Testing the Waters: What did we learn?

Article for Fall 2016 Rock River Coalition Newsletter

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We learned a great deal from our eleven-day paddling trip down the Rock River with our water quality arrays (see accompanying article). With our new device, we gathered a tremendous amount of data – over 30,000 individual data points – that are allowing us to look at our river in a way that few, if any, rivers have been looked at before. Our metrics were basic – temperature, pH, dissolved oxygen, and conductivity – with a few phosphorus samples taken along the way, and we knew this wouldn't and couldn't tell us everything. So, besides learning that we should buy more comfortable kayak seats next time around, we learned quite a bit of detail about what our Rock River looks like in spring – a snapshot to be built upon in the future -- along with lessons about our testing system and what it can do. We also added to a list of questions about what else we'd like to know. The trip was the first step into a new way of learning about and monitoring change in our river.

Our setup combined off-the-shelf components in a novel way. We connected conventional water quality probes with Arduino microcontrollers, cell phones, and a web server to create testing arrays. We attached our arrays to the front of two kayaks which paddled sequentially down the river (usually within a mile of each other). Unit #1 stuck to the stream centerline while Unit #2 captured the centerline plus side trips into sloughs and the first hundred meters or so into tributaries. This gave us repeated measurements along the centerline plus insights into various habitats along the stream periphery.

You've seen the notice "provisional data subject to revision" on government websites such as USGS. We're in the same "boat" and need to process our data a bit before conducting our final analysis. So far, we've "linearized" the data along the stream centerline – moving each sample to the stream center and calculating how far it falls on that centerline yielding a consistent "x" coordinate for our graph – to generate a graphable profile along the Rock River. Later, we'll be conducting additional processing including: 1) filtering the data for known issues and spurious data points and 2) accounting for sensor calibration and drift throughout the day (most evident in the conductivity data). Our plan is to eventually publish the data collected during the trip. We're enlisting expertise from UW-Madison to review our analysis procedures and our final interpretation of the data.

So on to what we've learned so far. First of all, our water quality testing system worked almost flawlessly. We developed a novel and technologically complicated system and pilot tested it in a *very* public fashion. Personally, I was praying that the system would make it through the first day without quitting. Our devices and mapping servers worked for the duration of the trip – our servers never quit and we only lost data twice when the GPS on one of the phones refused to update (missing a total of around 4 hours of data that the duplicate unit did not miss). We also identified issues with our calibration procedures that we believe we can partially fix with the process noted above. The data between the two units was very similar and where we had calibration issues (conductivity days 3, 7, and 8) both units measure similar relative change. Overall, we conclusively demonstrated the feasibility of the system and its future use and expansion.

Second, we collected a substantial amount of *comparable* data. Including a preliminary (Day 0) trip through Horicon Marsh (the South Branch of the Rock River), we collected a total of 34,699 data points across 12 days of paddling. We were incredibly lucky with the weather throughout our trip. We received no substantial rain, which would have compromised our ability to compare across sample dates. According to the weather recorded at Watertown Municipal Airport (KRYV), we received only 0.02 inches of rain except for during the final day when we received 0.11 inches. This allows us to take the unique view of the river profile and compare across river segments – something that traditional sampling methods don't allow for.

While we're still working on the data, we're already noticing interesting patterns. You can see the whole river profile for each metric from Mayville down to Beloit in Figure 1. Pause a moment and ponder. It's a lot to absorb, but this shows us data collected for each day as we paddled down the river (shown on a map in Figure 2). Overall, the data shows a springtime flow that's relatively healthy. Using Milwaukee Riverkeepers targets[1] – dissolved oxygen > 5 mg/L, pH from 6 to 9, conductivity from 150 to 500 µS/cm, and temperature < 31.7 °C, the river met all of these targets except for high conductivity for the full extent of our paddle. High conductivity values, though, are likely more an indication of river's baseflow – water entering the stream through subsurface flow – through mostly carbonate rocks and are not an indicator of poor water quality. There's nothing in this flow data that indicates an overall issue with our river.

