CONTROLS INFLUENCING THE TREATMENT OF EXCESS AGRICULTURAL NITRATE WITH DENITRIFYING BIOREACTORS

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

William T. Pluer

August 2015

ABSTRACT

Denitrifying bioreactors encourage reduction of excess nitrogen, specifically nitrate and nitrite (NOx), in agricultural runoff. This study used lab-scale and in-situ field reactors to determine the effectiveness of bioreactors in central New York and controls that may optimize the process. Lab reactors removed up to 10.0 mg L^{-1} NOx-N and 19.8 g N m^{-3} d^{-1}. Three factors tested, inflow NOx concentration, inflow pH, and residence time, were significant. The field bioreactors showed significant concentration reduction (up to 8.2 mg L^{-1} NOx-N) but insignificant load reduction in most sites. The load removal rates were lower than found in the lab, possibly due to varied environmental conditions. Neither lab nor field data showed significant difference for bioreactor media, comparing only woodchips with woodchips and biochar. Based on positive identification of controlling factors, improvements to field reactor design could significantly improve bioreactor technology and improve water quality in agricultural areas of New York.

BIOGRAPHICAL SKETCH

Since the days of playing in the woods behind his house and splashing in the creek with his brother, Will knew that he wanted to work outdoors, protecting nature. Activities like this combined the qualities that are most important to him: people, nature, and discovery. He had numerous opportunities to explore the intersection of these through family vacations to incredible places, Boy Scouts, and Science Olympiad. He continued this in studies at NC State, with a study abroad on the Galapagos Islands, internships, and teaching a course on endangered ecosystems (along with becoming a lifelong Wolfpacker). Now he pursues these in Ithaca through his studies, along with cooking, piddling in his garden, and playing volleyball.

This is dedicated to those that provided immeasurable support for me on this journey:

-Mom, Dad, and Benjamin, who love me unconditionally, encourage me to be all that I can be, and listen when I nerd out about science

-Friends, especially those in the Soil & Water Lab, who have been a sounding board for my work and made the experience a blast

-God, who will always have my back and be my peace and foundation

ACKNOWLEDGMENTS

I would like to thank Dr. M. Todd Walter and Dr. Larry Geohring for that support and comments on my project and thesis and to Dr. Ruth Richardson for her explanations and guidance. I would also like to thank the Upper Susquehanna Coalition and the farmers that allowed us to install and monitor on their farms. This would not have been possible without many others, including Shree, Shane, Siobhan, Anne Elise, Sarah, Bahar, and Mike, who helped with sampling and analysis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION

Nonpoint nutrient pollution from agriculture remains a significant issue despite continued efforts to mitigate it. Nutrients in excess concentrations, especially nitrogen (N) and phosphorus (P), lead to lowered water quality in freshwater and coastal regions, degrading the biological, ecological, social, and economic value of the environment (Galloway, et al., 2004). Excess N, most commonly found as nitrate (NO_3^-) in water, is particularly a problem for estuarine and marine systems, where it is often the limiting nutrient (Shirmohammadi, et al., 1995; Kemp, et al., 2005). Biological assimilation and denitrification are the two primary pathways for removing NO_3^-. Denitrification is the reduction of NO_3^- along the pathway of NO_3^- → nitrite (NO_2^-) → nitric oxide (NO) → nitrous oxide (N_2O) → dinitrogen gas (N_2) (Groffman, et al., 2006). Engineering solutions employing denitrification to address N pollution seek to completely reduce NO_3^- and NO_2^- (NOx) to N_2. They are designed to avoid the intermediate products which have harmful environmental impacts, such as ozone depletion, greenhouse effect, or nitrite poisoning (Seitzinger, et al., 2006).

One solution under investigation is a denitrification wall or a denitrifying bioreactor; these structures intercept runoff and shallow groundwater from agricultural fields for treatment before it is released to a receiving water body (Figure 1) (Blowes & Robertson, 1994; Schipper & Vojvodić-Vuković, 1998). The reactors are designed to

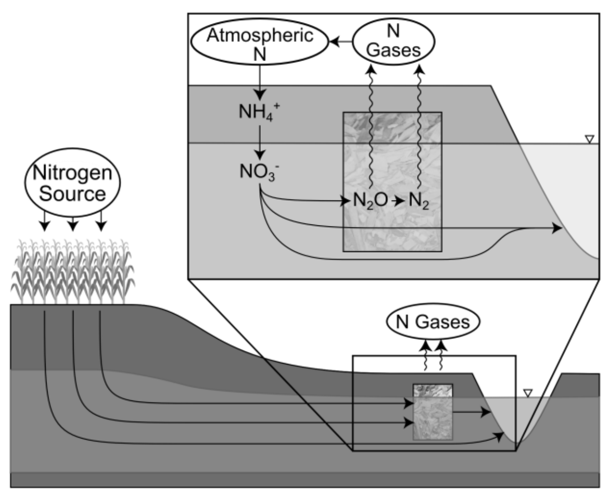

Figure 1: Denitrifying bioreactors treat runoff and shallow groundwater associated with agriculture to reduce N flow into receiving surface water.

provide ideal conditions for denitrification – an anaerobic environment, organic matter as a carbon source, and abundant NOx (Blowes & Robertson., 1994; Schipper & Vojvodić-Vuković, 2001). While the idea of using organic matter to remove agricultural N is not new (Williford, et al., 1971), the past 20 years have seen significant development and improvement of these field edge best management practices (Schipper, et al., 2010a). While many forms of carbon substrate have been used, woodchips are the most common and effective (Greenan, et al., 2006; Cameron & Schipper, 2010; Warneke, et al., 2011a). Results from reactor studies show high removal rates of NOx from influent, up to 95% in some cases (Blowes & Robertson, 1994; Greenan, et al., 2001; Robertson, 2010; Warneke, et al., 2011b).

To date, installations of similar reactors or the related denitrification walls have been concentrated in industrial agricultural areas in the Midwestern United States, Ontario, and New Zealand (Moorman, et al., 2010; Robertson, 2010; Schipper, et al., 2010b). Studies have not explored applications on smaller agricultural scales. Field and lab reactor studies have not addressed many known denitrification controls and their effect on N reduction rates (Seitzinger, et al., 2006; Schipper, et al., 2010a). Cursory investigations have been conducted on flow patterns (Christianson, et al., 2011a), residence time (Greenan, et al., 2001), pH (Warneke, et al., 2011b), temperature (Warneke, et al., 2011b), and microbial communities (Zoski, et al., 2013).

With denitrification as the primary process in the reactors, the singular focus on N treatment is to be expected. However, similarly-designed reactors applied to other situations, such as septic fields, have shown success in P treatment as well (Robertson, et al., 2008). Excess P can disrupt freshwater systems, where it is typically a limiting nutrient (Sharpley, et al., 1994). N and P are closely coupled in agricultural fertilizer pollution, so it is reasonable for solutions targeting N to also provide some treatment for P (Kovacic, et al., 2000; Groffman, et al., 2006). Treatment of P requires different processes than N because of its contrasting properties; removal typically focuses on sorption instead of biological processes (Sharpley, et al., 1994). Few studies on reactors have measured P or attempted a common strategy of other similar reactors: combining medias that each treat respective pollutants (Jaynes, et al., 2008; Schipper, et al., 2010a: Anderson, et al., 2011). Biochar is a soil additive proposed to target phosphate and other anions through sorption to cations sorbed to it (Anderson, et al., 2011; Angst, et al., 2013). It has not yet been used in previous reactors, which warrants investigation of its P treatment as a media augmentation.

This study addresses the lack of knowledge on the influences and controls on the effectiveness of reactors for better design and application of this technology. Here, lab reactor experiments are coupled with field monitoring of several reactors to determine both the effect of potential key denitrification controls and the applicability of lab findings to actual field reactors. Lab experiments and field monitoring were designed to test the effects of inflow NOx concentration, pH, residence time, and reactor media on reduction of NOx levels. Additionally, two types of media were used, woodchip only and woodchip/biochar mixes, in an attempt to increase P removal while maintaining high N treatment. Factors and levels are summarized below, along with expected relationships between the controls and outflow NOx and P concentrations.

SECTION 2

METHODS AND MATERIALS

Lab Reactors

Lab reactors were constructed to mimic field reactors as closely as possible. These reactors allowed for analysis of control variables that would not be possible at the field scale due to constraints on time and resources. Rubbermaid® containers, 46 cm wide by 66 cm long by 23 cm deep, were filled with 8 kg of media and sealed in March 2013. Three reactors were filled with woodchips while the other three were filled with alternating layers of woodchips and biochar, in a 9:1 volumetric ratio, and the media was mixed during the filling process. Woodchips used in the reactors were primarily ash (*Fraxinus* sp.), ranging in size from 2 to 12 cm in length and 0.5 to 3 cm in width and thickness. The biochar was produced through slow pyrolysis by Biochar Now®, mostly of pine origin (*Pinus* sp.) and was in chip form, roughly 2 to 6 cm in length and 0.5 to 1 cm in width and thickness. The biochar was not rinsed so biochar powder was included.

Inflow and outflow spouts were screwed into the ends of the containers 2 cm from the bottom. Tubing (0.64 mm ID) connected the inflow spouts to shared tanks of inflow water and ran through a peristaltic pump to control flow rate and residence time. Water was backed up in the reactor to ensure the entire media was saturated and exited at the bottom to mimic field reactors. A hole was drilled into the center of the container lid and plugged with a septum to allow for headspace gas sampling. Results from all gas sampling are not shown in this study.

Experiments conducted with the lab reactors tested variables thought to influence N reduction and allowed comparison to field reactor results. P was not added to the water or measured due to negative preliminary results from continuous monitoring of the field reactors.

The base conditions used an inflow concentration of 12 mg L^{-1} NOx-N, a pH of 7.0, a residence time of 6 hours, and 22.0 °C. The first experiment consisted of 4 runs of varied inflow concentrations of NOx (5, 9, 12, 20 mg L^{-1} NOx-N). Higher inflow levels were expected to result in greater concentration and load reductions of NOx but still show higher outflow levels than the lower inflow concentrations. The second experiment of 2 runs altered pH (6.7, 7.0), and higher NOx reduction was predicted from slightly more basic pH. The final experiment consisted of 6 runs varying residence times in the reactors (2, 4, 6, 8, 10, 12 hours). Increased residence time was expected to reduce NOx the most, but low inflow load was considered as a likely limitation on load removal at the high residence times.

Tap water was augmented with mixtures of KNO_3, HCl, and NaOH in 55 gal tanks to meet the desired inflow concentrations for each run. Samples of inflow and outflow water and dissolved gas were collected at regular intervals until equilibrium was reached. Headspace gases in the reactors, water flow rate, and temperature were also monitored. Tap water was pumped through the reactors for at least 8 hours prior to runs to flush the reactors, restore anaerobic conditions, and refresh microbial activity.

Field Reactors

Paired denitrifying bioreactors were constructed at three agricultural field sites in central New York State. Each reactor consisted of a pit that was 7 m long by 3.5 m wide by 1.5 m deep, just to the water table. The pits were lined on all sides with North Plastics® 5 mil polyethylene and sealed to contain flow and gases. Perforated drain pipes were laid in the bottom of the reactor at the entrance and exit to distribute and collect water. AgriDrain® groundwater table control boxes connected the reactor inflow pipes to field tile drains to allow management of the water depth and head gradient in the reactors (Figure A2). One reactor at each site was filled with woodchips while the other was filled with woodchips and biochar, in a 9:1 volumetric ratio. The mixtures and filling methods were the same as used for the lab reactors described above.

Field sites and reactor constructions are summarized in Table 1. The first site was at the Homer C Thompson Vegetable Research Farm, located in Tompkins County, NY and operated by Cornell College of Agriculture and Life Sciences. The reactors, built in October of 2012, were located adjacent to Fall Creek, in the Seneca River watershed draining into the Great Lakes. The reactors received inflow from a 250 m tile drain, which drained approximately 4 ha of fields. Soils in the drainage area are mostly Howard gravelly loam, with some Eel silt loam in the lowest field.

The second set of reactors was at a dairy farm in Chemung County, NY and was constructed in June 2013. The tile drains drain approximately 5 ha of mixed Chenango and Papakating silt loams; reactor outflow drains to Post Creek, which is part of the Susquehanna River watershed. The Chemung Dairy Farm fields were applied with organic fertilizers, in both spring and late fall, as opposed to the inorganic fertilizer applied in the spring only by the vegetable farm.

The third location was at a dairy farm in Steuben County, NY, and its reactors were designed differently than the first two sites. These reactors were constructed in June 2013 with separate inflows, designated as west and east. They drain 6 ha and 9 ha, respectively, of predominately Fremont silt loam fields, which received organic fertilizer. Reactor outflows drain to Neils Creek, which is part of the Susquehanna Watershed. These reactors used 200 Woven Geotextile Fabric liners from Granite Environmental® in place of the gas impervious liner. The biochar-augmented reactor also only contained a third of the biochar applied in the similar biochar reactors, giving a 25:1 volumetric ratio.

Table 1: Reactor properties and details. WC and BC indicate woodchip and biochar, respectively

Site	Install Date	Reactor	Size	WC:BC Ratio	Drainage Area	Liner	Field Fertilizer
Tompkins	October 2012	WC	5700 kg	-	4 ha shared	Gas sealed	Inorganic
		WC+BC	5700 kg	9:1			
Chemung	June 2013	WC	4700 kg	-	5 ha shared	Gas sealed	Organic
		WC+BC	4700 kg	9:1			
Steuben	June 2013	WC	6500 kg	-	6 ha	Gas pervious	Organic
		WC+BC	6500 kg	25:1	9 ha		

Field water samples were taken weekly from October through November of 2012 and from April through November of 2013. This initially included only the Tompkins reactors until Steuben and then Chemung reactor constructions were completed. Samples consisted of inflow and outflow grabs from the flow control boxes and were filtered using 0.45 μm filters and stored at 4°C. Storage before analysis did not exceed 48 hours for anions or 72 hours form metals (Pfaff, 1993; Martin, et al., 1994).

Sample and Data Analysis

Samples were analyzed for NO_3^- and NO_2^-, combined for NOx-N values, using a Dionex ICS-2000 Ion Chromatograph (Pfaff, 1993). Dissolved reactive P (DRP) was analyzed on a Thermo Jarrell Ash Inductively Coupled Plasma Spectrometer (Martin, et al., 1994).

Box-Cox transformations were applied to normalize data for each individual reactor. Student t-tests were used to compare inflow and outflow. ANOVA and post-hoc Tukey Honest Significant Difference analysis were then used to compare reductions between the field reactors (Shumway, et al., 2002). Reductions were compared for both reactors and runs within each experiment for the lab results. Multivariable linear models were used to determine which factors in the lab experiments exhibited significant influences on the observed NOx reductions.

SECTION 3

RESULTS AND DISCUSSION

Lab Reactors

NOx-N concentration reductions ranged widely and demonstrated strong linear relationships with the controlled variables (Figure 2). The reactors also stabilized over the course of the experimentation period. This resulted in smaller standard error for samples in the residence time and inflow pH experiments in comparison to the inflow concentration experiment that was run first (1.2 g N m^{-3} d^{-1} compared to 0.3 g N m^{-3} d^{-1} for both other experiments). This did not affect the strength of correlation for the inflow concentration linear model, but did narrow the 95% confidence interval. In each of the linear models, the individual reactor was also a highly significant variable, more so than the media type. This suggests that, while trends remain the same, expectations for any reactor are specific to that one reactor only.

Inflow NOx concentration showed a strong first-order relationship with both concentration and load, normalized by total volume of reactor, removal (Figure 2 a, b). The slight dip at 12 mg L^{-1} NOx-N could be potentially due to a statistically insignificant lower water temperature in the reactors. Load removal rates of almost 20 g N m^{-3} d^{-1} at the highest inflow NOx level are above rates found in field reactors (Schipper, et al., 2010a; Warneke, et al., 2011b). However, the removal at the 5 mg L^{-1} NOx-N inflow was very low, suggesting these reactors may not be an ideal mitigation for low level N pollution. Several field studies have attributed low NOx removal to N limitation from low inflows (Schipper, et al., 2008; Robertson & Merkley, 2009; Schipper, et al., 2010a). Based on the range tested here, rates of denitrification are still N-limited, even up to inflows of 20 mg L^{-1} NOx-N, roughly the highest concentration of the field reactor inflows in this study. Extending this range may find a level at which NOx is no longer limiting and relationship with inflow concentration reaches zero-order.

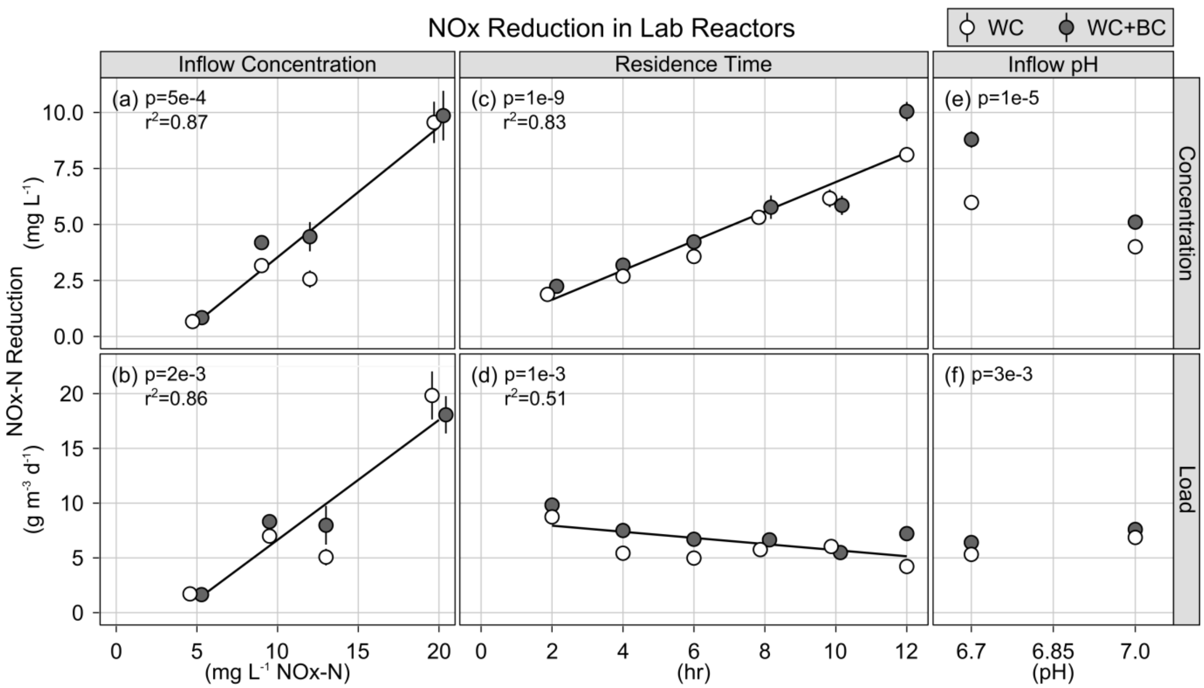

Figure 2: Nitrate and nitrate nitrogen (NOx-N) reduction in lab reactor experiments. White and gray points are averages for triplicate sampling of triplicate woodchip (WC) and woodchip/ biochar (WC+BC) reactors, respectively. Standard error is shown, when visible. Some points have been shifted horizontally to avoid overlapping, if necessary. Left plots show (a) NOx-N concentration reduction and (b) NOx-N load reduction in inflow concentration experiment, with lines and the significance of inflow concentration (p value) and strength of linear fit (r^2). Middle plots show (c) concentration reduction of NOx-N and (d) load removal of NOx-N in residence time experiment, with lines and the significance of inflow concentration (p value) and strength of linear fit (r^2). Rightmost plots show (e) NOx-N concentration reduction and (f) NOx-N load reduction in inflow pH experiment. Linear analysis was not performed with only 2 pH levels. Instead p values show significant difference between the average reduction of concentration and load of all reactors from pH 6.7 to 7.

