USER'S MANUAL

Next-Generation Rainfall IDF Curves for the Virginian Drainage Area of Chesapeake Bay

SERDP Project RC18-1569

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Next-generation probability-based rainfall intensity-duration-frequency (IDF) curves for the state of Virginia were created to reflect the non-stationarity of the future climate. The curves were created both at the rain gauge and USGS (U.S. Geological Survey) 8-digit hydrologic unit code (HUC) levels. Such curves are useful tools for the planning, design, and management of Department of Defense (DoD) as well as civic water flow-relevant infrastructure in the changing climate. This manual takes the IDF curves for one rain gauge and one HUC as examples to demonstrate how to use them in practice.

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1. Introduction

Next-generation probability-based rainfall intensity-duration-frequency (IDF) curves for the state of Virginia were created to reflect the non-stationarity of the future climate. The curves were created both at the rain gauge and USGS (U.S. Geological Survey) 8-digit hydrologic unit code (HUC) levels. Such curves are useful tools for the planning, design, and management of Department of Defense (DoD) as well as civic water flow-relevant infrastructure in the changing climate.

This manual takes the IDF curves for one rain gauge and one HUC as examples to demonstrate how to use them in practice.

2. Rain Gauge-Level IDF Curves

Figure 1 shows the 6-hour (hr) probability-based IDF curves for gauge 442044 (Cobington Filter Plant). This gauge (37° 48′36″ N, 79° 59′17″ W) is located near the south-western border of Virginia and has an altitude of 374.9 meters (m). The observed rainfall intensities at this gauge exhibited a marginally significant decreasing trend at a significance level of $\alpha = 0.05$. The IDF curves for the other durations and gauges can be found in the final report.

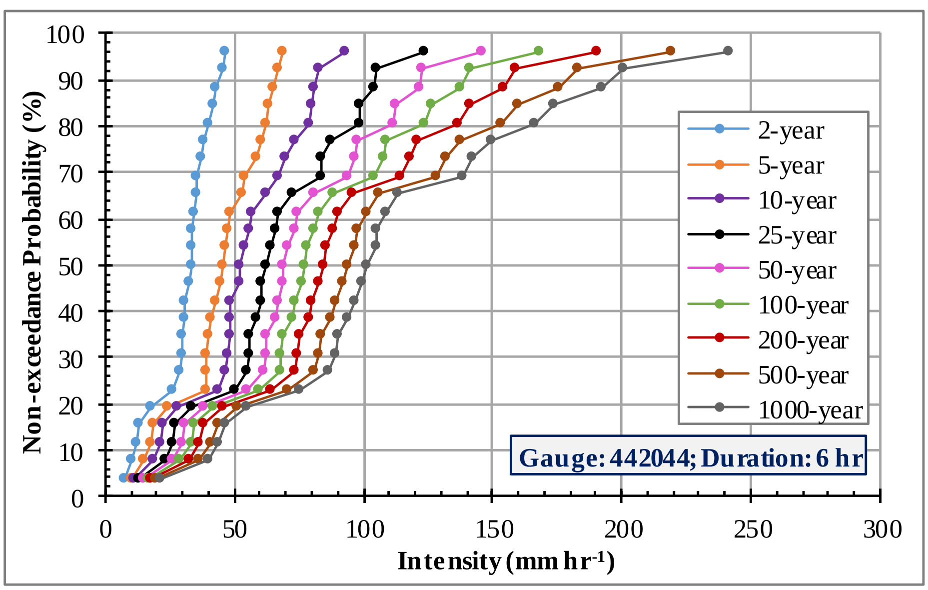

Figure 1. The 6-hr probability-based IDF curves for gauge 442044.

For the duration and return period of interest, the rainfall intensities associated with the responding non-exceedance probabilities are read from the curve. To design an infrastructure, the intensity of the synthetic storm can be determined using one of the following two methods.

Method I: In terms of a selected acceptable risk for the infrastructure, this method determines the design storm intensity as follows:

First, compute the non-exceedance probability associated with the acceptable risk as:

$$P_r = (1 - r_{isk})^{\frac{1}{L}} \tag{1}$$

where P_r is the adopted non-exceedance probability; r_{isk} is the acceptable risk for the infrastructure; and L is the lifespan of the infrastructure.

r_{isk} is defined as the chance to incur at least one storm event with an intensity larger than that responding to P_r in the consecutive L years.

Second, read the curve to obtain the intensity that is paired with P_r and use it as the design storm intensity.

Method II: This method does not consider risk; instead, it considers the entire IDF curve. In terms of the intensities that are paired with the non-exceedance probabilities of 10, 25, 50, 75, and 95%, this method determines the design storm intensity as follows:

First, read the curve to obtain the intensities that are associated with the five non-exceedance probabilities.

Second, compute the design storm intensity as:

$$i = \sum_{j=1}^{4}\left[\left(P_{r,j+1} - P_{r,j}\right)\frac{i_{i+1} + i_i}{2}\right] \tag{2}$$

where $P_{r,j}$ and $P_{r,j+1}$ are the two closest non-exceedance probabilities; i_{j+1} and i_j are the intensities associated with $P_{r,j}$ and $P_{r,j+1}$, respectively.

[**Example 1**] If a drainage system, located near rain gauge 442044, is to be designed to have a lifespan of 10 years. Based on the relevant criteria, a 6-hr 50-year design storm should be used. Determine the design storm intensity using the:

(1) Method I for an acceptable risk of 0.1

(2) Method II

[**Solution**] L = 10 years, D = 6 hr, T = 50-year

(1) Eq. (1) → $P_r = (1 - 0.1)^{\frac{1}{10}} = 0.99$ → from Figure 1, the intensity is i = 190 millimeter (mm) hr^{-1}

(2) From Figure 1, one can read the intensities as given in Table 1.

