VILLANOVA UNIVERSITY
COLLEGE OF ENGINEERING

CENTER FOR RESILIENT WATER SYSTEMS

# Assessment of Flooding by Extreme Rainfall Events

**Starkey, Richard[1], Smith, Virginia[1]**
[1]Villanova University, Villanova, PA, USA

## OVERVIEW

The Pennsylvania Department of Transportation supplied a dataset of Road Closures due to Flooding in District 6, spanning from January 2016 to November 2021. The road closure dataset serves as a proxy for flooding. The analysis explores the significance that *physical variables have on road closures associated with flooding when considering different extreme rainfall events and explores the impact that these events have on a roadway network.*

**Table 1**. Summary of Road Closures due to Flooding during Extreme Rainfall Events.

| Rainfall Event | Date | Number of Road Closures | Type of Event |
|---|---|---|---|
| Snowmelt Event | Nov. 2018 | 13 | Dynamic Event, Snow followed by Rain |
| Hurricane Isaias | Aug. 2020 | 90 | Short Duration, High Intensity |
| Hurricane Ida | Sep. 2021 | 137 | Long Duration, High Volume |

The road closures are spatially projected, and the distribution of closures is assessed, as seen in **Figure 1**. The Snowmelt Event and Hurricane Isaias had closures centralized around urbanized areas while Hurricane Ida had closures distributed throughout District 6.

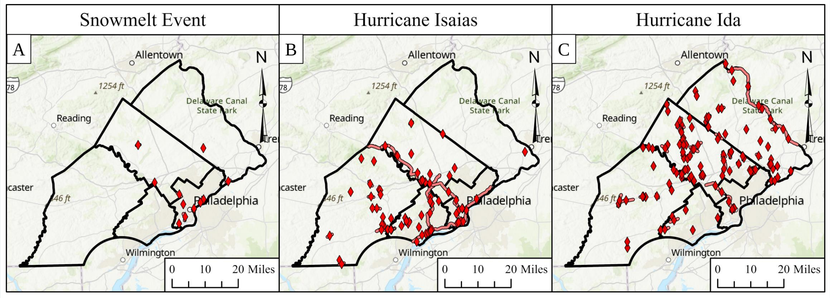


**Figure 1.** Distribution of Road Closures due to Flooding during A.) Snowmelt Event, B.) Hurricane Isaias, and C.) Hurricane Ida.

## METHODS

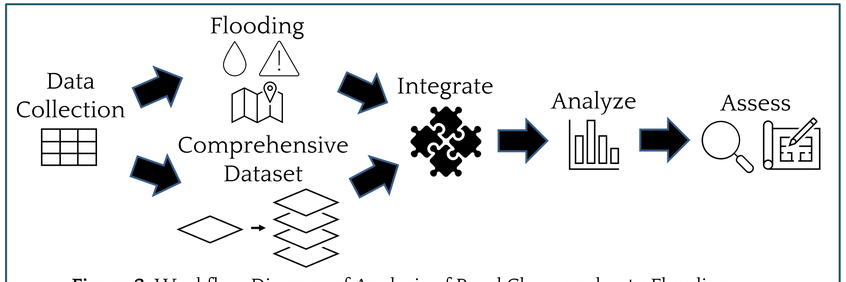


**Figure 2.** Workflow Diagram of Analysis of Road Closures due to Flooding.

## SPATIAL ANALYSIS

The spatial analysis (**Figure 4**) produces a comprehensive dataset, joining watershed data (**Figure 3**) to the bridges within District 6. However, the data must be in a comparable format to run a regression analysis. **Table 2** includes how each variable is represented in the regression analysis.

