

Title: Present and Future Damage: Quantifying Urban Flood Impacts in Philadelphia

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Highlights:

The Presentation will include an overview of 1D/2D modeling conducted in key sewersheds across Philadelphia. Decision making required during both sewershed selection and the modeling process will be presented with a focus on optimizing model results and level of effort. Model results and accompanying analysis determining locations of sewer backups, basement flooding, and first floor elevation flooding will be presented in addition to considerations for application of similar programs in other locations.

Introduction:

Water service in Philadelphia began in 1801. The Philadelphia Water Department (PWD) is now tasked with mitigating the risk of its aging infrastructure through evaluation and recommendation of both structural and non-structural solutions. Aging or undersized infrastructure is an increasing concern across many municipalities - and will only accelerate in the future.

Targeted flood modeling across their service area is a key pillar of PWD's asset evaluation, risk assessment, and long-term capital planning. 1D/2D modeling has been utilized on an individual sewershed scale to determine urban pluvial flood risk within the city. To date, 6,100 acres across approximately 40,400 acres making up the city's service area have been modeled, with the ultimate goal to model all sewersheds. Sewersheds are prioritized and selected by PWD based on known flooding issues, known upcoming development, or customer complaint logs.

The ultimate objective of this ongoing project is to determine areas across the city prone to flooding, sewer backups, or basement/first floor elevation flooding. As in all modeling, data quality directly impacts quality of model results. What implications should be considered if input data is outdated or modeling is being conducted in an area of rapid redevelopment and infrastructure changes? What is the best way to leverage existing models (such as existing 1D planning level models) to accelerate creation of flood models?

Methodology

Jacobs began supporting PWD with their linear asset management planning program in 2022, though it has evolved over the last several years. Progress includes:

- a comparison of a 1D/2D PCSWMM 1D/2D and a 2D only HEC-RAS approach
- addition of a basement flood analysis methodology
- refinement of model expansion techniques from planning level models to more representative 1D networks
- incorporation of climate perturbed rainfall data for 2100, from PWD's 2022 *Climate-Resilient Planning and Design Guidance*

Once a sewershed is selected, an integrated 1D/2D PCSWMM model is built with an approach designed to optimize a variety of considerations including overall level of effort, accuracy, and model run time. PWD's existing 1D network models are utilized with incorporation of 2D terrain, inlet connections, varied rainfall, expansion of pipe network, and building footprints. Validation of the model is conducted using a historical event time series, documented backflow preventor installations, and problem areas which received flood calls from the public were utilized to confirm areas of flooding.

Key Findings

Final outcomes of this work are flood depths across the modeled area, identified locations of sewer backups and locations of basement and first floor elevations. The following results will be summarized and presented in this presentation:

- Model setup and validation (Figure 1)
- Flood model results
- Analysis of sewer backups, basement flooding, and first floor elevation flooding (Figures 2 and 3)

Once flood modeling is completed, the use and application of model results is just as important as the model build itself. For PWD, these flood model results are utilized to help enforce private development stormwater standards called the Public Health and Safety Release Rate, which dictates that a maximum release rate based on sewer capacity must be used in design in certain watersheds where known flooding occurs.

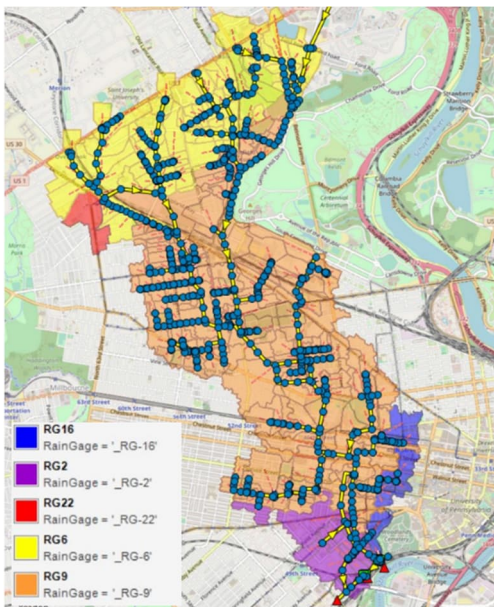


Figure 1 – 1D model elements, 2D model domain, and applied rain gauge information for the historical validation event

