Multi-Instrument Stream Surveys
Canoeing for Big Data in Small Streams

WISCONSIN Geological & Natural History Survey

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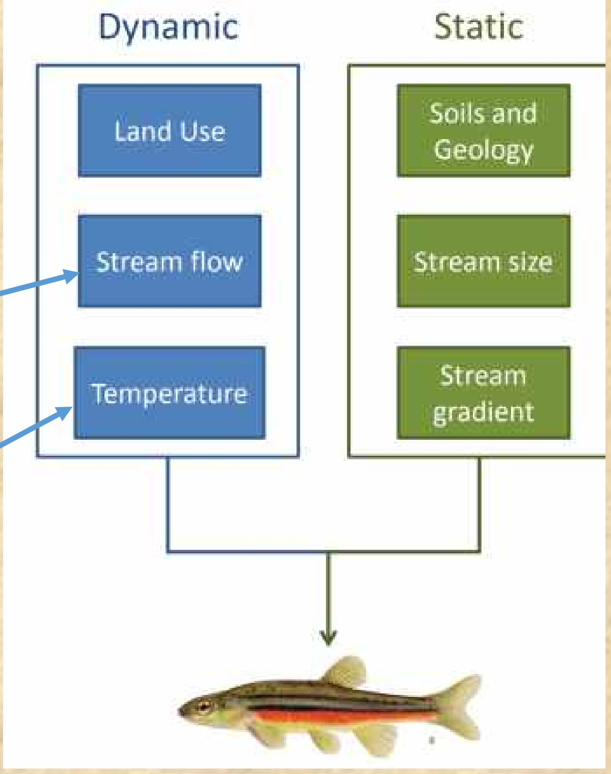
Issue – Decisions concerning our natural resources are relying on ever more complex modeling and data.

For example
ELOHA – Ecological Limits of Hydrologic Alteration

Groundwater Flow Model

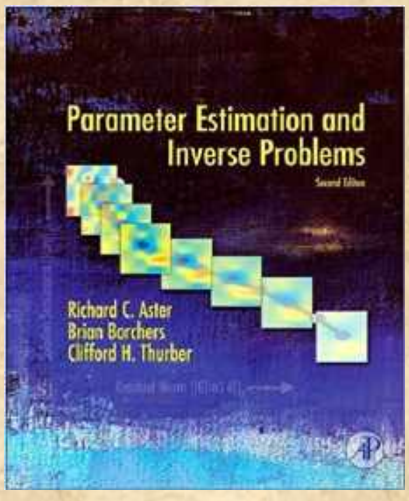
Stream Temperature Model



http://dnr.wi.gov/topic/Groundwater/documents/GCC/Minutes/talkDiebel201311.pdf

Complex models require more and better data to constrain the models

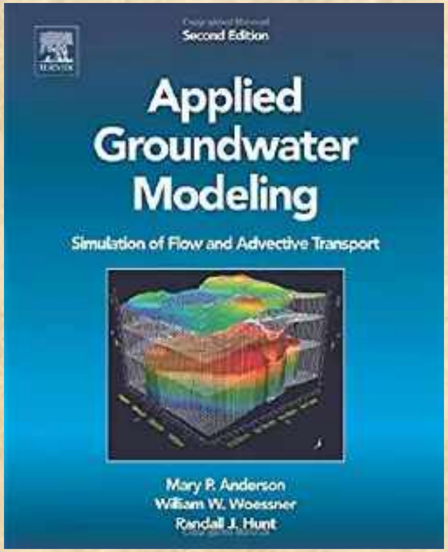
Observations related to model and parameters



Data Model Parameters

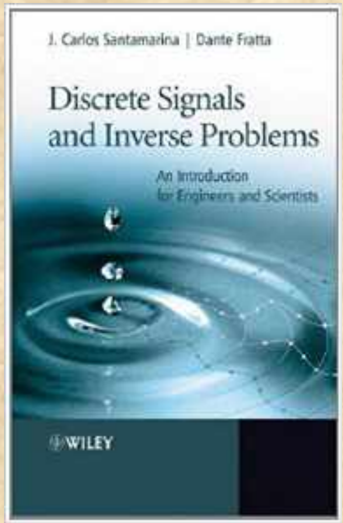
$$d_i = M_{ij} p_j$$

Groundwater -
This side needs to keep up.

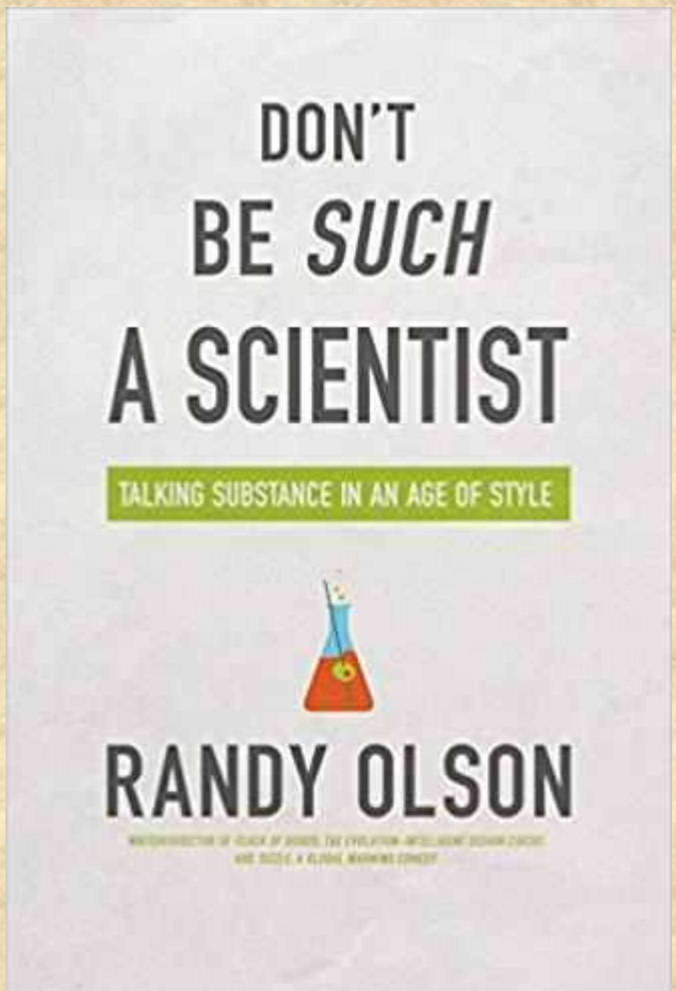


Groundwater -
Saw lots of work on this side

Larger computers allow for more complexity (greater model lengths)

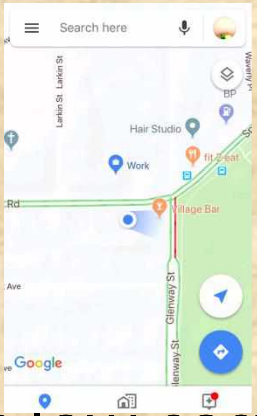


Issue - Importance of communicating science and results



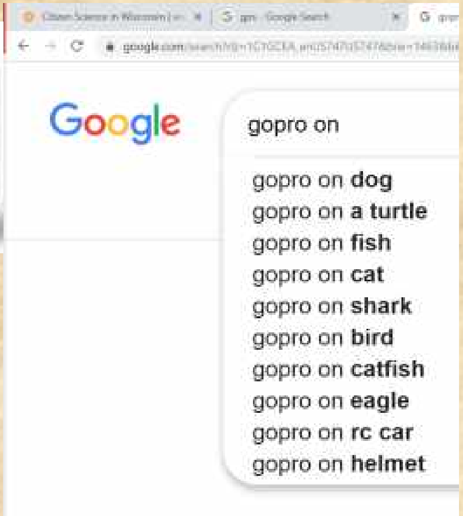
- Decisions on groundwater and geology often made county and town levels.
- Our job is to provide and communicate useful science.
- Citizen science

Response makes use of several trends



- Locating data is now easy

- Storing large amounts of data is low cost



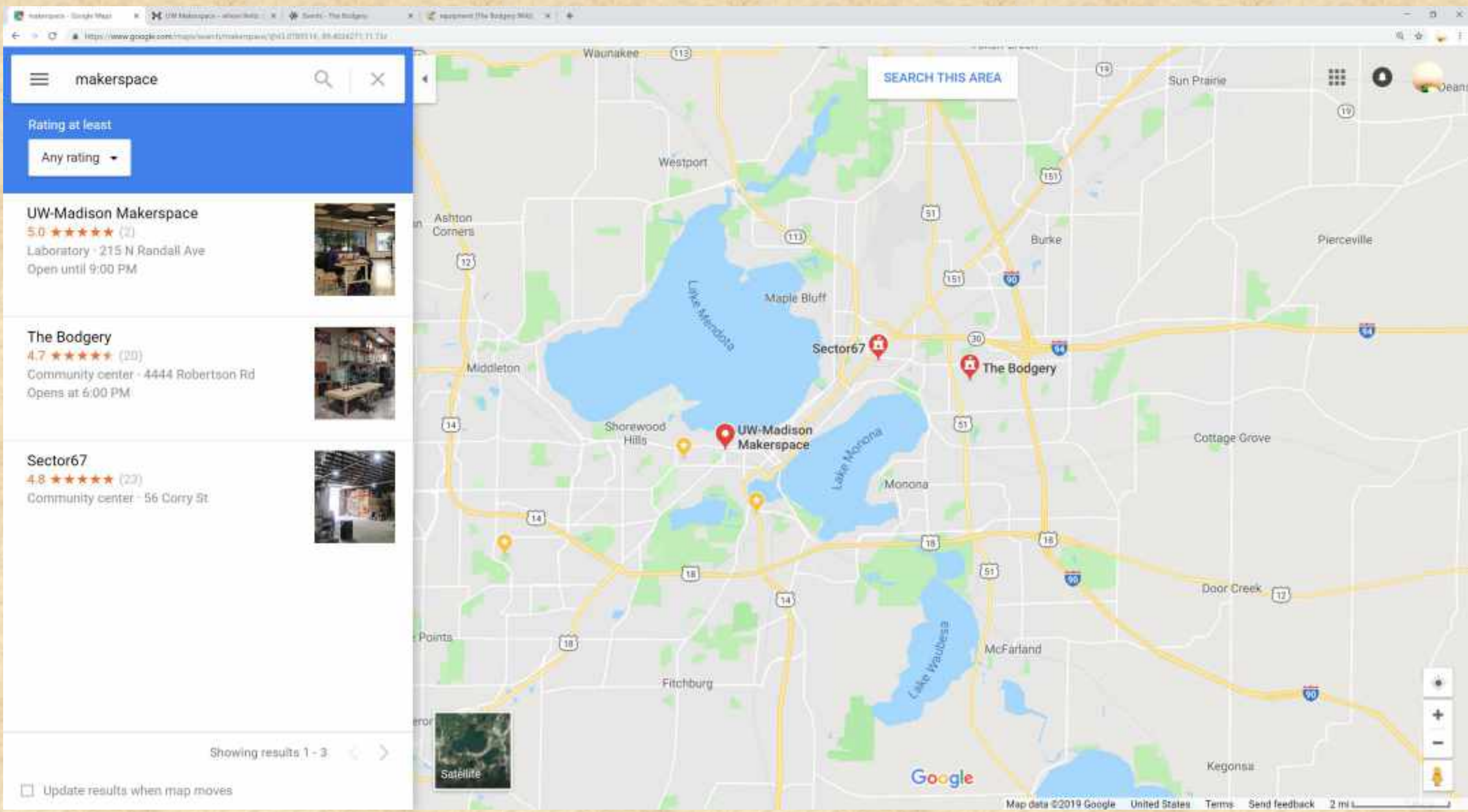
- Inexpensive video is everywhere.

- Easier to develop prototype instruments
  - Low cost micro-controllers
  - Wide range of sensors
  - Internet Project Hubs

Maker Culture - Combination of DIY, Hacker, and Artisan Cultures.

Cut-and-paste approach to standardized hobbyist technologies

Three makerspaces in Madison



Who We Are

We're a non-profit organization providing the tools, workspace, and guidance to people of all ages who want to make things. Whether learning a tool, honing a craft, building a business, or finding a creative group of makers – this is your place to build skills and community!

Our Tools

We have a full woodworking shop, welding and blacksmithing, a sewing studio, 3D printing, electronics lab, laser cutting/engraving, a machine shop, prop making and leather work, CNC milling and routing, screen printing, auto repair, and a giant wall of yarn.

A list of **our current tools** is on our wiki.

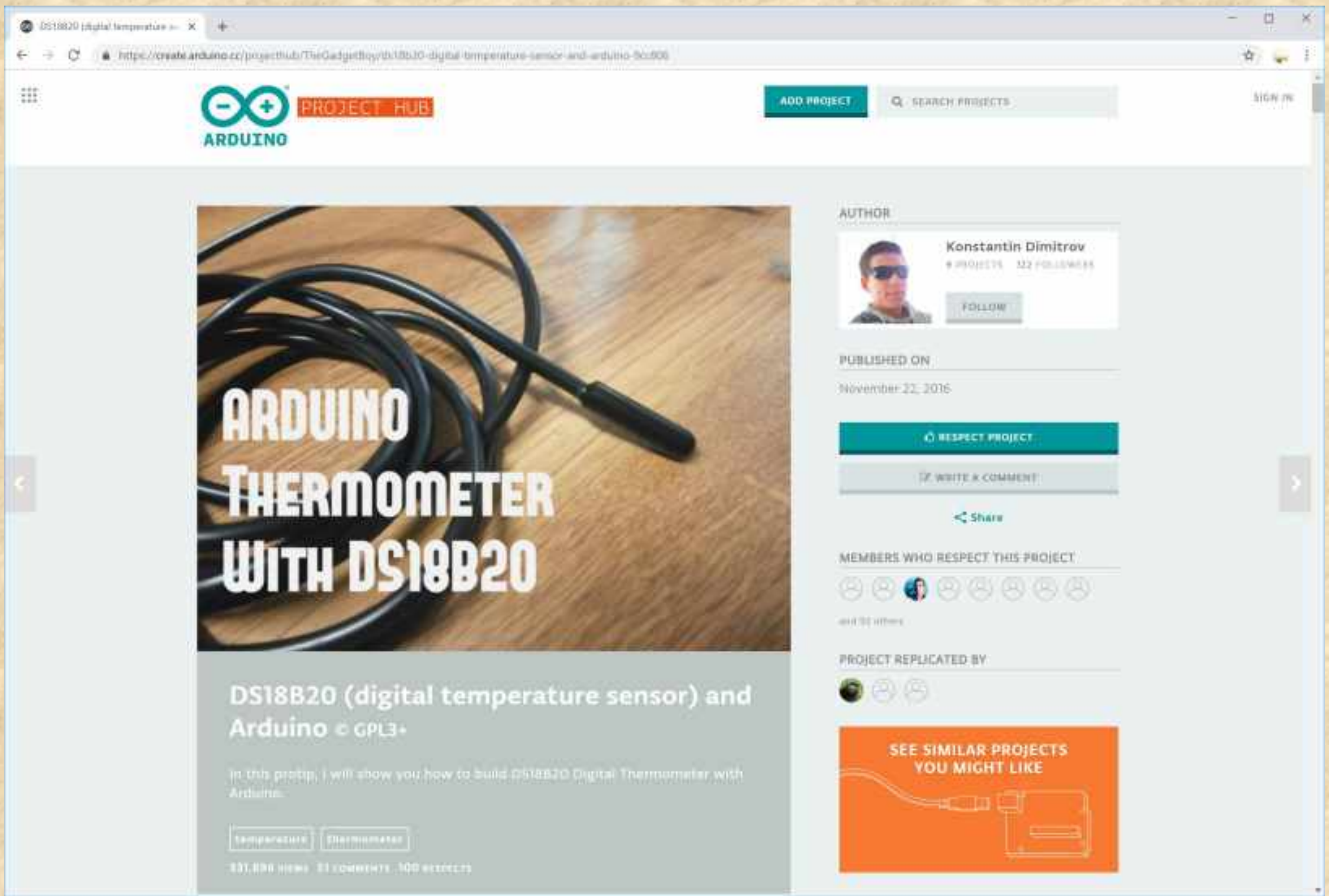
Check out the shop in our **Virtual Tour**!

