

# PHOSPHORUS ASSIMILATION BELOW A POINT SOURCE IN BIG CREEK

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*REFERENCE:* *Proceedings of the 2001 Georgia Water Resources Conference*, held March 26-27, 2001, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, the University of Georgia, Athens, Georgia.

**Abstract.** Big Creek is a tributary of the Chattahoochee River that has received effluent from a poultry processing plant since 1987. Using the elevated concentrations of phosphorus and chloride in the effluent, we determined the stream's ability to remove phosphorus from the water by measuring the uptake length for soluble reactive phosphorus (SRP) on five dates from November 1999 through August 2000. Uptake length is the average distance traveled downstream by a molecule of phosphorus before it is removed from the water column. Shorter uptake lengths imply higher chemical and biological assimilation of added P. We collected water samples above the point of effluent discharge, immediately downstream of the discharge, and at seven sites downstream (ca. 40 km). Samples were analyzed for SRP and chloride, which we used as a conservative tracer to factor out concentration changes resulting from dilution. SRP concentrations in the effluent ranged from 21.2 to 27.5 mg P/L and decreased to 0.2 - 0.5 mg P/L before reaching the Chattahoochee River. Uptake lengths ranging from 15 to 138 km were not related to discharge, but were positively related to effluent SRP concentration. This suggests that Big Creek has a very limited capacity to assimilate SRP, and that SRP added to the stream by this point source is being transported long distances and contributing to excess nutrients downstream. Contemporary total phosphorus concentrations in Big Creek are an order of magnitude higher than was observed in the late 1970's when this point source of phosphorus was not present.

## INTRODUCTION

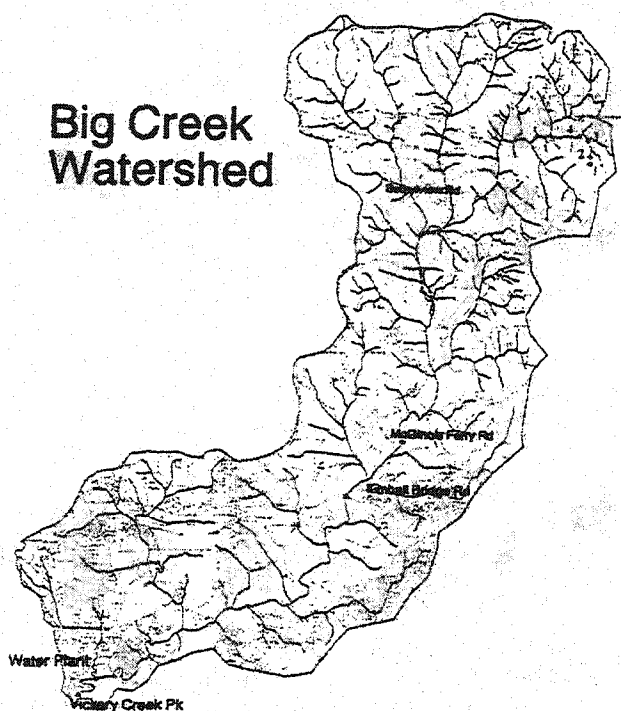
Phosphorus is an element of concern in freshwater ecosystems because it can cause nuisance algal blooms when it is present in excess. The State of Georgia has established limits on the amount of phosphorus that rivers can deliver to several Georgia reservoirs (e.g. Westpoint Lake) because of concerns with reservoir

eutrophication. Phosphorus is added to rivers from both point and non-point sources. Some added phosphorus is removed from the water column by biological and chemical uptake on the stream bottom, while the rest is transported downstream where it contributes to phosphorus loading of rivers and downstream reservoirs and estuaries. Hence the ability of streams to assimilate added phosphorus is one of the goods and services provided by healthy aquatic ecosystems that reduces the concentration of phosphorus in river water and the eutrophication of the river and downstream ecosystems.