NOx-N concentration and load removal in the residence time experiment was significant at all residence times (Figure 2 c, d). The concentration reduction showed a strong first-order relationship similar to the inflow concentration runs (Figure 2 a, b). This did not apply to the load removal, which actually showed a negative relationship. Increasing retention was achieved by reducing the inflow rate and not by increasing the size of the reactor as would be done in a field design. Therefore, the concentration removal was offset by the inversely proportional flow rates resulting in a lower correlation for the load. Focus should be placed on the concentration removal plot for the purpose of designing reactors (Christianson, et al., 2011b). NOx concentration reduction likely continues to increase beyond a 12 hour residence time though this becomes economically less feasible. Approximately half of the N was removed in 8 to 10 hour residence times, which is an appropriate compromise between benefit and cost, according to Christianson, et al. (2011b).

Concentration and load removal of NOx-N from the inflow pH experiment were addressed differently due to there only being two runs (Figure 2 e, f), i.e. using ANOVA rather than a linear regression. Attempts to alter pH were buffered by the hardness of the tap water used so inflow pHs were 6.7 and 7.0 instead of the intended 6.2 and 8.7, respectively. Despite this small difference in pH, we were compelled to include our results because there were significant differences for both concentration and load runs. Both of these are within pH ranges that reportedly support denitrification, but the more basic range tends to be better for complete denitrification (Bakken, et al., 1982). The difference between concentration and load was due to a difference in flow rate potentially from clogging in the outflow tubing. Load removal for pH 7.0 was the higher of the two runs; however a wider range is needed to generalize a trend. Alkalinity was not measured, though it was altered through the buffering of the acid and base additions, and could be a key contributor to the observed differences. More pH runs with alkalinity testing are needed to develop boundaries of effectiveness and determine whether the apparent relationship holds true.

Field Reactors

The field reactors removed between 2.7 and 8.2 mg L^{-1} NOx-N, which was 34% to 54% of inflow NOx, but removed lower loads than the lab reactors (Figure 3). While sample concentrations varied over time (coefficients of variation in concentrations ranged from 0.7 to 1.4), the reduction was significant ($p<0.01$) in all except the Chemung woodchip reactor. Load removal ranged from 0.1 to 2.0 g N m^{-3} d^{-1}, and only the Tompkins reactors showed any significant reduction in overall load. This scales up to between 40 and 650 g N m^{-3} annually removed within reactors. These load reductions were at the lower end of what has been demonstrated in other reactors (Blowes & Robertson, 1994; Schipper, et al., 2010a; Warneke, et al., 2011b). This performance is likely due to a combination of hydrological, environmental, and internal reactor conditions as discussed below.

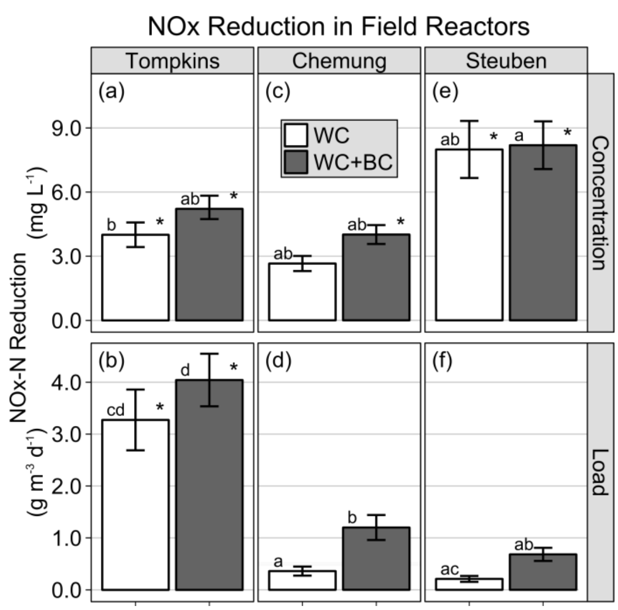

Figure 3: Nitrate and nitrate nitrogen (NOx-N) reductions in continuous monitoring of field reactors over two growing seasons, with standard error bars. White and gray bars indicate woodchip and woodchip/biochar reactors, respectively. * indicates significant reduction ($p<0.05$) from inflow. Letters indicate significant differences in reduction between reactors ($p<0.05$). (a) Concentration reduction of NOx-N, (b) load reduction of NOx-N from 6 field reactors.

The disparity between load and concentration is mostly attributable to highly variable flow rates (Figure A5) (Christianson, et al., 2011a), where coefficients of variation ranged from 1.4 to 4.3. Resulting residence times ranged from a couple hours to longer than two days. Statistically, the variability led to high standard error and prevented detection of significant differences. However, it is possible that the flow variability lowered the reduction rate as well. The baseflows were low and brought in low concentrations and loads of NOx, creating an N-limited system. This was intermittently disrupted with high flow rates, which brought large quantities of NOx, similar to the findings of Woli, et al. (2010). The high flows also caused a drop in residence time at the same time when holding water for treatment was most necessary (Christianson, et al., 2011a). These disruptions may encourage a highly variable and adaptive microbial community more focused on resilience with inflow unpredictability rather than optimal denitrification.

With the shallow groundwater in the study area, it is also possible that these high flow events, all from rainfall events, could have contained more oxygenated water, decreasing the volume of anoxic conditions where denitrification occurs. This would be especially disruptive in the reactors in this study because they are smaller than most field-scale reactors receiving agricultural inflow (Schipper, et al., 2010a; Woli, et al., 2010). The larger reactors are associated with larger, industrial agriculture equipped with irrigation and more level groundwater tables, which create more constant flow rates. Additionally, pH ranged from 5.4 to 7.7 and water temperatures ranged between less than 1 to 23°C. Despite variability in all these environmental factors, the reactors showed removal in 44 out of 50 samplings.

Some P uptake was expected in the reactors from biological processes based on microbial growth and the Redfield ratio (Galloway, et al., 2004; Groffman, et al., 2006). Instead, P was leached from the reactors, especially during the first growing season, reaching rates over 2 g P m^{-}

^{3} d^{-1} on some occasions following large storm events. The peak DRP in the outflow decreased in the second year as the media was flushed and stabilized, leading to moderate DRP reduction. This flushing was more obvious in the biochar, which did show some increased sorptive capacity. Rinsing the biochar before use, as per the manufacturer's direction, could push the reactor into the reduction period more quickly. With just two growing seasons, the net impact on P export from agriculture was not significantly reduced in any reactor, though this may emerge in future seasons after they have been flushed. Continued sampling is necessary to confirm this. Additional sampling of digestible P in new woodchips and biochar compared to aged media may indicate how much more P from the media could become biological available as the reactors age.

SECTION 4

CONCLUSIONS

The reactors proved effective for treating NOx in the conditions of upstate New York, which is their primary design purpose. The high removal rates can significantly reduce N inputs to receiving water bodies to mitigate nutrient-induced eutrophication in agricultural landscapes and surface waters. While the removal rates were significant, field reactors had lower load removal than lab reactors at almost all conditions as well as larger-scale reactors from other studies (Schipper, et al., 2010a; Warneke, et al., 2011b). The lab experiments showed strong first-order effects on NOx removal from inflow NOx and residence time. Additionally, the pH experiment, while only having two treatments, indicated that this factor has a potentially significant influence on reactor denitrification. These observations suggest that optimization of the reactor systems could further improve benefits from them.

Optimal sizing for reactors and moderation of inflow concentrations and rates could improve reactor function and increase cost-effectiveness (Christianson, et al., 2011b). This will require more testing of potential controls, including pH, temperature, and loading variability, in both the lab and field settings, which could then be used to develop models to inform design and removal expectations. Due to the microbial scale at which denitrification occurs and the watershed scale at which excess N has environmental impacts, future reactor research should address broader concerns. It should consider the micropore scale and microbial communities as well as the watershed and regional scale to capture variability and improve global implications. Linking lab and field reactors could be an ideal way to fill holes in knowledge of reactors at multiple scales. However, other factors, such as geography, seasonality, land use, and environmental conditions, will likely require widespread testing of reactors to fully understand their impacts and capabilities (Warneke, et al., 2011c).

Dissimilatory nitrate reduction to ammonium (DNRA) is an alternate pathway to denitrification that also results in lower levels of measured NOx (Seitzinger, et al., 2006; Greenan, et al., 2006). While several samples for ammonium did not show high levels, it is possible that this process, and not denitrification, is a main driver in the reduction of NOx. Anammox could also be occurring along with denitrification, using ammonium as it is produced; if this is the case, reactor conditions may need to be altered to consider this mechanism in addition to or in place of denitrification (Seitzinger, et al., 2006; Schipper, et al., 2010a). Measurements of greenhouse gas emissions, a potential drawback to these reactors, are also necessary for rounding out impacts of the reactors, and are the subject of ongoing investigation.

The simplicity of the design, installation, and maintenance, coupled with treatment efficacy support more widespread use of this technology and possibly its application in other settings. Possibilities include treatment of stormwater, suburban nutrients, and concentrated outfalls from a variety of sources (industrial, greenhouse, stormwater overflow, etc.). While it is improbable that field reactors could be designed to remove NOx at the efficiency seen in the lab reactors of this study, attention to specific and controllable factors could improve reduction rates observed in the field. Further work on these reactors should involve an interdisciplinary approach to address both the function of the reactors and their implementation and could further improve reactor design and placement. Partnerships and community outreach can expand reactor installations to significantly reduce the nutrient footprint of agriculture in the northeastern US.

REFERENCES

Anderson, C. R., Condron, L. M., Clough, T. J., Fiers, M., Stewart, A., Hill, R. A., & Sherlock, R. R. (2011). Biochar induced soil microbial community change: Implications for biogeochemical cycling of carbon, nitrogen and phosphorus. *Pedobiologia*, *54*(5-6), 309–320.

Angst, T. E., Patterson, C. J., Reay, D. S., Anderson, P., Peshkur, T. A., & Sohi, S. P. (2013). Biochar diminishes nitrous oxide and nitrate leaching from diverse nutrient sources. *Journal of Environmental Quality*, *42*(3), 672–82.

Bakken, L. R., Bergaust, L., Liu, B., & Frostegard, a. (2012). Regulation of denitrification at the cellular level: a clue to the understanding of N2O emissions from soils. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1593), 1226–1234.

Blowes, D. & Robertson, W. (1994). Removal of agricultural nitrate from tile-drainage effluent water using in-line bioreactors. *Journal of Contaminant Hydrology*, *15*, 207–221.

Cameron, S. G. & Schipper, L. A. (2010). Nitrate removal and hydraulic performance of organic carbon for use in denitrification beds. *Ecological Engineering*, *36*(11), 1588–1595.

Christianson, L. E., Hanly, J. A., & Hedley, M. J. (2011a). Optimized denitrification bioreactor treatment through simulated drainage containment. *Agricultural Water Management*, *99*(1), 85–92.

Christianson, L. E., Bhandari, A., & Helmers, M. (2011b). Potential design methodology for agricultural drainage denitrification bioreactors. In *World Environmental and Water Resources Congress 2011* (pp. 2740–2748).

Galloway, J. N., Dentener, F. J., Capone, D. G., Boyer, E. W., Howarth, R. W., Seitzinger, S. P., Asner, G. P., Cleveland, C. C., Green, P. A., Holland, E. A., Karl, D. M., Michaels, A. F., Porter, J. H., Townsend, A. R., & Vorosmarty, C. J. (2004). Nitrogen cycles: past, present, and future. *Biogeochemistry*, *70*, 153–226.

Greenan, C. M., Moorman, T. B., Parkin, T. B., Kaspar, T. C., & Jaynes, D. B. (2001). Denitrification in wood chip bioreactors at different water flows. *Journal of Environmental Quality*, *38*(4), 1664–71.

Greenan, C. M., Moorman, T. B., Kaspar, T. C., Parkin, T. B., & Jaynes, D. B. (2006). Comparing carbon substrates for denitrification of subsurface drainage water. *Journal of Environmental Quality*, *35*(3), 824–9.

Groffman, P. M., Altabet, M. A., Bohlke, J. K., Butterbach-Bahl, K., David, M. B., Firestone, M. K., Giblin, A. E., Kana, T. M., Nielsen, L. P., & Voytek, M. A. (2006). Methods for measuring denitrification: Diverse approaches to a difficult problem. *Ecological Applications*, *16*(6), 2091–2122.

Jaynes, D. B., Kaspar, T. C., Moorman, T. B., & Parkin, T. B. (2008). In situ bioreactors and deep drain-pipe installation to reduce nitrate losses in artificially drained fields. *Journal of Environmental Quality*, *37*(2), 429–436.

Kemp, W., Boynton, W., Adolf, J., Boesch, D., Boicourt, W., Brush, G., Cornwell, J., Fisher, T., Glibert, P., Hagy, J., Harding, L., Houde, E., Kimmel, D., Miller, W., Newell, R., Roman, M., Smith, E., & Stevenson, J. (2005). Eutrophication of Chesapeake Bay: historical trends and ecological interactions. *Marine Ecology Progress Series*, *303*, 1–29.

Kovacic, D. A., David, M. B., Gentry, L. E., Starks, K. M., & Cooke, R. A. (2000). Effectiveness of constructed wetlands in reducing nitrogen and phosphorus export from agricultural tile drainage. *Journal of Environment Quality*, *29*(4), 1262–1274.

Martin, T. D., Brockhoff, C. A., & Creed, J. T. (1994). Method 200.7 Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry. *USEPA Environmental Monitoring Systems Lab, Cincinnati, OH*, 1–58.

Moorman, T. B., Parkin, T. B., Kaspar, T. C., & Jaynes, D. B. (2010). Denitrification activity, wood loss, and N_2O emissions over 9 years from a wood chip bioreactor. *Ecological Engineering*, *36*(11), 1567–1574.

Pfaff, J. (1993). Method 300.0 Determination of inorganic anions by ion chromatography. *USEPA Environmental Monitoring Systems Lab, Cincinnati, OH*, (August), 1–28.

Robertson, W. D., Vogan, J. L., & Lombardo, P. S. (2008). Nitrate Removal Rates in a 15-Year-Old Permeable Reactive Barrier Treating Septic System Nitrate. *Ground Water Monitoring & Remediation*, *28*(3), 65–72.

Robertson, W. D., & Merkley, L. C. (2009). In-stream bioreactor for agricultural nitrate treatment. *Journal of Environmental Quality*, *38*(1), 230–237.

Robertson, W. D. (2010). Nitrate removal rates in woodchip media of varying age. *Ecological Engineering*, *36*(11), 1581–1587.

Schipper, L. A. & Vojvodić-Vuković, M. (1998). Nitrate removal from groundwater using a denitrification wall amended with sawdust: field trial. *Journal of Environmental Quality*, *27*(3), 664–668.

Schipper, L. A. & Vojvodić-Vuković, M. (2001). Five years of nitrate removal, denitrification and carbon dynamics in a denitrification wall. *Water Research*, *35*(14), 3473–7.

Schipper, L. A., Barkle, G. F., & Vojvodić-Vuković, M. (2005). Maximum rates of nitrate removal in a denitrification wall. *Journal of Environmental Quality*, *34*(4), 1270–6.

Schipper, L. A., Robertson, W. D., Gold, A. J., Jaynes, D. B., & Cameron, S. G. (2010a). Denitrifying bioreactors—An approach for reducing nitrate loads to receiving waters. *Ecological Engineering*, *36*(11), 1532–1543.

Schipper, L. A., Cameron, S. G., & Warneke, S. (2010b). Nitrate removal from three different effluents using large-scale denitrification beds. *Ecological Engineering*, *36*(11), 1552–1557.

Seitzinger, S., Harrison, J. A., Böhlke, J. K., Bouwman, A. F., Lowrance, R., Peterson, B., Tobias, C., Van Drecht, G. (2006). Denitrification across landscapes and waterscapes: a synthesis. *Ecological Applications*, *16*(6), 2064–90.

Sharpley, A. N., Chapra, S. C., Wedepohl, R., Sims, J. T., Daniel, T. C., & Reddy, K. R. (1994). Managing Agricultural Phosphorus for Protection of Surface Waters: Issues and Options. *Journal of Environment Quality*, *23*(3), 437–451.

Shirmohammadi, A., Wenberg, R. D., Ritter, W. F., & Wright, F. S. (1995). Effect of agricultural drainage on water quality in mid-Atlantic states. *Journal of Irrigation and Drainage Engineering*, *121*(4), 302–306.

Shumway, R. H., Azari, R. S., & Kayhanian, M. (2002). Statistical approaches to estimating mean water quality concentrations with detection limits. *Environmental Science & Technology*, *36*(15), 3345–3353.

Warneke, S., Schipper, L. A., Matiasek, M. G., Scow, K. M., Cameron, S. G., Bruesewitz, D. A., & McDonald, I. R. (2011a). Nitrate removal, communities of denitrifiers and adverse effects in different carbon substrates for use in denitrification beds. *Water Research*, *45*(17), 5463–75.

Warneke, S., Schipper, L. A., Bruesewitz, D. A., McDonald, I. R., & Cameron, S. G. (2011b). Rates, controls and potential adverse effects of nitrate removal in a denitrification bed. *Ecological Engineering*, *37*(3), 511–522.

Warneke, S., Schipper, L. A., Bruesewitz, D. A., & Baisden, W. T. (2011c). A comparison of different approaches for measuring denitrification rates in a nitrate removing bioreactor. *Water Research*, *45*(14), 4141–51.

Williford, J. W., Mckeag, J. A., & Johnston, W. R. (1971). Field Techniques for Removing Nitrates From Drainage Water. *Transactions of the ASAE*, *14*(1), 167–171.

Woli, K. P., David, M. B., Cooke, R. A., McIsaac, G. F., & Mitchell, C. A. (2010). Nitrogen balance in and export from agricultural fields associated with controlled drainage systems and denitrifying bioreactors. *Ecological Engineering*, *36*(11), 1558–1566.

Zoski, E. D., Lapen, D. R., Gottschall, N., Murrell, R. S., & Schuba, B. (2013). Nitrogen, Phosphorus, and Bacteria Removal in Laboratory-Scale Woodchip Bioreactors Amended with Drinking Water Treatment Residuals. *Transactions of the ASABE*, (3), 1339–1347.

APPENDIX

Lab Reactor Diagram

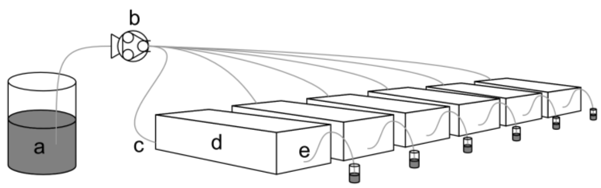

Figure A1: Lab reactor setup diagram. (a) common inflow source spiked with KNO_3 and other chemicals necessary for each run; (b) peristaltic pump to control flow rate and residence time; (c) inflow fitting into reactor; (d) denitrifying bioreactor; (e) outflow piping with loop to insure complete media saturation.