The Electric Long Board

Hi my name is Charlie and I built an electric longboard! The idea first came about a year ago when I saw a student on my campus blast past me while I was biking to class. I did a little research and learned that I desperately wanted one. Unfortunately a high quality electric skateboard is going to run around $1,000 to $2,000. I basically gave up hope.

Fast forward to a month ago. I'd just moved to Madison for an internship and was looking for a project. I discovered that building your own electric skateboard isn't all that difficult. With a bit of research, and a lot of hands on learning, you can quickly and easily build a board that goes 30 mph and 10 or more miles. It all depends on your budget. I chose to go with a 6S1P battery system. Basically this meant that I can go about 7 miles, and up to 26 mph on a single charge. After completing my first board in the Bodgery shop, I'm already planning my next. In fact, as I ...

Google Arduino and temperature



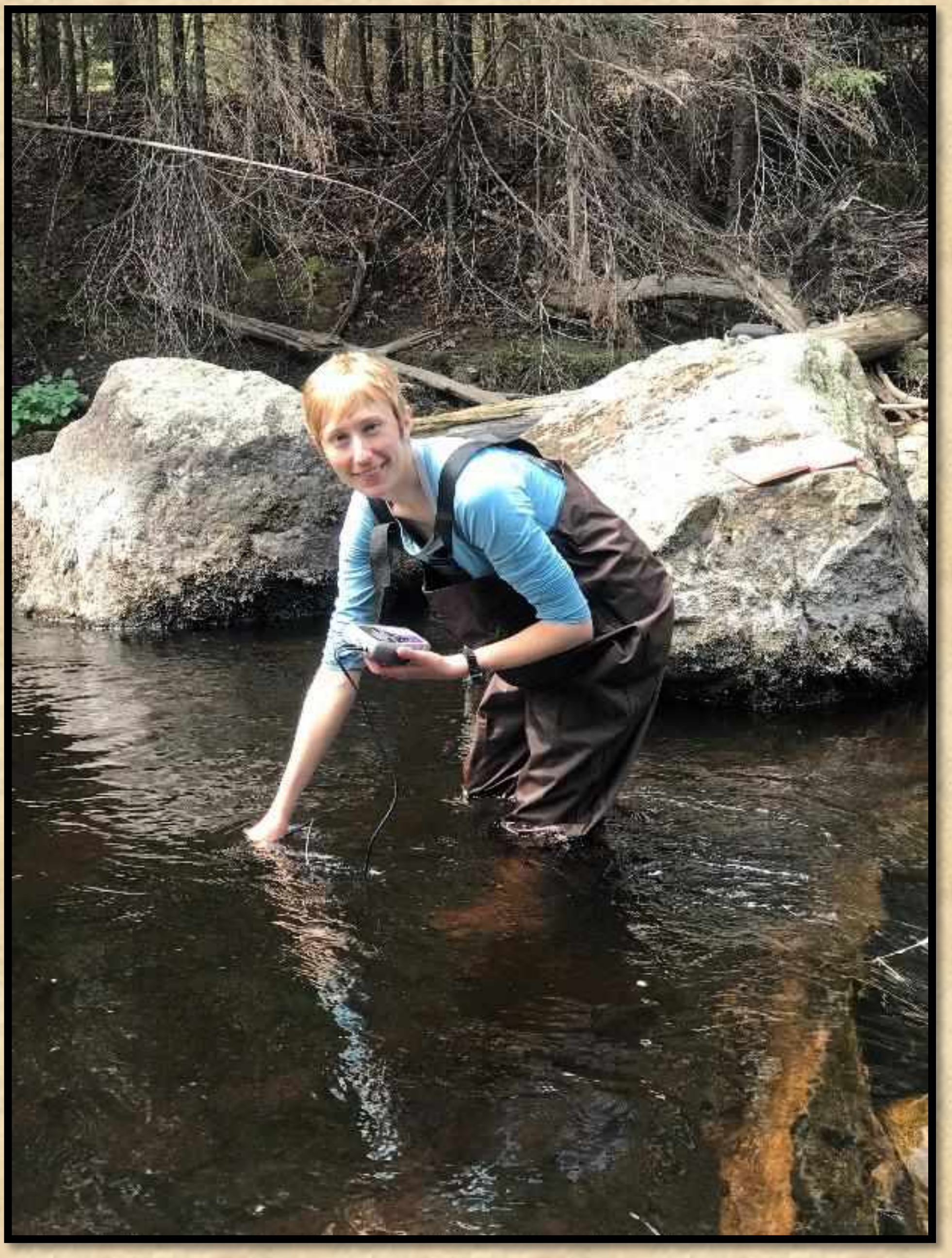
This page explains what materials are needed, how to connect the sensor and provides a working program or sketch. The DS18B20 sensor is accurate, water proof, easy to install, and many can be connected into a single port pin.

Research Question/Focus

Can we design a method to collect spatially and temporally dense geolocated sets of hydrologic data on small streams to help understand stream quality and groundwater/surface water interaction?

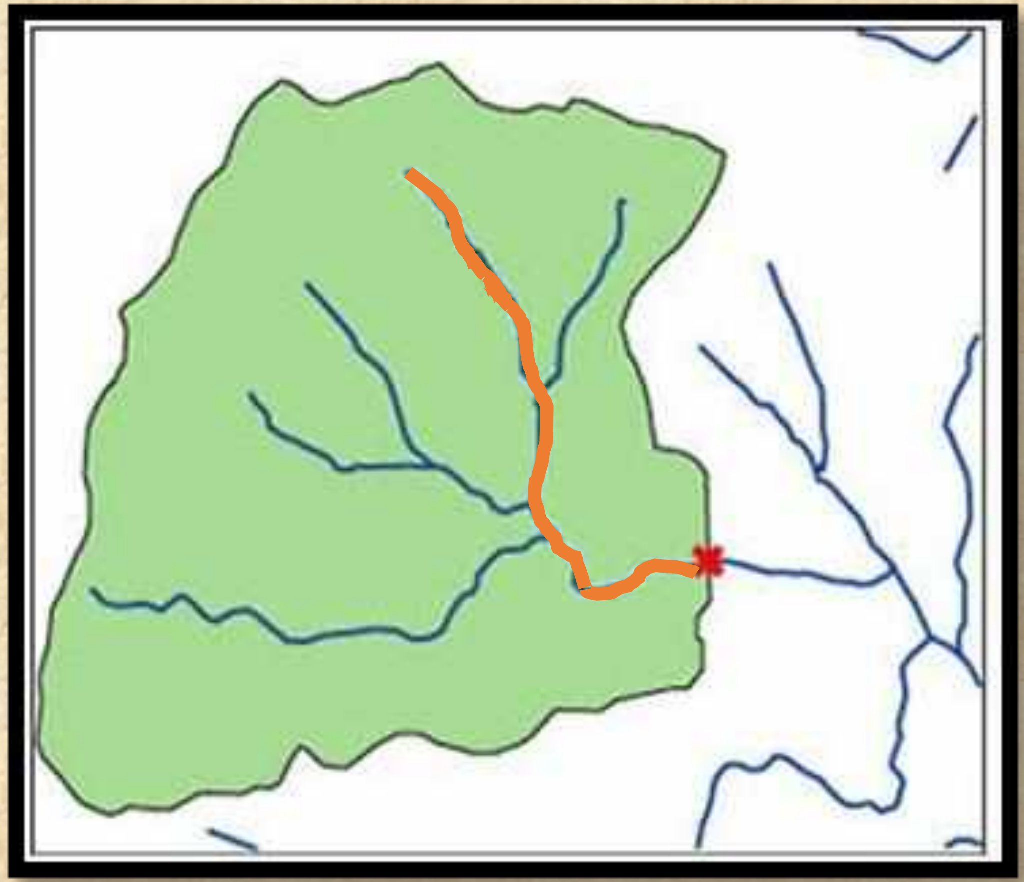
Background

- Hydrologic data most commonly collected as point scale measurements
  - Logging through time at a “fixed” station
- Data volume and locations often limited by cost

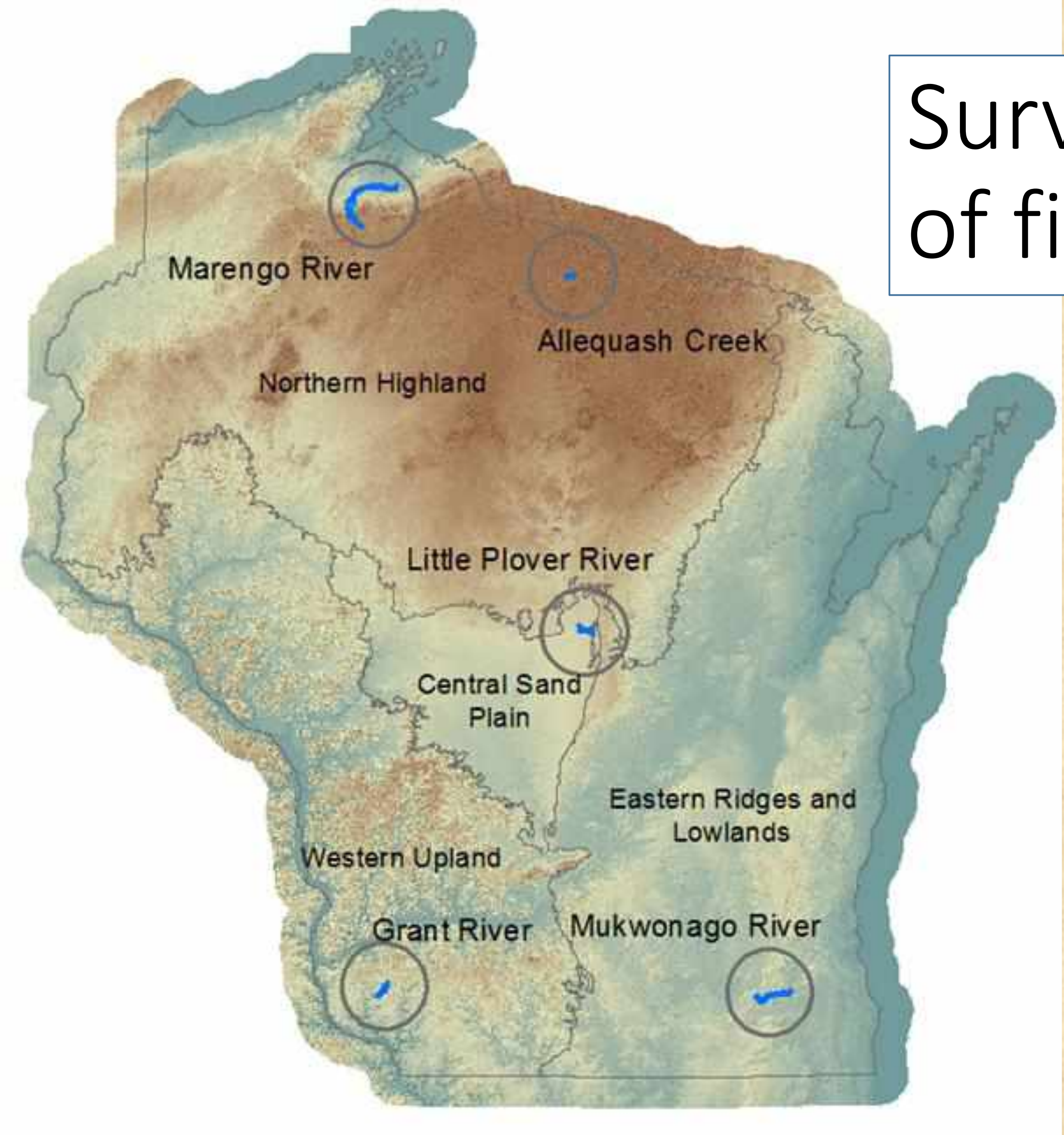


Response - Groundwater/Surface Water

- Collect multiple data sets simultaneously from a canoe
  - Data sets all geolocated
  - Data collected every second or so
  - Data collected on decimeter to meter scale
- Targeted at groundwater/small stream interactions
  - Small streams most susceptible to impacts
  - Expected to show most variation
  - Small streams support large amount of diversity and native species
- Data will
  - Support groundwater models for use as targets and input
  - Data relationships might be informative and will likely serve other purposes



Survey reaches of five streams



Criteria for selection

- Previously studied
- Smaller – flows of cfs or 10s of cfs (cubic feet/sec)
- Different geographic provinces

Collected Parameters

Water Quality

- Temperature
- Dissolved Oxygen
- pH
- Specific Conductance
- Nitrate
- Chloride

Ecological

- GoPro Video

Location

- *Water Quality*
- *Geophysical*
- *RTK GPS*
  - *Centimeter horizontal and close to centimeter vertical accuracy*

Not needed with access to Lidar elevations

Geophysical

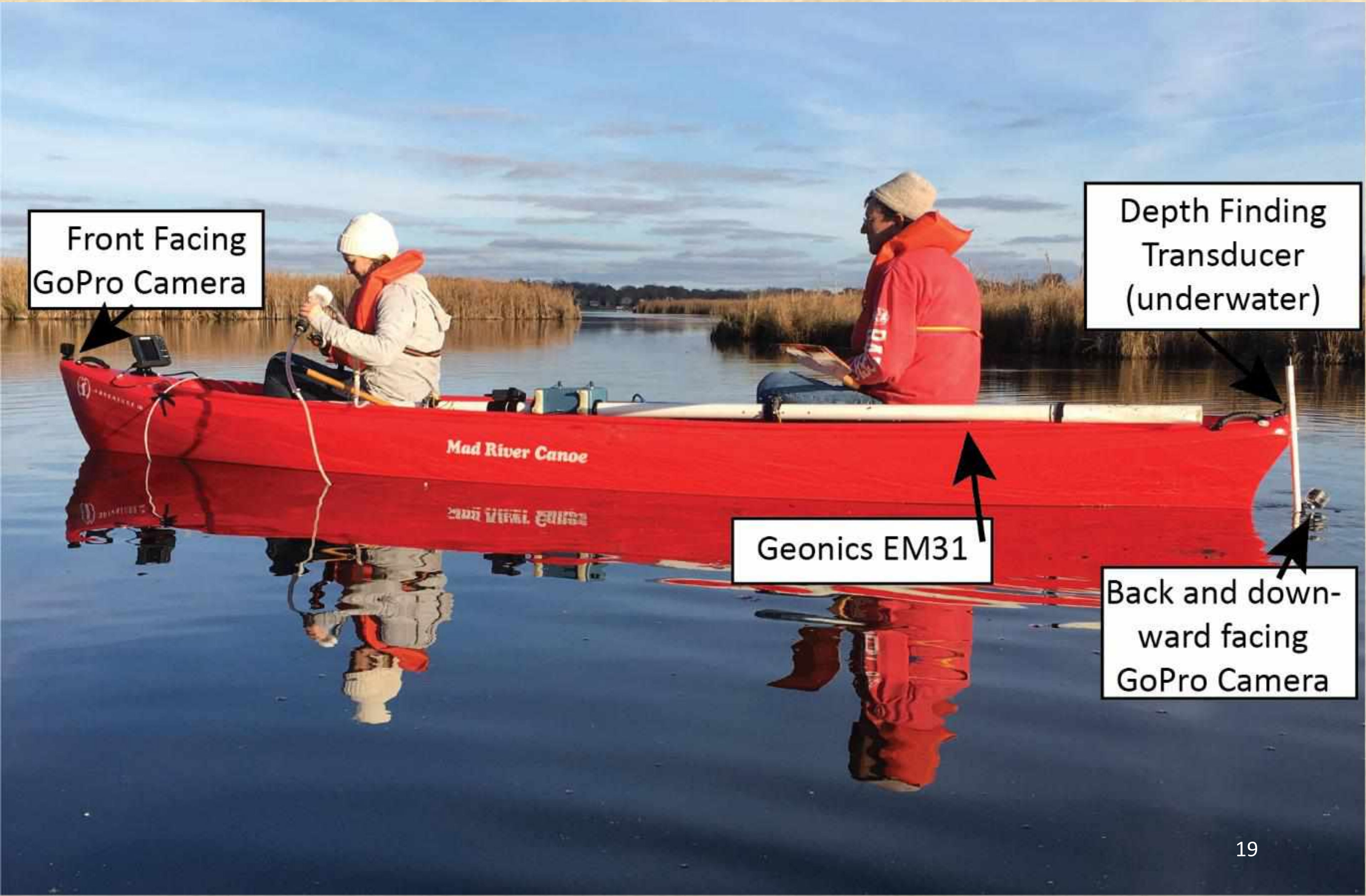
- Ground Conductivity (EM31)
- Depth of Water
- Ground Penetrating Radar