Nutrient assimilation, or removal of nutrients from the water column, can be quantified by measuring the uptake length of the nutrient of interest (Stream Solute Workshop 1990). Phosphorus uptake length is defined as the average distance traveled downstream by a phosphorus molecule before it is removed from the water column by biological or chemical processes. Uptake length is typically measured by dripping enriched solutions of phosphate and a conservative tracer into a stream and following the decline in concentration downstream, using the concentration of the conservative tracer to factor out declines in concentration resulting from dilution and dispersion (Webster and Ehrman 1996). In this study we used the phosphorus and chloride being added to Big Creek from a point source to determine phosphorus uptake lengths and thereby assess the ability of Big Creek to assimilate added phosphorus. The point source is a poultry processing plant in Cumming, which was constructed in 1987 and which currently has no phosphorus limits on its NPDES permit under which it is discharging effluent into a tributary of Big Creek.

## METHODS

Streamwater from Big Creek and tributaries was sampled at nine locations (Figure 1) on five dates from November 1999 through August 2000. The sites sampled included the effluent from the poultry



**Figure 1. Sites sampled on Big Creek. Numbers refer to the following sites: 1. Industrial Park Road (background). 2. Effluent pipe. 3. Castleberry Road. 4. Tolbert Road.**

processing plant, a tributary just upstream from the effluent (used to provide background concentrations), and seven sites at distances from 0.1 to 40 km downstream of the effluent. Big Creek enters the Chattahoochee River just below the sampling site furthest downstream. Samples were filtered through glass fiber filters in the field and returned to the laboratory on ice. Chloride was analyzed using a Braun-Luebbe Auto Analyzer II Continuous Flow System. Filtered samples were analyzed for soluble reactive phosphorus (SRP), and unfiltered samples were analyzed for total phosphorus (TP) using standard spectrophotometric methods (Wetzel and Likens 2000). Sediments retained on the filters were dried and weighed to determine concentration of total suspended solids (TSS) in the sample.

After correcting SRP and Cl measures at each site for background concentrations using concentrations measured in the upstream tributary,  $\ln(\text{SRP}/\text{Cl})$  was plotted vs. distance downstream. SRP uptake length is calculated as the inverse of the slope of this regression (Webster and Ehrman 1996). Relationships between

uptake length, discharge, and effluent SRP concentration were explored.

## RESULTS

Extremely high concentrations of total phosphorus (TP) were measured in effluent from the poultry processing plant, ranging from 21.6 to 32.6 mg/L. SRP accounted for most of the TP in the effluent, with SRP concentrations ranging from 21.2 to 27.5 mg/L (Table 1). SRP concentrations upstream from the effluent were four orders of magnitude lower, ranging from 0.001 to 0.016 mg/L. Chloride concentrations in the effluent were also elevated, ranging from 114 to 137 mg/L, whereas concentrations upstream were 3 - 4 mg/L. These elevated levels of chloride provided a reliable indicator for dilution of the added effluent. Concentrations declined downstream to 0.102 - 0.613 mg/L TP, 0.035 - 0.490 mg/L SRP, and 6 - 15 mg/L chloride at the site 40 km from the effluent.

SRP uptake lengths varied from 15 to 138 km (Table 1). Stormflow was not sampled, and discharge measured at the Kimball Bridge USGS gaging station on the five dates of this study ranged from 1048 - 1812 L/s. Uptake length was not related to mean daily discharge ( $p = 0.56$ ). Uptake length increased as effluent SRP concentration increased [ $\ln(\text{uptake length in km}) = 8.18 \ln(\text{effluent SRP in mg/L}) - 22.45$ ,  $r^2 = 0.87$ ,  $p = 0.01$ ].

