Preliminary Report

Assessment of the Quality of Groundwater Discharging from the University of Washington Bothell Stormwater System

by

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&
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Abstract

In the spring of 2007, a group of UW Bothell students initiated an investigation of the quality of the water discharging from the campus into the wetland. Given support from the CUSP program and a Curriculum for Undergraduate Research award from the UWB Teaching and Learning Center, over 300 water chemistry data points were collected at five locations on campus and in the wetland. Sampling quickly centered on the continuous discharge of groundwater from beneath the campus into a bioswale on the western edge of the restored wetland. Nitrate concentrations of this water approached or exceeded the maximum total daily load limits for North Creek tributaries of 1 mg/l. However, subsequent sampling revealed that the water was apparently cleansed of the nitrate in its journey through the bioswale and a culvert prior to flowing into North Creek. The small number of samples collected during a 7 week period raises questions about how representative this data set is and provides almost no information of the quality of the water collecting and discharging through the larger overland runoff storm sewer system. A more extensive student-driven sampling program, covering more sites will be initiated in the spring quarter 2008 to verify and expand this data set.

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Introduction

In the 2006-2007 school year, University of Washington Bothell (UWB) matriculated its first freshman class. In the spring quarter of 2007, all freshmen enrolled in a section of BCUSP 133 – Freshman Interest Group. The primary objective of BCUSP 133 was to provide students with a research experience. The students in the BCUSP 133e section were given the opportunity to assess the quality of the campus stormwater runoff.

Thanks to the receipt of a Collaborative Undergraduate Research (CUR) project award from the Teaching and Learning Center, the assessment was able to include laboratory-based nutrient analysis of samples collected in the field. These nutrient parameters included inorganic nitrogen (in the forms of nitrite, nitrate, and ammonia) and phosphate. Other parameters routinely measured in the field using hand-held instruments included dissolved oxygen, temperature, conductivity, turbidity, and pH. Not counting sampling and analyses that occurred in conjunction with laboratory experiments or at Piper's Creek, samples were collected and in situ parameters were measured on 6 different dates at 5 locations on campus (see Fig. 1). Taking into account triplicate samples and field blanks, this effort yielded over 300 distinct data points. The full data set is reproduced in Appendix 1.

Sampling of campus runoff extended from March 28 to May 18, 2007, generally taking place on Friday afternoons when the class met. Having sampling largely restricted to Friday afternoons proved to be a significant limitation in that heavy rain events did not happen to coincide with these days. As a result, the initial objective of analyzing the quality of overland runoff collected in the campus stormwater system had to be modified. With no overland runoff to sample, we sampled what was available.

Sampling conducted in a catch basin on the southeast corner of campus (site 5) and in a pond that receives campus stormwater input (Site 4) was eventually abandoned as the water quality was not considered representative of campus runoff. There was only one site where water flowed from the campus stormwater system on a continuous basis.

Site 1 marks the location of a pipe that discharges campus groundwater into a bioswale (see Fig. 1 and Fig. 2). A bioswale is an ecology term for a vegetated ditch that is meant to intercept runoff, slow its transport to lakes and streams, and provide some wetland habitat. The continual discharge of water from the campus into the bioswale gave us something we could work with given our time constraints. As a result, the study morphed into an assessment of the quality of this campus groundwater and the evolution of the water quality as it flowed along the bioswale and made its way to the wetland and North Creek.

Because the pipe that discharges campus-derived water at Site 3 is close to North Creek, it is an appropriate location for water quality monitoring. This is particularly true since suburban groundwater typical exhibits elevated nutrient levels and North Creek is a stressed water body. Accordingly, this study constitutes a first step in assessing:

- the quality of campus groundwater;
- the efficacy of the bioswale in its potential to remediate the water discharged into it; and
- the potential impacts of campus runoff to North Creek.

Figure 1. 2002 aerial photograph of the UWB and Cascadia Community College campus and wetland showing the location of the sampling sites. A pipe discharges groundwater at Site 1 (see Fig. 2) into a bioswale (green line). The water flows to Site 2, turns a corner and enters another pipe (see Figures 3 and 4), which extends under the wetland fringe. The pipe reemerges at Site 3, where the water is discharged into a bog before continuing as surface flow to North Creek. The dotted yellow line is a very rough approximation of the area that could contribute recharge to the groundwater that is collected in a french drain and piped to Site 1. Samples were also analyzed from a pond (Site 4) and a stormwater catch basin (Site 5). The photo is a section of a USGS (2003) high resolution orthoimage.

