Green Infrastructure Impact on Stormwater Control and Water Quality

Ashley Rolon-Marlowe[1], Dr. Jennifer Cherrier[2], Dr. Brianne Smith[3]

[1]UWIN URP 2017 student at Brooklyn College – City University of New York (ashley.rolon65@myhunter.cuny.edu), [2,3] Brooklyn College – City University of New York

INTRODUCTION

New York City is home to 8,537,673 people (US Census data), 14 wastewater treatment plants and is working to reduce water pollution caused by Combined Sewer Overflows (CSO) and flooding influenced by storm surge. CSOs can contain sewage, suspended solids, litter, and excess nutrients among other potentially harmful substances. Increased urbanization and stormwater discharge into waterways can lead to more frequent flooding, increased temperature, habitat degradation and erosion.

According to the New York City Panel on Climate Change annual precipitation is expected to increase by 5-10% for middle range predictions or by 15% for high range predictions by the year 2050. Sea level is expected to rise 11 to 24 inches for middle range predictions or by 31 inches for high range estimates (Horton et al. 2015).

The NYC Department of Environmental Protection CSO Consent Order modified in 2012 called for an investment of over $600 million for at least 10 years in the use of green infrastructure (GI) to capture 10% of storm water from each sewershed.

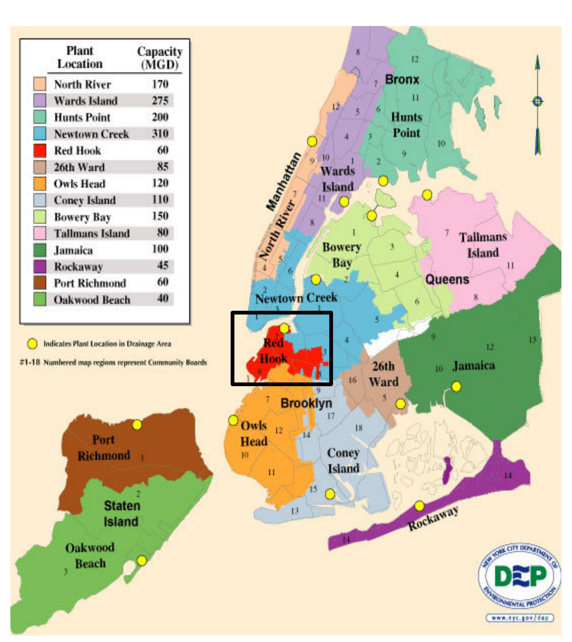
RESEARCH QUESTIONS

This project studies the impact of green infrastructure (GI) design on water control and quality.

- What percent of the input volume will outflow through the mesocosm systems?
- What concentration of phosphate and ammonium will remain in the system outflow?
- Which green infrastructure design provides more efficient stormwater control?
- Which design is more effective at reducing nutrients in the water that filters through the system?

STUDY SITE

Red Hook, Brooklyn



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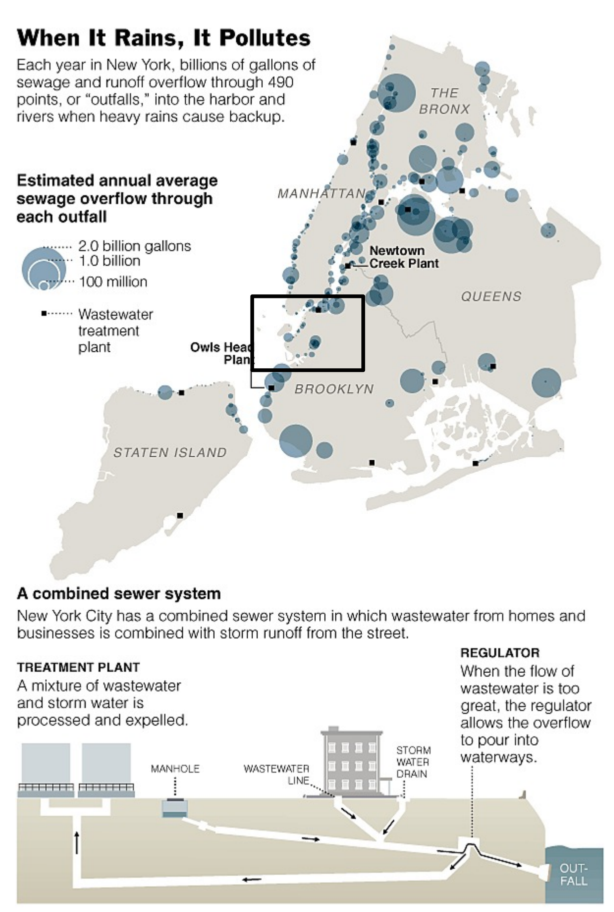

