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Three Co-Located GSI and Their Response to Large Storms

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OVERVIEW

Figure 1: Aerial View of Villanova University, Courtesy of Villanova Webpage

OBJECTIVE

- Assess the performance of three different GSI systems to 4 storm events in 2023.
- The sites are all located within a 1-mile radius of each other, exposed to the same rainfall events.
- Explore the significance of the design and construction of the systems in managing the incoming flow.
- Begin to quantify GSI type comparison by drainage area, cost, and performance.

How was the weather in 2023?

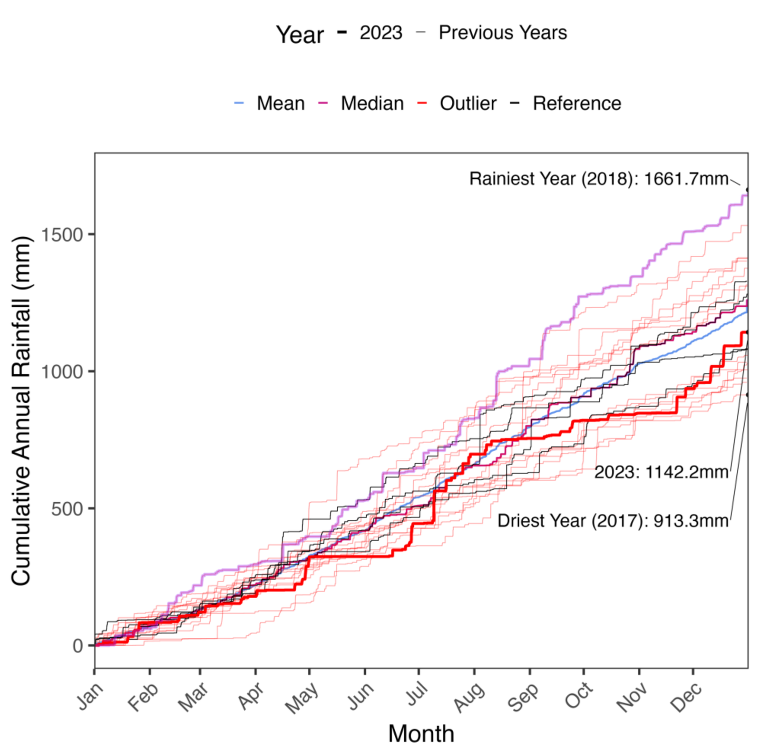


Figure 2: Annual Cumulative Rainfall 2003-2023.

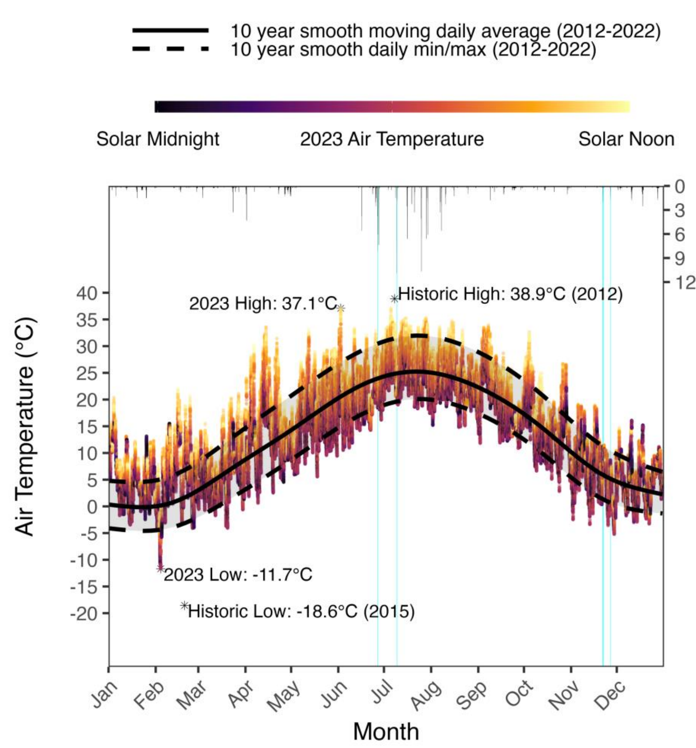


Figure 3: Air Temperature, Highlighting Storms.

