

Accounting for Climate Change in Rainfall Intensity-Duration-Frequency (IDF) Curves for Stormwater Management¹

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Introduction

Structures and systems for stormwater management, including dams, spillways, canals, roads, drainage networks, and pumping stations, are designed based on understanding storm event characteristics found in historical data. The frequency of a storm of a given size occurring at a certain frequency is estimated using rainfall intensity-duration-frequency (IDF) curves. As the name implies, these curves can be used to determine the amount of rainfall of a given duration (e.g., the amount that may occur over one hour or one day) that is expected to occur at a given frequency (e.g., expected to recur every 10 or 100 years) (Her et al. 2018). The statistics of the historical observed rainfall at a given location are used to calculate the curves. These IDF curves are then used in engineering design, such as stormwater infrastructure.

One major problem with IDF curves is they assume that the historical rainfall used to create the curves is “stationary” (i.e., not changing over time). If rainfall changes over time due to climate change, the curves may provide an insufficient estimate (or an excessive estimate) of future rainfall intensities or depths. Thus, their use could result in under-designed (or overdesigned) engineering projects. However, climate change is an evolving science, and forecasting how

rainfall patterns and IDFs will change in response to it remains an imprecise analysis.

Accounting for climate change in IDF curves is a topic of considerable ongoing research; to date, there is no single “best” way to do so (Hathaway et al. 2024). This publication is meant to describe three major approaches to account for climate change in IDF curves and the pros and cons of each approach. This document aims to provide information to practicing engineers, Extension agents, and others interested in how projected changes in rainfall patterns can be considered for water resources management.

Three Approaches to Account for Climate Change in IDF Curves

Scaling Existing IDF Curves

Scaling IDF curves created with historical rainfall records is the most straightforward approach to account for climate change in IDF curves. For this approach, an existing IDF curve (e.g., from the NOAA Atlas 14 website [<https://www.weather.gov/owp/hdsc>]) is adjusted by a given amount to estimate a future IDF curve, or more specifically, a rainfall intensity of a duration and return frequency is scaled by a factor. For example, the United Kingdom applies a 20%

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increase to the amount of rainfall that may occur for a given duration and frequency to create future IDF curves (UK Department for Infrastructure 2020). An example is provided in Figure 1. This figure shows the historical IDF curves for Gainesville, Florida in the top half. The adjusted (i.e., by 20%) IDF curves are shown in the bottom half. For example, the 24-hour rainfall with an expected 100-year recurrence interval based on historical rainfall is 9.5 inches (shown in the red circle, Figure 1a). For the adjusted curve, the amount would be 11.4 inches (shown in the red circle, Figure 1b).

