# Rainfall Analysis and Climate Change Projections for Municipal Infrastructure Planning

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## Highlights

- Much of public discussion around climate change has focused on how temperatures will increase in the coming decades, but climate change is not limited to temperature alone
- Precipitation changes will also have an impact on communities, particularly in urban areas, that are vulnerable to increased flooding and property damage.

## Introduction

While much of the public discussion around climate change has focused on how temperatures will increase in the coming decades, climate change is not limited just to temperature. Precipitation changes will also have an impact on communities, particularly in urban areas with high impervious surfaces that are vulnerable to increased flooding and property damage. Many municipalities are responding to this risk by analyzing their local rainfall patterns and developing climate change rainfall projections to inform local strategies to reduce the impacts of increasing rainfall. Completing a rainfall analysis with climate change projections allows municipalities to make informed decisions related to stormwater management and flood resiliency.

Intensity-duration-frequency (IDF) curves are often used by municipalities in design standards (green infrastructure, road drainage, land development), prioritizing future projects, or implementing flood mitigation. It is often the case that IDF curves used in these important decisions are outdated and fail to represent current precipitation patterns, let alone represent precipitation patterns that are likely to occur with infrastructure lifespans spanning to 2050, 2070, or beyond.

## Methodology or Background (for case study)

The official IDF curves for Pennsylvania, from NOAA Atlas 14, Volume 2 IDF, were last revised in 2006 and used precipitation data through the year 2000. In order to update these existing IDF curves, historic rainfall data from NOAA is collected and analyzed for completeness and quality. Several stations with both long and complete records that are within and/or surround the target municipality should be selected. Using a statistical analysis similar to the method used by NOAA, IDF curves that includes data up to the most recent full year are created.

Once the updated baseline IDF curve has been created, the municipality should select their planning horizons of interest. Future climate projections using available climate models can be made up to the year 2100 and most often two or three horizons are selected. This allows different IDF curves to be considered for decisions that require different lifespans. For example, a new water main or wastewater treatment plant have long expected lifespans, so a planning horizon around 2100 would most likely be used for sizing decisions. A shorter-term planning horizon, such as 2040, can be useful for infrastructure with shorter lifespans.

The selected planning horizon years are then used to project the updated baseline IDF curves to the future, using modeling software such as SimCLIM and an ensemble of global climate models (GCMs). When projecting rainfall data, there are four Representative Concentration Pathways (RCPs) to choose from which offer a range of expected emission outcomes. Typically, two different RCPs will be chosen and used as “high” and “low” ends of likely scenarios. The RCPs chosen will depend on the risk tolerance of the municipality as the RCPs range from more to less conservative.

Using these inputs of planning horizon, GCM ensemble, and RCP, a percent increase in extreme precipitation can be calculated based on climate change models and SimCLIM modeling software. This percentage is then applied to the updated baseline IDF curve generated for the municipality to produce projected IDF curves for each year and climate change scenario that was selected.

## Key Findings

This presentation will focus on results for the City of Lancaster as a case study. For this analysis, results were projected for the years 2040, 2060, and 2100 for three different global emissions scenarios. This case study will demonstrate the impact that climate may have on precipitation in the City of Lancaster over the next 80 years, and how this information can supplement the City’s Municipal Climate Action Plan. Upcoming changes to climate science will also be covered.

## Recommendations

Climate change is an increasingly important consideration that will affect all municipalities and should be considered during decision making to ensure that existing and proposed infrastructure can withstand the precipitation that will occur throughout its lifespan. Updated baseline and projected future IDFs can help municipalities in various ways such as: updating development and design standards, saving money by combining infrastructure upgrades with safeguards against climate change (i.e., increasing pipe sizes during a planned replacement), planning lifespans of existing infrastructure, and identifying areas of increased or future flooding.