High effort
Low impact

Following work of others

- Geophysics
  - Lin, Y.T., Schuettpelz, C., Wu, C.H., and Fratta, D. (2009) (UW-Madison) A combined acoustic and electromagnetic wave-based technique for bathymetry and subbottom profiling in shallow waters. Journal of Applied Geophysics, 68, 203-219, 2009.
  - Baierlipp, M. and Kean, W. (2011) (UW-Milwaukee) A hydrogeophysical study of the Fox River south of Waukesha, WI. Paper No. 22-3 Northeastern and North-Central Joint Meeting, Geological Society of America Abstracts with Programs, Vol 43, No 1, p. 83
- Water Quality
  - Eric Compas (UW-Whitewater) and Suzanne Wade (UW-Extension) – Testing the Waters
  - Fast Limnological Automated Measurements (FLAME) UW-Madison, Center for Limnology) – https://flame.wisc.edu/
- Video
  - Lots of canoeing and kayaking GoPro videos.
  - Also, many much less relaxing videos.

Method Overview



Method Overview

Arduino water chemistry instrumentation

"Arduino is an open-source electronics platform based on easy-to-use hardware and software."

GPS

These data will be stored on the Arduino board and geolocated with GPS board at sample rate of once every 2 seconds.
Total cost ~ $1000 mostly sensors. Dr. Fratta and Susie Richmond

Arduino Mega Microcontroller

Turbidity/preliminary

pH

Temperature

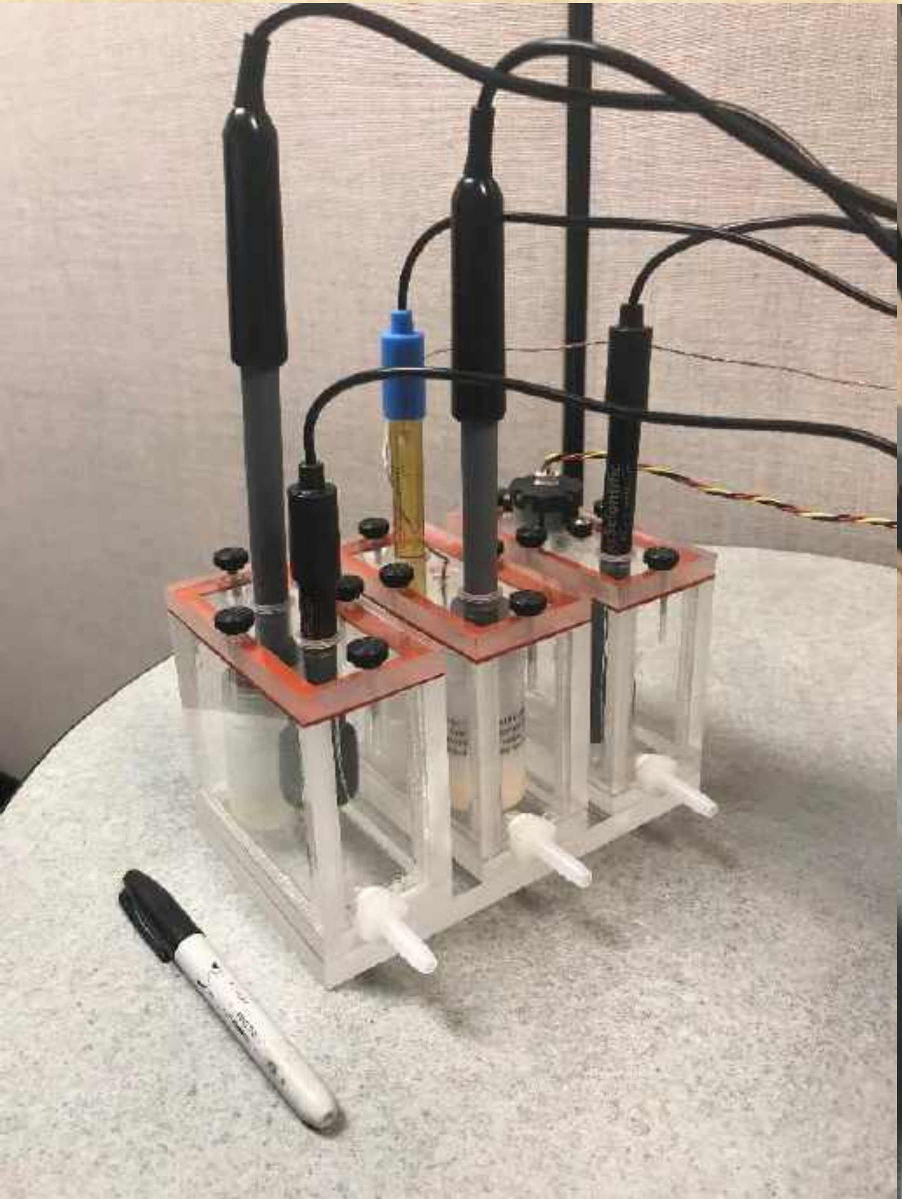
Nitrate

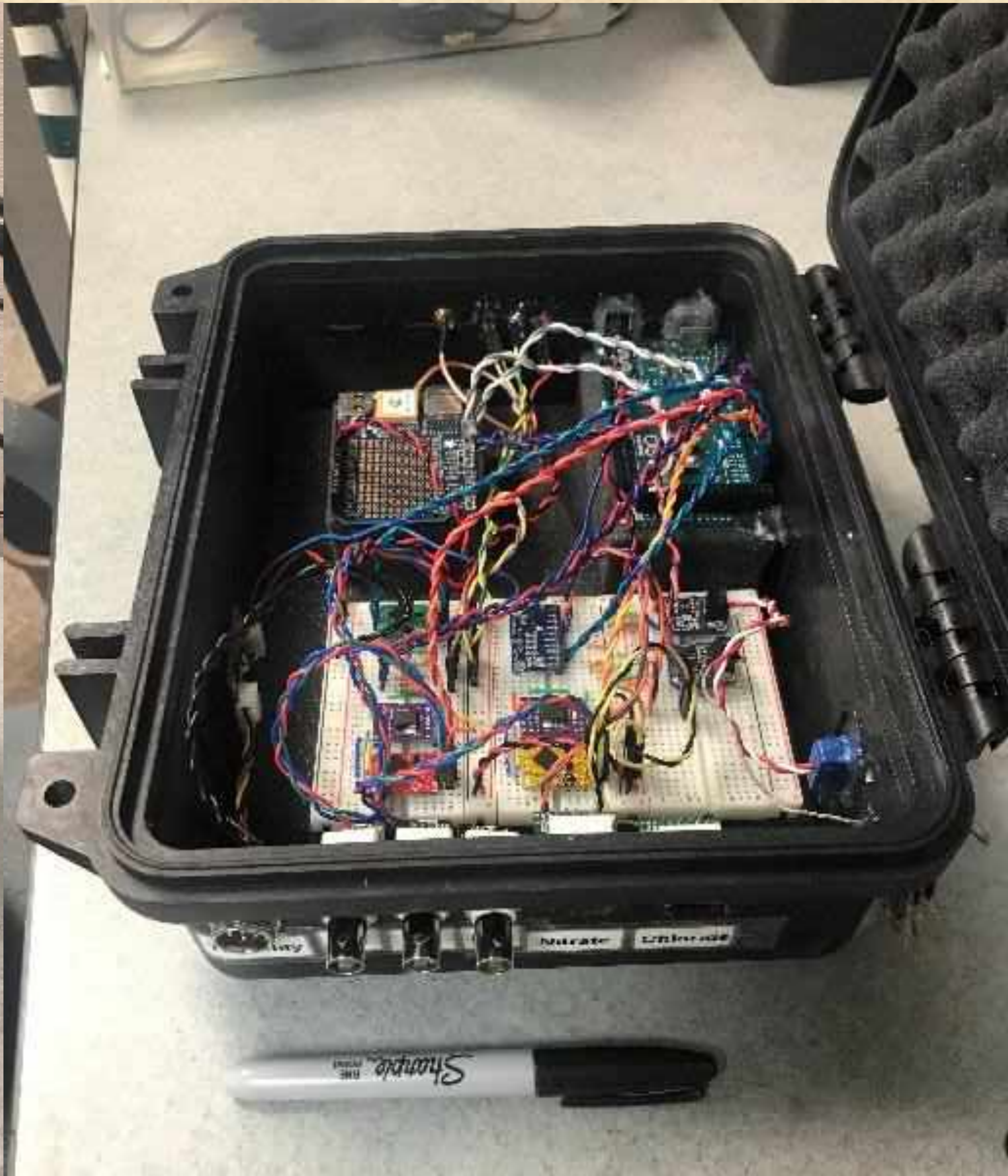
Chloride

Conductivity

Dissolved Oxygen

Water-quality data collection

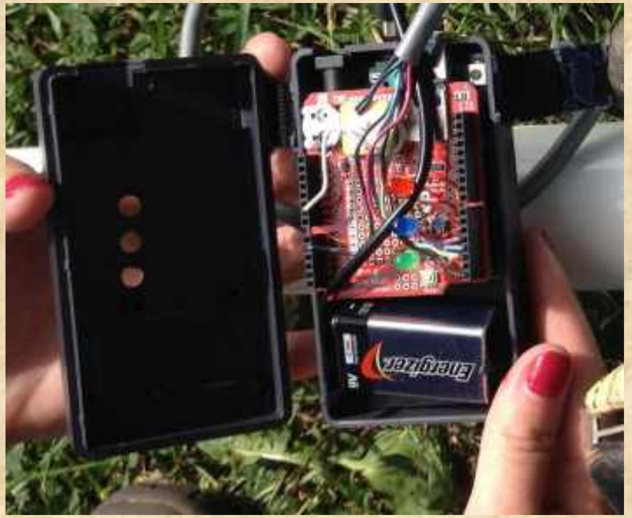




Geophysical methods

EM-31 Ground Conductivity Meter

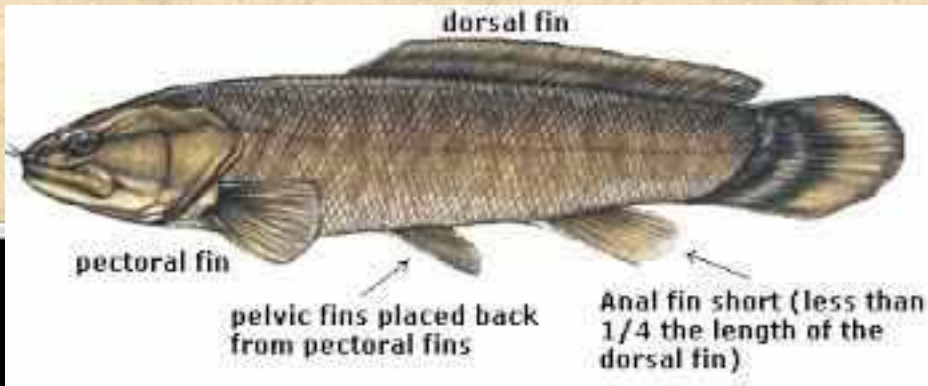
- Example of Arduino application.
  - Created card to record data, time and location.



Go Pro Camera

	HERO4 Session
Max Video Resolution	1440/30p
Photo Resolution	3264 x 2448
Waterproof (without a housing)	Yes
Max Still Burst	10 fps
Weight	74 g
Street price	$200

