Greening the Hill: Analyzing UNC's Battle Grove Regenerative Stormwater Conveyance System

Sustainable Triangle Field Site Team: Anna Coley, Sophia Sload, Hanna Berger, Brooke Kongmany, Claudia Sandoval, Brenda Palacios Rodriguez, Sarah Dean

Environment, Ecology and Energy Program at UNC Chapel Hill

Sustainable Carolina

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Background

With urbanization on the rise, the increase of developed areas means more impervious surfaces that prevent stormwater from absorbing into soil, replenishing aquifers, or flowing into streams and rivers. Instead, when heavy rain events occur, water runs rapidly across surfaces causing flooding, erosion, and infrastructure damage. The water also carries particles and pollutants from runoff that contaminates bodies of water. Stormwater control measures (SCM) are techniques or structural controls used to mitigate these issues. An upcoming SCM involving green architecture is regenerative stormwater conveyance (RSC) that functions as both stormwater management and stream restoration. An RSC consists of a series of step pools that slow water flow and filter the water as it moves through cobbles in between each pool. RSCs reduce erosion and flooding by addressing water quantity and improve stream health by improving water quality. RSC have been shown to:

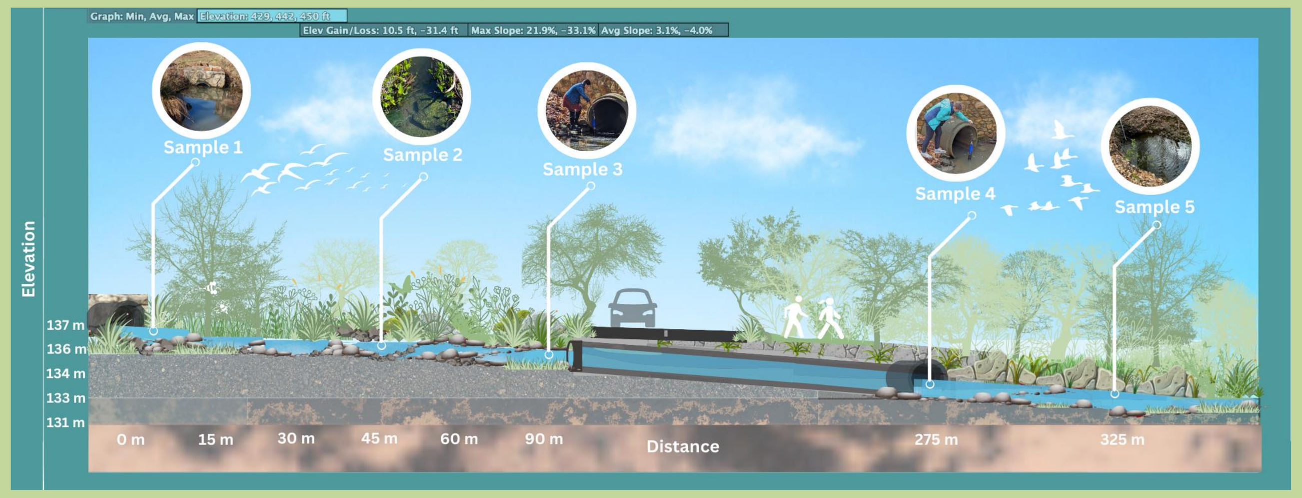
- Reduce surface flow by 84% (Cizek et al., 2017)
- Reduce volume and peak flow by 78% and 76% respectively and reduce suspended solids by 70%, phosphorus by 20%, and nitrogen by 26% (Cizek et al., 2018).

Water quality impacts of RSCs have not been fully validated in different conditions, which lead us to our **research question:** How does the presence of regenerative stormwater conveyance on UNC's campus affect the quality, quantity, and velocity of stormwater runoff on the UNC campus and surrounding areas? We focused on addressing how regenerative stormwater conveyance alters the following water quality conditions as water moves through the system: temperature, nutrient levels, and dissolved oxygen levels. We analyzed how these results compared to other creeks in Chapel Hill without an RSC.