Field Reactor Diagram

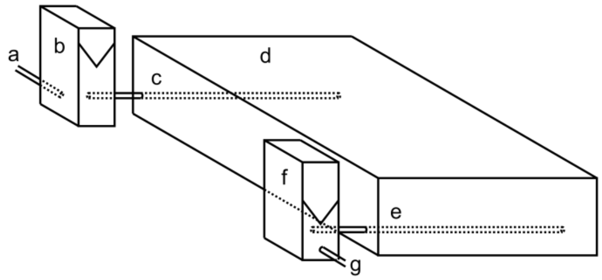

Figure A2: Field reactor diagram. (a) connection to tile drains from field; (b) inflow control box with weir to control water depth in the reactor; (c) perforated, 4 inch diameter piping for distribution of inflow into the bottom of the reactor across its entire width; (d) denitrifying bioreactor; (e) perforated piping for distributed outflow; (f) outflow control box with weir to control head gradient and residence time; (g) outflow pipe to receiving water.

Lab Full Run

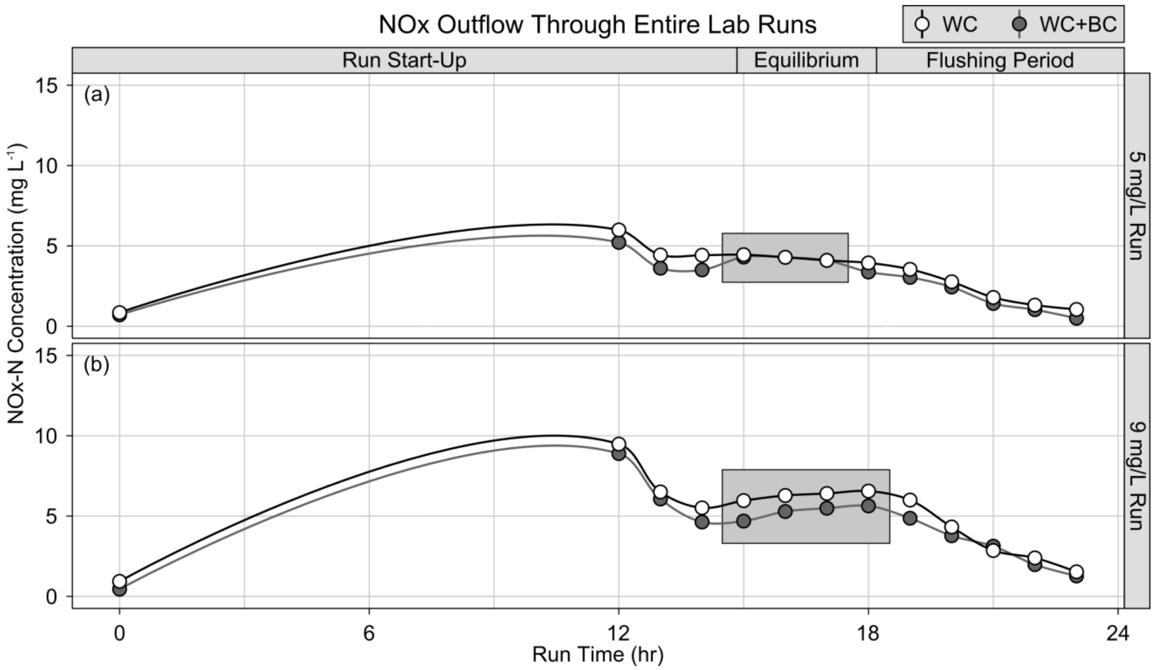

Figure A3: Nitrate and nitrate nitrogen (NOx-N) concentrations through the entire lab reactor runs for the first experiment. White and gray points are averages for triplicate sampling of triplicate woodchip (WC) and woodchip/biochar (WC+BC) reactors, respectively. Standard error lines are not visible because they are too small. Lines are smooth estimates of potential outflow NOx-N between sample points. Inflow NOx-N was stopped after 18 hours of run time so drops after that indicate sample collected during flushing period. Gray boxes indicate samples that were not significantly different and therefore considered to be at equilibrium. Based on these runs, equilibrium was established as greater than 2.5 times the residence time.

Lab NOx-N Reduction

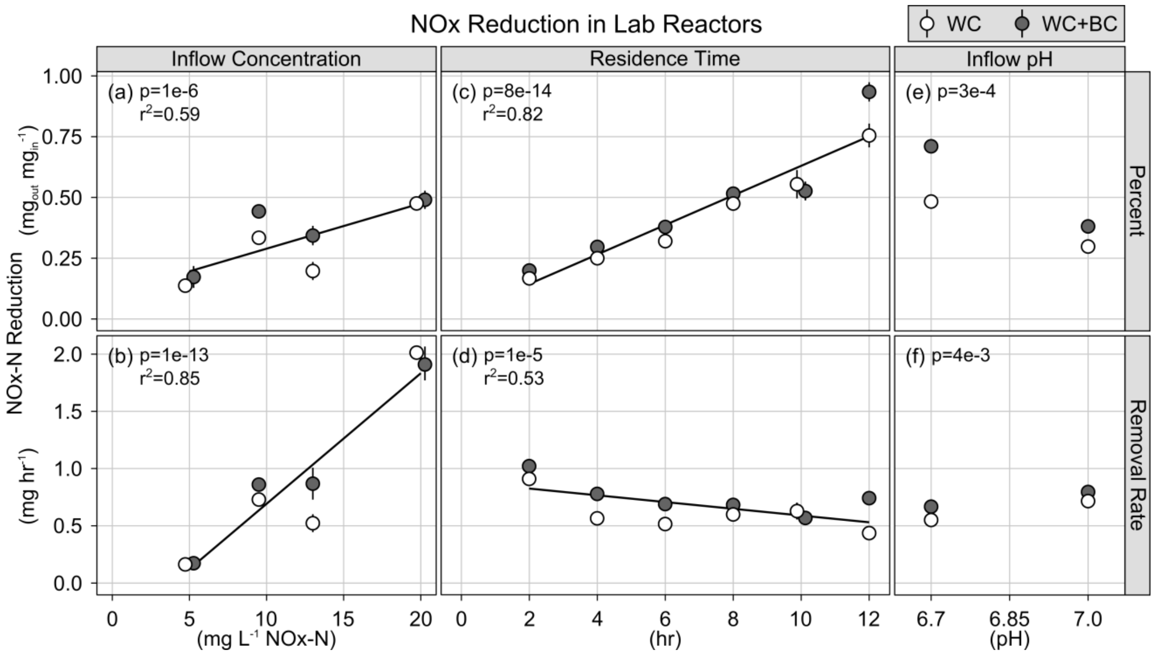

Figure A4: Nitrate and nitrate nitrogen (NOx-N) reduction in lab reactor experiments. White and gray points are averages for triplicate sampling of triplicate woodchip (WC) and woodchip/ biochar (WC+BC) reactors, respectively. Standard error is shown, when visible. Some points have been shifted horizontally to avoid overlapping, if necessary. Left plots show (a) NOx-N percent reduction and (b) NOx-N removal rate in inflow concentration experiment, with lines and the significance of inflow concentration (p value) and strength of linear fit (r^2). Middle plots show (c) percent reduction of NOx-N and (d) rate of removal of NOx-N in residence time experiment, with lines and the significance of inflow concentration (p value) and strength of linear fit (r^2). Rightmost plots show (e) NOx-N percent reduction and (f) NOx-N rate of removal in inflow pH experiment. Linear analysis was not performed with only 2 pH levels. Instead p values show significant difference between the average percent reduction and removal rate of all reactors from pH 6.7 to 7.

Field Weir Calibration

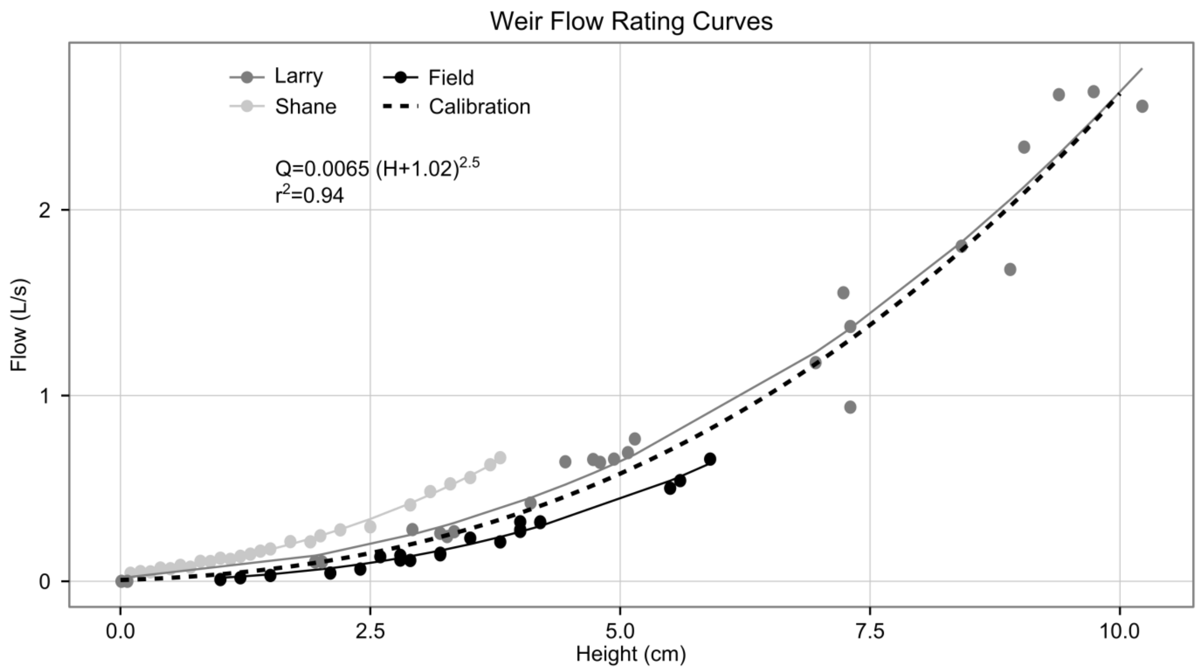

Figure A5: Rating curve over AgriDrain® V-notch weirs based on two lab calibration datasets and one field dataset. The calibration equation is based on the Kindsvater-Shen equation for V-notch weirs that are not at 90°, and it includes all three datasets to determine the values of the two coefficients.

Field Hydrographs

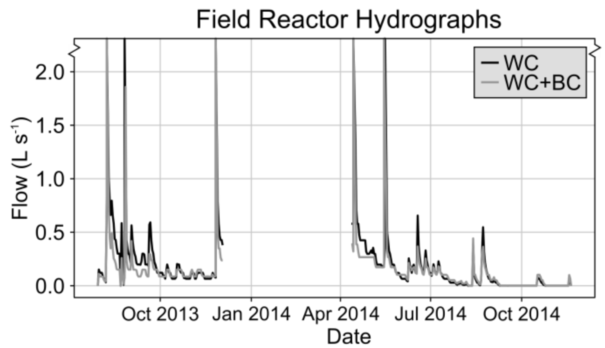

Figure A6: Field hydrographs for Tompkins bioreactors through over two growing seasons as measured by pressure transducers recording depth over a V-notch weir. Black and gray lines indicate woodchip and woodchip/biochar reactors, respectively. Loggers were removed between December 2013 and April 2014 due to weather. Events exceeding 6 L s^{-1} had water heights that exceeded the V-notch weir and were beyond the range of weir calibration. Estimated values for these flows are presented in Table A1.

Table A1: Estimated flows in Tompkins bioreactors for events that exceeded the V-notch weir in depth along with estimated overflow in the inflow weir that bypassed the bioreactors

Date	**Bypass (L s^{-1})**	**WC Weir (L s^{-1})**	**WC+BC Weir (L s^{-1})**
08/09/2013	Entire site flooded, no flows estimated		
08/27/2013	0.0	2.3	1.9
11/27/2013	0.1	34.2	33.1
04/15/2014	0.0	3.1	2.7
05/16/2014	0.0	0.4	28.2
05/17/2014	0.0	6.4	8.2

Field Dissolved Reactive Phosphorus

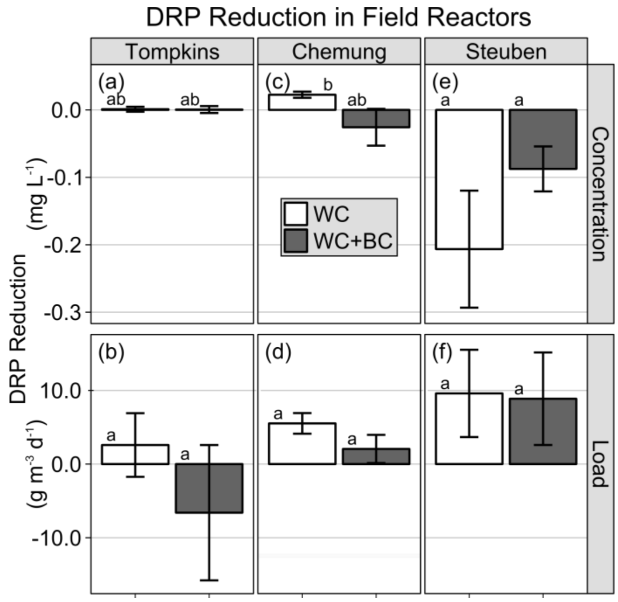

Figure A7: Dissolved reactive phosphorus (DRP) reductions in continuous monitoring of field reactors over two growing seasons, with standard error bars. Blue and pink bars indicate woodchip and woodchip/biochar reactors, respectively. None of these levels were significant difference ($p<0.05$) from inflow. Letters indicate differences in reduction between reactors ($p<0.05$).

Field Dissolved Organic Carbon

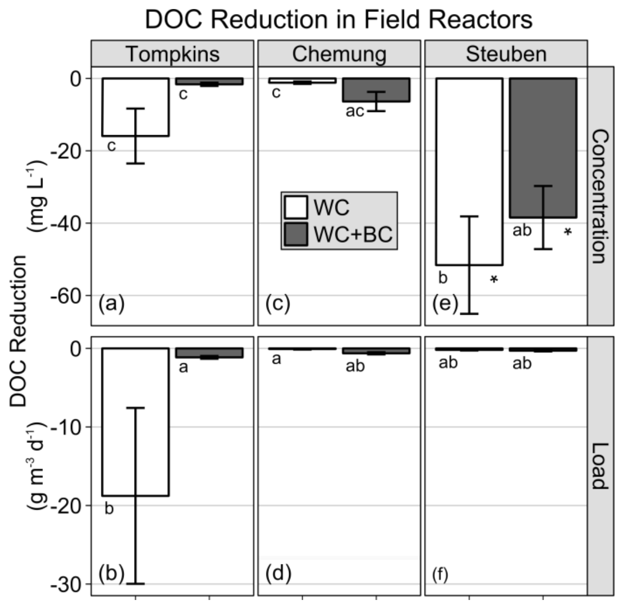

Figure A8: Dissolved organic carbon (DOC) reductions in continuous monitoring of field reactors over two growing seasons, with standard error bars. Blue and pink bars indicate woodchip and woodchip/biochar reactors, respectively. * indicate significant difference ($p<0.05$) from inflow. Letters indicate significant differences in reduction between reactors ($p<0.05$).

Lab Complete Dataset

Table A2: Complete set of data collected from lab reactors during three experiments. Reactor fills (first letters of the site field) In, BC, and WC refer to inflow, woodchip reactor, and woodchip with biochar reactor outflow, respectively. Numbers after the dash indicate replicates.

Table A2 **Sample Date Time**	**Run**	**Site**	**Temp (°C)**	**Flow (mL s^{-1})**	**Res Time (hr)**	**pH**	**NOx-N (mg L^{-1})**
04/24/2013 19:00	05ppm	In-1	15.1			7.71	6.24
04/24/2013 19:00	05ppm	In-2	15.1			7.78	5.93
04/24/2013 19:00	05ppm	In-3	15.1			7.68	5.82
04/24/2013 19:06	05ppm	BC-1	20.2	1.32	5.88	7.40	0.73
04/24/2013 19:06	05ppm	BC-2	20.2	1.44	5.39	7.45	0.72
04/24/2013 19:06	05ppm	BC-3	20.3	1.50	5.17	7.38	0.69
04/24/2013 19:06	05ppm	WC-1	20.1	2.10	3.69	7.44	0.95
04/24/2013 19:06	05ppm	WC-2	19.9	2.42	3.21	7.47	0.92
04/24/2013 19:06	05ppm	WC-3	20.3	1.52	5.10	7.41	0.67
04/25/2013 07:00	05ppm	BC-1	18.1	2.12	3.66	7.46	5.43
04/25/2013 07:00	05ppm	BC-2	18.4	1.36	5.70	7.44	5.34
04/25/2013 07:00	05ppm	BC-3	18.8	1.46	5.31	7.41	4.88
04/25/2013 07:00	05ppm	WC-1	18.7	2.10	3.69	7.39	6.21
04/25/2013 07:00	05ppm	WC-2	18.3	2.38	3.26	7.44	5.94
04/25/2013 07:00	05ppm	WC-3	18.7	1.48	5.24	7.41	5.83
04/25/2013 07:11	05ppm	In-1	21.8			7.81	4.37
04/25/2013 07:11	05ppm	In-2	20.5			7.66	5.38
04/25/2013 07:11	05ppm	In-3	20.7			7.86	5.20
04/25/2013 08:00	05ppm	BC-1	18.6	2.10	3.69	7.26	2.99
04/25/2013 08:00	05ppm	BC-2	18.4	1.40	5.54	7.35	3.79
04/25/2013 08:00	05ppm	BC-3	18.8	1.50	5.17	7.32	4.06
04/25/2013 08:00	05ppm	WC-1	18.7	2.16	3.59	7.21	4.42
04/25/2013 08:00	05ppm	WC-2	18.0	2.40	3.23	7.30	4.45
04/25/2013 08:00	05ppm	WC-3	18.0	1.52	5.10	7.27	4.44
04/25/2013 09:00	05ppm	BC-1	19.1	2.10	3.69	7.25	3.42
04/25/2013 09:00	05ppm	BC-2	18.8	1.38	5.62	7.35	3.41
04/25/2013 09:00	05ppm	BC-3	18.9	1.50	5.17	7.35	3.68
04/25/2013 09:00	05ppm	WC-1	18.7	2.06	3.77	7.36	4.14
04/25/2013 09:00	05ppm	WC-2	18.5	2.24	3.46	7.43	4.92
04/25/2013 09:00	05ppm	WC-3	18.8	1.48	5.24	7.35	4.21
04/25/2013 10:01	05ppm	BC-1	19.2	2.02	3.84	7.41	4.32
04/25/2013 10:01	05ppm	BC-2	19.0	1.36	5.70	7.40	4.34
04/25/2013 10:01	05ppm	BC-3	19.1	1.48	5.24	7.36	4.25
04/25/2013 10:01	05ppm	WC-1	18.5	2.08	3.73	7.41	4.18
04/25/2013 10:01	05ppm	WC-2	18.5	2.30	3.37	7.51	4.95
04/25/2013 10:01	05ppm	WC-3	18.8	1.44	5.39	7.40	4.23
04/25/2013 10:54	05ppm	In-1	17.4			7.89	4.76
04/25/2013 10:54	05ppm	In-2	17.4			7.90	5.37
04/25/2013 10:54	05ppm	In-3	18.8			7.84	4.45
04/25/2013 11:01	05ppm	BC-1	19.2	2.10	3.69	7.36	4.05
04/25/2013 11:01	05ppm	BC-2	19.1	1.32	5.88	7.48	4.50
04/25/2013 11:01	05ppm	BC-3	19.3	1.48	5.24	7.43	4.32
04/25/2013 11:01	05ppm	WC-1	18.9	2.12	3.66	7.36	3.89
04/25/2013 11:01	05ppm	WC-2	18.7	2.30	3.37	7.37	4.70
04/25/2013 11:01	05ppm	WC-3	18.9	1.52	5.10	7.43	4.27
04/25/2013 12:01	05ppm	BC-1	19.4	2.08	3.73	7.34	3.97
04/25/2013 12:01	05ppm	BC-2	19.4	1.36	5.70	7.32	3.98
04/25/2013 12:01	05ppm	BC-3	19.5	1.58	4.91	7.24	4.34

