City of Worcester Drainage & Green Infrastructure Master Plan

A Plan to Mitigate Flooding in Worcester

Presentation to the Green Worcester Advisory Committee

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MVP Municipal Vulnerability Preparedness

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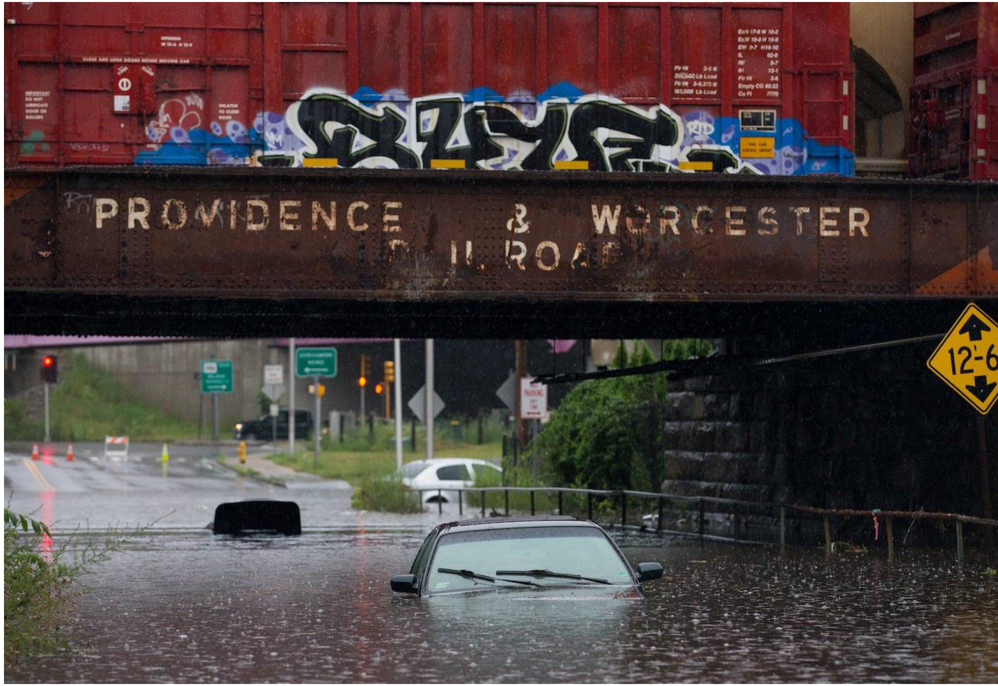
Agenda

- Introduction
- Drainage system
- H&H Modeling
- Green Infrastructure / Nature-based Solutions

Introduction

Flooding in Worcester

Highland Street, August 2, 2017, 3:30 PM
Photograph by Greg Doerchler

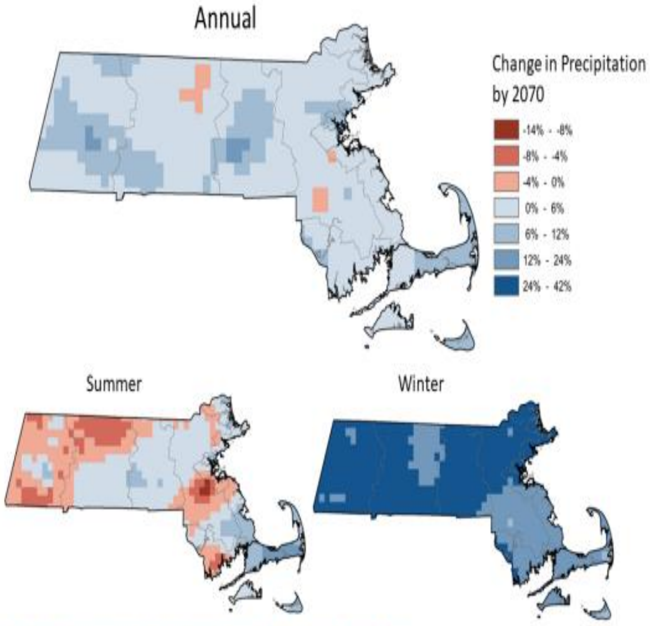


Railroad Bridge on Cambridge Street, July 17, 2018
Photograph from the Boston Globe

Projected Future Climate & Impacts

Precipitation amounts from the heaviest storms in the Northeast have increased by 55% since 1958.

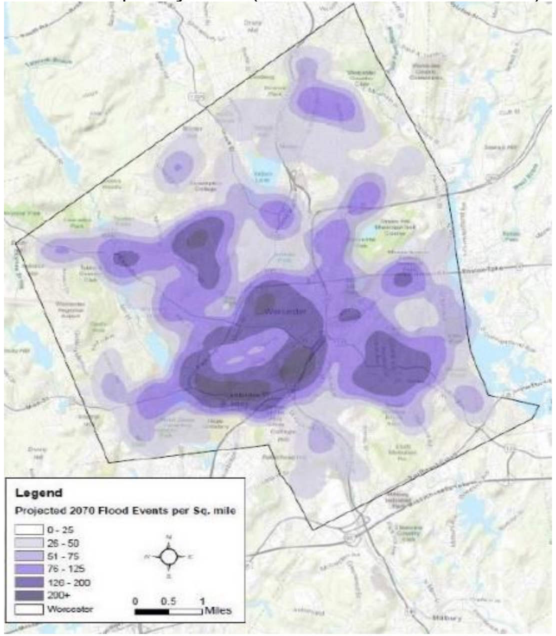
The volume and intensity of rainfall events/storms **are predicted to increase in intensity and duration.**



Source: Commonwealth of Massachusetts (2022), using SWG data.
Differences between the 50th percentile of projections for 2060-2080 and a baseline of 1986-2005.

