CHATTAHOOCHEE-APALACHICOLA RIVERS WATER QUALITY SAMPLING A LAGRANGIAN SAMPLING PROJECT

Robert C. Fuller

AUTHORS: North Georgia College & State University – Physics, 106 Rogers Hall, Dahlonega, Georgia 30597

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Abstract. The field work portion of this project began September 22, 2012, with an expected completion date of November 10, 2012. The field work will involve traveling by canoe down the entire Chattahoochee-Apalachicola River system from the source spring near Chattahoochee Gap to the Gulf of Mexico, collecting water quality data, documenting illegal incursions into the river channel, and gathering such other information as may seem to be valuable. As of September 30, 2012, 89.4 miles of the river system has been covered. What makes this project unique and of particular value will be the Lagrangian design of the observations. The purpose of a Lagrangian sampling scheme is to follow an initial mass or "parcel" of water as it moves through its containing channel, tracking changes to the water's constituents over space and time. Hydraulic modeling work done by others was used to make initial estimates of average river velocities along the length of the system, which were used to calculate doses of a tracking dye sufficient to be detected but not so large as to violate EPA guidelines. Rhodamine WT dye was chosen for tracking and it was detected using a fluorometer. The concept of an initial water mass is used in recognition of the fact that a small mass of water emerging from the source spring will be increasingly dispersed as the mass moves downstream due to the mixing within the channel and the variability of water velocity across the channel. Because of this, it is easier to think of trying to follow the centroid of the dispersing mass than it is to think of predicting the likely position of a single molecule that emerges from the source. Due to low rhodamine WT doses used, the dye is re-dosed at roughly 25 to 50 kilometer intervals along the system.

INTRODUCTION

How much can one person do? That was the principal question, although certainly not the only question, to be tested by this project. This was a question that I had posed, pondered, and tested a number of times, but the current project was designed to thoroughly test the question. The project was designed around the a core water quality study of a 537-mile stretch of river in Georgia and Florida, but the over-riding element of the study design was that it was to be carried out by a sole researcher operating on foot and out of a canoe. The mechanism for testing the question of how much a sole researcher can accomplish was the performance of a water quality study of the entire Chattahoochee River and its receiving river, the Apalachicola River, but the hypothesis to be tested was that a sole researcher, operating initially on foot and later from a human-powered canoe, could generate meaningful and useful water quality data over extensive spatial and temporal distance.

The principal goal of water quality sampling is to learn what is dissolved or suspended in the water (the load). In planning a water quality monitoring project, two of the issues that need to be addressed early on are the spatial and temporal variables. Are you looking at relatively immobile water? This might be the case in a small pond, but larger lakes are apt to display more variability due to circulation than smaller water bodies. In rivers, of course, the water is moving, by the very definition of the term. Impounded rivers tend to fall somewhere between lakes and rivers. The Chattahoochee River, one of the two rivers that were the subject of this study, is impounded by 16 dams (USGS, 2012; Brownsguides, 2012) that impact approximately 60 percent of its 430-mile length (USACE, 2012; Fuller, 2012). The Apalachicola River is unimpounded for its entire 107-mile length (Apalachicola Riverkeeper, 2012). The two major temporal variables to consider are variability in flow rate and changes in the concentrations of dissolved and suspended materials in the water. Grab sampling from a fixed location is poorly suited to understanding water quality where either of these is highly variable (Facchi et al., 2007).

There are two fundamentally different approaches to sampling river water and numerous variations within those. The two fundamental approaches are 1) sampling from a fixed point on the river and 2) following a water mass down the river, sampling the same mass as it is modified by dilution or the addition of load. The first method is far more common than the second for a variety of reasons, among them that it is simpler and that we are generally focused on the condition of a river at a particular location as it relates to human activities or environmental concerns. With the fixed location method, one may collect discrete grab samples or composite samples over time, which normally comprise a mixture of grab samples taken at regular intervals but may also be collected by aggregating a small, continuous flow over some time period (King and Harmel, 2003). Composite samples may be made up of uniform sample volumes or may be proportional to some variable, usually water level or flow rate. Of course, the more variables one introduces into the sampling process, the more uncertainty there will be in the results (Harmel et al., 2006). This first method is ideally suited to monitoring water quality conditions over extended time periods, both to provide alerts to pollution events and to provide long-term trend data (Fuller, 2008). The second method is more suited to understanding the processes taking place throughout the length of a river, but it is more difficult to implement and, while it does provide information on the spatial variability of these processes, a single sampling pass down the river only captures the impact of what was taking place at a given moment at each location along the river (Moody, 1993). This second method was chosen for this study.