# Future Climate Impact on Raingarden Effectiveness in a Suburban Watershed

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## Highlights

- By end of century annual precipitation and daily high temperature increase 10.6% and 1.8°C, respectively
- On average, raingardens provide significant control of event peak flow through end of century
- However, extreme events are not well controlled by raingardens after mid-century

## Introduction

Stormwater management practices are designed to reduce the peak rate and total volume of runoff leaving impervious surfaces (PA DEP, 2006) using current and historic climate data. However, climate change is expected to increase the total amount and variability of precipitation, as well as the average daily temperature. These factors have a significant influence on the volume and rate of inflow to SMPs, the volume of evapotranspiration from SMPs, and the volume and rate of discharge from SMPs. This study examined the influence of expected climate conditions in the near future (2025-2055), in mid-century (2040-2070), and in the far future (2070-2099) on the performance of 9.3 $m^2$ raingardens (RG) installed on 75% of residential parcels in the Roychester Park drainage area of Abington Township, Montgomery County, Pennsylvania.

## Methodology

**Current Climate**

Current climate was defined using 15-minute precipitation and daily minimum and maximum temperatures from 1990-2020. The precipitation data was collected by the Philadelphia Water Department (PWD) at Rain Gage 21 located in northwest Philadelphia, approximately 14 km west-southwest of Roychester Park. The temperature data were collected by NOAA at the Philadelphia International Airport, located approximately 30 km southwest of Roychester Park.

**Future Climate**

Future climate data was first developed by applying monthly adjustment factors to the current climate data using a process similar to the SWMM – Climate Adjustment Tool (Rossman, 2014). However, for this study, the adjustment factors were derived from the monthly average of daily output for 6 downscaled models (MACA, 2021) from the Intergovernmental Panel on Climate Change's Coupled Model Intercomparison Project Phase 5 (CMIP5). PCSWMM v7.4 (CHI, 2021) was run using both the unadjusted current climate data and with the application of these monthly adjustment factors to the current climate data. These model runs were used to assess the impact of RG on the event total runoff volume ($V_{Tot}$) and event peak runoff rate ($Q_{Pk}$) under current and potential future climate.

Recognizing that application of monthly adjustment factors to current climate data may not adequately account for future changes in precipitation or daily temperature patterns, we next aggregated the 15-minute PWD precipitation data to daily values and reran our model 7 times—using the aggregated current data and the daily output from each of the 6 CMIP5 models. We then estimated the 1-day flood flowrate with a 2-yr, 5-yr, and 10 yr recurrence interval (${}_1Q_2$, ${}_1Q_5$ and ${}_1Q_{10}$) and the associated total flood volumes with and without RG in each future climate period.

## Key Findings

RG perform very well at reducing $Q_{Pk}$ (Fig 1a). When RG are installed on 75% of parcels, $Q_{Pk}$ would be just 54% of what it would be today without RG. As the climate warms, performance decreases slightly such that by the 2070-2099period, $Q_{Pk}$ with RG is projected to be 62% of what it would be today without RG. While the reduced effectiveness is concerning, without RG $Q_{Pk}$ is expected to be 106.0% of today's $Q_{Pk}$ in the 2025-2055 period and

113.2% of today's $Q_{Pk}$ in the 2070-2099 period. Similar, though smaller, changes are expected with respect to $V_{Tot}$ (Fig1b). $V_{Tot}$ with RG is projected to be 90.3% of $V_{Tot}$ without RG today, and in the 2070-2099 period, $V_{Tot}$ with RG is projected to be 103.7% of $V_{Tot}$ without RG today. However, if RG are never installed, $V_{Tot}$ is projected to be 103.8% of today's $V_{Tot}$ in the 2025-2055 period and 113.7% of today's $V_{Tot}$ in the 2070-2099 period.

