**CTRF Project Report: January, 2017**

**Project Title:** The impact of golf courses on nutrient loss and overall pollutant export from developed areas

**Principal Investigator**: Dr. Chris Murray, Lakehead University

**Summary:**

This project is aimed at quantifying the effect golf course maintenance has on the quality of runoff and groundwater, especially where nutrients, volume of flow and sediment are concerned. Three seasons of testing were carried out on simulated turfgrass plots. The effects of rainfall, polluted runoff influent on turfgrass and snowmelt were all measured as a function of grass type, fertility regime and seed density. In general, there was no significant effect of fertilizer, grass type or seed density on the concentration of dissolved nutrients measured in runoff or infiltrate during simulated rain events, but levels of pollution in samples decreased with time since seeding, consistent with the assumption that as the grass plants grow their ability to utilize nutrients and restrict the passage of sediment increases. Storm simulations demonstrated that turfgrass is capable of reducing the nutrient and TSS concentrations in resulting groundwater and runoff when influent water is already polluted at levels typical of stormwater.

**Personnel:**

Ms. Amanda Grant will be completing her M.Sc. in Biology this semester and is currently finishing her thesis. Professor Nanda Kanavillil (Associate Professor of Biology, Lakehead University) is, along with Dr. Murray, advising Amanda and tracking her progress, and serves as co-supervisor for Amanda's M.Sc. project.

**Progress since last report:**

Beginning in the summer of 2016, ten new plots were established with Kentucky bluegrass seed at a density of 3 lbs/1000 $ft^2$ and treated with either no fertilizer or a typical (1 lb/1000 $ft^2$/year) level of P-free fertilizer. The aim of this testing was to validate the general trend of decreasing nutrient and sediment concentration with time observed for the 2015 season. A smaller number of experimental parameters were varied and increased number of replicates (three in 2016, versus two in 2015) were used. Because sampling procedures were still being finalized at the beginning of the 2015 season, it was important to confirm that high pollutant concentrations measured then were not artifacts of sampling procedures. Samples gathered throughout the 2016 season confirmed the same overall decrease in phosphate export with time observed for plots in 2015, but demonstrated a clearer reduction in phosphate concentration and less of a trend in sample volume than was indicated by 2015 measurements. Additionally, samples frozen throughout the 2015 and 2016 seasons were sent for analysis to Lakehead University's Thunder Bay campus, yielding values of total nitrogen and total phosphorus to complement existing measurements of nitrate, phosphate and total suspended solids (TSS).

**Rationale, experimental set-up:**

The choice of experimental parameters to vary and the values of those parameters used were based on interviews with golf course superintendents and head greens keepers for five golf courses in the Orillia area. Two grass types were used in the 2015 study: Kentucky bluegrass ("Barrister" brand) and Creeping bentgrass ("Shark" brand), each provided by Quality Seeds Limited. Five different fertilizer treatments were applied to the grass plots in 2015: no fertilizer, "lower than typical" fertilizer: 0.5 lbs N/1000 $ft^2$, "typical" fertilizer: 1 lbs

N/1000 $ft^2$, “higher than typical” fertilizer: 2 lbs N/1000 $ft^2$, and “with phosphorus”: 1 lbs N/1000 $ft^2$ plus 1 lbs P/1000 $ft^2$. Summer applications of fertilizer were made using slow-release polymer-coated urea (XCU 46-0-0) and fall applications consisted of quick-release ammonia sulphate (34-0-0). The “with Phosphorus” treatment included application of monoammonium phosphate (11-52-0). All fertilizers were provided by Alliance Agri-Turf in Orillia. The majority of plots were seeded at a rate of 3 lbs/1000 $ft^2$ but a subset of plots containing Kentucky bluegrass involved two different seed densities in the 2015 growing season: 1 and 5 lbs/1000 $ft^2$. Those plots were treated with a “typical” fertilizer regime. In the 2016 growing season, all plots were seeded with Kentucky bluegrass at a rate of 3 lbs/1000 $ft^2$, and treated with either no fertilizer or the “typical” fertility regime described above.

**Plot design:**


Figure 1: Experimental plots in 2015 (left) and 2016 (right) allowed for both runoff and infiltrate to be collected.

