



STORMWATER EFFECTIVENESS OF AN OPERATING GREEN ROOF STORMWATER TREATMENT SYSTEM AND COMPARISON TO SCALED DOWN GREEN ROOF STORMWATER TREATMENT SYSTEM CHAMBERS

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ABSTRACT

This report presents the results of a successful operating green roof in the state of Florida. The green roof is located on the Student Union building at the University of Central Florida. This green roof has thrived for more than two years hosting more than 50 tours educating architects, engineers, and policy makers on the many benefits green roofs provide.

Comparison of this full sized operating green roof stormwater treatment system with scaled down green roof stormwater treatment system chambers showed that the full size system can be described by the previously reported equivalent experimental chamber data. Thus the experimental chamber data can be used to predict full scale operation of an active green roof designed for Florida climate conditions.

The data used for the comparison included both water quality and quantity results. It is shown that evapotranspiration rates and filtrate factors for the regular irrigated chambers are comparable for the irrigation schedules used on the full scale roof. It is also noted that a cistern with irrigation of the green roof must be used to meet water quality reduction goals. Larger cistern sizes will improve the mass reduction from the system.

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INTRODUCTION

The success of the green roof stormwater treatment system at the University of Central Florida has served as a model for how green roofs should be designed and operated in the state of Florida. This green roof has supported healthy, vibrant plant growth for more than two years offering a valuable educational resource for the State. In addition, this roof has provided environmental benefits in the form of reduced energy consumption (Sonne, 2006), significantly reduced stormwater runoff as well as reduced nutrient mass loading from the roof.

An energy study was preformed on the green roof by the Florida Solar and Energy Center which found green roofs to be more energy efficient than high albedo energy star roofs (Sonne, 2006). Sonne, 2006 found that the green roof, when compared to a new high albedo roof, had 18.3% less heat gain in the summer months and 45% less heat loss whenever the ambient temperature was less than 55°F. Sonne, 2006 notes that as the high albedo roof ages and turns a darker color this difference will increase. This difference translates directly into energy savings in the form of requiring less energy to cool or heat a building with a green roof.

After a five month vegetation establishment period and allowing for verification of measurement equipment, water quantity measurements and water quality sampling began at the end of August 2005. The green roof is located on the Student Union building and is 1600 square feet with a 1400 gallon cistern to store roof filtrate that comes from irrigation and rainfall. A comparison 1600 square foot conventional roof (not green) was along side of the green roof.

To compare irrigation rates and pollution control materials, and for data analysis purposes, 18 experimental chambers were built to simulate the green roof on the student union. Each chamber was 16 square feet and was equipped with a 50 gallon cistern. The experimental chambers were constructed in the same way as the full sized roof. Each chamber, except for the two control chambers, had the same water proofing membrane, protection layer, drainage layer, separation fabric, and depth of growing media. The control chambers had the same water proofing membrane but were left bare to mimic the control roof on the Student Union building and provide a basis for comparison. For the purposes of this analysis, hydrologic data from 6 chambers were compared to the full sized green roof and control roof on the Student Union building. Two of the chambers were the control chambers while the other four were the expanded clay vegetated chambers, two with regular irrigation and two with over irrigation. Both irrigation volumes were used since the full sized green roof irrigation varied over the course of the year.

APPROACH

This experiment required both water quality analysis and a water budget to be preformed. At the full scale student union roof, the water depth used for the water budget was measured with a depth tape attached to the exterior of the cistern. At various and frequent times, automatic measuring equipment were used, but their operation was not reliable. The cistern depth was measured upon arrival for the irrigation event, after supplemental water was added if needed, and after irrigation was complete. This allowed for calculation of the filtrate, irrigation, and makeup water volume. The overflow had to

be calculated based on some basic assumptions due to the flow meters malfunction. The assumptions used to calculate the overflow were as follows: overflow is the portion of filtrate that left the cistern, whenever the cistern depth was 8.1 feet overflow occurred, overflow was calculated by assuming a green roof water storage of 20% of the green roof depth, the remainder of the water was filtrate, the filtrate was the difference between the final cistern depth from the previous event and the new hypothetical depth, the overflow was the difference between the available cistern storage and the total volume of filtrate. The evapotranspiration was calculated using a mass balance approach assuming that the change in green roof storage was insignificant.

The water quality analyses were performed weekly with sampling occurring from the cistern. The water quality parameters studied were the following: ortho-phosphorus, total phosphorus, nitrate + nitrite, ammonia, TKN, total nitrogen, total suspended solids, total dissolved solids, total solids, pH, and alkalinity.

The testing procedures used for the determination of ortho-phosphorus was the Hach method for the low range concentration detection which was adopted from the Standard Methods 4500-P E ascorbic acid method, the Hach DR 5000 spectrophotometer was used for this procedure. The testing procedures used for the determination of total phosphorus was the Standard Methods 4500-P B 5 persulfate digestion method for the conversion of organic phosphorus to ortho-phosphorus and the previously mentioned Hach method for the final concentration determination.

The testing procedure for the determination of nitrate + nitrite was the Hach method for the low range concentration detection which was adopted from the Standard

Methods 4500-NO₃⁻ E cadmium reduction method, the Hach DR 5000 spectrophotometer was used for this procedure.

The testing procedure for the determination of ammonia was the Standard Methods 4500-NH₃ D using the Accumet™ AR50 Dual Channel pH/Ion/Conductivity Meter with the Thermo Electron Corporation Orion 9512 Ammonia selective probe. The testing procedure for the determination of TKN was the Standard Methods procedure 4500-N_{org} B Macro-kjideal method. The total nitrogen was determined by adding up the nitrogen species. The total suspended and dissolved solids were determined using the Standard Methods 2540 D and C respectively.

The total solids were determined by summing the total suspended and dissolved solids. The pH was determined using the Accumet™ AR50 dual channel pH/Ion/Conductivity Meter with the AccutupH⁺™ selective probe. The alkalinity was determined using the Standard Methods titration method 2320 B. Each sample was collected weekly and stored according to EPA Test Methods Technical Additions to Methods for Chemical Analysis of Water and Wastes. All of the analysis was performed in a timely manner, according to proper analyses and within 36 hours of sampling.

RESULTS

Water Budget:

The results from the hydrologic comparison of a full sized green roof and experimental chambers are presented in this section. The purpose of this comparison is to gage the accuracy of the previously reported data and results from the experimental

chambers (Hardin, 2006). This section focuses on the comparison of the student union green roof and experimental chamber evapotranspiration rates and filtrate factors. The filtrate factor is the quantity of water drained from the green roof relative to the quantity of rainfall and irrigation added to the green roof.

The results of the evapotranspiration analysis comparison show that there is no significant difference in ET rates for the student union green roof and any of the experimental chambers, $\alpha = 0.05$ (see Table 1). From Table 1 it can be seen that for the regular irrigated chambers the z score is a large negative number indicating that the ET rate is higher for the student union green roof just not at the 95% confidence level. The graphs presented below in Figures 1 through 4 shows that when the monthly average ET rates for the experimental chambers are plotted versus the monthly average ET rates for the student union green roof similar results are obtained. This is evident due to the slope of the lines being close to one.

A comparison of the seasonal variability of ET was also preformed for the experimental chambers and the student union green roof (see Figure 5). This graph shows that during the winter months the ET rates are lower than during the summer months. This was consistent for both the student union green roof and the experimental chambers.

Table 1: ET Hypothesis Test

ET Hypothesis Tests

H_{01} Roof construction is constant & irrigation is variable, Student Union ET = Experimental Chamber ET

H_{a1} Roof construction is constant & irrigation is variable, Student Union ET > Experimental Chamber ET

$\alpha = 0.05 \quad z_{\alpha} = 1.645$

Note: R = Reject H_0 & A = Accept H_0

	SUGR	EVO1	EVO2	EVR1	EVR2
Average	0.14	0.14	0.13	0.12	0.12
S	0.083	0.063	0.063	0.058	0.055
s^2	0.007	0.004	0.004	0.003	0.003
N	88	100	100	100	100
z_1		0.178	-0.348	-1.217	-1.534
H_{01}		A	A	A	A

