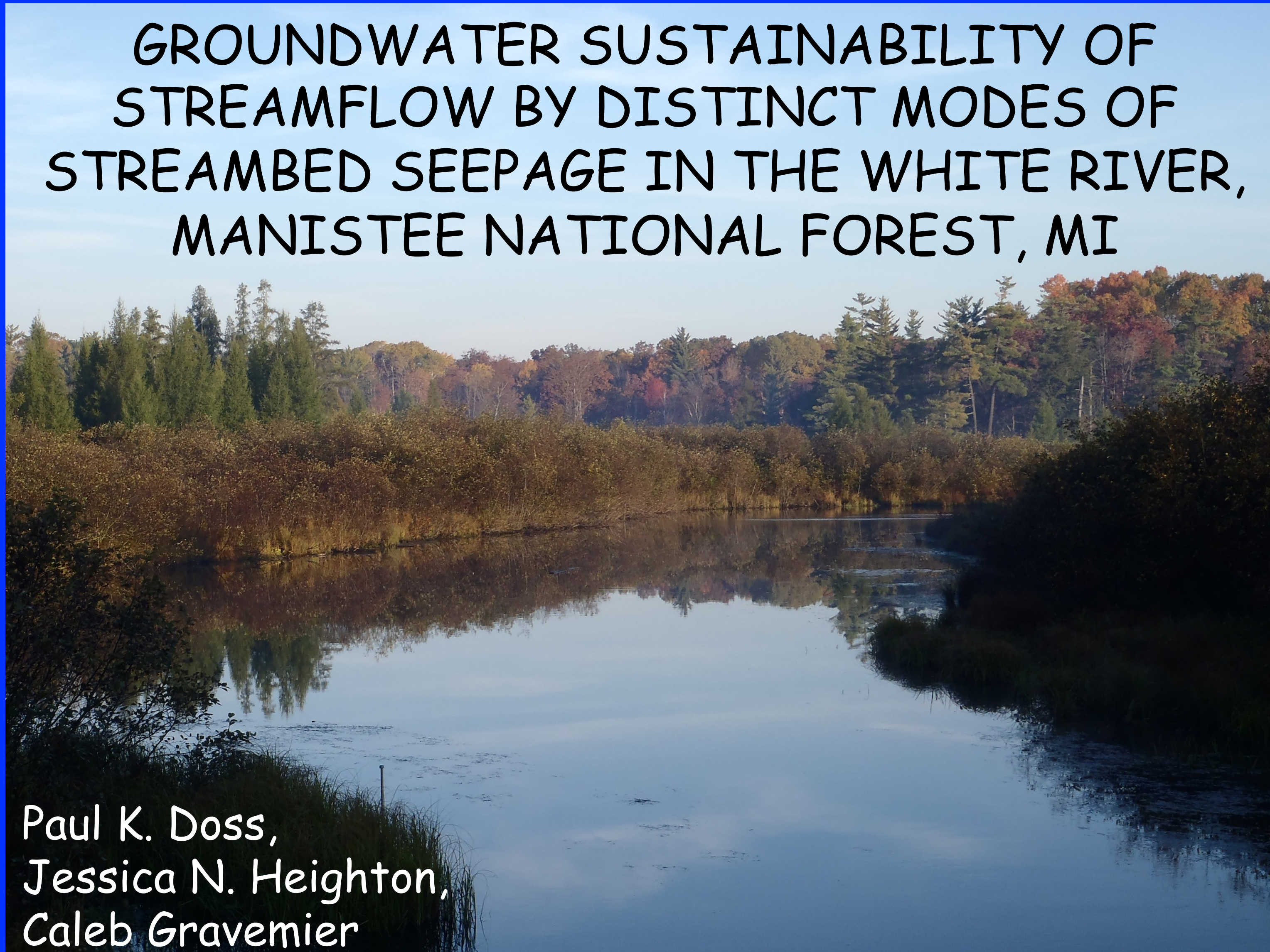

# GROUNDWATER SUSTAINABILITY OF STREAMFLOW BY DISTINCT MODES OF STREAMBED SEEPAGE IN THE WHITE RIVER, MANISTEE NATIONAL FOREST, MI