The entire length of the Chattahoochee River and its receiving river, the Apalachicola River, were chosen for the study (Figure 1). The initial goal of the study was to perform a Lagrangian sampling study for the entire 537-mile length of the combined river system, although it was clear from the beginning that the many impoundments on the Chattahoochee River would require that the study be broken into numerous, smaller, free-flowing reaches. There was also a financial constraint brought about by the high cost of the water tracing dye chosen for the study; the best price that could be obtained for rhodamine WT liquid, the dye of choice for water tracing studies, was $240 per gallon. That resulted in a practical limit of ten gallons of dye for the study, which turned out to be enough to cover the free-flowing sections of the Chattahoochee River and a major section of the Apalachicola River.

METHODOLOGY

The availability of a safe, water-tracing dye, rhodamine WT, made possible a range of approaches to studying the Chattahoochee-Apalachicola River system. One approach, which was the author's original intent, was to perform a transect of the river system, moving from the headwaters to the river mouth at something approximating the average speed of the river, but without the need to track dye. The intention was to estimate average velocities with Manning's Equation or some similar technique and proceed downriver at an average daily speed equal to that which had been calculated. Scientists at both the U. S. Geological Survey (USGS) and the Georgia Department of Natural Resources, Environmental Protection Division (EPD) counseled that this would be far more difficult than was being envisioned by this researcher, methods of dye-tracing were considered. When EPD offered the use of one of their fluorometers for this study, that opened up the possibilities of performing Lagrangian sampling and performing a dye-tracing study.

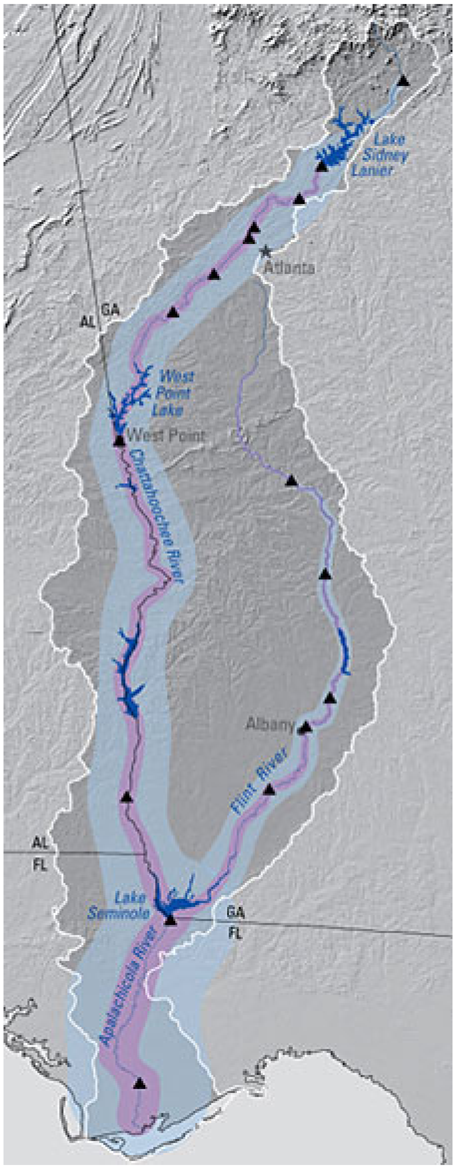

Figure 1. Study area. Source: http://pubs.usgs.gov/fs/2007/3034/images/mainpicture.jpg retrieved 12/28/2012.