Where: SUGR is the **S**tudent **U**nion **G**reen **R**oof

EVO1 is the **E**xpanded clay **V**egetated **O**ver irrigated chamber #1

EVO2 is the **E**xpanded clay **V**egetated **O**ver irrigated chamber #2

EVR1 is the **E**xpanded clay **V**egetated **R**egular irrigated chamber #1

EVR2 is the **E**xpanded clay **V**egetated **R**egular irrigated chamber #2

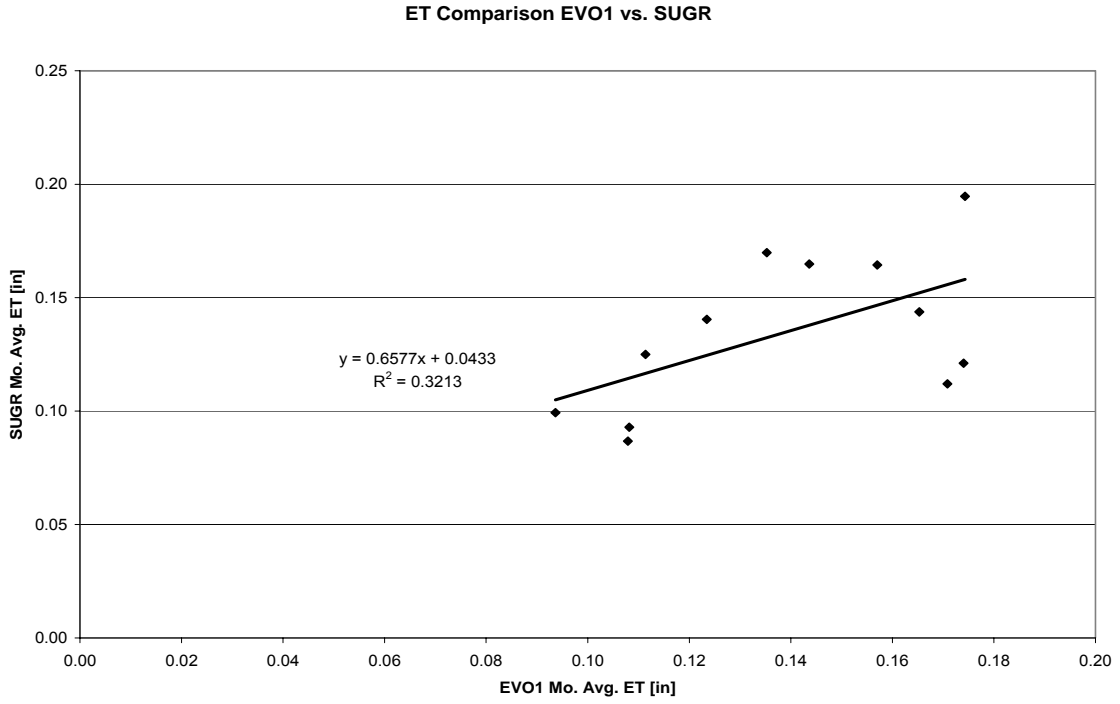


Figure 1: ET Comparison EVO1 vs. SUGR

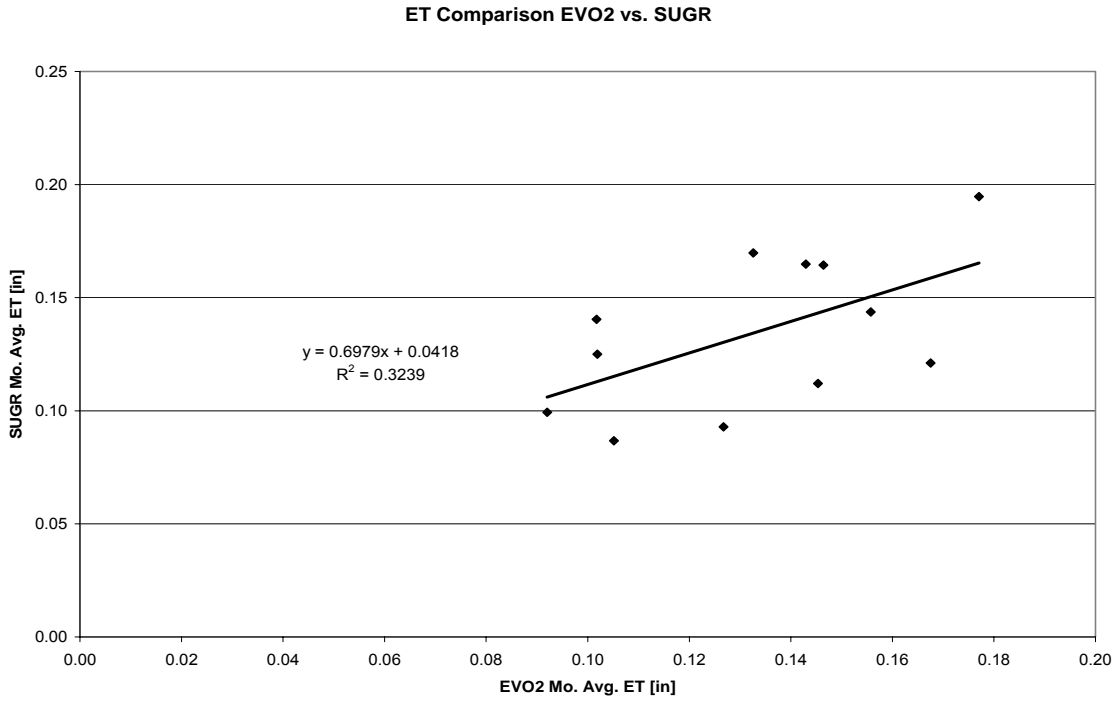


Figure 2: ET Comparison EVO2 vs. SUGR

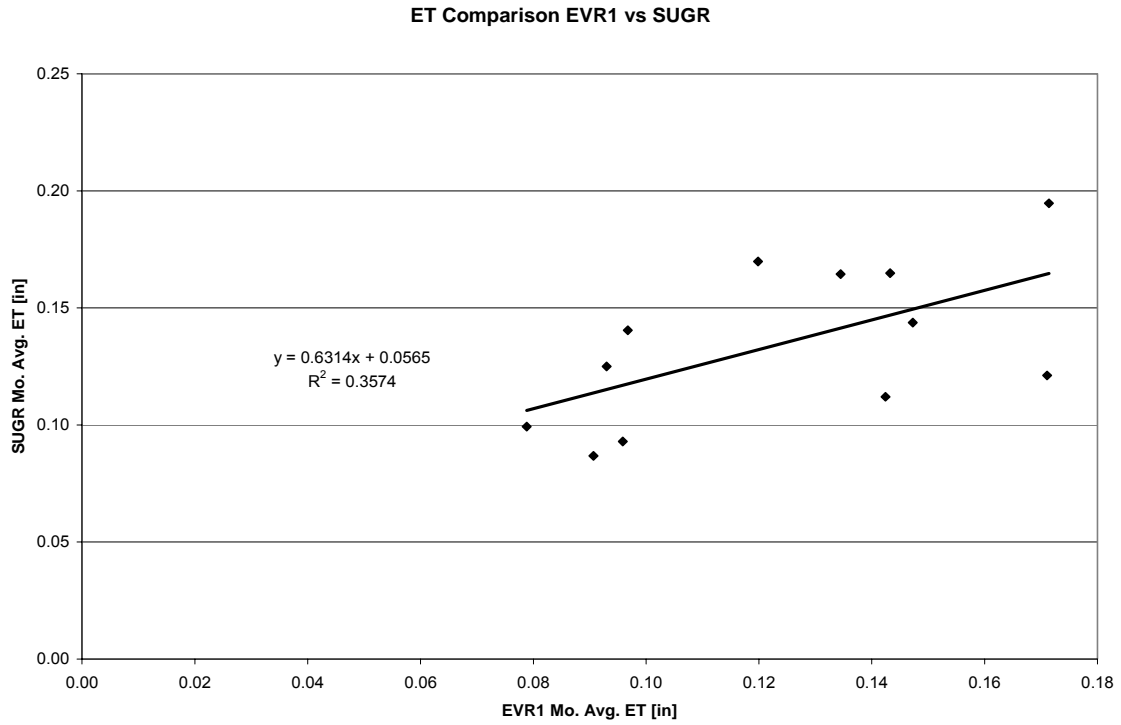


Figure 3: ET Comparison EVR1 vs. SUGR

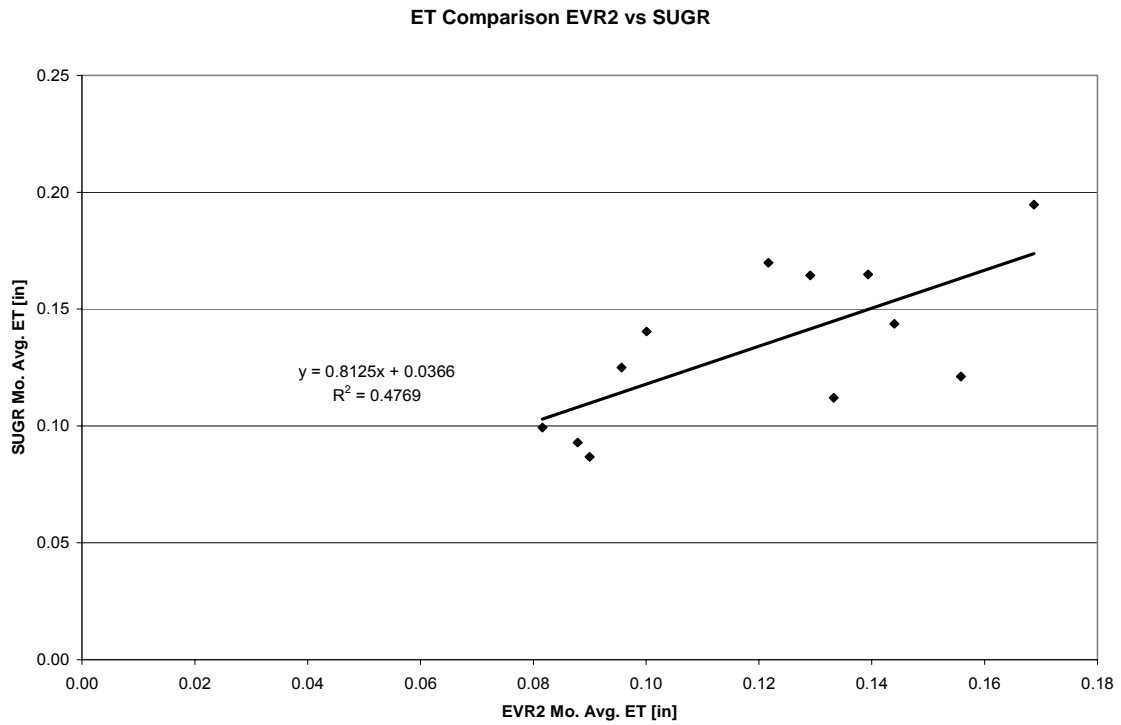


Figure 4: ET Comparison EVR2 vs. SUGR

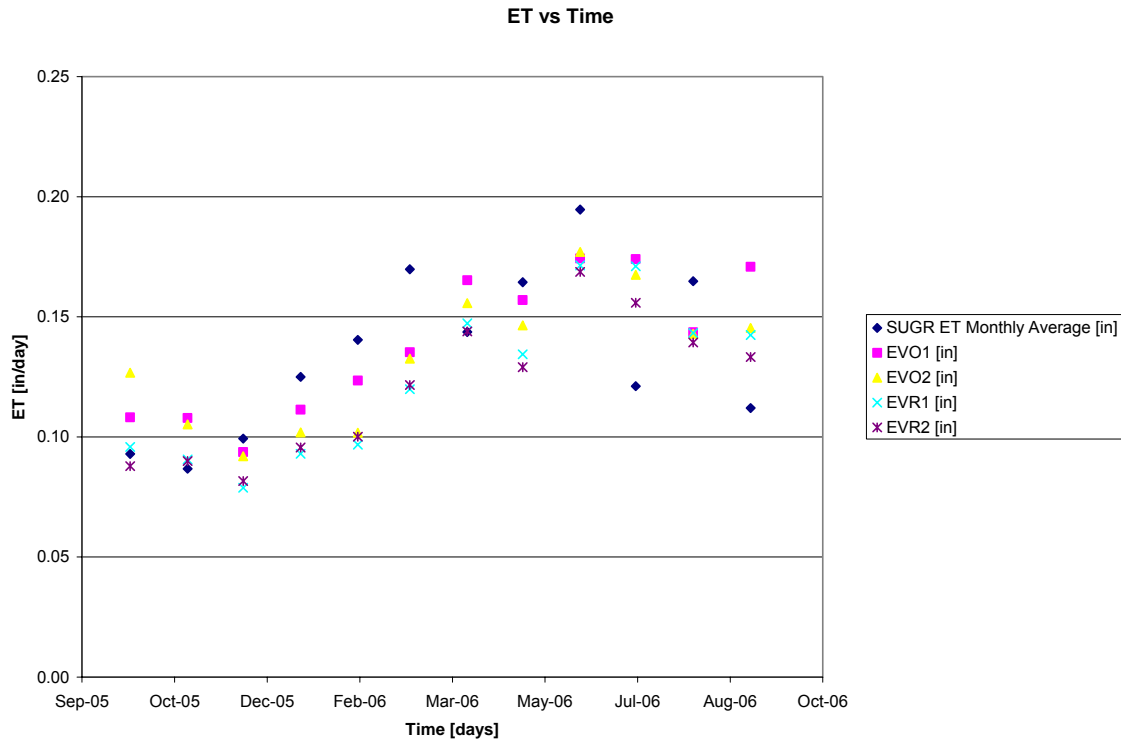


Figure 5: Comparison of ET Seasonality

The results for the filtrate factor comparison analysis hypothesis tests show that there is no significant difference between the student union green roof and the regular irrigated experimental chambers $\alpha = 0.05$ (see Table 2). The hypothesis tests show that for the over irrigated chambers there is a significant difference. The large positive z score indicates that the f factor for the over irrigated experimental chambers is higher than the student union green roof. The student union green roof was irrigated at approximately the same rate as the regular irrigated test chamber.

The graphs in Figures 6 through 9 shows the experimental chambers verse the student union green roof monthly average filtrate factor. These graphs show similar

results as the hypothesis tests, showing no difference between the regular irrigated experimental chambers and the student union green roof with slopes close to one ranging from 1.128 to 1.2234 (see Figures 8 and 9). The over irrigated experimental chambers verse the student union green roof monthly average filtrate factor show significant difference with slopes ranging from 2.2865 to 2.4893 (see Figures 6 and 7).

Table 2: Filtrate Factor (f) Hypothesis Tests

f Factor Hypothesis Tests

H_{O1} Roof construction is constant & irrigation is variable, Student Union f Factor = Experimental Chamber f Factor

H_{a1} Roof construction is constant & irrigation is variable, Student Union f Factor > Experimental Chamber f Factor

$\alpha = 0.05$ $z_{\alpha} = 1.645$

Note: R = Reject H_0 & A = Accept H_0

	SUGR	EVO1	EVO2	EVR1	EVR2
Average	0.42	0.61	0.63	0.41	0.42
S	0.290	0.153	0.140	0.242	0.241
s^2	0.084	0.023	0.020	0.059	0.058
N	87	99	98	98	99
z_1		5.555	6.036	-0.395	-0.131
H_{O1}		R	R	A	A

f Factor Comparison EVO1 vs SUGR

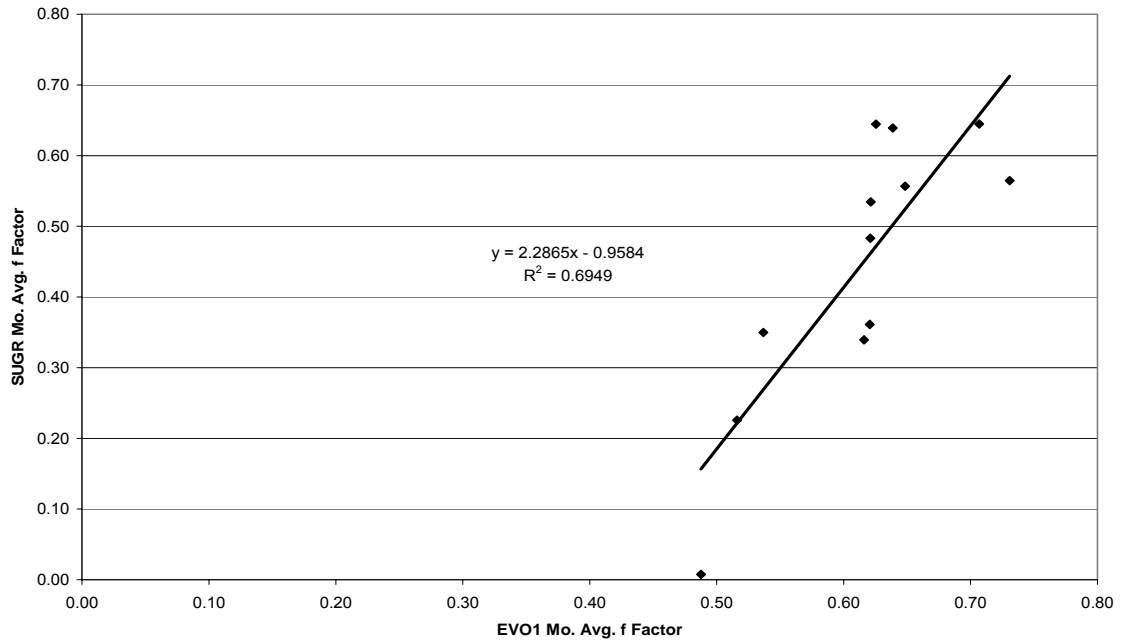


Figure 6: f Factor Comparison EVO1 vs. SUGR

f Factor Comparison EVO2 vs SUGR

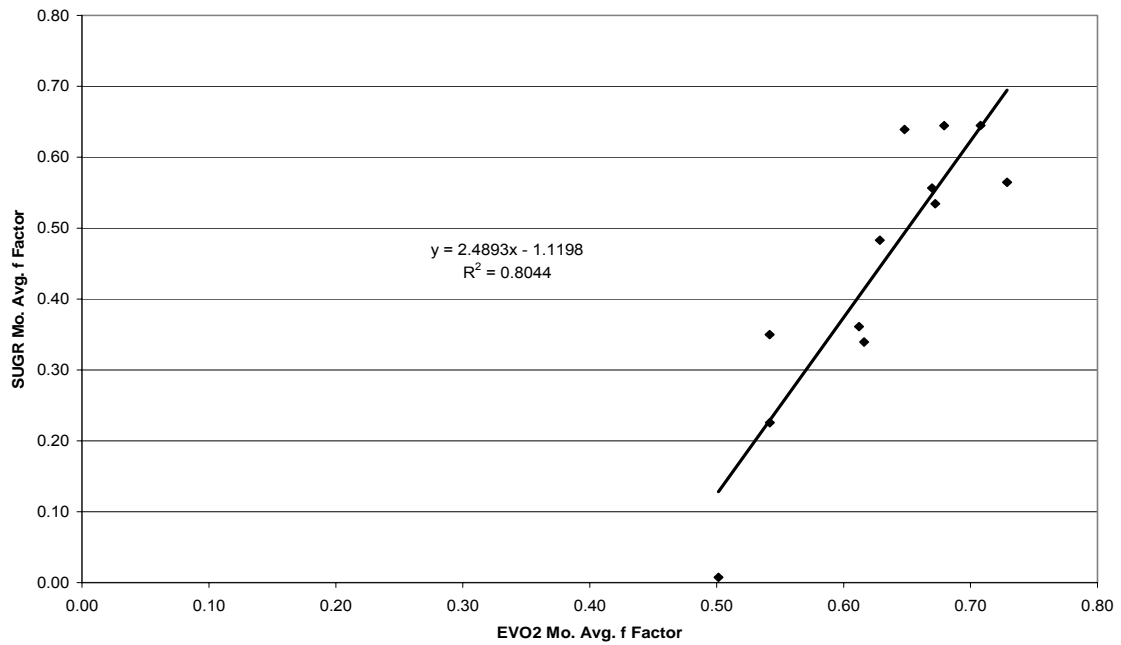


Figure 7: f Factor Comparison EVO2 vs. SUGR

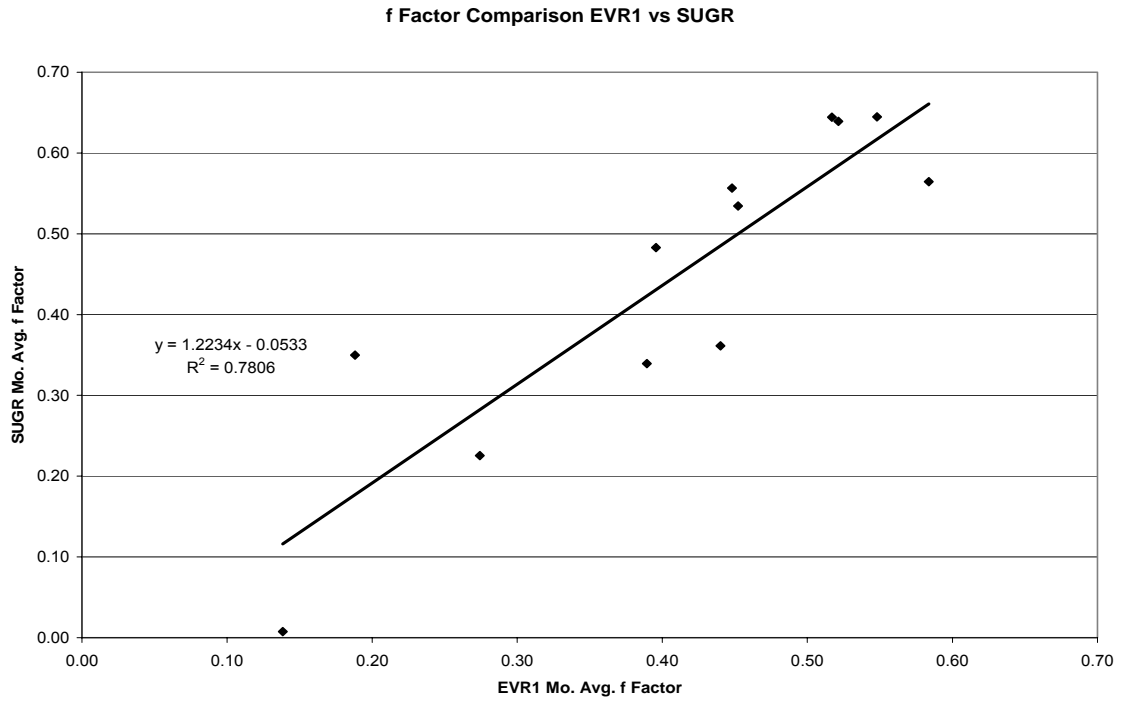


Figure 8: f Factor Comparison EVR1 vs. SUGR

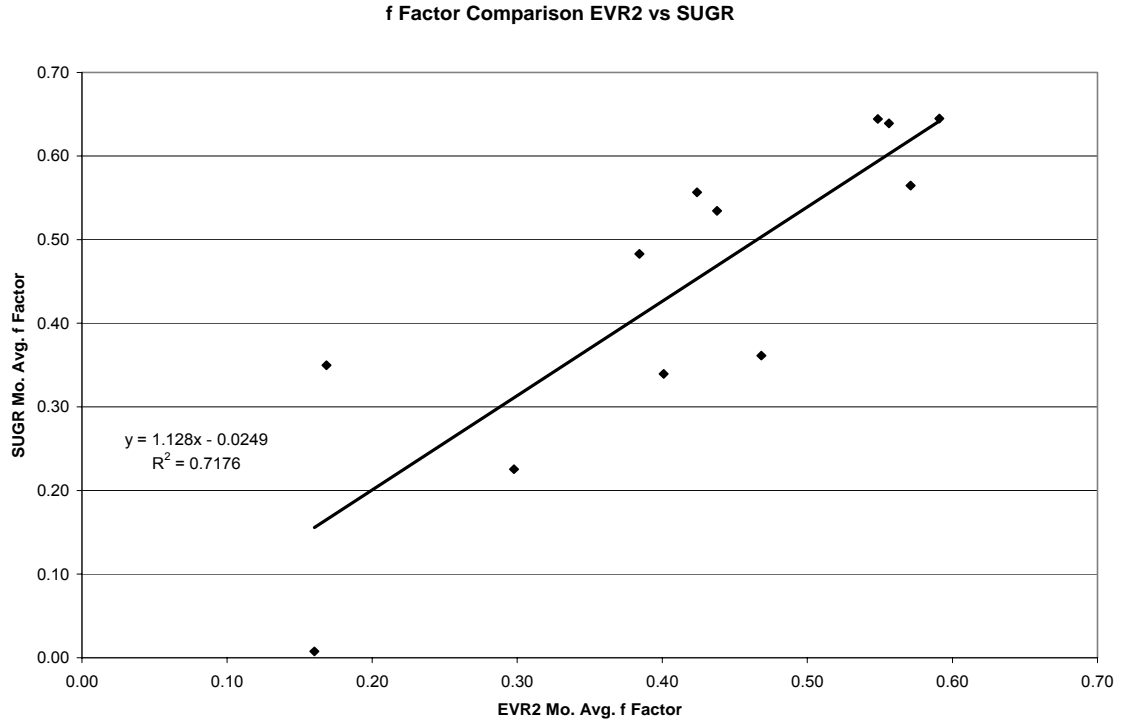


Figure 9: f Factor Comparison EVR2 vs. SUGR

Water Quality:

Water quality analysis was also performed for the duration of this project. The parameters of interest are those mentioned in the introduction section of this report. The results show a comparison of the water quality results of the full sized green roof and control roof with the water quality results of the equivalent experimental green roof and control roof chambers.