Example of video – Large fish



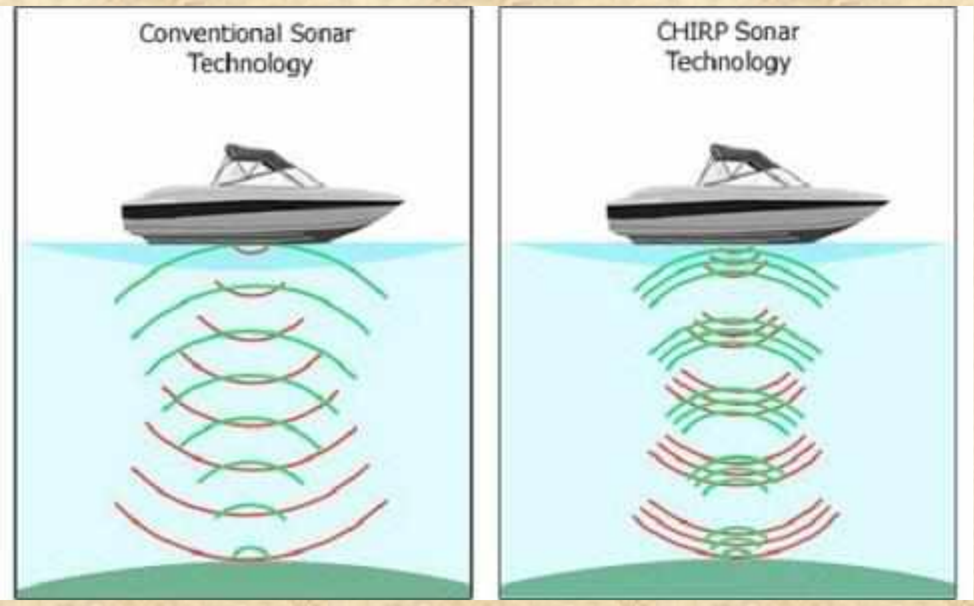
Dog Fish/Bowfin

Photo from GoPro video during stream float

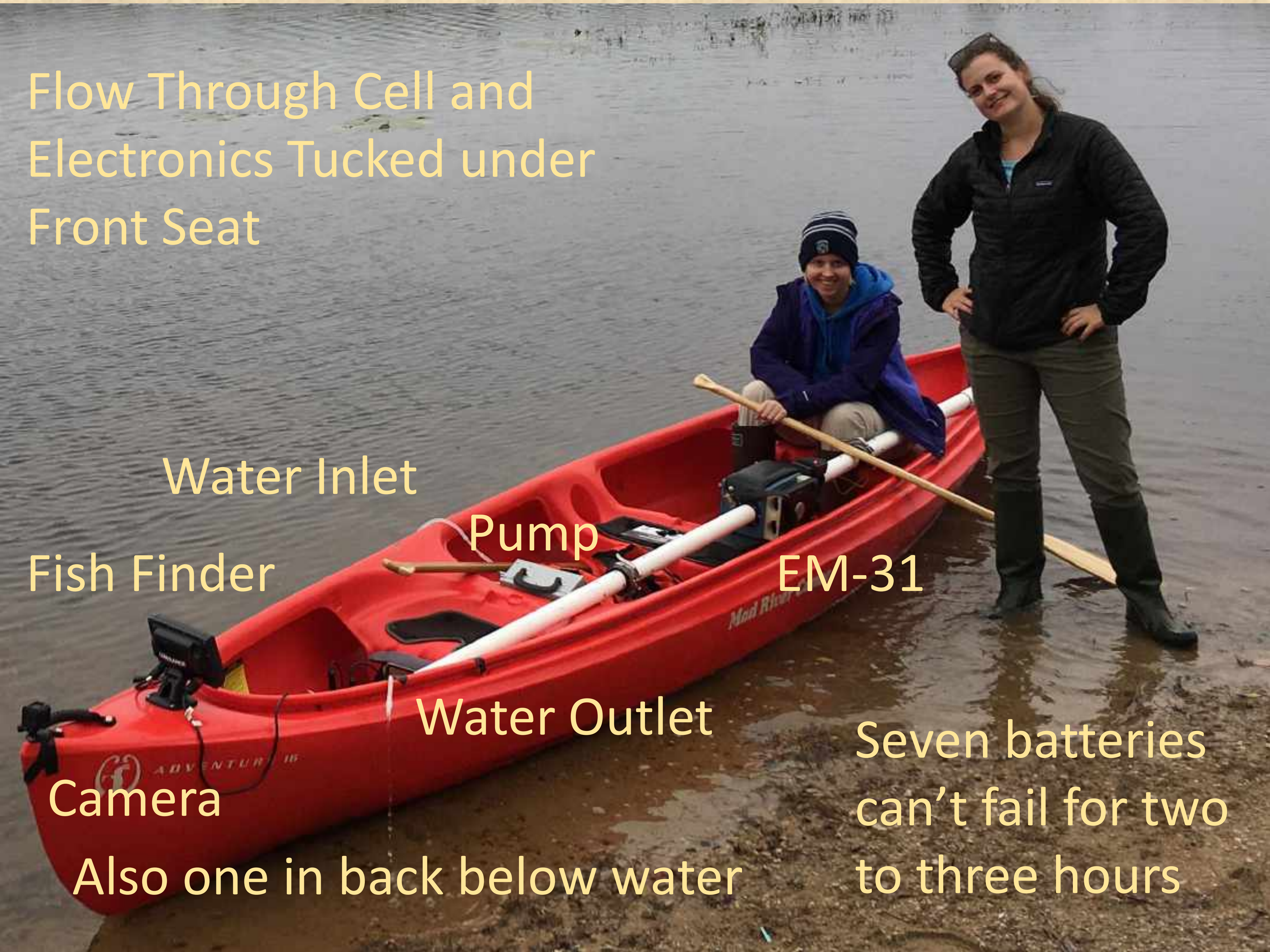
Example of video – Marengo River Beaver

Video from GoPro video during stream float

Depth/Fish Finder



Data also geolocated and stored


Flow Through Cell and
Electronics Tucked under
Front Seat
Water Inlet
Pump
Fish Finder
EM-31
Water Outlet
Seven batteries
can't fail for two
to three hours
Camera
Also one in back below water

Data Quality Assurance

- Sensor calibration
  - Same protocol before every survey
  - Dependent on transducer
- Comparison to “grab” samples sent to laboratory
  - Collect sample in bottle and send to lab for analysis.
- Data reproducibility
  - Go upstream and then downstream or
  - Circle the lake clockwise and then counter clockwise

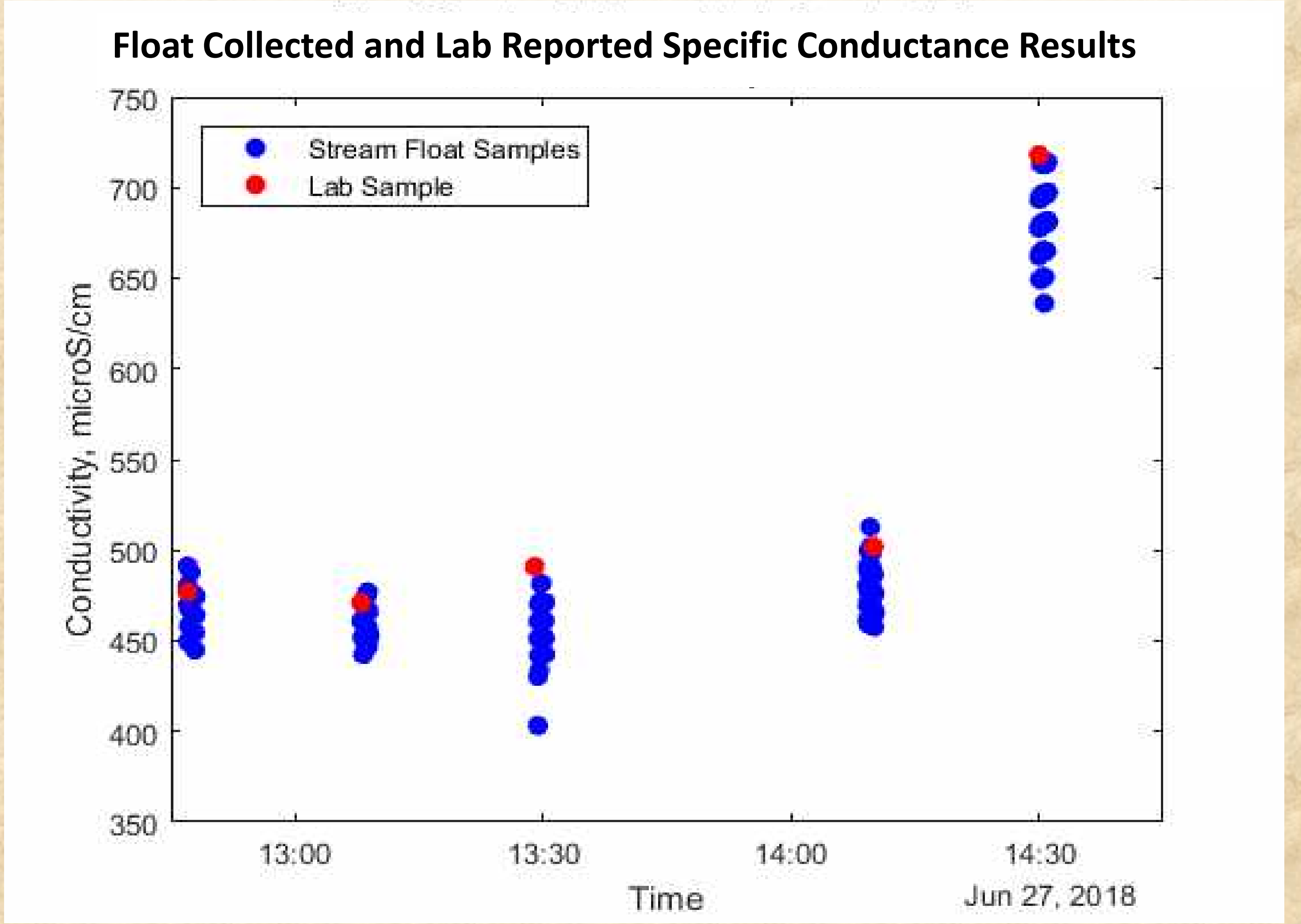
Data Quality Assurance – Sensor Calibration

Standards

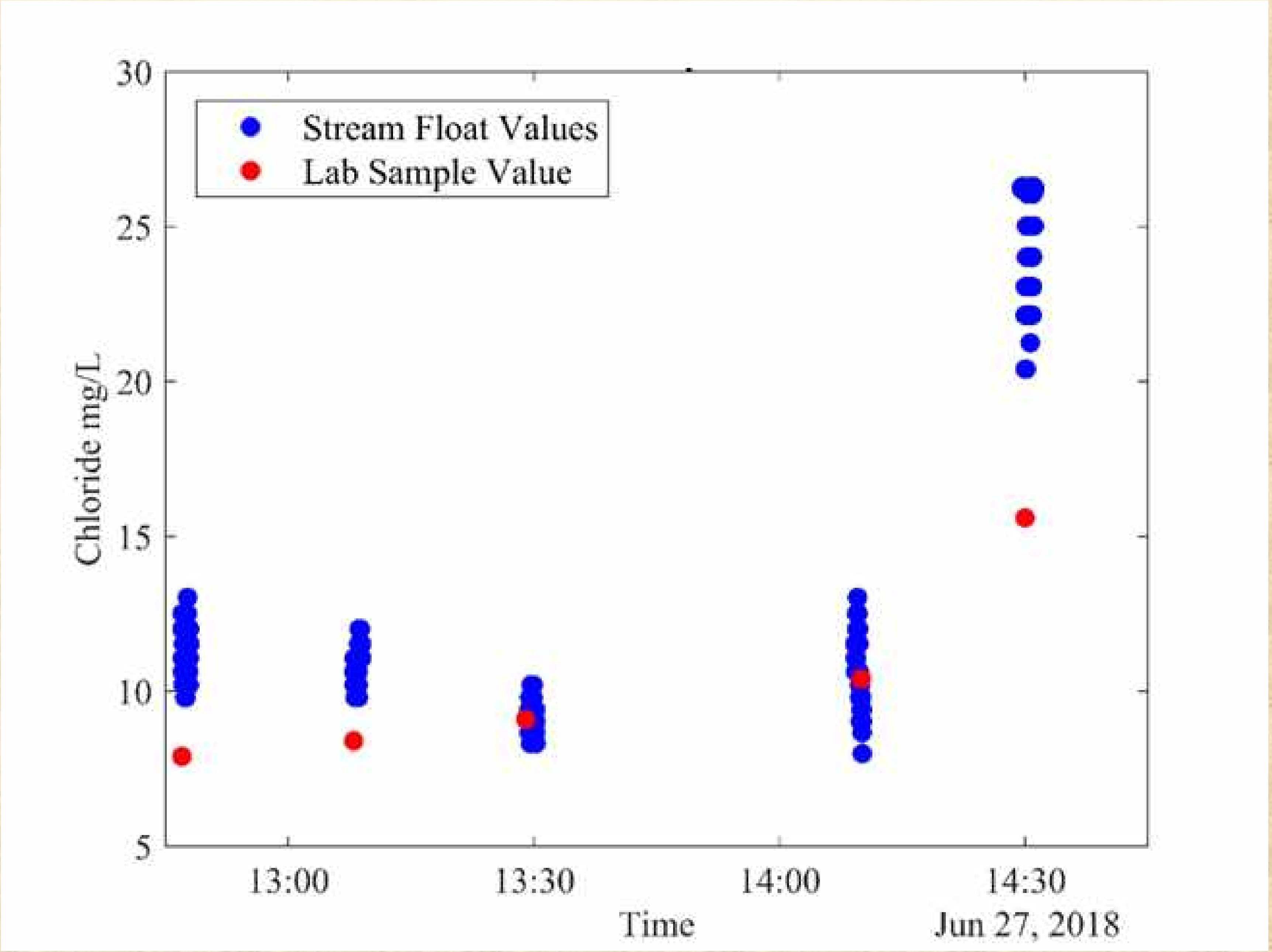
Table 1. Water-Quality Sensor Details, Accuracy, and Calibration Information

Parameter	Probe Type	Flow through cell chamber	Response Time	Accuracy	Calibration Proceedure	Cost
Dissolved Oxygen	Atlas Scientific	3	~0.3mg/L/sec	+/- 0.05 mg/L	1 point calibration to 100% saturation weekly	$283
Temperature	K Type Thermocouple	2	99% in 1s	+/- 2.2 degC	1 time calibration	$20
Specific conductance	Atlas Scientific	2	90% in 1s	+/- 2%	2 point calibration to 14.13 and 1413 uS/cm weekly	$215
pH	Atlas Scientific	2	95% in 1s	+/- 0.002	3 point calibration to pH 4, 7, and 10 weekly	$164
Nitrate (NO3-)	Vernier Nitrate Ion-Selective Electrode	1	varies	+/- 0.1 ppm	2 point calibration to 1ppm and 50ppm daily	$199
Chloride	Vernier Chloride Ion-Selective Electrode	3	varies	+/- 10% of full scale	2 point calibration to 2ppm and 50ppm daily	$199
Additional Temperature	DS182B20 Digital Temperature Sensor	N/A	90% in 35s	+/-0.01degC	--	$3.95

Lab v. Float collected parameters- Mukwonago River

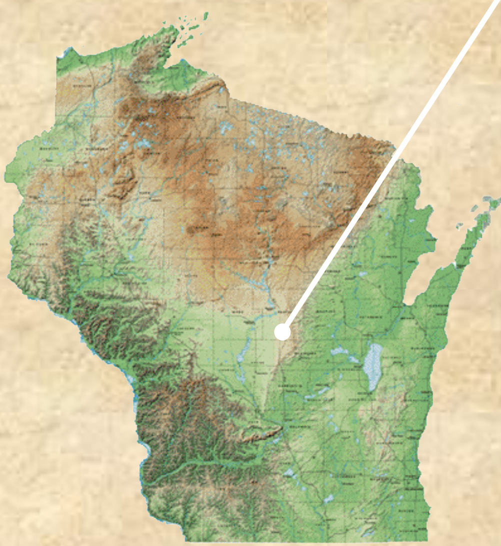


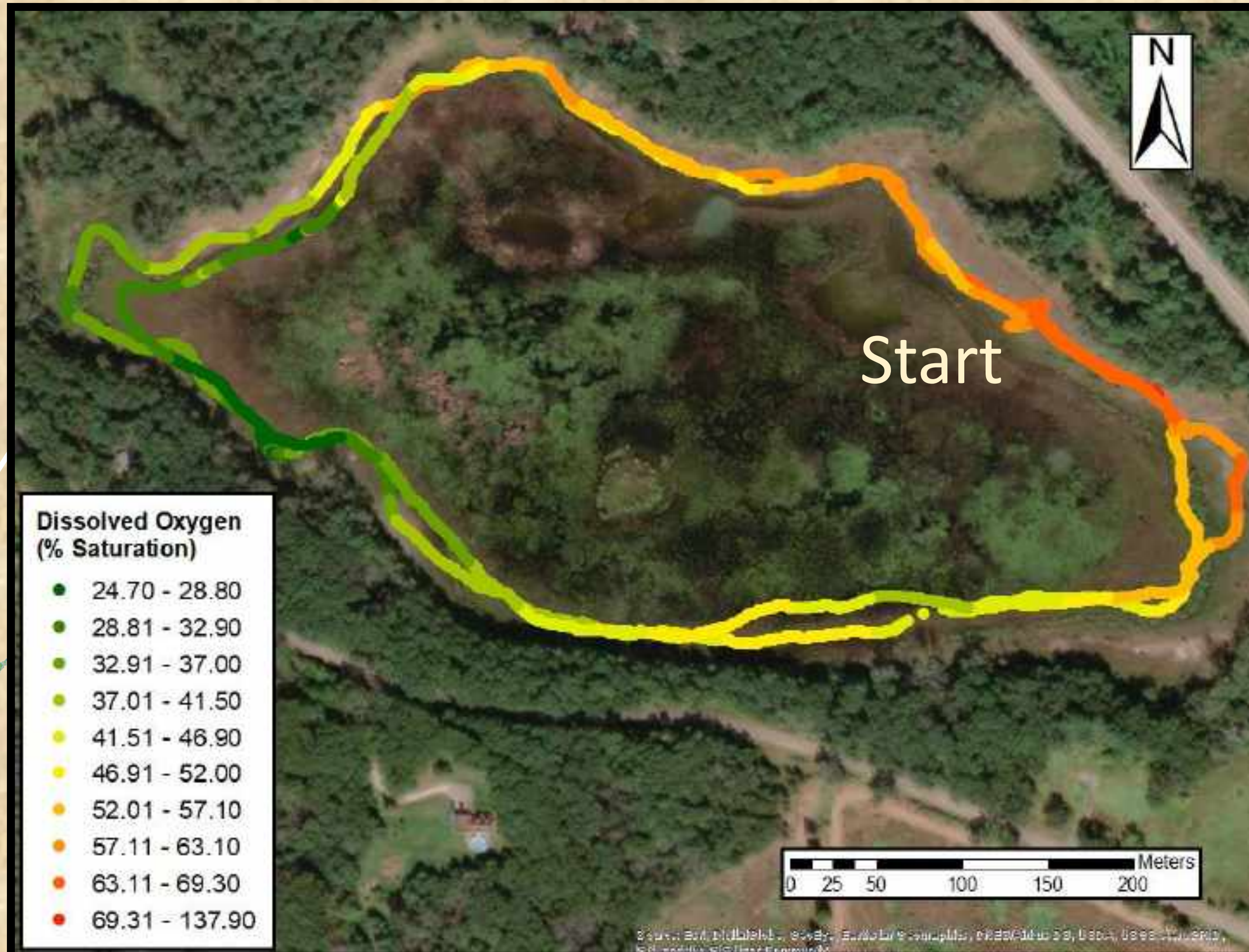
Lab v. Float collected parameters- Mukwonago River