Specific metrics tell a similar story. Temperature values revealed a steady increase that anecdotally reflected the warming spring temperatures throughout the paddle. Spikes visible in the data are not errors – these mostly warmer temperatures are from the second boat paddling into warmer, shallower waters. Interestingly, the larger thermal masses of the lakes we paddled through, Lakes Sinissippi and Koshkonong, do not show up as colder stretches of water.

Our pH values were relatively high (indicating basic/alkaline conditions) throughout the river profile. Like conductivity, these alkaline conditions are likely due to the substrates that the river's water flows through and over – high calcium and magnesium content drawn from the river bed and the region's geology. Wisconsin fish, in general, can tolerate the high pH and that may protect them from absorbing mercury and other heavy metals into their bodies (Brown et al.

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[1] Note that the Rock River Coalition hasn't officially adopted these targets, but they serve as a useful local target for identifying problems.

2010) – good news for anglers. Interestingly, one study documented that survival of common carp is decreased above a pH of 8 (Heydarnejad 2012). High pH may be helping to ameliorate the impact of carp on the river. Also, there is indication of a diurnal cycle of pH on days 2, 6, 7, and 8. Dissolved carbon dioxide generated by respiration of aquatic life can lower pH values and as this CO_2 is removed throughout the day through photosynthesis, pH values can rise (Fondriest Environmental 2013). These trends may indicate stream stretches with healthier aquatic plant communities. Again, the downward spikes in pH aren't flukes; those are from Unit #2 boat's forays into side streams where the pH dropped. While I'm not certain of the cause, it's likely due to the substrate these side streams flow through.

First glancing at dissolved oxygen (DO), I thought our sensors were either incorrect or had a bias at high dissolved oxygen (perhap a non-linear inflation of higher values). Along our whole route, 60.7% of our readings are at or above 100% saturation. That's incredible. However, our units were consistent with one another. Supersaturated oxygen levels occur in two situations – stagnant water with abundant photosynthesizing plants or with rapid temperature changes. I believe that we mostly encountered the latter with warm days and relatively cool water. Cold water holds more oxygen and, as the surface of the water warms, becomes supersaturated for awhile until equilibrium concentrations at that temperature are reached. This may also explain the relatively high DO readings we had in Lake Sinissippi (Day 3) and Lake Koshkonong (Day 9) – these larger thermal masses would have higher temperature gradients near the surface. Of note is general lack of the dissolved oxygen diurnal cycle (lowest in the morning and increasing with photosynthetic activity throughout the day) for several stream segments. In a stream with a healthy plant community, we might expect to see general daily trends such as those visible in Days 5, 6 (error in Unit #2), 7, 8, and the first half of 9. For Days 1, 4, 10, and 11 we see no visible increase in dissolved oxygen as the day progressed. This may be attributable to compromised aquatic plant communities – not something we explicitly observed or documented – in these sections of the river.

Conductivity (or electrical conductivity or specific conductance), the measure of dissolved solids such as magnesium or calcium, proved to be our most temperamental probe. There was strong agreement between our two units on the *change* in conductivity, but their *absolute* values differed for several days (e.g. Days 3 and 7) indicating a difference in calibration. Due to these differences, we made a change to our calibration procedures, and once we apply these corrections and remove the "provisional" from our data title, we should see better alignment of the two units. The profile appears to highlight the role of the two lakes in conductivity. Values are highest before the lakes and drop through them (Lake Sinissippi on Day 3 and Lake Koshkonong on Day 9). Dissolved solids are ions like CA^{++} in the water and are not the same as suspended solids (what a turbidity probe would measure), so we wouldn't necessarily expect the slowing water of the lakes to reduce dissolved solids. However, there may be a relationship between suspended solids and dissolved solids – clay and organic matter may be serving as a flocculant to which ions are binding and settling out of the water column. With conductivity, we did notice the impact of at least one side stream on the Rock. The Rubicon River (around 71,000 meters on the graph) showed a spike in conductivity that appears to have increased the overall conductivity levels of the river by around 40 μS/cm – an indication of at least one tributary whose influence was significant on the main stem that perhaps warrants further investigation.