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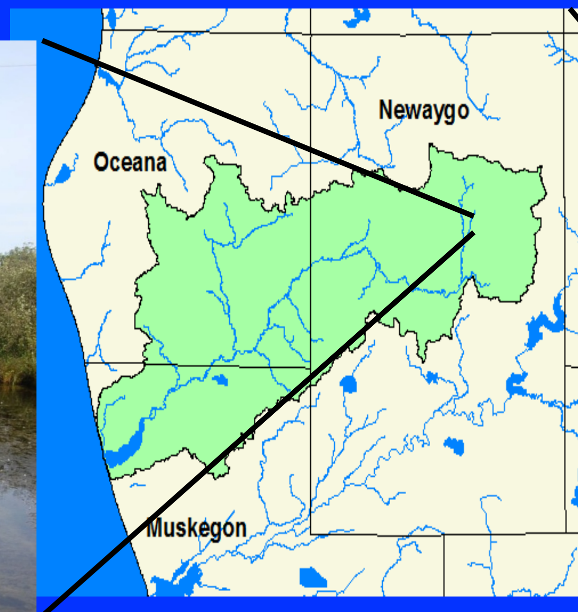
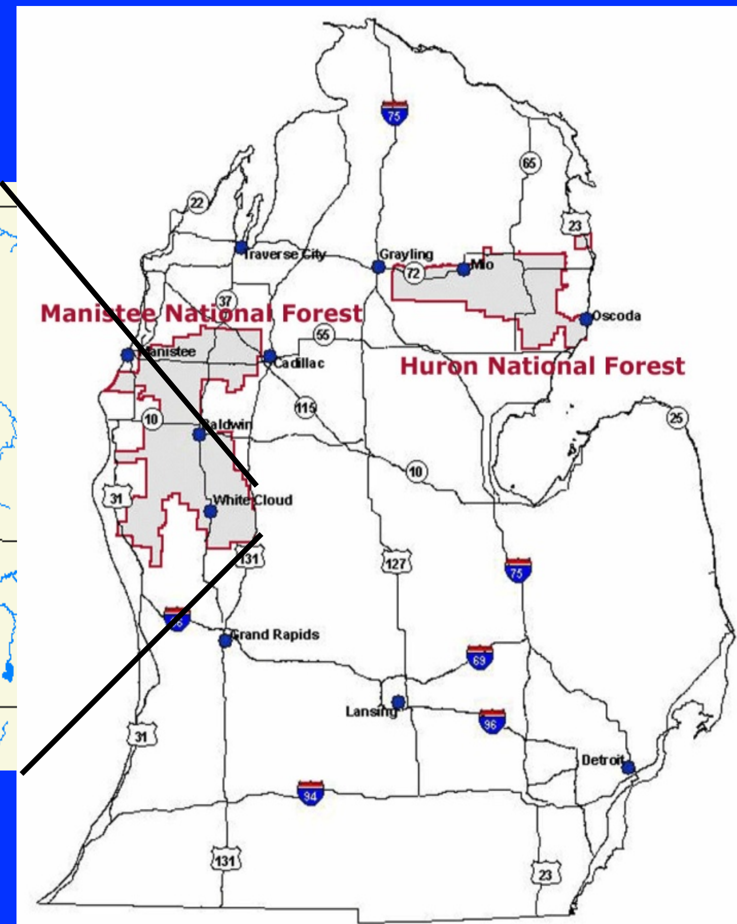
# White River in Manistee NF is Michigan State Natural River & candidate federal Wild and Scenic River