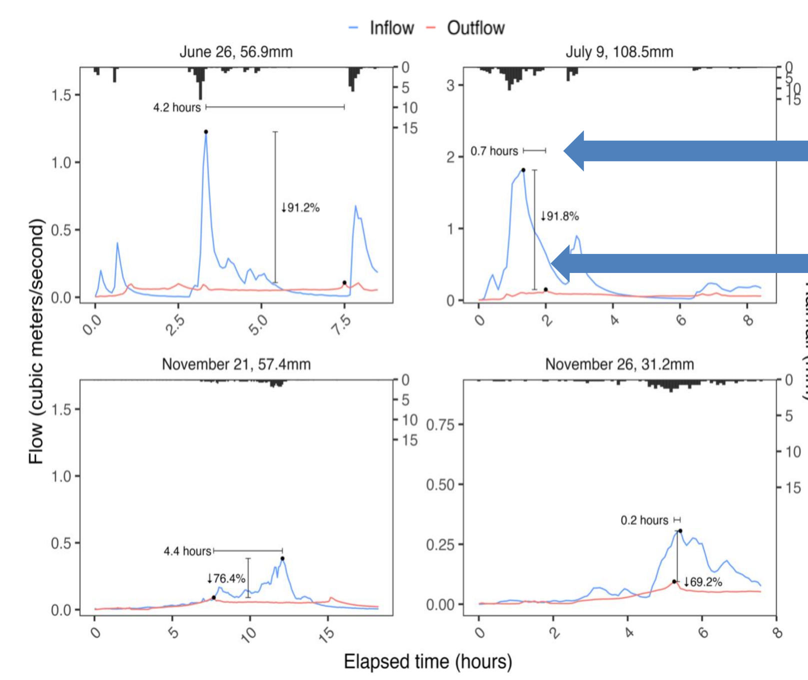
KEY POINTS

System	Commons	CSW	BTI	GSI Type Scale
Analysis facilitates understanding of how GSI can be implemented at the watershed scale, understanding how the success can be limited or aided, and how the shortcomings of one system can be compensated by others.	The system of rain gardens, while managing more stormwater than pre-construction conditions with no stormwater management, were found to be underperforming, largely based on a disconnect between design and construction realities.	The wetland was found to manage the largest percentage of the total rainfall that occurred for all four storms and provides promising benefits for reducing erosive velocities in the form of peak flow reduction.	The bio-infiltration rain garden provides a high degree of management, largely based on the system that controls flow out from the rain garden, which allows the system to retain more rainfall than it was designed for.	A wetland will have greater peak flow reduction, but a rain garden will have a higher percent removal. When comparing these two GSI by drainage area and/or cost, a watersheds needs can determine the most effective GSI.

CONSTRUCTED STORMWATER WETLAND

Figure 4: Aerial View of CSW, from Villanova Drone Imaging.