Phosphorus, along with turbidity, is one of the key metrics for which the Rock River has been deemed “impaired” under the Clean Water Act. Unfortunately, it’s a difficult and expensive test to make a measurement of total phosphorus. With the help of local municipal wastewater treatment facilities, we were able to take phosphorus readings at 55 locations along the river with key measurements above and below major tributaries to gauge their impact. Overall, our levels were generally relatively low with 5 of our 55 samples (9%) falling below the Rock River Recovery target threshold of 0.1 mg/L. These results are not surprising for this time of year which typically holds the lowest P values in an annual cycle. Our paired samples did not reveal any significant impacts of side streams on the Rock. Of the paired readings (18 total), 6 led to increases in P levels (average of 0.04 mg/L) and 12 led to decreases in P (average of -0.04 mg/L) perhaps indicating that overall, tributaries had lower levels of P and may be helping to improve downstream quality. These changes may warrant further investigation and the addition of tributary flow to better gauge phosphorus loads both on tributaries and the main stem.

As you can tell, there’s a lot of speculation here that needs further refinement. However, the potential relationships between pH and dissolved oxygen, the potential connection between conductivity and turbidity, the role of the lakes in “cleaning” the water, and the different chemistry of the Rock’s tributaries all highlight the insights that our high spatial sampling allows us to explore that traditional point samples could not reveal.

I wouldn’t be a responsible researcher if I didn’t point out all the questions that this project raised (and why I’ll have to do a lot more paddling). This snapshot captured the Rock in its spring condition and that’s apparent particularly in the temperature and dissolved oxygen values. How do these change throughout the season? Which stream segments show a high degree of variability and which are more stable (hinting as to which stream segments may be more susceptible to extreme weather events or pollutants)? Why did we find lower dissolved oxygen levels the last two days? Ideally, we’d repeat this sampling for three or four times throughout the spring, summer, and fall to capture both spatial and temporal trends throughout the river. And, I’d give one of my rear molars for a turbidity sensor. Anecdotally we observed very distinct sections of the river in regards to turbidity (high turbidity above and below Lake Sinnissippi, moderate levels around Fort Atkinson, and very low levels below Lake Koshkonong). Since it, along with phosphorus, is one of the metrics identified in the Rock’s “impaired” status, it would be great to know more about the turbidity patterns and speculate on causes of both high and low values. Finally, more phosphorus measurements, particularly seasonal trends, would help pinpoint sources of phosphorus and lead to more targeted actions for its reduction, and, in the long run, monitoring the success of phosphorus mitigation.

So, Suzanne Wade, I’ll be looking forward to the funding and support to repeat “Testing the Waters” for three or four dates next year. It’s the least we can do for our river and my paddling

schedule.

Thanks to Peter Jacobs, Mark Riedel, Jane Carlson, and others who have contributed comments on the data collected. Thanks to the wastewater treatment labs of Horicon, Oconomowoc, Watertown, Jefferson, Fort Atkinson, Janesville, and Beloit for providing total phosphorus results for the project.