Table A2

Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
04/25/2013 12:01	05ppm	WC-1	19.5	2.12	3.66	7.25	3.48
04/25/2013 12:01	05ppm	WC-2	19.1	2.38	3.26	7.24	4.52
04/25/2013 12:01	05ppm	WC-3	19.2	1.52	5.10	7.27	4.25
04/25/2013 13:02	05ppm	BC-1	19.5	2.06	3.77	7.41	3.86
04/25/2013 13:02	05ppm	BC-2	19.4	1.36	5.70	7.32	3.30
04/25/2013 13:02	05ppm	BC-3	19.5	1.52	5.10	7.28	2.97
04/25/2013 13:02	05ppm	WC-1	19.5	2.02	3.84	7.20	3.16
04/25/2013 13:02	05ppm	WC-2	19.4	2.20	3.53	7.24	4.59
04/25/2013 13:02	05ppm	WC-3	19.4	1.48	5.24	7.40	4.08
04/25/2013 13:17	05ppm	In-1	19.5			7.91	4.68
04/25/2013 13:17	05ppm	In-2	19.3			7.95	5.48
04/25/2013 13:17	05ppm	In-3	19.5			7.91	5.32
04/25/2013 14:01	05ppm	BC-1	19.7	1.96	3.96	7.40	2.98
04/25/2013 14:01	05ppm	BC-2	19.5	1.40	5.54	7.31	3.19
04/25/2013 14:01	05ppm	BC-3	19.7	1.56	4.97	7.27	2.95
04/25/2013 14:01	05ppm	WC-1	19.8	2.14	3.63	7.22	3.45
04/25/2013 14:01	05ppm	WC-2	19.5	2.24	3.46	7.35	3.52
04/25/2013 14:01	05ppm	WC-3	19.5	1.58	4.91	7.30	3.66
04/25/2013 15:01	05ppm	BC-1	19.7	2.02	3.84	7.41	2.00
04/25/2013 15:01	05ppm	BC-2	19.7	1.52	5.10	7.33	2.50
04/25/2013 15:01	05ppm	BC-3	19.8	1.68	4.62	7.21	2.83
04/25/2013 15:01	05ppm	WC-1	19.9	1.90	4.08	7.34	2.65
04/25/2013 15:01	05ppm	WC-2	19.5	2.38	3.26	7.38	2.65
04/25/2013 15:01	05ppm	WC-3	19.5	1.56	4.97	7.30	3.01
04/25/2013 16:01	05ppm	BC-1	19.5	2.08	3.73	7.46	1.20
04/25/2013 16:01	05ppm	BC-2	19.5	1.50	5.17	7.47	1.60
04/25/2013 16:01	05ppm	BC-3	19.8	1.54	5.04	7.34	1.44
04/25/2013 16:01	05ppm	WC-1	19.9	2.10	3.69	7.37	1.67
04/25/2013 16:01	05ppm	WC-2	19.5	2.30	3.37	7.45	1.63
04/25/2013 16:01	05ppm	WC-3	19.5	1.56	4.97	7.37	2.08
04/25/2013 17:03	05ppm	BC-1	19.5	2.08	3.73	7.41	1.12
04/25/2013 17:03	05ppm	BC-2	19.6	1.82	4.26	7.34	1.10
04/25/2013 17:03	05ppm	BC-3	19.8	1.68	4.62	7.30	0.87
04/25/2013 17:03	05ppm	WC-1	19.8	2.10	3.69	7.22	1.20
04/25/2013 17:03	05ppm	WC-2	19.5	2.34	3.32	7.34	1.19
04/25/2013 17:03	05ppm	WC-3	19.6	1.62	4.79	7.34	1.56
04/25/2013 18:01	05ppm	BC-1	19.5	2.18	3.56	7.32	0.59
04/25/2013 18:01	05ppm	BC-2	19.5	1.40	5.54	7.39	0.52
04/25/2013 18:01	05ppm	BC-3	19.8	1.42	5.46	7.31	0.38
04/25/2013 18:01	05ppm	WC-1	19.7	1.96	3.96	7.38	0.95
04/25/2013 18:01	05ppm	WC-2	19.3	2.16	3.59	7.43	1.00
04/25/2013 18:01	05ppm	WC-3	19.5	1.50	5.17	7.39	1.19
04/25/2013 19:07	09ppm	In-1	17.7			7.87	11.40
04/25/2013 19:07	09ppm	In-2	17.7			7.90	10.72
04/25/2013 19:07	09ppm	In-3	17.7			7.93	12.42
04/25/2013 19:10	09ppm	BC-1	19.5	1.90	4.08	7.48	0.33
04/25/2013 19:10	09ppm	BC-2	19.5	1.51	5.14	7.40	0.49
04/25/2013 19:10	09ppm	BC-3	19.6	1.38	5.62	7.38	0.53
04/25/2013 19:10	09ppm	WC-1	19.6	2.10	3.69	7.41	0.93
04/25/2013 19:10	09ppm	WC-2	19.3	2.31	3.36	7.43	0.93
04/25/2013 19:10	09ppm	WC-3	19.5	1.51	5.14	7.50	0.91
04/26/2013 07:15	09ppm	BC-1		1.91	4.06	7.54	9.32
04/26/2013 07:15	09ppm	BC-2		1.48	5.25	7.45	8.30
04/26/2013 07:15	09ppm	BC-3		1.38	5.64	7.45	9.05
04/26/2013 07:15	09ppm	WC-1		2.02	3.84	7.63	10.17
04/26/2013 07:15	09ppm	WC-2		2.24	3.46	7.52	8.88

Table A2 Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
04/26/2013 07:15	09ppm	WC-3		1.43	5.41	7.47	9.39
04/26/2013 07:18	09ppm	In-1	20.4			7.76	7.97
04/26/2013 07:18	09ppm	In-2	20.7			7.88	8.58
04/26/2013 07:18	09ppm	In-3	20.7			7.96	9.95
04/26/2013 08:15	09ppm	BC-1	18.6	1.87	4.15	7.06	5.56
04/26/2013 08:15	09ppm	BC-2	19.5	1.54	5.04	6.98	5.63
04/26/2013 08:15	09ppm	BC-3	18.9	1.56	4.97	7.05	6.99
04/26/2013 08:15	09ppm	WC-1	18.8	2.06	3.77	7.03	6.70
04/26/2013 08:15	09ppm	WC-2	19.5	2.28	3.40	6.96	5.86
04/26/2013 08:15	09ppm	WC-3	18.8	1.49	5.21	7.05	6.95
04/26/2013 09:12	09ppm	BC-1	19.1	1.90	4.08	6.72	5.49
04/26/2013 09:12	09ppm	BC-2	19.5	1.50	5.17	6.66	3.65
04/26/2013 09:12	09ppm	BC-3	19.4	1.38	5.62	6.74	4.74
04/26/2013 09:12	09ppm	WC-1	19.5	2.00	3.88	6.59	5.87
04/26/2013 09:12	09ppm	WC-2	19.8	2.08	3.73	6.49	5.56
04/26/2013 09:12	09ppm	WC-3	19.1	1.46	5.31	6.60	5.12
04/26/2013 10:09	09ppm	BC-1	19.5	1.94	4.00	6.54	5.70
04/26/2013 10:09	09ppm	BC-2	19.9	1.60	4.85	6.48	3.79
04/26/2013 10:09	09ppm	BC-3	19.5	1.34	5.79	6.43	4.58
04/26/2013 10:09	09ppm	WC-1	19.9	1.88	4.13	6.52	6.52
04/26/2013 10:09	09ppm	WC-2	20.1	2.06	3.77	6.45	6.14
04/26/2013 10:09	09ppm	WC-3	19.5	1.48	5.24	6.48	5.24
04/26/2013 11:09	09ppm	BC-1	19.7	1.88	4.13	6.63	5.99
04/26/2013 11:09	09ppm	BC-2	20.1	1.54	5.04	6.55	4.67
04/26/2013 11:09	09ppm	BC-3	20.1	1.36	5.70	6.43	5.20
04/26/2013 11:09	09ppm	WC-1	20.1	1.94	4.00	6.62	6.41
04/26/2013 11:09	09ppm	WC-2	20.2	2.06	3.77	6.64	6.34
04/26/2013 11:09	09ppm	WC-3	19.7	1.46	5.31	6.57	6.10
04/26/2013 12:10	09ppm	BC-1	19.9	1.86	4.17	7.01	6.01
04/26/2013 12:10	09ppm	BC-2	20.3	1.62	4.79	6.99	4.99
04/26/2013 12:10	09ppm	BC-3	20.3	1.54	5.04	6.93	5.48
04/26/2013 12:10	09ppm	WC-1	20.3	2.02	3.84	6.84	6.48
04/26/2013 12:10	09ppm	WC-2	20.5	2.08	3.73	7.00	6.42
04/26/2013 12:10	09ppm	WC-3	19.8	1.52	5.10	6.93	6.32
04/26/2013 13:11	09ppm	BC-1	20.1	1.74	4.46	6.98	6.05
04/26/2013 13:11	09ppm	BC-2	20.4	1.58	4.91	6.87	5.42
04/26/2013 13:11	09ppm	BC-3	20.3	1.38	5.62	6.56	5.42
04/26/2013 13:11	09ppm	WC-1	20.7	1.90	4.08	7.09	6.49
04/26/2013 13:11	09ppm	WC-2	20.7	2.06	3.77	7.10	6.58
04/26/2013 13:11	09ppm	WC-3	20.1	1.46	5.31	7.06	6.61
04/26/2013 13:16	09ppm	In-1	19.9			7.62	9.92
04/26/2013 13:16	09ppm	In-2	20.7			7.39	8.65
04/26/2013 13:16	09ppm	In-3	20.7			7.25	9.83
04/26/2013 14:11	09ppm	BC-1	20.2	2.00	3.88	6.79	4.82
04/26/2013 14:11	09ppm	BC-2	20.3	1.50	5.17	6.85	4.88
04/26/2013 14:11	09ppm	BC-3	20.3	1.40	5.54	6.83	4.91
04/26/2013 14:11	09ppm	WC-1	20.9	2.16	3.59	6.83	5.99
04/26/2013 14:11	09ppm	WC-2	20.7	2.38	3.26	6.98	5.67
04/26/2013 14:11	09ppm	WC-3	20.0	1.42	5.46	6.89	6.33
04/26/2013 15:15	09ppm	BC-1	20.1	2.10	3.69	6.78	2.95
04/26/2013 15:15	09ppm	BC-2	20.5	1.34	5.79	6.68	3.86
04/26/2013 15:15	09ppm	BC-3	20.1	1.26	6.16	6.53	4.52
04/26/2013 15:15	09ppm	WC-1	20.9	2.18	3.56	6.83	3.93
04/26/2013 15:15	09ppm	WC-2	20.3	2.46	3.15	6.87	3.44
04/26/2013 15:15	09ppm	WC-3	20.1	1.40	5.54	6.64	5.61
04/26/2013 16:10	09ppm	BC-1	20.1	2.10	3.69	6.90	2.43

Table A2 **Sample Date Time**	**Run**	**Site**	**Temp (°C)**	**Flow (mL s^{-1})**	**Res Time (hr)**	**pH**	**NOx-N (mg L^{-1})**
04/26/2013 16:10	09ppm	BC-2	20.3	1.28	6.06	6.71	3.19
04/26/2013 16:10	09ppm	BC-3	20.5	1.36	5.70	6.54	3.76
04/26/2013 16:10	09ppm	WC-1	20.7	2.06	3.77	6.70	1.99
04/26/2013 16:10	09ppm	WC-2	20.3	2.42	3.21	6.93	1.75
04/26/2013 16:10	09ppm	WC-3	20.3	1.34	5.79	6.71	4.83
04/26/2013 17:05	09ppm	BC-1	19.6	1.84	4.22	7.11	1.71
04/26/2013 17:05	09ppm	BC-2	20.0	1.46	5.31	7.01	2.15
04/26/2013 17:05	09ppm	BC-3	20.3	1.32	5.88	6.96	2.08
04/26/2013 17:05	09ppm	WC-1	19.9	2.06	3.77	7.15	1.44
04/26/2013 17:05	09ppm	WC-2	19.5	2.40	3.23	7.04	1.44
04/26/2013 17:05	09ppm	WC-3	20.2	1.34	5.79	6.99	4.32
04/26/2013 18:07	09ppm	BC-1	19.2	1.80	4.31	7.09	1.17
04/26/2013 18:07	09ppm	BC-2	19.5	1.26	6.16	6.97	1.46
04/26/2013 18:07	09ppm	BC-3	19.8	1.24	6.26	6.99	1.18
04/26/2013 18:07	09ppm	WC-1	19.2	1.88	4.13	7.09	1.09
04/26/2013 18:07	09ppm	WC-2	18.9	2.30	3.37	7.10	1.26
04/26/2013 18:07	09ppm	WC-3	19.8	1.34	5.79	6.97	2.25
04/26/2013 19:10	12ppm	In-1	16.8			7.54	16.17
04/26/2013 19:10	12ppm	In-2	16.8			7.54	15.62
04/26/2013 19:10	12ppm	In-3	16.8			7.55	15.44
04/26/2013 19:11	12ppm	BC-1	19.1	1.55	5.01	6.97	1.32
04/26/2013 19:11	12ppm	BC-2	19.0	1.34	5.79	7.06	1.33
04/26/2013 19:11	12ppm	BC-3	19.5	1.12	6.93	7.05	0.95
04/26/2013 19:11	12ppm	WC-1	17.5	1.48	5.24	7.00	1.10
04/26/2013 19:11	12ppm	WC-2	18.5	2.85	2.72	7.02	1.14
04/26/2013 19:11	12ppm	WC-3	19.4	1.28	6.06	6.89	1.59
04/27/2013 07:10	12ppm	BC-1	18.7	1.85	4.19	7.24	15.22
04/27/2013 07:10	12ppm	BC-2	18.7	1.25	6.22	7.22	14.46
04/27/2013 07:10	12ppm	BC-3	19.2	1.37	5.65	7.10	12.63
04/27/2013 07:10	12ppm	In-1	19.8			7.47	13.39
04/27/2013 07:10	12ppm	In-2	21.2			7.61	13.24
04/27/2013 07:10	12ppm	In-3	20.9			7.55	12.53
04/27/2013 07:10	12ppm	WC-1	18.3	1.44	5.39	7.23	14.93
04/27/2013 07:10	12ppm	WC-2	18.7	1.60	4.85	7.26	15.69
04/27/2013 07:10	12ppm	WC-3	18.6	1.05	7.39	7.14	14.36
04/27/2013 08:07	12ppm	BC-1	18.6	2.05	3.78	7.06	9.24
04/27/2013 08:07	12ppm	BC-2	19.1	1.42	5.46	6.79	9.59
04/27/2013 08:07	12ppm	BC-3	19.0	1.34	5.79	6.99	10.26
04/27/2013 08:07	12ppm	WC-1	19.5	1.76	4.41	7.12	12.80
04/27/2013 08:07	12ppm	WC-2	19.4	2.08	3.73	6.96	9.49
04/27/2013 08:07	12ppm	WC-3	20.1	1.40	5.54	7.03	10.45
04/27/2013 09:07	12ppm	BC-1	18.7	1.72	4.51	7.09	9.29
04/27/2013 09:07	12ppm	BC-2	19.4	1.40	5.54	6.84	5.40
04/27/2013 09:07	12ppm	BC-3	19.7	1.36	5.70	6.93	6.96
04/27/2013 09:07	12ppm	WC-1	19.1	1.78	4.36	6.95	9.69
04/27/2013 09:07	12ppm	WC-2	19.5	2.10	3.69	6.97	7.24
04/27/2013 09:07	12ppm	WC-3	19.1	1.32	5.88	6.96	7.15
04/27/2013 10:10	12ppm	BC-1	19.2	1.36	5.70	7.01	10.40
04/27/2013 10:10	12ppm	BC-2	19.5	2.18	3.56	6.79	4.50
04/27/2013 10:10	12ppm	BC-3	19.8	1.76	4.41	7.01	6.87
04/27/2013 10:10	12ppm	WC-1	19.4	1.30	5.97	7.11	10.92
04/27/2013 10:10	12ppm	WC-2	19.5	1.32	5.88	7.01	9.66
04/27/2013 10:10	12ppm	WC-3	19.2	1.76	4.41	6.95	6.96
04/27/2013 11:10	12ppm	BC-1	19.5	1.74	4.46	7.03	11.21
04/27/2013 11:10	12ppm	BC-2	19.9	1.32	5.88	6.92	5.94
04/27/2013 11:10	12ppm	BC-3	19.9	1.30	5.97	6.95	7.74