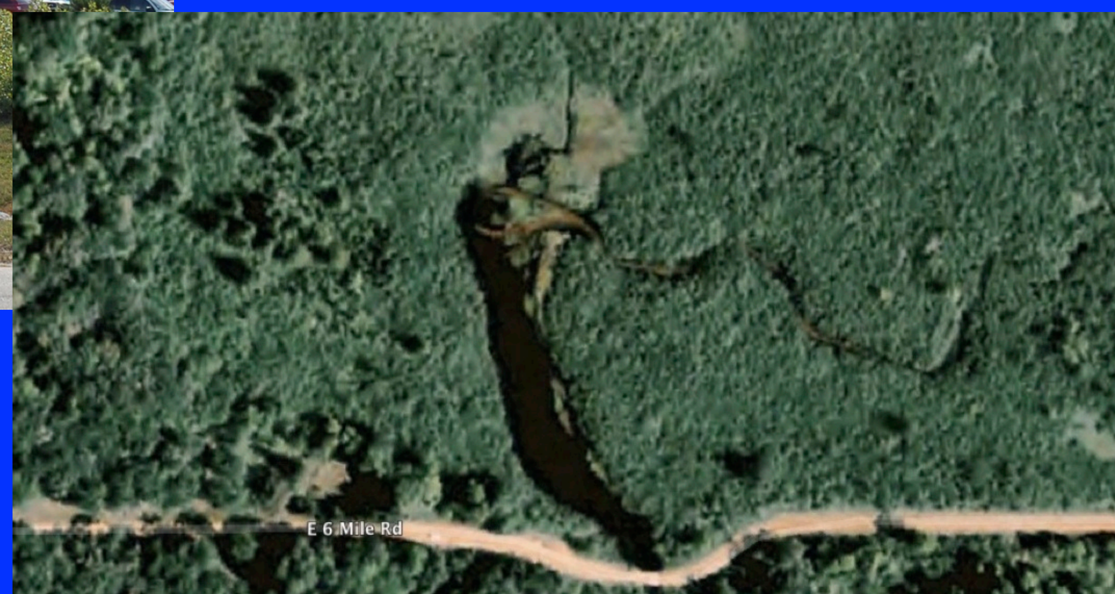


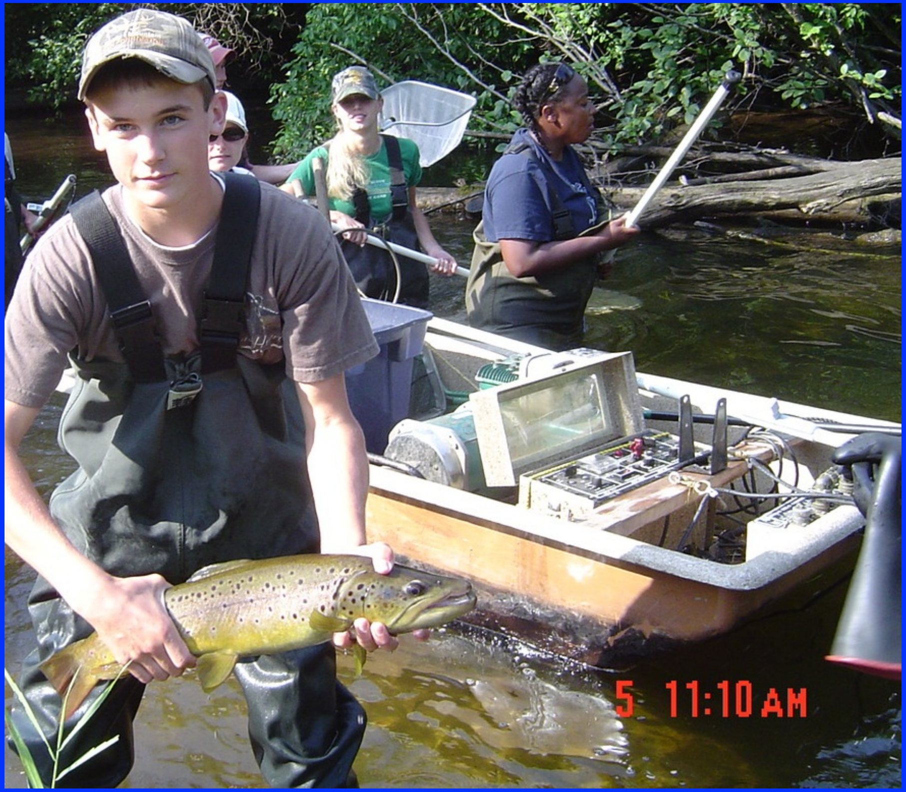

White River watershed



High profile public and regulatory “water wars” in Michigan resulted in large part from proposed commercial development and extraction of ground water resources:


White River headwaters
“The Pool”

