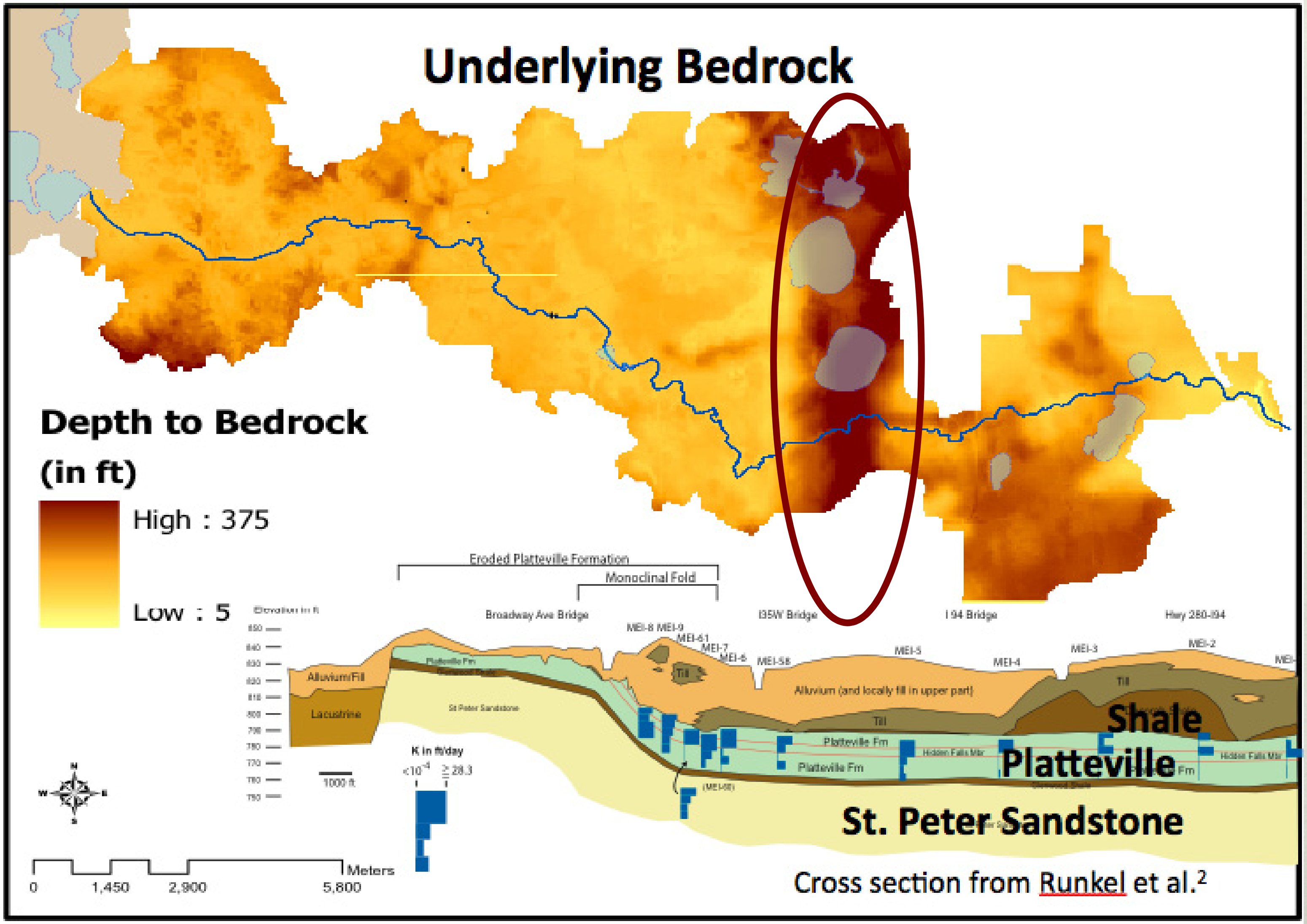
Surface and groundwater features



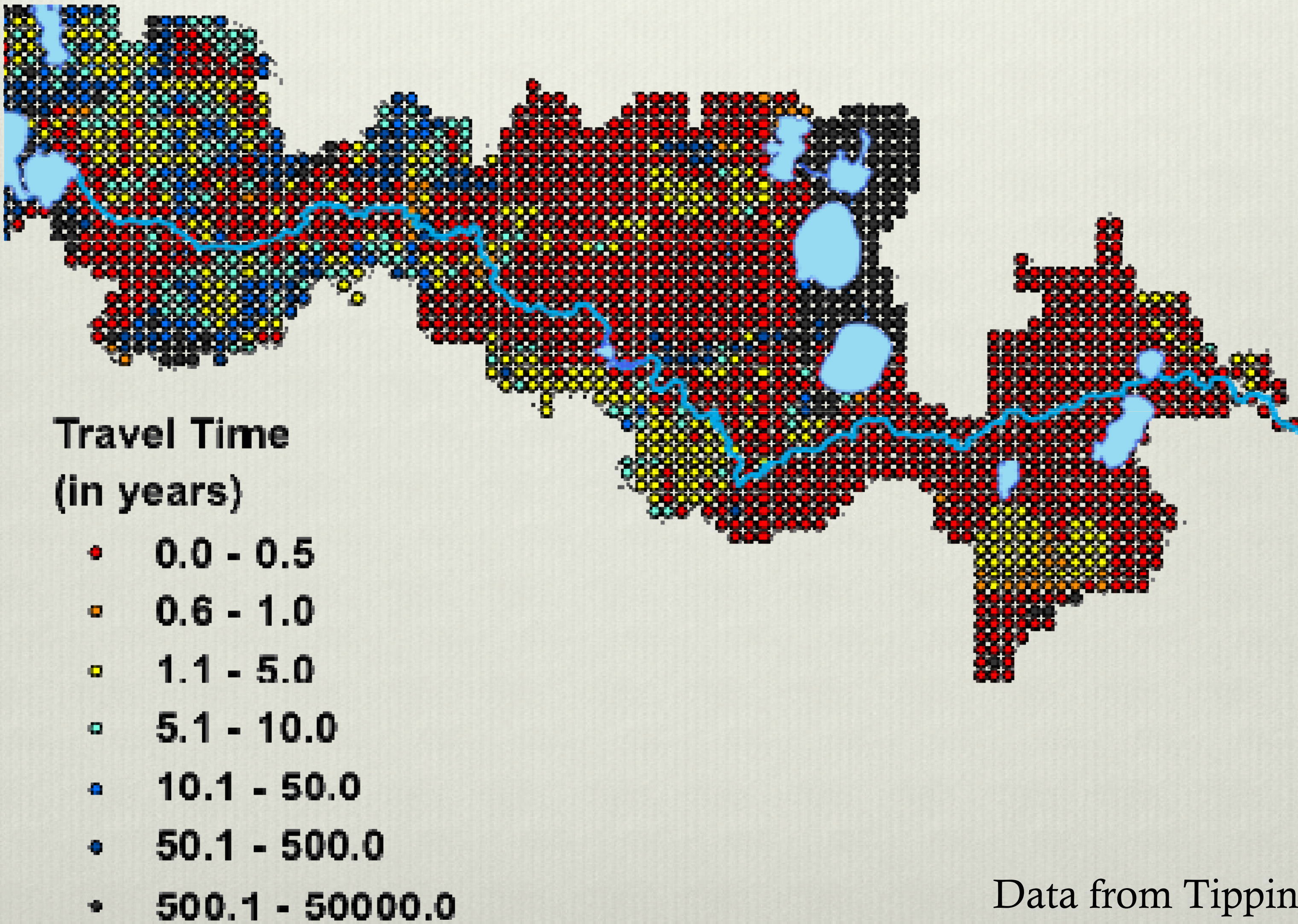
Minnehaha Creek wetland inventory



Watershed geology



Watershed geology : Rapid vertical transit through quaternary aquifer



Data from Tipping, 2011

Inferring aquifer characteristics through streamflow analysis