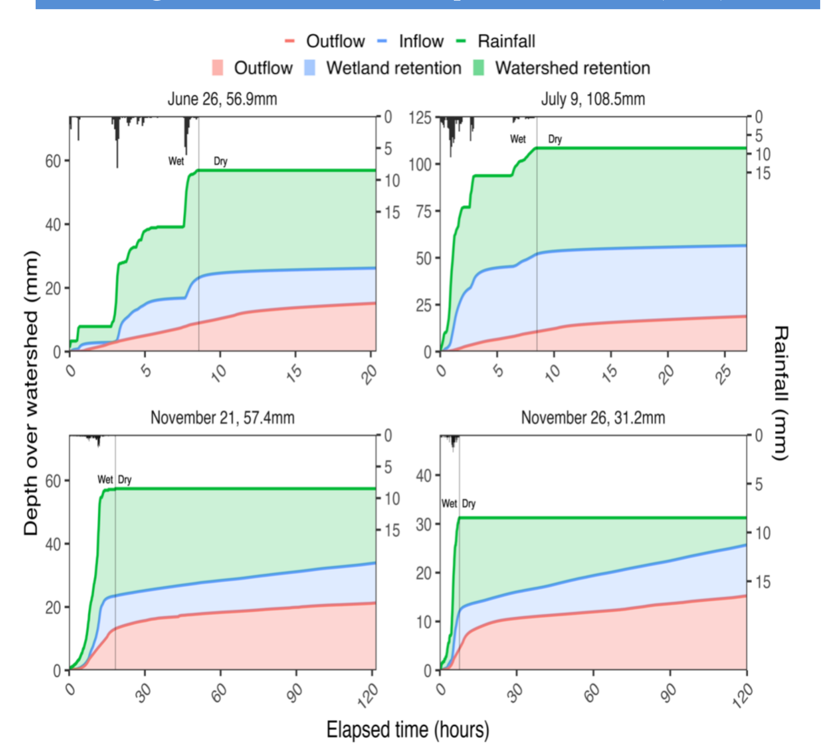
46-acre Drainage Area. / 47% Impervious Surfaces.



Time difference between peak inflow and outflow(hours)

Reduction from peak inflow to peak outflow (percentage reduction)

Figure 5: Continuous flow and peak flow reduction (CSW).

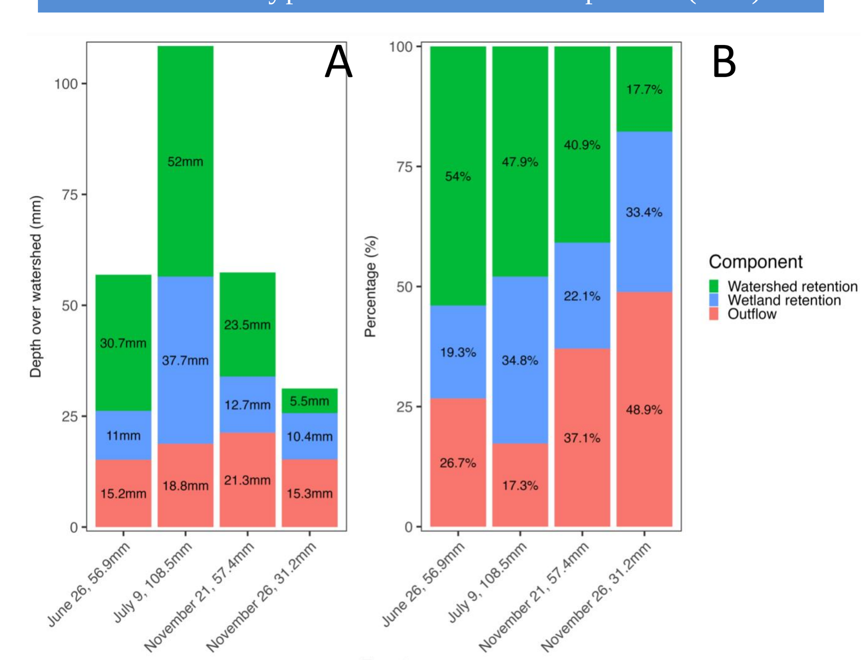


Shaded regions indicate:

- Outflow
- Wetland retention (difference between inflow and outflow),
- Watershed retention (difference between rainfall and inflow)

Volumes are standardized as a depth over the watershed

Figure 6: Cumulative outflow, inflow, and rainfall through the duration of the storms and the dry period after as a function of elapsed time (CSW).



Specific components of the water balance could not be determined and are therefore labeled for their fate (component).