Faye et al. (1980) sampled TSS and TP over a wide range of discharges at Kimball Bridge on Big Creek in the late 1970s. They report a regression of TP concentration (mg/L) vs. suspended silt and clay (SSC, mg/L, which is the laboratory measure of TSS) ( $\text{TP} = 0.00681 \text{ SSC}^{0.639}$ ), which we used to estimate the TP concentrations expected for the range of TSS concentrations we measured at that site. TSS concentration at Kimball Bridge ranged from 3 to 25 mg/L on the five sampling dates. If the Faye et al. (1980) regression still applied to current conditions in Big Creek, we would expect to measure TP concentrations ranging from 15 to 63  $\mu\text{g/L}$ . Yet the TP concentrations measured at Kimball Bridge ranged from 235 to 898  $\mu\text{g/L}$  on the five dates in 1999 - 2000, an order of magnitude higher concentration than predicted from the regression based on data from the late 1970s. This suggests that TP concentrations in Big Creek have increased considerably in the past two decades.

**Table 1. Big Creek discharge at Kimball Bridge, SRP concentration at selected sites, and SRP uptake length measured on five dates.**

Date	11/14/99	1/28/00	2/25/00	3/31/00	8/12/00
Discharge (L/s)	1048	1812	1359	1767	1218
SRP in effluent (mg/L)	22.9	21.2	25.0	23.9	27.5
SRP background (mg/L)	0.008	0.003	0.001	0.001	0.016
SRP 40 km downstream (mg/L)	0.455	0.035	0.303	0.298	0.490
SRP uptake length (km)	20	15	33	35	138

## DISCUSSION

SRP concentrations declined below the point source, but dilution rather than uptake by the stream biota accounted for most of this decline. On two of the five dates sampled, the uptake length was similar to the length of Big Creek, implying that the average phosphorus molecule traveled nearly to the Chattahoochee River before being removed from the water column. On one date, the average phosphorus molecule discharged by the point source was not removed from the water column of Big Creek before its confluence with the Chattahoochee River. The uptake lengths measured in Big Creek are an order of magnitude higher than has been reported for smaller streams without point sources of phosphorus (Marti and Sabater 1996) and two orders of magnitude longer than what is measured in headwater streams in southeastern forested watersheds, where uptake lengths never exceed 0.1 km (Munn and Meyer 1990). These longer uptake lengths are in part a consequence of higher discharges in Big Creek than in the other streams where uptake length has been measured, since uptake length is usually directly related to stream discharge (e.g. Butturini and Sabater 1998). Interestingly, differences in discharge cannot explain the pattern of uptake lengths measured in Big Creek, because seasonal variations in discharge were not correlated with measured variations in uptake length.

Although variations in uptake length in Big Creek were not related to discharge, they were positively related to effluent SRP concentration. If phosphorus

were limiting in this stream, we would expect the opposite relationship, namely shorter uptake lengths (i.e. greater uptake rates) with increasing SRP concentration. The positive relationship between effluent SRP concentration and SRP uptake length implies that the assimilatory capacity of the stream for phosphorus is being exceeded. As more SRP is added to the stream, a smaller proportion of it is assimilated in Big Creek before the water enters the Chattahoochee River.

SRP being added by a point source is not effectively assimilated in Big Creek, and hence phosphorus is transported downstream to the Chattahoochee River. Increased phosphorus additions to Big Creek combined with a low assimilatory capacity are the likely reasons for the elevated TP concentrations in Big Creek observed in this study when compared with predictions based on data from the late 1970s.

## CONCLUSIONS AND RECOMMENDATIONS

High phosphorus concentrations in Big Creek are a result of elevated phosphorus additions to the stream from point sources such as the effluent from a poultry processing plant, non-point sources associated with the rapid development that has occurred in this watershed over the past decade, and a limited assimilative capacity. Current phosphorus additions are exceeding Big Creek's assimilative capacity. On average, a molecule of SRP travels from 15 to over 100 km downstream before it is removed from the water column. Hence SRP entering Big Creek far upstream

is contributing to the phosphorus load in the Chattahoochee River and reservoirs downstream.

The amount of phosphorus entering from point sources in the watershed could be reduced by placing a P limit on the poultry plant's NPDES permit. This action should reduce P loading to rivers and reservoirs downstream. However, it may take several years for the system to respond to a reduction in loading because stream sediments are probably a large reservoir of phosphorus in this system.

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