Table A2

Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
04/27/2013 11:10	12ppm	WC-1	19.8	1.64	4.73	7.09	11.37
04/27/2013 11:10	12ppm	WC-2	20.3	2.08	3.73	7.01	10.66
04/27/2013 11:10	12ppm	WC-3	19.7	1.38	5.62	6.97	8.22
04/27/2013 12:08	12ppm	BC-1	19.5	1.64	4.73	7.12	11.86
04/27/2013 12:08	12ppm	BC-2	19.9	1.32	5.88	6.99	6.78
04/27/2013 12:08	12ppm	BC-3	19.9	1.36	5.70	6.99	7.69
04/27/2013 12:08	12ppm	WC-1	20.2	1.64	4.73	7.14	12.64
04/27/2013 12:08	12ppm	WC-2	20.2	2.06	3.77	7.05	11.67
04/27/2013 12:08	12ppm	WC-3	19.5	1.40	5.54	7.07	9.23
04/27/2013 13:07	12ppm	BC-1	19.8	1.41	5.50	7.14	11.82
04/27/2013 13:07	12ppm	BC-2	20.2	1.41	5.50	7.00	9.51
04/27/2013 13:07	12ppm	BC-3	20.5	1.41	5.50	6.92	7.92
04/27/2013 13:07	12ppm	In-1	19.5			7.66	13.36
04/27/2013 13:07	12ppm	In-2	20.1			7.72	13.21
04/27/2013 13:07	12ppm	In-3	20.1			7.74	12.34
04/27/2013 13:07	12ppm	WC-1	19.7	1.72	4.51	7.06	12.01
04/27/2013 13:07	12ppm	WC-2	20.3	2.10	3.69	7.11	11.92
04/27/2013 13:07	12ppm	WC-3	19.5	1.44	5.39	7.00	9.64
04/27/2013 14:08	12ppm	BC-1	20.1	1.80	4.31	7.01	9.64
04/27/2013 14:08	12ppm	BC-2	20.5	1.54	5.04	6.95	7.60
04/27/2013 14:08	12ppm	BC-3	20.7	1.40	5.54	6.84	7.15
04/27/2013 14:08	12ppm	WC-1	20.5	1.70	4.56	7.03	11.53
04/27/2013 14:08	12ppm	WC-2	20.9	2.02	3.84	7.02	10.50
04/27/2013 14:08	12ppm	WC-3	20.3	1.46	5.31	6.98	8.46
04/27/2013 15:07	12ppm	BC-1	19.9	2.00	3.88	7.03	8.89
04/27/2013 15:07	12ppm	BC-2	20.3	1.47	5.28	6.93	7.22
04/27/2013 15:07	12ppm	BC-3	20.4	1.44	5.39	6.95	5.16
04/27/2013 15:07	12ppm	WC-1	21.1	1.63	4.76	6.64	10.50
04/27/2013 15:07	12ppm	WC-2	20.9	2.12	3.66	6.96	8.44
04/27/2013 15:07	12ppm	WC-3	20.3	1.43	5.43	6.97	6.74
04/27/2013 16:07	12ppm	BC-1	21.1	2.00	3.88	7.09	7.07
04/27/2013 16:07	12ppm	BC-2	20.9	0.00		7.06	6.09
04/27/2013 16:07	12ppm	BC-3	21.1	1.34	5.79	6.99	4.12
04/27/2013 16:07	12ppm	WC-1	20.9	1.56	4.97	7.04	8.76
04/27/2013 16:07	12ppm	WC-2	20.7	0.00		7.02	6.18
04/27/2013 16:07	12ppm	WC-3	20.7	2.00	3.88	7.04	4.55
04/27/2013 17:08	12ppm	BC-1	21.1	2.02	3.84	6.99	5.54
04/27/2013 17:08	12ppm	BC-2	20.7	1.50	5.17	6.88	5.80
04/27/2013 17:08	12ppm	BC-3	21.5	1.40	5.54	6.89	3.70
04/27/2013 17:08	12ppm	WC-1	21.1	1.70	4.56	7.06	7.32
04/27/2013 17:08	12ppm	WC-2	21.1	2.06	3.77	7.05	4.80
04/27/2013 17:08	12ppm	WC-3	20.9	1.40	5.54	6.97	4.12
04/27/2013 18:07	12ppm	BC-1	20.7	2.03	3.82	6.99	3.75
04/27/2013 18:07	12ppm	BC-2	20.9	1.48	5.24	6.94	4.83
04/27/2013 18:07	12ppm	BC-3	21.1	1.35	5.75	6.79	3.22
04/27/2013 18:07	12ppm	WC-1	21.1	1.80	4.31	6.98	5.53
04/27/2013 18:07	12ppm	WC-2	21.5	2.14	3.63	7.01	4.02
04/27/2013 18:07	12ppm	WC-3	20.9	1.45	5.35	6.96	3.78
04/27/2013 19:11	20ppm	BC-1	21.1	1.96	3.96	7.17	2.85
04/27/2013 19:11	20ppm	BC-2	21.1	0.80	9.70	7.15	3.78
04/27/2013 19:11	20ppm	BC-3	21.1	1.20	6.47	7.08	2.28
04/27/2013 19:11	20ppm	In-1	19.2			7.60	18.62
04/27/2013 19:11	20ppm	In-2	15.1			7.67	17.97
04/27/2013 19:11	20ppm	In-3	17.2			7.66	18.35
04/27/2013 19:11	20ppm	WC-1	21.8	1.68	4.62	7.19	4.17
04/27/2013 19:11	20ppm	WC-2	21.5	1.82	4.26	7.01	3.19

Table A2

Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
04/27/2013 19:11	20ppm	WC-3	21.1	1.26	6.16	7.15	3.53
04/28/2013 07:10	20ppm	BC-1	19.5	1.70	4.56	7.27	13.37
04/28/2013 07:10	20ppm	BC-2	18.6	1.48	5.24	7.30	7.27
04/28/2013 07:10	20ppm	BC-3	18.8	1.30	5.97	7.16	8.64
04/28/2013 07:10	20ppm	In-1	19.1			7.54	19.34
04/28/2013 07:10	20ppm	In-1	20.1			7.49	19.79
04/28/2013 07:10	20ppm	In-2	18.7			7.60	18.08
04/28/2013 07:10	20ppm	In-2	20.2			7.70	20.33
04/28/2013 07:10	20ppm	In-3	18.8			7.64	19.10
04/28/2013 07:10	20ppm	In-3	20.2			7.86	19.05
04/28/2013 07:10	20ppm	WC-1	20.3	1.52	5.10	7.22	21.39
04/28/2013 07:10	20ppm	WC-2	18.7	1.98	3.92	7.28	6.95
04/28/2013 07:10	20ppm	WC-3	19.0	1.36	5.70	7.25	13.26
04/28/2013 08:07	20ppm	BC-1	19.8	1.68	4.62	6.97	11.61
04/28/2013 08:07	20ppm	BC-2	18.9	1.51	5.14	6.91	5.94
04/28/2013 08:07	20ppm	BC-3	19.1	1.42	5.46	6.87	7.06
04/28/2013 08:07	20ppm	WC-1	20.5	1.72	4.51	6.93	14.34
04/28/2013 08:07	20ppm	WC-2	19.1	1.97	3.94	6.81	7.16
04/28/2013 08:07	20ppm	WC-3	18.9	1.41	5.50	8.86	7.98
04/28/2013 09:10	20ppm	BC-1	19.7	1.69	4.59	7.14	11.82
04/28/2013 09:10	20ppm	BC-2	19.2	1.50	5.17	7.02	5.57
04/28/2013 09:10	20ppm	BC-3	19.4	1.31	5.92	7.01	5.54
04/28/2013 09:10	20ppm	WC-1	20.4	1.64	4.73	7.10	16.32
04/28/2013 09:10	20ppm	WC-2	19.5	1.82	4.26	7.12	5.85
04/28/2013 09:10	20ppm	WC-3	19.1	1.34	5.79	7.02	10.53
04/28/2013 10:07	20ppm	BC-1	20.2	1.74	4.46	7.17	13.25
04/28/2013 10:07	20ppm	BC-2	19.1	1.51	5.14	7.05	6.94
04/28/2013 10:07	20ppm	BC-3	19.3	1.40	5.54	6.99	6.33
04/28/2013 10:07	20ppm	WC-1	20.6	1.54	5.04	7.04	14.91
04/28/2013 10:07	20ppm	WC-2	19.6	1.96	3.96	7.09	8.79
04/28/2013 10:07	20ppm	WC-3	19.5	1.50	5.17	6.97	7.83
04/28/2013 11:08	20ppm	BC-1	20.3	1.72	4.51	7.23	14.36
04/28/2013 11:08	20ppm	BC-2	19.5	1.51	5.14	7.04	8.16
04/28/2013 11:08	20ppm	BC-3	19.8	1.40	5.54	7.03	7.26
04/28/2013 11:08	20ppm	WC-1	20.6	1.61	4.82	7.13	15.38
04/28/2013 11:08	20ppm	WC-2	19.9	2.00	3.88	7.17	9.64
04/28/2013 11:08	20ppm	WC-3	19.6	1.41	5.50	7.12	8.44
04/28/2013 12:09	20ppm	BC-1	20.2	1.71	4.54	7.27	14.87
04/28/2013 12:09	20ppm	BC-2	19.8	1.52	5.10	7.18	14.87
04/28/2013 12:09	20ppm	BC-3	19.9	1.40	5.54	7.12	7.45
04/28/2013 12:09	20ppm	WC-1	20.7	1.62	4.79	7.17	14.66
04/28/2013 12:09	20ppm	WC-2	20.2	1.94	4.00	7.20	9.13
04/28/2013 12:09	20ppm	WC-3	19.8	1.40	5.54	7.14	8.14
04/28/2013 13:10	20ppm	BC-1	20.1	1.82	4.26	7.27	14.58
04/28/2013 13:10	20ppm	BC-2	19.8	1.60	4.85	7.24	8.24
04/28/2013 13:10	20ppm	BC-3	20.1	1.10	7.05	7.22	6.65
04/28/2013 13:10	20ppm	In-1	19.1			7.74	19.85
04/28/2013 13:10	20ppm	In-2	20.1			7.74	20.34
04/28/2013 13:10	20ppm	In-3	20.0			7.80	20.12
04/28/2013 13:10	20ppm	WC-1	20.9	1.53	5.07	7.12	13.18
04/28/2013 13:10	20ppm	WC-2	20.2	2.00	3.88	7.23	8.44
04/28/2013 13:10	20ppm	WC-3	19.8	1.46	5.31	7.16	8.02
06/30/2013 20:05	6.7pH	In-1	31.8			7.37	11.78
06/30/2013 20:05	6.7pH	In-2	34.2			7.63	11.95
06/30/2013 20:05	6.7pH	In-3	37.1			7.50	11.79
07/01/2013 07:45	6.7pH	In-1	25.8			7.11	11.93

Table A2

Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
07/01/2013 07:45	6.7pH	In-2	26.7			7.50	11.93
07/01/2013 07:45	6.7pH	In-3	28.0			7.51	12.01
07/01/2013 08:27	6.7pH	In-1	26.4			7.76	12.30
07/01/2013 08:27	6.7pH	In-2	27.5			7.78	12.34
07/01/2013 08:27	6.7pH	In-3	27.7			7.77	12.40
07/01/2013 08:28	6.7pH	BC-1	24.1	0.56	13.85	6.65	4.23
07/01/2013 08:28	6.7pH	BC-2	25.0	0.62	12.51	6.82	4.76
07/01/2013 08:28	6.7pH	BC-3	24.9	0.62	12.51	6.72	2.82
07/01/2013 08:28	6.7pH	WC-1	23.9	0.68	11.41	6.51	5.93
07/01/2013 08:28	6.7pH	WC-2	24.6	0.70	11.08	6.61	5.94
07/01/2013 08:28	6.7pH	WC-3	25.2	0.80	9.70	6.70	5.78
07/01/2013 11:18	6.7pH	BC-1	24.1	0.55	14.11	6.36	4.58
07/01/2013 11:18	6.7pH	BC-2	24.3	0.59	13.15	6.60	4.11
07/01/2013 11:18	6.7pH	BC-3	24.3	0.58	13.38	6.51	2.26
07/01/2013 11:18	6.7pH	WC-1	23.5	0.70	11.08	6.25	6.89
07/01/2013 11:18	6.7pH	WC-2	24.3	0.67	11.58	6.31	5.77
07/01/2013 11:18	6.7pH	WC-3	24.7	0.83	9.35	6.43	6.42
07/01/2013 12:16	6.7pH	BC-1	23.9	0.64	12.12	6.36	4.94
07/01/2013 12:16	6.7pH	BC-2	24.3	0.56	13.85	6.70	3.99
07/01/2013 12:16	6.7pH	BC-3	24.3	0.56	13.85	6.61	2.16
07/01/2013 12:16	6.7pH	WC-1	23.5	0.66	11.76	6.45	7.05
07/01/2013 12:16	6.7pH	WC-2	24.1	0.64	12.12	6.42	6.01
07/01/2013 12:16	6.7pH	WC-3	24.5	0.72	10.78	6.57	6.17
07/01/2013 13:18	6.7pH	BC-1	23.3	0.58	13.30	6.65	4.92
07/01/2013 13:18	6.7pH	BC-2	24.1	0.62	12.51	6.80	3.89
07/01/2013 13:18	6.7pH	BC-3	24.1	0.60	12.93	6.68	2.02
07/01/2013 13:18	6.7pH	WC-1	23.5	0.76	10.21	6.55	6.94
07/01/2013 13:18	6.7pH	WC-2	24.1	0.70	11.08	6.57	6.04
07/01/2013 13:18	6.7pH	WC-3	24.5	0.80	9.70	6.73	6.35
07/01/2013 14:18	6.7pH	BC-1	22.9	0.58	13.30	6.44	4.53
07/01/2013 14:18	6.7pH	BC-2	24.1	0.58	13.38	6.78	3.61
07/01/2013 14:18	6.7pH	BC-3	23.3	0.60	12.93	6.68	1.91
07/01/2013 14:18	6.7pH	WC-1	23.5	0.66	11.76	6.56	6.90
07/01/2013 14:18	6.7pH	WC-2	23.9	0.68	11.41	6.55	5.87
07/01/2013 14:18	6.7pH	WC-3	24.3	0.80	9.70	6.71	6.27
07/01/2013 14:20	6.7pH	In-1	24.9			7.63	12.32
07/01/2013 14:20	6.7pH	In-2	25.3			7.76	12.26
07/01/2013 14:20	6.7pH	In-3	25.9			7.75	12.52
07/01/2013 20:00	7.0pH	In-1	34.7			7.51	13.43
07/01/2013 20:00	7.0pH	In-2	26.6			7.61	13.42
07/01/2013 20:00	7.0pH	In-3	28.4			7.60	13.43
07/02/2013 07:50	7.0pH	In-1	24.5			7.51	13.26
07/02/2013 07:50	7.0pH	In-2	23.9			7.49	13.16
07/02/2013 07:50	7.0pH	In-3	23.6			7.36	13.27
07/02/2013 08:05	7.0pH	BC-1	24.1	0.96	8.08	6.84	4.66
07/02/2013 08:05	7.0pH	BC-2	23.9	1.20	6.47	6.92	5.54
07/02/2013 08:05	7.0pH	BC-3	23.7	1.22	6.36	6.91	5.73
07/02/2013 08:05	7.0pH	WC-1	24.3	1.26	6.16	6.96	7.01
07/02/2013 08:05	7.0pH	WC-2	24.1	1.32	5.88	6.85	5.18
07/02/2013 08:05	7.0pH	WC-3	24.1	1.52	5.10	6.94	7.73
07/02/2013 08:10	7.0pH	In-1	25.5			7.32	13.28
07/02/2013 08:10	7.0pH	In-2	25.1			7.50	13.07
07/02/2013 08:10	7.0pH	In-3	25.0			7.56	13.41
07/02/2013 11:00	7.0pH	BC-1	24.0	0.96	8.08	6.89	5.95
07/02/2013 11:00	7.0pH	BC-2	23.9	1.28	6.06	7.01	8.30
07/02/2013 11:00	7.0pH	BC-3	23.6	1.30	5.97	7.01	8.13

Table A2

Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
07/02/2013 11:00	7.0pH	WC-1	24.2	1.18	6.58	6.83	8.56
07/02/2013 11:00	7.0pH	WC-2	24.0	1.38	5.62	6.88	8.41
07/02/2013 11:00	7.0pH	WC-3	24.2	1.56	4.97	6.97	9.94
07/02/2013 12:00	7.0pH	BC-1	24.0	1.29	6.01	6.73	7.03
07/02/2013 12:00	7.0pH	BC-2	24.1	1.48	5.24	6.81	8.83
07/02/2013 12:00	7.0pH	BC-3	23.9	1.26	6.16	6.79	8.54
07/02/2013 12:00	7.0pH	WC-1	24.3	1.20	6.47	6.64	8.93
07/02/2013 12:00	7.0pH	WC-2	24.1	1.37	5.66	6.73	8.97
07/02/2013 12:00	7.0pH	WC-3	24.3	1.64	4.73	6.78	10.34
07/02/2013 13:00	7.0pH	BC-1	23.9	1.12	6.93	6.89	7.62
07/02/2013 13:00	7.0pH	BC-2	23.9	1.26	6.16	7.09	9.47
07/02/2013 13:00	7.0pH	BC-3	23.9	1.00	7.76	7.03	9.27
07/02/2013 13:00	7.0pH	WC-1	24.3	1.36	5.70	6.83	9.11
07/02/2013 13:00	7.0pH	WC-2	24.1	1.38	5.62	6.95	9.39
07/02/2013 13:00	7.0pH	WC-3	24.3	1.58	4.91	7.06	10.69
07/02/2013 14:00	7.0pH	BC-1	24.0	1.18	6.58	7.04	7.99
07/02/2013 14:00	7.0pH	BC-2	24.5	1.28	6.06	7.17	9.43
07/02/2013 14:00	7.0pH	BC-3		1.20	6.49	7.02	9.22
07/02/2013 14:00	7.0pH	In-1	24.3			7.61	13.40
07/02/2013 14:00	7.0pH	In-2	23.5			7.68	13.06
07/02/2013 14:00	7.0pH	In-3	23.7			7.79	13.79
07/02/2013 14:00	7.0pH	WC-1	24.2	1.36	5.70	7.19	8.95
07/02/2013 14:00	7.0pH	WC-2	24.2	1.34	5.79	7.11	8.91
07/02/2013 14:00	7.0pH	WC-3	24.3	1.46	5.31	7.15	10.79
07/09/2013 09:25	02hRT	In-1	23.7			7.52	11.27
07/09/2013 09:25	02hRT	In-2	23.0			7.46	11.34
07/09/2013 09:25	02hRT	In-3	22.7			7.54	11.19
07/09/2013 14:25	02hRT	BC-1	23.8	3.60	2.16	6.86	8.72
07/09/2013 14:25	02hRT	BC-2	23.1	3.80	2.04	6.89	9.14
07/09/2013 14:25	02hRT	BC-3	23.2	3.60	2.16	6.87	8.69
07/09/2013 14:25	02hRT	WC-1	23.6	4.10	1.89	6.79	9.11
07/09/2013 14:25	02hRT	WC-2	23.0	4.00	1.94	6.96	9.41
07/09/2013 14:25	02hRT	WC-3	23.1	3.40	2.28	6.90	9.04
07/09/2013 14:55	02hRT	BC-1	23.7	3.35	2.32	6.73	8.84
07/09/2013 14:55	02hRT	BC-2	23.1	3.80	2.04	6.87	9.44
07/09/2013 14:55	02hRT	BC-3	23.2	3.30	2.35	6.85	8.84
07/09/2013 14:55	02hRT	WC-1	23.6	4.00	1.94	6.77	9.22
07/09/2013 14:55	02hRT	WC-2	23.0	3.75	2.07	6.88	9.47
07/09/2013 14:55	02hRT	WC-3	23.1	3.30	2.35	6.87	9.47
07/09/2013 15:25	02hRT	BC-1	23.8	3.30	2.35	7.05	9.10
07/09/2013 15:25	02hRT	BC-2	23.1	3.80	2.04	7.03	9.15
07/09/2013 15:25	02hRT	BC-3	23.2	3.35	2.32	6.99	8.91
07/09/2013 15:25	02hRT	WC-1	23.5	3.80	2.04	6.91	9.17
07/09/2013 15:25	02hRT	WC-2	22.8	3.85	2.02	6.99	9.62
07/09/2013 15:25	02hRT	WC-3	23.1	3.80	2.04	6.96	9.59
07/09/2013 15:30	02hRT	In-1	23.5			7.22	10.54
07/09/2013 15:30	02hRT	In-2	22.8			7.47	11.51
07/09/2013 15:30	02hRT	In-3	22.9			7.52	11.47
07/12/2013 23:31	04hRT	In-1	23.3			7.50	11.04
07/12/2013 23:31	04hRT	In-2	24.1			7.21	10.86
07/12/2013 23:31	04hRT	In-3	25.2			7.52	10.64
07/13/2013 09:30	04hRT	BC-1	23.1	1.94	4.00	6.77	7.55
07/13/2013 09:30	04hRT	BC-2	23.1	1.98	3.92	6.89	7.65
07/13/2013 09:30	04hRT	BC-3	23.7	1.74	4.46	6.93	6.88
07/13/2013 09:30	04hRT	WC-1	23.1	1.62	4.79	6.94	8.06
07/13/2013 09:30	04hRT	WC-2	23.1	1.54	5.04	6.96	8.16