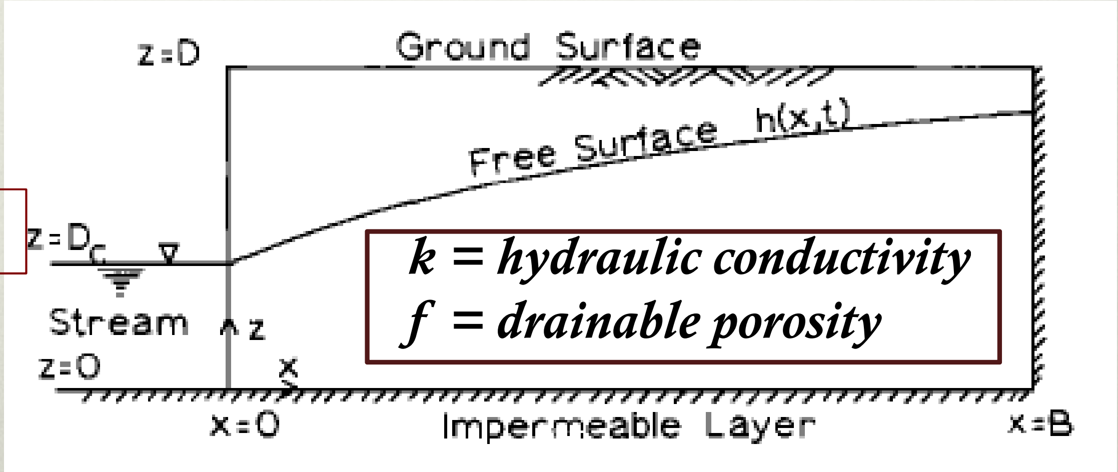
- Brutsaert and Nieber (1977) approach:
  - Relates ΔQ/Δt with watershed and aquifer parameters

$$-dQ/dt = aQ^b$$

$$a = 4.8k^2 L / f(\alpha A)^{3/2}$$

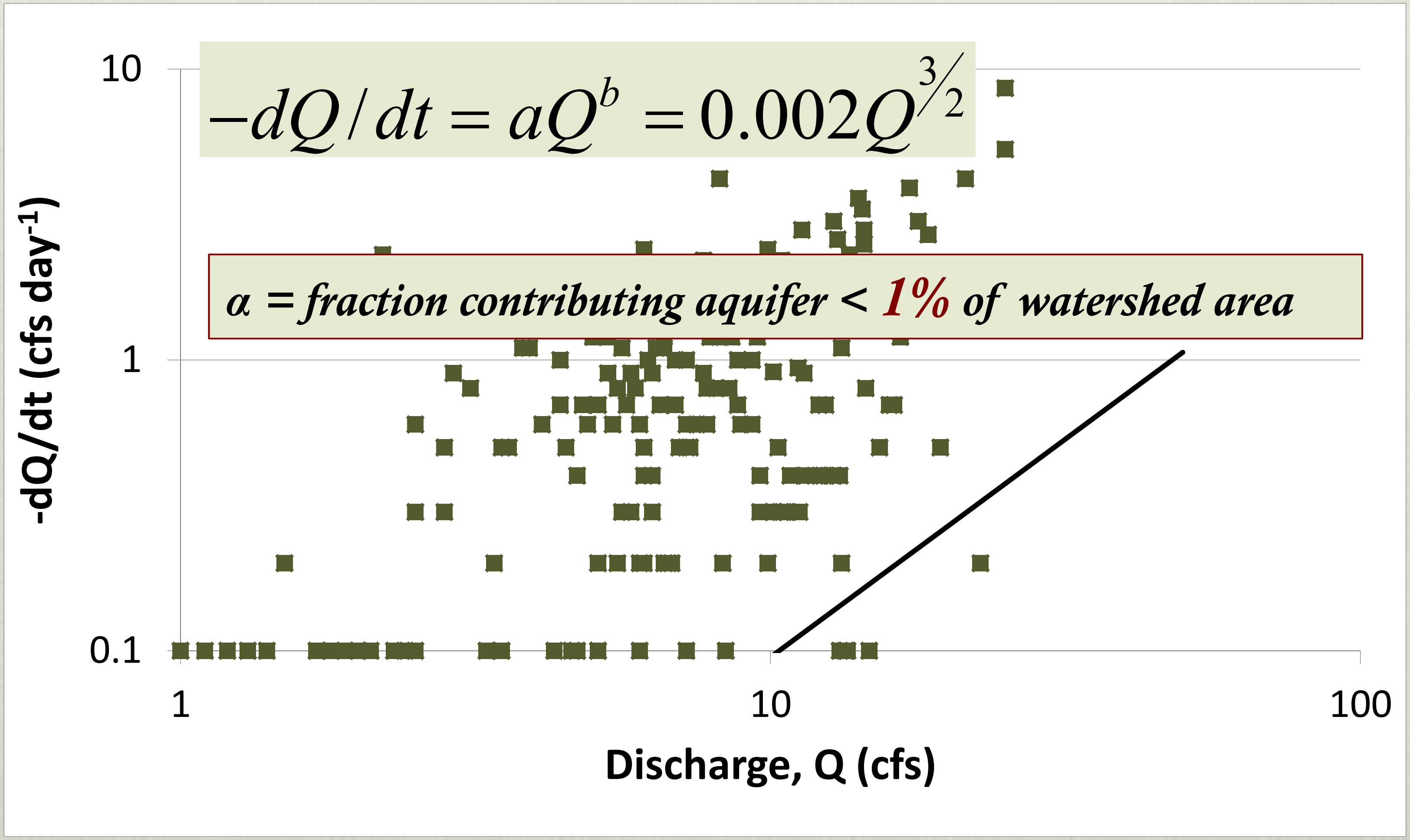
L = total stream length
A = watershed area