Site Characteristics

The photographs in Figures 2, 3 and 4 provide visuals of sampling sites 1-3 and the surrounding area. The locations of these sites relative to the UWB campus can be seen in Figure 1.

Figure 2. Photograph A shows a view of the bioswale into which campus groundwater is discharged. The view in photo A is to the south and the black arrow shows the location of the discharge point. Photo B is a close-up of the pipe. Photographs taken on 10/9/2007.

Figure 3. Sampling Site 2 is in the foreground of Photo A, which contains a view of the bioswale to the northwest. Photo B shows the culvert at the end of the bioswale. Water enters here and flows in an underground pipe to Site 3. Both photos are from March 2007. The culvert was completely obscured by vegetation in October 2007.

Figure 4. Photographs showing the location of Site 3. The dashed green arrow in Photo A indicates the location of the underground pipe and the discharge point at Site 3. Photo B shows the open pipe at Site 3 (black arrow) and the wet area to the left. Note the lush green growth in the bioswale (lower right of Photo A) relative to the adjacent grassy area. Photos taken on 10/9/2007.

It is assumed that the great majority of the water in the bioswale and discharging from the pipes at both Site 1 and Site 3 is derived from precipitation that has infiltrated the soil on campus. Some portion of the shallow campus groundwater within the area outlined in Figure 1 is intercepted by a french drain at the base of the slope to the west and north of the library (Egdorf, 2007). This water is then transported via a system of underground pipes and catch basins (see Figure 5) to the discharge point at Site 1. This system is in place to keep the ground surface adjacent to the library dry.

The quality of the groundwater will be influenced by several factors. The rainwater will bear with it measurable nutrient concentrations, which may or may not be diminished during the infiltration of the water through the soil. This infiltrating water will also pick up nutrients from the breakdown of organic matter in and on the soil (decomposing leaf litter, animal feces, etc.).

Finally, the quality of the groundwater that is discharged into the bioswale will also be influenced by the land management of the UWB and Cascadia Community College (CCC) campus. To the credit of the facilities services staff, chemical insecticides, herbicides, or fungicides are not routinely applied on the UWB/CCC campus. Fertilization of highly managed lawns and plantings does occur, however. Approximately one ton of lawn fertilizer is applied in a year. This fertilizer is composed of steamed pork bone meal, bird feather meal, and potassium sulfate (Kemper, 2007). 600 pounds of this fertilizer was applied on Feb 22, 2007, as well as on June 15. The fertilizer was characterized "as 9-3-4 which means that 54lbs. of nitrogen went onto the lawns" (Kemper, 2008). Fertilization of campus plantings takes place on a more irregular and frequent basis. A wider variety of fertilizers is used, including compost, compost tea, fish meal, and alfalfa. Additional characteristics of the materials applied to the grounds of the campus are outlined in Appendix 1.

Applications of fertilizers, even organic ones based on bones and feathers, have the potential to increase nutrient concentrations in the groundwater. Not all of the nutrients applied are utilized by the grass and other plantings and particulate and dissolved organic nitrogen in the fertilizer can be converted by fungi and bacteria to the inorganic forms of nitrogen measured in this study. However, most of the campus area uphill of the library, i.e., most of the recharge area for the groundwater discharging into the bioswale, receives no fertilization treatment.

When the groundwater effluent is discharged into the bioswale it is joined by an unknown and variable amount of natural groundwater seepage (derived from infiltration on campus or farther uphill) and direct precipitation. The quality of the groundwater discharged into the bioswale will be modified not only by the co-mingling of water from these other sources, but also by the community of plants and animals that reside in and visit the bioswale. Figures 2 and 3 show that plant growth is vigorous and diverse in this bioswale. The continual presence of water in moderate amounts has contributed to a thriving ecosystem. Despite the likely influence of organisms on the water quality measured at Sites 2 and 3, no ecological surveys of the bioswale were conducted for this study.

Methodology

Standard sampling methods were employed for this study. See Appendix 2 for a breakdown of the nutrient sampling methodology.