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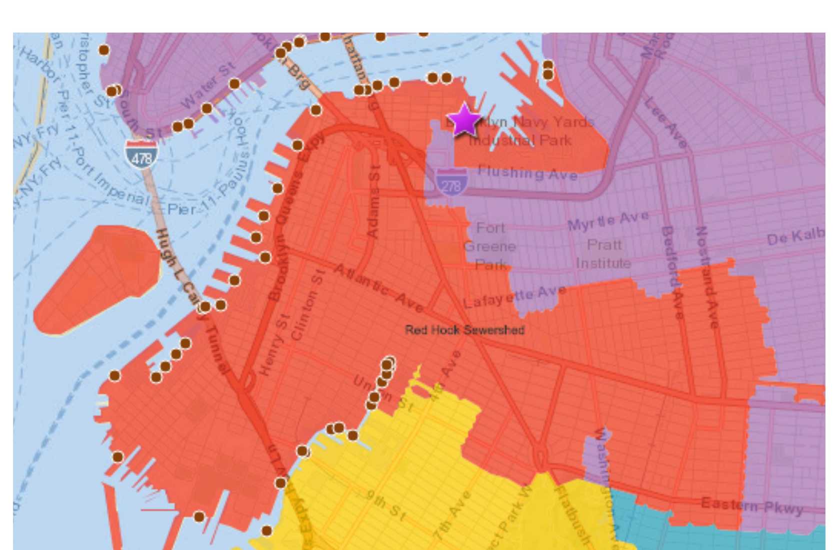

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Figure 1. (A) Sewershed map of New York City. Sewersheds span individual neighborhoods and some, such as Newtown Creek span two separate boroughs. The Red Hook sewershed is highlighted by the black box (NYC DEP). **(B)** CSO outfall map of NYC. Blue circles represent estimated annual volume of sewage overflow into surrounding waters. Black dots represent wastewater treatment plants. The combined sewer system diagram outlines what occurs when the flow of waste and storm water is too high (NY Times). **(C)** Red Hook sewershed. The purple star is the location of the WWTP and the small dots represent locations of CSO outfall into the Gowanus Canal and Upper New York Bay. (Open Sewer Atlas)