α = fraction contributing aquifer



k = hydraulic conductivity
f = drainable porosity

Inferring aquifer characteristics through streamflow analysis

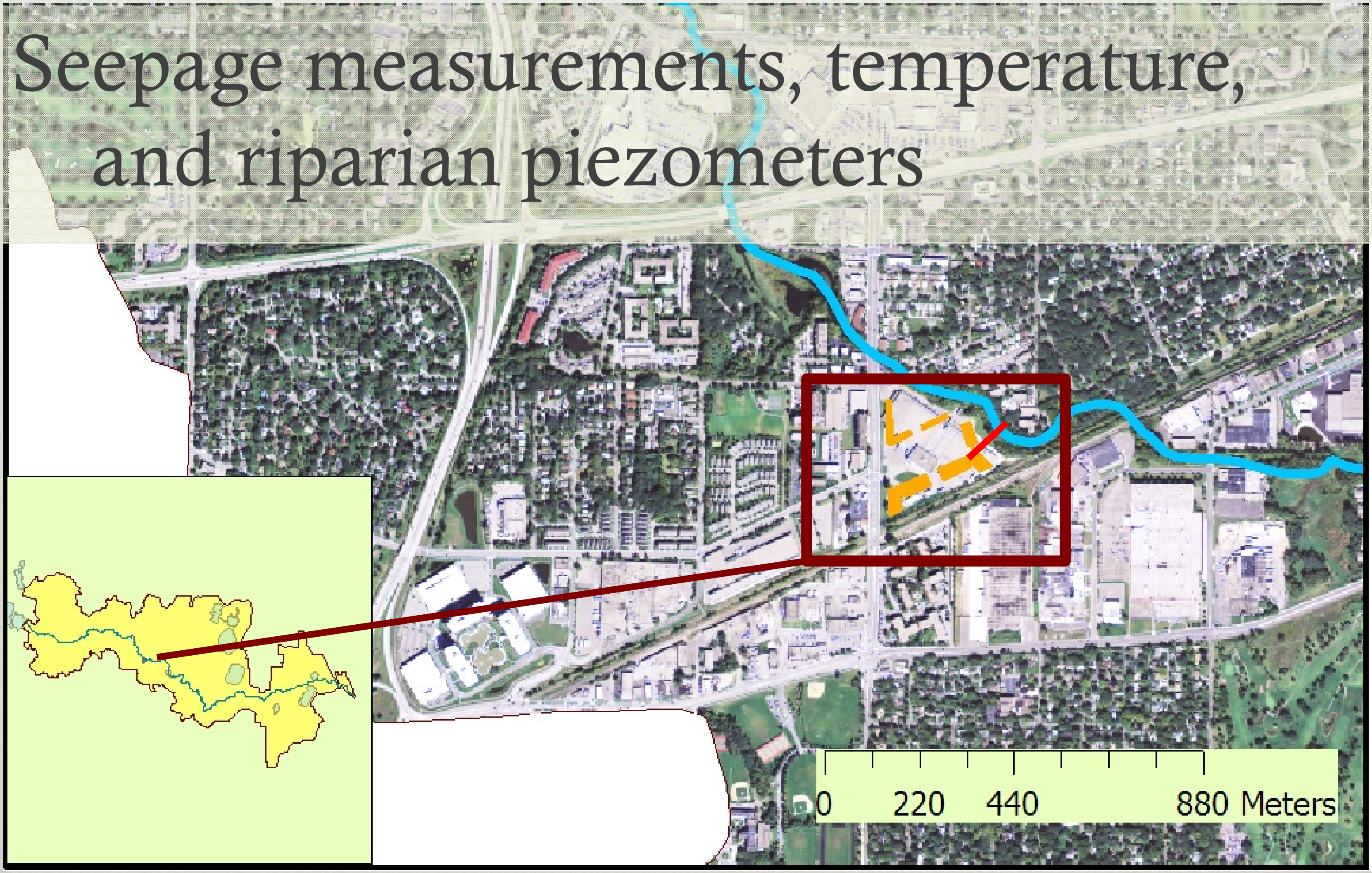


Surface-groundwater interactions: field approaches

- Isotope analysis
- Seepage measurements
- Well installation/piezometer installation
- Temperature