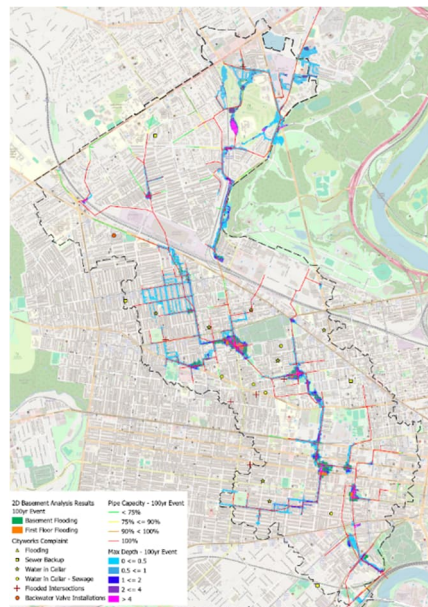


Figure 2 – Identified locations of sewer backups determined using 1D node hydraulic grade lines and basement elevations

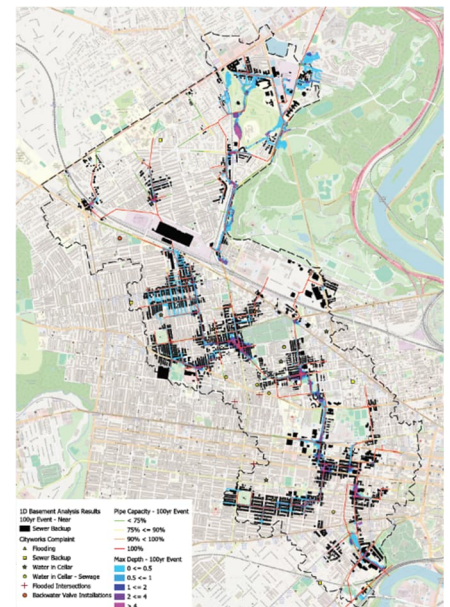


Figure 3 – Identified locations of basement flooding determined using 2D node hydraulic grade lines and ground elevation



Development? Inevitable. Storms? Unstoppable; Flooding Evaluation of the Route 51 Corridor

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- Flood depth, extent, and risk caused by the drainage overflow
- Urban flooding issues caused by insufficient drainage capacity (Pluvial Flood)
- Identify feasible long term solutions to mitigate the flooding

Introduction

The Route 51 corridor is a vital transportation link in the South Hills area of Pittsburgh. Along it is Saw Mill Run, a 10-mile-long urban stream that runs north to the Ohio river. Its tributary watershed covers approximately 19 square miles and drains all or part of 12 municipalities, including portions of the City of Pittsburgh. Flooding has always been common in this region and has increased in frequency in recent years. The U.S. Army Corps of Engineers started studying flooding in this area all the way back to the 1940s. To remedy some issues, in 2017 a councilor representing the area floated the idea of purchasing homes and properties and turning the area into a greenspace. This idea was not a new one, as FEMA bought out 25 properties in the area in 1996. Over the years, there have been many attempts to mitigate flooding by individual municipal communities, but no long-term plan to address the flooding issues has ever been implemented.