Water balance is represented with shaded portions for each component A. relative to the depth of the storm event (millimeters) and B. the percentage of the water balance occupied by each component (percentage)

Figure 7: Quasi water balance of the four storm events of interest at the CSW through the duration of each storm and the dry period that followed.

BIO-INFILTRATION TRAFFIC ISLAND

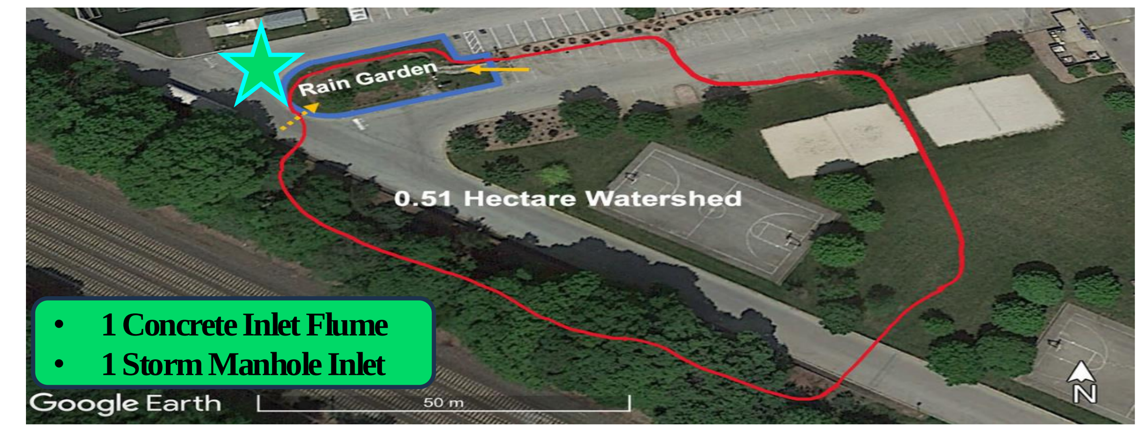
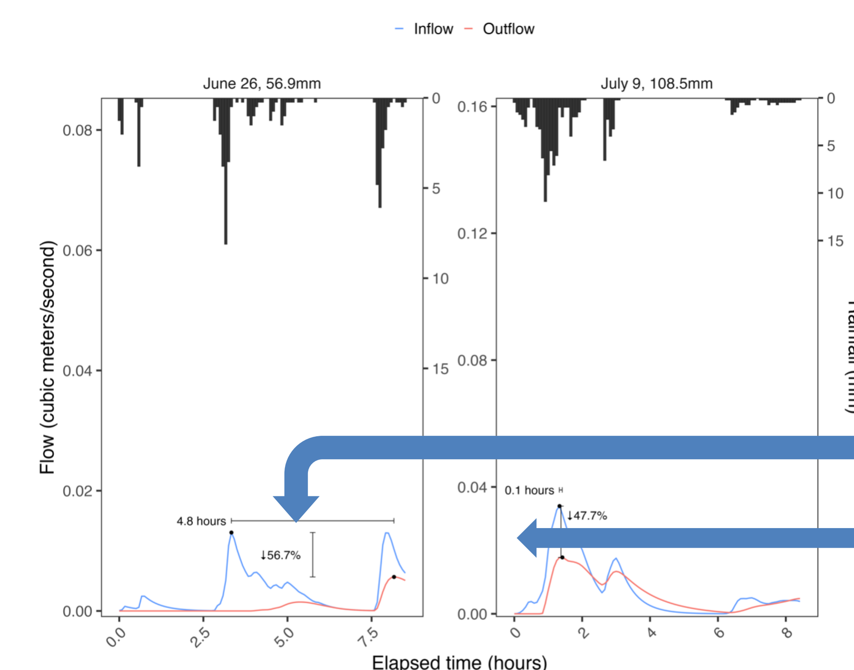


Figure 8: Aerial View of BTI Watershed, Courtesy of Google Earth.