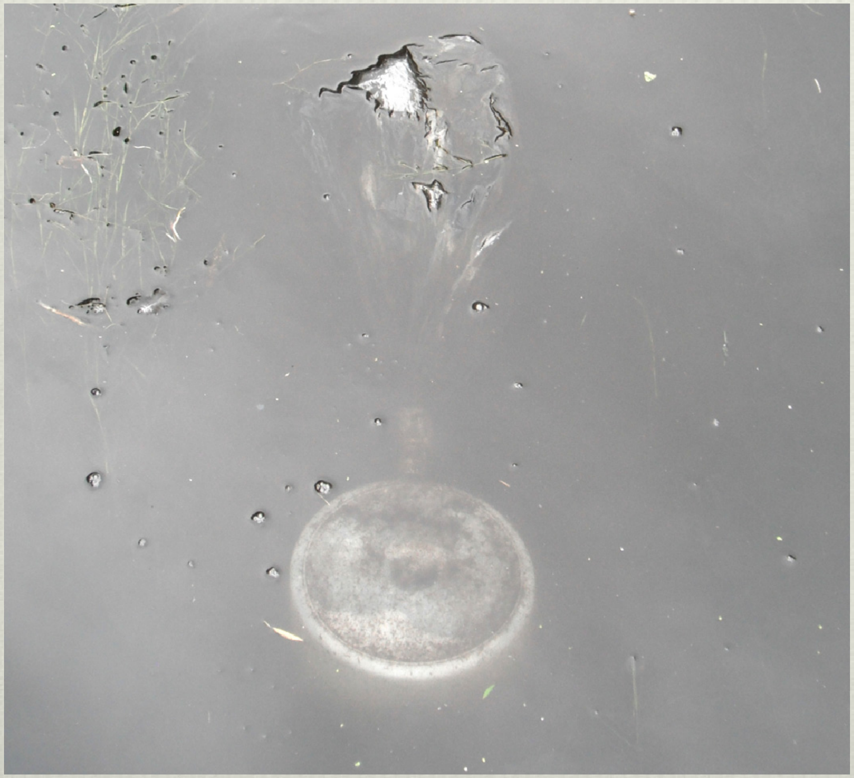
Drilling down to the site scale…

Seepage measurements, temperature, and riparian piezometers

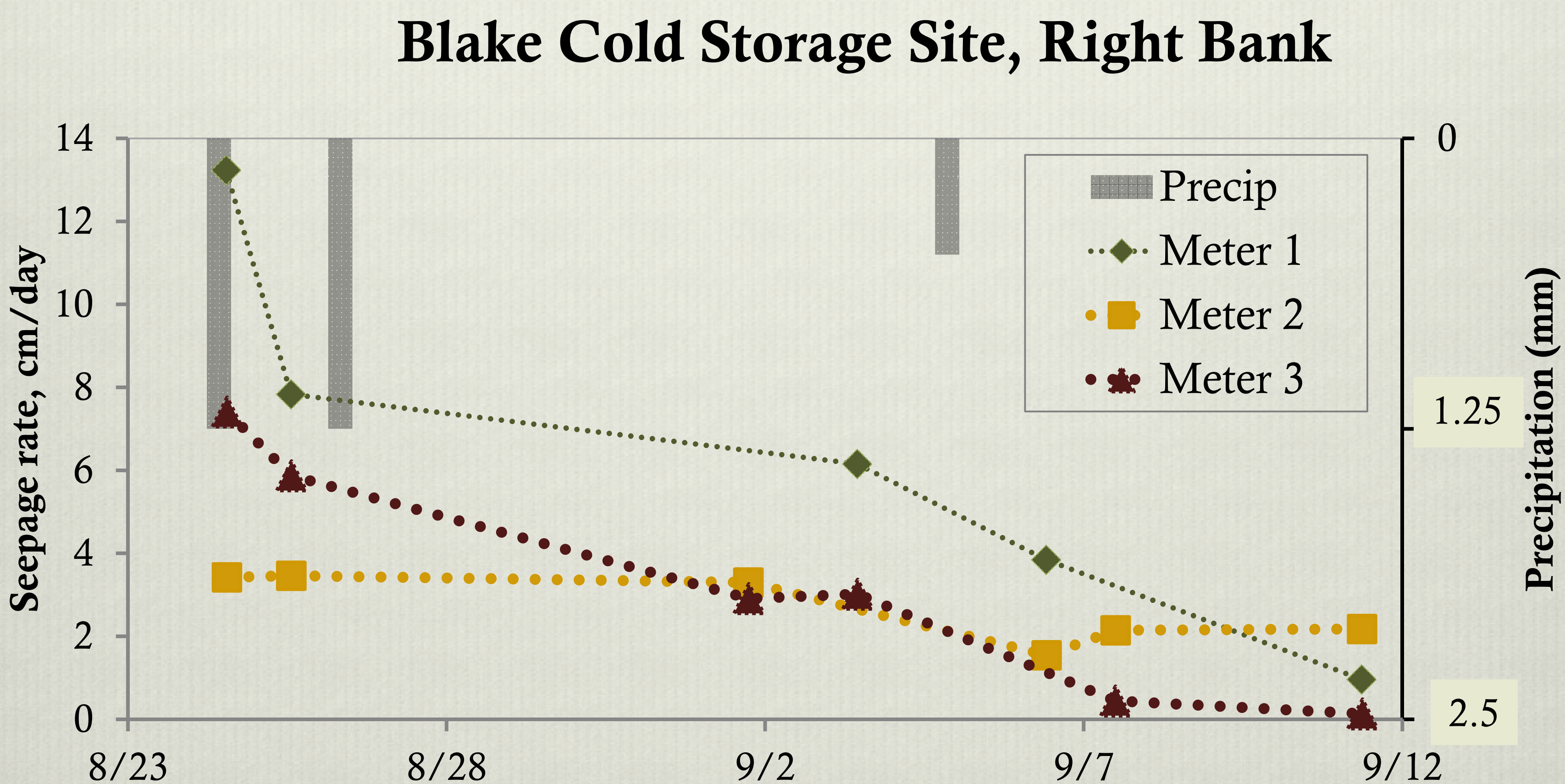


Seepage Measurements