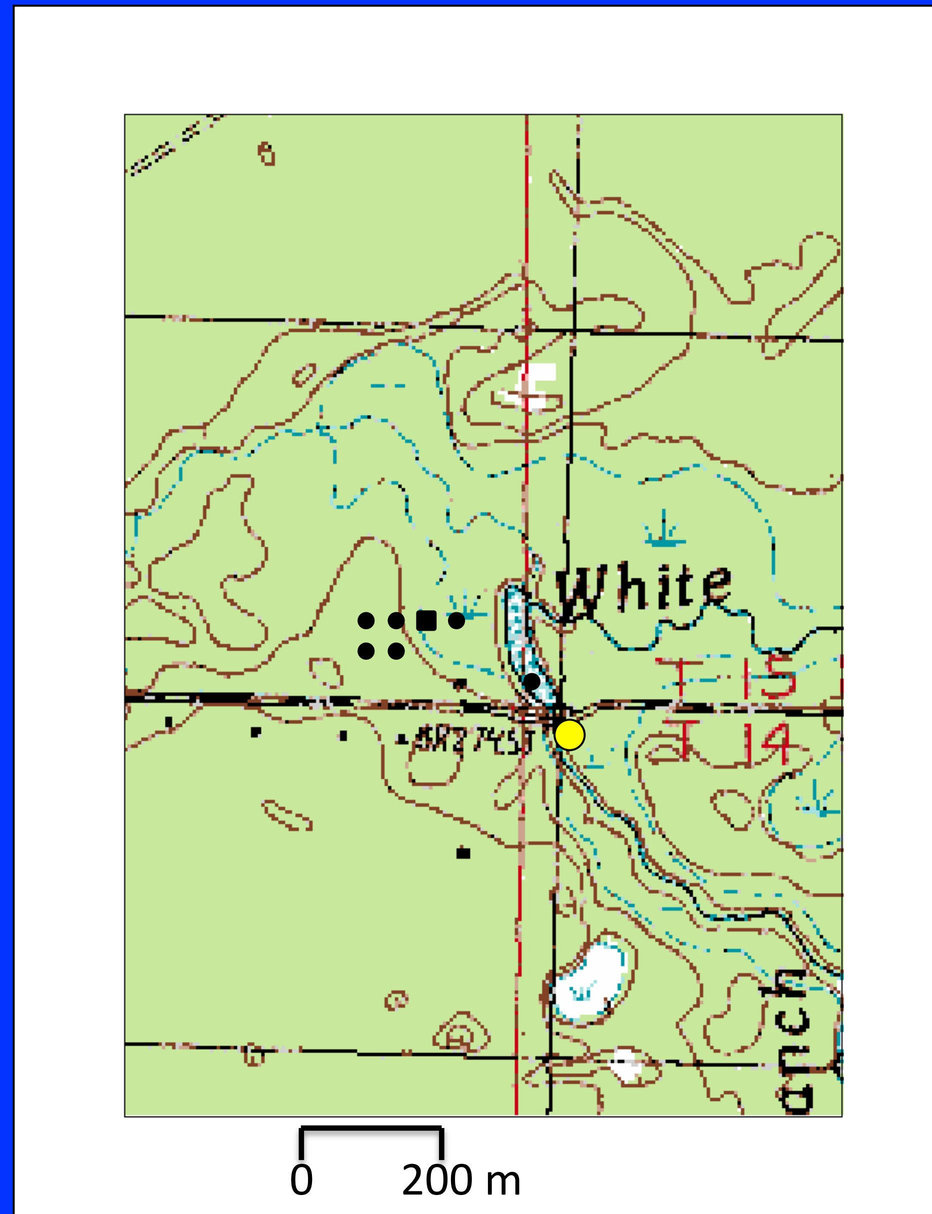


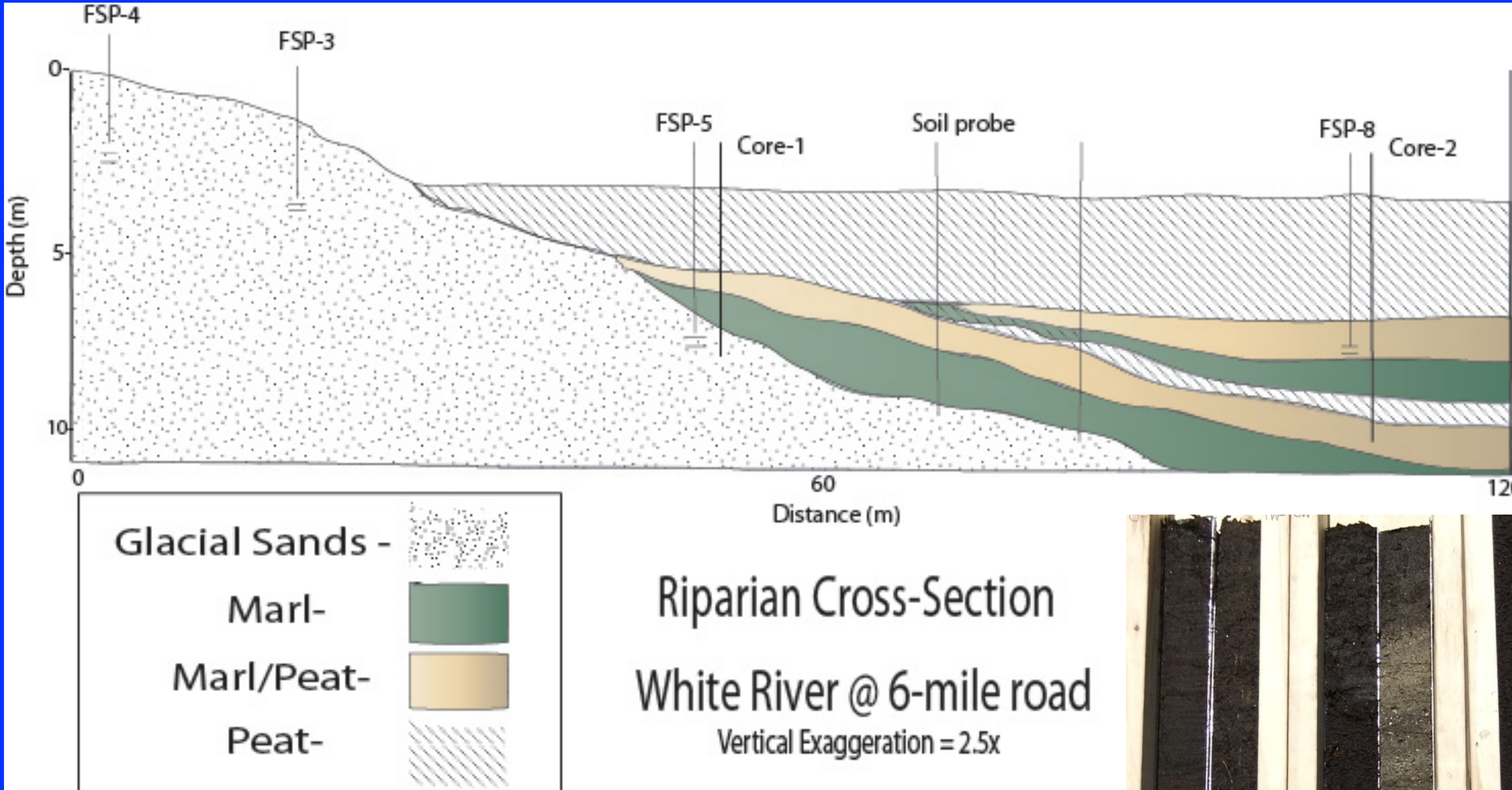


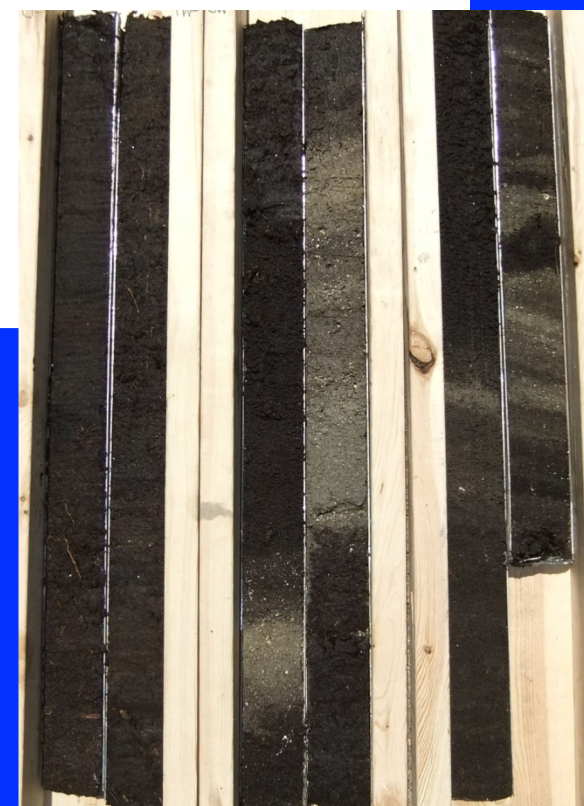

White and other streams in NF are ecologically & economically valuable systems

Aquatic & recreational resources