Turbidity data was collected in the field using a Hach model 2100P portable turbidimeter. Dissolved oxygen concentrations and temperatures were collected in the field using a YSI model 58 dissolved oxygen meter. Conductivity was measured in the field with a Cole Parmer model 19815-00 conductivity meter, while pH levels were measured in the field using an Oakton pHTestr 1. All of this equipment was calibrated immediately prior to the beginning of the study. All of the aforementioned procedures were conducted by the freshman in BCUSP 133e.

Nutrient analysis was conducted by research assistants (Scott Christy and Elsa Piekarski) under the direction of Christy Cherrier, the science lab coordinator for the Interdisciplinary Arts and Science Program. After thawing the frozen samples, the research assistants filtered them with Whatman GF/F glass fiber filters to remove particulates and the samples were returned to the refrigerator overnight. Within 24 hours of thawing and filtering, the samples were analyzed for ammonia, nitrate+nitrite, and phosphate on a Lachat 8000 flow injection autoanalyzer, using QuickChem methods 10-107-06-1-F, 10-107-04-1-B, and 10-115-01-1-M respectively. Nitrite was measured separately, using method 10-107-04-1-B without the cadmium reduction column. Nitrate was then calculated by subtracting the nitrite measurement from the nitrate+nitrite measurement. Samples were diluted as needed to stay within the detection limits of each method. Standard QA/QC techniques were used.

Results

This section of the report relates the findings of the study. The bulk of the sampling conducted for this study took place in less than a month. In that time, UWB students generated over 300 data points on a wide range of parameters. The parameters discussed here include those measured in the field (i.e., dissolved oxygen, temperature, conductivity, turbidity, and pH) and the nutrients analyzed in the laboratory, including nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), and phosphate (PO_4^{3-}). BCUSP 133 students also collected samples for analysis of fecal coliform counts and total suspended solids, but these data sets are not discussed in this report.

Qualitative findings of relevance include our observations. For example, the groundwater flowing in the stormwater system and discharging at Site 1 always looked clear and had no perceptible odor (see Figure 5). Meanwhile, we were able to observe the growth of nutrient-loving aquatic plants like duckweed at Site 2 (see Figure 3).

Figure 5. Photograph showing groundwater flowing from the pipe connected to the french drain (top) into a catch basin located just north of the library. When the water reaches a sufficient depth, it flows into the pipe on the left, which carries the water on to the discharge point at Site 1. Note the clarity of the water, which is a manifestation of the filtering it receives in the ground. This clarity is vastly different from the water observed in catch basins that receive overland runoff.

A summary of the temperature, conductivity, dissolved oxygen, and pH data collected at Sites 1-5 are displayed in Table 1.

Site 1 - Groundwater discharge from pipe into bioswale					
Date	Temp (°C)	pH	Cond (uS)	Turb. (NTU)	DO (mg/l)
3/28	10.3	7.6	336	0.27	11.1
4/20	10.7	6.9	386	0.20	9.9
4/27	11.0	8.1	417	0.95	8.7
5/04	12.2	7.6	386	0.69	-
5/11	11.5	7.5	418	0.24	10.8
5/18	12.6	7.8	420	0.30	10.2
Site 2 - Surface water in bioswale					
Date	Temp (°C)	pH	Cond (uS)	Turb. (NTU)	DO (mg/l)
4/27	12.3	8.0	420	2.64	5.3
5/04	13.1	7.3	264	2.05	-
5/11	12.2	7.1	-	3.47	7.1
5/18	17.2	7.4	387	1.02	6.1
Site 3 - Bioswale discharge from pipe into wetland					
Date	Temp (°C)	pH	Cond (uS)	Turb. (NTU)	DO (mg/l)
5/18	16.4	8.4	415	1.19	7.8
Site 4 - Pond in wetland fringe that receives campus stormwater					
Date	Temp (°C)	pH	Cond (uS)	Turb. (NTU)	DO (mg/l)
4/06	17.5	9.3	161	1.75	10.0
5/11	16.9	7.8	132	4.6	10.8
Site 5 - Catch basin below south garage by oil/water separator					
Date	Temp (°C)	pH	Cond (uS)	Turb. (NTU)	DO (mg/l)
4/27	11.2	8.6	147	5.81	2.5
5/04	13.5	7.6	48	4.34	-