Table A2 Sample Date Time	Run	Site	Temp (°C)	Flow (mL s^{-1})	Res Time (hr)	pH	NOx-N (mg L^{-1})
07/13/2013 09:30	04hRT	WC-3	23.5	1.50	5.17	6.96	7.69
07/13/2013 10:25	04hRT	BC-1	23.1	2.08	3.73	7.10	7.54
07/13/2013 10:25	04hRT	BC-2	23.1	1.84	4.22	7.16	7.99
07/13/2013 10:25	04hRT	BC-3	23.7	1.82	4.26	7.14	7.41
07/13/2013 10:25	04hRT	WC-1	23.2	1.66	4.67	7.17	8.10
07/13/2013 10:25	04hRT	WC-2	23.1	1.68	4.62	7.18	8.30
07/13/2013 10:25	04hRT	WC-3	23.5	1.58	4.91	7.18	7.57
07/13/2013 11:30	04hRT	BC-1	23.1	2.02	3.84	7.20	7.31
07/13/2013 11:30	04hRT	BC-2	23.1	1.85	4.19	7.19	7.99
07/13/2013 11:30	04hRT	BC-3	23.6	1.86	4.17	7.15	7.62
07/13/2013 11:30	04hRT	In-1	23.1			7.65	10.65
07/13/2013 11:30	04hRT	In-2	23.6			7.65	10.62
07/13/2013 11:30	04hRT	In-3	23.1			7.64	10.57
07/13/2013 11:30	04hRT	WC-1	23.1	1.75	4.43	7.11	8.27
07/13/2013 11:30	04hRT	WC-2	23.1	1.62	4.79	7.21	8.30
07/13/2013 11:30	04hRT	WC-3	23.5	1.73	4.48	7.14	7.90
07/10/2013 16:30	06hRT	In-1	27.0			7.59	11.32
07/10/2013 16:30	06hRT	In-2	24.9			7.70	10.99
07/10/2013 16:30	06hRT	In-3	24.3			7.72	11.09
07/11/2013 07:27	06hRT	BC-1	23.9	1.36	5.70	6.65	5.86
07/11/2013 07:27	06hRT	BC-2	23.3	1.28	6.06	6.73	7.68
07/11/2013 07:27	06hRT	BC-3	23.1	1.24	6.26	6.78	6.45
07/11/2013 07:27	06hRT	WC-1	23.7	1.14	6.81	6.70	6.87
07/11/2013 07:27	06hRT	WC-2	23.1	1.12	6.93	6.85	7.31
07/11/2013 07:27	06hRT	WC-3	23.1	1.10	7.05	6.84	7.72
07/11/2013 08:55	06hRT	BC-1	23.7	1.38	5.62	6.72	6.08
07/11/2013 08:55	06hRT	BC-2	23.1	1.18	6.58	6.87	7.65
07/11/2013 08:55	06hRT	BC-3	23.1	1.18	6.58	6.91	6.96
07/11/2013 08:55	06hRT	WC-1	23.6	1.12	6.93	6.84	7.03
07/11/2013 08:55	06hRT	WC-2	23.1	1.07	7.25	6.98	7.70
07/11/2013 08:55	06hRT	WC-3	22.9	1.06	7.32	7.01	7.99
07/11/2013 10:25	06hRT	BC-1	23.7	0.96	8.08	6.83	6.38
07/11/2013 10:25	06hRT	BC-2	23.1	1.78	4.36	7.00	7.94
07/11/2013 10:25	06hRT	BC-3	23.1	1.32	5.88	6.98	7.32
07/11/2013 10:25	06hRT	In-1	23.3			7.34	11.34
07/11/2013 10:25	06hRT	In-2	22.5			7.40	11.02
07/11/2013 10:25	06hRT	In-3	22.6			7.45	11.10
07/11/2013 10:25	06hRT	WC-1	23.6	1.30	5.97	6.82	7.44
07/11/2013 10:25	06hRT	WC-2	23.1	1.12	6.93	6.93	7.99
07/11/2013 10:25	06hRT	WC-3	22.9	1.08	7.18	6.89	8.12
07/09/2013 16:05	08hRT	In-1	24.0			7.05	11.23
07/09/2013 16:05	08hRT	In-2	24.6			7.20	11.11
07/09/2013 16:05	08hRT	In-3	25.9			7.22	11.18
07/10/2013 11:55	08hRT	BC-1	22.8	1.06	7.32	6.92	6.17
07/10/2013 11:55	08hRT	BC-2	22.9	0.86	9.02	6.99	7.14
07/10/2013 11:55	08hRT	BC-3	23.2	0.90	8.62	6.97	3.09
07/10/2013 11:55	08hRT	WC-1	22.9	0.88	8.82	6.99	6.66
07/10/2013 11:55	08hRT	WC-2	22.9	1.00	7.76	7.04	5.88
07/10/2013 11:55	08hRT	WC-3	23.1	0.84	9.24	6.96	5.32
07/10/2013 13:55	08hRT	BC-1	23.0	1.00	7.76	6.91	5.36
07/10/2013 13:55	08hRT	BC-2	23.0	0.78	9.95	6.99	7.25
07/10/2013 13:55	08hRT	BC-3	23.2	0.90	8.62	6.98	3.82
07/10/2013 13:55	08hRT	WC-1	22.8	0.88	8.82	6.97	6.67
07/10/2013 13:55	08hRT	WC-2	22.8	0.92	8.43	7.07	5.77
07/10/2013 13:55	08hRT	WC-3	23.2	0.82	9.46	7.01	5.37
07/10/2013 15:55	08hRT	BC-1	22.9	1.04	7.46	7.10	4.57

Table A2 **Sample Date Time**	**Run**	**Site**	**Temp (°C)**	**Flow (mL s^{-1})**	**Res Time (hr)**	**pH**	**NOx-N (mg L^{-1})**
07/10/2013 15:55	08hRT	BC-2	22.9	0.88	8.82	7.06	7.15
07/10/2013 15:55	08hRT	BC-3	23.2	0.90	8.62	7.04	4.21
07/10/2013 15:55	08hRT	In-1	23.1			7.31	11.21
07/10/2013 15:55	08hRT	In-2	22.2			7.55	11.25
07/10/2013 15:55	08hRT	In-3	22.6			7.62	11.16
07/10/2013 15:55	08hRT	WC-1	22.9	0.86	9.02	7.01	6.40
07/10/2013 15:55	08hRT	WC-2	22.8	0.85	9.13	7.10	5.31
07/10/2013 15:55	08hRT	WC-3	23.2	0.84	9.24	6.96	5.47
07/11/2013 11:00	10hRT	In-1	23.7			7.15	10.93
07/11/2013 11:00	10hRT	In-2	24.8			7.33	11.16
07/11/2013 11:00	10hRT	In-3	25.3			7.24	11.42
07/12/2013 12:00	10hRT	BC-1	23.2	0.86	9.02	6.95	6.05
07/12/2013 12:00	10hRT	BC-2	23.2	0.72	10.78	7.07	7.36
07/12/2013 12:00	10hRT	BC-3	23.4	0.73	10.63	7.04	4.89
07/12/2013 12:00	10hRT	WC-1	23.1	0.80	9.70	7.04	6.29
07/12/2013 12:00	10hRT	WC-2	23.1	0.80	9.70	7.07	5.56
07/12/2013 12:00	10hRT	WC-3	23.2	0.76	10.21	7.10	5.93
07/12/2013 14:30	10hRT	BC-1	23.4	0.80	9.70	6.80	4.49
07/12/2013 14:30	10hRT	BC-2	23.2	0.75	10.34	6.91	5.31
07/12/2013 14:30	10hRT	BC-3	23.4	0.72	10.78	6.97	5.23
07/12/2013 14:30	10hRT	WC-1	23.1	0.78	9.95	6.94	4.92
07/12/2013 14:30	10hRT	WC-2	23.1	0.78	9.95	7.04	4.54
07/12/2013 14:30	10hRT	WC-3	23.3	0.76	10.21	7.09	6.13
07/12/2013 16:55	10hRT	BC-1	23.5	0.78	9.95	7.18	2.44
07/12/2013 16:55	10hRT	BC-2	23.4	0.70	11.08	7.04	6.01
07/12/2013 16:55	10hRT	BC-3	23.5	0.75	10.34	7.08	5.57
07/12/2013 16:55	10hRT	In-1	23.9			7.53	10.63
07/12/2013 16:55	10hRT	In-2	22.5			7.59	11.07
07/12/2013 16:55	10hRT	In-3	22.9			7.57	11.48
07/12/2013 16:55	10hRT	WC-1	23.4	0.94	8.25	7.05	3.92
07/12/2013 16:55	10hRT	WC-2	23.2	0.74	10.48	7.03	2.51
07/12/2013 16:55	10hRT	WC-3	23.4	0.77	10.08	7.07	4.73
07/15/2013 07:35	12hRT	In-1	23.9			7.60	11.20
07/15/2013 07:35	12hRT	In-2	23.4			7.62	9.62
07/15/2013 07:35	12hRT	In-3	23.5			7.31	11.30
07/15/2013 13:40	12hRT	BC-1	23.5	0.72	10.78	6.82	0.29
07/15/2013 13:40	12hRT	BC-2	23.2	0.58	13.38	6.86	0.94
07/15/2013 13:40	12hRT	BC-3	23.5	0.62	12.51	6.87	0.12
07/15/2013 13:40	12hRT	WC-1	23.2	0.60	12.93	6.77	2.98
07/15/2013 13:40	12hRT	WC-2	23.2	0.44	17.63	6.84	0.52
07/15/2013 13:40	12hRT	WC-3	23.2	0.46	16.87	6.71	2.64
07/15/2013 16:40	12hRT	BC-1	23.6	0.68	11.41	7.12	1.99
07/15/2013 16:40	12hRT	BC-2	23.5	0.58	13.38	7.13	2.12
07/15/2013 16:40	12hRT	BC-3	23.6	0.62	12.51	7.18	0.47
07/15/2013 16:40	12hRT	WC-1	23.5	0.45	17.24	7.09	4.52
07/15/2013 16:40	12hRT	WC-2	23.4	0.40	19.40	7.17	1.83
07/15/2013 16:40	12hRT	WC-3	23.4	0.42	18.47	7.09	4.69
07/15/2013 19:35	12hRT	BC-1	23.9	0.38	20.42	7.15	0.09
07/15/2013 19:35	12hRT	BC-2	23.6	0.54	14.37	7.12	0.12
07/15/2013 19:35	12hRT	BC-3	23.8	0.52	14.92	7.15	0.15
07/15/2013 19:35	12hRT	In-1	23.6			7.76	11.23
07/15/2013 19:35	12hRT	In-2	22.8			7.87	9.89
07/15/2013 19:35	12hRT	In-3	22.8			7.84	11.23
07/15/2013 19:35	12hRT	WC-1	23.6	0.38	20.42	6.98	3.35
07/15/2013 19:35	12hRT	WC-2	23.5	0.34	22.82	7.05	0.10
07/15/2013 19:35	12hRT	WC-3	23.5	0.30	25.86	7.07	3.02

Field Complete Dataset

Table A3: Complete set of data collected from field sites during sample period. Site names (first letters of the site field) T, C, and S refer to Tompkins, Chemung, and Steuben, respectively. The sample locations (indicated after the dash in the site field) In, WC, and BC indicate inflow, woodchip reactor, and woodchip with biochar reactor outflow, respectively. Duplicate samples were averaged and statistically treated as a single sample.

Table A3 **Sample Date Time**	**Site**	**Flow** ($L\ s^{-1}$)	**NO_3-N** ($mg\ L^{-1}$)	**NO_2-N** ($mg\ L^{-1}$)	**NOx-N** ($mg\ L^{-1}$)	**DRP** ($mg\ L^{-1}$)	**DOC** ($mg\ L^{-1}$)
03/20/2013 15:00	T-In	0.32	10.81	0.05	10.86	0.04	4.30
03/20/2013 15:00	T-In	0.32	10.83	0.05	10.88	0.07	4.60
03/20/2013 15:00	T-WC	0.13	0.05	0.38	0.43	0.05	12.80
03/20/2013 15:00	T-WC	0.13	0.07	0.36	0.43	0.04	11.20
03/20/2013 15:00	T-BC	0.20	10.05	0.34	10.39	0.03	4.10
03/20/2013 15:00	T-BC	0.20	9.94	0.29	10.23	0.05	5.40
04/16/2013 13:00	T-In	0.46	9.56	0.04	9.60	0.02	2.90
04/16/2013 13:00	T-In	0.46	9.60	0.04	9.64	0.04	6.00
04/16/2013 13:00	T-WC	0.16	8.93	0.34	9.27	0.01	5.80
04/16/2013 13:00	T-WC	0.16	8.95	0.34	9.29	0.01	6.10
04/16/2013 13:00	T-BC	0.30	9.04	0.04	9.08	0.01	5.00
04/16/2013 13:00	T-BC	0.30	9.11	0.04	9.15	0.01	3.70
04/25/2013 10:30	T-In	0.00	10.34	0.06	10.40	0.01	2.60
04/25/2013 10:30	T-In	0.00	10.38	0.04	10.42	0.01	1.20
04/25/2013 10:30	T-WC	0.00	2.77	0.09	2.86	0.01	5.00
04/25/2013 10:30	T-WC	0.00	2.96	0.07	3.03	0.01	5.70
04/25/2013 10:30	T-BC	0.00	3.49	0.38	3.87	0.01	3.20
04/25/2013 10:30	T-BC	0.00	3.37	0.36	3.73	0.01	3.40
05/03/2013 14:00	T-In	0.41	10.31	0.04	10.34	0.01	5.56
05/03/2013 14:00	T-WC	0.16	0.04	0.04	0.07	0.01	115.59
05/03/2013 14:00	T-BC	0.25	4.86	0.31	5.17	0.01	3.34
05/10/2013 12:00	T-In	0.21	10.32	0.13	10.46	0.01	0.67
05/10/2013 12:00	T-WC	0.10	0.10	0.04	0.13	0.01	154.20
05/10/2013 12:00	T-BC	0.11	0.04	0.04	0.07	0.01	15.82
05/13/2013 14:00	T-In	0.06	9.86	0.09	9.95	0.01	7.29
05/13/2013 14:00	T-WC	0.02	0.14	0.04	0.17	0.01	182.31
05/13/2013 14:00	T-BC	0.04	0.04	0.04	0.07	0.01	15.21
05/29/2013 12:30	T-In	0.33	11.16	0.55	11.71	0.01	3.84
05/29/2013 12:30	T-WC	0.18	0.04	0.04	0.07	0.01	309.19
05/29/2013 12:30	T-BC	0.15	0.13	0.04	0.16	0.01	5.92
06/17/2013 12:00	T-In	0.24	11.69	0.04	11.72	0.01	
06/17/2013 12:00	T-In	0.24	11.82	0.04	11.86	0.01	
06/17/2013 12:00	T-WC	0.13	0.04	0.04	0.07	0.01	
06/17/2013 12:00	T-WC	0.13	0.04	0.04	0.07	0.01	
06/17/2013 12:00	T-BC	0.12	0.04	0.04	0.07	0.01	
06/17/2013 12:00	T-BC	0.12	0.04	0.04	0.07	0.01	
06/27/2013 13:25	T-In	0.63	1.33	0.08	1.41	0.01	
06/27/2013 13:25	T-In	0.63	1.04	0.08	1.12	0.01	
06/27/2013 13:25	T-WC	0.39	0.04	0.04	0.07	0.01	
06/27/2013 13:25	T-WC	0.39	0.04	0.04	0.07	0.01	
06/27/2013 13:25	T-BC	0.24	0.04	0.04	0.07	0.01	
06/27/2013 13:25	T-BC	0.24	0.04	0.04	0.07	0.01	
07/02/2013 15:30	T-In	0.14	10.79	0.04	10.82	0.01	
07/02/2013 15:30	T-WC	0.08	9.61	0.04	9.64	0.01	
07/02/2013 15:30	T-BC	0.05	4.11	0.38	4.48	0.01	

Table A3 Sample Date Time	Site	Flow (L s^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NOx-N (mg L^{-1})	DRP (mg L^{-1})	DOC (mg L^{-1})
07/10/2013 12:50	T-In	0.17	12.05	0.06	12.12	0.01	
07/10/2013 12:50	T-WC	0.09	3.21	0.10	3.31	0.01	
07/10/2013 12:50	T-BC	0.08	0.04	0.04	0.07	0.01	
07/15/2013 13:00	T-In	0.05	12.19	0.13	12.33	0.01	
07/15/2013 13:00	T-WC	0.03	0.05	0.04	0.09	0.01	
07/15/2013 13:00	T-BC	0.02	0.21	0.04	0.25	0.01	
07/15/2013 15:45	T-In	0.05	11.94	0.50	12.44	0.07	3.80
07/15/2013 15:45	T-In	0.05	11.91	0.52	12.43	0.01	3.90
07/15/2013 15:45	T-In	0.05	12.13	0.35	12.48	0.01	0.80
07/15/2013 15:45	T-WC	0.03	0.05	0.24	0.30	0.01	9.80
07/15/2013 15:45	T-WC	0.03	0.08	0.28	0.36	0.03	11.20
07/15/2013 15:45	T-WC	0.03	0.04	0.04	0.07	0.01	0.20
07/15/2013 15:45	T-BC	0.02	0.04	0.38	0.41	0.11	12.90
07/15/2013 15:45	T-BC	0.02	0.04	0.43	0.47	0.07	14.10
07/15/2013 15:45	T-BC	0.02	0.04	0.42	0.45	0.07	0.90
07/25/2013 14:20	T-In	0.32	10.75	0.23	10.97	0.01	2.10
07/25/2013 14:20	T-In	0.32	10.82	0.04	10.85	0.01	2.30
07/25/2013 14:20	T-WC	0.20	7.87	0.24	8.11	0.01	4.80
07/25/2013 14:20	T-WC	0.20	7.93	0.20	8.13	0.03	2.80
07/25/2013 14:20	T-BC	0.13	1.49	0.22	1.71	0.01	4.30
07/25/2013 14:20	T-BC	0.13	1.44	0.23	1.67	0.01	4.10
08/08/2013 16:30	T-In	0.03	11.64	0.07	11.70	0.17	0.80
08/08/2013 16:30	T-In	0.03	11.61	0.07	11.67	0.10	0.96
08/08/2013 16:30	T-WC	0.02	0.04	0.10	0.14	0.08	3.20
08/08/2013 16:30	T-WC	0.02	0.04	0.04	0.07	0.04	3.02
08/08/2013 16:30	T-BC	0.01	0.04	0.04	0.07	0.04	6.81
08/08/2013 16:30	T-BC	0.01	0.04	0.04	0.07	0.05	7.33
08/13/2013 09:50	T-In	0.85	9.82	0.04	9.85	0.08	1.13
08/13/2013 09:50	T-In	0.85	9.92	0.04	9.96	0.09	1.03
08/13/2013 09:50	T-WC	0.58	9.55	0.07	9.61	0.09	1.64
08/13/2013 09:50	T-WC	0.58	9.53	0.06	9.59	0.10	1.49
08/13/2013 09:50	T-BC	0.27	7.15	0.04	7.19	0.10	1.55
08/13/2013 09:50	T-BC	0.27	7.15	0.04	7.18	0.06	1.63
08/23/2013 15:05	T-In	0.80	3.19	0.13	3.31	0.03	1.60
08/23/2013 15:05	T-In	0.80	3.01	0.21	3.22	0.02	1.50
08/23/2013 15:05	T-WC	0.56	2.63	0.16	2.79	0.03	1.80
08/23/2013 15:05	T-WC	0.56	2.66	0.22	2.88	0.02	1.80
08/23/2013 15:20	T-BC	0.24	0.44	0.21	0.64	0.10	1.90
08/23/2013 15:20	T-BC	0.24	0.43	0.20	0.63	0.11	2.00
08/29/2013 14:00	T-In	0.38	9.73	0.04	9.77	0.06	0.50
08/29/2013 14:00	T-In	0.38	9.90	0.04	9.93	0.02	0.50
08/29/2013 14:00	T-WC	0.27	8.96	0.20	9.16	0.02	0.60
08/29/2013 14:00	T-WC	0.27	8.95	0.15	9.10	0.01	0.50
08/29/2013 14:00	T-BC	0.12	3.58	0.11	3.68	0.02	0.70
08/29/2013 14:00	T-BC	0.12	3.47	0.27	3.74	0.02	1.00
09/11/2013 14:00	T-In	0.18	10.19	0.04	10.22	0.11	3.61
09/11/2013 14:00	T-In	0.18	10.31	0.04	10.34	0.03	2.93
09/11/2013 14:00	T-WC	0.12	7.79	0.21	8.00	0.02	4.70
09/11/2013 14:00	T-WC	0.12	7.80	0.21	8.01	0.01	5.04
09/11/2013 14:00	T-BC	0.06	1.05	0.21	1.26	0.05	6.58
09/11/2013 14:00	T-BC	0.06	0.99	0.23	1.23	0.02	5.28
10/09/2013 13:15	T-In	0.18	10.55	0.04	10.59	0.01	4.43
10/09/2013 13:15	T-In	0.18	10.37	0.04	10.40	0.01	3.31
10/09/2013 13:15	T-WC	0.10	8.27	0.23	8.50	0.01	4.16
10/09/2013 13:15	T-WC	0.10	8.31	0.13	8.44	0.01	4.77
10/09/2013 13:15	T-BC	0.08	4.88	0.24	5.13	0.01	5.49