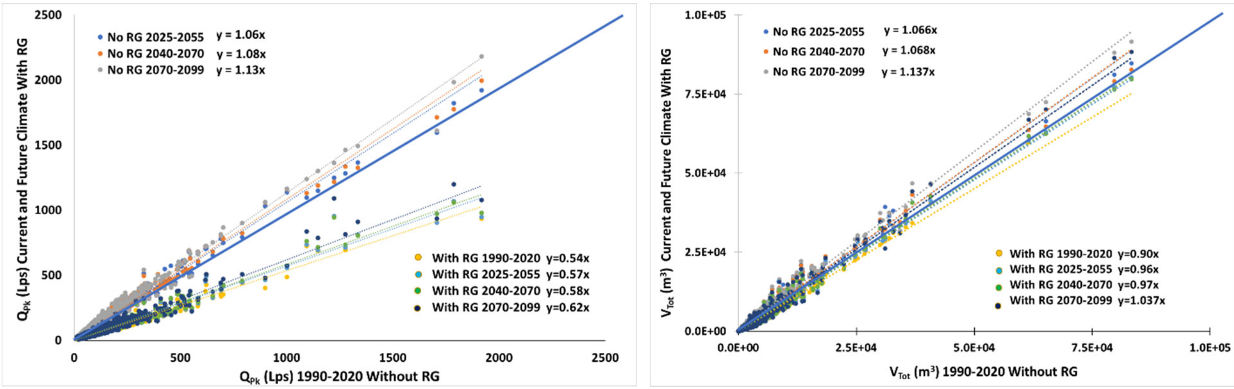


**Figure 1.** Effectiveness of RG in controlling (a) $Q_{Pk}$ and (b) $V_{Tot}$ when installed on 75% of parcels. Thick blue line is the 1:1 line. Dashed lines are trends for each current and future climate scenario with and without RG. RG are much more effective in reducing $Q_{Pk}$ than $V_{Tot}$.

Accounting for expected changes in precipitation and temperature patterns, extreme precipitation events are also expected to increase under future climate conditions. This will result in larger ${}_1Q_2$, ${}_1Q_5$ and ${}_1Q_{10}$ and the associated $V_{Tot}$. For example, today, RG would reduce the ${}_1Q_2$ by 31.4% (Fig2a). However, by the 2040-2070 period, RG would reduce today's ${}_1Q_2$ by just 6.6% (Fig2a) and by the 2070-2099 period, the ${}_1Q_2$ with RG is projected to be 23% greater than today's ${}_1Q_2$ without RG. If, on the other hand, no RG are installed, the ${}_1Q_2$ is projected to increase by 8.1% by the 2025-2055 period, 15.6% by the 2040-2070 period and 28.3% by the 2070-2099 period. Volume reductions follow a similar pattern, with 31% reduction projected under current climate and <1% reduction by the 2040-2070 period. The ${}_1Q_5$ and ${}_1Q_{10}$ data (not shown) follow similar patterns.

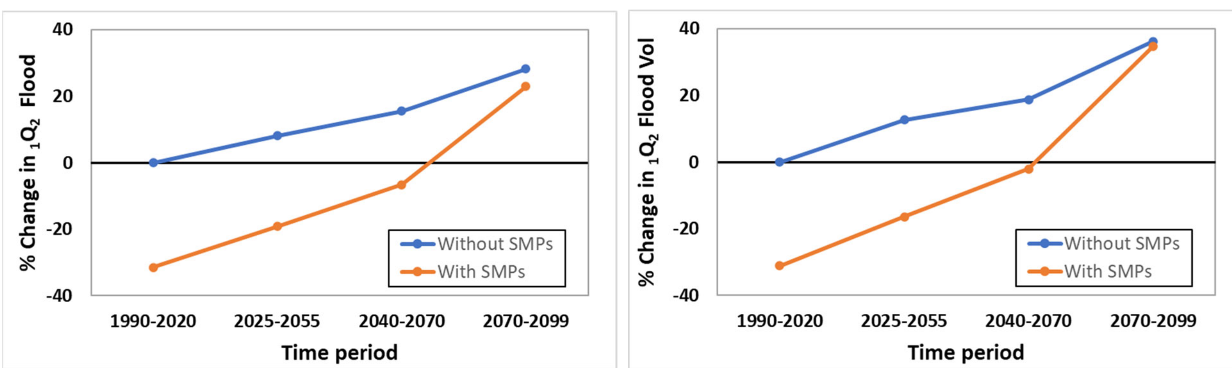


**Figure 2.** Change in (a) ${}_1Q_2$ and (b) $V_{Tot}$ for the ${}_1Q_2$ relative to the expected value in the current climate without RG. Significant flow reductions are projected through the mid-century period and significant volume reductions are projected through the near future period. After these times, RG provide little or no protection against extreme events.

