An Analysis of the Thermal Effects of Villanova's Constructed Stormwater Wetland

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OVERVIEW

The treatment of water temperature by Stormwater Control Measures (SCMs) is both understudied and varied. The 2006 PADEP BMP manual assumes temperature treatment (as well as other water quality goals) are met if SCMs are used, however there is literature that shows different types of SCMs have different levels of efficacy at dealing with thermal loading due to runoffs. For example:

- SCMs with good shading and high volumes of infiltration reduce thermal loading, but SCMs without good shading tend to have warming in summer and cooling in winter (Kieser et al 2003).
- Constructed stormwater wetlands tend to have large temperature changes if there is no shading (Jones et al 2007).
- Changes in water volumes were often not factored into the previous discussions of temperature treatment by SCMs (Sherwood 2001) and without that maybe difficult to see effects of SCM on downstream systems (Figure 1).

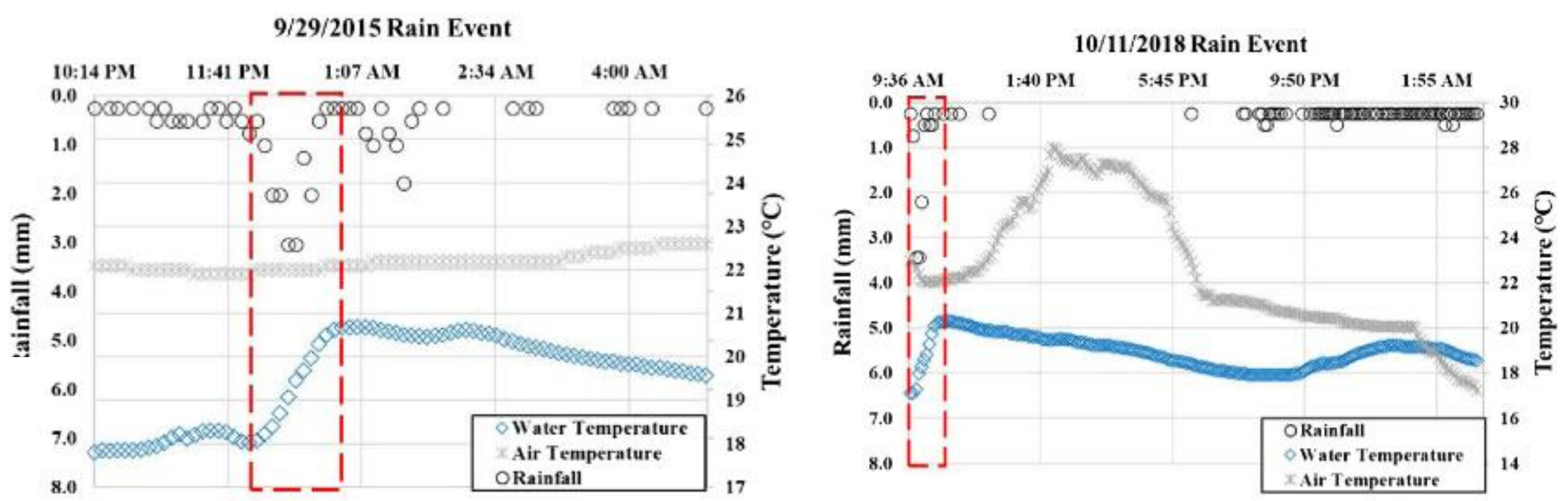

Figure 1: Rainfall, air temperature, and water temperature downstream pre-installation (left) and post-installation of a rain garden (right) for similar storms Martin et al. 2021)

This study looks at the temperature contribution of the non-tree-shaded Constructed Stormwater Wetland (CSW) on Villanova's campus.

METHODS

- Inflow discharge, outflow discharge, water temperature and rainfall data from April 1, 2014 to March 31, 2015 was used for this analysis.
- Data separated into storm events with the rainfall volume greater than 0.1 inches with a minimum of 6-hour dry period between events resulted in 64 storms to be considered (see Figure 2).
- For the events, total rainfall, mean inlet and outlet temperature and total discharge were calculated (Figure 3) and comparisons between inlet and outlet were performed (Figure 4) and categorized seasonally.