Source: ResilientMass Plan (2023)

By 2070, Worcester is projected to experience an additional 8 inches of rainfall per year. (ResilientMass, 2023).



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Existing Infrastructure and Climate Change

The majority of the City's existing drain infrastructure **was constructed over 50 years ago.**

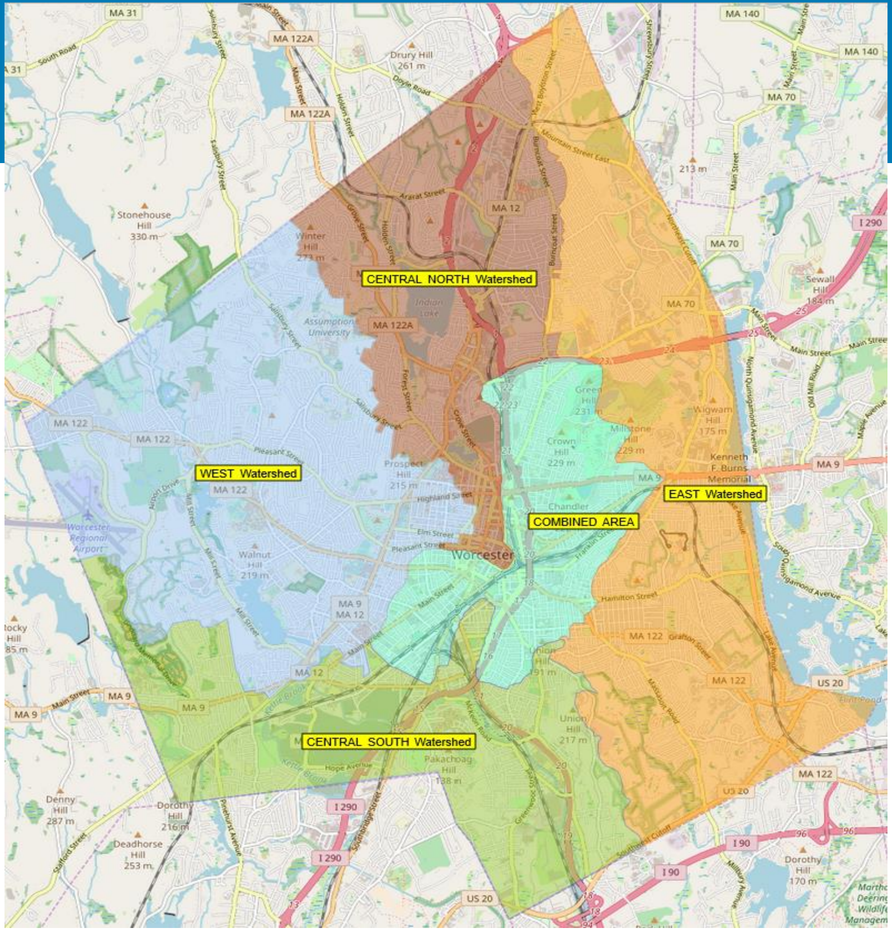
The system was not constructed to manage the storms we experience now, never mind predicted future storms. In addition, and in that time, the City became more urbanized with increased impervious surfaces.

Worcester Drainage & Green Infrastructure Master Plan Objectives

- **Continue the city's commitment** to the stormwater system and an overall system improvement plan.
- **Develop a Hydrologic/Hydraulic computer model (H&H Model)** of the existing City owned closed pipe drainage infrastructure to identify areas of system capacity deficiencies.
- **Select priority areas** for alternatives analysis of both grey and green infrastructure improvements.
- **Develop grey and green concepts** for flood mitigation.