Table A3

Sample Date Time	Site	Flow (L s^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NOx-N (mg L^{-1})	DRP (mg L^{-1})	DOC (mg L^{-1})
10/09/2013 13:15	T-BC	0.08	4.92	0.24	5.17	0.03	4.97
11/06/2013 14:15	T-In	0.06	10.69	0.04	10.73	0.02	3.52
11/06/2013 14:15	T-In	0.06	10.73	0.04	10.77	0.02	3.41
11/06/2013 14:15	T-WC	0.03	7.13	0.21	7.34	0.01	4.88
11/06/2013 14:15	T-WC	0.03	7.11	0.21	7.32	0.01	5.27
11/06/2013 14:15	T-BC	0.04	1.39	0.19	1.58	0.01	6.07
11/06/2013 14:15	T-BC	0.04	1.34	0.19	1.53	0.03	6.20
11/20/2013 14:15	T-In	0.06	10.79	0.04	10.83	0.09	0.59
11/20/2013 14:15	T-In	0.06	10.79	0.04	10.83	0.06	0.45
11/20/2013 14:15	T-WC	0.02	7.46	0.12	7.57	0.12	1.21
11/20/2013 14:15	T-WC	0.02	7.64	0.25	7.89	0.12	0.51
11/20/2013 14:15	T-BC	0.04	1.43	0.26	1.69	0.09	1.44
11/20/2013 14:15	T-BC	0.04	1.41	0.11	1.52	0.06	1.22
12/05/2013 14:30	T-In	0.46	9.85	0.04	9.88	0.06	3.18
12/05/2013 14:30	T-In	0.46	9.74	0.04	9.77	0.13	3.30
12/05/2013 14:30	T-WC	0.30	9.54	0.23	9.77	0.12	3.35
12/05/2013 14:30	T-WC	0.30	9.49	0.24	9.72	0.10	3.67
12/05/2013 14:30	T-BC	0.16	9.29	0.24	9.53	0.05	3.36
12/05/2013 14:30	T-BC	0.16	9.32	0.25	9.57	0.03	3.76
01/15/2014 14:30	T-In	0.93	8.71	0.04	8.75	0.03	3.49
01/15/2014 14:30	T-In	0.93	8.68	0.04	8.72	0.04	3.49
01/15/2014 14:30	T-WC	0.66	8.64	0.04	8.68	0.04	3.57
01/15/2014 14:30	T-WC	0.66	8.63	0.04	8.67	0.02	4.17
01/15/2014 14:30	T-BC	0.27	8.33	0.26	8.58	0.15	3.61
01/15/2014 14:30	T-BC	0.27	8.36	0.24	8.61	0.15	4.02
04/24/2014 14:30	T-In	0.46	8.37	0.04	8.41	0.14	3.99
04/24/2014 14:30	T-In	0.46	8.30	0.04	8.34	0.14	3.40
04/24/2014 14:30	T-WC	0.30	8.46	0.18	8.64	0.13	4.18
04/24/2014 14:30	T-WC	0.30	8.53	0.18	8.71	0.15	3.50
04/24/2014 14:30	T-BC	0.16	7.96	0.17	8.14	0.10	4.00
04/24/2014 14:30	T-BC	0.16	7.91	0.17	8.08	0.17	3.45
05/01/2014 14:30	T-In	0.41	8.64	0.04	8.67	0.12	3.45
05/01/2014 14:30	T-In	0.41	8.66	0.04	8.70	0.08	4.09
05/01/2014 14:30	T-WC	0.25	8.10	0.11	8.22	0.06	4.23
05/01/2014 14:30	T-WC	0.25	8.08	0.18	8.27	0.10	4.28
05/01/2014 14:30	T-BC	0.16	8.04	0.21	8.25	0.10	3.82
05/01/2014 14:30	T-BC	0.16	8.08	0.20	8.28	0.08	3.99
05/14/2014 13:30	T-In	0.21	9.86	0.04	9.90	0.11	4.38
05/14/2014 13:30	T-In	0.21	9.75	0.04	9.79	0.15	3.83
05/14/2014 13:30	T-WC	0.10	8.65	0.20	8.85	0.22	4.31
05/14/2014 13:30	T-WC	0.10	8.65	0.20	8.86	0.15	4.70
05/14/2014 13:30	T-BC	0.11	7.64	0.23	7.86	0.12	4.45
05/14/2014 13:30	T-BC	0.11	7.60	0.22	7.82	0.04	3.47
06/04/2014 13:40	T-In	0.06	10.41	0.04	10.45	0.09	3.87
06/04/2014 13:40	T-In	0.06	10.44	0.04	10.48	0.01	3.94
06/04/2014 13:40	T-WC	0.02	5.92	0.20	6.12	0.11	5.41
06/04/2014 13:40	T-WC	0.02	5.87	0.22	6.08	0.13	4.79
06/04/2014 13:40	T-BC	0.04	5.35	0.18	5.53	0.01	4.04
06/04/2014 13:40	T-BC	0.04	5.42	0.17	5.59	0.10	3.71
06/09/2014 14:50	T-In	0.33	10.21	0.04	10.24	0.01	5.34
06/09/2014 14:50	T-In	0.33	10.03	0.04	10.06	0.01	5.85
06/09/2014 14:50	T-WC	0.18	8.94	0.24	9.18	0.01	6.60
06/09/2014 14:50	T-WC	0.18	8.76	0.22	8.98	0.01	6.54
06/09/2014 14:50	T-BC	0.15	6.61	0.22	6.84	0.01	5.26
06/09/2014 14:50	T-BC	0.15	6.74	0.22	6.96	0.01	7.06
06/10/2014 15:00	T-In	0.24	10.14	0.04	10.18	0.01	

Table A3 Sample Date Time	Site	Flow (L s-1)	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NOx-N (mg L^{-1})	DRP (mg L^{-1})	DOC (mg L^{-1})
06/10/2014 15:00	T-In	0.24	10.14	0.04	10.17	0.01	
06/10/2014 15:00	T-WC	0.13	9.25	0.20	9.45	0.01	
06/10/2014 15:00	T-WC	0.13	8.50	0.24	8.73	0.01	
06/10/2014 15:00	T-BC	0.12	8.12	0.22	8.34	0.01	
06/10/2014 15:00	T-BC	0.12	8.11	0.24	8.35	0.01	
06/18/2014 14:30	T-In	0.63	8.38	0.04	8.42	0.01	7.32
06/18/2014 14:30	T-In	0.63	8.32	0.04	8.36	0.01	6.95
06/18/2014 14:30	T-WC	0.39	8.02	0.23	8.25	0.01	7.88
06/18/2014 14:30	T-WC	0.39	7.99	0.12	8.12	0.01	7.24
06/18/2014 14:30	T-BC	0.24	7.10	0.07	7.16	0.01	8.07
06/18/2014 14:30	T-BC	0.24	7.33	0.27	7.59	0.01	8.02
06/24/2014 14:30	T-In	0.14	10.65	0.04	10.68	0.01	6.93
06/24/2014 14:30	T-In	0.14	10.66	0.04	10.70	0.01	6.84
06/24/2014 14:30	T-WC	0.08	8.27	0.25	8.52	0.01	10.02
06/24/2014 14:30	T-WC	0.08	8.21	0.32	8.54	0.01	6.89
06/24/2014 14:30	T-BC	0.05	6.75	0.31	7.06	0.01	6.88
06/24/2014 14:30	T-BC	0.05	6.72	0.30	7.02	0.01	5.80
06/30/2014 14:10	T-In	0.17	10.81	0.04	10.84	0.01	6.07
06/30/2014 14:10	T-In	0.17	10.88	0.04	10.91	0.01	6.72
06/30/2014 14:10	T-WC	0.09	8.90	0.15	9.05	0.02	6.40
06/30/2014 14:10	T-WC	0.09	8.99	0.27	9.27	0.01	7.58
06/30/2014 14:10	T-BC	0.08	7.27	0.27	7.55	0.01	5.46
06/30/2014 14:10	T-BC	0.08	7.25	0.29	7.54	0.01	7.32
07/15/2013 11:30	C-In	0.00	7.81	0.04	7.84	0.01	1.80
07/15/2013 11:30	C-In	0.00	7.70	0.04	7.74	0.01	2.30
07/15/2013 11:30	C-WC	0.00	0.07	0.04	0.11	0.01	5.20
07/15/2013 11:30	C-WC	0.00	0.41	0.38	0.79	0.02	6.60
07/15/2013 11:30	C-BC	0.00	0.06	0.04	0.09	0.77	57.40
07/15/2013 11:30	C-BC	0.00	0.04	0.40	0.44	0.76	94.00
07/25/2013 09:15	C-In	0.07	14.37	0.08	14.44	0.05	2.40
07/25/2013 09:15	C-In	0.07	14.39	0.32	14.70	0.02	2.60
07/25/2013 09:15	C-WC	0.03	9.10	0.83	9.93	0.02	3.00
07/25/2013 09:15	C-WC	0.03	9.13	0.91	10.04	0.01	2.60
07/25/2013 09:15	C-BC	0.04	1.76	1.40	3.15	0.02	6.70
07/25/2013 09:15	C-BC	0.04	1.72	1.40	3.12	0.09	5.70
08/08/2013 11:30	C-In	0.04	3.84	0.04	3.87	0.18	2.07
08/08/2013 11:30	C-In	0.04	3.88	0.04	3.92	0.13	2.31
08/08/2013 11:30	C-WC	0.03	0.11	0.04	0.14	0.07	3.16
08/08/2013 11:30	C-WC	0.03	0.04	0.04	0.07	0.05	3.51
08/08/2013 11:30	C-BC	0.01	0.08	0.04	0.12	0.11	4.95
08/08/2013 11:30	C-BC	0.01	0.04	0.04	0.07	0.07	4.92
08/13/2013 11:30	C-In	0.15	8.91	0.04	8.95	0.11	1.61
08/13/2013 11:30	C-In	0.15	8.93	0.04	8.96	0.11	1.55
08/13/2013 11:30	C-WC	0.05	5.89	0.32	6.22	0.09	1.82
08/13/2013 11:30	C-WC	0.05	5.91	0.34	6.25	0.07	2.09
08/13/2013 11:30	C-BC	0.07	2.48	0.81	3.29	0.11	2.34
08/13/2013 11:30	C-BC	0.07	2.47	0.79	3.26	0.09	3.76
08/23/2013 12:15	C-In	0.03	8.57	0.04	8.60	0.12	1.10
08/23/2013 12:15	C-In	0.03	8.65	0.26	8.91	0.09	0.80
08/23/2013 12:15	C-WC	0.01	2.37	0.44	2.81	0.05	1.40
08/23/2013 12:15	C-WC	0.01	2.31	0.33	2.65	0.04	1.20
08/23/2013 12:15	C-BC	0.02	0.04	0.32	0.36	0.12	1.60
08/23/2013 12:15	C-BC	0.02	0.35	0.32	0.66	0.07	2.00
08/29/2013 10:00	C-In	0.04	5.29	0.04	5.33	0.03	1.00
08/29/2013 10:00	C-In	0.04	5.36	0.04	5.40	0.03	1.00
08/29/2013 10:00	C-WC	0.01	0.06	0.34	0.40	0.03	1.90

Table A3 **Sample Date Time**	**Site**	**Flow** (L s^{-1})	**NO_3-N** (mg L^{-1})	**NO_2-N** (mg L^{-1})	**NOx-N** (mg L^{-1})	**DRP** (mg L^{-1})	**DOC** (mg L^{-1})
08/29/2013 10:00	C-WC	0.01	0.04	0.36	0.40	0.02	1.70
08/29/2013 10:00	C-BC	0.02	0.04	0.04	0.07	0.02	12.40
08/29/2013 10:00	C-BC	0.02	0.04	0.04	0.07	0.02	11.90
09/11/2013 09:30	C-In	0.02	4.16	0.04	4.20	0.05	4.00
09/11/2013 09:30	C-In	0.02	4.29	0.04	4.32	0.02	4.75
09/11/2013 09:30	C-WC	0.00	0.04	0.04	0.07	0.01	13.15
09/11/2013 09:30	C-WC	0.00	0.04	0.04	0.07	0.01	13.63
09/11/2013 09:30	C-BC	0.01	0.04	0.04	0.07	0.02	20.93
09/11/2013 09:30	C-BC	0.01	0.04	0.04	0.07	0.02	23.05
10/09/2013 10:45	C-In	0.03	3.25	0.04	3.28	0.01	5.61
10/09/2013 10:45	C-In	0.03	3.17	0.04	3.20	0.04	5.21
10/09/2013 10:45	C-WC	0.01	0.05	0.04	0.08	0.01	9.10
10/09/2013 10:45	C-WC	0.01	0.12	0.04	0.15	0.01	9.45
10/09/2013 10:45	C-BC	0.02	0.08	0.04	0.11	0.01	15.63
10/09/2013 10:45	C-BC	0.02	0.08	0.04	0.12	0.01	14.71
11/06/2013 11:30	C-In	0.03	5.87	0.04	5.91	0.01	4.43
11/06/2013 11:30	C-In	0.03	5.86	0.04	5.90	0.05	4.11
11/06/2013 11:30	C-WC	0.01	2.21	0.26	2.47	0.02	4.73
11/06/2013 11:30	C-WC	0.01	2.20	0.27	2.46	0.03	4.50
11/06/2013 11:30	C-BC	0.02	1.02	0.29	1.31	0.01	5.57
11/06/2013 11:30	C-BC	0.02	1.02	0.28	1.30	0.01	5.84
11/20/2013 09:45	C-In	0.03	4.77	0.04	4.80	0.20	1.50
11/20/2013 09:45	C-In	0.03	4.72	0.04	4.76	0.17	0.81
11/20/2013 09:45	C-WC	0.01	3.45	0.44	3.89	0.11	0.91
11/20/2013 09:45	C-WC	0.01	3.46	0.46	3.92	0.13	1.10
11/20/2013 09:45	C-BC	0.02	1.74	0.45	2.19	0.13	1.27
11/20/2013 09:45	C-BC	0.02	1.75	0.47	2.21	0.09	1.01
12/05/2013 10:00	C-In	0.11	13.16	0.04	13.20	0.13	5.56
12/05/2013 10:00	C-In	0.11	13.12	0.04	13.16	0.09	5.65
12/05/2013 10:00	C-WC	0.03	12.20	0.38	12.59	0.07	5.31
12/05/2013 10:00	C-WC	0.03	12.36	0.37	12.73	0.11	5.16
12/05/2013 10:00	C-BC	0.04	5.94	0.45	6.40	0.07	4.56
12/05/2013 10:00	C-BC	0.04	5.87	0.43	6.30	0.09	4.75
01/15/2014 10:15	C-In	0.09	6.57	0.04	6.60	0.08	3.68
01/15/2014 10:15	C-In	0.09	6.61	0.04	6.64	0.07	3.92
01/15/2014 10:15	C-WC	0.01	7.82	0.33	8.15	0.06	3.88
01/15/2014 10:15	C-WC	0.01	7.82	0.32	8.14	0.03	3.73
01/15/2014 10:15	C-BC	0.02	4.68	0.42	5.10	0.04	4.02
01/15/2014 10:15	C-BC	0.02	4.61	0.40	5.01	0.06	4.09
04/24/2014 09:30	C-In	0.05	5.20	0.04	5.23	0.06	3.53
04/24/2014 09:30	C-In	0.05	5.26	0.04	5.29	0.05	3.23
04/24/2014 09:30	C-WC	0.01	4.45	0.17	4.63	0.05	3.55
04/24/2014 09:30	C-WC	0.01	4.49	0.16	4.65	0.03	3.46
04/24/2014 09:30	C-BC	0.02	2.82	0.12	2.94	0.04	3.87
04/24/2014 09:30	C-BC	0.02	2.77	0.24	3.00	0.07	4.34
05/01/2014 10:00	C-In	0.10	5.90	0.18	6.08	0.16	7.03
05/01/2014 10:00	C-In	0.10	5.93	0.19	6.12	0.12	7.47
05/01/2014 10:00	C-WC	0.02	5.78	0.21	5.99	0.09	8.59
05/01/2014 10:00	C-WC	0.02	5.77	0.21	5.99	0.11	8.56
05/01/2014 10:00	C-BC	0.03	2.89	0.26	3.15	0.16	7.69
05/01/2014 10:00	C-BC	0.03	2.83	0.26	3.09	0.11	7.78
05/14/2014 09:30	C-In	0.06	4.28	0.04	4.31	0.05	3.92
05/14/2014 09:30	C-In	0.06	4.22	0.04	4.25	0.03	4.15
05/14/2014 09:30	C-WC	0.01	2.28	0.18	2.46	0.09	4.37
05/14/2014 09:30	C-WC	0.01	2.27	0.19	2.46	0.02	4.27
05/14/2014 09:30	C-BC	0.04	1.67	0.24	1.90	0.12	4.79