Reproducibility – Circle lake counter clockwise and then back clockwise

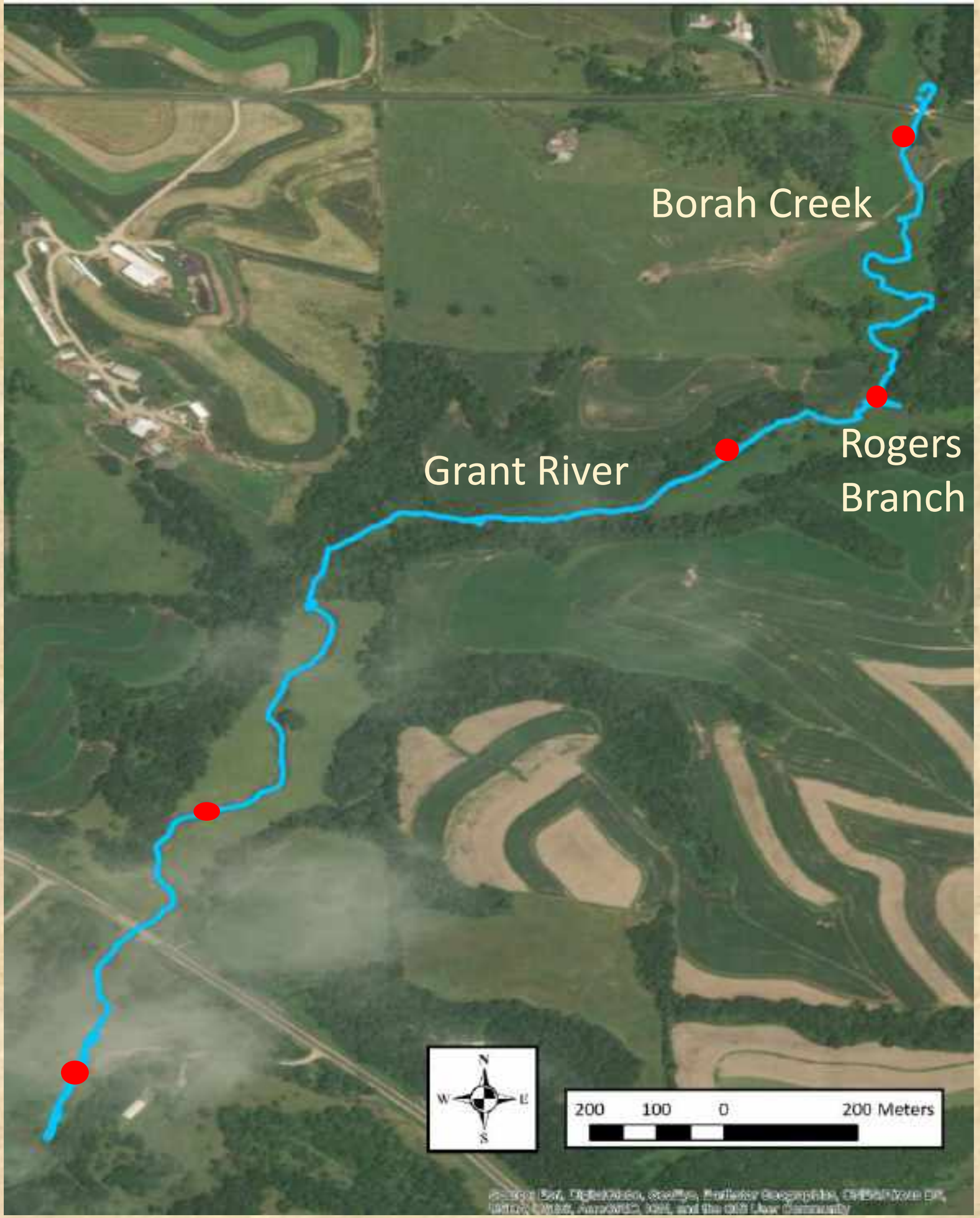
Plainfield Lake, 9/20/2018

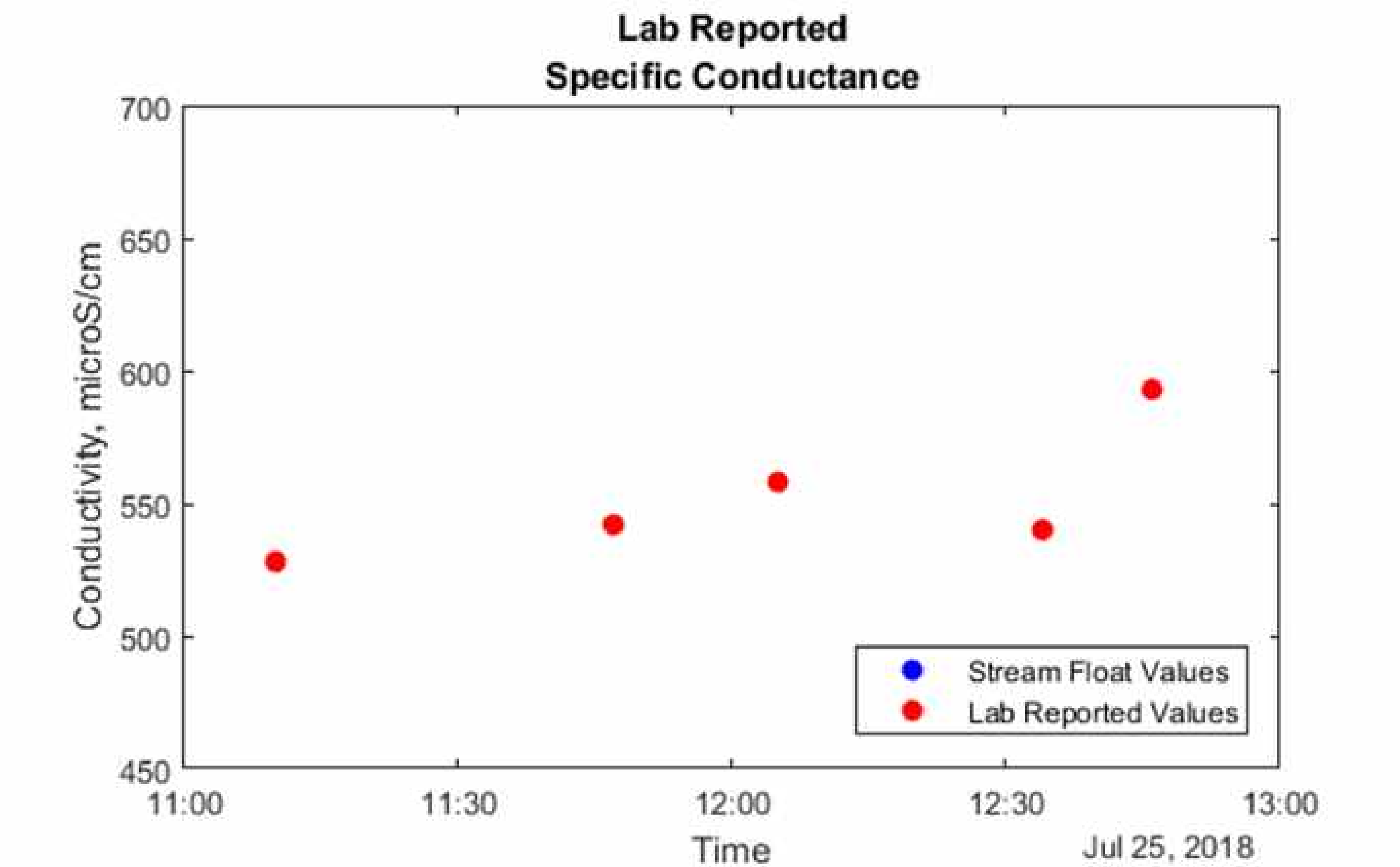


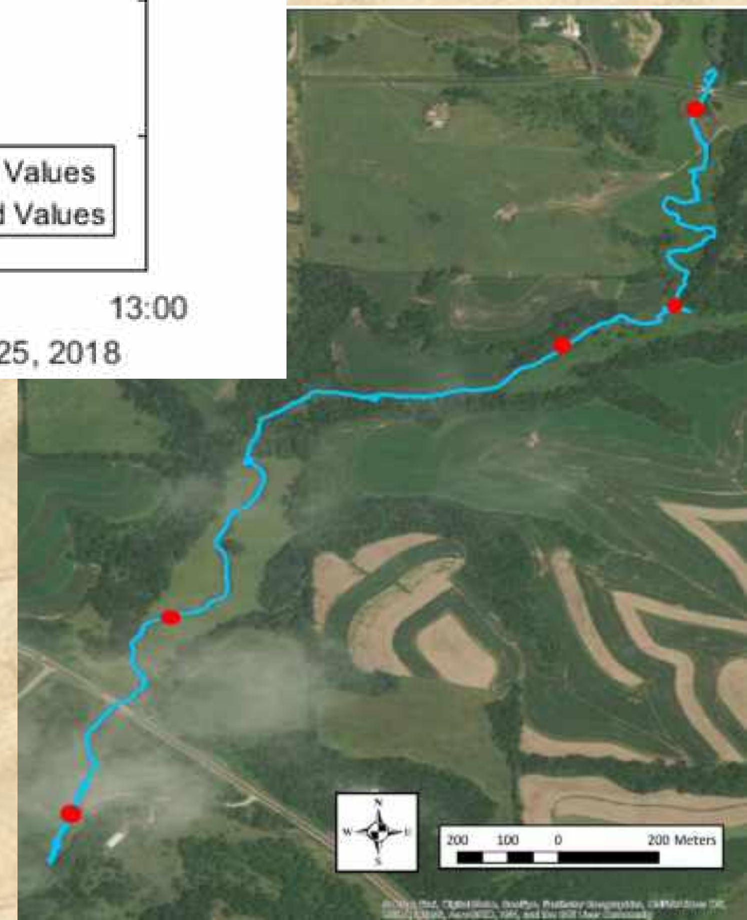


Grant River Results 7/25/18

- Specific Conductance
  - How well does the water conduct electricity
  - Related to the amount of total dissolved solids (salts)
- Illustrates value of collecting continuous data