Table 1. Probe-measured parameter values at Sites 1-5. Dashes indicate no data recorded.
uS = microsiemens, Turb. = turbidity, NTU = Nephelometric Turbidity Units, DO = dissolved oxygen

The data set in Table 1 yields a few interesting trends and comparisons. For example, water discharged at Site 1 always had dissolved oxygen concentrations at or near saturation. But in the short journey of the water from Site 1 to Site 2, dissolved oxygen concentrations always dropped significantly. This drop in dissolved oxygen was accompanied by an order of magnitude increase in turbidity levels. Dissolved oxygen concentrations measured in the pond at Site 4 were encouragingly high on the two sampling occasions. In contrast, the water in the catch basin at Site 5 had the lowest dissolved oxygen concentration and highest turbidity levels measurement recorded during the study.

A summary of the average nutrient concentrations from samples collected at Sites 1-5 are displayed in Table 2.

Site 1 - Groundwater discharge from pipe into bioswale				
Date	NO_3 (mg/l)	NO_2 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)
3/28	0.863	-	0.009	0.026
4/20	1.407	0.001	0.099	0.023
4/27	0.589	0.000	0.009	0.016
5/4	0.688	0.002	0.009	0.016
5/11	0.815	0.000	0.022	0.050
5/18	0.629	0.000	0.086	0.029
Site 2 - Surface water in bioswale				
Date	NO_3 (mg/l)	NO_2 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)
4/27	0.738	0.001	0.020	0.020
5/4	0.248	0.002	0.023	0.043
5/11	0.381	0.003	0.072	0.356
5/18	0.499	0.001	0.042	0.065
Site 3 - Bioswale discharge from pipe into wetland				
Date	NO_3 (mg/l)	NO_2 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)
5/11	0.046	BDL	0.031	0.023
5/18	0.034	0.001	0.067	0.021
Site 4 - Pond in wetland fringe that receives campus stormwater				
Date	NO_3 (mg/l)	NO_2 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)
4/6	0.134	BDL	0.009	0.012
5/11	0.003	0.002	0.028	0.009
Site 5 - Catch basin below south garage by oil/water separator				
Date	NO_3 (mg/l)	NO_2 (mg/l)	NH_3 (mg/l)	PO_4 (mg/l)
4/27	0.192	0.0004	0.553	0.015
5/4	0.120	0.0030	0.026	0.025

Table 2. Summary of nutrient data. All values represent the average concentrations from triplicate samples, with the exception of the data from Site 4 on 4/6/07, which are the average results from 6 contemporaneous samples. NO_3 values for Site 1 on 3/28 are actually NO_3+NO_2 values. BDL stands for below detection limit, while mg/l = milligrams per liter. All nutrient data, including standard deviations of triplicate samples and analytical values from field blanks, can be seen in Appendix 3.

As can be seen in table 2, nitrite, ammonia, and phosphate concentrations were generally low at all sites, with two exceptions. Phosphate concentrations at Site 2 on 5/11 were an order of magnitude higher than all other values. Likewise, ammonia concentrations were an order of magnitude higher at Site 5 on 4/27. The most revealing aspects of the nutrient data set are the variations in the nitrate (NO_3) values between Sites 1-3. The variations in range and standard deviations around these average concentrations are better displayed in Figure 6.