# At this headwater site:
# Upland to Riparian transect
# With 8 monitoring wells





HMVC-2 (wetland)
6.9 m depth w/
1.2 m peat compaction

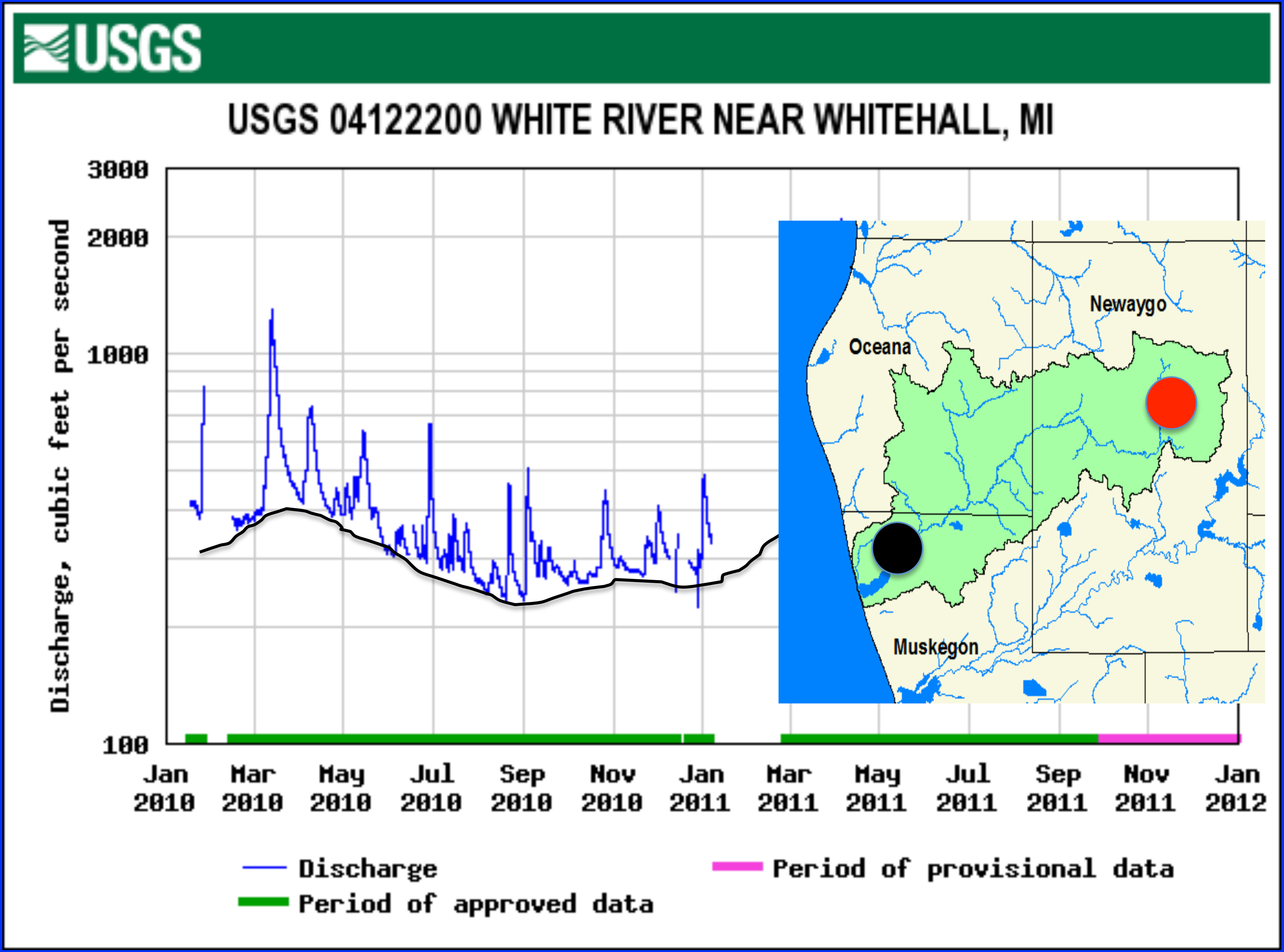
# Headwaters of the White River: kettle basin