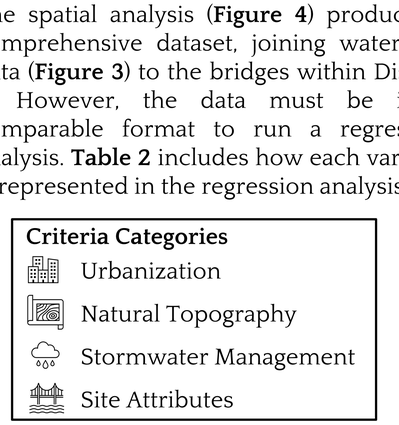


**Figure 3.** Categories Summarizing Flooding Variables.

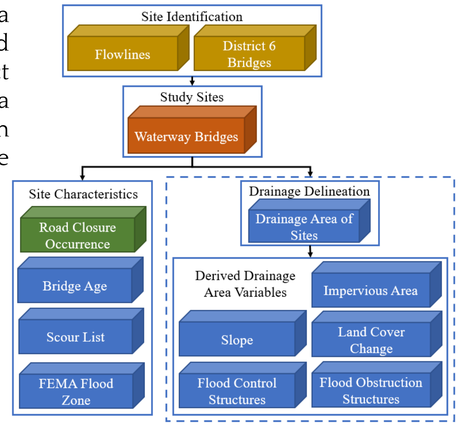


**Figure 4.** Technical Workflow of Spatial Analysis.

**Table 2**. Classification of the Values for Variables Considered in Analysis.

| Variables | | Data Representation |
|---|---|---|
| $y$ | Road Closure Occurrence | value = [no road closure = 0 or road closure = 1] |
| $x_1$ | Bridge Age | value = current year – [year of reconstruction or year built] |
| $x_2$ | Scour-Critical | value = reclassification of scour grade |
| $x_3$ | FEMA Flood Zone | value = reclassification of flood zone |
| $x_4$ | Drainage Area | value = drainage area in square miles |
| $x_5$ | Impervious Area | value = weighted average of impervious cells in drainage area |
| $x_6$ | Slope | value = average change in elevation of cells in drainage area |
| $x_7$ | Land Cover | value = percentage of changed cells in drainage area |
| $x_8$ | Flood Control Structures | value = number of structures in drainage area |
| $x_9$ | Flood Obstruction Structures | value = number of structures in drainage area |

## REGRESSION ANALYSIS

**Table 3**. Summary of Results from Regression Analysis Indicating the Variables with the Greatest Significance in Road Closures Associated with Flooding.

| Rainfall Event | Type of Event | Significance Ranking | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Snowmelt Event | Dynamic Event, Snow followed by Rain | | | | |
| Hurricane Isaias | Short Duration, High Intensity | | | | |
| Hurricane Ida | Long Duration, High Volume | | | | |

## PENNDOT DISCLAIMER



## IMPACT OF FLOODING ON ROADWAYS

To assess the impact of flooding on roadways during different extreme rainfall events, the congestion index of bridges is analyzed (**Figure 3**). The congestion index is a value that compares average vehicle speeds during extreme rainfall events to average historical speeds.

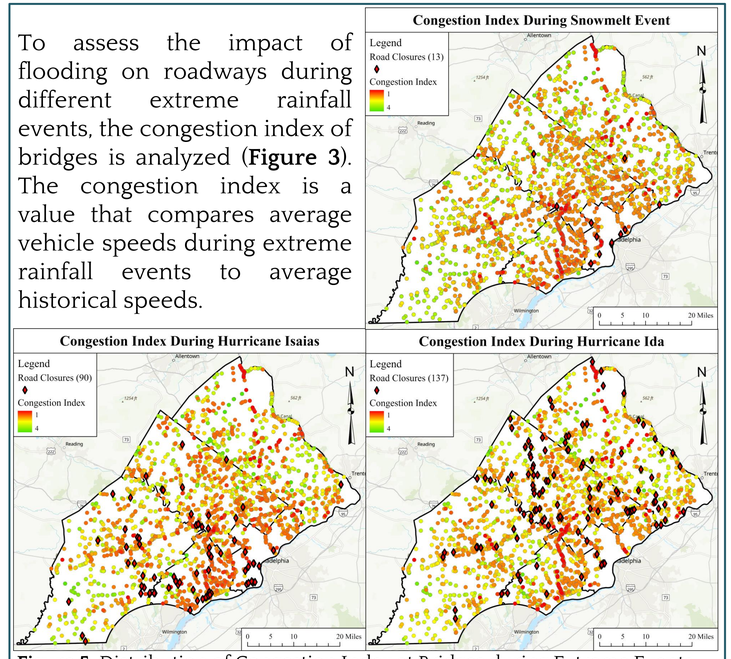


**Figure 5.** Distribution of Congestion Index at Bridges during Extreme Events.

**Table 4**. Average Congestion Index of Roadway Types during Extreme Events.

| Functional Road Class | | Snowmelt Event | Hurricane Isaias | Hurricane Ida |
|---|---|---|---|---|
| 1 | National Highway Network | 1.41 | 1.44 | 1.25 |
| 2 | State Highway Network | 1.54 | 1.46 | 1.50 |
| 3 | Interconnecting Network | 1.89 | 1.68 | 2.54 |
| 4 | Major Connectors | 2.03 | 1.81 | 1.94 |
| 5 | Minor Roads | 1.97 | 1.79 | 2.00 |

## CONCLUSION

This analysis aids in improving the understanding of flooding. Highlighted results from the analysis are included below:

- Urbanization and topography have the greatest significance for why closures associated with flooding happen during extreme rainfall events.
- Congestion is more severe for high-volume carrying roadways during extreme weather events.

## DATA SOURCES

- Pennsylvania Department of Transportation (PennDOT)
- Pennsylvania Spatial Data Access (PASDA)
- Unites States Geological Survey (USGS)
- Nation Land Cover Dataset (NLCD)

**Funded by: Pennsylvania Department of Transportation**