A Lagrangian study would involve using the dye to track an initial water mass from the source of the river to the headwaters of the first impoundment, from the outflow of that impoundment to the headwaters of the next impoundment, and so on from each dam outflow to the headwaters of the next until the mouth of the Apalachicola River was reached. Collecting water samples and performing in situ water tests within the mass of water as it moved down each of these free-flowing river segments would facilitate some understanding of the locations of significant sources of pollution and dilution of the river.

At the request of EPD, another element was added to the study: an attempt to take dye concentration measurements as they varied over time at a point on the river in order to understand the potential for dispersion of pollutants that might enter the river. An alternative approach of moving downriver through the dispersing dye cloud in the river, taking spatially-varied dye concentration readings was also used. One other element was added at the request of Georgia Power Corporation (GPC) in response to the author's request that they give him some task to perform for their benefit. This was in response to an unsolicited gift from GPC to North Georgia College & State University of two sets of Hydrolab water testing equipment. This small study called for closely spaced dissolved oxygen measurements in the river directly downstream of West Point Lake Dam.

Ultimately, a combination of approximate velocity-matched transect, static setup to observe dye concentrations in passing water, and dynamic measurement of dye concentrations while paddling the canoe downriver were employed. All three yielded some interesting results.

Preparations for the fieldwork involved collecting maps, river characteristics, information about drinking water intakes, equipment, and logistical supplies, and performing calculations of appropriate dye doses to be released at various locations in the free-flowing sections of the river. EPD provided valuable information on river geometry. These data did not cover the entire river, but they were very useful for the section from Buford Dam (Lake Lanier) to the upper reaches of West Point Lake near Franklin, Georgia. One of the more important categories of information that was needed was the locations of all drinking water withdrawals from the river. This was needed in order to calculate dye doses that could be used without exceeding the U.S. Environmental Protection Agency's (EPA) recommendation that rhodamine WT not be introduced at drinking water intakes in concentrations exceeding ten parts per billion (10 ppb). To the author's frustration, someone within EPD decided that providing me with these locations should not be done for "homeland security reasons". I was never able to overcome that concern, but I was able to get the necessary data from old EPD maps, Google Earth, Maps, and other sources.

Equations developed by Wilson et al. (1986) were implemented in Microsoft Excel™ to calculate a dye dose based on estimated channel geometry, depth, velocity, maximum reach flow rate, and the location of drinking water intakes in order to achieve measurable concentrations, ideally greater than or equal to 1 ppb, without exceeding 10 ppb at any drinking water intake. As a safety factor, due both to the lack of precision of drinking water intake locations and anticipated errors in estimating the various factors entering into the calculations, no calculated concentrations greater than 2 ppb were allowed at drinking water intakes. The equation, as implemented, was:

$$\mathrm{Vol} = 0.002*((Q_m*L/V)\hat{}0.93)*C_{min}$$

where,

Vol = dye volume in liters

Qm = maximum reach flow rate in m^3/s (from online gaging data)

L = reach length in kilometers

V = average reach velocity in m/s, calculated from estimated geometry and average flow

C_{min} = minimum dye concentration in ppb, usually 1.0, but as low as 0.67

This equation was rearranged to calculate dye concentrations at drinking water intakes, substituting the appropriate flow, length, and velocity values for the water intake. When this showed a concentration greater than 2.0 ppb, dye volume was decreased or, in some cases, reaches were split in order to stay well within EPA recommendations of 10 ppb for drinking water intakes.

The first measurements and dye dosing was done at Chattahoochee Spring, the source of the Chattahoochee River. This spring was reached on foot from Jack's Gap, across the Appalachian Trail, and then down a side trail to the spring. Two different instruments were used to measure a variety of water parameters. A Hydrolab Surveyor with MS5 sonde was used to measure dissolved oxygen (DO) percent saturation and concentration, water temperature (T), specific conductance (SPC) , pH, and turbitity (Tu). A YSI Pro Plus was used for duplicate DO, T, SPC, and pH measurements, and also to measure nitrate (NO_3) concentrations. A Garmin GPSMap 76S with Wide Area Augmented Service enabled was used to capture location data. Following the recording of all water quality and location data, I dosed the water with 0.15 L of 20% liquid rhodamine WT dye, and then headed downriver on foot, staying well ahead of the dye. This was a bit challenging, as there was no trail for approximately three miles.