Roxbury Street, September 8, 2023, 230 PM
Photograph by Greg Doerchler

Worcester Drainage & Green Infrastructure Master Plan Project Limits



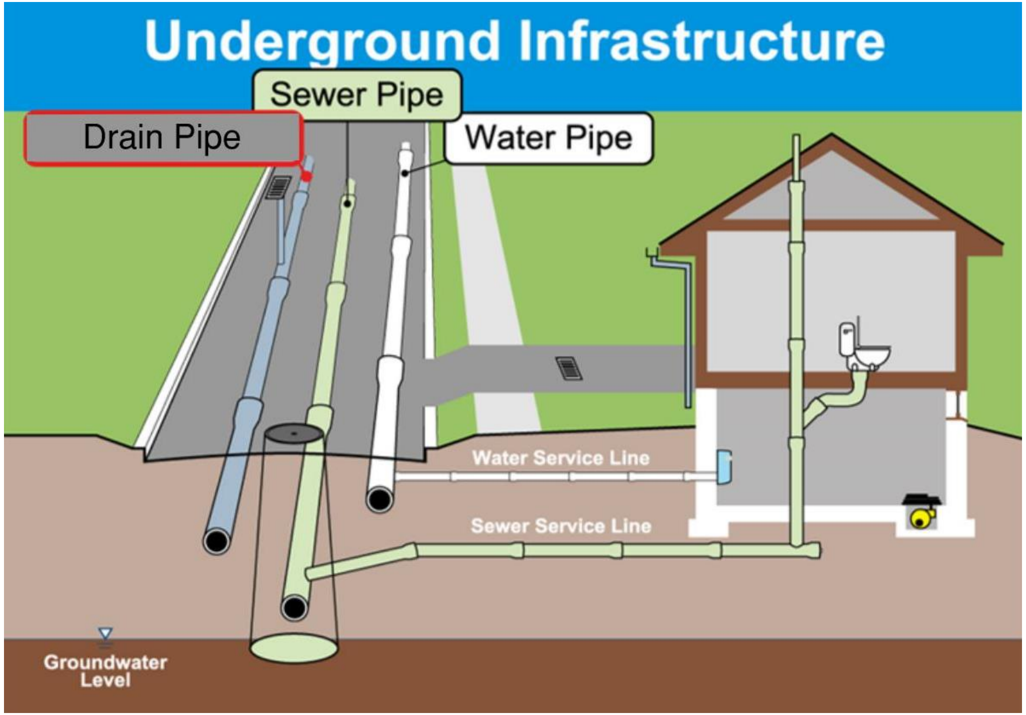
- **City-wide drainage master plan limits of work included:**
  - East Watershed
  - West Watershed
  - Central North Watershed
  - Central South Watershed
- **The Combined Sewer Area** was not included in current analysis and is being studied under a separate project

Drainage System

What is a Drainage System

A drainage system is made up of:

- Drain Pipes
- Drain Manholes
- Catch Basins
- Outfalls
- Inlet Structures
- Open Channel/Streams
- Culverts



Worcester's Local Drainage System

Worcester Department of Public Works & Parks manages:

- **374** miles of drain pipes
- **15,000** drain manholes
- **370** outfalls
- **44** culverts
- **29,000** catch basins

Drain Manholes and Catch Basins

- Drain manholes are **structures that allow access to the drainage system** for inspection and cleaning.
- Drain manholes are **located where pipes change direction.**

Catch Basins are structures with surface grates that collect stormwater from city streets

Outfall and Inlet Structure

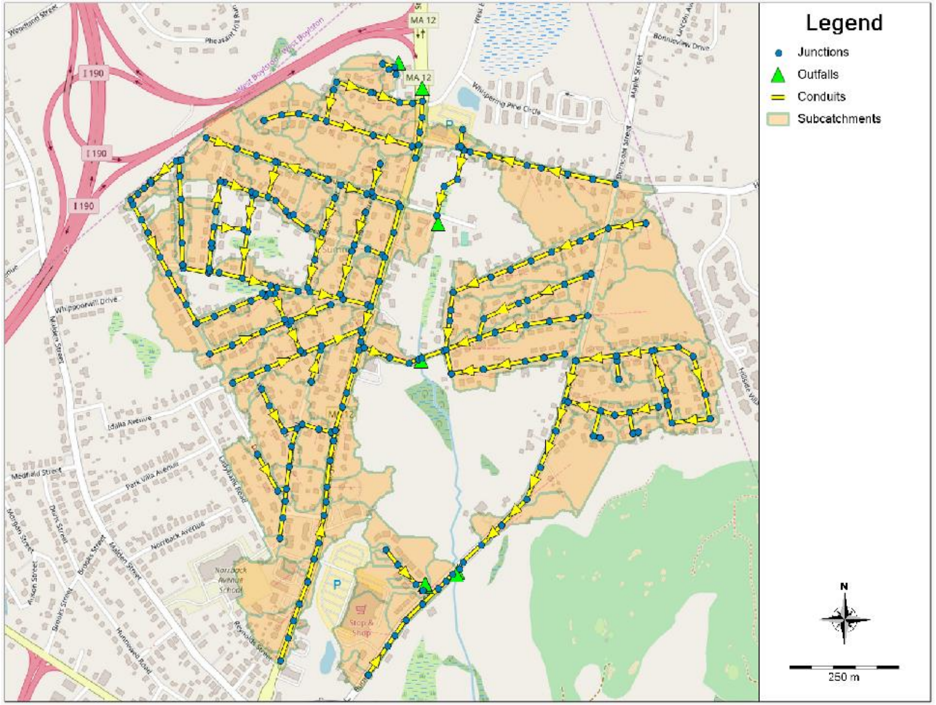
An outfall is the location in the drainage system where stormwater exits the pipe network and discharges to a waterbody, wetland, drainage swale, or culvert.

An inlet structure is the location in the drainage system where stormwater enters the pipe network from a waterbody, wetland or drainage swale.