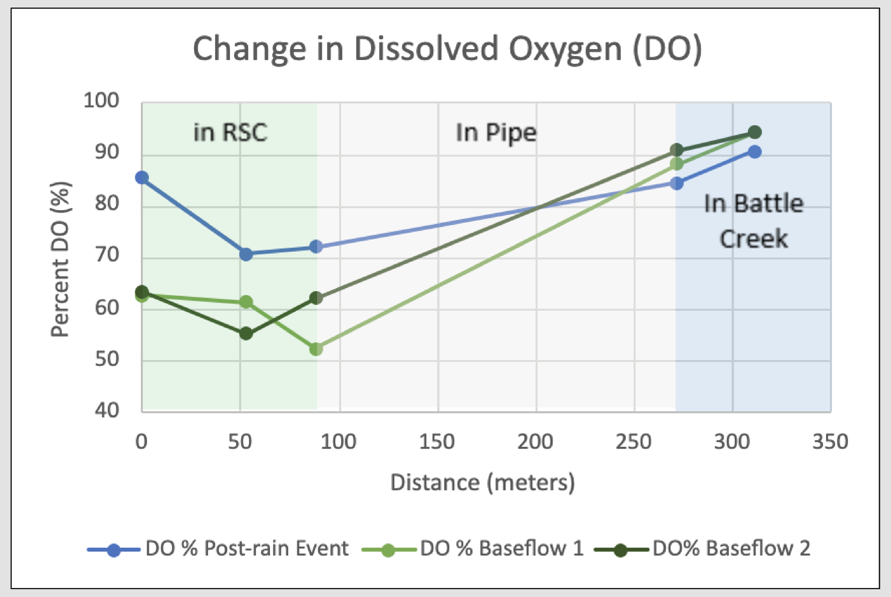
Methodology

Data collection and sampling were necessary to analyze water quality and flow as an indicator of the effectiveness of green stormwater infrastructure. Battle Grove was chosen as the location for data collection due to its use of regenerative stormwater conveyance (RSC) technology. In addition, it serves as a connection between the UNC pipe shed and the Chapel Hill community through outward flow from streams following flow through the Battle Grove RSC. Sample sites 1-3 exist within the RSC, with sample site 1 located directly after water flows out of a pipe into the RSC, sample site 2 located after water flows through three RSC pools, and sample site 3 located after water flows through the entire RSC system. Directly following water flow through the RSC, it enters a pipe and exits into Battle Creek. The water flows through a pipe and then into sample sites 4 and 5, with sample site 4 located after exit from the pipe and sample site five occurring after about 50 meters of flow through the creek.