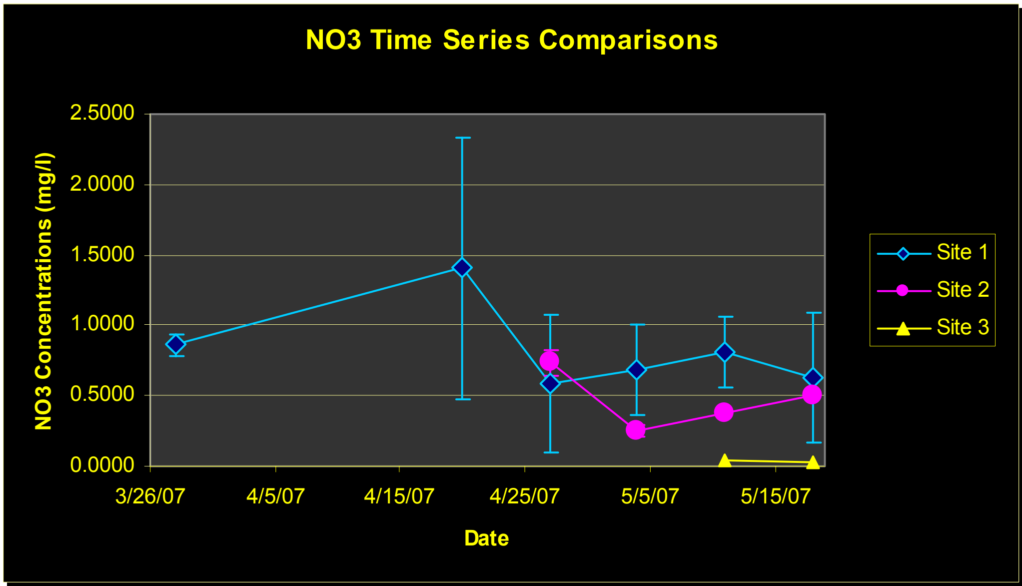

Figure 6. Nitrate concentrations for all samples collected at Sites 1, 2 and 3 during the study. Each point represents a mean concentration value from 3 samples collected at the same place and time. Error bars represent one standard deviation away from the mean concentration value.

It is unclear why Site 1 suffered from such a large range of nitrate concentrations in triplicate samples, although the need to dilute them for analysis may have played a role. Despite the lack of precision in the Site 1 data, nitrate concentrations tend to be highest there and diminish at Sites 2 and 3. It is important to note that the acceptable limit for Nitrate+Nitrite is less than 1 mg/l in North Creek (Meehan and Kalenius, 2004). Groundwater discharging from the campus stormwater sewer system was close to or in exceedance of this level on a few occasions during the study period.

It is apparent in Figure 6 that nitrate concentrations diminished significantly between Sites 1 and 3 on May 11 and May 18. This trend is examined more closely in Figure 7. This graph displays total inorganic nitrogen concentrations at Sites 1-3 on May 11 and May 18. The total inorganic nitrogen values plotted represent additions of the mean values of nitrate + nitrite + ammonia for each site.

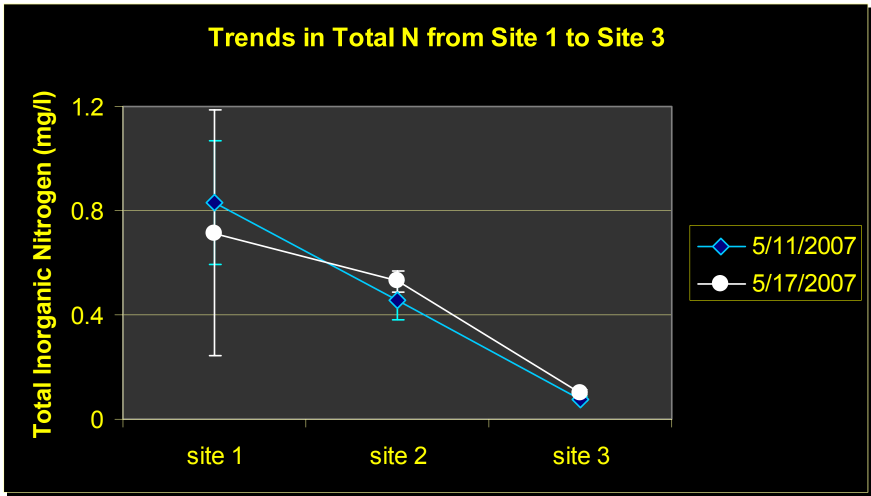

Figure 7. Comparison of total inorganic nitrogen (NO_3^- + NO_2^- + NH_3^+) concentrations on the two dates when samples were collected at all three sites. As the campus runoff traveled from Site 1 to Site 3 on these dates, there was a significant reduction in total inorganic nitrogen. This is presumably a function of plant uptake in the bioswale.

Discussion

During 7 weeks of sampling during the spring of 2007, water discharging from the campus stormwater system into the bioswale at Site 1 had nitrate concentrations that averaged 0.83 mg/l. The highest average nitrate concentration during the study was 1.47mg/l (see Figure 6). These values are high enough to warrant further monitoring, given that the total maximum daily load limits for discharge into North Creek is 1 mg/l (Meehan and Kalenius, 2004).