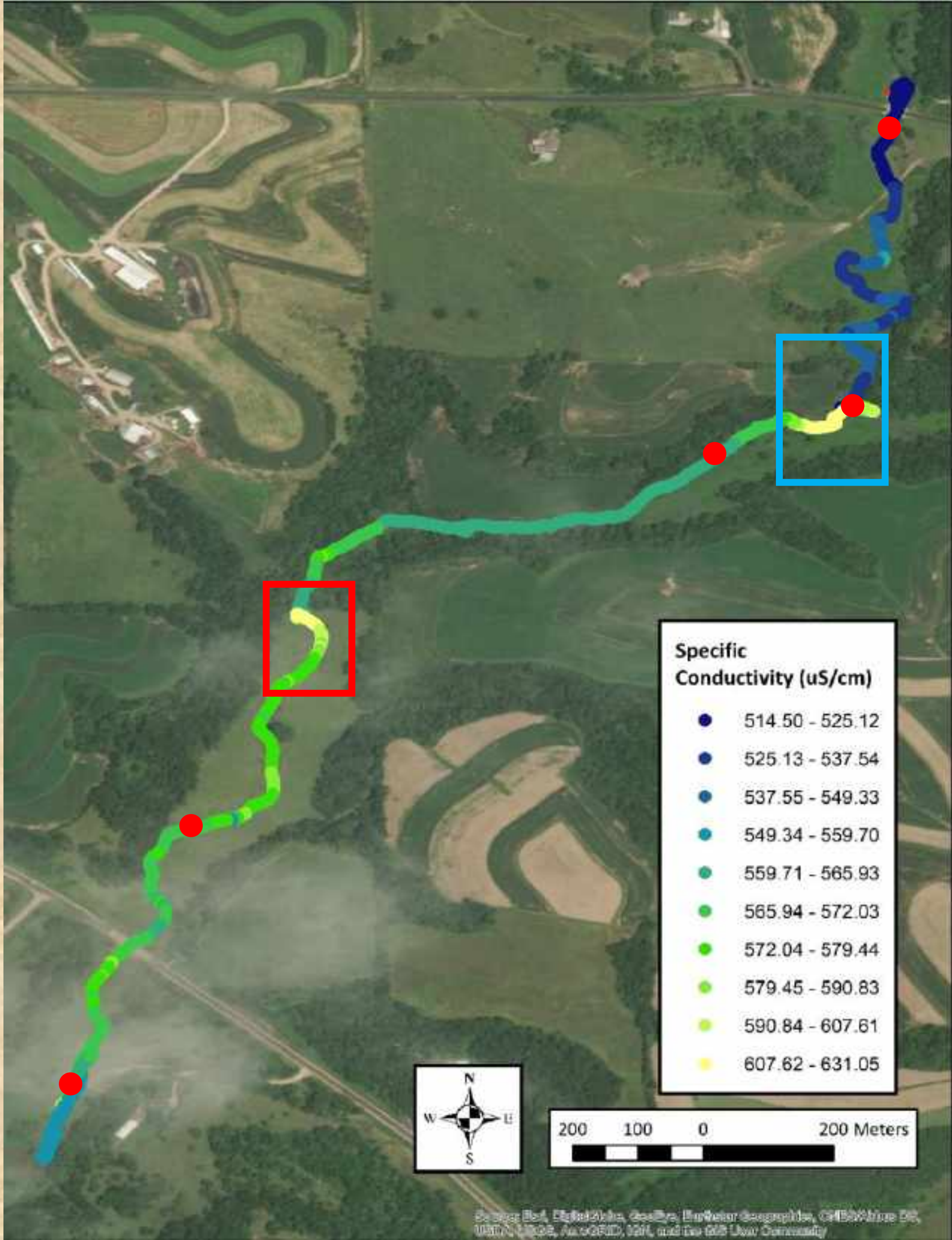


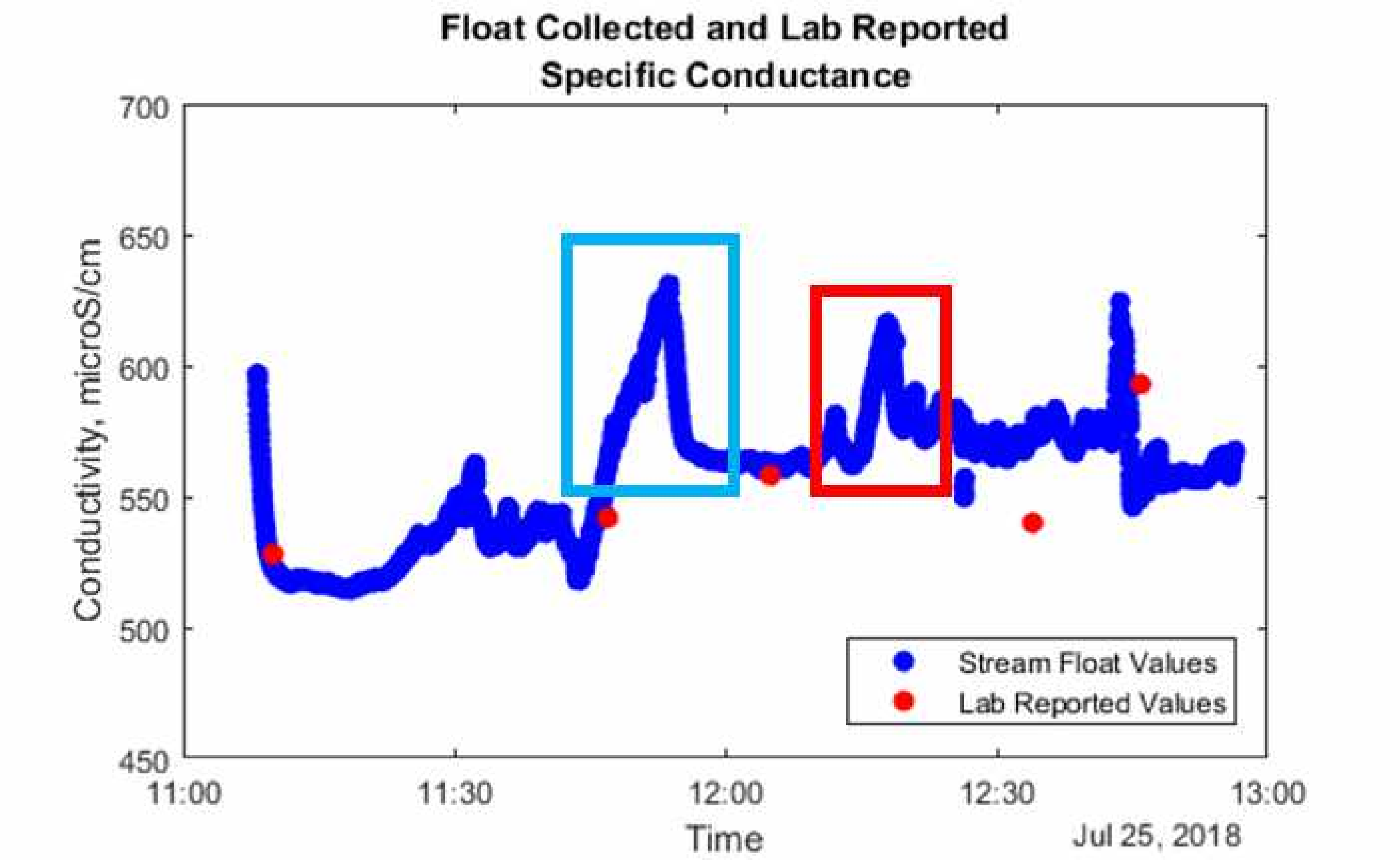


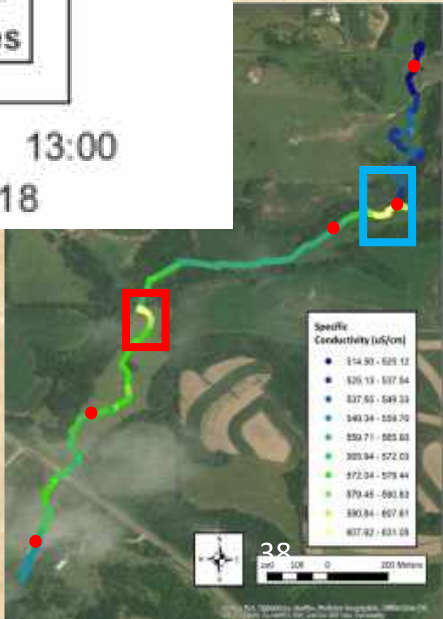


Not a lot of variation seen in this data.

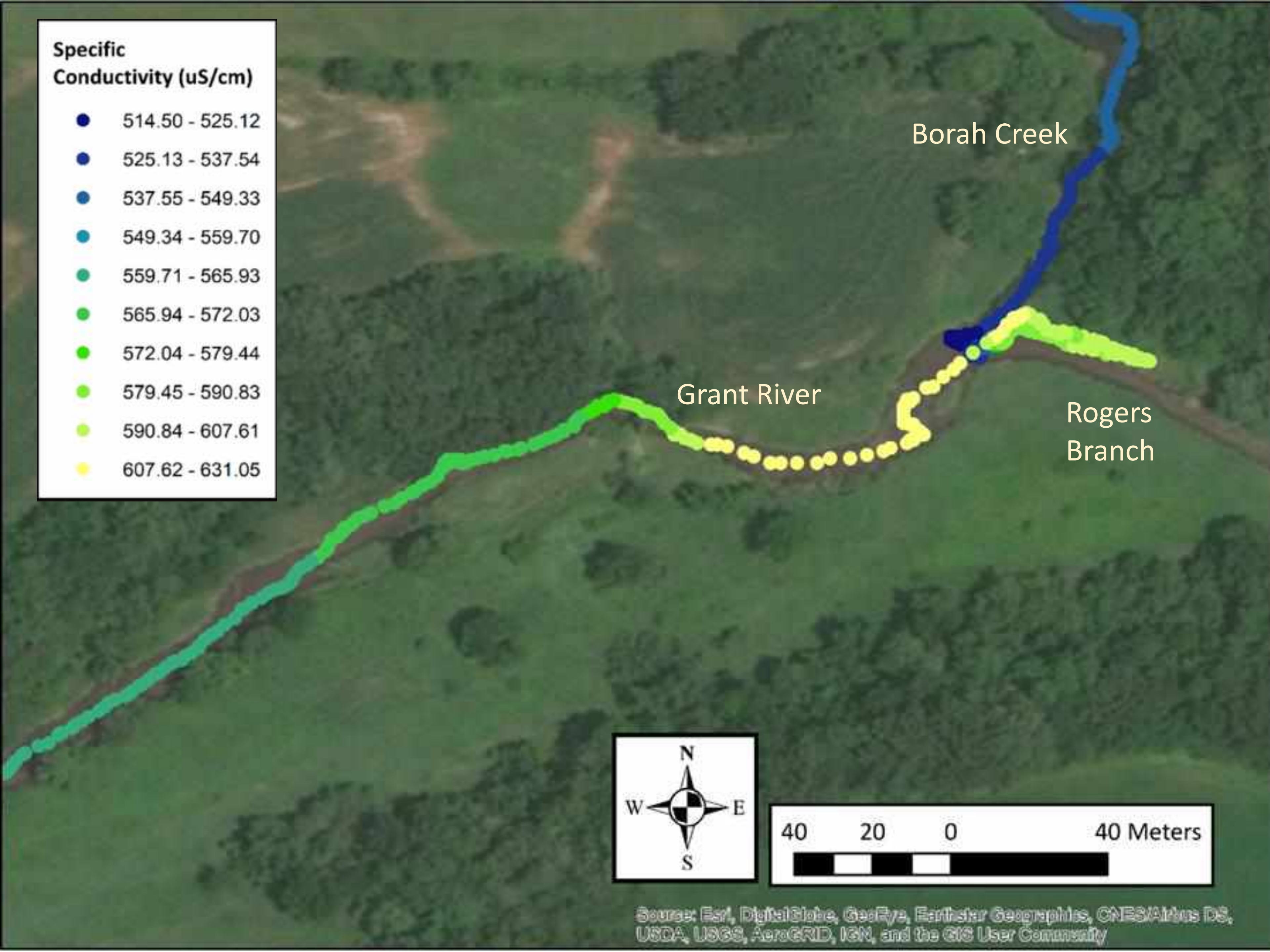
Grant River Results 7/25/18





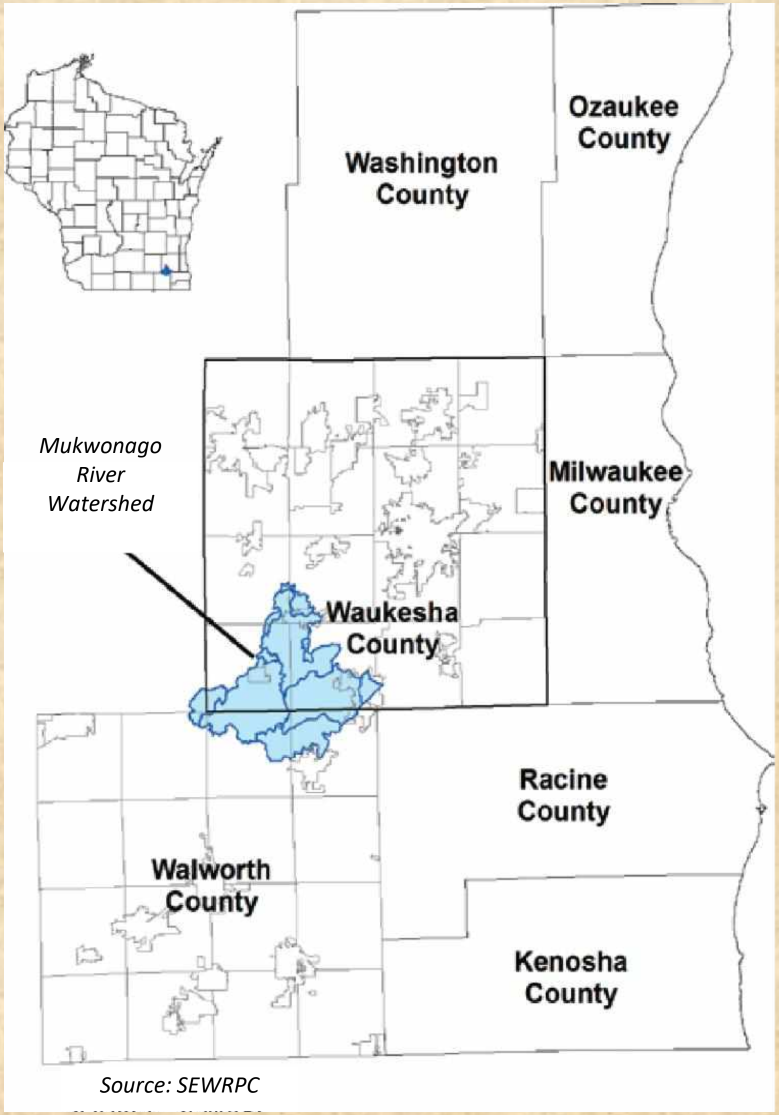


See peaks where Rogers Branch and unnamed small tributary enter.



Specific Conductivity (uS/cm)
514.50 - 525.12
525.13 - 537.54
537.55 - 549.33
549.34 - 559.70
559.71 - 565.93
565.94 - 572.03
572.04 - 579.44
579.45 - 590.83
590.84 - 607.61
607.62 - 631.05
Borah Creek
Grant River
Rogers Branch
N
W
E
S
40 20 0 40 Meters
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Mukwonago River Watershed



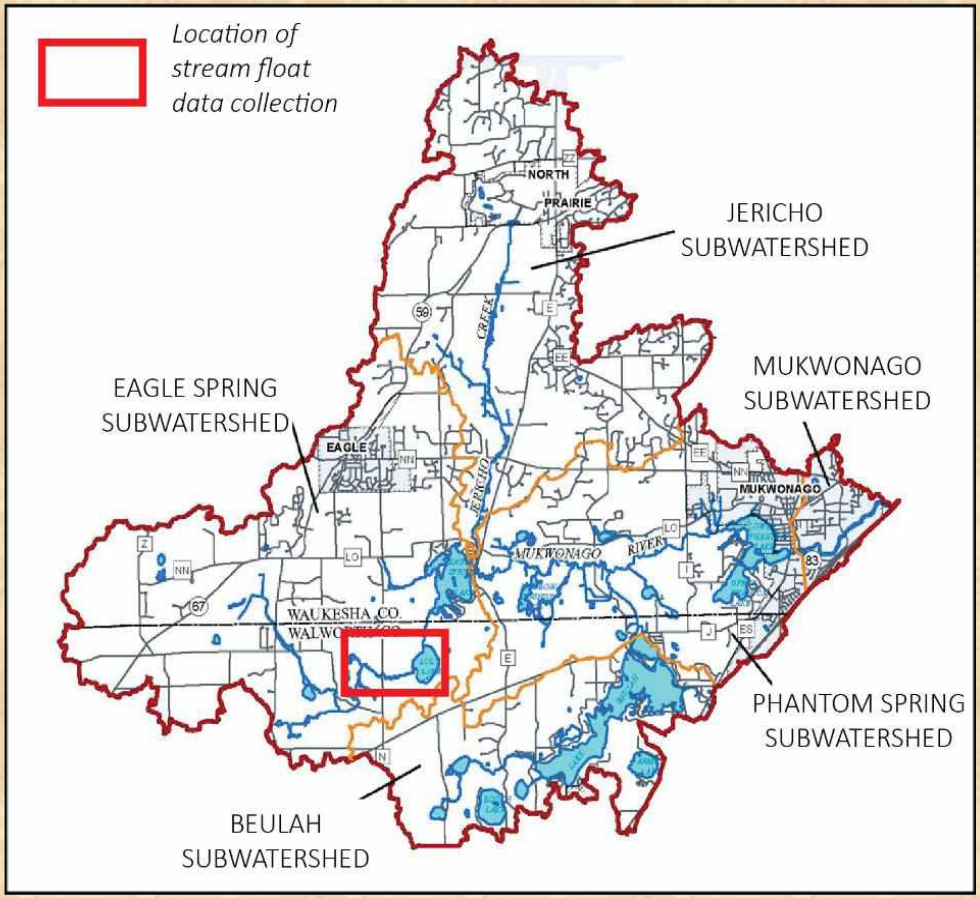
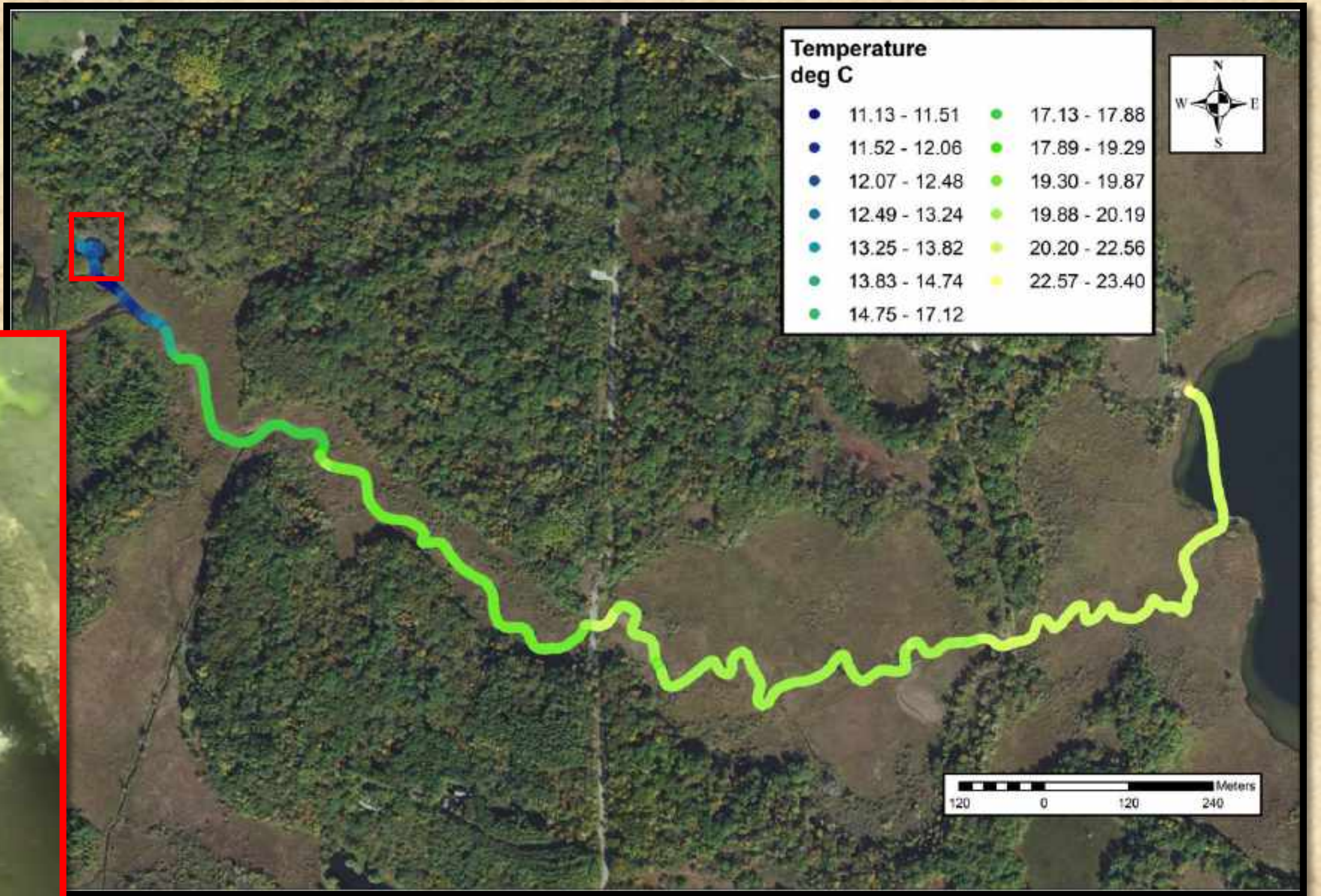