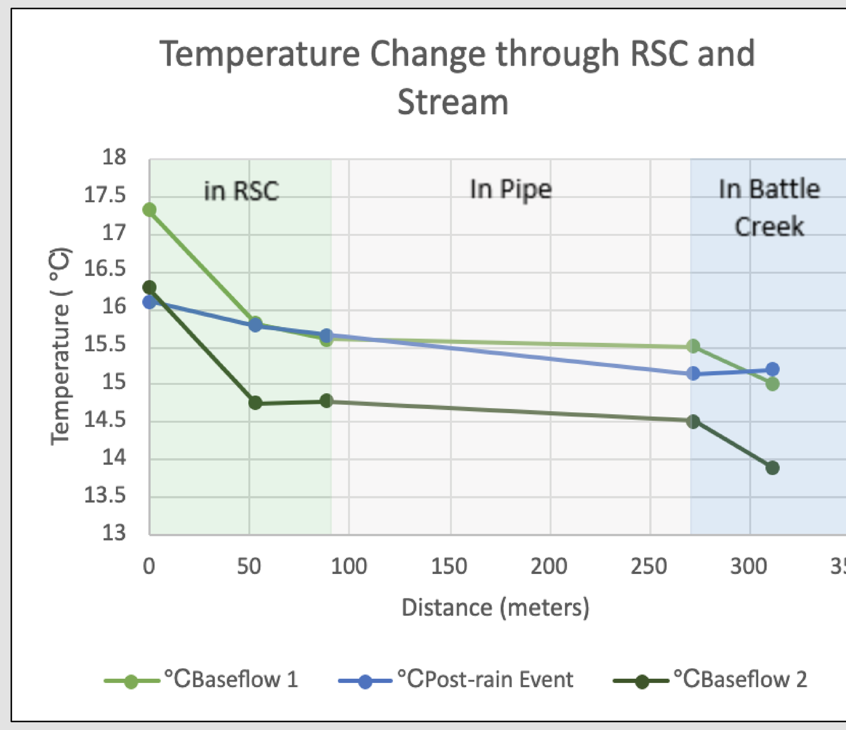
Two baseflow datasets were collected from these five sites on February 28th and March 23rd. An additional dataset from these five sites occurred on March 2nd after a rain event. Additional creek data was collected on March 21st from Bolin creek, Booker creek, Morgan creek, and at the Meeting of the Waters with one sample site for each additional creek. It was initially collected for a community education project but was used within this study for nutrient comparisons. Water quality measurements were collected using a YSI EXO Multi-Parameter Water Quality Sonde and flow data was collected using a flow probe. Water samples were collected at each sample site for chlorophyll and nutrient data. These samples were pumped through a filter on site and then processed by a separate laboratory team from UNC's Institute for the Environment. The data was analyzed within Excel, and distances between sample sites were taken into consideration when analyzing the water quality data.



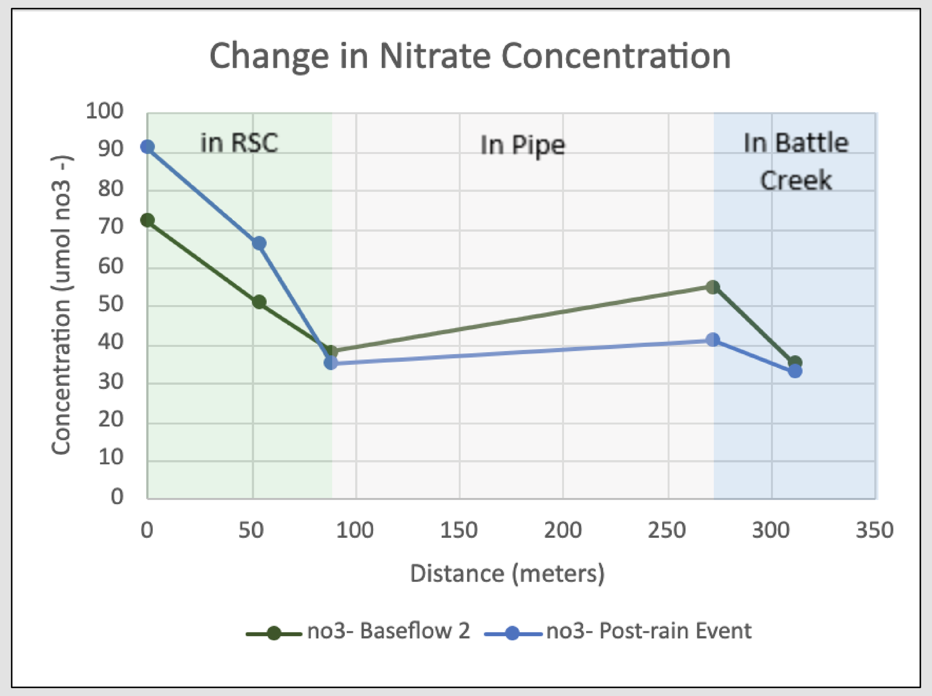
Results



- In the RSC system, dissolved oxygen remained **relatively stable throughout the system in the baseflow events.** Dissolved oxygen was highest at all three data points in the post-rain event.
- In the post-rain event, dissolved oxygen was shown to decrease from site 1 where water enters the system from a pipe to site 3 at the end of the RSC system where water re-enters a pipe.
- Dissolved oxygen consistently **increased in value through the pipe into battle creek** and reached similar values at **approximately 90% DO** for both baseflow events and rain event.