H&H Modeling

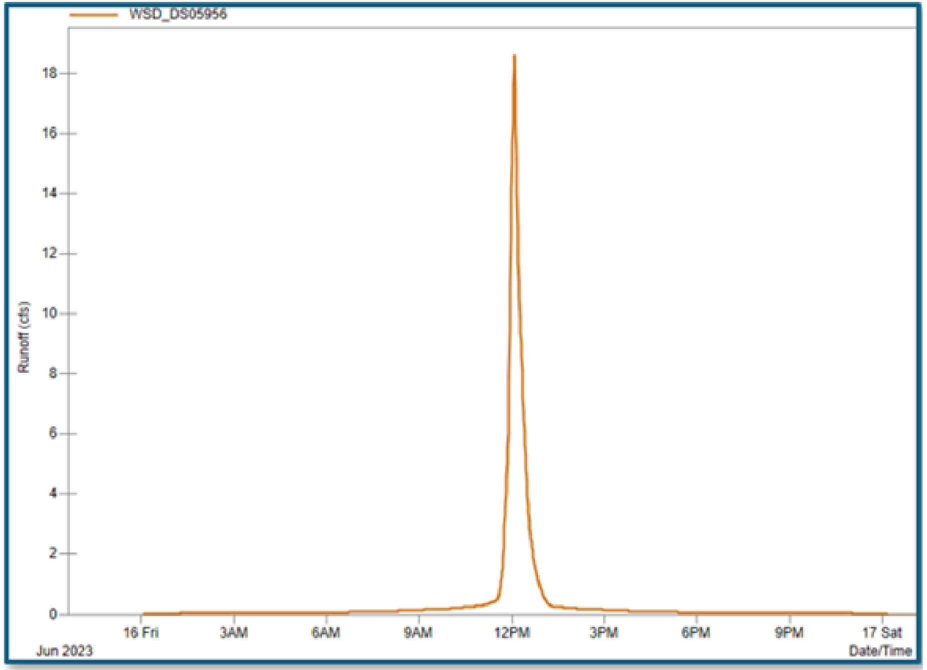
What is a H&H Model? (Two Major Components)

- **Hydrologic Model** is the development of stormwater runoff hydrographs for rain events entering the system.
- **Hydraulic Model** is the routing of runoff hydrographs thru the stormwater network system.
- **Future phases of the Master Plan will include** expanding the model to develop an existing conditions city-wide H&H Model of tributary streams, open channels, and natural storage areas.



What is a Hydrograph

- **A Hydrograph** is a graph showing the rate of flow versus time past a specific component.
- **A Runoff Hydrograph** is a graph showing the rate of surface flow from a subcatchment.
- **A Flow Hydrograph** is a graph showing the rate of system flow in the drainage network accumulated from the input runoff hydrographs.

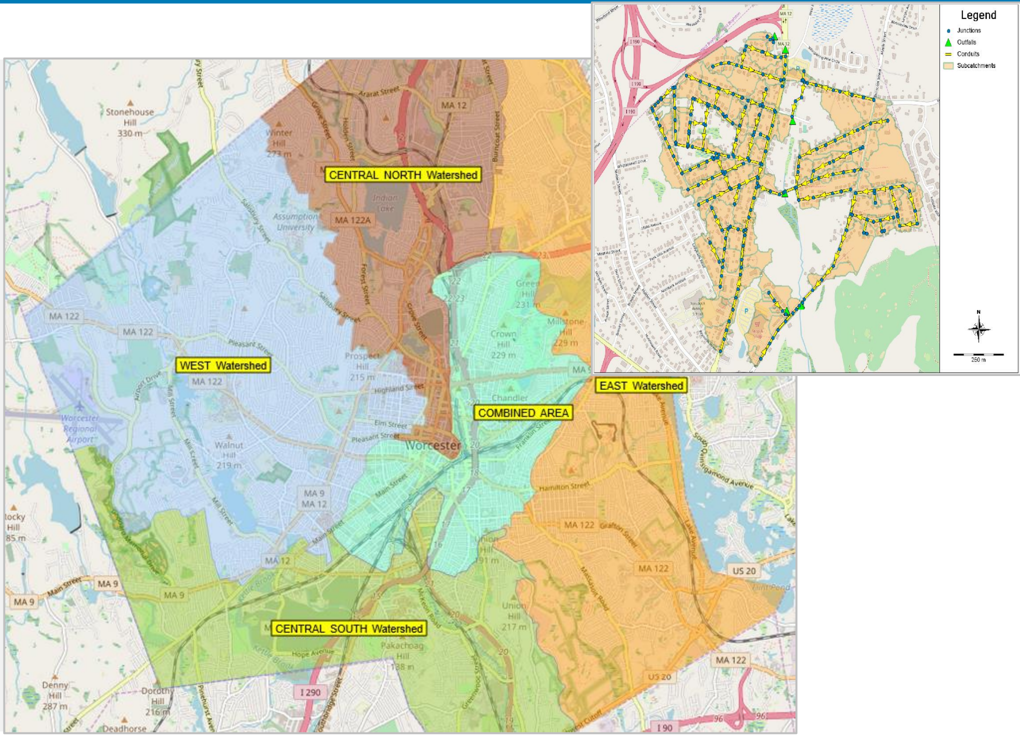


H&H Model
Field Data Collection of Drainage System

- **Weston & Sampson reviewed previous drainage studies, and the City drain GIS** to identify missing system data needed for the H&H model:
  - manhole depths
  - pipe elevations
  - pipe size (diameter and shape)
  - pipe length
  - pipe material
- **Weston & Sampson developed manhole inspection work plan** to determine number of inspections required
- **Weston & Sampson conducted 4,380 manhole inspections** to establish pipe size and pipe invert elevations (over 4 months of field work with up to 5 crews)