# Recommendations

- Watershed modeling for future climate is inherently uncertain and IPCC CMIP output continues to change.
- This uncertainty must be considered in SMP design to ensure adequate stream and flood protection.
- Larger or additional parcel-scale SMPs, which allow for infiltration or evapotranspiration, should be considered.
- Neighborhood-scale SMPs which can be more easily oversized should be considered

# References


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# Design of Stormwater Control Measures for Extreme Rainfall

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## Highlights

- State Water Plan survey: Extreme rainfall events are impacting municipal budgets.
- Adapting stormwater control measures (SCM) for extreme rainfall is primarily an inflow problem.
- Includes the 2022 Pennsylvania Post Construction Stormwater Management Manual's approach.

## Introduction

This presentation is proposed for the Villanova Stormwater Symposium October 12, 13, and 14 of 2021. The presentation will include the results of a survey conducted for the State Water Plan update on the needs and understanding of 31 municipalities in the Delaware Estuary regarding the management of extreme rainfall. The survey will be used to illustrate the needs of local governments as well as to discuss the scarcity of the resources necessary for adaption. Next, we will explore proposed solutions currently included in the Draft 2022 Pennsylvania Post Construction Stormwater Management (PCSM) Manual and how they apply to existing basin retrofits that could reduce the cost of flood management for municipalities.

## Methodology or Background

**Survey of Municipalities for the State Water Plan Update**

NTM assembled a questionnaire which was subsequently reviewed by the Pennsylvania Department of Environmental Protection. The questionnaire was adopted by the Delaware Basin Regional Water Resource Committee (DBRC) to help inform the writing of the State Water Plan. DBRC appointed NTM to conduct the survey. NTM reviewed local government information, regional planning organization information, and leveraged our understanding of the communities to determine who to contact in each community. Statistical data from the survey that will be presented.

**Development of Approach to Climate Adaptation for Inclusion in the PCSM Manual**

NTM and Villanova are collaborating to develop the 2022 PCSM Manual for the State of Pennsylvania. Although much is unknown about the implications of changing rainfall patterns, preliminary investigations and research indicate that inlet capacity is a major limiting factor in the function of an SCM during extreme rainfall events. Adjusting inlet design criteria and small storm rainfall depths is the solution used in the 2022 PCSM Manual. The guidance included in the 2022 PCSM Manual was developed by using NOAA rainfall information compared to EPA SWMM's Climate Adjustment Tool, recent work by NTM employees, and many peer-reviewed publications.

## Key Findings

Preliminary findings from the survey of Delaware Estuary Municipalities indicates a growing awareness of changing rainfall patterns but a lack of resources to address the problem. There is a need for guidance on how to to adapt to the changing rainfall patterns. The proposed guidance in the 2022 PCSM Manual provides a cost-effective way to adapt existing SCMs to accept more intense rainfall. This work can be performed by existing municipal engineers and public works crews. Reducing the cost of climate adaption and merging the effort with other stormwater programs are needed to meet changing stormwater objectives with the limited budgets available to most municipalities.

## Recommendations

Local municipalities are requesting education, engineering support, state and regional government support, and funding to adapt to changing rainfall patterns. This presentation, and the survey it is based on, are intended to begin to address the needs of municipalities. Both the State Water Plan and the 2022 Pennsylvania PCSM Manual can be utilized as resources for municipalities to perform climate adaptation and address changing rainfall patterns.