METHODS

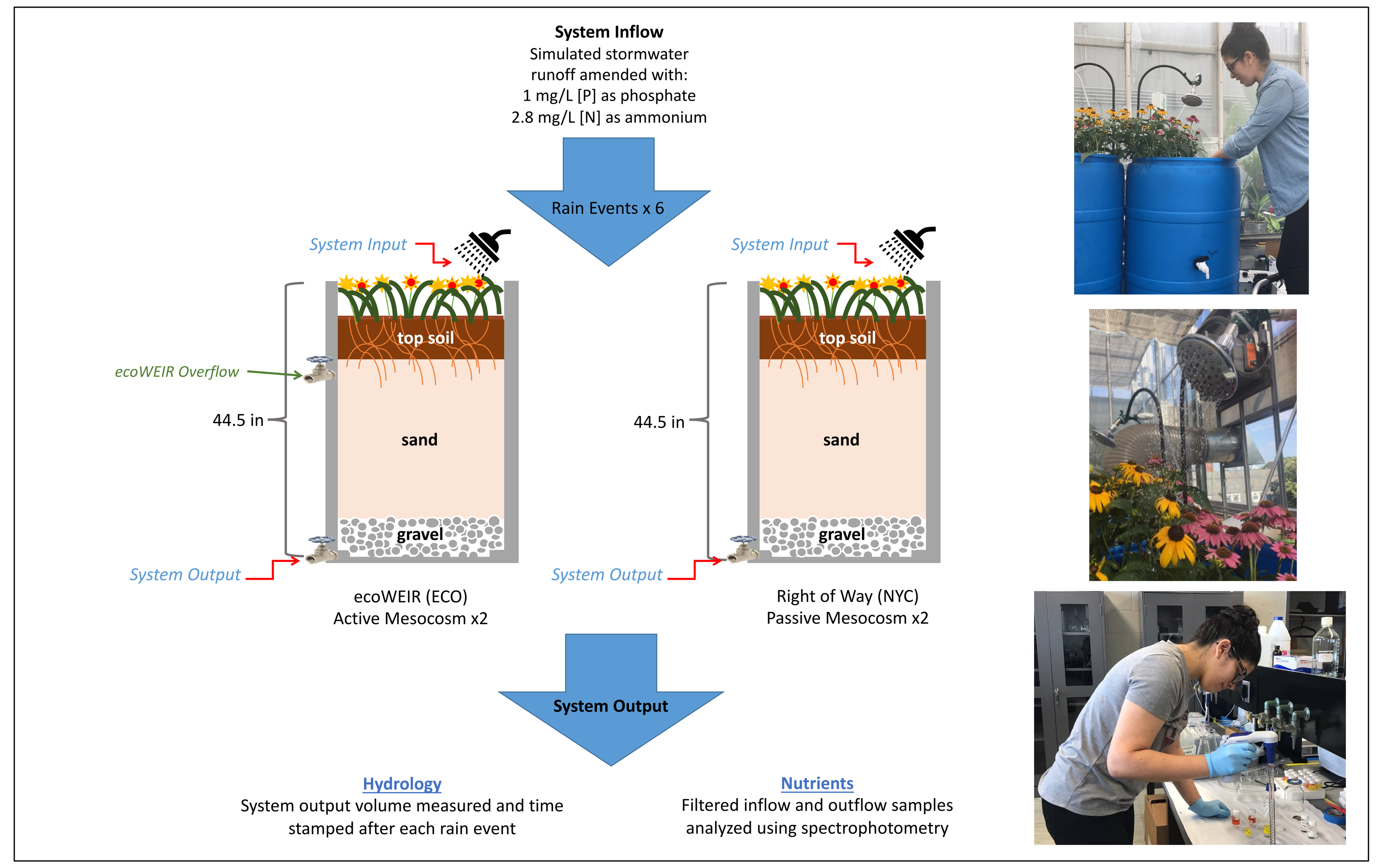


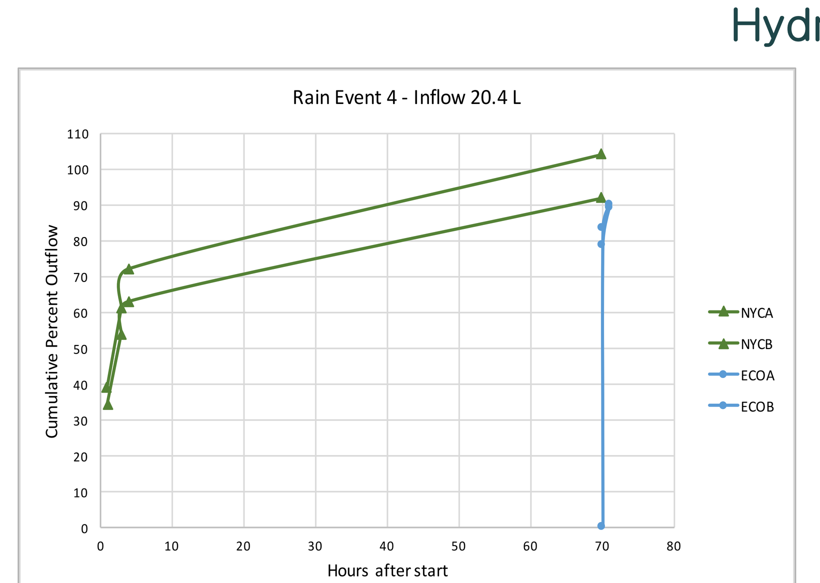
Figure 2. Mesocosm diagrams: ecoWEIR mescosms (ECO) allow active water control, water detained and controlled. NYC mesocosms are passive in control of water. ECO and NYC mesocosms were created in duplicate. Six simulated rain events occurred over a 14-day period using historical precipitation data (Aug – Sep 2011) and trends from Red Hook, Brooklyn. Prior to each rain event start, water inflow samples were collected into 20 mL scintillation vials. Following each rain event water samples were collected from the bottom valve of each mesocosm (4 total) into 500ml bottles, filtered and then frozen in 20 mL scintillation vials. NYC mesocosms allowed constant outflow with open valves. ECO mesocosms retained water and outflow volumes and samples were collected at least 24 hours following the end of the rain event.