The graphs presented below in Figures 10 and 11 shows the ortho- and total phosphorus concentration comparison between the student union green roof, the student union control roof, the experimental green roof chambers, and the experimental control roof chambers. The ortho-phosphorus concentrations for the student union green roof show very little discrepancy from the green roof experimental chambers. The student union control roof, however, does show a significant difference in concentration with the control roof experimental chambers. All student union green roof data have higher concentration of ortho-phosphorus than the control roof data.

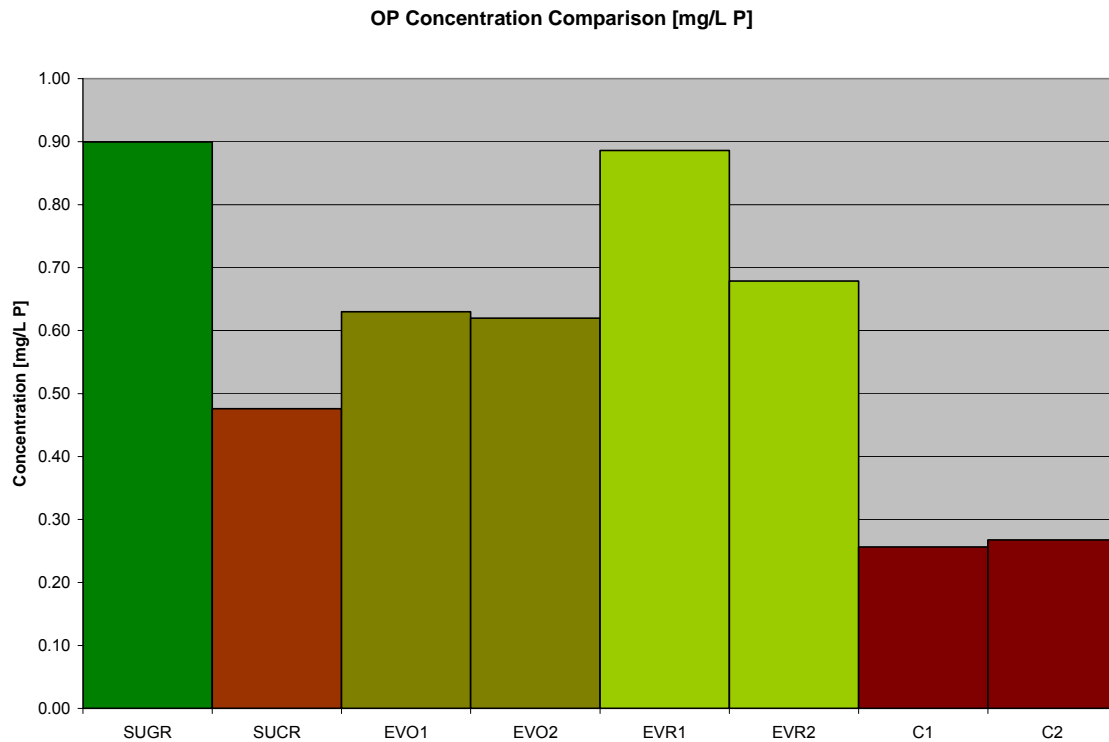


Figure 10: Ortho-Phosphorus Concentration Comparison

The total phosphorus concentration comparison graph shows similar results as the ortho-phosphorus comparison graph. The green roof concentrations are close to the same while the control roof concentrations are different from one another. Again, the green roof concentrations are higher than the control roof concentrations for total phosphorus.

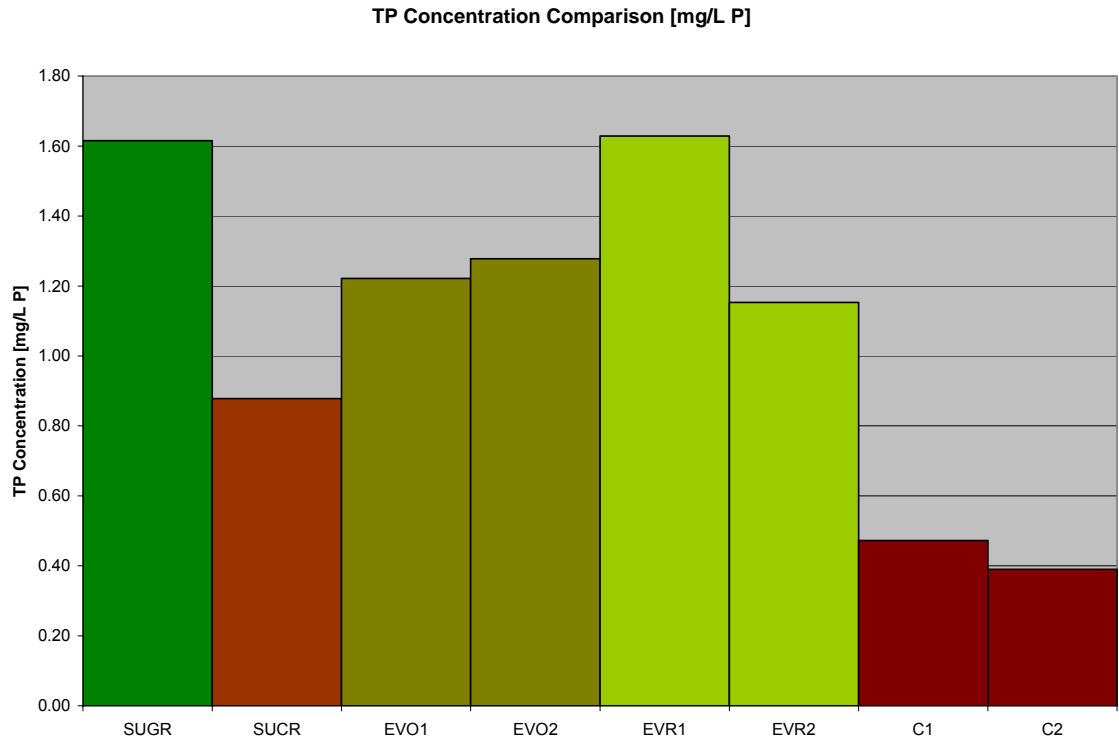


Figure 11: Total Phosphorus Concentration Comparison

The results for the nitrate+nitrite concentration comparison are shown below in Figure 12. From this graph it can be seen that there is a significant difference between the student union green roof and the green roof chambers nitrate+nitrite concentrations. A similar difference can be seen in the student union control roof and the control roof chambers. Figure 12 also shows that for all cases the control roofs have a higher nitrate+nitrite concentration than the green roofs.

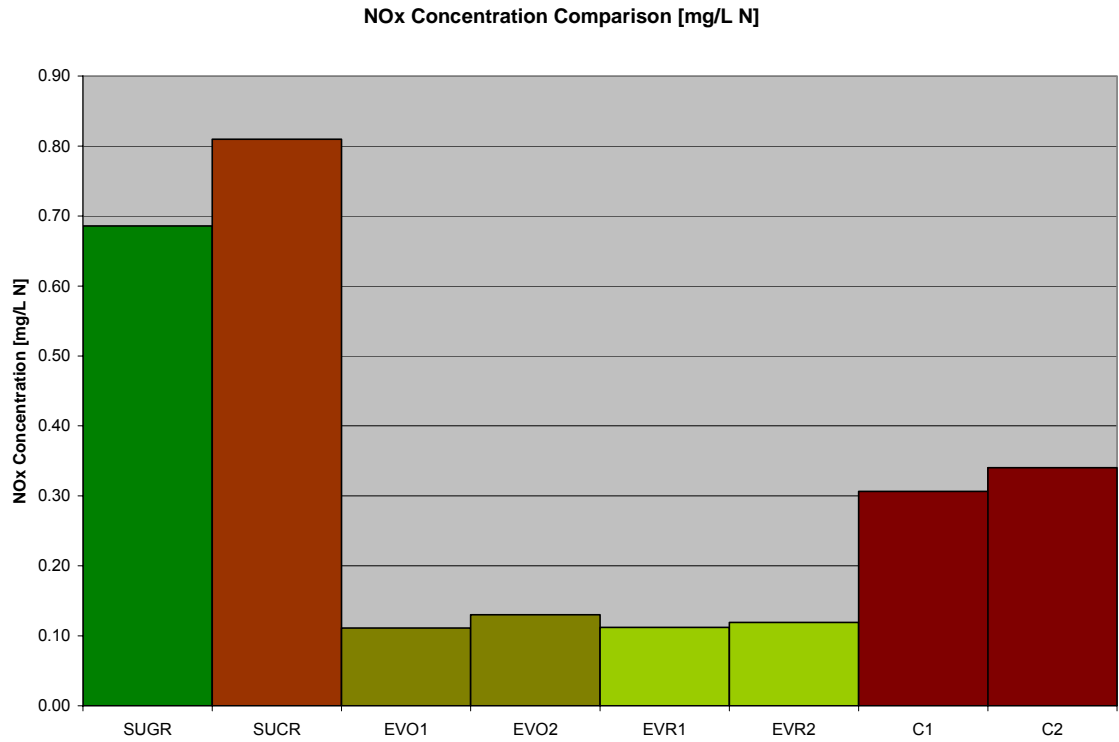


Figure 12: Nitrate+Nitrite Concentration Comparison

The results for the ammonia concentration comparison are shown below in Figure 13. From this graph it can be seen that there is a significant difference between the student union green roof and the green roof chambers ammonia concentrations. A similar difference can be seen in the student union control roof and the control roof chambers. Figure 12 also shows that for all cases the control roofs have a higher ammonia concentration than the green roofs.

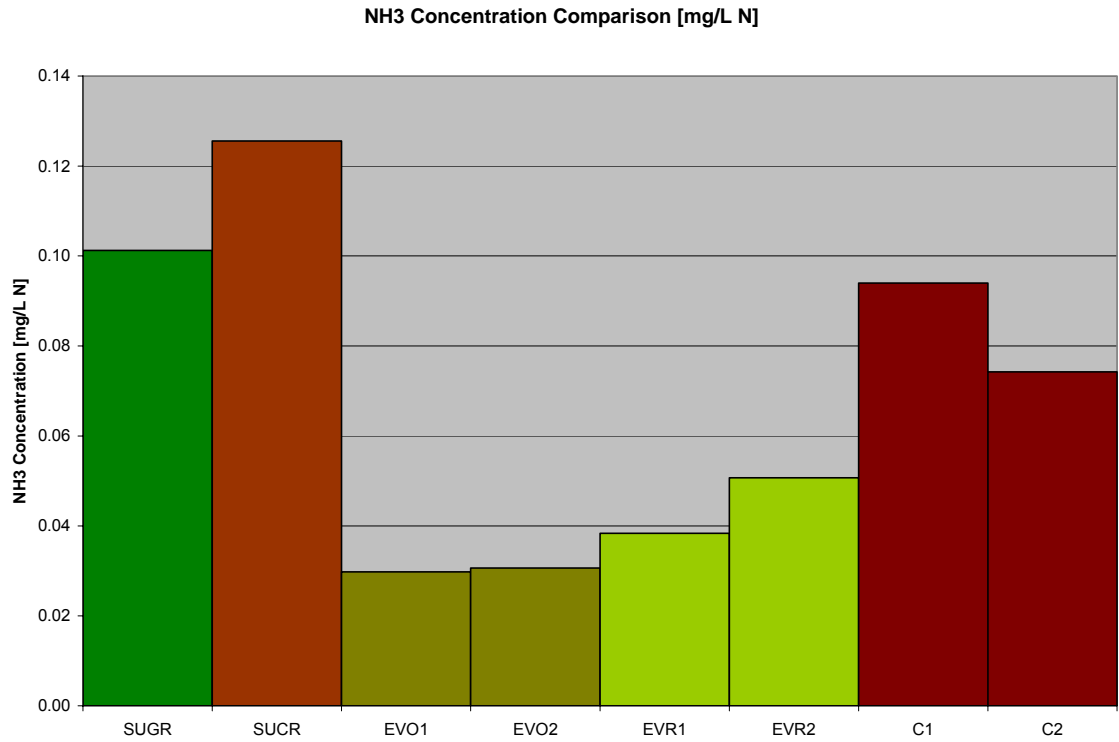


Figure 13: Ammonia Concentration Comparison

Analysis of TKN concentration was also performed. The results are presented in Figure 14. The TKN concentration analysis shows no significant difference between any of the green roof chambers, the full size green roof and the control roofs for the chambers and the full size roof. When looking at TKN on a mass basis however, it can be seen that the green roof is effective at significantly reducing the mass when compared to the control roofs (see Table 3).

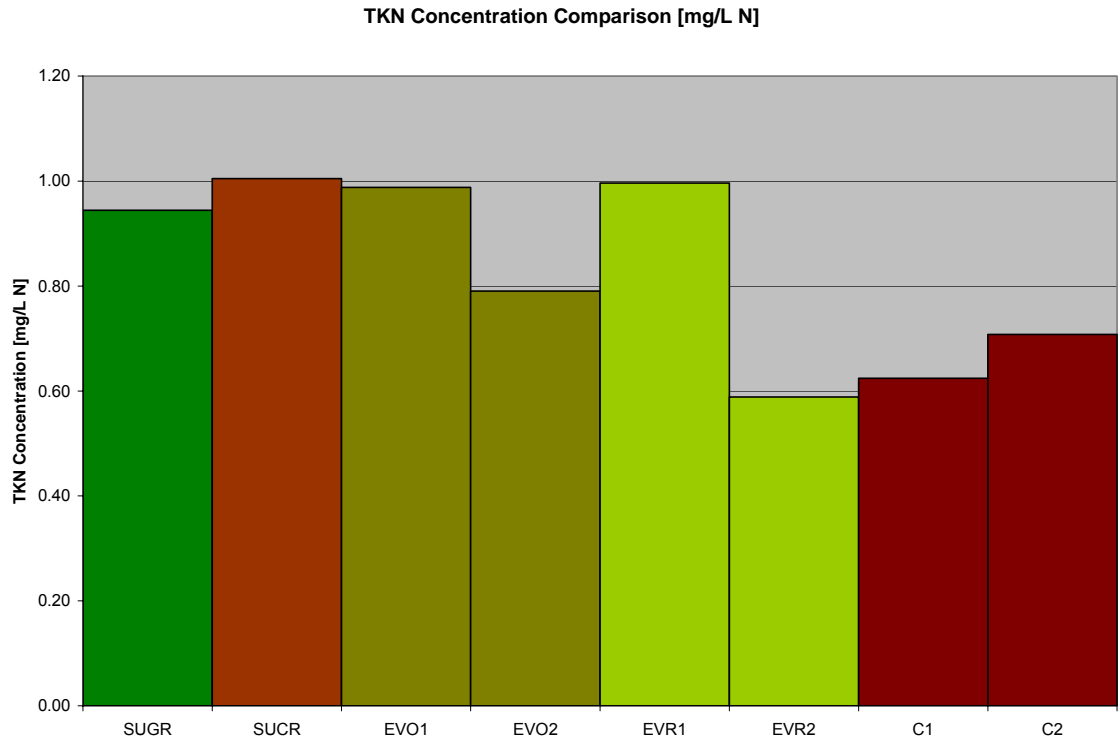


Figure 14: TKN Concentration Comparison

The results for the total nitrogen comparison analysis are shown below in Figure 15. As with the TKN results the total nitrogen results show no significant difference between the green roof concentration and the control roof concentration. Looking at a mass comparison however, shows that the control roofs have a much higher mass loading leaving than the green roofs (see Table 3).