H&H Model
Hydrologic Data Collection

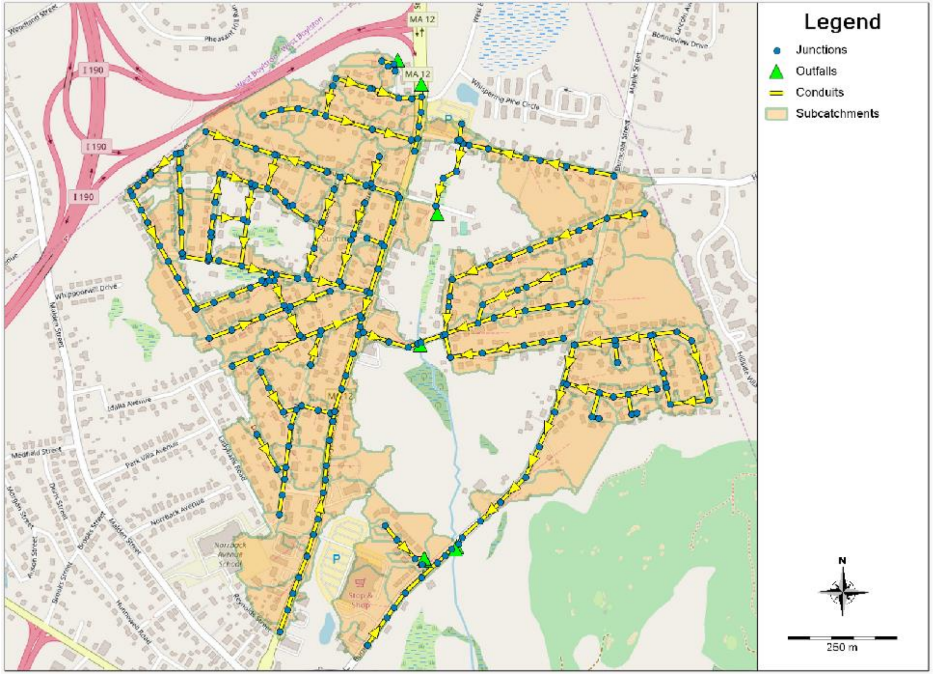
- **Each of the 4 Major watersheds** was split up into 48 subareas and 7,000+ subcatchments.
- **Key Hydrologic data collected** for each subcatchment include:
  - Area (AC)
  - Land Cover (Open Space/Wooded)
  - % Impervious Land Cover
  - Land Cover Slope
  - Soil Infiltration Rates
  - MassGIS layer features were utilized to collect the hydrologic data.



Worcester's H&H Model Metrics

H&H Model analyzed:

- 48 Subareas City Wide
- 7,280 Subcatchments
- **12,550 Total Acres (95%)**
- **49 to 59% Impervious**
- 12,250 Model Nodes (typically at drain manhole location)
- 370 Outfalls
- **315 Miles of Drain Pipe (85%)**