Rain Event	Inflow Volume (L)	Time Between Events
1	99.7	
2	70.9	91h 05m
3	21.9	53h 32m
4	20.4	41 h 29m
5	23.7	70h 32m
6	76.3	27h 02m

Table 1. Rain Event Volume and Time. The first rain event flowed 99.7L into each mesocosm. 91 hours and 5 minutes later rain event 2 began, with 70.9L flowing into each mesocosm. Some time between events included weekend days. The timing between events impacted the hydrology and volume collected. Some periods occurred where mesocosms were allowed to dry out longer than previous rain events.

RESULTS

Hydrology



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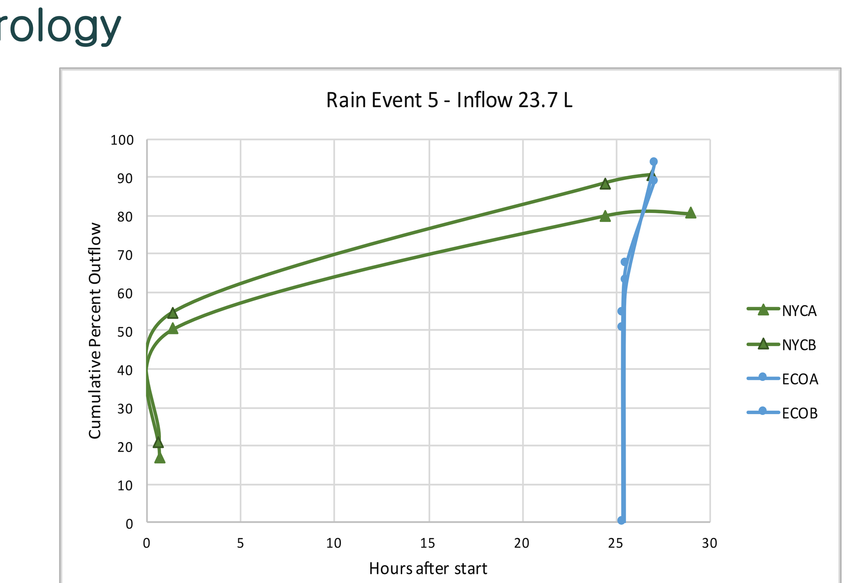

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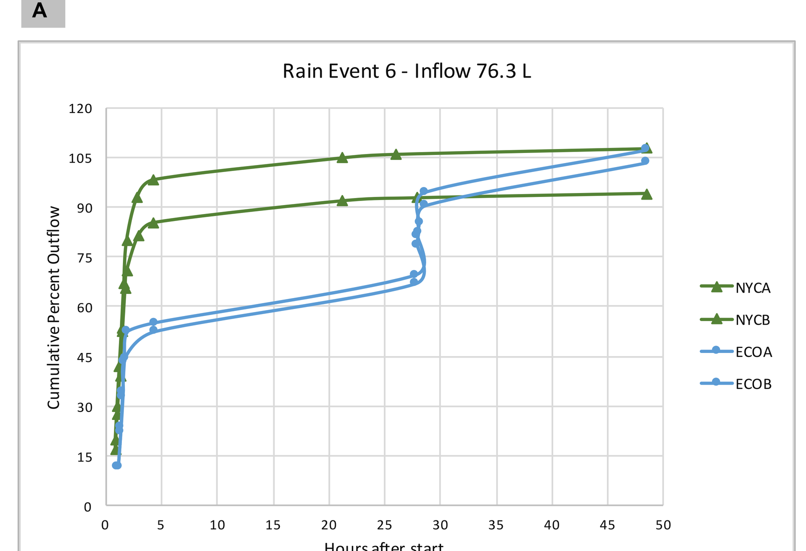