- In the RSC system, **temperature was shown to decrease from site 1,** where water enters the system, **to site 3,** where it exits the RSC and re-enters a pipe, at an average of 7% for each sample set.
- Temperatures remained steady through the pipe and slightly decreased again once water flow was daylit in Battle Creek.
- Temperatures in the RSC were most steady after the rain event, and both baseflow data sets showed similar dramatic decreases in temperature between the first and second data sites.
- Baseflow 1 and Baseflow 2 data show nearly identical trends, with Baseflow 1 averaging approximately 1°C higher than Baseflow 2.



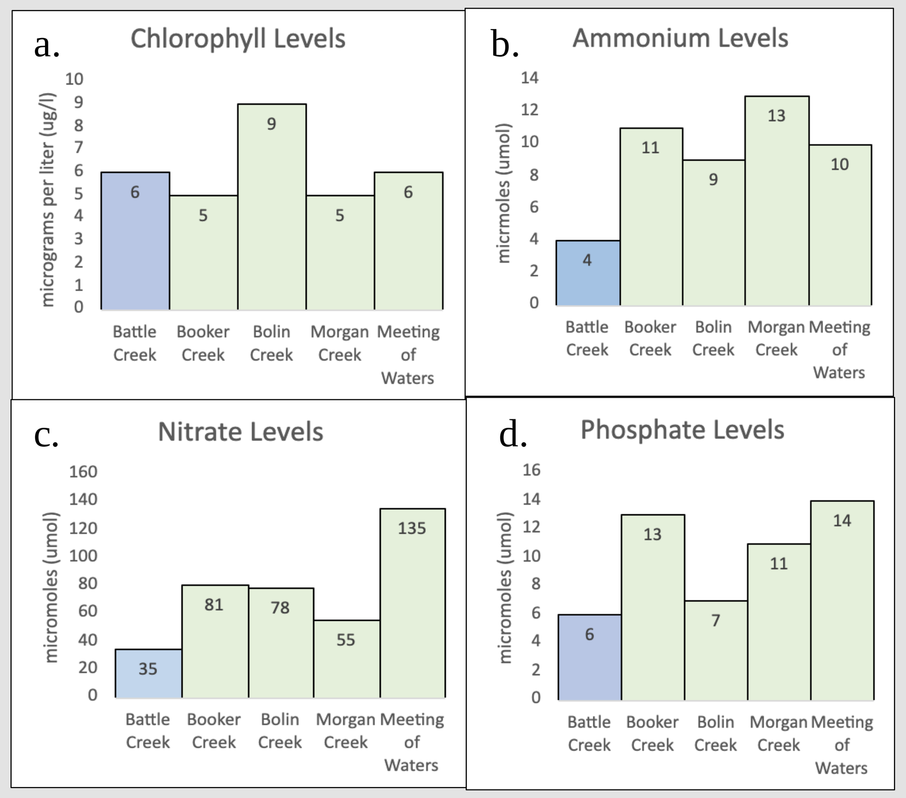
- Nitrate concentration were shown to **decrease by 47% in baseflow and by 62% in post-rain** event conditions in the RSC system from where water enters the system to where it exits.
- RSC nitrate concentrations were **relatively higher in post-rain event conditions** but decreased to approximately the same concentration as baseflow conditions as it moved through the system.
- Additionally, through the pipe and into battle creek, nitrate concentrations remain relatively the same and do not increase to pre-RSC conditions.

a. **6.25 ug/l average chlorophyll** level in neighboring creeks **> Battle Creek at 6 ug/l**

b. **10.75 umol average ammonium** concentration in neighboring creeks **> Battle Creek at 4 umol**

c. **87.25 umol average nitrate** concentration in neighboring creeks **> Battle Creek at 35 umol**

d. **11.25 umol average phosphate** concentration in neighboring creeks **> Battle Creek at 6 umol**



Conclusions

Nitrate Concentrations:

- The Battle Grove RSC decreased nitrates in baseflow and post-rain event conditions indicating that the system is working appropriately and filtering the water passing through for potentially harmful nutrients. This reduces the risk of nutrification and potential downstream eutrophication from excess nitrates and phosphates.
- RSC would be applicable to be placed in areas of excess runoff, especially near areas with potential agricultural or fertilizer runoff which contains higher concentrations of these nutrients.