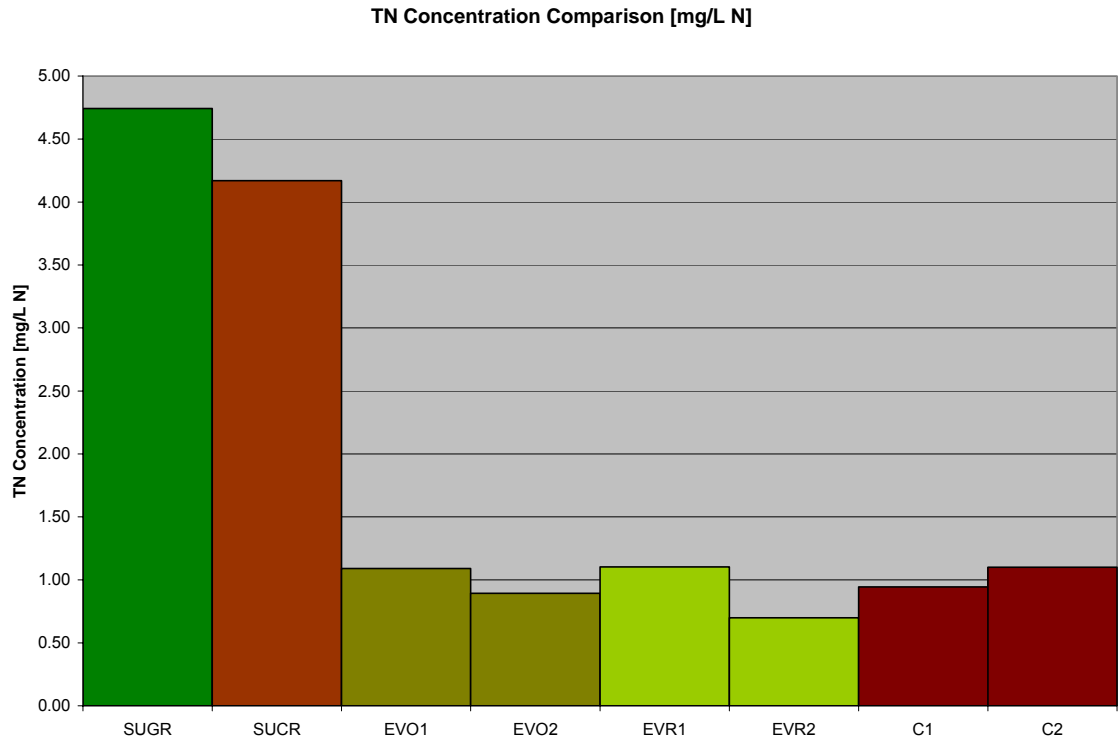


Figure 15: Total Nitrogen Concentration Comparison

Total suspended solids were also examined in this work. Figure 16 below shows the results from this analysis. It can be seen from the graph in Figure 16 that there is no significant difference between the green roofs and the control roofs, although, the control roofs have a slightly higher concentration. When looking at total suspended solids on a mass basis however, it can be seen that the green roofs significantly reduce the mass leaving the system when compared to the control roofs (see Table 3).

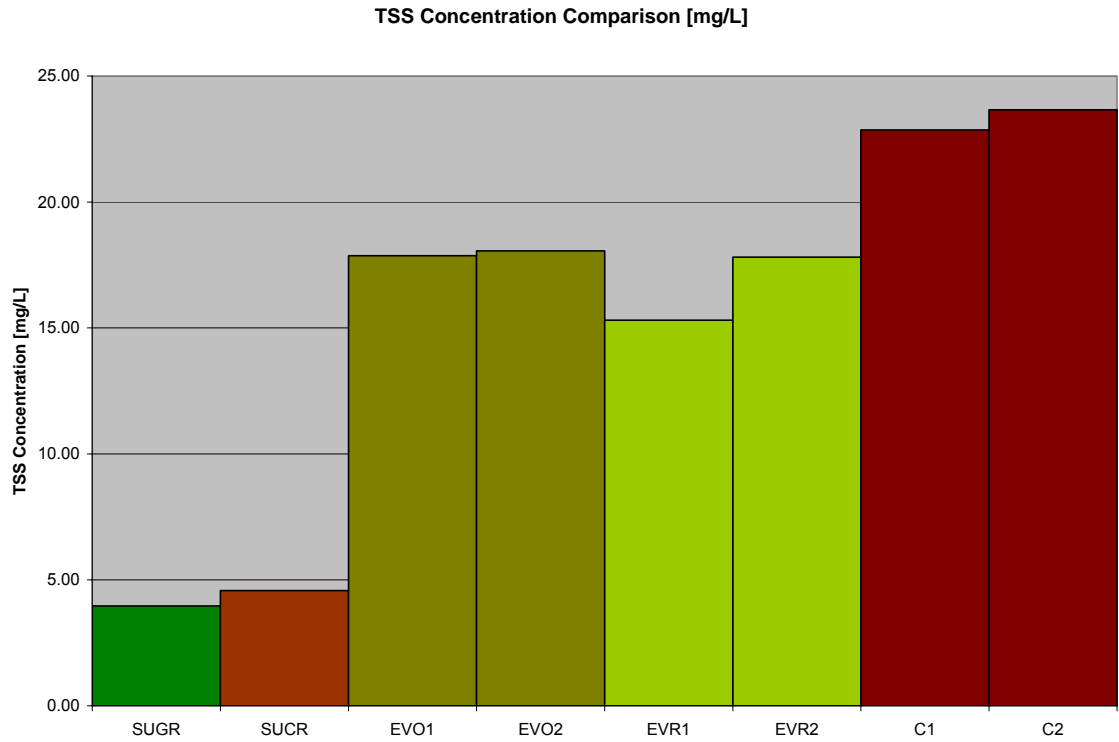


Figure 16: Total Suspended Solids Concentration Comparison

Total dissolved solids concentration comparison results are shown below in Figure 17. The results of this analysis show that green roofs significantly increase the concentration of dissolved solids in runoff when compared to the control roofs. When examining the mass comparison in Table 3 it can be seen that the green roofs significantly increase the mass loading of dissolved solids when compared to the control roofs.

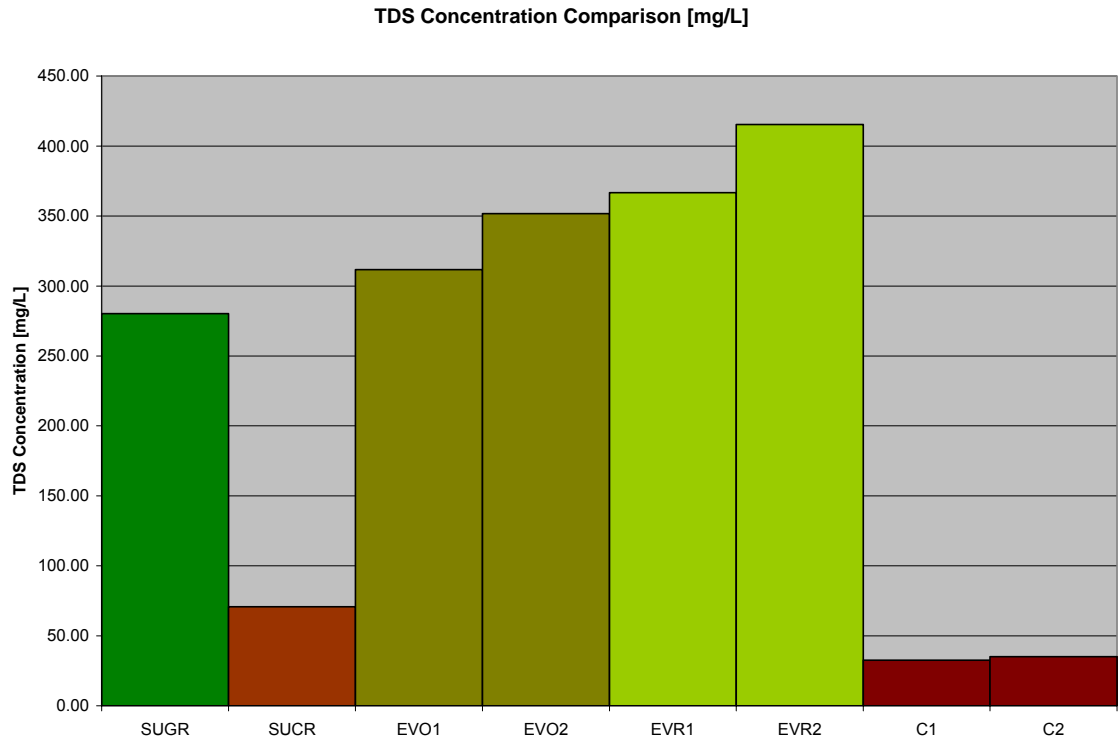


Figure 17: Total Dissolved Solids Concentration Comparison

The results of the total solids analysis, which is the sum of the total suspended and total dissolved solids, are presented below in Figure 18. This analysis shows that the concentration of total solids in green roof runoff is significantly higher than that of the control roofs. The mass comparison in Table 3 shows similar results, that is, the green roofs have a higher mass loading than the control roofs.

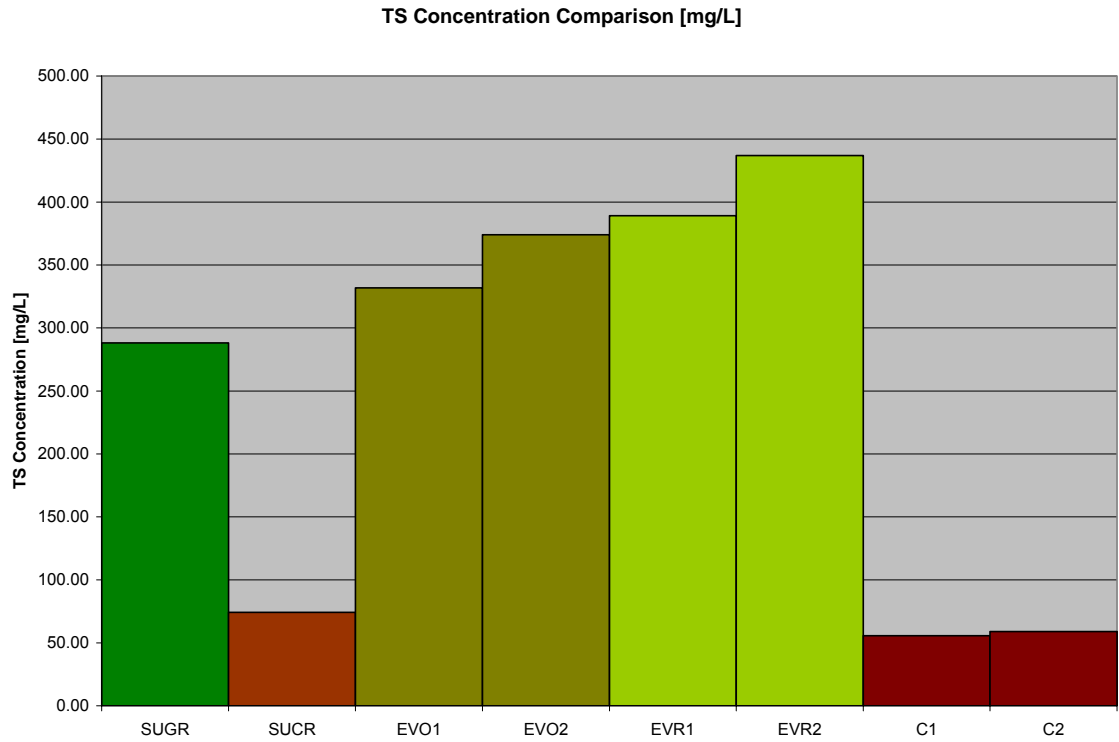


Figure 18: Total Solids Concentration Comparison

The alkalinity concentration comparison presented below in Figure 19 shows that green roofs significantly increase the buffering capacity of the stormwater runoff when compared to the control roofs. Examination of the mass comparison shows that green roofs have significant mass loading of alkalinity when compared to the control roofs (see Table 3).

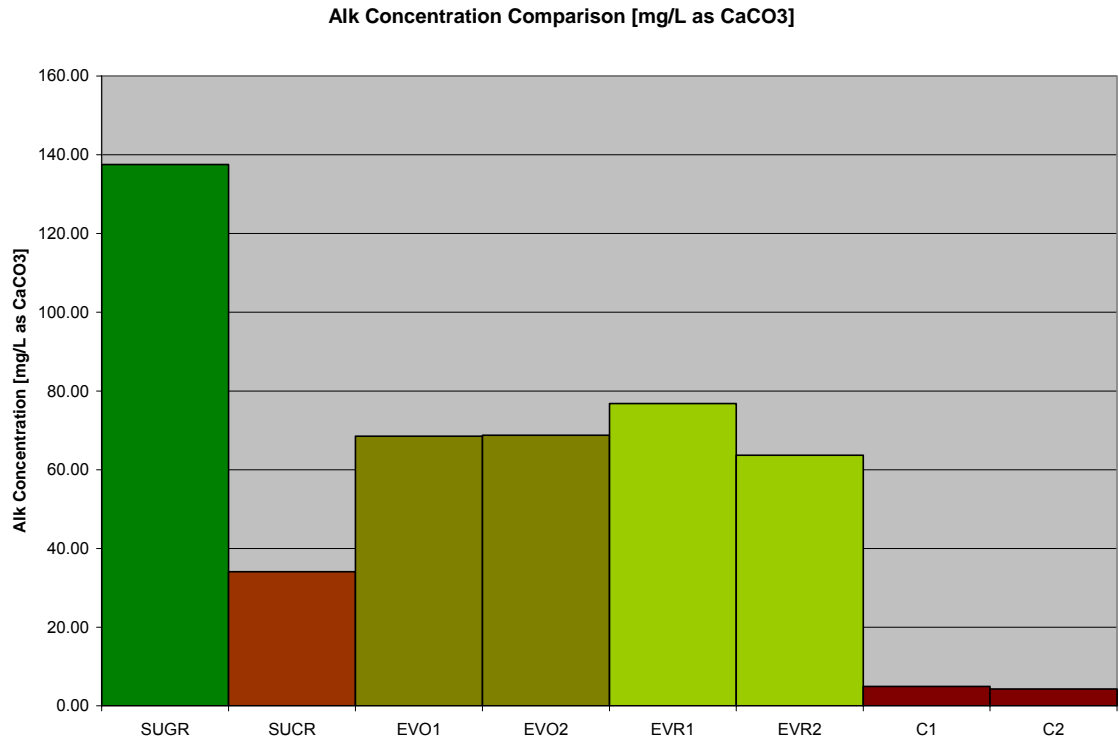


Figure 19: Alkalinity Concentration Comparison

The pH comparison shown below in Figure 20 shows that for both the green roofs and the control roofs the pH is close to neutral. The green roofs did have a higher pH than the control roofs, about 8 to 9 compared to 6 to 7.

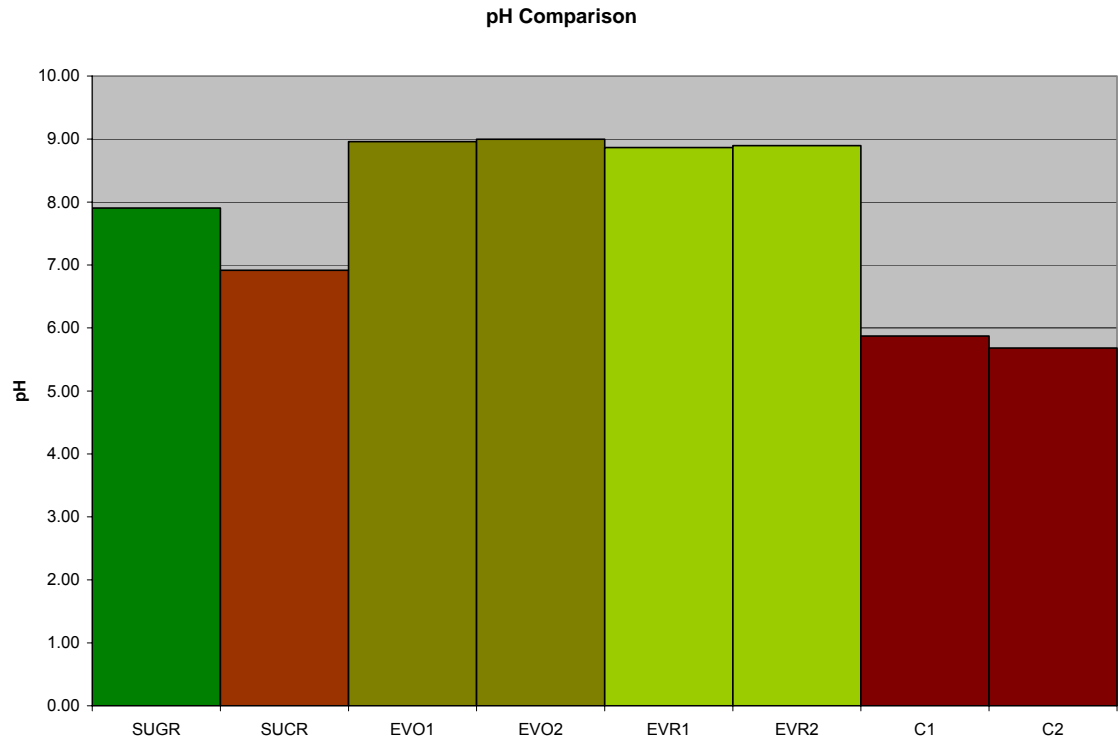


Figure 20: pH Comparison

Table 3: Green Roof vs. Control Roof Mass Comparison

	Mass Out Comparison With Control Roof									
	OP [mg P]	TP [mg P]	NO _x [mg N]	NH ₃ [mg N]	TKN [mg N]	TN [mg N]	TSS [mg]	TDS [mg]	TS [mg]	Alkalinity [mg as CaCO ₃]
SUGR	57043.36	102426.05	43490.80	6420.72	59891.57	300710.20	251692.38	17773602.88	18271508.45	8721259.30
RPD Between Control	-26.38	-29.04	-97.67	-101.38	-89.51	-73.67	-95.86	46.41	44.64	48.40
SUCR	74375.43	137228.80	126515.99	19620.65	156938.40	651410.00	715053.46	11078188.81	11603274.07	5322439.19
EVO1	179.55	348.27	31.69	8.48	281.56	310.71	5091.47	88818.48	94590.85	19532.31
RPD Between Control 1	-81.88	-77.66	-176.71	-179.53	-115.03	-134.23	-153.00	47.81	1.59	80.93
RPD Between Control 2	-85.51	-60.89	-178.91	-174.43	-123.13	-142.24	-154.39	40.90	-4.24	93.35
EVO2	199.98	412.44	42.03	9.88	255.04	288.30	5828.52	113466.73	120730.87	22184.82
RPD Between Control 1	-72.71	-62.85	-169.68	-176.34	-121.46	-138.24	-147.10	70.14	25.84	91.30
RPD Between Control 2	-76.50	-45.17	-172.50	-170.51	-129.09	-145.84	-148.64	63.68	20.09	103.01
EVR1	252.21	463.64	31.95	10.93	283.62	313.90	4357.85	104381.93	110811.16	21865.58
RPD Between Control 1	-51.79	-52.12	-176.53	-174.01	-114.54	-133.67	-159.08	62.72	17.37	90.15