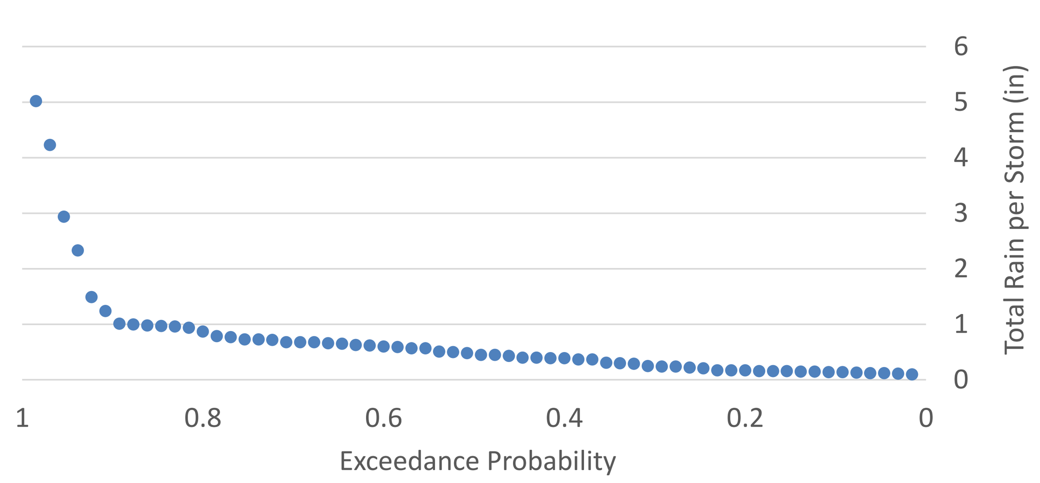

Figure 2: Exceedance Probability of the Analyzed Storms

RESULTS

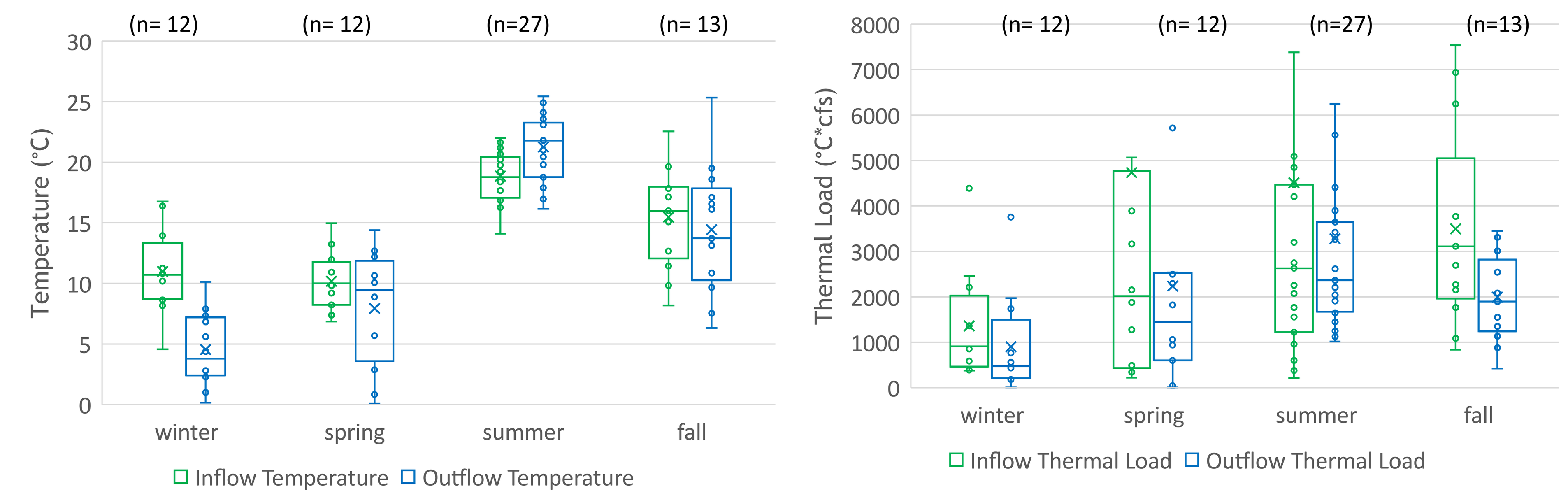

Figure 3. Inflow and outflow and temperature (left) and thermal load (right) by season