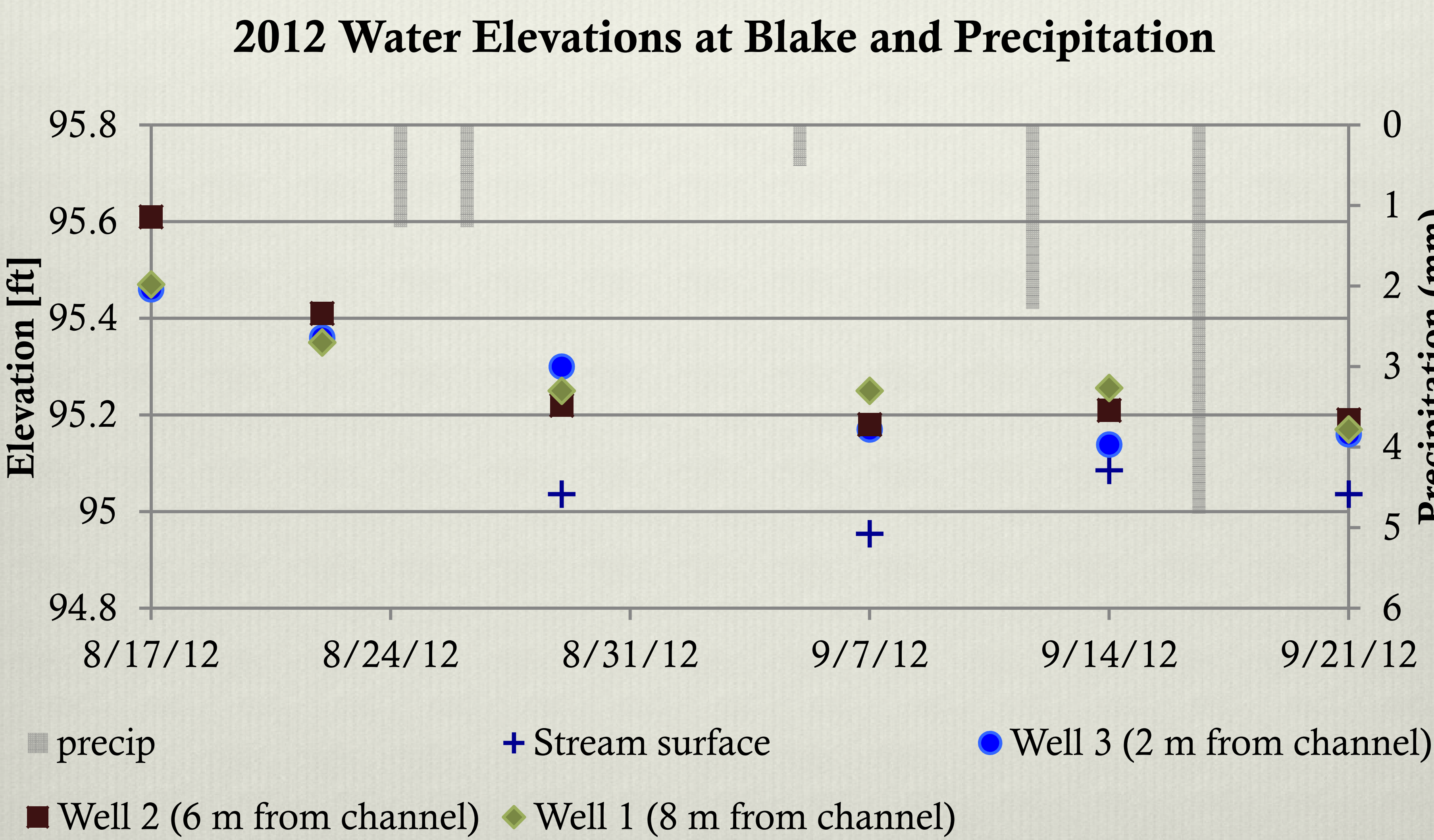
- Allows direct measurement of groundwater fluxes in streambed



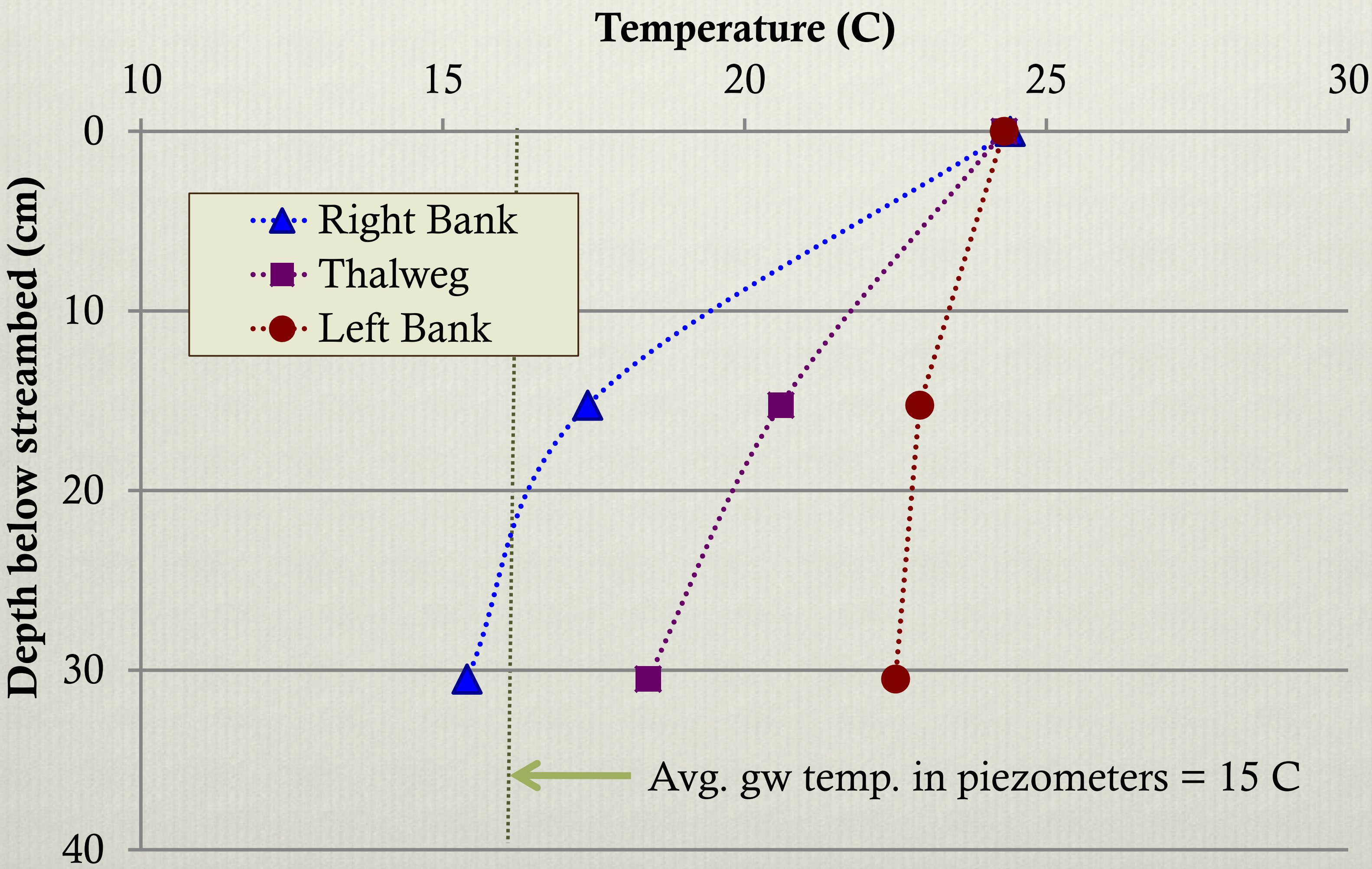
Preliminary seepage results:
Decline with time during dry period