Background and Methodology

Case Study Background

Flooding in the Lewis Run Rd & Rt 51 Intersection Watershed (2.8 Sq Mi) has been aggravated by the addition of hard, impervious cover where there previously was greenspace. The hill and valley terrains in and around the study area creates low spots (aka bathtub and bowls) which also exasperates the flooding problem. Approximately 44% of the study area can be characterized as impervious area, with the remaining 56% as pervious area. The watershed has approximately 134,481 linear feet of storm sewer pipes ranging in size from 8" to 96". Runoff from Lebanon Church Road enters a 72" 4,943 feet long pipe which travels beneath a slag pile, upon reaching Route 51, the 72" pipe intersects with a 54" pipe from the northeast, where they combine into an 84" pipe. This 84" pipe daylights into a 9.6' x 12' culvert opening, running behind businesses in the strip. These convergence of pipes contributes to the flooding at Lewis Run Rd. & Rt 51 Intersection. The existing level of service and overtopping flood for the intersection of Rt 51 and Lewis Run Road is less than the 2-year design storm event.

Hydraulic Modeling Methodology

An integrated 1D-2D dual drainage (minor/major system) model approach using CHI PCSWMM software (EPA SWMM 5 computational engine) was utilized for the modeling analysis. The modeling of overland flood flows was deemed problematic for a strictly 1D solution because there are multiple flow pathways. The minor system is comprised of the underground conveyance storm sewer system while the major system is comprised of overland/street flows, swales etc. The minor and major system dynamically run in tandem, to simulate flow transfers more accurately between surface and subsurface drainage systems. The 1D component of the model was connected to the 2D overland mesh using bottom orifices. The hydrology for the model was set such that precipitation drains directly into the 2D junctions. Calibrated radar rainfall data at 15-minute intervals was used as model input and introduced as a time series to every 2D junction. This method mimics rainfall on the ground and allows water to flow naturally, revealing flow paths based on topography that flow into the minor system. The model was run with the Dynamic Wave routing method which utilizes the full Saint Venant equations. The model was calibrated / verified using a high water mark following a flood event on July 8, 2021, as shown in Figure 1. Max/Full Flow and Max/Full Depth parameters were used to assess pipe capacity utilization and



deficiencies for the minor system, depth of water on the roadway was used to evaluate flooding extents in the major system, and alternatives which included increased conveyance, storage enhancements, and green infrastructure were developed and ranked based on flooding reduction, estimated construction and long-term maintenance costs, permitting, construction feasibility, and community impacts.



Figure 1. July 8, 2021, High Water Mark at the Intersection of Route 51 and Lewis Run Road

Data Collection and Analysis

A vast amount of data was requested and gathered from several municipalities and evaluated using desktop analysis. Data was preprocessed using geoprocessing tools in ArcMap and excel spreadsheets. Data review and gap analyses were performed regularly and data quality was reviewed using a comparative process for each data source. Data gaps and missing data as well as conflicting information were inferred and estimated using auditing tools, institutional knowledge, and best engineering judgment. Survey data was also collected by a professional surveyor. Comprehensive QA/QC measures were implemented to ensure the model yields meaningful, accurate, and reliable results that adequately meet the project objectives. Auditing and troubleshooting the model involved specific debugging steps including validating model attributes, checking for warnings and error messages in the model output file and resolving all major warnings and errors.

Key Findings

- Hydraulic capacities for a lot of storm pipes are exceeded during low / moderate rainfall events.
- The overtopping flood for many roads are less than the 10-year design storm event.
- Utilizing a combination of alternatives is more impactful towards flood mitigation than as stand-alone versions.

Recommendations

- Municipalities and other agencies need to collect information relevant to addressing flooding and be willing to share this information as well as coordinate flood mitigation efforts to ensure the greatest benefit to the community.
- Perform periodic CCTV surveys to ensure the existing system doesn't have severe structural issues, such as pipe collapses, that are impeding system operation.
- Regular cleaning is needed throughout the system and is the most cost-effective technique to ensure design flow capacity and prevent debris buildup.
- Continue to update and refine the developed models as additional data becomes available so it can be continually used as a predictive tool for flood forecasting and planned construction improvements.

References

- Computational Hydraulics Int. (CHI) Website: <https://support.chiwater.com/>.