Following refinement of a plot design during the summer of 2014, 26 experimental plots were established in 2015 using plastic containers (Figure 1, left) to hold a combination of drainage gravel, plastic mesh, geotextile landscape fabric and soil, into which grass seed was introduced. Infiltrate was allowed to pass through the layered structure into the bottom of the container, where it ran into another empty container for collection. Any runoff resulting from rain simulations, storm simulations or winter snow melt was collected at the lower end of the plots in a trough that directed runoff into another collection container. All plots were adjusted to have a slope of 5%. Because of problems associated with flexible container walls and increasing fragility with prolonged environmental exposure, waterproofed wooden containers were used for the 10 experimental plots studied in 2016 (Figure 1, right). The slope of plots was maintained at 5%, and runoff and infiltrate was similarly collected.

**Precipitation simulations:**

Figure 2: Rain simulations were performed by flowing water through an array of permeable hose (left) so that it dripped down onto the plots. Storm simulations were carried out by pumping water with a well-defined amount of nutrient and sediment from a barrel onto a sheet that directed it to the uphill end of the plot (right).

Rain events were simulated by holding an array of permeable tubing over each plot in turn and allowing water to drop at a well-defined rate onto the turfgrass (Figure 2, left). Storms were simulated by preparing a large volume of influent water pre-mixed with dissolved nutrient and sediment, and pumping that water over a sheet that spread the flow over the top edge of the turf plots (Figure 2, right). The flow rate varied as a function of time during storm simulations according to design storms as specified by the New Jersey Department of Environmental Protection, a common reference for stormwater management. The flow rate began low, increased to a maximum and then was decreased again before stopping.

**Results:**

**Rain simulations, 2015/2016:**

In 2015, rainfall was simulated during four different intervals for each plot, and measurements generally showed decreasing volumes of groundwater infiltrating through the plot with each sampling interval (Figure 3). While nitrate and phosphate concentrations in infiltrate samples generally decreased over the same season, the correlation with time was not as strong as that of the volume decrease. For the plots treated with P-containing fertilizer (both Kentucky bluegrass and Creeping bentgrass) the phosphate concentration in the groundwater increased following the fall fertilization (Figure 4). Other than this expected increase in phosphate concentration for the samples receiving phosphorus-containing fertilizer, there was no systematic dependence of nitrate concentration, phosphate concentration nor groundwater volume on grass type, seed density or fertilizer treatment.

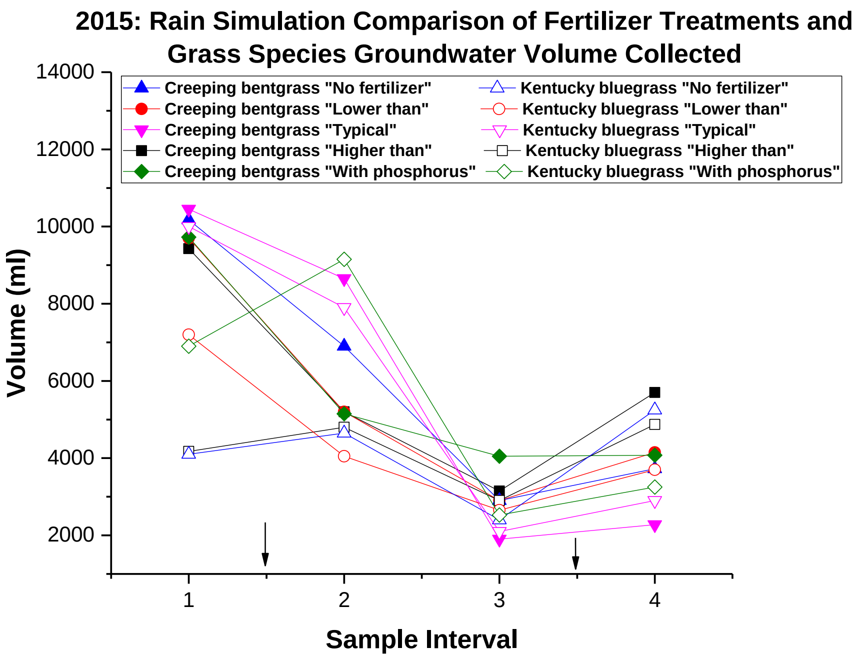
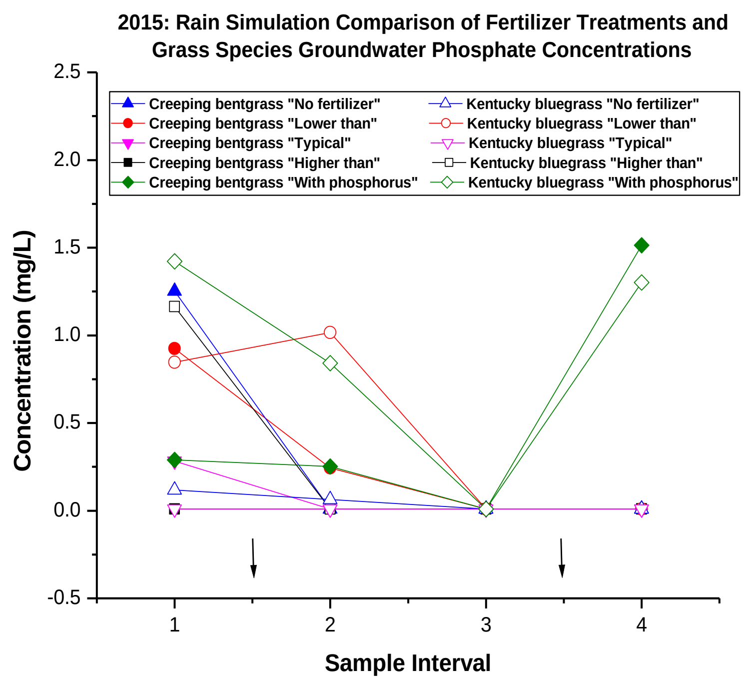



