Quantifying Surface water-Groundwater exchange using Temperature Profile Inverse modeling in a Riparian Wetland

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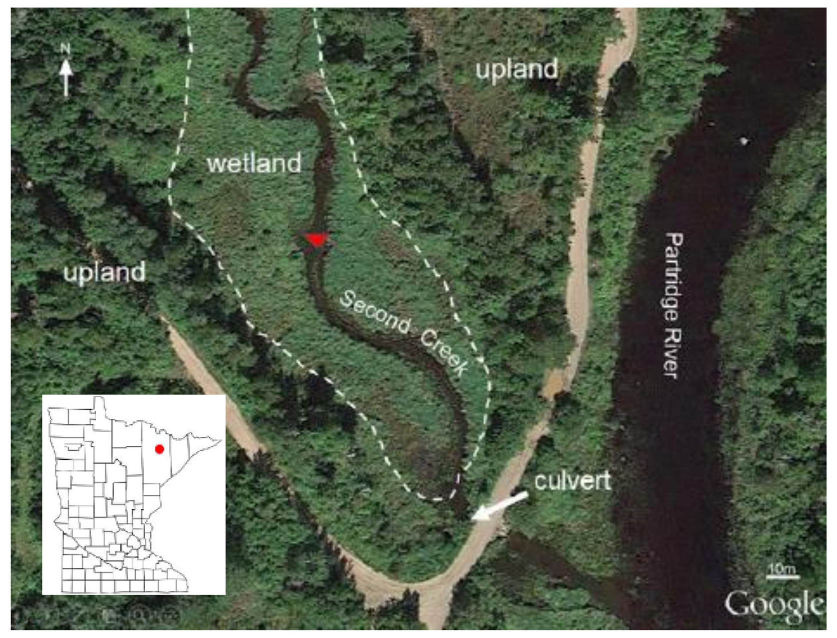
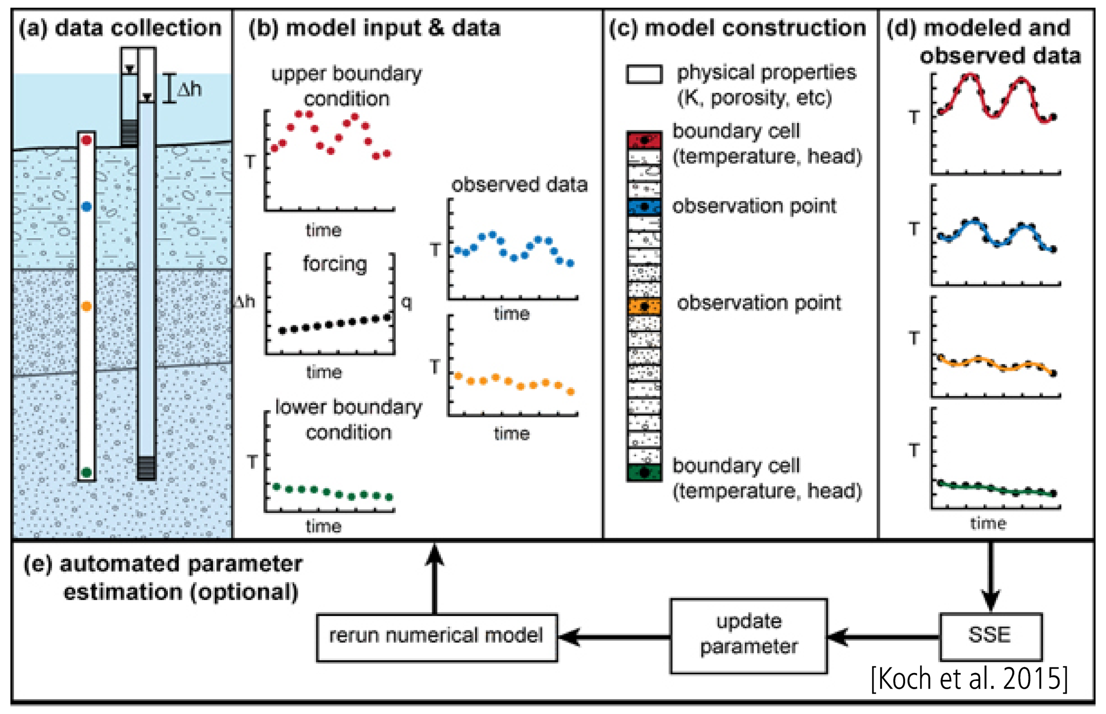
number