RPD Between Control 2	-55.87	-33.93	-178.74	-167.64	-122.68	-141.74	-160.31	56.08	11.58	101.94
EVR2	221.73	376.63	38.91	16.55	192.28	228.20	5817.55	135678.14	142660.31	20797.23
RPD Between Control 1	-63.59	-70.91	-171.77	-161.90	-137.78	-149.49	-147.18	85.30	42.04	86.11
RPD Between Control 2	-67.52	-53.70	-174.41	-152.95	-144.10	-155.89	-148.72	79.26	36.44	98.18
C1	428.45	790.42	512.47	157.20	1043.91	1578.92	38241.98	54545.64	93100.66	8278.33
C2	447.74	653.11	569.21	124.14	1183.55	1841.12	39563.79	58662.30	98686.45	7101.23

CONCLUSIONS

A 1600 square foot green roof on the student union at the University of Central Florida has demonstrated over a two year period water quality improvement and runoff volume and rate reductions as stormwater benefits of a green roof system. The system must have a cistern or other detention volume from which green roof filtrate water is reused to irrigate the green roof. Native plants were shown to be the plants of choice.

Water Budget:

The water budget comparisons of the student union green roof with smaller experimental chambers was preformed to determine if the experimental chambers (Hardin, 2006) can be used to predict the operation of a full scale green roof, namely the student union green roof on the campus of the University of Central Florida. Whereas the experimental chambers cross section are exactly the same as the full sized green roof, one main difference in the operation of both was the irrigation amount. The experimental chambers were operated with the same irrigation rate for the duration of the experiment or one year. The full sized green roof was operated with varying irrigation rates (see Figure 21). The average weekly irrigation amount for the full sized green roof was one inch, which is the same volume as the constant rate irrigated experimental chambers.

For evapotranspiration rates, there is no significant difference between any of the experimental chambers and the student union green roof. They all followed the same seasonal variation (see Figure 5). The results of the hypothesis tests show similar results (see Table 1). It can be seen, however, in Table 1 that the z scores for the regular

irrigated chambers are large negative numbers. This indicates that the evapotranspiration rates for the regular irrigated chambers are lower than the full sized green roof. This is probably due to the fact that the full sized green roof was irrigated with a larger volume than the regular irrigated experimental chambers for several of the irrigation events.

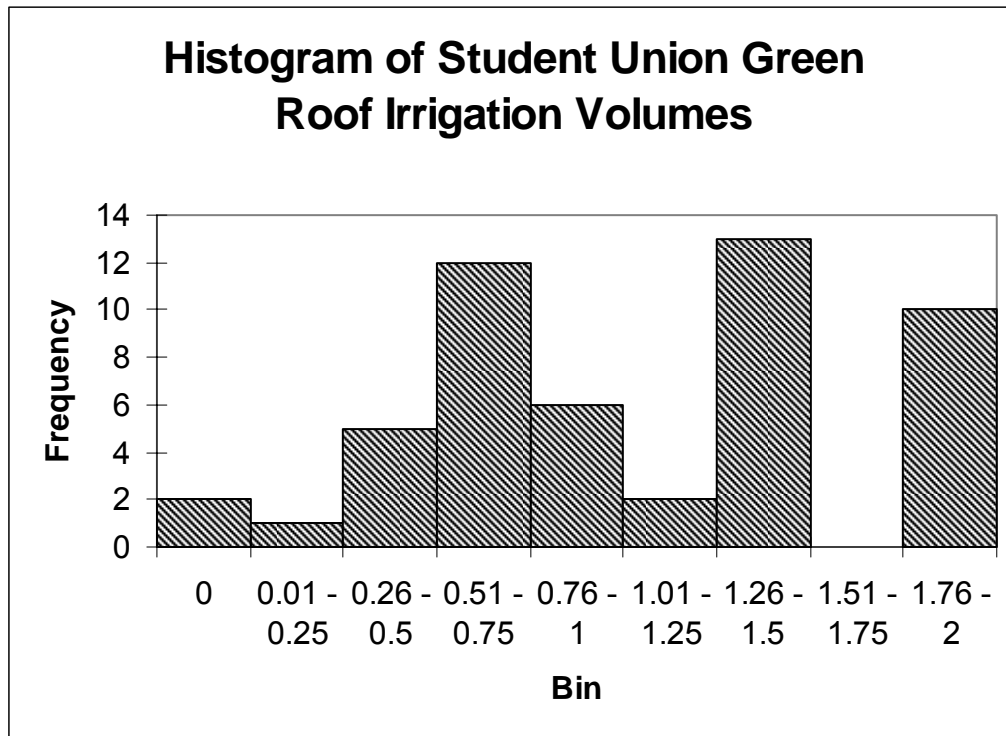


Figure 21: Student Union Green Roof Irrigation Frequencies (Bin is irrigation volume inches/week)

The results for the filtrate factor comparative analysis show that the regular irrigated experimental chambers were a better representation of the full sized green roof. This can be seen in Figures 6 through 9 which show the monthly average filtrate factor comparison for the experimental chambers verses the full sized green roof. Figures 6 and 7 show that the over irrigated chambers had a much higher filtrate factor than the full sized green roof which is evident since the slope of the line is much larger than the perfect fit line of one. Figures 8 and 9 show that the full sized green roof closely matches

the regular irrigation experimental chambers which is evident since the slope of the line is close to the perfect fit line of one. This is reasonable since the total water added to the full sized green roof is close to that of the regular irrigated experimental chambers (see Figure 22). The hypothesis tests showed similar results with the null hypothesis rejected for the regular irrigated experimental chambers and accepted for the over irrigated experimental chambers, $\alpha = 0.05$.

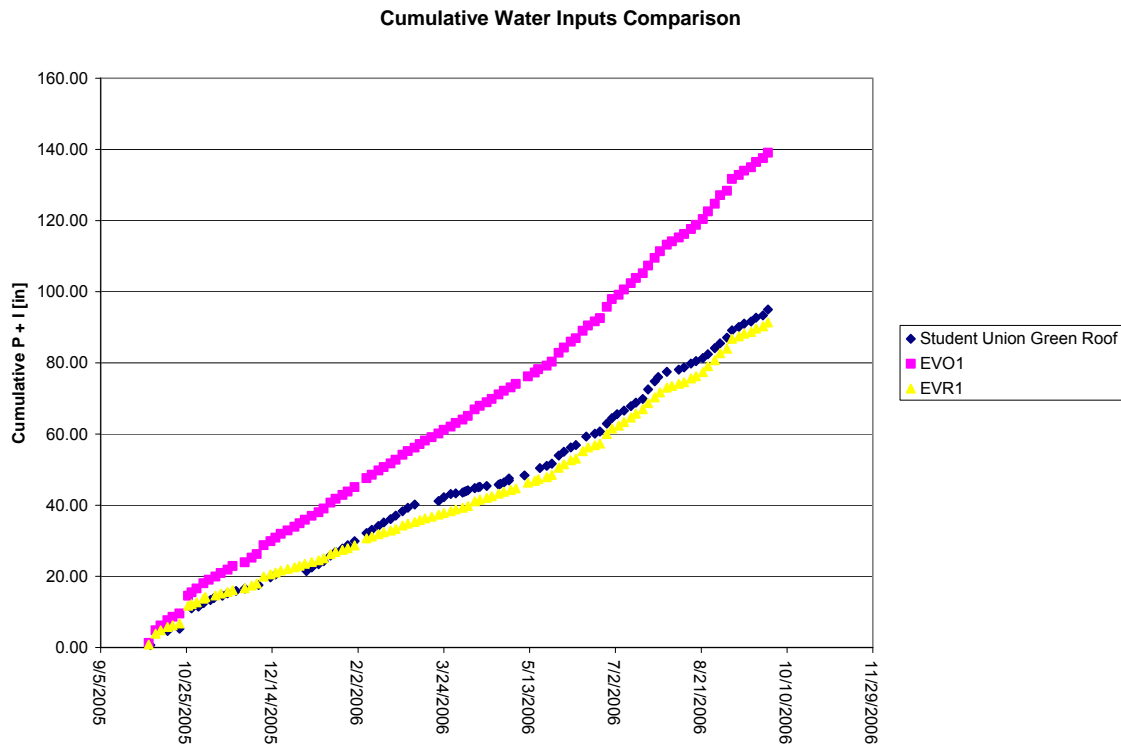


Figure 22: Comparison of Cumulative Water Inputs

Water Quality:

A comparative analysis of the water quality from a full sized green roof and the experimental chambers was performed as part of this study (Hardin, 2006). This analysis

compares the water quality results of the full sized student union green roof with the experimental chambers and also compares the control roofs of both.

The ortho- and total phosphorus results show that the concentrations for the green roof and experimental chambers are equivalent (see Figures 10 and 11). The student union control roof, however, shows a significant difference in phosphorus concentration when compared to the experimental control chambers (see Figures 10 and 11). This is likely due to the full sized control roof receiving over spray from the full size green roof irrigation. It is probable that the use of spray irrigation on the full sized green roof contributed to the nutrient pollution measured from the control roof. Another potential source for this discrepancy is wind blown particles and the green roof leaking under the aluminum retaining wall separating the green roof from the control roof.

The mass comparison for ortho- and total phosphorus shows that green roofs are effective at reducing the mass when compared to control roofs (see Table 3). This result was consistent for both the full sized roofs as well as the experimental chambers. A notable discrepancy is that the mass reduction for the full sized green roof was not as pronounced as with the experimental chambers. This could be due to the concentration difference of the full sized control roof and the experimental control roof chambers. Another potential source for this difference could be that the full sized green roof was not operated in an optimal manner. Frequently makeup water was added when it was not necessary for irrigation. This would cause more overflow events than was experienced with the experimental chambers. This difference could also be explained by the fact that the full sized green roof had a cistern storage volume equal to 1.5 inches over the green roof area while the experimental chambers had a storage volume equal to 5 inches over

the green roof area. All three of the aforementioned reasons could explain the noted discrepancy, but, it is likely a result of all three.

The nitrate+nitrite and ammonia concentration comparison results show that for all cases the green roof had a lower concentration than the control roof (see Figures 12 and 13). Examining the nitrate+nitrite and ammonia concentration comparisons it is clear that the full sized green roof and control roof concentration was much higher than the experimental green roof and control roof chambers (see Figures 12 and 13). This difference is attributed to the extensive use of fertilizer on the full sized green roof in comparison to the experimental chambers and the issue of overspray on the control roof mentioned above. The mass comparison presented in Table 3 shows that green roofs are effective at reducing the mass of nitrate+nitrite and ammonia when compared to a control roof. Similar differences exist as those mentioned above in the discussion of ortho- and total phosphorus.

The results of the TKN concentration comparative analysis show no significant difference between the full sized green roof, the full sized control roof, the experimental green roof chambers, or the experimental control roof chambers (see Figure 14). The TKN mass comparison results presented in Table 3 show that green roofs are an effective solution, when compared to the control roofs, achieving a significant mass reduction. This is due mostly to the reduction of runoff volume.

The total nitrogen concentration comparison results show similar results as the TKN analysis. There exists no significant difference between the green roofs and the control roofs total nitrogen concentration (see Figure 15). There is a significant difference between the full sized green roof and control roof when compared to the

experimental green roof and control roof chambers (see Figure 15). This is due to the addition of fertilizer on the full sized green roof and the overspray conditions explained in the phosphorus conclusions. The mass comparison shown in Table 3, however, shows that the mass loading of the green roofs are much less than that of the control roofs.

The results of the total suspended solids show no significant difference between the green roofs and the control roofs, although the control roofs had a slightly higher concentration (see Figure 16). The comparison in Figure 16 also shows that the full sized green roof and control roof had a much lower concentration than the experimental green roof and control roof chambers. This could be due to several reasons such as; the full sized green roof irrigation water was filtered to reduce maintenance on the irrigation equipment, the experimental chambers were closer to the ground allowing for a higher potential of wind blown particles, and algae was noted growing in the clear catchment basins to name a few. The mass comparison presented in Table 3 shows that green roofs are effective at reducing the total suspended solids mass loading when compared to the control roofs.

The results for total dissolved solids and total solids are almost identical (see Figures 17 and 18). Both results show that green roofs have a significantly higher concentration than that of the control roofs (see Figures 17 and 18). A comparison of the full sized green roof and the experimental green roof chambers shows that there is no significant difference in concentration. The same conclusion can be made from a comparison of the full sized control roof and the experimental control roof chambers. The mass comparison analysis presented in Table 3 shows that for both total dissolved solids and total solids there is a significant increase in mass loading for the green roofs

when compared to the control roofs. This analysis along with the total suspended solids analysis (see Figure 16) shows that, as would be expected, the major component of the total solids leaving a green roof in stormwater runoff is the dissolved solids component.

The results of the alkalinity concentration comparison (see Figure 19) show that green roofs significantly increase the concentration when compared to the control roofs. The analysis shows that the control roofs have almost no alkalinity where as the green roofs have a high alkalinity concentration (see Figure 19). The mass comparison shows that green roofs, as expected, increase the alkalinity significantly when compared to the control roofs (see Table 3).

The results of the pH comparison shown in Figure 20 shows that green roofs increase the pH when compared to the control roofs. The control roofs had a pH close to neutral with a range of 6 to 7 while the green roofs had a higher pH with a range of 8 to 9.

SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

The use of green roof stormwater treatment systems as an urban stormwater treatment method shows great potential. Green roof stormwater treatment systems offer several advantages over conventional stormwater treatment methods. Some of the expected benefits include reduction of urban heat island effect, reduction in heating and cooling costs, longer roof life, the ability to treat and store stormwater using previously wasted space and not requiring additional ground level space, and improvement of

building aesthetics, just to name a few. The ability of this treatment method to offer so many other, non-stormwater related, benefits makes this option a particularly attractive one.

The results of this study present several outcomes worth mentioning. First, the results of the full sized green roof stormwater treatment system can be described by the results of the experimental green roof stormwater treatment system chambers for both water quality and quantity. Next, green roof stormwater treatment systems are a promising stormwater treatment method with the ability to reduce the concentration of nitrogen species and suspended solids and reduce the mass of all nutrients studied. Green roof stormwater treatment systems also reduce the volume of stormwater while attenuating the rate of flow. Again it is highly recommended that the green roof system includes a cistern. The cistern addition is needed to achieve the water quality mass reductions noted in this report.

During the course of this project several areas of future study were noted. First, an effective way to measure the overflow from the cistern needs to be examined. A major issue with this project was that the flow meters did not work as intended and other devices need to be examined. Also, an automated irrigation system should be used which incorporates the addition of makeup water. The full sized green roof stormwater treatment system for this study was irrigated by usually manually turning on a pump for irrigation and if makeup water is needed, it was manually added. This caused excess makeup water to be added which resulted in increased overflow events or lower retention efficiency. It is the recommendation of the authors to use a more reliable device to

monitor the cistern depth and add makeup water according to the required irrigation amount.

The authors also recommend that the technique for irrigation application should be drip applied at the surface. The full sized green roof used a spray irrigation scheme which resulted in significant overspray. The use of a surface drip irrigation system will minimize this overspray while training the plant roots to grow out rather than down, as opposed to root zone drip irrigation.

A complete analysis of the cistern environment also needs to be performed. This includes but is not limited to a profile of the bacterial communities prevalent and a detailed analysis of the dissolved oxygen levels and how they relate to cistern depth. This analysis will allow for determination of the potential for nitrification and denitrification.