Figure 3 (left): Volume of groundwater collected in plots for four sampling intervals in the 2015 season. Black arrows indicate the time fertilizer treatment (if any) was applied.

Figure 4 (right): Phosphate concentration in groundwater samples measured for four sampling intervals in 2015 season. Black arrows indicate fertilizer application.




The Total Suspended Sediment (TSS) measured in samples generally decreased with each sampling interval, and when the decreasing sample volumes are accounted for the total sediment associated with each rain event clearly decreased with sampling interval, irrespective of grass type and fertilizer treatment (Figure 5).

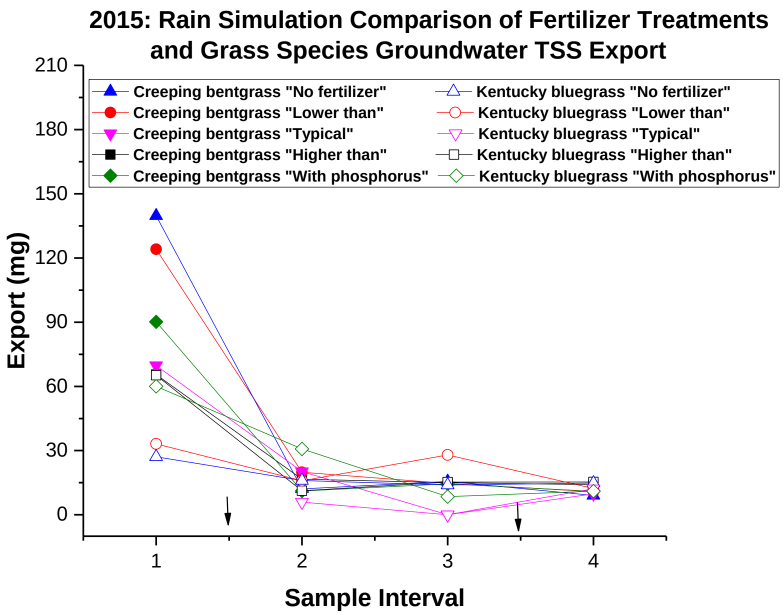
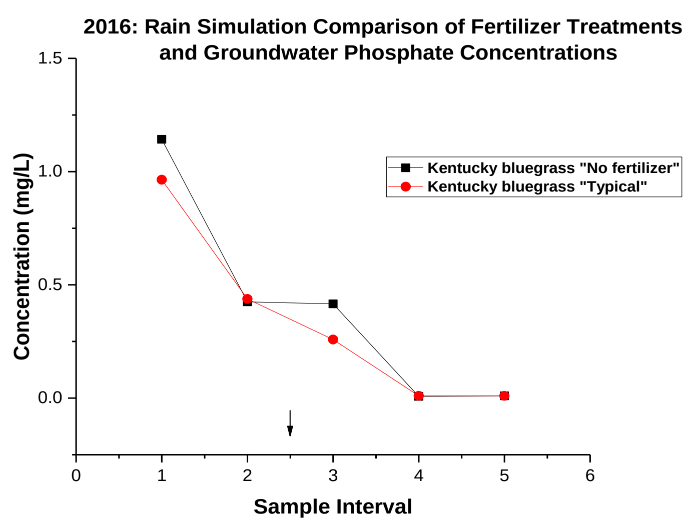