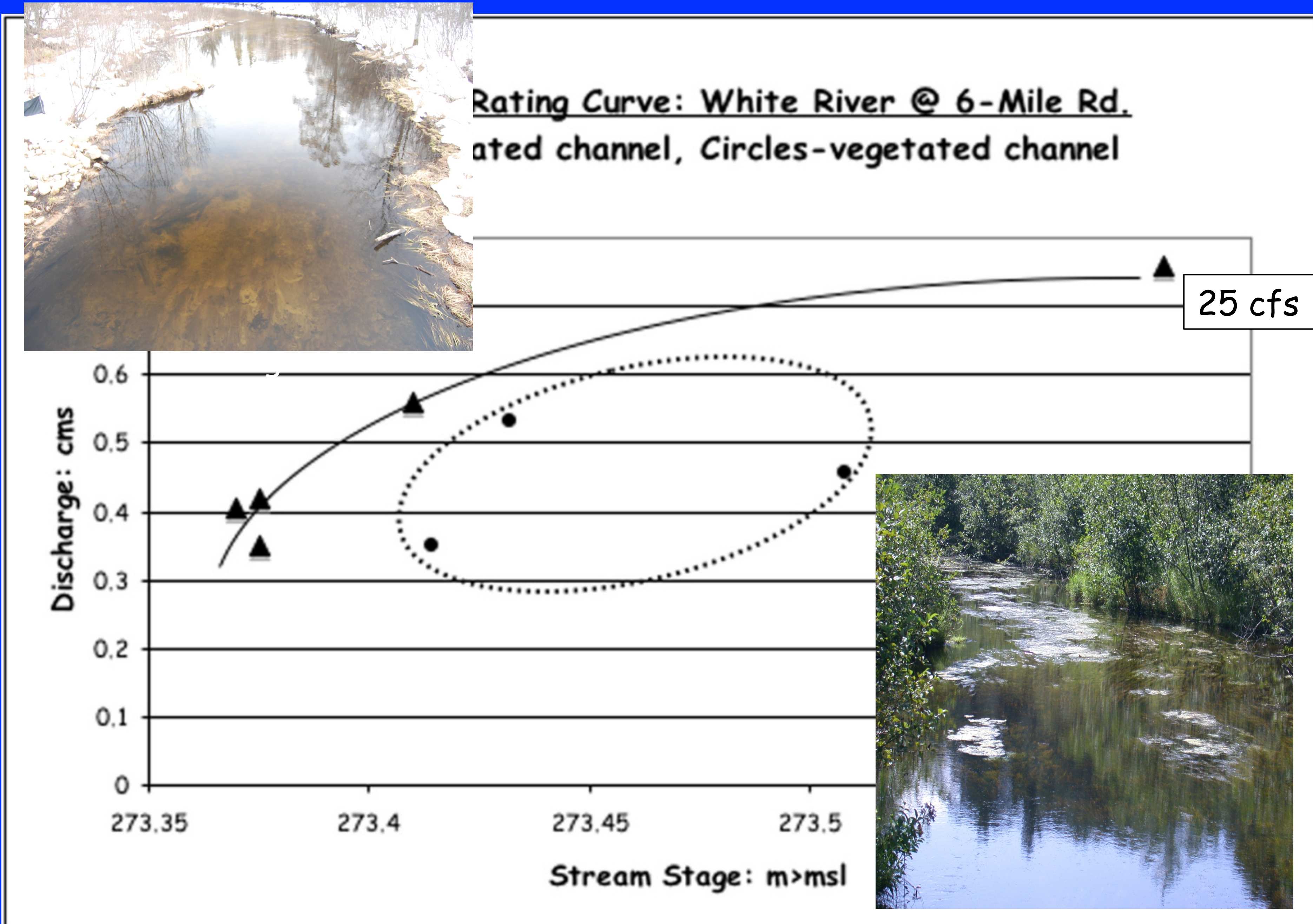
<u>Stratigraphic setting/history</u> = outwash sand