Corroborating with piezometer data



Corroborating temperature…



Streambed temperature profiles to estimate groundwater flux

❖ 1D, steady-state heat transfer:

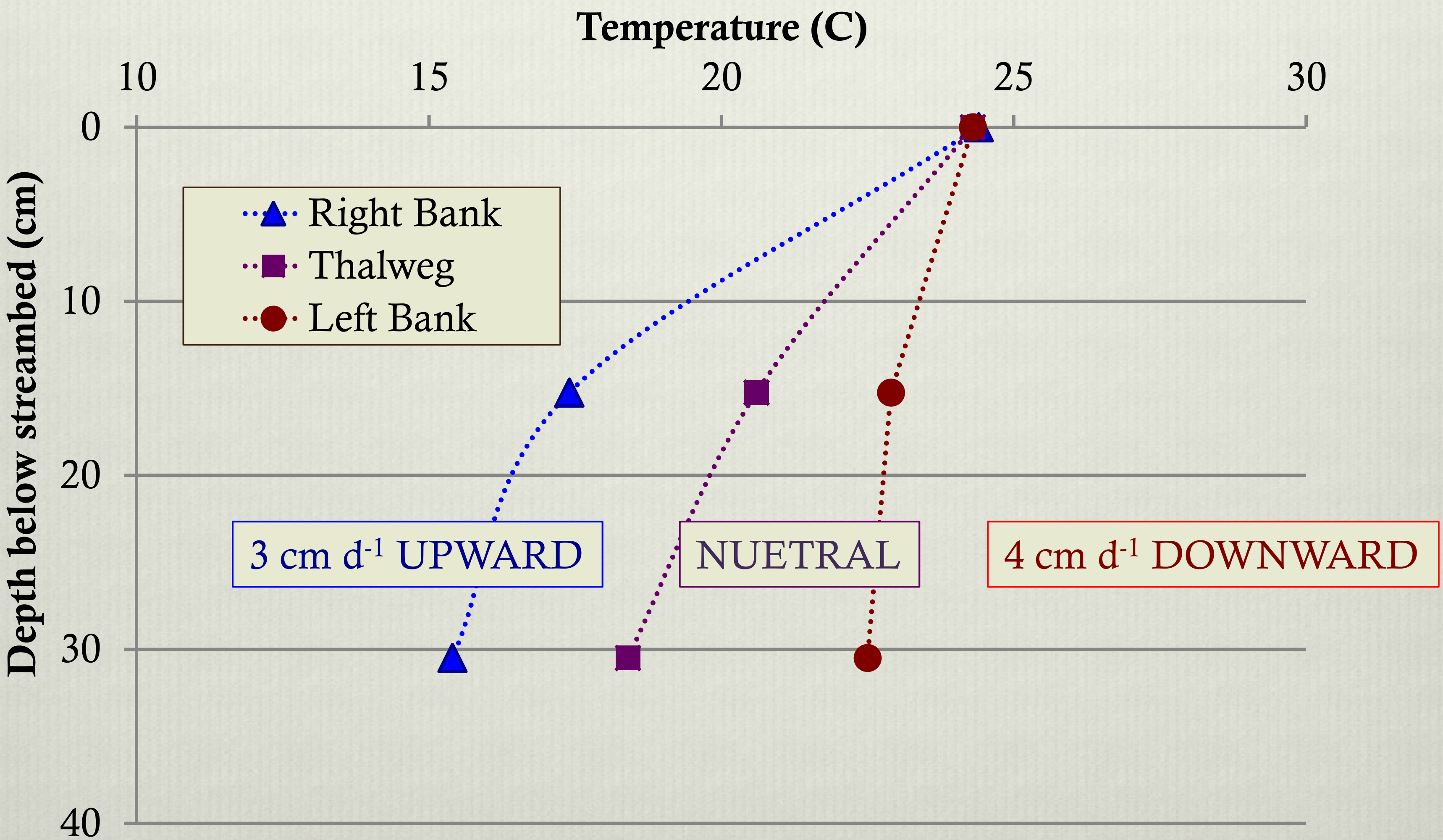
$$q_z \frac{\partial T}{\partial z} = \frac{k_{fs}}{\rho C_f} \cdot \frac{\partial^2 T}{\partial z^2}$$

Vertical groundwater flux

W
h
e
r
e

k

Corroborating temperature…



Summary and future work

- Sustained baseflow during drought periods likely limited by rapid vertical transit
  - Vertical travel time calculations by Tipping (2011)
  - Contributing aquifer fraction very small by Brutsaert and Nieber (1977) approach
- UPWARD discharging groundwater to creek has been observed BUT magnitude and direction varies by reach and across channel