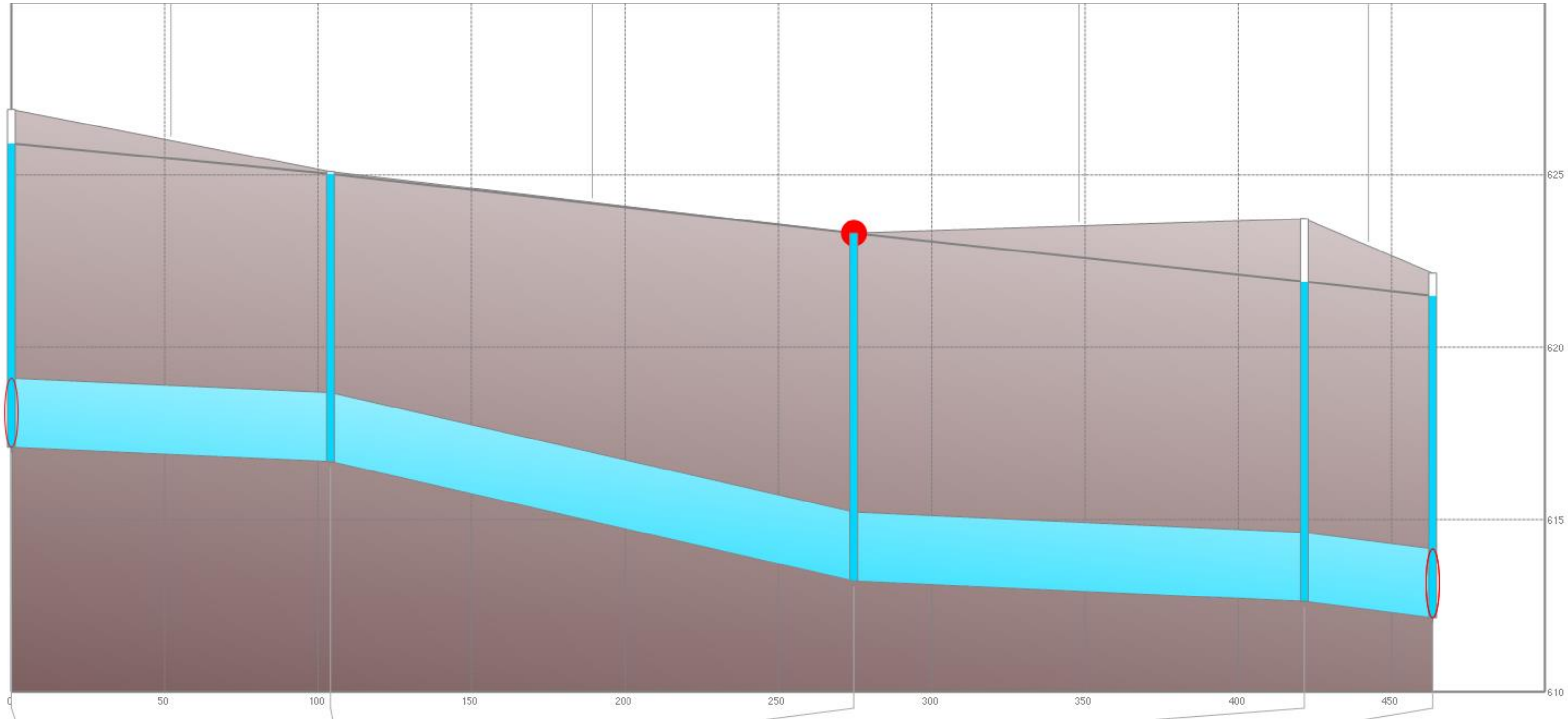


H&H PCSWMM[1] Model Analysis Scenarios Completed

Rainfall Events Analyzed	Duration	Recurrence Interval	Total Rainfall (In)
NOAA Atlas 14	24 Hour	10 Year	4.90
	1 Hour	10 Year	1.67
2070 Projected Rainfall Climate Resilient Design Standards Tool	24 Hour	10 Year	6.60
	24 Hour	5 Year	5.60
Green Infrastructure Screening	6 Hour	2 Year	2.14

[1]PCSWMM stands for Personal Computer Storm Water Management Model

H&H PCSWMM Model Results
Existing Conditions Model Profile System Flooding



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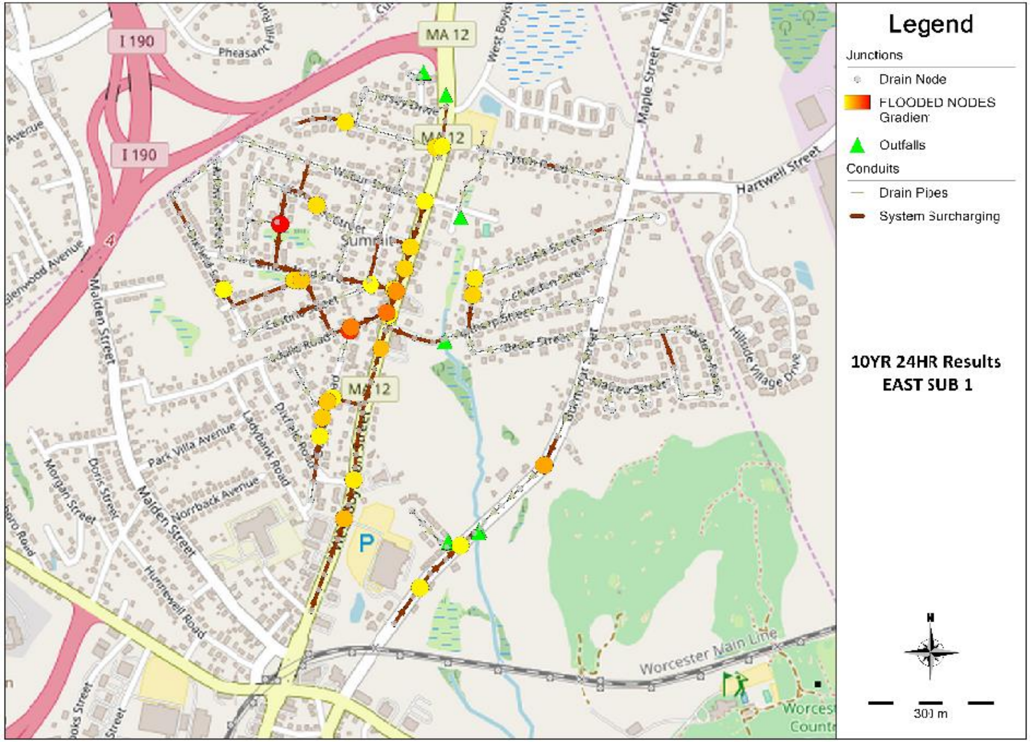
H&H PCSWMM Model Results
Existing Conditions Model - System Deficiencies