Pluvial Flooding in Karst Watersheds: Simulation Example and Design Guidance Review

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What I will be presenting:

With changing rainfall patterns, pluvial flooding in urban and suburban areas is becoming increasingly common. The nexus of increasing rainfall intensities, aging infrastructure, and inadequately designed stormwater management practices are worsening existing pluvial flooding hot spots and causing new problem areas to emerge. In central and eastern Pennsylvania, these factors compound with the unique challenges of computing accurate hydrology in areas of karst geology. This presentation will explore the regulatory history, emerging rainfall patterns, potential of combined 1D and 2D hydrologic and hydraulic modeling, and recent DCNR design guidance to help communicate incremental solutions to policy makers and the public. Throughout the presentation, Palmer Township, Northampton County - a historical flooding hot spot where a PCSWMM model applying this approach was used for long-term planning - will be highlighted as a case study. Further it will include a summary of the DCNR document "Stormwater Best Management Practices in Karst", which advocates for distributed, low-impact development practices that maintain predevelopment hydrology, promote diffuse infiltration, and avoid large centralized systems.

What the audience will learn:

The desired impact of the presentation would be to inform the attendees of the how karst area flooding issues emerge over time and how development patterns and regulatory issues resulted in today's pluvial flooding problems. The topic will be expanded with a review of the impact of changing rainfall patterns has on karst area drainage problems, and how modern engineering resources allow for effective communication with the public and municipal leaders. It will also relay a review of current approaches and guidance available for design professionals.



Flood Forecasting for Real-Time Decision Support and Resilient Planning

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What I will be presenting:

As communities across the nation face escalating exposure to extreme rainfall, riverine flooding, coastal storm surge, and compound flooding events, the need for data-informed, forward-looking resilience strategies has never been greater. Leveraging flood intelligence to accurately forecast the precise location, time, duration, and extent of flooding has become foundational to smart planning efforts that support adaptation to climate-driven hazards at every scale, from local municipalities to major metropolitan regions.

Flood forecasting systems are emerging as transformative tools, bridging the gap between long-range infrastructure planning and real-time operational response. By integrating hydrologic and hydraulic (H&H) modeling with real-time and forecasted data inputs, these platforms deliver actionable intelligence that strengthens both preparedness and emergency management. This presentation introduces scalable, real-time flood forecasting capable of accounting for rainfall-driven flooding and storm surge. Drawing on case studies from communities navigating diverse and converging flood risks, the presentation will demonstrate how integrated modeling, real-time data assimilation, and intuitive visualization tools can be deployed to support smarter planning, emergency response, and meaningfully reduce recovery timelines, empowering communities to shift from a reactive posture to proactive, dynamic flood resilience.

What the audience will learn:

Attendees will gain an understanding of how real-time flood forecasting can fundamentally transform the way communities prepare for, mitigate, and recover from flood events. The presentation will equip practitioners, such as engineers, planners, and emergency managers, with practical frameworks for integrating live hydrologic and hydraulic (H&H) modeling into both long-term infrastructure planning and day-to-day operational decision-making.

Key takeaways will include how to leverage continuously simulated (24/7/365) flood intelligence system to protect critical infrastructure, optimize resource prepositioning, and improve public notice before, during, and after a flood event. Attendees will also explore the critical role of data visualization and communication, specifically, how translating complex modeling outputs into easily interpreted, accessible, decision-ready dashboards enhance situational awareness and cross-agency coordination in high-stakes environments.

Beyond operational applications, the audience will learn how these systems directly advance broader stormwater and resilience program goals, strengthening capital improvement planning, informing level-of-service evaluations, and building the foundation for policy and decision-making. Scalable methodologies and lessons learned from real-world deployments will provide attendees with a blueprint they can adapt to their communities, regardless of geography, hazard profile, or organizational capacity, to build more resilient, responsive, and informed flood management programs.