Photo from: www.nature.org

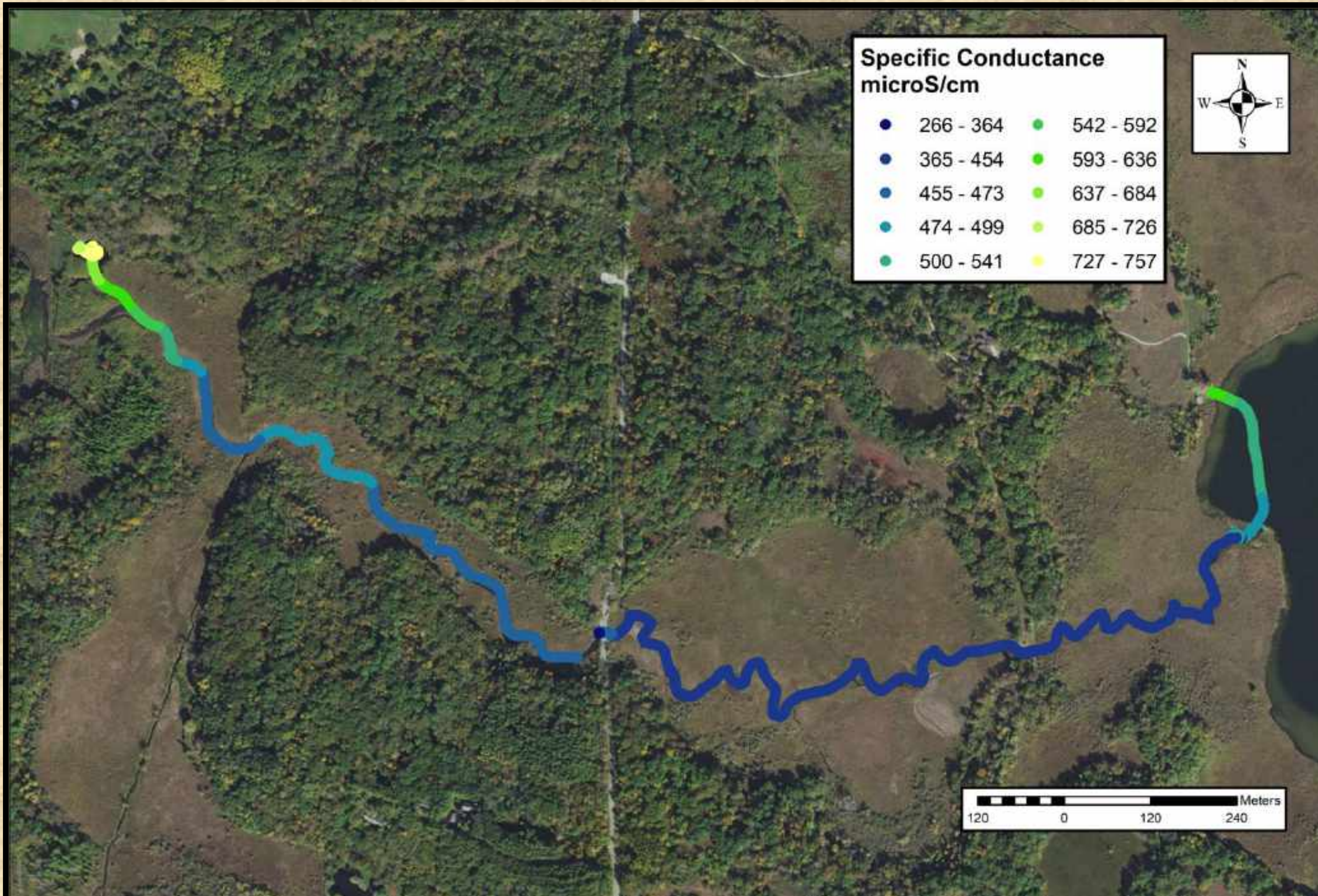
Photos from GoPro video during stream float

Mukwonago River 6/27/2018 (Spring Pool to Lulu Lake) Temperature (C)

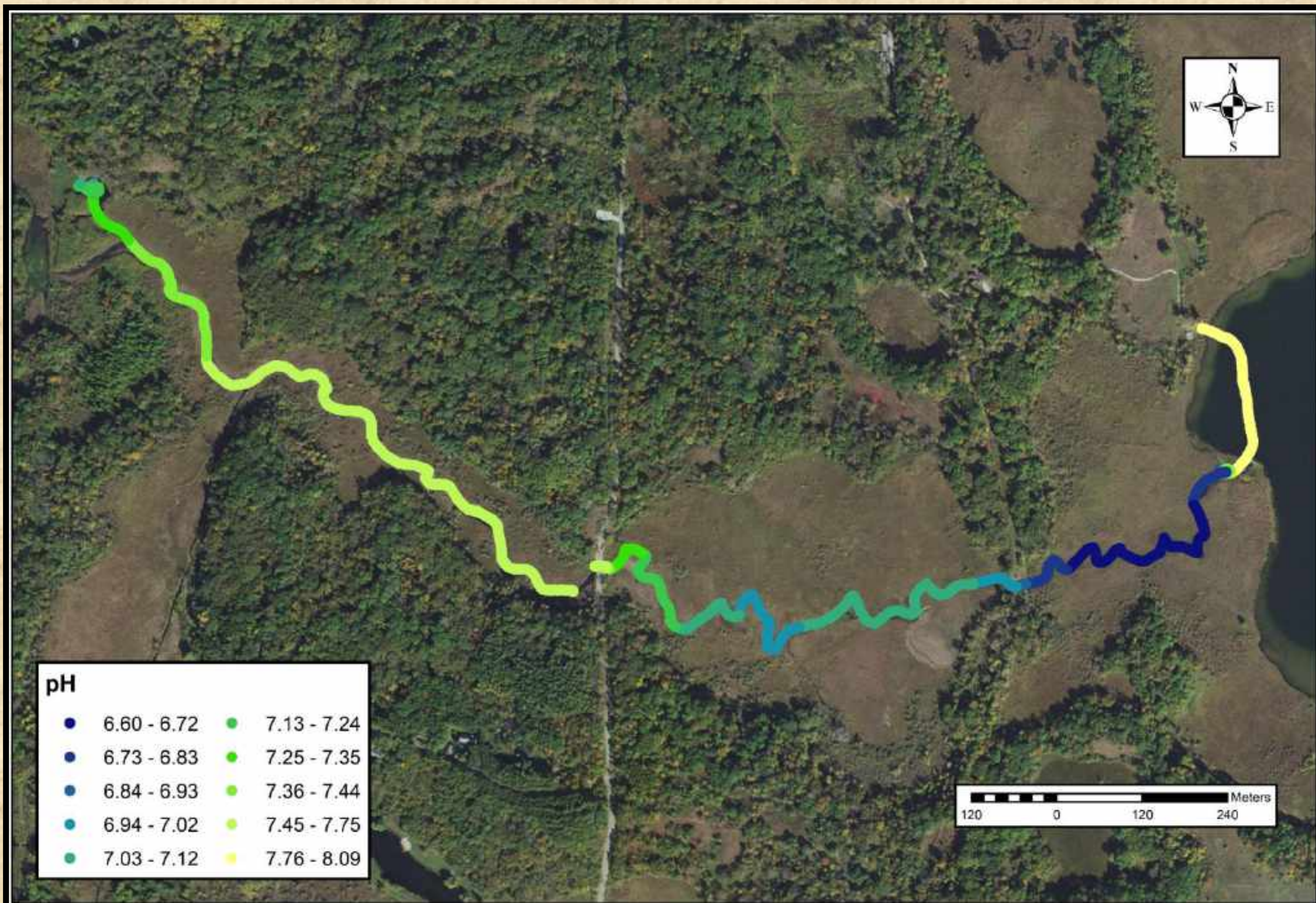


Mukwonago River 6/27/2018 (Spring Pool to Lulu Lake)
Dissolved Oxygen (% Saturation)

Mukwonago River 6/27/2018 (Spring Pool to Lulu Lake)
Specific Conductance



Mukwonago River 6/27/2018 (Spring Pool to Lulu Lake) pH



Method Limitations

- **Site Accessibility**
- **Sensor Response Time**
- **Sensor Quality**
- **Start up effort**

Electrical Conductivity (EC)

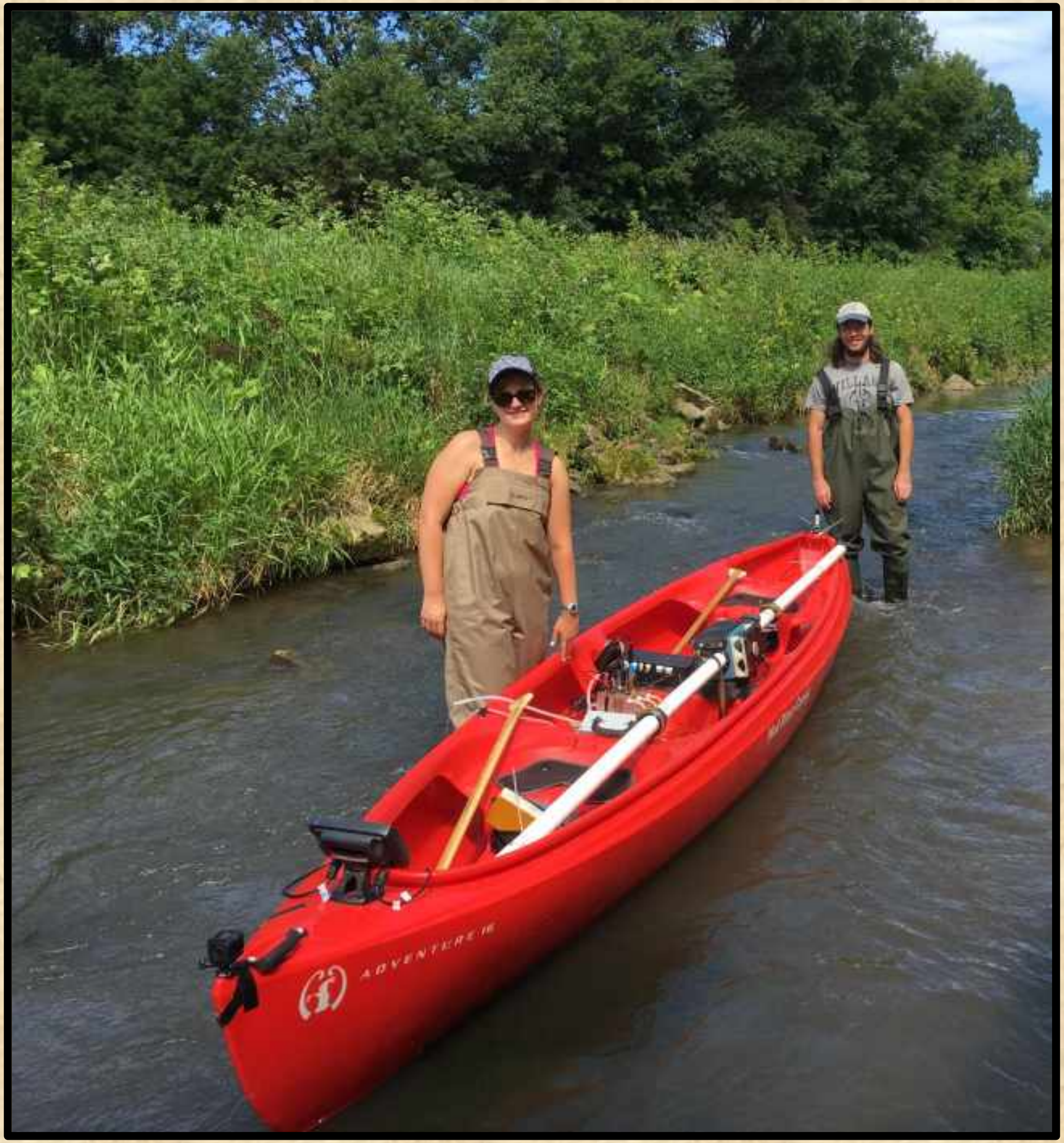
- EC is the measure of a material's ability to conduct electrical current

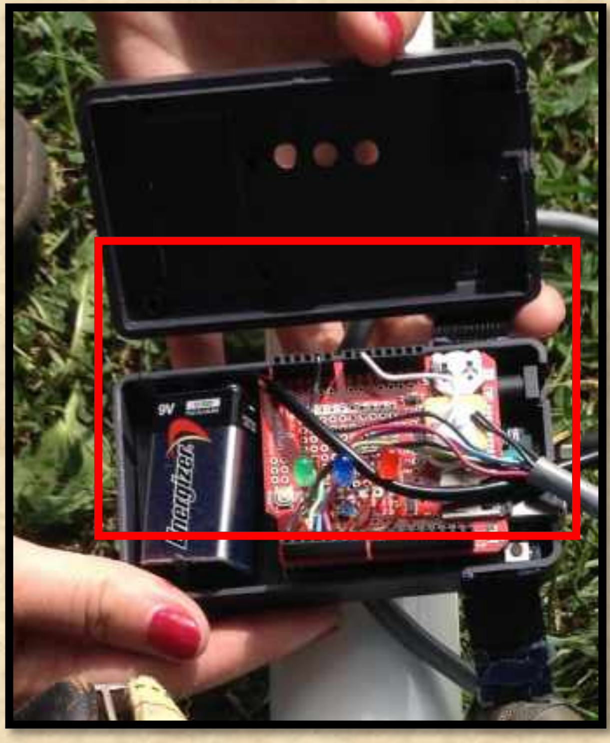
- EC serves as an indicator of lithology:
  - Higher EC → more clay, silt, organic material→ lower hydraulic conductivity
  - Lower EC → more sand, gravel → higher hydraulic conductivity