APPENDIX A: Water Budget Raw Data

Student Union Green Roof Master Spreadsheet

Date	Volume of Rain [liters]	Initial Volume [liters]	Filtrate volume [liters]	Overflow [liters]	Water added [liters]	Post irrigation volume [liters]	Irrigation volume [liters]	ΣET [liters]	ET [in/day]	ET (Monthly Average) [in/day]	f factor	f factor (Monthly Average)
10/4/2005	717	4393	2292	0	0	2610	1783	144	0.01		0.94	
10/14/2005	13292	5157	10543	7996	0	3311	1846	4531	0.12		0.70	
10/21/2005	340	3629	318	0	0	1592	2037	1868	0.07		0.15	
10/28/2005	19862	5157	17368	13803	0	3374	1783	4531	0.17	0.09	0.79	0.64
11/1/2005	0	3820	446	0	0	2037	1783	1337	0.09		0.25	
11/4/2005	1888	4393	2356	0	0	2515	1878	1315	0.12		0.64	
11/8/2005	0	2674	159	0	1146	637	3183	1719	0.11		0.08	
11/10/2005	0	3374	2738	0	0	1464	1910	446	0.06		0.86	
11/15/2005	151	2992	1528	0	955	1401	2547	533	0.03		0.74	
11/18/2005	0	2419	1019	0	1273	1210	2483	1528	0.13		0.40	
11/23/2005	38	2483	1273	0	2037	1846	2674	1247	0.07		0.51	
11/28/2005	0	2865	1019	0	2292	2578	2578	1655	0.09	0.09	0.38	0.48
12/6/2005	982	4584	2005	0	0	1910	2674	1555	0.05		0.56	
12/13/2005	5400	5157	3542	296	0	2547	2610	4531	0.17		0.44	

Date	Volume of Rain [liters]	Initial Volume [liters]	Filtrate volume [liters]	Overflow [liters]	Water added [liters]	Post irrigation volume [liters]	Irrigation volume [liters]	Σ ET [liters]	ET [in/day]	ET (Monthly Average) [in/day]	f factor	f factor (Monthly Average)
12/16/2005	151	4456	1910	0	0	1592	2865	851	0.08	0.10	0.69	0.56
1/3/2006	151	3247	1655	0	1273	1019	3501	1361	0.02		0.55	
1/6/2006	378	3056	2037	0	1401	1019	3438	1842	0.16		0.53	
1/10/2006	0	2929	1910	0	1528	1019	3438	1528	0.10		0.56	
1/13/2006	0	3120	2101	0	1401	1146	3374	1337	0.12		0.61	
1/17/2006	2492	3820	2674	0	1337	1719	3438	3192	0.21		0.46	
1/20/2006	529	3692	1974	0	1273	1528	3438	1993	0.18		0.50	
1/24/2006	0	3883	2356	0	1082	1528	3438	1082	0.07		0.69	
1/27/2006	151	3565	2037	0	1592	1655	3501	1552	0.14		0.57	
1/31/2006	906	4138	2483	0	0	891	3247	1925	0.13	0.13	0.56	0.56
2/7/2006	5060	4329	3438	0	828	1655	3501	4869	0.18		0.41	
2/10/2006	0	2929	1273	0	1655	1146	3438	2228	0.20		0.36	
2/14/2006	491	3565	2419	0	891	764	3692	1509	0.10		0.62	
2/17/2006	0	3056	2292	0	1401	828	3629	1401	0.12		0.62	
2/21/2006	0	3120	2292	0	1337	828	3629	1337	0.09		0.63	
2/24/2006	0	2610	1783	0	2037	1082	3565	1846	0.16		0.49	
2/28/2006	1284	4011	2929	0	573	1019	3565	1920	0.13	0.14	0.60	0.53
3/3/2006	0	3120	2101	0	1528	1082	3565	1464	0.13		0.59	
3/7/2006	0	2547	1464	0	1974	1019	3501	2101	0.14		0.41	
3/21/2006	0	2547	1528	0	2292	1210	3629	1974	0.04		0.44	
3/24/2006	566	1910	700	0	2674	1146	3438	3495	0.31		0.17	
3/28/2006	0	2037	891	0	2419	955	3501	2547	0.17		0.26	
3/31/2006	0	1783	828	0	2738	3788	732	2674	0.24	0.17	0.24	0.35
4/4/2006	0	3788	0	0	0	2992	796	732	0.05		0.00	
4/5/2006	0	2992	0	0	0	2228	764	796	0.21		0.00	
4/6/2006	0	2228	0	0	0	1464	764	764	0.20		0.00	
4/7/2006	0	1528	64	0	0	764	764	700	0.19		0.08	
4/11/2006	1737	764	0	0	1719	1719	764	2501	0.17		0.00	

Date	Volume of Rain [liters]	Initial Volume [liters]	Filtrate volume [liters]	Overflow [liters]	Water added [liters]	Post irrigation volume [liters]	Irrigation volume [liters]	ΣET [liters]	ET [in/day]	ET (Monthly Average) [in/day]	f factor	f factor (Monthly Average)
4/13/2006	0	1719	0	0	0	955	764	764	0.10		0.00	
4/14/2006	0	955	0	0	955	1210	700	764	0.20		0.00	
4/18/2006	0	1210	0	0	1210	1687	732	700	0.05		0.00	
4/25/2006	529	1687	0	0	-32	828	828	1261	0.05		0.00	
4/26/2006	0	828	0	0	1146	828	1146	828	0.22		0.00	
4/28/2006	0	828	0	0	2547	2101	1273	1146	0.15	0.14	0.00	0.01
5/1/2006	0	2101	0	0	764	828	2037	1273	0.11		0.00	
5/1/2006	0	828	0	0	2165	796	2196	2037	0.18		0.00	
5/10/2006	642	2260	1464	0	2005	1687	2578	1374	0.04		0.52	
5/19/2006	5135	3947	2260	0	0	1401	2547	5454	0.16		0.29	
5/23/2006	0	1878	477	0	1942	1337	2483	2069	0.14		0.19	
5/26/2006	38	1783	446	0	2260	1662	2381	2075	0.18		0.18	
5/30/2006	6193	5138	3476	0	0	2884	2254	5098	0.34	0.16	0.41	0.23
6/2/2006	1586	3037	153	0	1280	1751	2566	3687	0.33		0.04	
6/6/2006	2379	2769	1019	0	1050	1655	2165	3926	0.26		0.21	
6/9/2006	0	2368	713	0	2025	1872	2521	1452	0.13		0.33	
6/15/2006	7288	5144	3272	0	0	3451	1693	6536	0.29		0.33	
6/20/2006	529	4125	675	0	0	1643	2483	1547	0.08		0.30	
6/23/2006	0	2165	522	0	1961	1700	2426	1961	0.17		0.21	
6/27/2006	6079	5150	3974	523	0	2820	2330	4531	0.30		0.47	
6/30/2006	3549	5157	5880	3543	0	2929	2228	0	0.00	0.19	1.00	0.36
7/3/2006	1926	4908	1980	0	0	2508	2400	2174	0.19		0.48	
7/7/2006	982	4004	1496	0	0	1439	2566	1886	0.12		0.44	
7/11/2006	2228	3973	2534	0	0	1522	2451	2260	0.15		0.53	
7/14/2006	1359	2578	1057	0	1725	1821	2483	2754	0.24		0.28	
7/18/2006	3927	4310	2489	0	0	4310	0	3921	0.26		0.39	
7/21/2006	10044	5163	10044	9191	0	5163	0	0	0.00		1.00	
7/25/2006	5891	5150	5891	5903	0	2489	2661	0	0.00		1.00	

Date	Volume of Rain [liters]	Initial Volume [liters]	Filtrate volume [liters]	Overflow [liters]	Water added [liters]	Post irrigation volume [liters]	Irrigation volume [liters]	ΣET [liters]	ET [in/day]	ET (Monthly Average) [in/day]	f factor	f factor (Monthly Average)
7/27/2006	1964	5150	4625	1964	0	2489	2661	0	0.00	0.12	1.00	0.64
8/1/2006	2945	4819	2330	0	0	2292	2527	3276	0.17		0.42	
8/8/2006	0	2949	657	0	801	1303	2447	1870	0.07		0.26	
8/11/2006	0	1939	636	0	1509	1002	2447	1810	0.16		0.26	
8/15/2006	1586	2211	1210	0	1396	1161	2447	2823	0.19		0.30	
8/18/2006	0	1797	636	0	2023	1373	2447	1811	0.16		0.26	
8/22/2006	944	2390	1017	0	1389	1333	2447	2374	0.16		0.30	
8/25/2006	1624	2676	1343	0	1150	1379	2447	2727	0.24		0.33	
8/29/2006	3814	5068	3688	0	0	2591	2477	2572	0.17	0.16	0.59	0.34
9/1/2006	5211	5153	7687	5126	0	5153	0	0	0.00		1.00	
9/5/2006	5966	5153	5966	5966	0	5153	0	0	0.00		1.00	
9/8/2006	7892	5153	7892	7892	0	5153	0	0	0.00		1.00	
9/12/2006	1208	5153	1208	1208	0	2708	2445	0	0.00		1.00	
9/15/2006	868	3801	1093	0	0	1357	2445	2220	0.20		0.33	
9/19/2006	38	2176	819	0	1438	1169	2445	1663	0.15		0.33	
9/22/2006	1510	2474	1305	0	974	1004	2445	2650	0.23		0.33	
9/26/2006	0	1811	807	0	1903	1269	2445	1638	0.14		0.33	
9/29/2006	3814	4273	3004	0	0	1828	2445	3254	0.29	0.11	0.48	0.64

APPENDIX B: Water Quality Raw Data

Water Quality Master Spreadsheet Student Union GR												
Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH
6/22/2005	-	-	0.03	0.423	-	-	5.13	1	704	704.5	230	7.61
6/22/2005	-	-	0.03	0.516	-	-	5.45	1	700	700.5	214	7.77
6/22/05*	0.745	1.243	0.006	0.566	-	2.443	-	-	-	-	191	7.63
8/29/2005	-	-	0.02	0.36	-	-	-	16	100	115.5	-	-
9/5/2005	-	-	-	-	-	-	-	0	288	288	150	7.86
9/12/2005	-	-	0.09	0.04	-	-	1.37	1	340	341	154	7.9
9/19/2005	-	-	0.17	0.04	-	-	0.69	-	280	-	152	7.92
9/26/2005	-	3.34	-	-	-	-	1.08	1	212	212.5	140	7.76
10/3/2005	-	2.11	-	0.08	-	-	2.19	0	236	236	146	7.77
10/10/2005	0.81	-	0.13	0.11	-	-	1.5	5	268	273	152	7.78
10/17/2005	0.85	2.39	-	0.004	-	-	0.66	6	320	326	164	7.94
10/17/2005	0.84	2.14	-	0.01	0.172	-	0.8	7	280	287	166	7.94
10/31/2005	0.53	1.87	0.01	0.11	-	-	1.27	3	336	339	155	7.68
11/7/2005	0.67	1.93	0.17	0.07	-	-	1.93	18	108	125.5	128	7.81
11/14/2005	0.55	1.62	0.03	0.01	-	-	2.46	3	244	247	172	7.81
11/28/2005	0.66	1.77	0.18	0.08	-	-	0.88	0	184	184	168	8.36
12/13/2005	0.6	1.82	0.02	0.008	-	-	-	4	208	212	-	-
1/10/2006	0.82	1.49	0.13	-	-	-	1.22	6	216	222	144	8.03
1/17/2006	-	5.11	0.08	-	0.956	1.036	1.3	3	152	154.5	149	7.86
1/24/2006	0.56	-	0.1	0.034	-	-	1.34	2	284	286	152	7.94
1/31/2006	0.53	-	0.1	0.019	-	-	1.04	3	320	322.5	151	7.9
2/7/2006	0.69	-	0.14	0.015	-	-	1.08	0	256	256	154	7.93
2/14/2006	0.54	0.96	0.13	0.032	-	-	1.15	7	548	555	138	8.13

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH
2/21/2006	0.5	0.57	0.74	0.067	-	-	0.93	2	276	277.5	134	7.84
2/28/2006	2.17	-	6.61	0.706	-	-	0.99	4	404	407.5	156	7.71
3/7/2006	0.97	1.14	6.26	0.068	1.44	7.7	3.54	5	368	372.5	166	7.89
3/7/2006	1.01	1.2	6.58	0.07	1.21	7.79	3.58	5	332	336.5	170	7.86
3/13/2006	0.86	2.14	3.93	0.024	-	-	1.12	0	240	240	182	7.96
3/21/2006	0.84	-	0.45	0.027	-	-	0.94	1	244	244.5	162	7.96
3/28/2006	-	-	0.25	0.044	-	-	0.93	-	-	-	164	7.89
4/4/2006	0.52	0.83	0.29	0.045	-	-	0.65	-	140	-	158	7.91
4/11/2006	0.49	1.03	0.15	0.038	-	-	-	-	256	-	162	7.85
4/18/2006	-	0.43	0.12	0.02	-	-	0.83	1	200	201	152	7.97
5/2/2006	0.52	0.69	0.16	0.065	-	-	3.07	-	-	-	166	7.72
5/23/2006	1.64	-	0.13	0.038	-	-	-	0	248	248	-	-
5/30/2006	1.04	1.93	0.13	0.052	-	-	-	2	232	234	-	-
6/6/2006	1.82	1.94	0.14	0.043	-	-	1.97	6	204	210	126	7.37
6/13/2006	1.78	1.83	0.13	0.06	-	-	3.84	3	196	199	140	7.56
6/20/2006	1.17	1.51	0.15	0.033	-	-	2.55	5	248	253	164	7.4
7/11/2006	1.06	1.34	0.15	0.054	-	-	10.1	11	332	343	102	8.76
7/18/2006	1.51	-	0.14	0.052	-	-	15.7	-	-	-	18.8	8.64
7/26/2006	1.17	-	0.13	0.055	-	-	6.21	-	-	-	14.6	7.8
8/1/2006	0.94	-	0.14	0.055	-	-	16	21	-	-	15.6	7.84
8/22/2006	0.53	0.57	0.13	0.05	-	-	1.29	1	244	245	22.1	8.7
9/6/2006	0.63	-	0.12	0.054	-	-	1.92	1	292	293	16.4	8.02
9/13/2006	0.86	0.93	0.11	0.053	-	-	-	1	276	277	-	-
9/20/2006	0.96	0.97	0.1	0.054	-	-	1.57	5	176	181	15	7.99
Average	0.90	1.62	0.69	0.10	0.94	4.74	2.83	3.97	280.29	288.14	137.54	7.90
Stand. Dev.	0.42	0.93	1.73	0.16	0.55	3.51	3.60	4.89	125.59	127.47	54.05	0.28
Variance	0.18	0.87	3.01	0.03	0.30	12.35	12.98	23.88	15773.11	16248.74	2921.01	0.08

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH
n	36	29	42	43	4	4	39	39	41	38	42	42
Mass Out	57043	102426	43491	6421	59892	300710		251692	17773603	18271508	8721259	
Median	0.83	1.51	0.13	0.052	1.083	5.0715	1.34	2.5	256	254.5	152	7.875

Water Quality Master Spreadsheet Student Union CR

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH
6/22/2005	-	-	0.03	0.236	-	-	2.04	1	12	12.5	8	6
6/22/2005	-	-	0.03	0.186	-	-	1.69	1	60	60.5	9	6.11
6/22/05*	<.001	0.103	0.127	0.234	-	0.855	-	-	-	-	7.3	6.12
8/29/2005	-	-	0.01	0.24	-	-	-	17	8	25	-	-
9/5/2005	-	-	0.19	-	-	-	-	-	-	-	4	5.85
9/12/2005	-	-	0.16	0.34	-	-	1.08	1	32	32.5	16	6.46
9/19/2005	-	-	0.08	0.14	-	-	1.02	-	72	-	34	7.28
9/26/2005	-	0.54	0.12	-	-	-	1.45	0	0	0	20	6.58
10/3/2005	-	0.44	0.12	0.04	-	-	0.84	0	0	0	8	6.76
10/10/2005	0.02	-	-	0.31	-	-	0.95	3	0	3	10	6.64
10/17/2005	0.41	0.53	-	0.06	0.08	-	0.69	6	0	6	7	6.54
10/17/2005	0.44	0.55	-	0.06	1.561	-	0.81	5	0	4.5	6	6.01
10/31/2005	0.07	0.46	0.02	0.2	-	-	0.92	6	36	42	12	6.75
11/7/2005	0.22	0.45	0.31	0.09	-	-	0.97	16	4	20	22	6.87
11/14/2005	0.2	0.49	0.08	0.04	-	-	0.96	4	96	99.5	44	7.14
11/28/2005	0.19	0.45	0.14	0.06	-	-	0.48	0	40	40	52	7.12
12/13/2005	0.17	0.48	0.06	0.039	-	-	-	5	8	12.5	-	-
1/10/2006	0.18	5.63	0.09	-	-	-	0.76	7	92	98.5	54	7.26
1/17/2006	-	0.62	0.06	-	1.151	1.211	1.5	3	132	135	39	7.4
1/24/2006	0.28	-	0.09	0.032	-	-	0.61	0	120	120	54	7.55
1/31/2006	0.15	-	0.15	0.02	-	-	1.22	3	140	142.5	48	7.42
2/7/2006	0.19	-	0.12	0.043	-	-	1.76	0	24	24	16	6.78
2/14/2006	0.07	0.56	0.13	0.04	-	-	1.58	4	120	124	36	7.15
2/21/2006	0.57	0.86	2.37	0.199	-	-	0.59	2	128	129.5	72	7.18
2/28/2006	0.58	1.87	6.29	0.277	-	-	1.02	4	144	147.5	38	7.41
3/7/2006	0.48	0.64	6.09	0.152	1.16	7.25	0.67	5	212	216.5	72	7.61
3/7/2006	0.49	0.54	6.29	0.14	1.07	7.36	0.69	5	192	197	70	7.59