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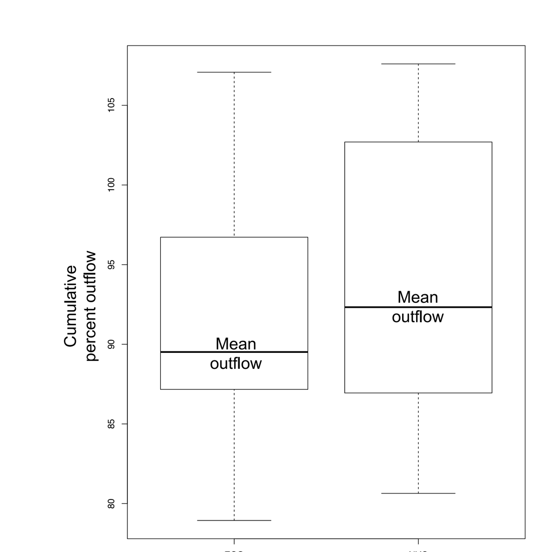

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Figure 3. Hydrology System Outflow charts of **(A)** rain event 4 **(B)** rain event 5 and **(C)** rain event 6 **(D)** comparative cumulative outflow of all rain events for NYC and ECO mesocosms. Rain event volumes varied from about 20L to over 75L and the time between events varied from 27 hours to 91 hours. The **NYC systems** drained 50% to 95% of the water input within the first ten hours following the start of a rain event. For large volume rain events the **ECO systems** allowed overflow via the top valve to prevent water logging the vegetation. Following at least 24 hours the ECO systems were drained for all events. For rain events 4 and 5 the ECO systems drained 90-95% of water input in less than 3 hours. NYC mesocosms had a wider range of cumulative outflow than ECO mesocosms.

RESULTS (cont.)