—development of a shallow marl producing lake

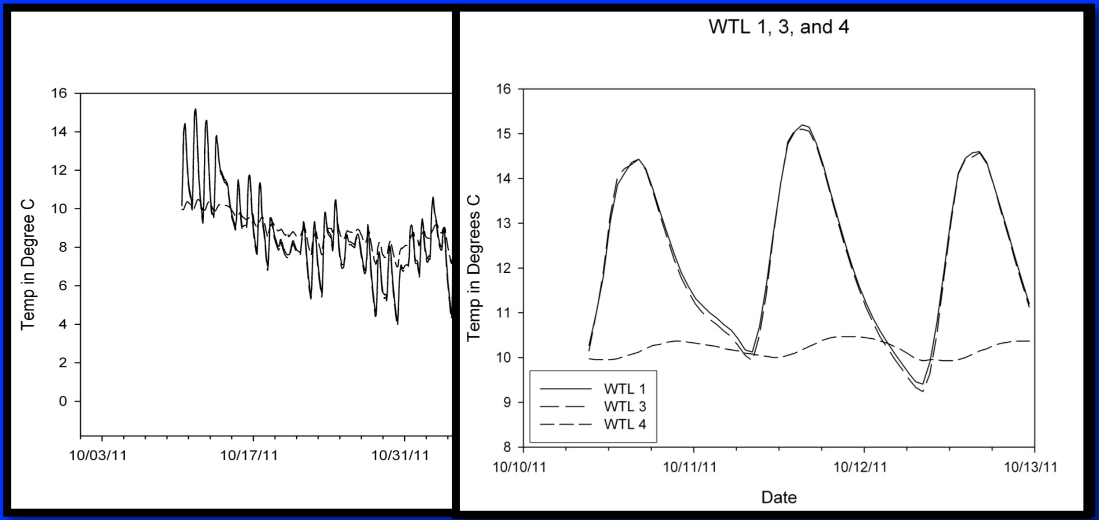
—transition to peat accumulating wetland.

# White River is baseflow dominated, typical in this terrane





Rating Curve: White River @ 6-Mile Rd.
ated channel, Circles-vegetated channel
25 cfs
Discharge: cms
0.6
0.5
0.4
0.3
0.2
0.1
0
273.35
273.4
273.45
273.5
Stream Stage: m>msl

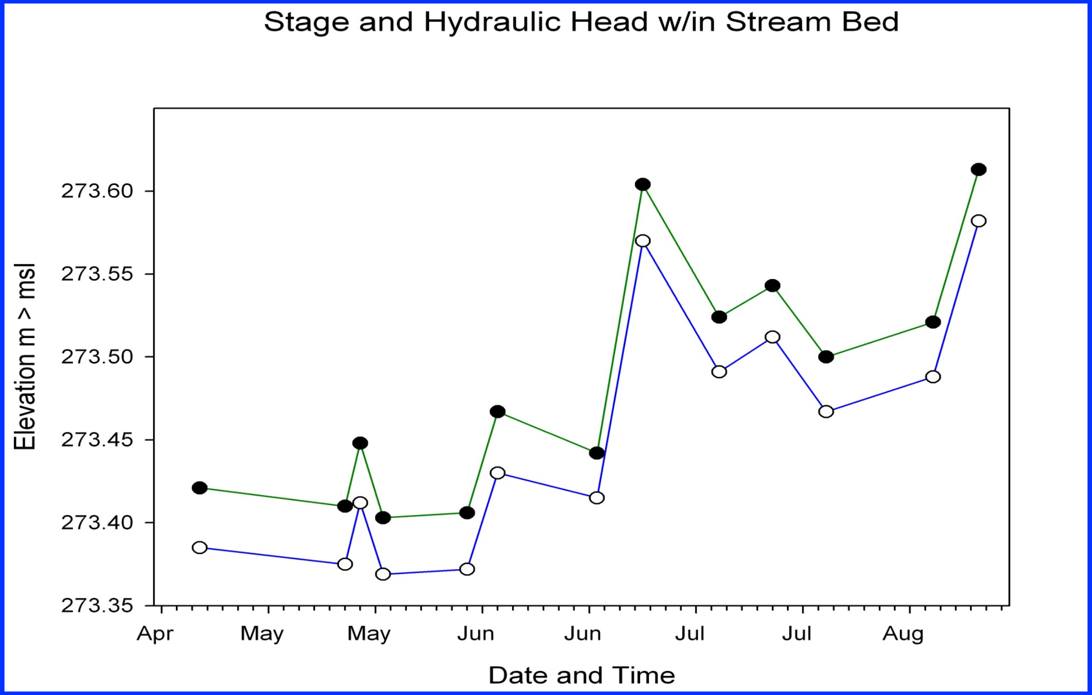



$$v = (v_t/\theta)\,(C_s/C_w)$$

# Occurrence of distinct seepage mechanisms

- Stream "center" seepage
- Littoral zone
- Discrete sand boils

Discrete streambed discharge points (boil sites) are common




Head at depth in streambed (littoral site) consistently 0.03-0.04m > stage

Significantly higher at boil sites

Hydraulic Conductivity of Sands:

- In-situ slug tests (at upland piezometer)
- Laboratory permeameter (of boil sand)

$K = 10^{-2}$ cm/sec

Hydraulic gradient & thermal data at littoral site

Direct seepage measurements* at stream-center

Hydraulic gradient & thermal data at sand-boil site


Conceptual model of "Contributing Areas"