Table 1. The 6-hr 50-year storm intensities for the non-exceedance probabilities.

Non-exceedance Probability (%)	Rainfall Intensity (mm hr-1)
10	30
25	75
50	90
75	125
95	180

Eq. (1) → $i = (25\% - 10\%) \times \frac{75+30}{2} + (50\% - 25\%) \times \frac{90+75}{2} + (75\% - 50\%) \times \frac{125+90}{2} + (95\% - 75\%) \times \frac{180+125}{2} = 86$ mm hr^{-1}

3. Watershed-Level IDF Curves

Figure 2 shows the 24-hr probability-based IDF curves for the U.S. Geological Survey (USGS) 8-digit HUC or watershed 442044. The IDF curves for the other durations and gauges can be found in the final report.

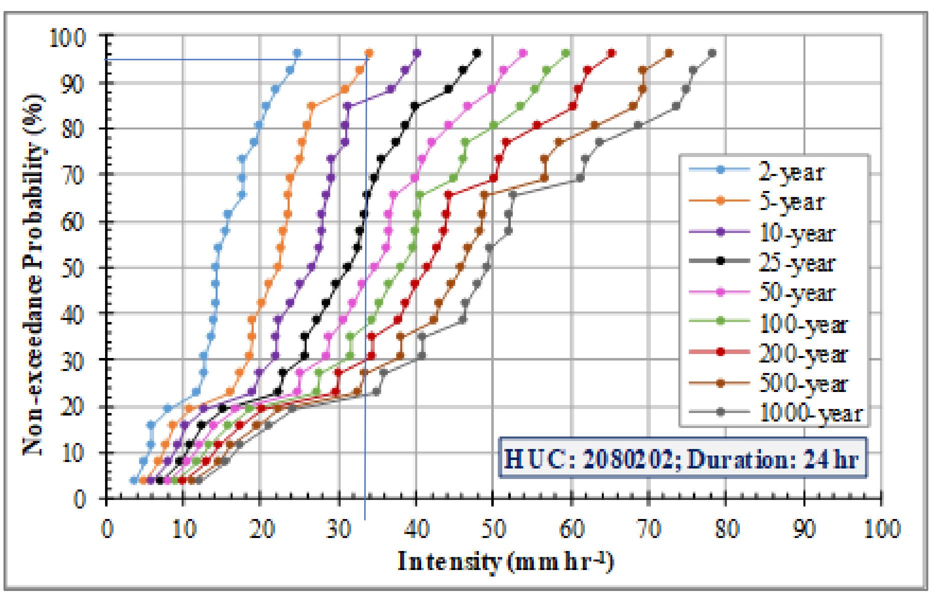

Figure 2. The 24-hr probability-based intensity-duration-frequency (IDF) curves for HUC 02080202.

For the duration and return period of interest, the rainfall intensities associated with the responding non-exceedance probabilities are read from the curve. To design an infrastructure, the intensity of the synthetic storm can be determined using one of the following two methods.

<u>Method I:</u> In terms of a selected acceptable risk for the infrastructure, this method determines the design storm intensity as follows:

First, compute the non-exceedance probability, P_r, associated with the acceptable risk using Eq. (1). *Second*, read the curve to obtain the intensity that is paired with P_r and use it as the design storm intensity.

<u>Method II:</u> This method does not consider risk; instead, it considers the entire IDF curve. In terms of the intensities that are paired with the non-exceedance probabilities of 10, 25, 50, 75, and 95%, this method determines the design storm intensity as follows:

First, read the curve to obtain the intensities that are associated with the five non-exceedance probabilities. *Second*, compute the design storm intensity using Eq. (2).

[**Example 2**] If a drainage system that drains a subwatershed of HUC 02080202 is to be designed to have a lifespan of 15 years. Based on the relevant criteria, a 24-hr 5-year design storm should be used. Determine the design storm intensity using the:

(1) Method I for an acceptable risk of 0.1

(2) Method II

[**Solution**] L = 15 years, D = 24 hr, T = 5-year

(1) Eq. (1) → $P_r = (1-0.1)^{\frac{1}{15}} = 0.99$ → from Figure 2, the intensity is i = 34 mm hr^{-1}

(2) From Figure 2, one can read the intensities as given in Table 2.

Table 2. The 24-hr 5-year storm intensities for the non-exceedance probabilities.

Non-exceedance Probability (%)	Rainfall Intensity (mm hr-1)
10	7
25	16
50	22
75	25
95	34

Eq. (1) → $i = (25\% - 10\%) \times \frac{16+7}{2} + (50\% - 25\%) \times \frac{22+16}{2} + (75\% - 50\%) \times \frac{25+22}{2} + (95\% - 75\%) \times \frac{34+25}{2}$ = 18 mm hr^{-1}

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4. Conclusions

In terms of a probability-based IDF curve of interest, the design storm intensity can be determined using one of the two methods. Method I computes the non-exceedance probability associated with an acceptable risk and then reads the IDF curve to obtain the design storm intensity as the one corresponding to the probability, whereas Method II determines the design storm intensity as the exceedance probability-weighted average of the intensities that are paired with the non-exceedance probabilities of 10, 25, 50, 75, and 95%. In general, the design storm intensity from Method I is larger than that from Method II, meaning that Method I is more conservative than Method II. In practice, the selection of one method over another will depend on the acceptable tolerance to the possible failure of the infrastructure. The application of such IDF curves will improve future Department of Defense (DoD) infrastructure planning processes and prevent over- or under-committing resources.