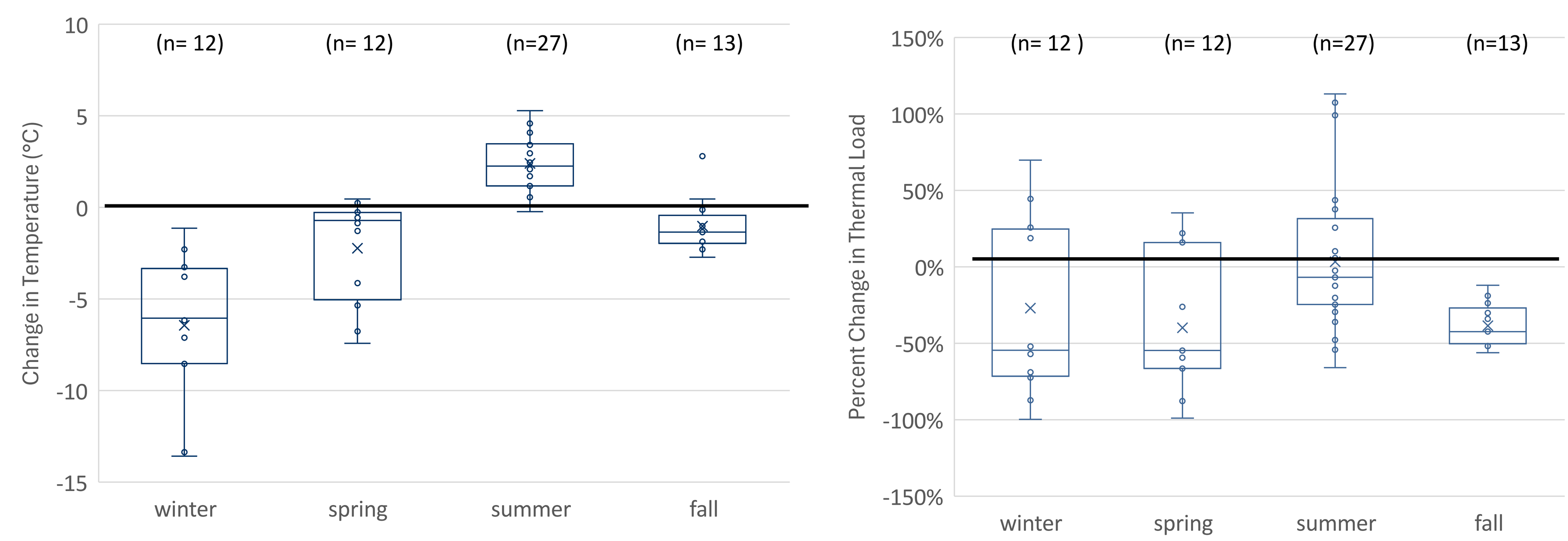

Figure 4. Percentage difference in thermal load (left) and temperature (right) from inflow to outflow by season. Black line indicates neutral temperature contribution.

DISCUSSION

- Temperature export of the CSW is highest in the summer, as expected. Temperature on average (besides in the summer) is lower in the outlet than the inlet. However, all seasons but winter contained at least one storm where the temperature output increases.
- When considering thermal load (volume-weighted temperature) in and out of the CSW, all seasons have a mean decrease in thermal load, with summer being approximately equivalent. All seasons but fall had at least one storm with a net increase in thermal load.
- Temperature and thermal load in terms of changes through the CSW system in general a net positive for both. In Figure 4 (right), the mean change in thermal load is a decrease for all seasons, even summer. It is important to note that there were storms where the wetland contributes to thermal loading in all season, especially in the summer.
- It is important to understand that thermal loading is variable depending on season, storm event size, intensity, and antecedent dry time.

SUMMARY

The CSW is a non-tree shaded SCM, which have been typically associated with having temperature export issues. It was found that the CSW mitigated thermal pollution generally from inflow to outflow on average, but storms regardless of season can lead to an increase in the thermal contribution. This inconsistency in thermal effects demonstrates the complexity of SCMs when it comes to temperature. This helps justify considerations of including shading considerations in the BMP Manual or requiring calculations to determine if thermal pollution mitigation is sufficient.

FUTURE WORK

Using an existing EPA SWMM model of the wetland inflows, the wetland's function was added to the model using measurements from a wetland survey.

This model can be used to estimate the wetland inlet and outlet volumes for design storms. These volumes can then be used along with average water temperatures to determine the effects of the wetland on more storms than just those in the existing data record.

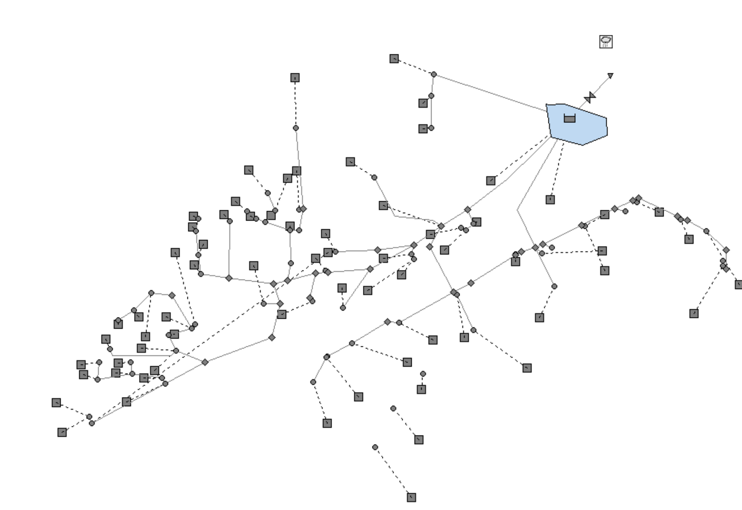

Figure 5. SWMM Model of Wetland Function

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