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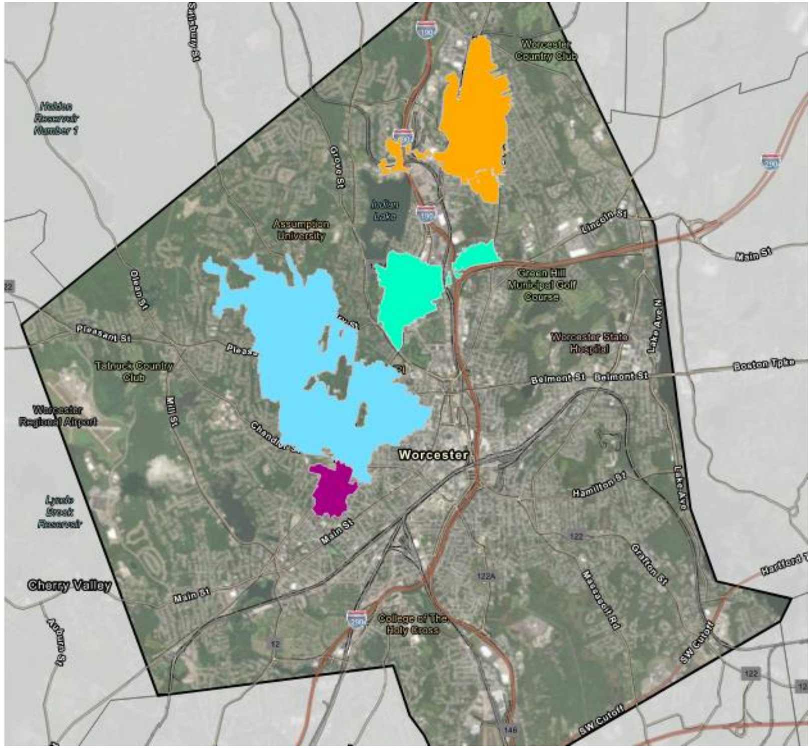
Priority Locations for Alternatives Development

- **The City selected four priority subareas out of forty-eight** for detailed analysis and alternatives development.
- **Criteria included** observed severity and volume of flooding, community impacts, and proximity to Environmental Justice Communities.
  - West Sub 5
  - West Sub 9
  - Central North Sub 10
  - Central North Sub 4



Alternatives Development

Alternative models were created for:

- **Present-day** NOAA Atlas 14 10-Year 24-Hour rainfall of 4.9 inches.
- **Projected 2070** 10-Year 24-Hour rainfall of 6.6 inches.

Solutions considered include a combination of the following:

- **Gray infrastructure** such as Culvert Upgrades, Underground Storage, Drain Piping Upgrades, and Maintenance
- **Green Infrastructure / Nature Based Solutions** such as bioretention basins, swales, and tree box filters.

Grey Infrastructure Alternatives Sample – CN Sub 10

Present-day NOAA Atlas 14 10-Year 24-Hour Rainfall (4.9 inches) Flood Mitigation Alternative

- Upgrade approximately **9,300 feet** of drain pipe ranging from **15-inch diameter to 60-inch diameter pipe**
- Estimate cost is **$14.3 million** for design and construction

2070 10-Year 24-Hour Rainfall (6.6 inches) Flood Mitigation Alternative Upgrade

- Approximately **9,800 feet** of drain pipe ranging from **15-inch diameter pipe to 5-foot by 10-foot box culverts**
- Estimate cost is **$27.7 million** for design and construction

Mitigating Flooding through Grey Infrastructure Improvements

Photos: Large Diameter Drain Replacement in Fitchburg, MA, Weston & Sampson

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Mitigating Flooding through Green Infrastructure


Worcester's Shore Park Rain Garden installed in mid-2010s

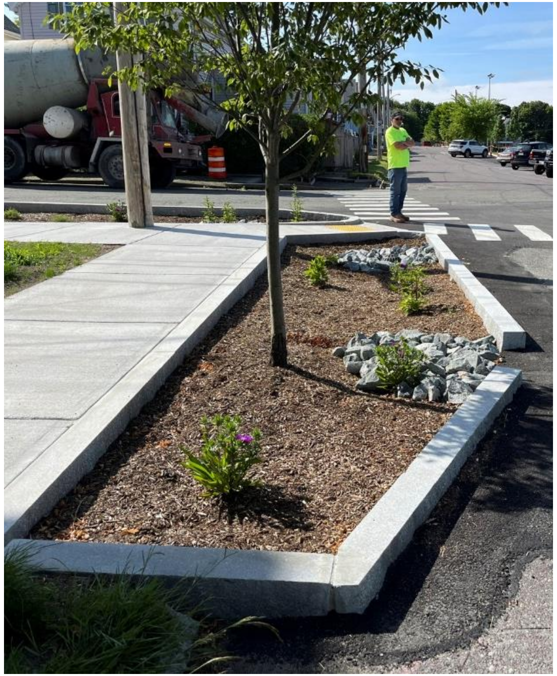

Rain garden installed in 2020 at Worcester Senior Center


Examples of tree pit filters installed

Green Infrastructure / Nature-based Solutions

- Flood reduction
- Water quality improvement
- Urban Heat Island reduction
- Ecological Habitat creation

Nature Based-Solutions Assessment



- Review existing plans, reports of flooding, planned capital improvements (sidewalk / roadway / parcel redevelopment)
- Desktop assessment looks at spatial data, reports of flooding problem areas, and 1D flood model results to identify priority areas to implement NBS
- Sites are reviewed for topography, existing drainage infrastructure, and nearby parcel ownership to determine what types of NBS are best suited for the area
- NBS are sized and approximate storage volume is calculated to input into the model and quantify flood reduction benefits
- NBS are prioritized based on flood reduction benefits, ease / feasibility of implementation, and co-benefits