The source of the elevated nitrate concentrations at Site 1 during this sampling period is unknown. The influence of groundskeeping activities on the groundwater quality is generally thought to be minimal as applications are few and far between and because there is very little managed lawn area up-gradient of the french drain that directs water to Site 1. Still, the application of fertilizer on campus in February 2007 is the most likely source of nutrient contamination. Other possible sources of contamination could have included the fertilization of the roses at the Truly House or even of the lawns in the Bothell graveyard. Although one might think that nutrient-rich recharge from further up the hill would join the deeper groundwater and discharge in the wetland rather than into the shallow french drain behind the library, it is possible that groundwater in this hill is running along the contact between the soil and the underlying, relatively impermeable glacial till or "hardpan" (City of Bothell, 2006). This could account for why there is always a strong flow of water discharging into the bioswale at Site 1, even during drought conditions. In any event, the groundskeeping staff intends to alter the management of the roses at the Truly House, restricting them to more environmentally-friendly compost tea for fertilization (Kemper, 2008).

Another unknown is how representative these nutrient values are for the water discharging into the bioswale. Were they unusually high when we sampled? Atypically low? We have no idea.

Even if the water discharging into the bioswale turns out to routinely carry elevated nitrate concentrations, it might not be a cause for concern based on our preliminary data set. It would appear that the bioswale, or more accurately the plant community in the bioswale, is doing its intended job of remediating the water quality. On the two occasions where we sampled at Sites 1, 2, and 3 – tracing the water's journey from the beginning of the bioswale to where the water discharges into the wetland – we noted an order of magnitude decrease in total nitrogen concentrations (see Figure 7).

Of course, this tiny data set can hardly be considered the final word on the quality of the water that discharges from the campus into the wetlands. Additional sampling in the bioswale is necessary to confirm or disconfirm these findings. Furthermore, Site 1 is not the only place where water is discharged from the campus into the wetland. There are 2 small ponds that receive the overland runoff from the campus stormwater system. That water is captured in a complex series of storm drains and catch basins before being directed to one of two oil/water separators.

The water that runs through the campus stormwater system has the potential to be contaminated by a wider variety of pollutants than the groundwater on campus, since it will collect water from the streets and parking areas. We did not focus our attention on this stormwater during our study because it rained very little. In fact, Seattle received only 0.69 inches of rain during April 2007, over 70% below the "normal" April precipitation amount of 2.59 inches (Beautiful Seattle, 2008). So our sampling of the catch basin at Site 5 on 4/27/07 and 5/04/07 was of water that had been sitting in the catch basin for some time. Accordingly, our data from this catch basin can not be considered representative of the quality of the campus overland runoff. Furthermore, we did not run any analyses of metals or petroleum hydrocarbons, pollutants that would be of interest in the stormwater.

Still, it is worth noting from our data set that water that sits in the catch basins during a dry spell will undergo biochemical transformations in quality. Presumably metals will attach to sediment particles and settle out of the water flow, while the oil/water separator will do its job in removing oil and particles once the stagnant water flows through the system. But dirty, stagnant water will also tend to foster microbial growth that will draw down the oxygen levels. On 4/27/07, the water in the catch basin at Site 5 had oxygen concentration of only 2.5 mg/l (see Table 1) and ammonia concentrations of 0.55 mg/l.

A relationship between oxygen concentrations and ammonia levels from our study is shown in Figure 8 below. When anaerobic conditions take over in stagnant water, bacteria can either reduce nitrate to ammonia or fail to oxidize already present ammonia to nitrate. In any event, the potential diminishment of oxygen and accumulation of ammonia in our catch basins is not a good thing as this water is eventually discharged into two small ponds in the wetland fringe. Ammonia is toxic to fish and can trigger algal blooms in these ponds, fostering eutrophication and further loss of oxygen. The residence time of water in these ponds is unknown, although it is shortening dramatically in the southernmost pond as the water from it is currently seeping out of the failing hillside between it and North Creek.