Study Site and Motivation



- Second Creek is a wild rice stream located in Minnesota's Iron Range
- Regional groundwater flow is west to east
- Want to understand how mining derived sulfate affects biogeochemical cycling at Second Creek
- Hyporheic flux controls the sediment geochemical gradient and in turn, influences aquatic plants rooted in the hyporheic zone [Hayashi & Rosenberry 2002; Kurtz et al. 2007.]
- Goal: quantify surface water – ground water exchange at Second Creek

Inverse Model Theory



Parameter	Symbol
Hydraulic conductivity	K
Porosity	ϕ
Saturated thermal conductivity	λ_s
Sediment heat capacity	C
Water heat capacity	C_w
head	h
Dispersivity	α
Hyporheic flux	q_z
Temperature	T

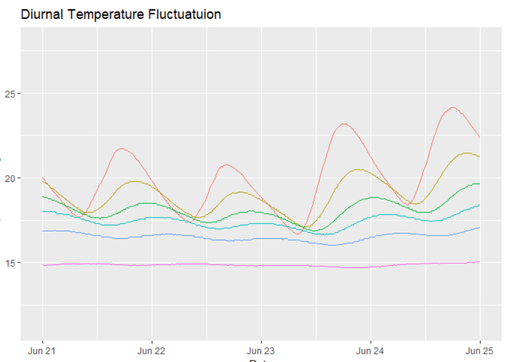
Forward model governing equations:

$$(\lambda_s + q_z \alpha C_w)\frac{\partial^2 T}{\partial t^2} - q_z C_w \frac{\partial T}{\partial z} = \frac{\partial T}{\partial t}(\phi C_w + (1-\phi) C_s)$$

$$q_z = -K\frac{dh}{dz}$$

[Healy, R.W., and A.D. Ronan. 1996]

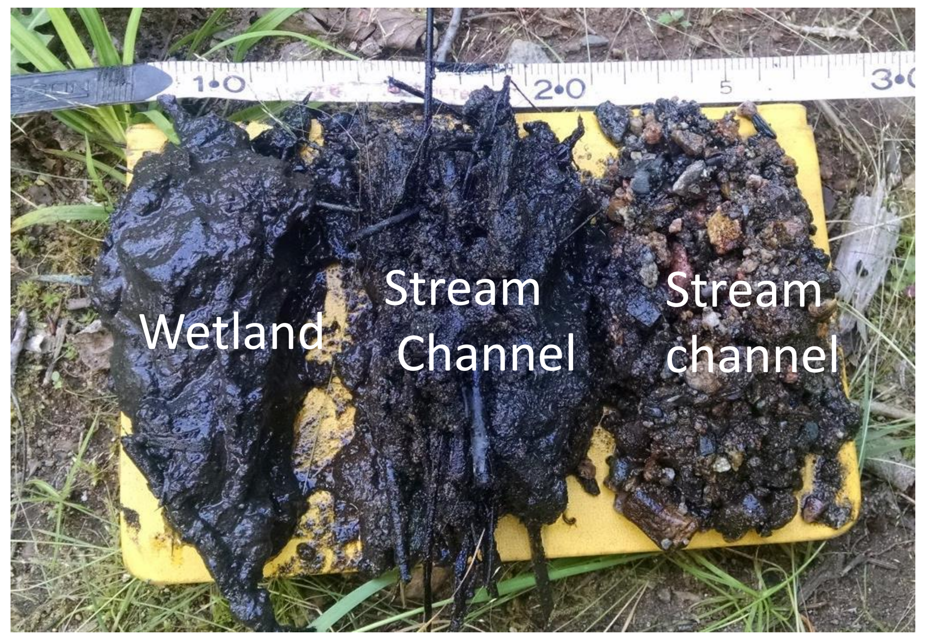
Data collection



- Three temperature probes were collocated with piezometers across the site
- Pressure and temperature was measured at 15 minute intervals to capture diurnal variability over the summer
- Rainfall data supplied by the nearby Embarrass, MN weather station