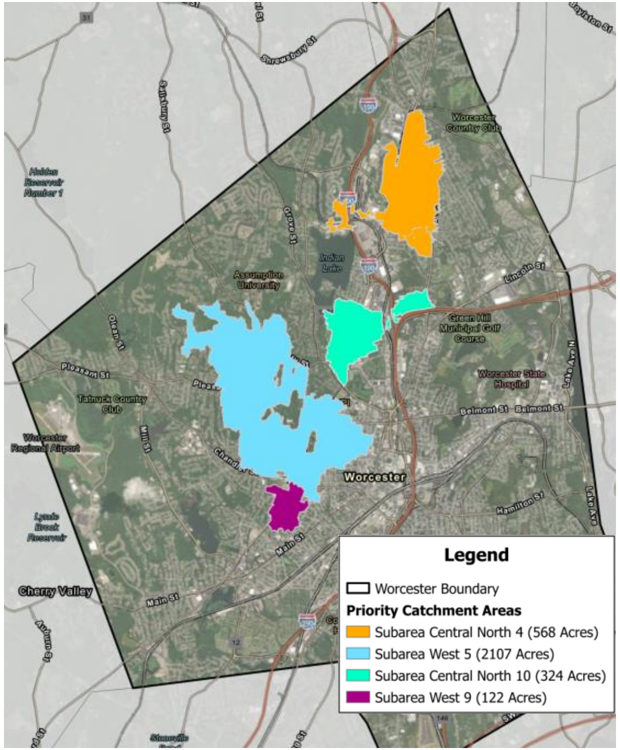
Goals for Screening

- **Identify large-scale projects** with ability to capture significant volumes of stormwater to provide flood reduction benefits across the sub-area
- **Identify medium- and small-scale projects** with the ability to capture localized surface flows and mitigate nuisance flooding
- **Projects strive to:**
  - Be implementable
  - Be eligible for grant funding
  - Provide co-benefit
    - Community
    - Ecosystem
    - Climate

Photo: BMP Maintenance Training in Fitchburg, MA, Weston & Sampson

Overview of Identified Green Infrastructure Opportunities in Selected Priority Areas

Catchment ID	Percent Impervious	Number of Proposed Features	Proposed GI Footprint (acres)	Estimated Storage (cubic feet)
Central North 4	49%	63	2.70	168,480
West 5	36%	94	2.33	149,440
Central North 10	53%	25	0.58	27,980
West 9	66%	13	2.16	104,560
Sum	**-**	**195**	**7.77**	**456,460**



Example Project
Sub-Area Central North 4

Bioretention swale
Photograph from EPA

Burncoat Preparatory School

- Bioretention in corner of parking lot to intercept sheet flow
- Provide shade and learning opportunity at the school without removing blacktop space for playing

Example Project
Sub-Area Central North 4

Burncoat Preparatory School

- Storage capacity for runoff from roof, parking lot and nearby flooding on Hastings Rd

Underground storage
Photograph from Weston & Sampson

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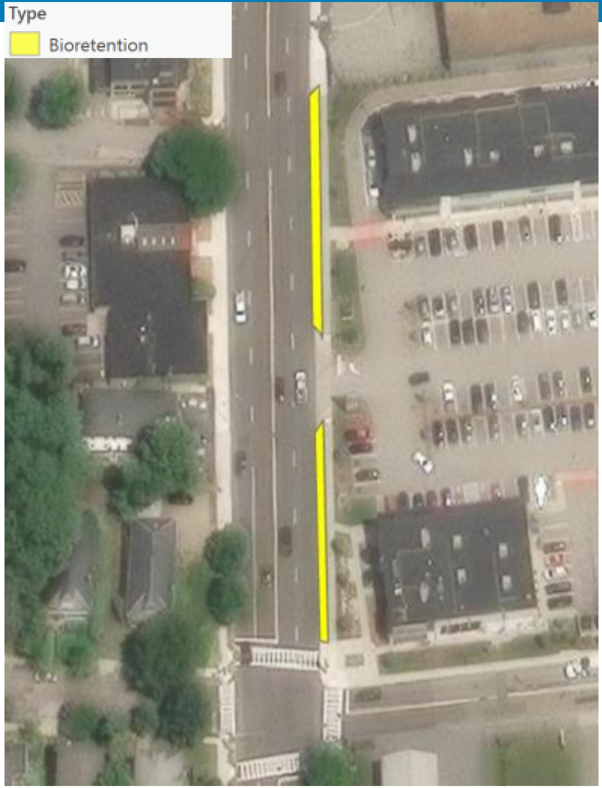
Example Project
Sub-Area Central N



Park Ave

- Existing grass strip
- Retrofit opportunity

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What's Next / Looking Forward

- **Phase 2 Model Expansion**
  - Perform flow and/or level monitoring to calibrate model
  - Expand to include open channels and water bodies
  - Incorporate combined sewer area model
  - Provide 2D flooding results
  - Will be an integrated model to evaluate proposed solution implementation
  - Will support future design efforts

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Figure 11 – August 19, 2021 Calibration Model, System Surface Flooding Limits.

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thank you

This project was funded in part by the Massachusetts Executive Office of Energy and Environmental Affairs' Municipal Vulnerability Preparedness (MVP) Grant program, which provides support for cities and towns to plan for climate change and to implement projects that build local resiliency

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