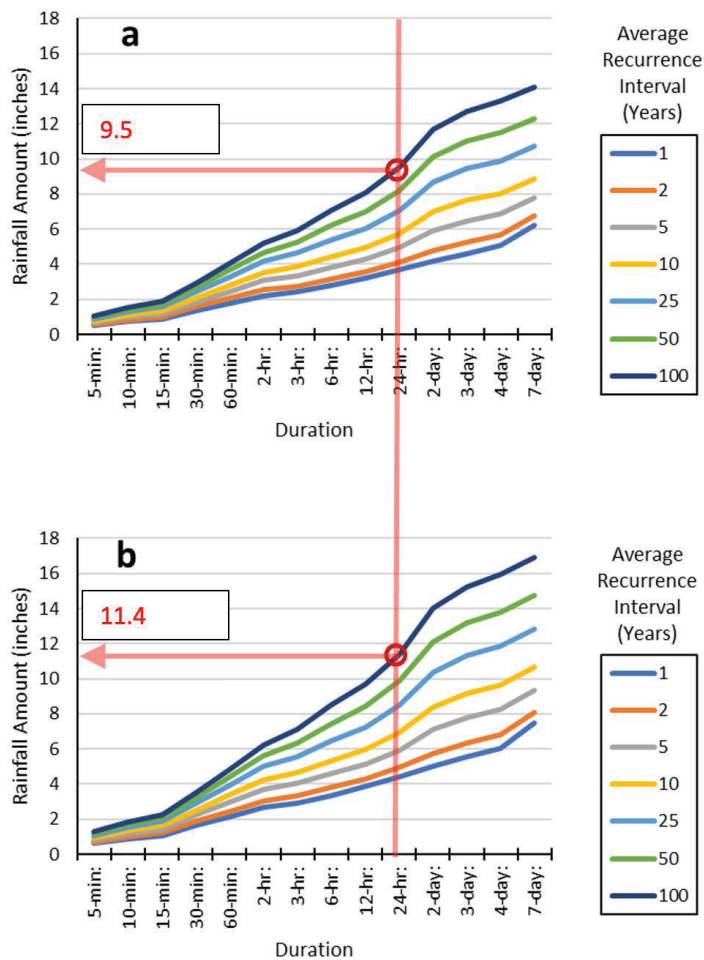


Figure 1. Existing (a) and scaled (b) IDF curves for Gainesville, Florida. The red circles highlight the 24-hour, 100-year recurrence interval. Data for the curves were obtained from the NOAA Atlas 14 website (<https://www.weather.gov/owp/hdsc>). Credits: UF/IFAS

One major downside to this simple scaling technique is that it is somewhat arbitrary. How much should a future IDF curve change without additional information to use as a guide? This issue is partially addressed in the next two approaches.

Scaling Existing IDF Curves Based on Projected Increase in Warming

According to the Clausius-Clapeyron relation, for every 1-degree Celsius increase in temperature, the atmosphere can hold 7% more water (Martel et al. 2021). More water held by the atmosphere increases the likelihood of more intense rainfall events. Adjusting IDF curves by 7% for each degree of warming expected in the future is a common practice. However, this can result in either an over- or underestimation of future rainfall amounts as well. The reasons for the biased rainfall amount estimation include whether there will be an increase or decrease in convective rainfall (which is common in Florida in the summer) and other changes that may occur in weather patterns for a given location. In addition, it is believed that the impact of warming will be greater than 7% for shorter (i.e., less than one day) rainfall events compared to longer durations. More in-depth information on this topic can be found in the articles listed at the end of this publication (Martel et al. 2021; Roderick et al. 2020; Schlef et al. 2023; Zhang et al. 2017; Kourtis and Tsihrintzis 2022).

Scaling Existing IDF Curves Using Projected Rainfall from Global Climate Models

Scaling IDF curves using projected future rainfall from global climate models (or a general circulation model) (Her et al. 2020) is an appealing alternative because changes seen in rainfall from the model output between historical and future periods should theoretically include both the changes caused by temperature as well as other aspects of weather patterns that may influence rainfall intensity in a given location. However, global climate models are run at a coarse resolution, and their output may not represent local conditions. Therefore, output from global climate models is typically translated to the local or regional level and corrected for bias; these processes are often called downscaling and bias correction, respectively (Her et al. 2020). Such scaling and correction processes can be computationally intensive, especially when done with regional climate models. More in-depth information on using global climate models to scale IDF curves can be found in the articles listed at the end of this publication (Zhang et al. 2017; Her et al. 2018; Her et al. 2020; Martel et al. 2021; Schlef et al. 2023).

Possible Extension Outreach Applications

Having a greater understanding of methods and applied science related to this subject matter, Extension agents and specialists can assist in disseminating information to stakeholders, communities, water managers, planners, and policymakers. Climate change involves uncertainty, which makes planning for the impacts difficult for the public and decision-makers. As rainfall patterns change, Extension can help these audiences to learn and understand how future events may affect them. For example, Extension specialists can put into context that a 10-year, 24-hour event that has occurred recently will occur more frequently because the same rainfall amount over that period may be expected to have an increased chance of occurring each year in the future. In addition, Extension agents can explain how a storm such as the 10-year, 24-hour event will have a greater rainfall amount in the future than it does now. This can also help the public understand why flooding may increase as the rainfall for these durations and frequencies increase above what stormwater systems were initially designed to convey. Lastly, this information could be used in emergency response planning to identify areas of increasing flood risk and set standards to protect agricultural and urban stakeholders.

Summary

Accounting for climate change in IDF curves is of growing importance as the need to include climate change considerations in engineering design grows. Currently, there is no consensus on the best way to incorporate climate change into IDF curves. This publication briefly describes three main approaches for accounting for climate change in IDF curves, and it will be updated with new research advances in the future.

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