Nutrient Removal

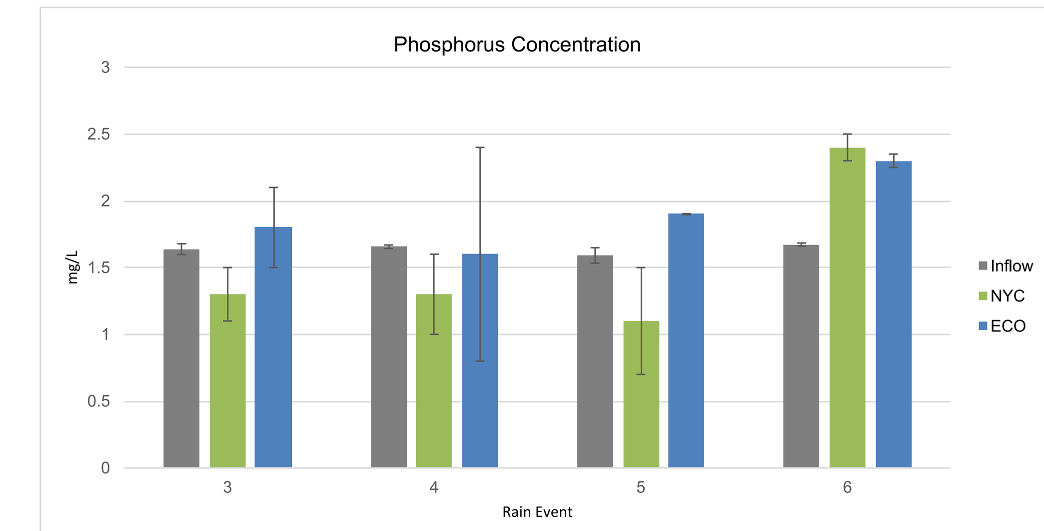

Figure 4. Phosphorus Concentration. 1 mg/L P as phosphate was added to tap water prior to the start of each rain event. NYC system outflow showed variable phosphate removal, with 3/4 events showing decrease in [P]. The ECO system outflow demonstrated in an increase in [P] for 3/4 rain events. It is likely that legacy phosphate was picked up in the ECO systems since water was held in the system for at least 24 hours, allow desorption. The NYC systems allowed open water flow, therefore it is likely phosphorous bonded to the sand layer.

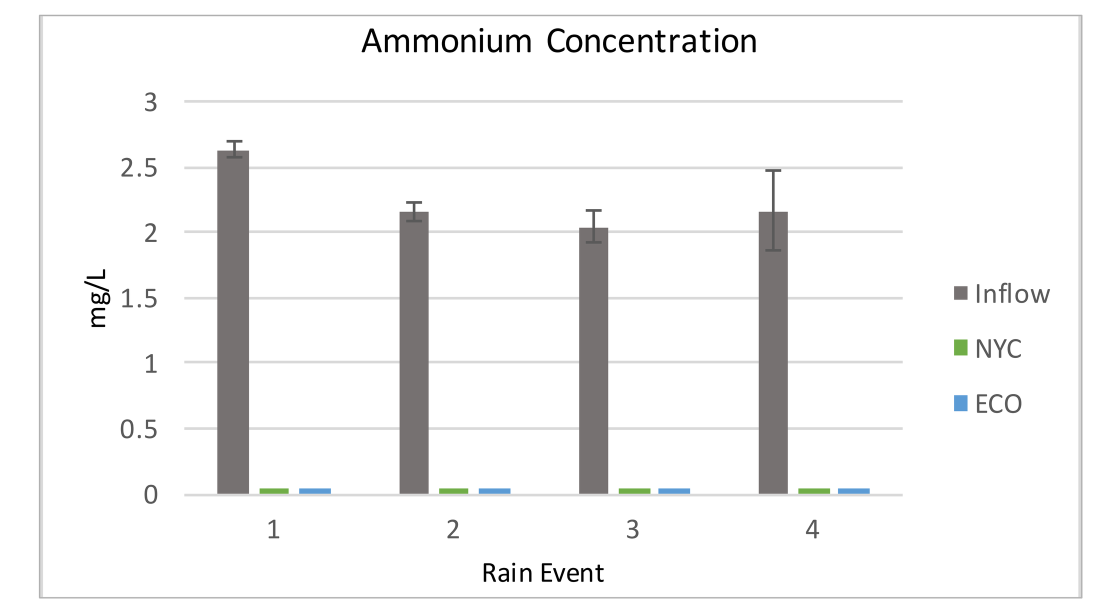

Figure 5. Ammonium Concentration. Approximately 2.8 mg/L N as ammonium was added to tap water prior to the start of each rain event. NYC and ECO systems showed a dramatic decrease in ammonium concentration. Outflow samples for all systems and rain events showed a concentration of < 0.05 mg/L N, which were too dilute to accurately measure.

CONCLUSIONS

- ECO systems released 81% to 107% of volume input after 24 hours, with some overflow once maximum storage capacity was reached. NYC systems released 82%-107% of volume input, with most of the volume released within the first 10 hours of a rain event.
- The ecoWEIR mesocosms are more effective and consistent at controlling water.
- The NYC passive system provides more efficient phosphate removal. The ECO mesocosm system may be more efficient at ammonium removal. More research is needed on the total nitrogen (TN) concentration of system inflow and outflow for greater accuracy.
- Holding water for a period of at least 24 hours encourages Phosphorous to desorb from the system and flow out.
- Results from this experiment can inform the optimized design and implementation of GI in urban areas, such as New York City.

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