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH
3/13/2006	0.54	0.56	5.49	0.023	-	-	1.11	0	116	116	77	7.69
3/21/2006	1.34	-	2.83	0.192	-	-	0.75	2	316	318	106	7.47
3/28/2006	-	-	0.61	0.257	-	-	1.04	-	-	-	102	7.41
4/4/2006	1.11	1.56	0.58	0.251	-	-	0.92	-	116	-	108	7.47
4/11/2006	0.47	0.72	0.18	0.06	-	-	2.05	1	120	121	52	7.08
4/18/2006	0.82	1.41	0.13	0.151	-	-	2.29	5	120	125	60	7.09
5/2/2006	0.77	0.95	0.19	0.156	-	-	2.87	-	-	-	78	7.27
5/23/2006	0.7	-	0.15	0.09	-	-	-	4	56	60	-	-
5/30/2006	1.84	-	0.14	0.087	-	-	-	6	44	50	-	-
6/6/2006	0.39	0.44	0.14	0.06	-	-	1.37	1	36	37	11	6.49
6/13/2006	0.42	0.48	0.14	0.106	-	-	4.62	2	0	2	6	6.3
6/20/2006	0.43	1.1	0.17	0.063	-	-	2.39	4	44	48	12	6.16
7/11/2006	0.65	-	0.15	0.099	-	-	5.59	0	0	0	-	-
7/18/2006	0.31	-	0.14	0.093	-	-	11.1	-	-	-	1.2	6.32
7/26/2006	0.41	-	0.13	0.084	-	-	3.13	-	-	-	1.4	6.57
8/1/2006	0.19	-	0.15	0.084	-	-	7.56	10	20	30	1.4	6.44
8/22/2006	0.3	0.33	0.12	0.066	-	-	5.06	9	84	93	4.5	7.18
9/6/2006	0.98	-	0.11	0.089	-	-	1.84	5	48	53	1.8	6.71
9/20/2006	0.28	0.95	0.11	0.085	-	-	8.01	36	44	80	16	8.31
Average	0.48	0.88	0.81	0.13	1.00	4.17	2.15	4.58	70.90	74.26	34.06	6.92
Stand. Dev.	0.38	1.03	1.78	0.09	0.55	3.62	2.32	6.54	69.89	70.83	31.66	0.56
Variance	0.15	1.06	3.17	0.01	0.30	13.14	5.37	42.80	4884.50	5017.37	1002.45	0.32
n	35	27	43	42	5	4	40	38	40	38	41	41
Mass Out	74375	137229	126516	19621	156938	651410		715053	11078189	11603274	5322439	
Median	0.41	0.55	0.14	0.09	1.151	4.2305	1.165	3.5	46	51	20	7.08

Water Quality Master Spreadsheet EVO1

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
10/3/2005	-	1.99	0.33	0.13	-	-	15.10	27	564	590.67	88.2	7.4	86.4
10/10/2005	1.46	-	0.13	0.09	-	-	1.30	17	344	360.67	96	7.42	82.2
10/17/2005	1.54	2.72	0.15	0.04	-	-	1.92	20	332	352	96	7.67	77.7
10/31/2005	2.11	2.87	0.01	0.03	-	-	2.45	30	240	270	76	8	70.9
11/7/2005	1.92	2.93	0.12	0.01	-	-	2.58	33	232	265	74	8.28	73
11/14/2005	1.27	2.79	0.03	0.01	-	-	4.30	7	236	242.67	81	9.14	72.1
11/28/2005	1.59	2.89	0.1	0.006	-	-	4.34	0	192	192	68	9.62	70.2
12/13/2005	1.77	2.92	0.01	0.007	2.347	2.357	-	67	240	306.67	-	-	-
12/13/2005	1.71	2.83	0.01	0.005	2.463	2.473	-	53	204	257.33	-	-	-
1/10/2006	0.5	0.54	0.12	-	-	-	1.25	27	-	-	90	9.33	60.4
1/17/2006	-	0.64	0.1	-	-	-	1.33	47	352	398.67	106	9	60.4
1/24/2006	0.48	0.53	0.08	0.052	-	-	1.00	10	404	414	88	8.73	-
1/31/2006	0.39	-	0.11	0.019	-	-	0.72	27	424	450.67	102	8.67	-
2/7/2006	0.34	-	0.13	0.027	-	-	1.91	0	360	360	72	9.75	-
2/14/2006	0.18	0.61	0.12	0.022	-	-	0.80	27	460	486.67	77	9.01	-
2/21/2006	0.14	0.23	0.09	0.022	-	-	2.06	0	380	380	86	8.46	-
2/21/2006	0.2	0.29	0.09	0.02	-	-	0.58	-	-	-	86	8.47	-
2/28/2006	0.09	0.43	0.1	0.023	-	-	1.03	20	312	332	86	9.12	-
2/28/2006	-	-	0.1	0.024	-	-	-	-	-	-	-	-	-
3/7/2006	0.31	0.39	0.1	0.018	-	-	1.61	33	368	401.33	82	8.67	-
3/13/2006	0.47	-	0.11	0.019	-	-	5.81	0	276	276.00	54	8.99	-
3/21/2006	0.21	-	0.15	0.027	0.643	0.793	0.89	30	324	354.00	46	9.25	-
3/28/2006	-	-	0.13	0.029	-	-	1.11	-	-	-	70	9.44	-
4/4/2006	0.33	0.55	0.17	0.029	-	-	1.27	-	224	-	88	8.98	-
4/11/2006	0.29	-	0.11	0.02	-	-	3.73	37	288	324.67	56	9.59	-
4/18/2006	0.48	-	0.12	0.02	-	-	0.98	7	260	266.67	94	8.55	-
5/2/2006	0.35	-	0.13	0.021	0.441	0.571	1.31	-	-	-	68	9.72	-

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
5/2/2006	0.31	-	0.12	0.019	0.328	0.448	1.31	-	-	-	66	9.71	-
5/23/2006	0.31	-	0.12	0.021	-	-	-	0	372	372.00	-	-	-
5/30/2006	0.4	0.43	0.12	0.021	0.554	0.674	-	3	240	243.33	-	-	-
6/6/2006	0.34	0.44	0.12	0.017	0.687	0.807	0.80	3	400	403.33	96	8.91	-
6/6/2006	0.39	0.5	0.12	0.015	0.63	0.75	0.94	10	340	350.00	96	8.82	-
6/13/2006	0.55	0.65	0.11	0.021	-	-	1.15	3	412	415.33	90	8.86	-
6/20/2006	0.44	-	0.12	0.018	-	-	1.00	23	420	443.33	106	8.64	-
7/11/2006	0.02	0.41	0.13	0.018	-	-	1.78	3	204	207.33	88	9.29	-
7/18/2006	0.47	-	0.1	0.04	-	-	2.14	-	-	-	9	9.59	-
7/26/2006	0.36	-	0.1	0.042	0.14	0.24	2.07	-	-	-	9	9.55	-
8/1/2006	0.14	-	0.12	0.042	1.2	1.32	3.94	1	264	265.00	9	9.54	-
8/22/2006	0.33	0.84	0.12	0.046	1.3	1.42	11.10	27	236	262.70	9	9.17	-
9/6/2006	1.12	-	0.11	0.05	1.05	1.16	10.00	1	288	289.00	12	8.92	-
9/13/2006	0.27	0.63	0.11	0.046	-	-	11.30	7	204	210.70	8	9.56	-
9/20/2006	0.36	0.5	0.1	0.054	1.06	1.16	12.10	9	200	209.00	8	9.68	-
Average	0.63	1.22	0.11	0.03	0.99	1.09	3.22	17.87	311.65	331.90	68.54	8.96	72.59
Stand. Dev.	0.58	1.08	0.05	0.02	0.72	0.68	3.74	17.06	89.46	91.17	32.10	0.63	8.77
Variance	0.34	1.18	0.00	0.00	0.51	0.46	13.95	290.96	8002.30	8312.84	1030.46	0.39	76.92
n	38	25	42	40	13	13	37	34	34	33	37	37	9
Mass Out	180	348	32	8	282	311		5091	88818	94591	19532		
Median	0.375	0.61	0.115	0.0215	0.687	0.807	1.61	13.335	300	332	81	9	

Water Quality Master Spreadsheet EVO2

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
10/3/2005	-	4.28	0.48	0.05	-	-	3.67	27	652	678.67	75.8	7.44	84
10/10/2005	1.45	-	0.41	0.28	-	-	2.21	10	364	374	105	7.75	81.3
10/17/2005	1.58	2.96	0.14	0.05	-	-	4.50	17	360	376.67	97	8.83	77.2
10/31/2005	1.78	2.94	0.01	0.02	-	-	7.72	13	296	309.33	76	9.29	71.4
11/7/2005	1.72	2.91	0.11	0.01	-	-	6.13	33	264	297	75	9.51	72.5
11/14/2005	1.48	3.09	0.04	0.01	-	-	6.73	27	272	298.67	72	9.67	71.8
11/28/2005	1.76	2.93	0.09	0.005	-	-	6.20	0	208	208	68	9.09	70.3
12/13/2005	1.99	3.09	0.01	0.011	1.828	1.838	-	57	268	324.67	-	-	-
12/13/2005	1.79	2.79	0.01	0.012	1.569	1.579	-	53	320	373.33	-	-	-
1/10/2006	0.4	0.47	0.1	-	-	-	2.70	23	-	-	98	9.29	60.3
1/17/2006	-	1.03	0.15	-	-	-	1.21	27	412	438.67	110	9.02	59.7
1/24/2006	0.44	-	0.09	0.049	-	-	0.79	10	464	474	101	8.43	-
1/31/2006	0.33	0.47	0.09	0.018	-	-	0.84	13	480	493.33	106	8.49	-
2/7/2006	0.41	-	0.13	0.026	-	-	1.37	0	440	440	88	9.23	-
2/14/2006	0.12	0.6	0.11	0.021	-	-	1.01	27	536	562.67	86	8.98	-
2/21/2006	0.17	0.19	0.1	0.024	-	-	0.53	7	508	514.67	78	8.69	-
2/21/2006	0.11	0.25	0.11	0.02	-	-	0.62	-	-	-	80	8.66	-
2/28/2006	0.21	0.33	0.1	0.025	-	-	0.82	30	364	394	86	8.89	-
2/28/2006	-	-	0.11	0.026	-	-	-	-	-	-	-	-	-
3/7/2006	0.37	0.66	0.11	0.019	-	-	1.74	40	484	524.00	76	8.42	-
3/13/2006	0.35	0.41	0.12	0.019	-	-	3.76	20	376	396.00	58	8.83	-
3/21/2006	0.21	-	0.11	0.028	0.585	0.695	0.56	30	404	434.00	48	9.02	-
3/28/2006	-	-	0.1	0.028	-	-	0.75	-	-	-	62	9.33	-
4/4/2006	0.41	0.56	0.13	0.026	-	-	0.91	-	204	-	90	8.78	-
4/11/2006	0.29	0.4	0.27	0.019	-	-	0.91	20	332	352.00	62	9.46	-
4/18/2006	0.42	0.59	0.3	0.02	-	-	1.18	3	288	291.33	90	8.74	-
5/2/2006	0.43	-	0.13	0.018	0.328	0.458	1.88	-	-	-	62	9.85	-

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
5/2/2006	0.42	-	0.13	0.017	0.215	0.345	1.37	-	-	-	60	9.86	-
5/23/2006	0.29	-	0.12	0.017	-	-	-	0	348	348.00	-	-	-
5/30/2006	0.43	0.49	0.13	0.02	0.5	0.63	-	7	188	194.67	-	-	-
6/6/2006	0.32	0.34	0.12	0.02	0.63	0.75	1.85	10	368	378.00	87	9.01	-
6/6/2006	0.35	-	0.13	0.017	0.63	0.76	1.90	13	392	405.33	91	9.10	-
6/13/2006	0.45	0.57	0.12	0.017	-	-	1.95	10	420	430.00	74	8.94	-
6/20/2006	0.41	-	0.13	0.014	-	-	2.74	23	420	443.33	118	8.85	-
7/11/2006	0.08	0.33	0.14	0.018	-	-	3.13	0	184	184.00	92	9.09	-
7/18/2006	0.41	-	0.11	0.029	-	-	3.25	-	-	-	8	9.39	-
7/26/2006	0.54	-	0.11	0.029	0.22	0.33	3.81	-	-	-	9	9.44	-
8/1/2006	0.32	-	0.12	0.029	0.6	0.72	4.76	-	-	-	9	9.35	-
8/22/2006	0.32	0.68	0.12	0.033	1	1.12	11.70	37	292	328.70	9	9.10	-
9/6/2006	0.2	-	0.11	0.04	1.02	1.13	8.31	3	280	283.00	19	8.31	-
9/13/2006	0.23	0.59	0.11	0.043	-	-	9.35	0	216	216.00	10	9.39	-
9/20/2006	0.56	0.56	0.11	0.048	1.15	1.26	8.35	7	200	206.70	9	9.43	-
Average	0.62	1.28	0.13	0.03	0.79	0.89	3.28	18.06	351.64	374.15	68.75	9.00	72.06
Stand. Dev.	0.58	1.26	0.09	0.04	0.50	0.46	2.90	15.02	111.61	113.91	32.48	0.51	8.29
Variance	0.33	1.58	0.01	0.00	0.25	0.22	8.40	225.73	12457.36	12975.24	1055.13	0.26	68.65
n	38	27	42	40	13	13	37	33	33	32	37	37	9
Mass Out	200	412	42	10	255	288		5829	113467	120731	22185		
Median	0.41	0.59	0.11	0.02	0.63	0.75	1.95	13.33	360	375.335	76	9.02	

Water Quality Master Spreadsheet EVR1

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
10/3/2005	-	2.09	-	0.04	-	-	2.87	13	672	685.33	76	7.41	83.5
10/10/2005	1.98	-	-	0.26	-	-	1.48	13	320	333.33	112	7.73	83.7
10/10/2005	1.91	-	-	0.25	-	-	1.69	13	356	369.33	112	7.78	-
10/17/2005	1.91	3.2	-	0.13	-	-	3.12	13	368	381.33	115	8.6	82
10/31/2005	1.86	3.19	0.01	0.04	-	-	6.20	20	308	328	104	9.47	77
11/7/2005	1.61	3.24	0.11	0.02	-	-	7.36	40	304	344	97	9.89	74.3
11/14/2005	1.78	3.33	0.03	0.01	-	-	4.70	13	320	333.33	94	9.7	73.2
11/28/2005	1.94	3.42	0.1	0.009	-	-	5.19	0	228	228	91	8.89	71.8
12/13/2005	2.04	3.46	0.01	0.009	2.953	2.963	-	50	536	586	-	-	-
1/10/2006	1.95	2.15	0.16	-	-	-	14.30	40	404	444	78	9.94	64.9
1/17/2006	-	1.97	0.11	-	-	-	11.40	63	500	563.33	72	9.72	60.6
1/24/2006	1.32	1.74	0.08	0.037	-	-	3.71	10	548	558	74	8.14	-
1/31/2006	1.16	1.19	0.12	0.021	-	-	1.48	27	444	470.67	114	8.15	-
1/31/2006	1.09	-	0.13	0.023	-	-	2.98	23	448	471.33	113	8.15	-
2/7/2006	1.06	-	0.1	0.012	-	-	3.14	7	476	482.67	104	8.07	-
2/14/2006	0.95	1.58	0.14	0.026	-	-	1.07	17	656	672.67	70	8.03	-
2/21/2006	0.83	-	0.13	0.024	-	-	1.68	0	616	616	72	7.82	-
2/28/2006	0.72	-	0.15	0.025	-	-	0.78	20	344	364	124	8.24	-
3/7/2006	0.55	-	0.14	0.017	-	-	1.22	30	452	482	130	8.36	-
3/13/2006	0.43	-	0.13	0.019	-	-	1.01	0	252	252	132	8.75	-
3/21/2006	0.25	-	0.11	0.015	0.354	0.464	1.77	10	276	286	102	9.04	-
3/21/2006	0.23	-	0.11	-	0.412	0.522	1.75	10	276	286	98	9.05	-
3/28/2006	-	-	0.11	0.023	-	-	1.50	-	-	-	96	9.27	-
4/4/2006	0.53	0.62	0.12	0.022	-	-	1.53	-	112	-	78	9.23	-
4/11/2006	0.26	-	0.11	0.017	-	-	1.34	13	208	221	76	9.21	-
4/18/2006	0.4	0.58	0.12	0.018	-	-	2.32	13	276	289	74	9.34	-
5/2/2006	0.33	0.41	0.12	0.016	0.836	0.956	2.51	-	-	-	60	9.83	-