- Low EC → High hydraulic conductivity → good connection to the aquifer

- Map lithology of entire reaches of streams

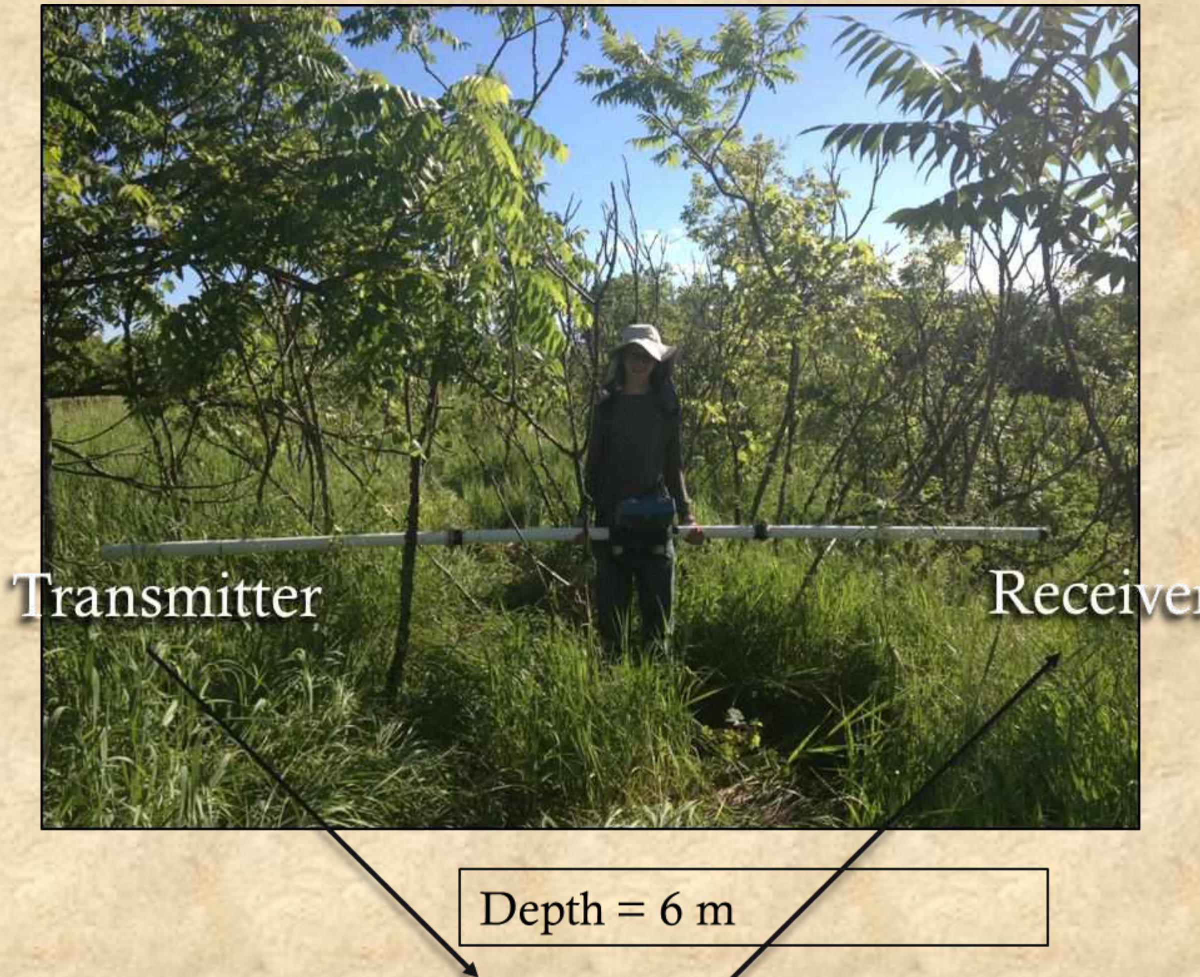
Electrical Conductivity



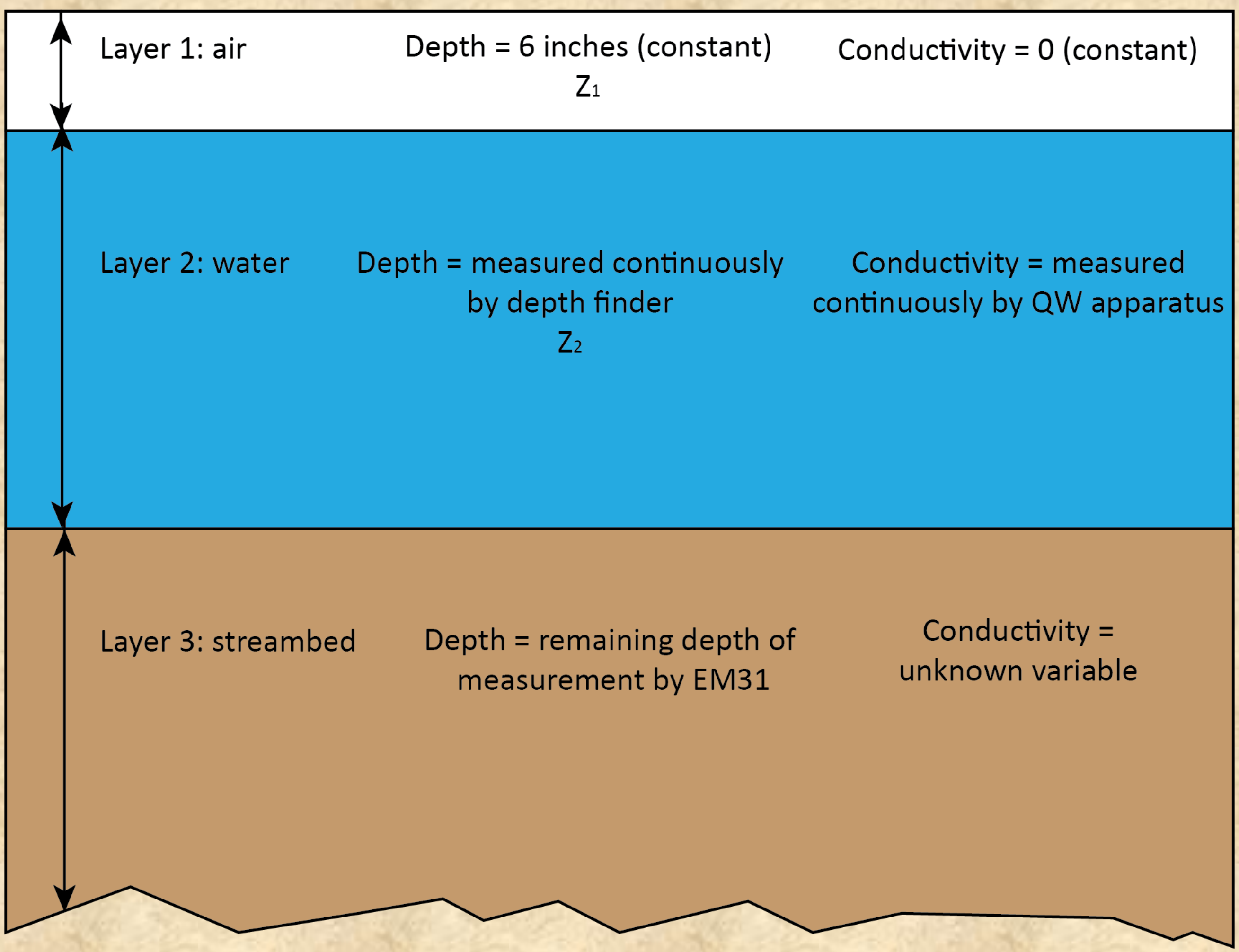


EM31 Operating Principles

- **Instrument induces electrical current in earth with alternating current in coil in one end of instrument**
- **More induced current ➔ Better conductor**

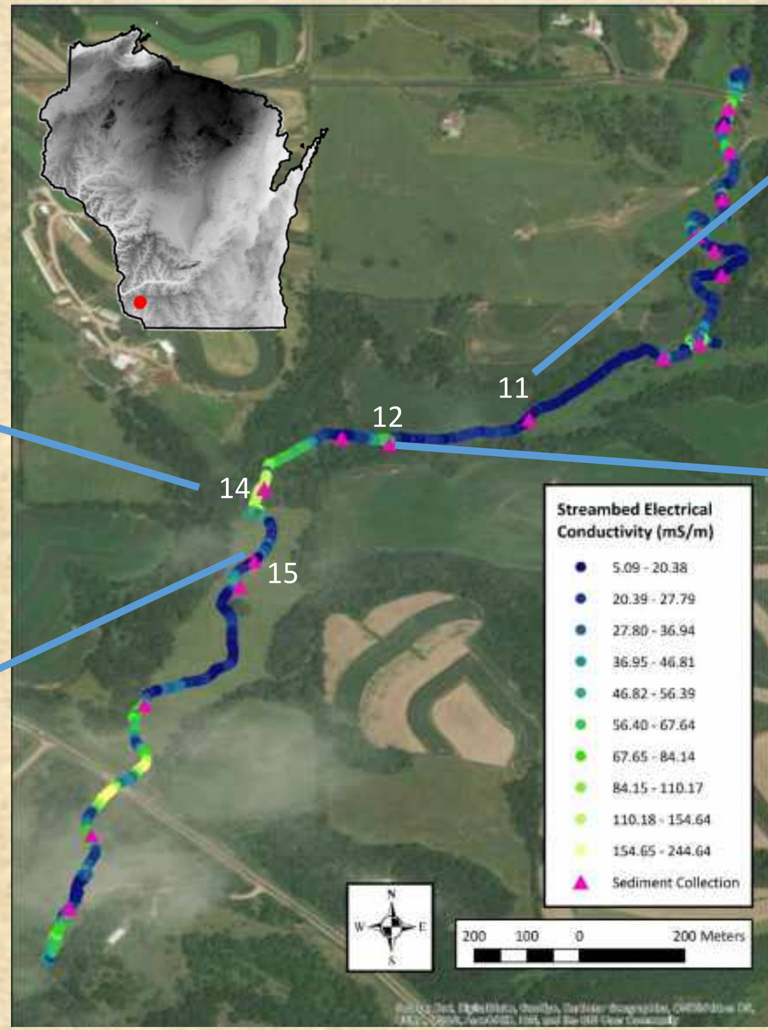


Streambed Conductance



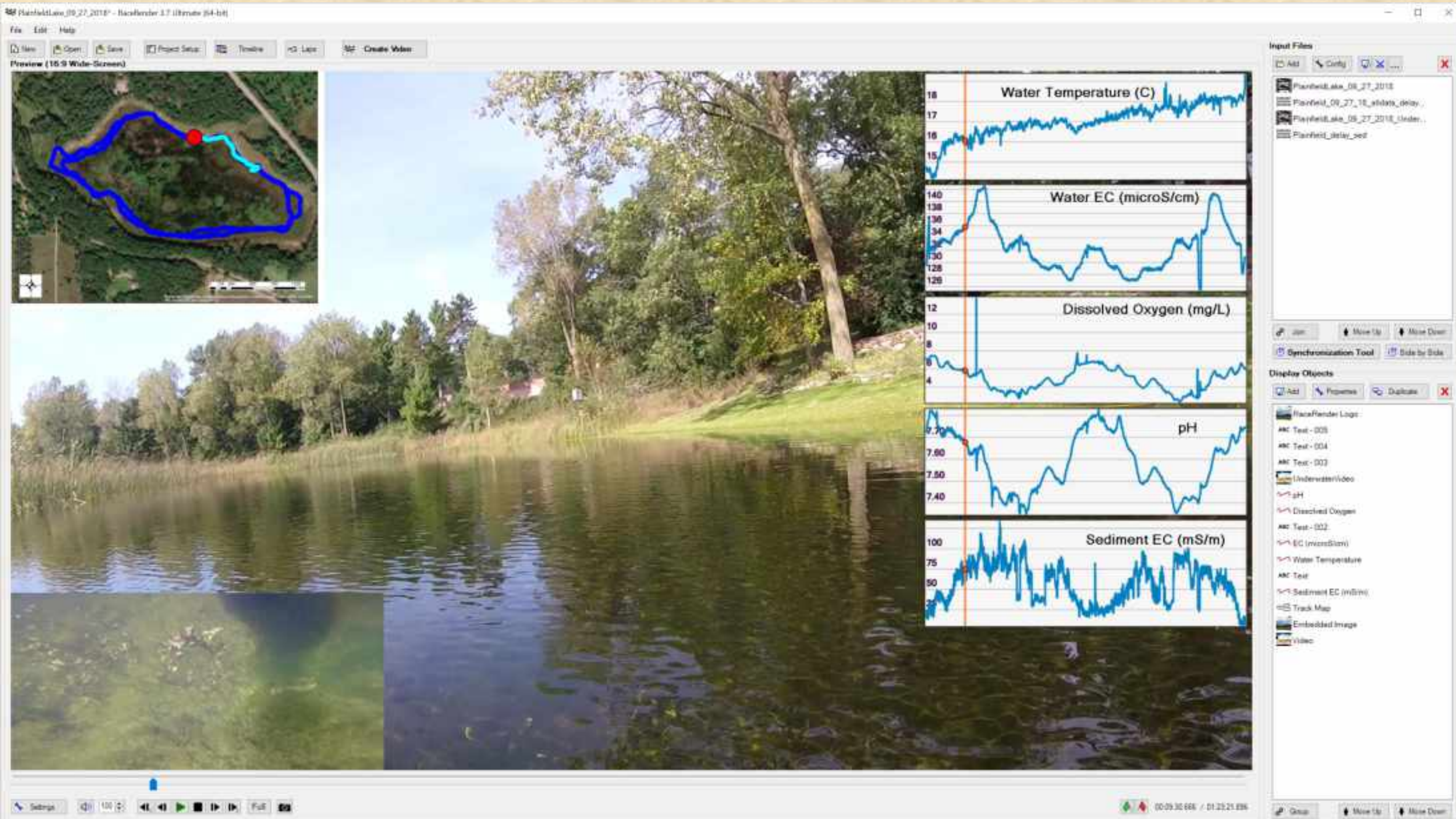
- EM31 measures both water and streambed conductivity
- Use both depth finder and fluid conductivity to remove water contribution to EM31 reading

Grant River



Low Electrical Conductivity (blue) – Gravel
High Electrical Conductivity (yellow) – Silts and Organics

Using Race Render software to combine data and video



Watch videos for Plainfield Lake and the Grant River at the Wisconsin Geological and Natural History's You Tube Channel
https://www.youtube.com/channel/UCwwucf9-W1qocovGx-uzs7w

Conclusion

- Developed method that is low-cost, easy to process compared to other methods
- Provides guidance to areas of interest within a surface water body related to groundwater discharge and water quality changes
- Repeated stream floats can help understand stream quality and dynamics under differing hydrologic conditions
- Movies help record surveys and understand the data

Water
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Geological & Natural History Survey

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GEOSCIENCE

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Questions?