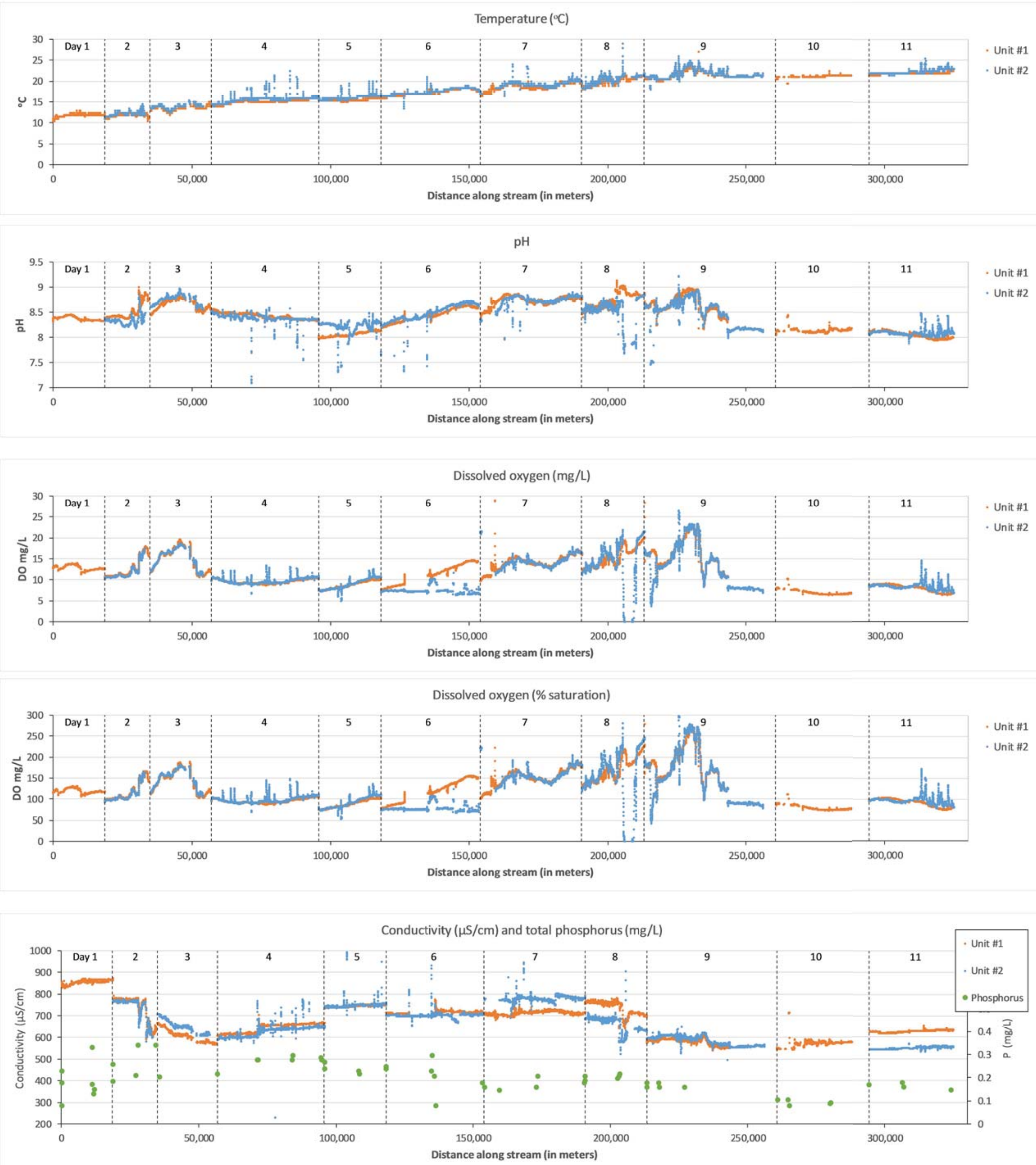
References

Brown, D., A. Goncharov, E. Paul, H. Simonin, and D.O. Carpenter. 2010. “The Relationship between Adirondack Lake pH and Levels of Mercury in Yellow Perch.” *Journal of Aquatic Animal Health* 22 (4): 280–90.

Fondriest Environmental, Inc. “pH of Water.” Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. http://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/

Heydarnejad, M.S. 2012. “Survival and Growth of Common Carp (*Cyprinus Carpio L.*) Exposed to Different Water pH Levels.” *Turkish Journal of Veterinary and Animal Sciences* 36 (3): 245–249.

Figure 1. Water quality metrics by day and distance along Rock River from Mayville to Beloit.