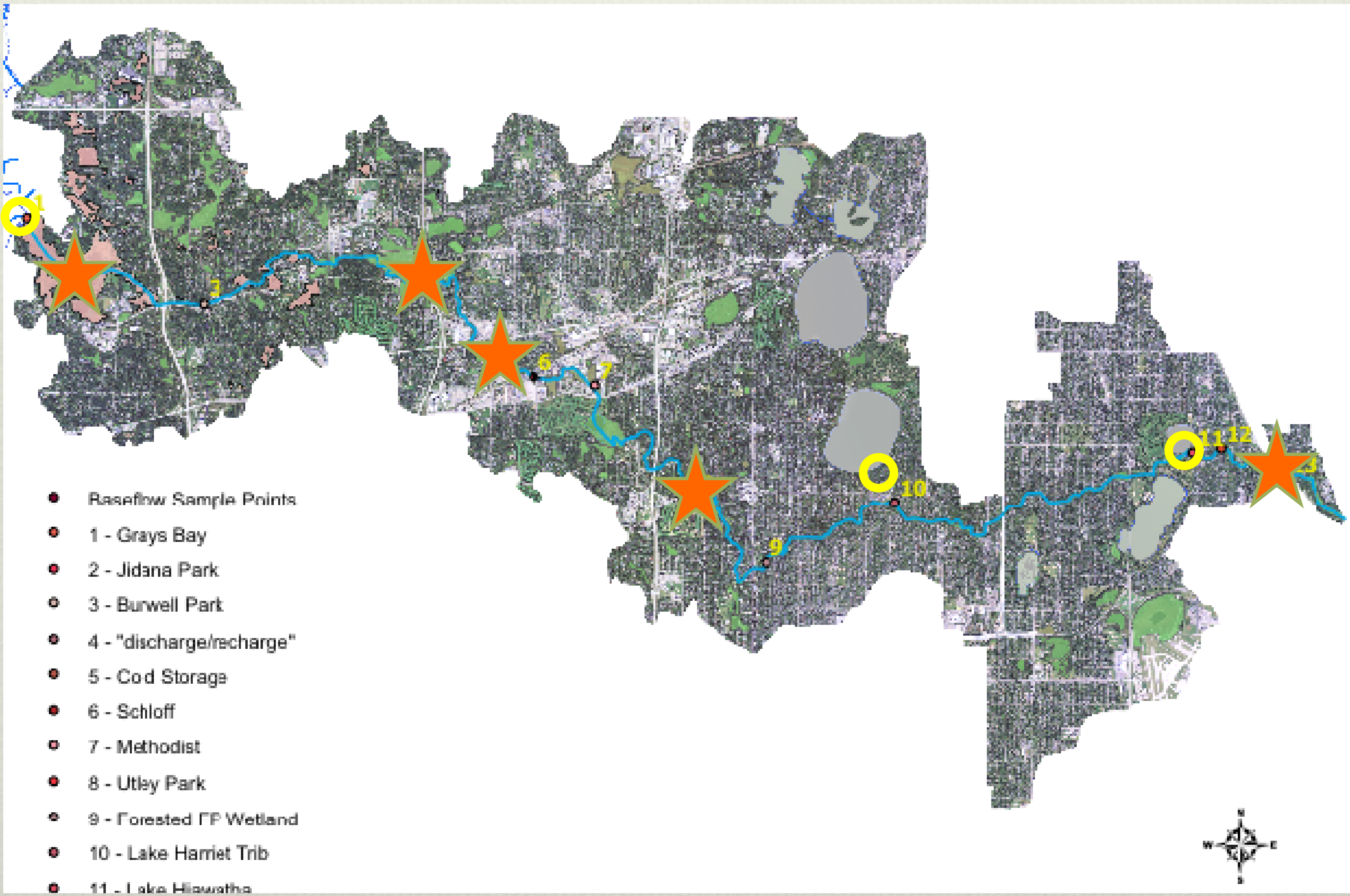
Summary and future work

- Continue temperature and seepage measurements at more locations along stream → use to identify areas with highest potential for stormwater infiltration
- Develop model to evaluate impact of total integration of infiltration practices on potential stream baseflow

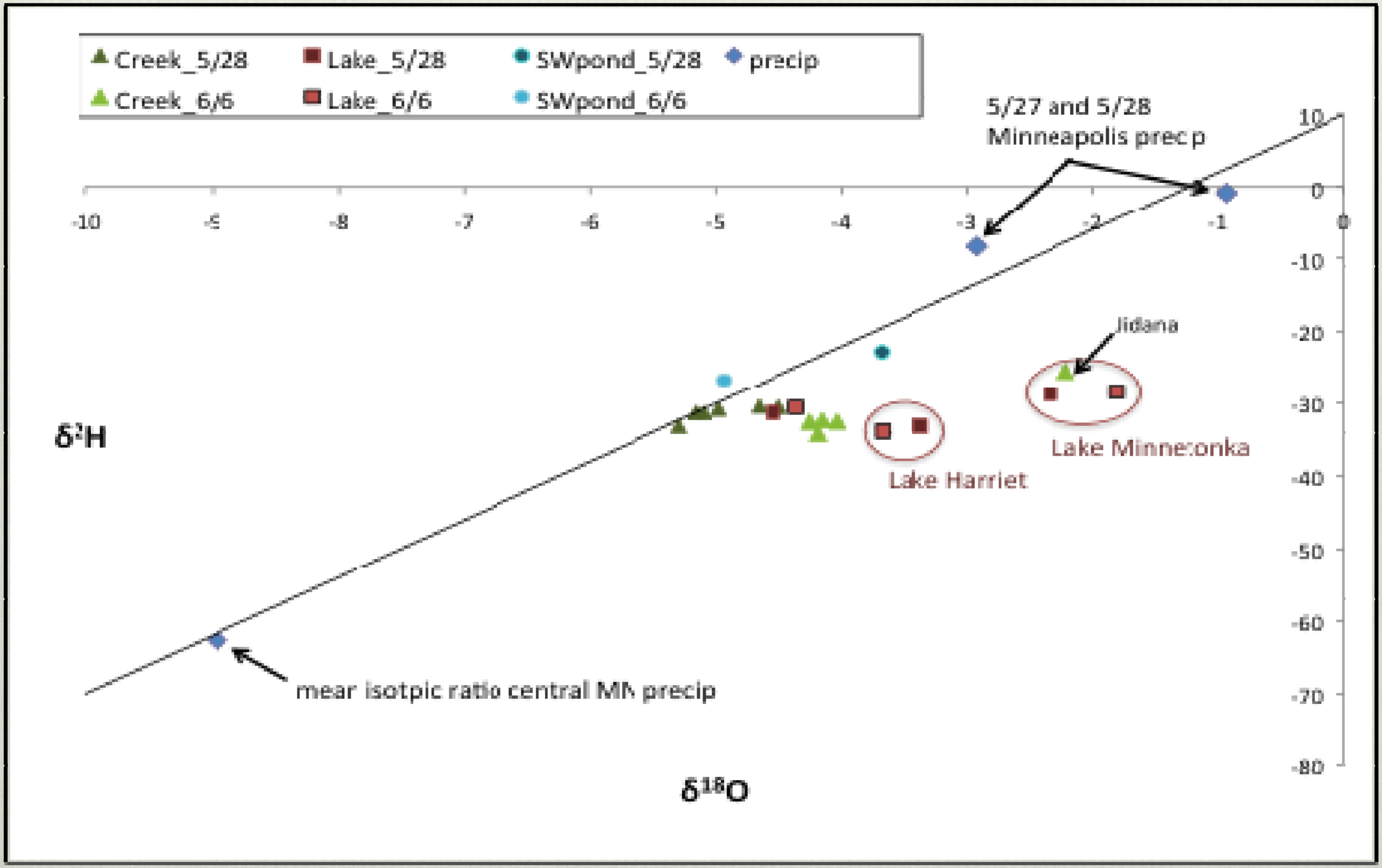
Thank you!