Dissolved Oxygen (DO):

- The RSC system relatively maintains DO values throughout the system. The increase in DO through the pipe into Battle Creek is most likely attributed to the churning of water resulting in increased aeration through the pipe that increased the DO% value.

Temperature:

- Temperature in the post-storm event conditions was relatively constant at all sites, most likely due to the increased volume and flow of water passing through the system, meaning water spent less time in the RSC system.
- The temperature pattern seen between Baseflow 1 (taken on Feb. 28) and Baseflow 2 (taken on Mar. 23) reflects how the system naturally cools water as it moves from larger pools where water sits and warms through smaller pools where water is more likely to flow and cool.

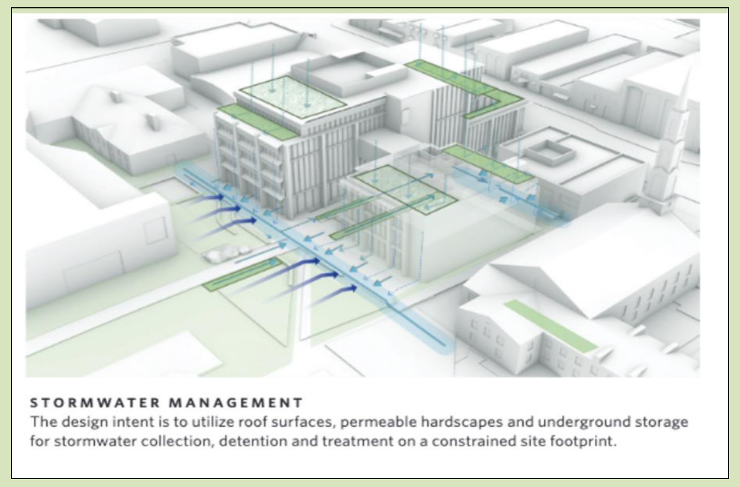
Nutrient Comparison of Neighboring Creeks:

- After sampling other creeks in Chapel Hill, it is evident that Battle Creek has the lowest levels of nitrate, ammonium, and phosphate. This provides evidence to suggest the RSC uniquely present at Battle Creek accomplishes some of the objectives of improving the water quality in the adjacent creek.

Future Applications

Regarding the experimental process used in this study, it would be beneficial to test the effectiveness of the RSC in rain events of greater than one inch which may pose greater flood risks to urban communities. Furthermore, while literature displayed that water flow rates decrease through RSC systems, the collected flow data within this study did not reflect this. This is likely due to a lack of precision within the equipment, experiential methods, and data collection occurring in an area that has low flow. Further experimentation would be beneficial in assessing flow changes as well as the water quantity portion of the research question since lack of flow data resulted in limited water quantity applications.

We plan to utilize our findings from the Battle Grove RSC to advise the reimagining of the Porthole Alley Project, which is an ongoing project that is working to redesign this connection point between the city and university. This project has been identified as a potential site for stormwater control measures. From findings within the literature as well as the water quality data collected, an RSC could be a beneficial addition to the project plans. This is especially relevant due to the large number of impervious surfaces in the area, leading to increased run-off, decreased infiltration, and increased likelihood of flooding in downstream areas, like the Lower Booker Creek sub-watershed. In addition, UNC Chapel Hill complies with the Jordan Lake watershed rules on nutrient levels. The data collected in this study indicated decreased nutrient levels within the RSC compared to other creeks indicating that this green infrastructure technology could address excess nutrification issues.



Design plan from Porthole Alley AP Report

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