Waiting on blurb/image from ANDY

Sediment characterization

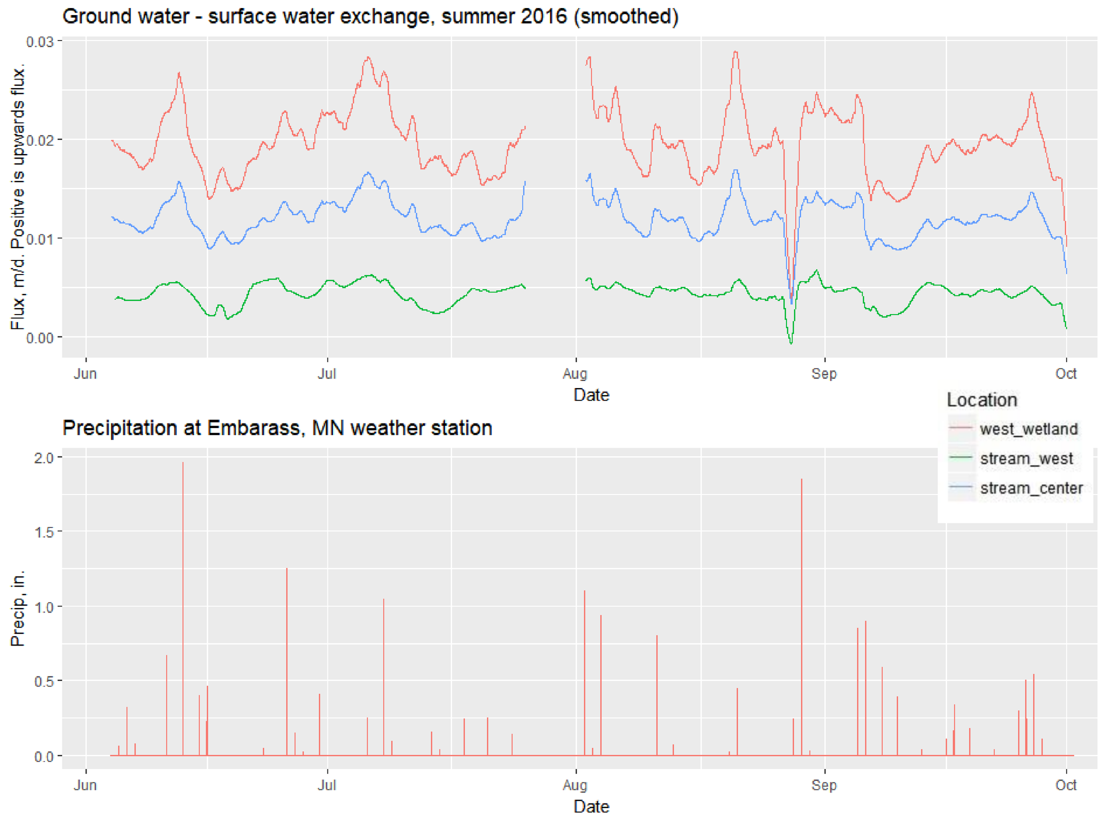


- Sediment is characterized by high organic content, low dry bulk density, high porosity [Mybro, A., 2013.]
- Measured dry bulk density from Mybro, A., 2013. used to estimate the fraction silicate and SOM
- 80-90% SOM, 10-20% silicate
- Thermal conductivity and sediment heat capacity constrained by computing upper and lower bounds based on Farouki, O., 1961

$$\lambda_{min} = \frac{x_{Si}}{\lambda_{Si}} + \frac{x_{Som}}{\lambda_{Som}} \qquad \lambda_{max} = x_{Si}\lambda_{Si} + x_{Som}\lambda_{Som}$$