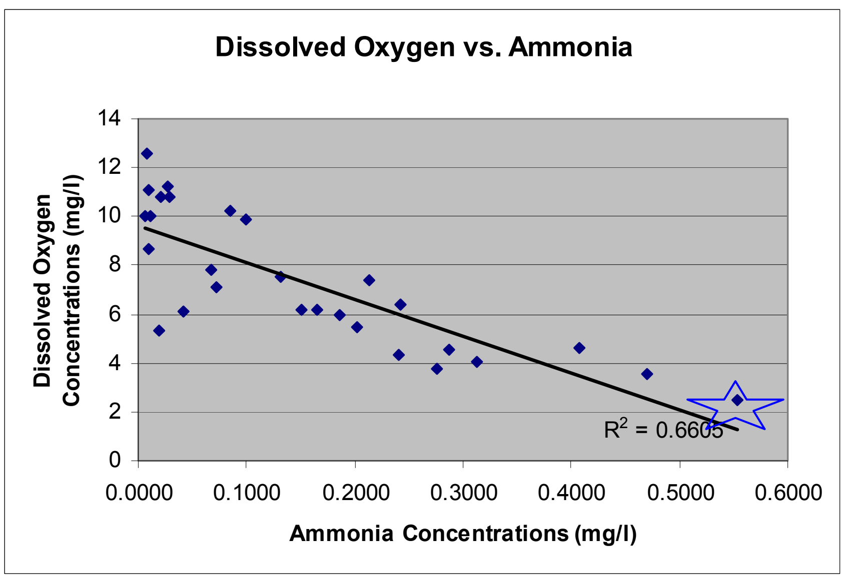

Figure 8. This plot shows the range of ammonia concentrations of all samples collected during this study. A weak inverse correlation between ammonia concentration and dissolved oxygen concentration is evident. The sample with the highest ammonia concentration and lowest oxygen concentration (within star outline) was collected in the catch basin near the south parking garage (Site 5). This organic rich water sat in the catch basin for an unknown period prior to sampling, accounting for the decrease in oxygen concentrations and transformation of nitrate and organic nitrogen to ammonia. Although this water quality is not characteristic of campus runoff, it will develop in stagnant catch basins, only to be periodically flushed out to the ponds and swales in the wetland fringe during peak runoff events.

Conclusions

Despite following a number of best management practices, including the use of native plantings, organic fertilizers, and a complex system of catch basins and oil/water separators, it is still possible for the UWB/CC campus to export contaminated water into the wetland and North Creek. Preliminary data collected during March-May of 2007 showed elevated nutrient concentrations in water that runs under the campus and discharges into a bioswale at the western margin of the wetland area. Somewhat elevated nutrient concentrations and low oxygen concentrations were also detected in a catch basin at the southern end of campus. The concern that these findings might trigger should be tempered by data that shows a great reduction in the nutrient concentrations in the water discharged at Site 1 as it travels in the bioswale and a culvert prior to making its way to North Creek. Still, it is unclear whether any of this data is representative of "normal" conditions or of how much seasonal variability there is in our runoff water quality.

Accordingly, a more extensive program of sampling over a longer period of time in a greater number of areas is called for to get a better idea of both the quality of water that is exported from the campus and of the ability of the drainage system under the campus and in the wetland to sequester and remove pollutants before the water makes its way to North Creek. As joint institutions of higher education that are moving to take leadership in environmental sustainability in the region, we should take care to "walk the talk" and ensure that our systems do their best at preserving and enhancing the ecosystems downstream of us. To this end, the UWB Teaching and Learning Center has provided another Curriculum for Undergraduate Research Program award to fund additional water quality investigations by students in the spring of 2008.

Acknowledgments

This study was made possible by a 2007 Curriculum for Undergraduate Education grant awarded by the Teaching and Learning Center of the UWB. Additional generous funding and support was also supplied by the Center for University Studies and Programs. Christy Cherrier provided critical training, time, and oversight, without which no nutrient data would have been generated. Elsa Piekarski and Scott Christy deserve high praise for learning a complex analytical method in very little time and devoting *many* tedious hours to ensuring the highest quality nutrient data for the study. Kudos go to the students in BCUSP 133[1] for doing all of the sampling and having the curiosity, adaptability, and wiling spirit required to collaborate on an ever-evolving investigation. John Egdorf and Jeff Truly of the UWB/CC Physical Plant deserve special acknowledgment for giving us the tour of the campus stormwater system and always cheerfully assisting us when we wanted to get into a catch basin. Thanks are also extended to the following UWB staff who provided invaluable assistance *indoors*: Gray Kochar-Lindgren, Becky Reed Rosenburg, Stephanie Stewart White, and Robyn Smidley.