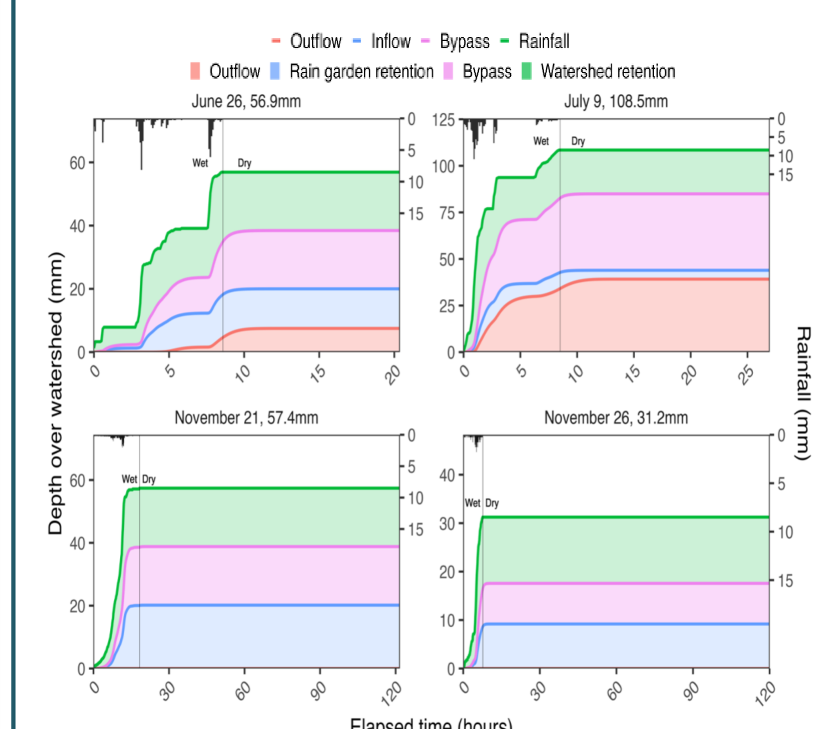
1-acre Drainage Area. / 50% Impervious Surfaces.



Time difference between peak inflow and outflow(hours)

Reduction from peak inflow to peak outflow (percentage reduction)

Figure 9: Continuous flow and peak flow reduction at the BTI for 2/4 storms of interest that produced measurable overflow.

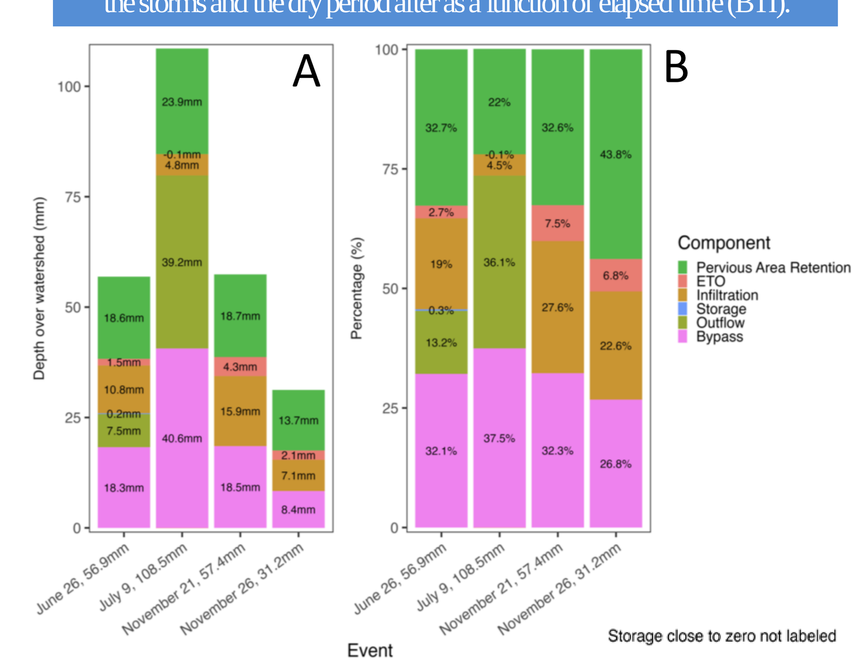


Shaded regions indicate:

- Outflow
- Wetland retention (difference between inflow and outflow),
- Watershed retention (difference between rainfall and inflow)

Volumes are standardized as a depth over the watershed

Figure 10: Cumulative outflow, inflow, and rainfall through the duration of the storms and the dry period after as a function of elapsed time (BTI).