- Dispersivity estimated from the range provided by Zheng & Bennet, 1995

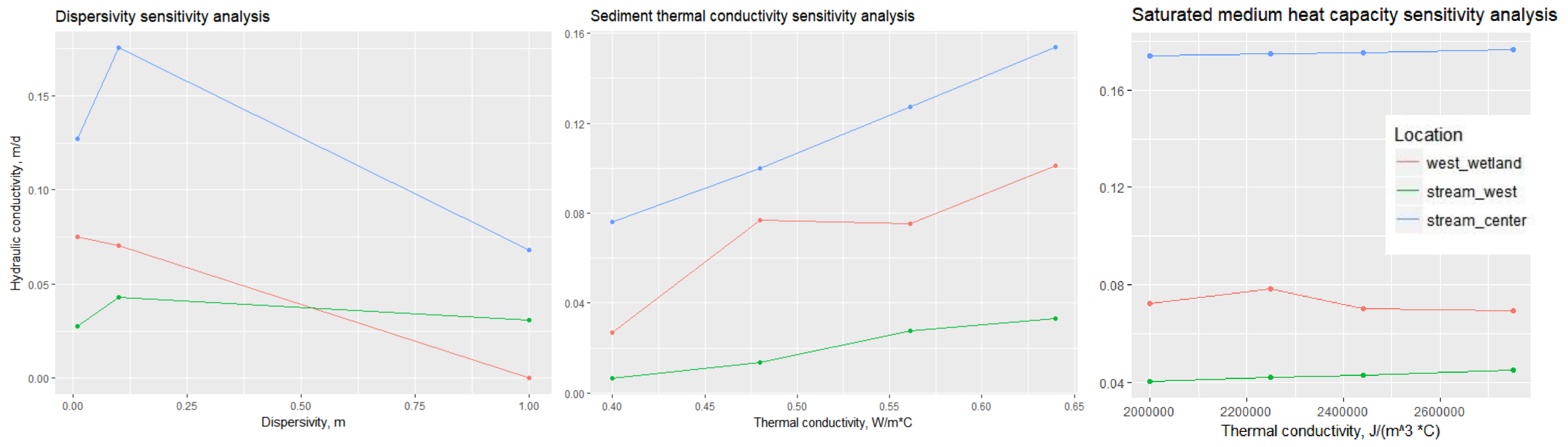
Results



Do you think the smoothed version or the unsmoothed version would be more informative?

Location	Hydraulic conductivity, m/d
West wetland	0.07
Stream west	0.04
Stream center	0.18

Model fit and sensitivity analysis



- The influence of dispersity is proportional to flux magnitude. At high dispersivity, low flux magnitude (K) is required to match the observations. At low dispersivity, higher K is required.
- As sediment conductivity increases, energy from the warm surface water is transferred downwards more easily, so higher hyporheic flux (K) is required to maintain the observed temperature profile
- Saturated heat capacity is relatively insensitive, it is dominated by the heat capacity of water due to the sediment's high porosity (0.51)

To do:
1. Increase font and line size on all R plots for readability
2. Give context to the X axis values on sensitivity analysis plots
3. Show a metric of goodness of fit for each point in the sensitivity analysis plots

Conclusions

- Flux in the hyporheic zone is consistently upwards throughout the summer
- The lowest magnitude of flux occurs in the west stream channel
- Flux in the west stream channel has smaller fluctuations than the stream center or west wetland
- One brief flux reversal occurred following a major storm event in late August

Future work

- Similar data with higher spatial resolution, and longer field time (may – October) was collected in 2017
- 2017 long term flux reversal, heterogeneity resolution
- 2018 field campaign: unique parameterization based on sediment collected at each probe location

References

Farouki, O., 1961. *Thermal properties of soils*. United States Army Corps of Engineers Cold Regions Research and Engineering Laboratory.; Hayashi, M. & Rosenberry, D.O., 2002. Effects of Groundwater Exchange on the Hydrology and Ecology on Surface Water. *Groundwater.*; Healy, R.W., and A.D. Ronan. 1996. Documentation of computer program VS2DH for simulation of energy transport in variably saturated porous media – modification of the U.S. Geological Survey's computer program VS2DT. *U.S. Geological Survey Water-Resources Investigations Report.*; Koch et al. 2015., 1DTempPro V2: New Features for Inferring Groundwater/Surface-Water Exchange, *Groundwater.*; Kurtz, A.M. et al., 2007. The importance of subsurface geology for water source and vegetation communities in Cherokee Marsh, Wisconsin. *Wetlands.*; Mybro, A., 2013. Wild Rice Sulfate Standard Field Surveys 2011, 2012, 2013: Final Report. *University of Minnesota.*; Yourd, A., 2017. *Using reactive transport modeling to link hydrologic flux and root zone geochemistry at Second Creek, a sulfate enriched wild rice stream in northeastern Minnesota, Masters Thesis, University of Minnesota.*; Zheng, C. & Bennett, G., 1995. *Applied Contaminant Transport Modeling* . John Wiley & Sons.