Table A3 Sample Date Time	Site	Flow (L s^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NOx-N (mg L^{-1})	DRP (mg L^{-1})	DOC (mg L^{-1})
05/14/2014 09:30	C-BC	0.04	1.64	0.09	1.73	0.12	4.48
06/04/2014 09:40	C-In	0.03	4.96	0.20	5.16	0.05	4.37
06/04/2014 09:40	C-In	0.03	4.96	0.04	4.99	0.04	4.24
06/04/2014 09:40	C-WC	0.00	1.21	0.21	1.42	0.02	5.07
06/04/2014 09:40	C-WC	0.00	1.20	0.21	1.41	0.02	5.53
06/04/2014 09:40	C-BC	0.02	2.23	0.28	2.51	0.01	4.76
06/04/2014 09:40	C-BC	0.02	2.66	0.28	2.94	0.03	5.06
06/10/2014 09:30	C-In	0.16	20.93	0.30	21.22	0.03	7.08
06/10/2014 09:30	C-In	0.16	20.94	0.17	21.11	0.02	7.09
06/10/2014 09:30	C-WC	0.09	21.03	0.35	21.38	0.01	8.47
06/10/2014 09:30	C-WC	0.09	21.21	0.31	21.52	0.01	6.40
06/10/2014 09:30	C-BC	0.07	21.70	0.24	21.94	0.01	7.63
06/10/2014 09:30	C-BC	0.07	21.77	0.34	22.11	0.01	7.75
06/18/2014 09:30	C-In	0.01	10.96	0.04	10.99	0.02	5.13
06/18/2014 09:30	C-In	0.01	10.88	0.04	10.91	0.01	5.45
06/18/2014 09:30	C-WC	0.01	9.84	0.29	10.12	0.04	5.20
06/18/2014 09:30	C-WC	0.01	9.88	0.30	10.19	0.01	6.25
06/18/2014 09:30	C-BC	0.00	9.19	0.27	9.46	0.01	6.49
06/18/2014 09:30	C-BC	0.00	9.09	0.28	9.37	0.01	5.69
06/24/2014 09:30	C-In	0.01	8.61	0.04	8.65	0.04	6.74
06/24/2014 09:30	C-In	0.01	8.57	0.04	8.61	0.01	7.50
06/24/2014 09:30	C-WC	0.00	5.00	0.35	5.35	0.01	7.34
06/24/2014 09:30	C-WC	0.00	5.02	0.36	5.38	0.01	7.65
06/24/2014 09:30	C-BC	0.00	6.36	0.38	6.74	0.01	8.30
06/24/2014 09:30	C-BC	0.00	6.10	0.35	6.45	0.01	6.38
06/30/2014 09:30	C-In	0.05	9.45	0.04	9.48	0.01	4.96
06/30/2014 09:30	C-In	0.05	9.51	0.04	9.55	0.01	5.39
06/30/2014 09:30	C-WC	0.01	6.05	0.34	6.39	0.01	5.18
06/30/2014 09:30	C-WC	0.01	6.02	0.34	6.36	0.01	5.24
06/30/2014 09:30	C-BC	0.04	6.60	0.18	6.78	0.01	7.13
06/30/2014 09:30	C-BC	0.04	6.65	0.39	7.03	0.01	6.66
07/15/2013 13:00	S-IB	0.00	17.08	1.11	18.18	0.01	2.50
07/15/2013 13:00	S-IB	0.00	17.26	0.55	17.82	0.01	2.70
07/15/2013 13:00	S-BC	0.00	1.36	17.25	18.61	0.19	133.00
07/15/2013 13:00	S-BC	0.00	1.23	17.35	18.58	0.21	89.00
07/15/2013 13:00	S-IW	0.00	16.52	0.62	17.13	0.01	5.30
07/15/2013 13:00	S-IW	0.00	16.62	0.57	17.19	0.01	8.10
07/15/2013 13:00	S-WC	0.00	0.53	0.04	0.57	0.56	144.30
07/15/2013 13:00	S-WC	0.00	0.65	0.04	0.68	0.55	128.60
07/25/2013 11:00	S-IB	0.00	15.42	0.20	15.62	0.01	1.60
07/25/2013 11:00	S-IB	0.00	15.44	0.20	15.64	0.01	1.50
07/25/2013 11:00	S-BC	0.00	2.66	0.04	2.70	0.65	134.10
07/25/2013 11:00	S-BC	0.00	2.62	0.04	2.65	0.48	124.10
07/25/2013 11:00	S-IW	0.00	8.03	0.42	8.45	0.05	5.30
07/25/2013 11:00	S-IW	0.00	8.09	0.39	8.48	0.02	3.70
07/25/2013 11:00	S-WC	0.00	0.23	0.04	0.26	1.41	287.00
07/25/2013 11:00	S-WC	0.00	0.08	0.04	0.12	1.36	337.00
08/08/2013 13:30	S-IB	0.00	10.17	0.05	10.22	0.13	1.83
08/08/2013 13:30	S-IB	0.00	9.84	0.06	9.90	0.14	2.24
08/08/2013 13:30	S-BC	0.00	0.09	0.04	0.13	0.95	99.00
08/08/2013 13:30	S-BC	0.00	0.06	0.04	0.09	0.90	104.00
08/08/2013 13:30	S-IW	0.00	1.52	0.04	1.55	0.09	2.90
08/08/2013 13:30	S-IW	0.00	1.46	0.04	1.49	0.09	2.70
08/08/2013 13:30	S-WC	0.00	0.04	0.04	0.07	2.24	228.00
08/08/2013 13:30	S-WC	0.00	0.04	0.04	0.07	2.20	257.00
08/13/2013 12:45	S-IB	0.07	5.38	0.04	5.41	0.10	2.98

Table A3

Sample Date Time	Site	Flow (L s^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NOx-N (mg L^{-1})	DRP (mg L^{-1})	DOC (mg L^{-1})
08/13/2013 12:45	S-IB	0.07	5.40	0.04	5.43	0.12	2.07
08/13/2013 12:45	S-BC	0.07	3.29	0.12	3.41	0.14	2.91
08/13/2013 12:45	S-BC	0.07	3.26	0.09	3.35	0.10	3.28
08/13/2013 12:45	S-IW	0.06	3.97	0.04	4.01	0.20	2.59
08/13/2013 12:45	S-IW	0.06	4.03	0.04	4.07	0.16	2.13
08/13/2013 12:45	S-WC	0.03	1.80	0.22	2.01	0.16	4.68
08/13/2013 12:45	S-WC	0.03	1.78	0.20	1.98	0.16	4.30
08/23/2013 10:15	S-IB	0.00	13.55	0.20	13.74	0.15	0.50
08/23/2013 10:15	S-IB	0.00	13.60	0.22	13.82	0.10	0.20
08/23/2013 10:15	S-BC	0.00	0.04	0.04	0.07	0.16	83.10
08/23/2013 10:15	S-BC	0.00	0.04	0.04	0.07	0.17	90.10
08/23/2013 10:15	S-IW	0.00	7.33	0.38	7.71	0.04	0.80
08/23/2013 10:15	S-IW	0.00	7.35	0.35	7.70	0.05	1.40
08/23/2013 10:15	S-WC	0.00	0.04	0.04	0.07	0.17	60.00
08/23/2013 10:15	S-WC	0.00	0.04	0.04	0.07	0.21	50.00
08/29/2013 11:30	S-IB	0.00	13.68	0.26	13.94	0.01	0.20
08/29/2013 11:30	S-IB	0.00	13.72	0.17	13.89	0.02	0.50
08/29/2013 11:30	S-BC	0.00	0.04	0.04	0.07	0.15	128.00
08/29/2013 11:30	S-BC	0.00	0.04	0.04	0.07	0.16	115.60
08/29/2013 11:30	S-IW	0.00	0.04	0.04	0.07	0.03	1.50
08/29/2013 11:30	S-IW	0.00	0.04	0.04	0.07	0.02	1.20
08/29/2013 11:30	S-WC	0.00	0.04	0.04	0.07	0.18	83.80
08/29/2013 11:30	S-WC	0.00	0.04	0.04	0.07	0.19	92.90
09/11/2013 11:00	S-IB	0.00	14.75	0.34	15.09	0.13	1.86
09/11/2013 11:00	S-IB	0.00	14.82	0.24	15.06	0.11	2.22
09/11/2013 11:00	S-BC	0.00	0.06	0.04	0.09	0.21	160.00
09/11/2013 11:00	S-BC	0.00	0.04	0.04	0.07	0.23	173.00
09/11/2013 11:00	S-IW	0.00	0.16	0.04	0.20	0.31	120.43
09/11/2013 11:00	S-IW	0.00	0.16	0.04	0.19	0.29	129.91
09/11/2013 11:00	S-WC	0.00	0.04	0.04	0.07	0.28	238.00
09/11/2013 11:00	S-WC	0.00	0.04	0.04	0.07	0.25	203.00
10/09/2013 09:10	S-IB	0.01	10.68	0.25	10.93	0.04	5.23
10/09/2013 09:10	S-IB	0.01	10.70	0.04	10.73	0.01	6.04
10/09/2013 09:10	S-BC	0.01	7.71	0.61	8.32	0.01	7.55
10/09/2013 09:10	S-BC	0.01	7.70	0.64	8.33	0.01	7.71
10/09/2013 09:10	S-IW	0.01	9.10	0.04	9.14	0.01	7.11
10/09/2013 09:10	S-IW	0.02	9.13	0.04	9.16	0.01	7.43
10/09/2013 09:10	S-WC	0.02	7.85	0.59	8.44	0.01	8.90
10/09/2013 09:10	S-WC	0.01	7.85	0.58	8.43	0.01	9.33
11/06/2013 10:15	S-IB	0.01	9.46	0.04	9.50	0.02	4.72
11/06/2013 10:15	S-IB	0.01	9.53	0.04	9.56	0.02	4.54
11/06/2013 10:15	S-BC	0.01	7.76	0.40	8.15	0.01	5.12
11/06/2013 10:15	S-BC	0.01	7.77	0.37	8.14	0.02	5.01
11/06/2013 10:15	S-IW	0.02	11.95	0.04	11.99	0.01	4.62
11/06/2013 10:15	S-IW	0.02	12.00	0.04	12.03	0.04	4.73
11/06/2013 10:15	S-WC	0.02	11.27	0.17	11.44	0.04	5.38
11/06/2013 10:15	S-WC	0.02	11.25	0.16	11.40	0.04	4.93
11/20/2013 11:15	S-IB	0.02	7.62	0.04	7.65	0.14	0.94
11/20/2013 11:15	S-IB	0.02	7.59	0.04	7.63	0.13	0.90
11/20/2013 11:15	S-BC	0.02	6.48	0.39	6.87	0.10	1.11
11/20/2013 11:15	S-BC	0.02	6.44	0.38	6.82	0.13	4.62
11/20/2013 11:15	S-IW	0.01	11.45	0.31	11.76	0.13	0.85
11/20/2013 11:15	S-IW	0.01	11.46	0.04	11.49	0.18	1.03
11/20/2013 11:15	S-WC	0.01	10.02	0.37	10.40	0.13	1.50
11/20/2013 11:15	S-WC	0.01	10.07	0.38	10.45	0.10	1.02
12/05/2013 11:30	S-IB	2.49	7.27	0.04	7.30	0.18	7.77

Table A3 Sample Date Time	Site	Flow (L s^{-1})	NO_3-N (mg L^{-1})	NO_2-N (mg L^{-1})	NOx-N (mg L^{-1})	DRP (mg L^{-1})	DOC (mg L^{-1})
12/05/2013 11:30	S-IB	2.49	7.22	0.04	7.26	0.12	7.84
12/05/2013 11:30	S-BC	0.41	6.76	0.22	6.98	0.11	7.55
12/05/2013 11:30	S-BC	0.41	6.85	0.25	7.10	0.09	7.78
12/05/2013 11:30	S-IW	2.48	9.20	0.26	9.46	0.19	8.60
12/05/2013 11:30	S-IW	2.48	9.20	0.26	9.45	0.21	8.19
12/05/2013 11:30	S-WC	0.20	9.16	0.20	9.36	0.10	9.93
12/05/2013 11:30	S-WC	0.20	9.13	0.24	9.37	0.10	9.16
01/15/2014 11:45	S-IB	0.05	9.20	0.04	9.24	0.06	3.90
01/15/2014 11:45	S-IB	0.05	9.26	0.04	9.30	0.05	4.11
01/15/2014 11:45	S-BC	0.05	8.40	0.26	8.66	0.06	4.17
01/15/2014 11:45	S-BC	0.05	8.34	0.30	8.64	0.04	4.14
01/15/2014 11:45	S-IW	0.02	9.76	0.04	9.79	0.07	4.05
01/15/2014 11:45	S-IW	0.02	9.83	0.04	9.86	0.05	4.16
01/15/2014 11:45	S-WC	0.02	8.50	0.26	8.76	0.05	4.51
01/15/2014 11:45	S-WC	0.02	8.47	0.28	8.75	0.04	4.51
04/24/2014 11:15	S-IB	0.01	7.84	0.21	8.05	0.18	5.97
04/24/2014 11:15	S-IB	0.01	7.86	0.20	8.06	0.19	5.45
04/24/2014 11:15	S-BC	0.01	1.69	0.24	1.92	0.18	6.18
04/24/2014 11:15	S-BC	0.01	1.69	0.27	1.96	0.26	6.97
04/24/2014 11:15	S-IW	0.01	7.79	0.28	8.08	0.29	9.23
04/24/2014 11:15	S-IW	0.01	7.80	0.27	8.07	0.28	8.96
04/24/2014 11:15	S-WC	0.00	0.08	0.15	0.23	0.30	10.65
04/24/2014 11:15	S-WC	0.00	0.07	0.14	0.21	0.29	10.83
05/01/2014 11:45	S-IB	0.49	20.39	0.19	20.58	0.18	8.49
05/01/2014 11:45	S-IB	0.49	20.46	0.21	20.67	0.12	8.67
05/01/2014 11:45	S-BC	0.04	19.57	0.23	19.80	0.22	9.53
05/01/2014 11:45	S-BC	0.04	19.72	0.21	19.93	0.12	9.44
05/01/2014 11:45	S-IW	0.41	26.65	0.29	26.93	0.15	11.46
05/01/2014 11:45	S-IW	0.41	26.67	0.28	26.95	0.23	11.09
05/01/2014 11:45	S-WC	0.01	13.76	0.54	14.31	0.19	14.50
05/01/2014 11:45	S-WC	0.01	14.07	0.55	14.62	0.20	14.14
05/14/2014 10:45	S-IB	0.04	32.55	0.23	32.78	0.14	7.45
05/14/2014 10:45	S-IB	0.04	32.71	0.22	32.94	0.16	8.00
05/14/2014 10:45	S-BC	0.03	21.03	0.28	21.30	0.11	7.58
05/14/2014 10:45	S-BC	0.03	20.97	0.27	21.24	0.13	7.96
05/14/2014 10:45	S-IW	0.03	30.26	0.32	30.58	0.20	6.99
05/14/2014 10:45	S-IW	0.03	30.31	0.32	30.63	0.20	7.72
05/14/2014 10:45	S-WC	0.01	18.82	0.39	19.21	0.21	7.06
05/14/2014 10:45	S-WC	0.01	18.77	0.39	19.15	0.22	8.14
06/04/2014 11:10	S-IB	0.01	16.85	0.15	17.00	0.03	4.17
06/04/2014 11:10	S-IB	0.01	16.84	0.16	17.00	0.03	4.45
06/04/2014 11:10	S-BC	0.01	0.04	0.04	0.07	0.07	27.16
06/04/2014 11:10	S-BC	0.01	0.04	0.04	0.07	0.07	24.48
06/04/2014 11:10	S-IW	0.00	15.29	0.38	15.67	0.14	5.29
06/04/2014 11:10	S-IW	0.00	15.31	0.43	15.73	0.11	4.68
06/04/2014 11:10	S-WC	0.00	0.04	0.04	0.07	0.19	46.37
06/04/2014 11:10	S-WC	0.00	0.04	0.04	0.07	0.19	44.69
06/10/2014 11:30	S-IB	0.06	35.10	0.24	35.34	0.02	7.60
06/10/2014 11:30	S-IB	0.06	35.02	0.23	35.25	0.02	7.28
06/10/2014 11:30	S-BC	0.05	32.37	0.27	32.64	0.01	7.75
06/10/2014 11:30	S-BC	0.05	32.44	0.14	32.58	0.01	9.03
06/10/2014 11:30	S-IW	0.07	44.09	0.32	44.41	0.06	9.49
06/10/2014 11:30	S-IW	0.07	43.85	0.33	44.18	0.05	9.66
06/10/2014 11:30	S-WC	0.05	41.46	0.44	41.91	0.02	9.82
06/10/2014 11:30	S-WC	0.05	41.52	0.45	41.97	0.02	12.29
06/18/2014 11:30	S-IB	0.01	17.46	0.28	17.75	0.04	8.60

Table A3 **Sample Date Time**	**Site**	**Flow** ($L\ s^{-1}$)	**NO_3-N** ($mg\ L^{-1}$)	**NO_2-N** ($mg\ L^{-1}$)	**NOx-N** ($mg\ L^{-1}$)	**DRP** ($mg\ L^{-1}$)	**DOC** ($mg\ L^{-1}$)
06/18/2014 11:30	S-IB	0.01	17.49	0.14	17.63	0.04	8.38
06/18/2014 11:30	S-BC	0.01	2.67	0.28	2.95	0.02	13.34
06/18/2014 11:30	S-BC	0.01	2.60	0.33	2.94	0.02	11.38
06/18/2014 11:30	S-IW	0.00	25.22	0.21	25.43	0.05	6.74
06/18/2014 11:30	S-IW	0.00	25.15	0.05	25.20	0.05	9.15
06/18/2014 11:30	S-WC	0.00	0.66	0.04	0.69	0.04	15.72
06/18/2014 11:30	S-WC	0.00	0.61	0.04	0.65	0.02	13.13
06/24/2014 11:30	S-IB	0.01	19.57	0.06	19.62	0.03	7.66
06/24/2014 11:30	S-IB	0.01	19.64	0.25	19.89	0.03	6.15
06/24/2014 11:30	S-BC	0.01	0.10	0.04	0.13	0.03	34.01
06/24/2014 11:30	S-BC	0.01	0.06	0.04	0.10	0.03	30.81
06/24/2014 11:30	S-IW	0.00	20.96	0.22	21.18	0.10	7.25
06/24/2014 11:30	S-IW	0.00	21.24	0.27	21.51	0.08	6.46
06/24/2014 11:30	S-WC	0.00	0.04	0.04	0.07	0.06	63.84
06/24/2014 11:30	S-WC	0.00	0.04	0.04	0.07	0.06	64.13
06/30/2014 11:15	S-IB	0.01	29.52	0.15	29.67	0.03	5.68
06/30/2014 11:15	S-IB	0.01	29.42	0.25	29.67	0.02	5.10
06/30/2014 11:15	S-BC	0.01	10.10	0.58	10.68	0.01	7.95
06/30/2014 11:15	S-BC	0.01	10.18	0.60	10.78	0.01	8.55
06/30/2014 11:15	S-IW	0.00	42.55	0.04	42.58	0.03	6.78
06/30/2014 11:15	S-IW	0.00	42.66	0.26	42.93	0.03	8.39
06/30/2014 11:15	S-WC	0.00	17.83	0.50	18.33	0.01	8.98
06/30/2014 11:15	S-WC	0.00	17.70	0.51	18.21	0.02	10.10