Water balance is divided into the hydrological components that manage water for storm events in the watershed developed in McGauley et al. (2023).

Water balance is represented with shaded portions for each component A. relative to the depth of the storm event (millimeters) and B. the percentage of the water balance occupied by each component (percentage).

Figure 11: Water balance of the four storm events of interest at the BTI through the duration of each storm and the dry period that followed.

LANCASTER AVENUE COMMONS

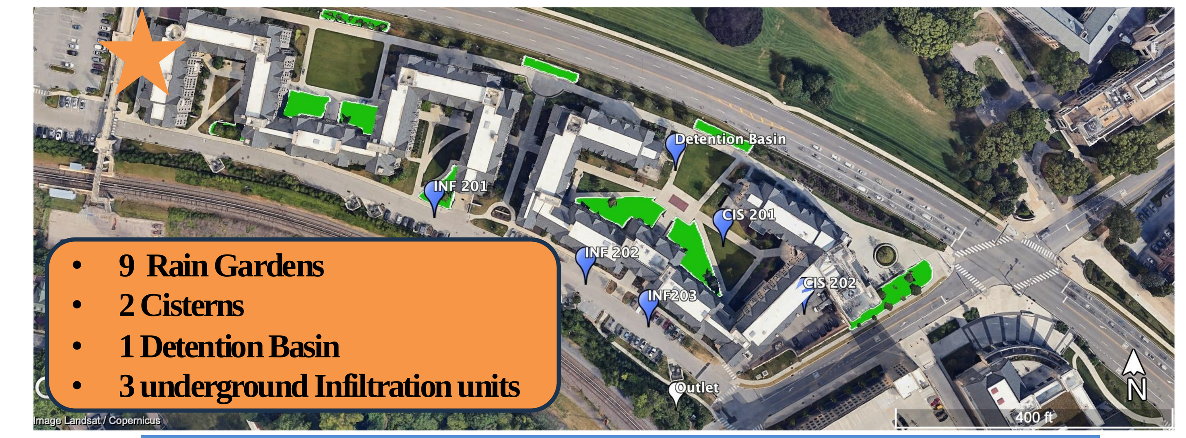
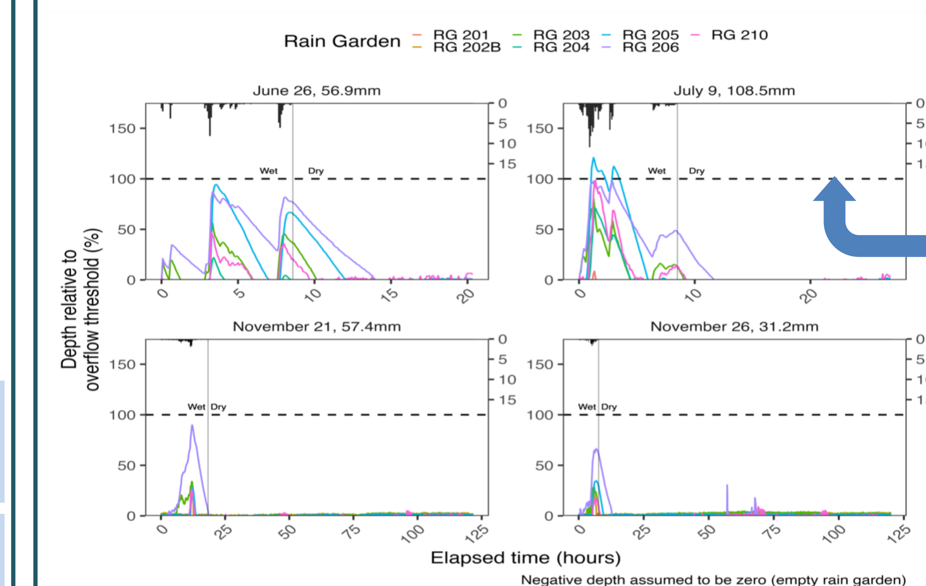