Diffuse streambed seepage

Littoral Zone seepage

Discrete, conduit-style sand boil discharge

Pool ≈ 5000 $m^2$, Mean Stream Q ≈ 0.45 $m^3$/sec

≈ 0.15 $m^3$/sec upstream input

Littoral zone: specific discharge = 4.3 X $10^{-5}$ m/s,

2000 $m^2$ provides approximately 0.1 $m^3$/sec

Channel-center: specific discharge = 3 X $10^{-8}$ m/s,

3000 $m^2$ provides ≈ 0.0001 $m^3$/sec

Boil sites: specific discharge = 0.002 m/s,

100 $m^2$ needed to provide ≈ 0.2 $m^3$/sec

**Discrete, conduit-style discharge points appear to dominate streamflow generation**


## Conceptual model of "Contributing Areas"

negligible

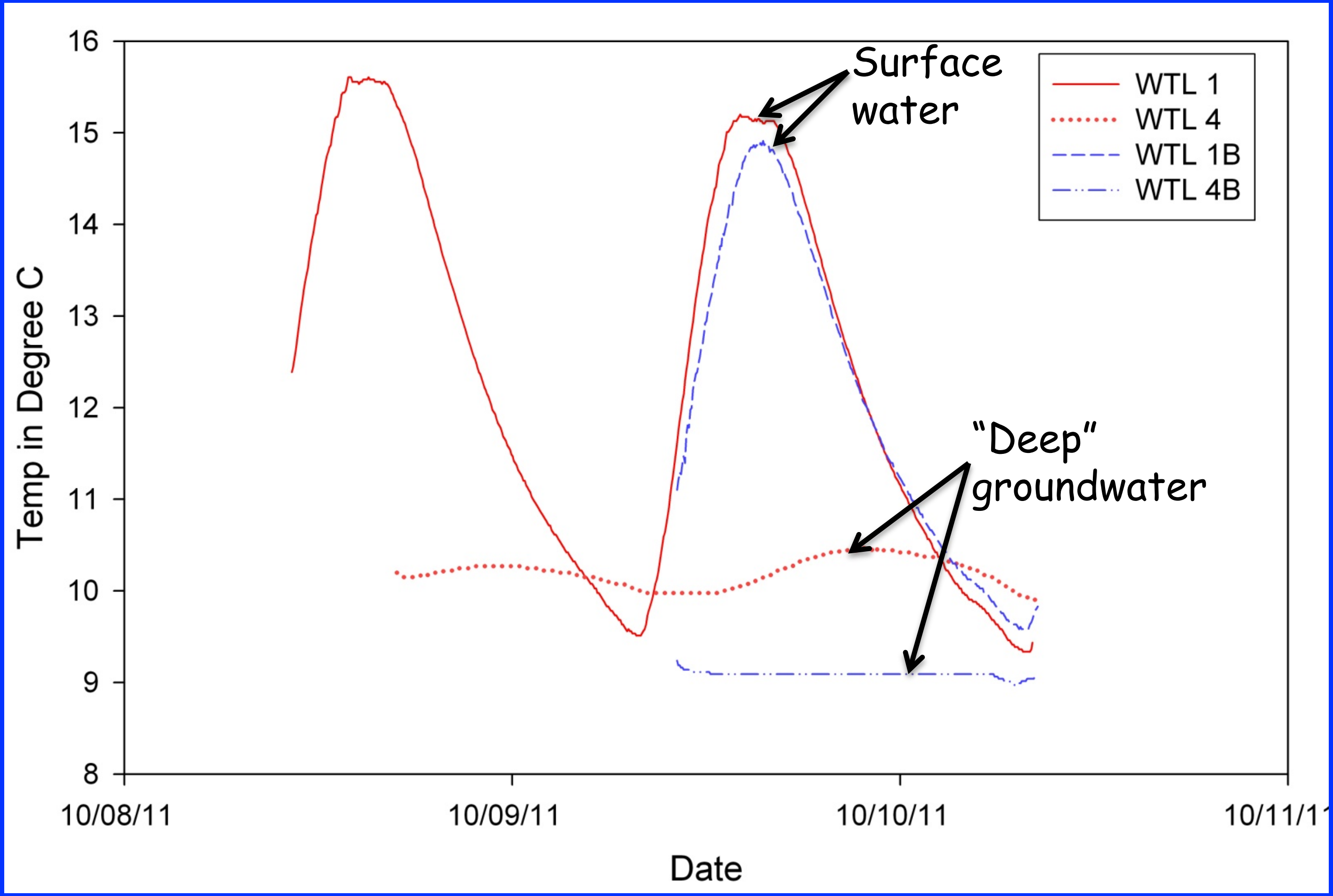
$0.1\ m^3/sec$ -- 22%

$0.2\ m^3/sec$ -- 45%

Upstream

$0.15\ m^3/sec$ -- 33%

# Surface water over focused discharge points nearly 0.5° C cooler than at littoral site;
# 0.5 m deep GW is > 1.0° C cooler at boil site than in littoral zone



# Summary and conclusions

Observe at least 3 distinct mechanisms of GW seepage through White River Streambed

Hydraulic gradients measurably different at littoral site and at conduit-style discharge points-boil sites

Seepage meter measurements suggest* low-magnitude, diffuse seepage in "stream-center"

Preliminary thermal data analysis corroborates gradient-based Q determinations at littoral site

"Sand boils" appear to contribute greatest portion of streamflow & impose strong temp. control on SW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MODERATE
TODAY!
SMOKEY
SMOKEY