Figure 5 (left): Total suspended solid export for rain simulations, calculated by multiplying the measured TSS concentration by the total groundwater volume.

The 2016 season aimed to replicate some of these 2015 results. Only Kentucky bluegrass was used at one seeding rate, and only samples without any fertilizer and with "typical" levels of fertilizer were studied. There was no clear systematic dependence of groundwater sample volume on time, nor a dependence of sample volume or concentration on the application of fertilizer, but there was a dramatic decrease in sample phosphate concentration with time (Figure 6). The same clear dependence on time was not observed in nitrate concentrations nor TSS for 2016 samples.

Figure 6 (right): Phosphate concentration measured in groundwater samples collected from plots in 2016 season.




The hydraulic conductivity of the turfgrass plots was such that no measureable runoff was generated for any of the simulated rain events.

**Storm simulations:**

Approximately 50 gallons of water was “spiked” with 4.5 g of fertilizer (21-0-21), 1 g of MAP (11-52-0), and 18.9 g of silica sediment to achieve target phosphorus, nitrogen and TSS concentrations of 3 mg/L, 5.5 mg/L and 100 mg/L, respectively. Average phosphate concentrations measured in the inlet water for the two simulated storms was 1.22 mg/L and 1.36 mg/L, but average nitrate concentration in the inlet water increased from 0.2 mg/L in the first storm to 6.28 mg/L in the second storm, indicating that the source of nitrogen required more time to fully dissolve and/or become available as nitrate than was allowed for in the first storm. As such, only nitrate measurements from the second round of storm testing are considered here. While nutrient concentrations in runoff and groundwater samples were generally lower than that measured in the influent sample, and nutrient concentrations were generally higher in runoff samples than in groundwater samples, there was no significant dependence of nutrient concentration or total export on fertility regime, seed density or grass type measured. Most notably, TSS was much lower in both the groundwater and runoff than in the influent: groundwater sample concentrations ranged from 1 to 15 mg/L and runoff sample concentrations ranged from 3 to 25 mg/L. There was no dependence of this reduction on fertility regime, grass type or seed density measured.

**Snowmelt:**

There was not enough sample collected from winter snowmelt to perform measurement of TSS, but phosphate concentrations in the resulting runoff ranged from 0.27 to 3.65 mg/L and nitrate concentrations ranged from 0.27 to 25 mg/L. No significant dependence of either nutrient concentration on fertilizer type was measured.

**Summary and Conclusion:**

Generally, a reduction in phosphate export with time was observed in response to simulated rainfall for each of the two sampling seasons, though for different reasons: in 2015 the volume of groundwater collected decreased significantly with time and the concentration of phosphate in groundwater samples generally decreased. In 2016 the phosphate concentration in groundwater samples dramatically decreased with time, but the volume of groundwater produced did not have a strong dependence on time since seeding. Other than an expected increase in phosphate concentration in samples following fertilization with P-containing fertilizer, there was no clear dependence of nutrient concentration, TSS concentration nor groundwater volume on the fertility regime used, grass type or seed density. Nitrate and TSS did not demonstrate a clear dependence on time for both seasons.

The storm simulation measurements demonstrated most clearly that turfgrass may be used to dramatically reduce the concentration of sediment in both runoff and groundwater resulting from polluted influent. Concentration of all pollutants were generally lower in groundwater than in runoff, and both types of effluent were generally less polluted than the influent water, though no clear systematic dependence of this pollution reduction on fertility regime, grass type or seed density was observed.

Winter snowmelt measurements yielded runoff samples with nutrient concentrations comparable to what is typical of stormwater, but (consistent with the other measurements presented in this study) there was no significant dependence of nutrient concentration in snowmelt on fertility regime, grass type or seed density.