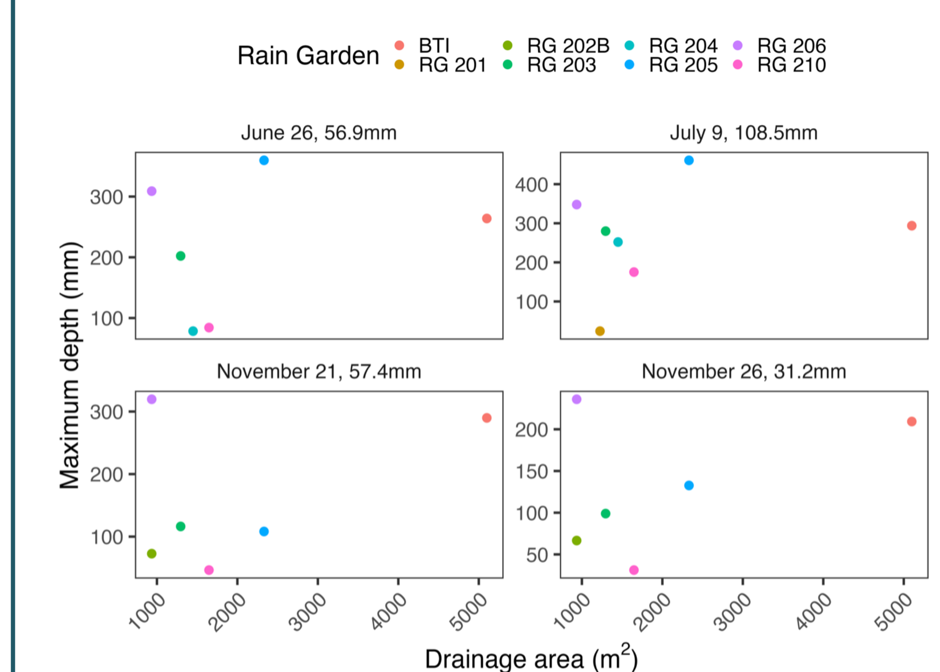
Figure 12: Aerial View of Commons GSI system, Courtesy of Google Earth.

16-acre Drainage Area / 41% Impervious Surfaces



100% (dashed line) indicates that the depth where the rain garden overflows.

Figure 13: Depth of the rain gardens as percentage relative to the overflow depth through the duration of each storm and the dry period that followed (Commons).



The x-axis displays the drainage area of each rain garden relative to the maximum recorded depth on the y-axis.

Figure 14: Maximum ponding depth of the rain gardens at Commons and BTI.

FUTURE WORK

- Repeat the same analysis for a larger collection of storms, and seasons.
- Strengthen knowledge of systems approach to GSI and it's effect on peak reduction at a watershed scale.
- Further the relationship between cost to construct, contributing drainage area, and GSI type.

REFERENCES

McGauley, M. W., A. Amur, M. Shakya, and B. M. Wadzuk. 2023. "A Complete Water Balance of a Rain Garden." *Water Resour. Res.*, 59 (12): e2023WR035155. https://doi.org/10.1029/2023WR035155.
Albright, C. M., and H. Schramm. 2018. "Improvements and Applications in Climate Data Analysis for Determining Reference Rainfall Years." *J. Appl. Meteorol. Climatol.*, 57 (2): 413–420. American Meteorological Society.

Thank You EPA 319 & Villanova Facilities!