- Special thanks to:
  - John Gulliver, John Nieber, and Joe Magner (U of M)
  - Laina Breidenbach, Tom Dietrich, Jess DeGennero & Lauren Sampedro (U of M)
  - Perry Jones & Mike Menheer (USGS)
  - Minnehaha Creek Watershed District and Mississippi Watershed Management Organization

Isotope analysis: sampling sites



Preliminary isotope analysis: Groundwater inputs not substantial



Isotope analysis:
Continuing work

- Sampling from riparian wells and during drought flow
- Apply mixing model

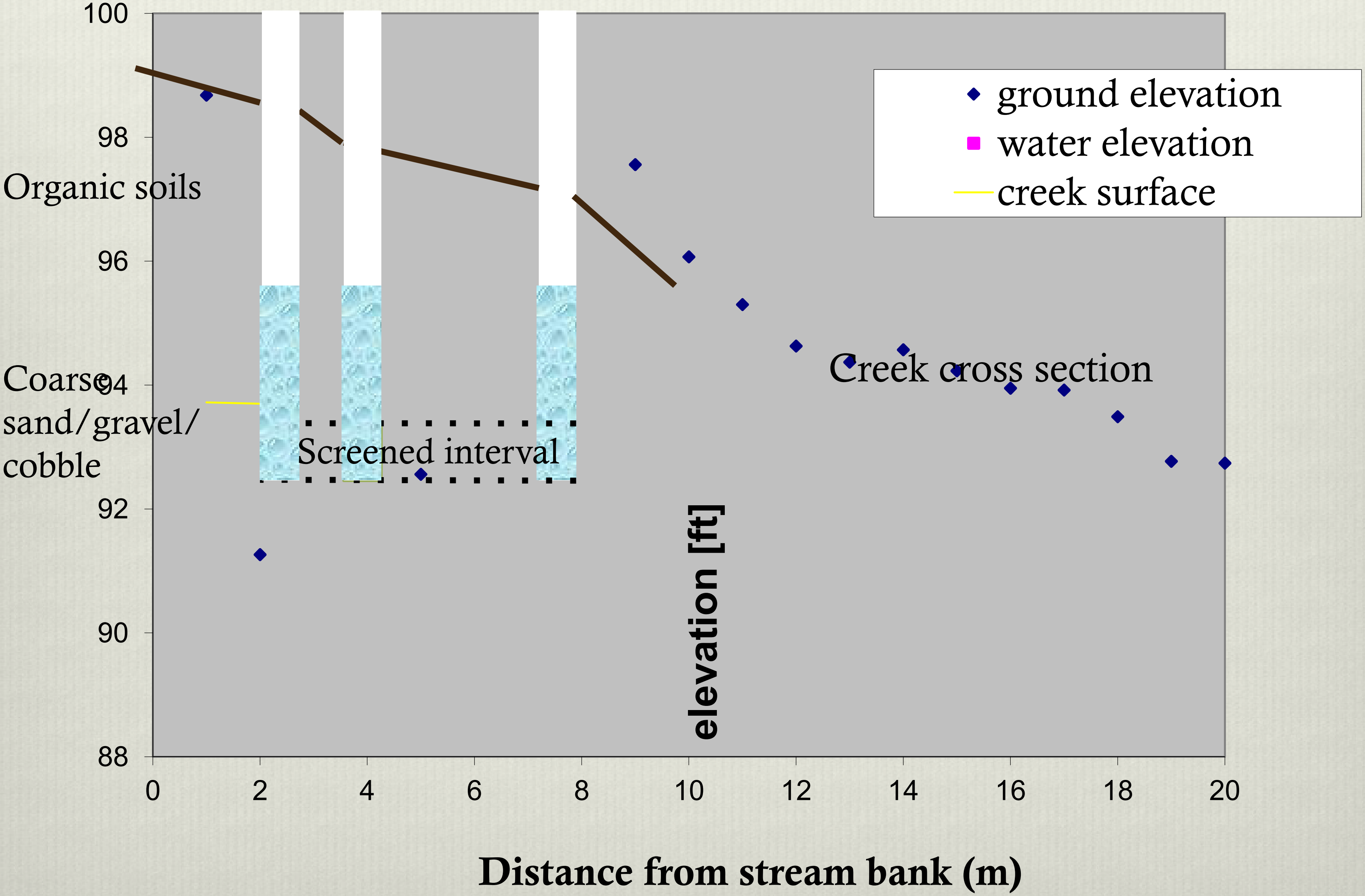
Is isotopic signature of groundwater different from that of creek and its surface water sources?

Does isotopic signature of creek reflect that of groundwater during low flow periods?

Summary – streamflow and geologic data

- Groundwater contributions to Minnehaha Creek likely small (~ 1.5 cm yr^{-1}, or average daily flow 5 cfs)
- Sustained baseflow during drought periods likely limited by rapid vertical transit
  - Contributing aquifer fraction of Brutsaert and Nieber approach
  - Vertical travel time calculations by Tipping (2011)

Piezometer installation at headwaters wetland site



Seepage measurements – past work

- Groundwater seepage measured by Lundy and Ferrey (2004) at Schloff Chemical Superfund site in St. Louis Park