I was met near the Upper Chattahoochee Campground with additional equipment and set up to take dye concentration readings with a Turner Designs 10AU fluorometer, equipped with a 12-volt pump, which provided continuous flow through the fluorometer. When the readings appeared to have peaked and begun to decline, water quality measurements were taken, and then I continued downriver. A carefully calculated dose of dye was added below the first dam on the river, just downriver of Helen, GA. It was here that I launched my canoe and began the canoe journey to the Gulf of Mexico. Fairly early in the study, the Hydrolab instrument was eliminated from the study due to its bulk, weight, and long, cumbersome cable. This resulted in the loss of turbidity data for the rest of the study, but a Secchi disk was added, to provide related information.

As each dye tracing run played out, I alternately tested for dye as I paddled downriver, catching up with the dye cloud and paddled ahead and set up at a fixed location to measure dye concentrations in the passing water. On numerous occasions, a full set of water quality measurements were taken independently of measuring a dye cloud peak, more in keeping with the philosophy of taking a water quality transect along the river. Reservoirs interrupted dye tracing, requiring redosing below the reservoir dam. In addition, logistical problems encountered at Morgan Falls Dam in Atlanta caused me to skip any additional dye tracing until I reached the vicinity of Fulton County Airport on the west side of Atlanta.

RESULTS

A total of 333 fluorometer readings were taken during the study. Ninety-five of these were taken at eight different fixed locations. The other 52 were taken while on the move in the canoe. Eighty-five sets of water quality data were collected. Of these, eight were associated with dye peaks at fixed locations, and six were associated with dye peaks encountered while paddling through the dye cloud. The other 71 sets of measurements were not located with dye peaks, but they were still associated with water moving down the river, and should yield interesting patterns. Six sets of biochemical oxygen demand (BOD) samples were taken and delivered to EPD.

The data are yet to be analyzed, but some trends are immediately apparent. Both specific conductance and nitrate levels peaked on the west side of Atlanta. Specific conductance levels dropped off slightly by West Point Lake, but remained on the order of five times greater upon reaching the Gulf of Mexico than it was near the source spring. Nitrate levels, which increased 40 times from Chattahoochee Spring to their peak just west of Atlanta, dropped back off to about 15% of peak levels by the time the water reached the Gulf of Mexico. Further, more detailed analyses will be conducted in the coming months.

DISCUSSION

I am not yet prepared to say whether or not I generated useful, meaningful data on this trip. That is yet to be determined, but I did learn that I could accomplish a great deal on my own, and I also became aware of limitations that I had not anticipated. I knew that trying to track water tracing dye by myself would be quite a challenge, but the challenge was even greater than I expected. Yet, I did manage to track the dye reasonably well, with a few notable exceptions. One of these was the result of a logistical conflict that occurred fairly early in the study, and one was the result of my being too exhausted to stay up all night taking measurements, which resulted in the dye peak passing while I was asleep.

Perhaps the biggest unanticipated challenge was finding a decent place to sleep. Much of the land along the upper Chattahoochee is posted with “No Trespassing” signs, which I respected, of course. With a little bit of good luck, I managed to get permission to camp, though. Below Buford Dam (Lake Lanier), the situation is different. From Buford Dam to a point near central Atlanta, the river and its shores are controlled by the National Park Service (NPS), which allows no camping anywhere in the corridor. Further, NPS rules prohibit boating at night. These two factors made it impossible to carry out this study without violating NPS rules. A group is now working to persuade NPS to make camping available and to encourage overnight canoeing and kayaking within this corridor.

While this began as a scientific expedition, I found the variety and general friendliness of people I met along the way to be one of the major personal benefits of the trip. I also found some likely pollution sources that I intend to investigate further in the future. These two rivers, the Chattahoochee and the Apalachicola, are beautiful rivers, but they are much used and much abused. I intend to continue my work on them, and I intend to continue having fun doing it.

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