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
5/23/2006	0.33	-	0.13	0.018	-	-	-	0	352	352	-	-	-
5/30/2006	0.45	0.54	0.13	0.019	-	-	-	13	152	165	-	-	-
6/6/2006	0.34	0.44	0.12	0.015	0.744	0.864	0.62	7	432	439	64	9.36	-
6/13/2006	0.52	0.54	0.12	0.019	-	-	1.32	10	444	454	86	8.37	-
6/20/2006	0.44	-	0.13	0.014	-	-	0.70	20	460	480	84	8.48	-
7/11/2006	0.17	0.36	0.14	0.017	-	-	1.35	0	88	88	88	8.87	-
7/18/2006	0.61	-	0.11	0.027	1.11	1.22	1.53	-	-	-	7.6	8.87	-
7/26/2006	0.39	-	0.11	0.029	1.2	1.31	1.29	-	-	-	7.8	9.15	-
8/1/2006	0.17	-	0.12	0.029	0.73	0.85	1.27	0	332	332	7.9	9.22	-
8/22/2006	0.28	0.44	0.12	0.03	0.44	0.56	3.44	10	308	318	7	9.17	-
9/6/2006	1.4	-	0.12	0.038	1.24	1.36	7.28	13	304	317	7.8	9.59	-
9/13/2006	0.29	0.94	0.12	0.039	-	-	4.24	2	296	298	6.4	9.32	-
9/20/2006	0.3	0.4	0.12	0.043	0.94	1.06	5.62	1	332	333	7.4	9.78	-
Average	0.89	1.63	0.11	0.04	1.00	1.10	3.16	15.31	366.67	389.25	76.81	8.86	74.56
Stand. Dev.	0.66	1.20	0.03	0.06	0.72	0.69	2.99	14.69	138.23	138.30	38.40	0.70	8.08
Variance	0.43	1.44	0.00	0.00	0.52	0.48	8.92	215.71	19107.66	19126.77	1474.93	0.48	65.31
n	37	22	36	37	11	11	37	35	36	35	37	37	9
Mass Out	252	464	32	11	284	314		4358	104382	110811	21866		
Median	0.55	1.385	0.12	0.022	0.836	0.956	1.75	13.33	338	352	84	9.04	

Water Quality Master Spreadsheet EVR2

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
10/3/2005	-	1.81	-	0.04	-	-	5.67	20	996	1016	78	7.25	85.8
10/10/2005	1.44	-	-	0.45	-	-	1.13	13	456	469.33	108	7.52	81.7
10/10/2005	1.42	-	-	0.47	-	-	1.15	17	468	484.67	108	7.63	-
10/17/2005	1.39	2.9	-	0.17	-	-	3.26	17	468	484.67	102	8.29	85.5
10/31/2005	1.62	2.65	0.01	0.05	-	-	4.19	10	364	374	89	9.35	74.5
11/7/2005	1.54	2.57	0.11	0.01	-	-	3.32	23	380	403	90	9.36	74.8
11/14/2005	1.28	2.27	0.04	0.01	-	-	5.15	13	356	369.33	88	8.97	74.1
11/28/2005	1.59	2.68	0.1	0.007	-	-	10.20	0	280	280	85	8.43	72
12/13/2005	1.75	2.7	<.01	0.006	0.934	0.934	-	70	252	322	-	-	-
1/10/2006	1.96	1.37	0.09	-	-	-	5.10	40	-	-	68	9.4	66.7
1/17/2006	-	1.52	0.13	-	-	-	3.24	63	568	631.33	64	8.96	61.3
1/24/2006	0.8	0.96	0.1	0.034	-	-	2.42	17	612	628.67	64	8.04	-
1/31/2006	0.62	0.69	0.11	0.028	-	-	2.09	20	512	532	118	8.19	-
1/31/2006	0.68	-	0.12	0.027	-	-	1.42	23	480	503.33	97	8.18	-
2/7/2006	0.52	-	0.14	0.018	-	-	4.85	10	528	538	100	8.39	-
2/14/2006	0.63	0.82	0.12	0.022	-	-	0.83	20	748	768	65	8.45	-
2/21/2006	0.23	0.35	0.14	0.024	-	-	1.58	13	752	765.33	66	8.95	-
2/28/2006	0.24	0.42	0.15	0.024	-	-	0.46	17	368	384.67	94	9.05	-
3/7/2006	0.32	-	0.14	0.017	-	-	1.53	37	452	488.67	102	8.74	-
3/13/2006	0.29	0.43	0.14	0.018	-	-	1.53	0	256	256	70	9.32	-
3/21/2006	0.15	-	0.1	0.02	0.1	0.2	0.44	27	232	258.67	56	9.47	-
3/21/2006	0.15	-	0.11	-	0.21	0.32	0.75	10	224	234	52	9.49	-
3/28/2006	-	-	0.11	0.028	-	-	0.60	-	-	-	58	9.29	-
4/4/2006	0.4	0.49	0.12	0.027	-	-	0.52	-	272	-	56	9.16	-
4/11/2006	0.26	0.49	0.12	0.019	-	-	0.62	27	192	219	60	9.4	-
4/18/2006	0.48	0.48	0.16	0.017	-	-	0.69	30	336	366	50	9.26	-
5/2/2006	0.38	0.5	0.14	0.016	0.158	0.298	1.02	-	-	-	54	9.61	-

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
5/23/2006	0.44	-	0.13	0.016	-	-	-	0	392	392	-	-	-
5/30/2006	0.5	-	0.14	0.016	-	-	-	3	208	211	-	-	-
6/6/2006	0.31	0.34	0.14	0.017	0.574	0.714	0.63	17	492	509	57	9.53	-
6/13/2006	0.5	0.57	0.13	0.018	-	-	0.71	7	564	571	56	8.32	-
6/20/2006	0.39	0.52	0.14	0.014	-	-	0.86	23	556	579	78	8.45	-
7/11/2006	0.11	0.25	0.15	0.016	-	-	2.98	0	268	268	72	9.31	-
7/18/2006	0.39	-	0.12	0.027	1.05	1.17	2.94	-	-	-	6.9	9.32	-
7/26/2006	0.37	-	0.12	0.031	0.6	0.72	4.48	-	-	-	6.8	9.32	-
8/1/2006	0.15	-	0.12	0.031	0.79	0.91	6.51	7	332	339	6.9	9.31	-
8/22/2006	0.23	0.25	0.12	0.029	0.31	0.43	5.92	7	312	319	6.1	9.13	-
9/6/2006	0.44	-	0.11	0.035	0.87	0.98	8.01	17	336	353	7.1	9.61	-
9/13/2006	0.48	0.8	0.12	0.033	-	-	9.03	6	296	302	9	9.39	-
9/20/2006	0.67	-	0.13	0.04	0.88	1.01	4.67	1	232	233	8.3	9.29	-
Average	0.68	1.15	0.12	0.05	0.59	0.70	2.99	17.81	415.43	436.81	63.68	8.90	75.16
Stand. Dev.	0.54	0.93	0.03	0.10	0.34	0.34	2.59	15.88	177.37	181.17	32.93	0.63	8.20
Variance	0.29	0.87	0.00	0.01	0.12	0.11	6.73	252.18	31460.84	32823.21	1084.20	0.40	67.28
n	37	25	35	37	11	11	37	35	35	34	37	37	9
Mass Out	222	377	39	17	192	228		5818	135678	142660	20797		
Median	0.48	0.69	0.12	0.024	0.6	0.72	2.09	16.67	368	388.335	65	9.16	

Water Quality Master Spreadsheet C1

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
8/29/2005	-	-	0.05	0.091	-	-	-	7	0	6.5	2	5.22	88.7
9/5/2005	-	-	-	0.19	0.395	-	-	18	-	-	0	4.54	85.6
9/12/2005	-	-	0.13	0.04	-	-	5.54	13	12	25	2	5.72	90.7
9/21/2005	-	-	-	-	-	-	1.17	-	-	-	2	5.95	-
10/3/2005	-	0.35	0.27	0.07	-	-	2.16	5	16	21	1	5.38	86.2
10/10/2005	0.01	-	0.28	0.04	-	-	1.52	5	0	4.5	10	4.6	83.5
11/14/2005	0.14	0.5	1.02	0.02	-	-	4.1	28	136	164	10	6.36	75.7
12/13/2005	0.13	0.53	0.1	-	-	-	-	22	0	21.5	-	-	-
1/17/2006	-	0.31	0.16	-	0.924	1.084	3.57	10	76	85.5	4	6.26	68.9
1/17/2006	-	0.07	0.16	-	0.924	1.084	3.32	9	56	64.5	5	6.3	-
1/24/2006	0.28	1.51	0.54	0.552	-	-	41.8	160	128	288	11	6.31	-
1/31/2006	0.13	0.27	0.16	0.032	-	-	20.1	35	56	91	9	6.74	-
2/7/2006	0.31	-	0.2	0.102	-	-	3.91	12	0	12	4	6.1	-
2/14/2006	0	0.67	0.45	0.424	-	-	20.2	48	80	128	9	6.66	-
2/28/2006	0.02	0.63	0.6	0.083	-	-	12.5	35	44	79	18	6.42	-
4/11/2006	0.35	0.75	0.19	0.05	0.828	1.018	7.68	23	4	27	12	6.9	-
4/11/2006	0.33	0.64	0.21	0.045	0.77	0.98	7.71	31	8	39	14	6.85	-
5/30/2006	0.37	0.38	0.35	0.061	0.635	0.985	-	15	36	51	-	-	-
5/30/2006	0.35	0.37	0.42	0.055	0.703	1.123	-	8	20	28	-	-	-
6/6/2006	0.19	0.36	0.66	0.05	-	-	1.56	14	44	58	1	5.65	-
6/13/2006	0.42	0.45	0.55	0.076	0.377	0.927	3.79	0	20	20	4	5.63	-
6/13/2006	0.33	0.41	0.5	0.068	0.386	0.886	-	5	12	17	-	-	-
6/20/2006	0.32	-	0.72	0.048	-	-	4.96	19	24	43	2	5.87	-
7/11/2006	-	0.09	0.21	0.062	-	-	1.56	0	0	0	2	5.56	-
7/18/2006	0.2	-	0.11	0.046	0.3	0.41	2.23	-	-	-	0.2	5.46	-
7/26/2006	0.35	-	0.11	0.044	-	-	2.27	-	-	-	0.2	6.16	-
8/1/2006	0.13	-	0.11	0.044	-	-	5.16	2	12	14	3	6.04	-

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
8/22/2006	0.2	0.4	0.11	0.044	-	-	2.94	3	36	39	0.2	5.27	-
9/6/2006	0.82	-	0.11	0.051	-	-	1.94	7	20	27	3	5.82	-
9/13/2006	-	0.29	0.1	0.056	-	-	2.2	87	8	95	0.1	4.89	-
Average	0.26	0.47	0.31	0.09	0.62	0.94	6.83	22.87	32.62	55.67	4.95	5.87	82.76
Stand. Dev.	0.18	0.31	0.24	0.12	0.24	0.21	9.11	32.99	37.28	62.06	4.99	0.65	7.75
Variance	0.03	0.10	0.06	0.01	0.06	0.05	82.94	1088.59	1389.69	3851.87	24.92	0.42	60.12
n	21	19	28	26	10	9	24	27	26	26	26	26	7
Mass Out	428	790	512	157	1044	1579		38242	54546	93101	8278		
Median	0.28	0.4	0.205	0.053	0.669	0.985	3.68	13	20	33.5	3	5.91	

Water Quality Master Spreadsheet C2

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
8/29/2005	-	-	0.08	0.1	-	-	-	9	0	8.5	6	6	85.1
9/5/2005	-	-	-	0.28	0.179	-	-	17	-	-	0	4.55	87.6
9/12/2005	-	-	0.51	0.05	-	-	2.27	6	24	29.5	4	5.2	80.6
9/19/2005	-	-	-	-	-	-	1.27	-	-	-	2	5.93	-
10/3/2005	-	0.35	0.19	0.07	-	-	1.3	5	16	20.5	1.4	5.21	82.9
10/10/2005	0.17	-	0.43	0.09	-	-	1.28	15	0	15	10	4.69	82.2
11/14/2005	0.09	0.38	1.47	0.13	-	-	63.1	107	220	326.67	12	6.14	76.1
12/13/2005	0.06	0.42	0.09	-	-	-	-	16	0	15.5	-	-	-
1/17/2006	-	0.21	0.21	-	1.119	1.329	7.04	35	68	103	3.4	6.35	68.4
1/17/2006	-	0.13	0.24	-	1.814	2.054	7.89	37	64	100.5	5.6	6.38	-
1/24/2006	0.19	0.49	0.44	0.237	-	-	13.5	39	116	154.67	7	6.39	-
1/31/2006	0.06	0.35	0.13	0.027	-	-	41.2	32	76	108	7	6.41	-
2/7/2006	0.16	-	0.17	0.058	-	-	5.01	11	0	11	4	5.93	-
2/14/2006	0	0.61	0.42	0.044	-	-	21.3	46	76	122	6	6.37	-
2/28/2006	0.09	0.41	0.5	0.03	-	-	9.18	48	48	96	6	6.49	-
4/11/2006	0.22	0.7	0.2	0.057	0.624	0.824	7.24	32	28	60	14	6.84	-
4/11/2006	0.26	0.64	0.21	0.056	0.624	0.834	8.03	34	36	70	10	6.86	-
5/30/2006	0.36	0.44	0.56	0.064	0.872	1.432	-	11	0	11	-	-	-
5/30/2006	0.44	0.47	0.61	0.069	0.838	1.448	-	16	0	16	-	-	-
6/6/2006	0.24	0.45	0.73	0.045	-	-	1.5	12	24	36	0.4	5.45	-
6/13/2006	0.39	0.41	0.4	0.065	0.318	0.718	3.21	1	8	9	4	5.44	-
6/13/2006	0.36	0.39	0.47	0.072	0.359	0.829	-	6	0	6	-	-	-
6/20/2006	0.29	-	0.55	0.05	-	-	2.22	15	44	59	2	5.02	-
7/11/2006	-	0.09	0.26	0.046	-	-	1.94	0	0	0	2	5.18	-
7/18/2006	0.22	-	0.11	0.05	0.33	0.44	1.61	-	-	-	0.2	5.56	-
7/26/2006	0.22	-	0.11	0.047	-	-	2.99	-	-	-	0.3	5.78	-
8/1/2006	0	-	0.11	0.047	-	-	6.47	0	8	8	2	5.47	-

Date	OP [mg/L P]	TP [mg/L P]	NO _x [mg/L N]	NH ₃ [mg/L N]	TKN [mg/L]	TN [mg/L N]	Turbidity [NTU]	TSS [mg/L]	TDS [mg/L]	TS [mg/L]	Alkalinity [mg/L as CaCO ₃]	pH	Temperature [°F]
8/22/2006	0.11	0.24	0.11	0.041	-	-	2.52	9	28	37	1	4.61	-
9/6/2006	1.76	-	0.11	0.054	-	-	1.2	17	12	29	0.1	5.07	-
9/13/2006	0.2	0.24	0.11	0.051	-	-	1.4	67	16	83	0	4.42	-
Average	0.27	0.39	0.34	0.07	0.71	1.10	8.94	23.66	35.08	59.01	4.25	5.68	80.41
Stand. Dev.	0.35	0.16	0.29	0.06	0.49	0.50	14.49	23.63	48.65	69.68	3.94	0.72	6.40
Variance	0.13	0.03	0.09	0.00	0.24	0.25	209.89	558.36	2367.11	4855.64	15.50	0.52	40.99
n	22	19	28	26	10	9	24	27	26	26	26	26	7
Mass Out	448	653	569	124	1184	1841		39564	58662	98686	7101		
Median	0.21	0.41	0.225	0.055	0.624	0.834	3.1	15.5	20	32.75	3.7	5.67	

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