TESTING THE WATERS
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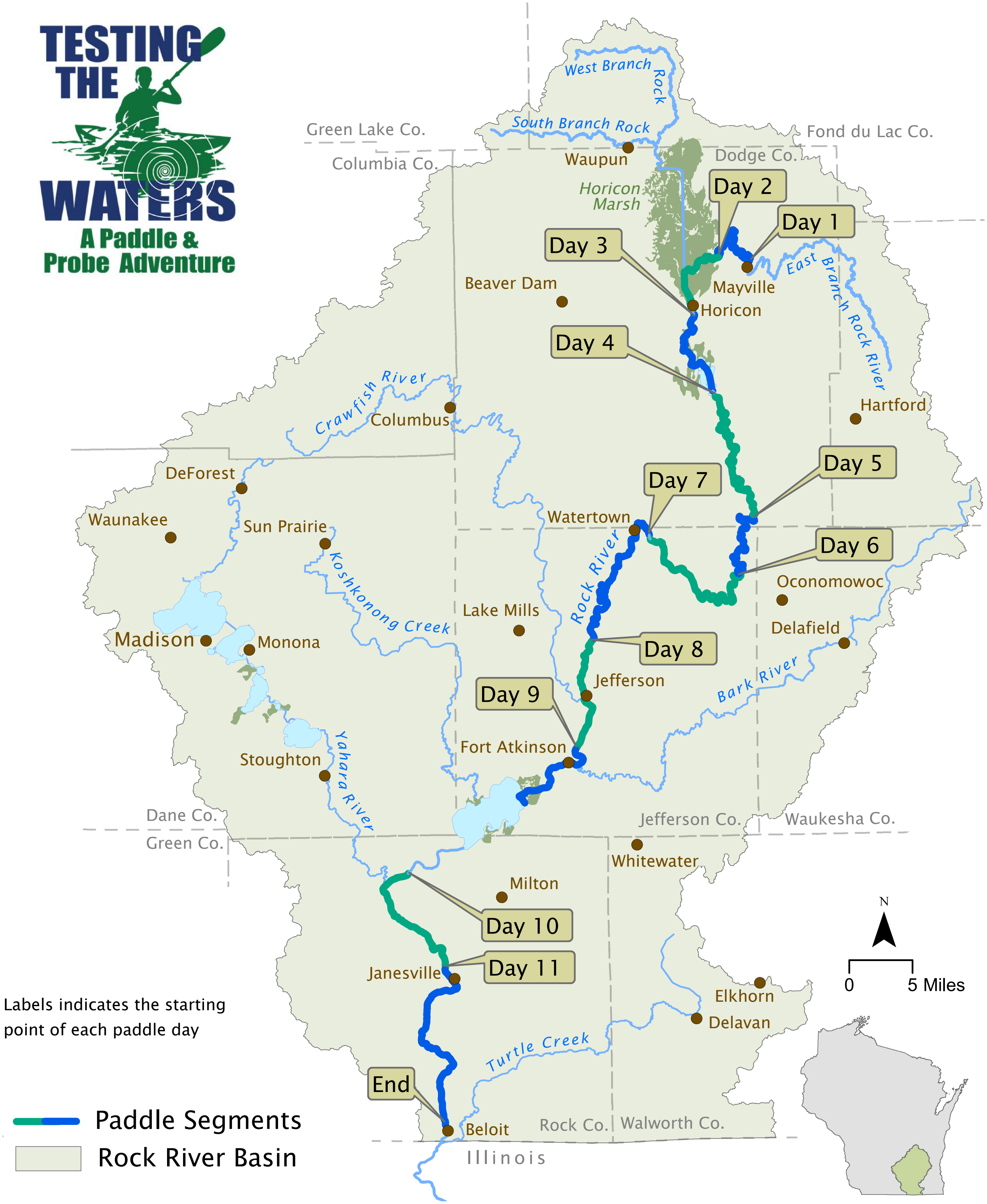

Source: USGS, 2010; ESRI, 2014

Cartography by Jeffrey Smyczek, 2016