Figure 9. Photos A, B and C depict the students of BCUSP 133e conducting sampling as part of the study. Christy Cherrier is leading the class in s'mores preparation in Photo D.

1) The 2007 BCUSP 133e students included: Brad Baker, Nick Brennan, Francis Fong, Rosa Hernandez, Emily Kim, Simon Lee, Ashley MacInnis, and Paul Pittman

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Appendix 1 – Summary of Groundskeeping Practices

What follows is an edited transcript of three personal communications from Tyson Kemper, Grounds and Nursery Specialist II of the UWB/CCC campus Physical Plant Staff.

From: Tyson Kemper
Sent: Fri 10/12/2007 7:13 AM
To: Robert Turner
Subject: RE: questions about grounds management

You are correct in your assumption that the campus uses no chemical insecticides, herbicides, fungicides, or fertilizers, with the small exception of spraying for bees or ants when they pose a safety or property damage risk, which is an extremely infrequent occurrence. The most significant inputs to the campus gardens are lawn fertilizer (one application in the spring and one in the fall totaling about 1 ton of fertilizer a year) and snow melt during snow and ice storms in the winter (multiple applications totaling about 2 to 3 tons; however with better management of snow storms we should be able to bring this number down this year). I have attached the MSDS for each of these products.

All of our herbicide is vinegar and plant oil based. Our fungicides are compost tea, sulfur, and copper sulfates all OMRI approved; the later two used extremely infrequently and typically only in the rose garden. Our insecticides are either biodegradable dish soap based, vegetable oil, or neem oil based and are all OMRI certified organic, and again are used very infrequently.

Most of the fertilization needs of our plants are met with compost, compost tea, and alfalfa. We supplement this in the flowering W and the promenade pots approximately every 2 to 4 weeks during the growing season with fish emulsion and all purpose natural fertilizers consisting of things like bone meal, feather meal, soybean meal, kelp meal, fish meal, feather meal, blood meal, etc.

From: Tyson Kemper
Sent: Monday, October 15, 2007 6:15 AM
To: Robert Turner
Subject: RE: questions about grounds management

This year our spring lawn fertilizer application occurred on June 15th. We only fertilize the highly managed lawns that we mow every week, so the taller grass uphill of UW2 is not fertilized. Also, nothing has been applied in the trees, or forested area, uphill of the library in the last two seasons. However, herbicide was likely sprayed up there in the years prior; 2000-2005.

From: Tyson Kemper
Sent: Friday, April 04, 2008 9:44 AM
To: Robert Turner
Cc: Tony Guerrero; Barney Harvey
Subject: RE: High Nitrogen count- what are you doing differently in the Truly rose garden?

Morning Rob,

I have been thinking this whole thing over and am as curious as you are about where the high levels of nitrogen are coming from. I have tried very hard to find ways in which our grounds management could have led to these numbers but have been as yet unable to come up with a likely source (I did however review the fertilization records a bit more in depth yesterday and found that 600lbs. of organic lawn fertilizer was applied on Feb 22, 2007 as well as in June as I reported to you. The fertilizer is analyzed as 9-3-4 which means that 54lbs. of nitrogen went onto the lawns 1 month before you sampled. Would that be enough to dramatically impact the water quality being discharged one month later during our wettest time of year?). Let me know your results this spring and maybe then we can talk further in person. Very cool, I'm glad you are doing this sampling; I hope we can reach a likely conclusion at some point.

Tyson

Appendix 2 – Nutrient Sampling Methodology

Nutrient samples were collected using the following procedure:

- 125 ml LDPE bottles were acid washed in the lab and rinsed with deionized water prior to use in the field
- At each sampling site, 3 sample bottles were triple rinsed with the water to be sampled.
- These bottles were then filled to the neck (leaving head space) with sample water.
- 20 drops of sulfuric acid (4 molar) were added to each sample bottle to lower the pH of the sample below 2 and halt microbial metabolism, thereby preserving the chemical characteristics of the sample.
- Sample bottles were capped and placed in a cooler with an ice pack (and the bottle numbers were recorded in field notes).
- A field blank was collected, which entailed rinsing a sample bottle with deionized water, filling it with deionized water, adding 20 drops of sulfuric acid, capping it, recording its number, and placing it in the cooler.
- Upon our return to the lab, the nutrient sample bottles and field blanks were immediately placed in a freezer for later analysis.