Nutrient Export from a Green Roof: A Comparison to Other Land Use Types

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Abstract

Recent studies on green roof effluent have indicated that extensive green roofs are a source of phosphorus and occasionally a source of nitrogen as compared to conventional roofing systems[1]. In this study, green roof outflow quality was compared to runoff quality from other vegetated areas, and to other stormwater control measures. Data were graphed against EPA recommended criteria for unaffected waterways. Results indicated that in terms of nutrient retention, the green roof performed similarly to other vegetated sites, and was outperformed by a rain garden and wetland. It is suggested that, if space is available, green roof effluent be diverted to other systems designed for nutrient removal.

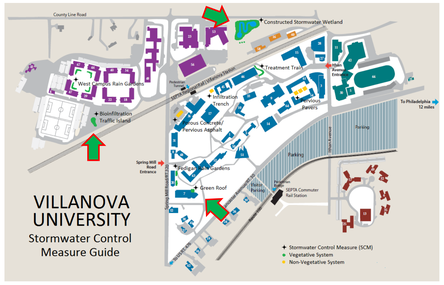
Figure 1a: Villanova green roof, site for water quality testing

Figure 1b: Villanova green roof retrofit

Introduction & Background

Green roofs (GRs) are proven effective stormwater control measures (SCMs), providing benefits of runoff volume reduction through hydrologic mechanisms, which include plant evapotranspiration and infiltration via growth media[2,3]. However, recent studies suggest that GR effluent may contribute to non-point source nutrient loading[1]. Phosphorus (P) and nitrogen (N) export are of concern due to their ecological impacts on stream and wetland health. Studies have generally compared GR systems to conventional roofs, although few have compared GRs to other vegetated land uses.

Figure 2: Map of Villanova's SCMs



Procedure

For this study, a GR was compared to several vegetated sites which are common contributors to nutrient loading in waterways and to SCMs which are designed for pollutant retention. The two-phase comparison study is summarized in Table 1.

Table 1: Summary of vegetated site comparison and SCM comparison.

Land Use Comparison I: Vegetated Sites				
Precipitation (GR P)	Green Roof (GR OUT 1, GR OUT 2)	Wooded area first flush (FFW)	Grassy lawn first flush (FFG)	Parking lot/lawn first flush (FF02)
Land Use Comparison II: SCMs				
Constructed stormwater wetland outflow (AS OUTLETs, OUTLET)	Rain garden outflow (OVER)	Green roof outflow (GR OUT 1, GR OUT 2)		

Extent of the study:

- Water quality monitoring occurred over a period of two years, 2012-2014
- A testing frequency of about once per month
- The GR was fertilized twice a year in accordance with maintenance specifications
- Storm sampling was collected for precipitation events with a total accumulation of ≥0.25 inches
- Nutrient testing was conducted using an EasyChem Plus discrete analyzer

Water quality/nutrient testing parameters included:

- Nitrites plus nitrates (NO_X)
- Orthophosphates (PO_4)
- Total Kjeldahl Nitrogen (TKN)
- Total Nitrogen (TN)
- Total Kjeldahl Phosphorus (TKP)

EPA Criteria

EPA recommended water quality criteria for N and P parameters were used as reference values for vegetated site and SCM effluent concentrations (see Table 2).

Table 2: Ambient Water Quality Criteria Recommendations for Nutrient Ecoregion IX, Sub-region 64

Pollutant	US EPA Rivers & Streams (mg/L)[4]	US EPA Lakes & Reservoirs (mg/L)[5]
TKN	0.300	0.350
NO_X	0.995	0.605
TN (Calculated)	1.295	0.955
TN (Reported)	2.225	0.818
TP	0.040	0.045

Results & Discussion

Using boxplot groupings, a relative comparison of data from the GR versus other sampling sites was performed for each nutrient parameter. Comparisons for TN and TKP are provided in Figures 3-6.

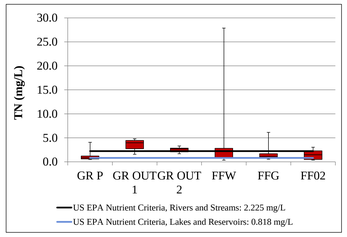
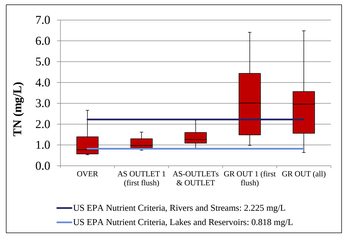


Figure 3: Land Use Comparison I for TN. Median TN concentrations from the GR first flush (GR OUT 1) and whole-storm composite (GR OUT 2) were similar to those of background vegetated sites.

Figure 4: Land Use Comparison II for TN. Median concentrations from the GR samples were slightly higher than effluent samples from other SCMs, and higher than EPA recommended criteria.



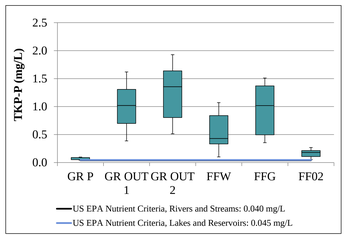
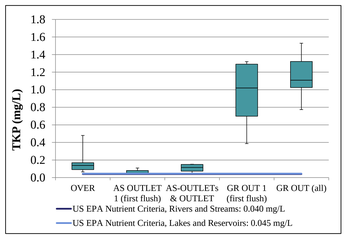


Figure 5: Land Use Comparison I for TKP or TP. Median TKP concentrations were greater for GR samples than vegetated background sites.

Figure 6: Land Use Comparison II for TKP or TP. TKP concentrations were greater for GR samples as compared to nutrient-retaining SCMs, and much higher than EPA recommended criteria.



When graphed against US EPA recommended regional criteria for rivers and streams, and for lakes and reservoirs, it is revealed that the GR effluent N concentrations are generally acceptable while P concentrations do not meet the recommended criteria. However, the wetland and rain garden had acceptable effluent nutrient concentrations, as was expected based on design goals.

Ongoing Research

A mass export analysis is currently being conducted to determine the portion of fertilizer applied to the green roof that is taken up by the plants as compared to the portion that is washed off during higher-volume storms. A preliminary graph is provided in Figure 7.

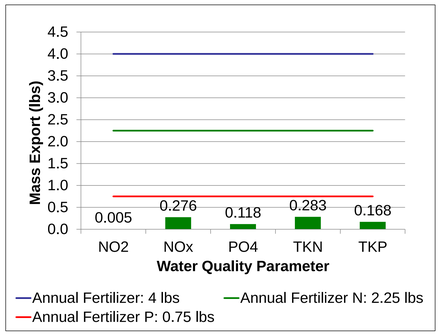


Figure 7: Nutrient mass export for the green roof versus quantities of fertilizer applied annually

Conclusions

Comparisons of GRs to other vegetated sites would suggest that GRs perform similarly to traditional urban sources of nutrient loading. Figures 4 and 6 suggest the GR is outperformed by the wetland and rain garden, two types of SCMs which are specifically designed for and proven effective at removing nutrients from stormwater. It is suggested that GRs be implemented in series with other SCMs, which are designed for nutrient removal. This is a practical solution where space for multiple SCMs is available.

References

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