Stoughton Town-wide Drainage Model, Vulnerability Assessment, and Adaptation Strategies to Mitigate Future Flooding:

Stoughton, MA
June 30, 2024



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EXECUTIVE SUMMARY

The Town of Stoughton, MA, with the assistance of community stakeholders, identified inland flooding as its primary climate hazard and collaborated with Kleinfelder for a Climate Change Vulnerability and Adaptation Strategies for Future Flood Mitigation Study, funded by State of MA Municipal Vulnerability Preparedness Program Action Grant RFR ENV 20 MVP 02. Unlike coastal communities, Stoughton's flooding issues stem from extreme precipitation concerns and increase in impervious areas due to development. To assess flood risk for the town under present-day and future conditions considering the effects of climate change, a 2D hydraulic and hydrologic (H+H) model was developed. The model was used to predict flooding from extreme precipitation events across a variety of storm return periods, durations, and climate projections, and yielded flood predictions from a highly calibrated model for the entirety of Stoughton.

The model was built to visualize and predict potential Town-wide flooding under present and future conditions (2030 and 2070) for both short duration intense storm and long duration storm (2-Hour and 24- Hour). Throughout the project a robust public outreach program was completed to ensure that the Stoughton community was involved in the flood study. Public meetings, a town-wide flood survey, school visits, and the creation of a climate task force were all completed. In particular, efforts were taken to ensure that Stoughton's growing environmental justice community was involved in the process and had opportunity to comment on the direction of the study.

Using the flood results for climate-change scenarios, a vulnerability assessment was completed to identify areas in the Town that were particularly vulnerable to flooding and served as critical locations for the community. Three areas were selected for the town to prioritize flood mitigation projects in: York Street, downtown, and the Ames-Long Pond Causeway. The downtown area was found to be particularly at-risk to the short duration, high intensity storms, while both York Street and Ames-Long Pond posed significant risk during the longer duration (24-hour) extreme storm events.

Flood mitigation alternatives were developed for each priority area to provide the town with flood mitigation options moving forward. Mitigation strategies analyzed include gray and green stormwater infrastructure, road-raising, and nature-based solutions. The study found that while interventions did not eliminate all flooding, they significantly reduced flood depths and provided peak flow attenuation. Some of the key findings of this study include:

- Long-term initiatives like road-raising and site-scale resiliency projects will reduce flood exposure and vulnerability before the projected increases intensify.

- Specific projects, such as green/gray storage and culvert replacement, offer multiple benefits, including flood reduction and ecological improvements.

For each priority area in Town identified, a proposed flood mitigation solution (or combination thereof) was identified. Two culvert replacements are recommended for York Street at crossings of Redwing Brook to provide a cost-effective solution for flood mitigation while also having the co-benefit of ecological stream restoration for the currently undersized culverts. In the downtown area, pipe-capacity improvements were found to be sufficient for addressing flood concerns up to 2030 climate projections, while in the long term (2070 horizon) additional storage from underground storage and green infrastructure is recommended to create a resilient downtown. Finally, culvert replacements along West Street through the Ames-Long Pond causeway can serve as an effective flood mitigation tool for the area while also providing better connectivity between the two sides of the pond.

1 INTRODUCTION

In 2022, the Town of Stoughton engaged Kleinfelder to assist in studying the potential impacts of flooding and identifying mitigation and resiliency opportunities as part of the *Town-wide Drainage Model, Vulnerability Assessment, and Adaptation Strategies to Mitigate Future Flooding* project. This study is funded by a Municipal Vulnerability Preparedness (MVP) Action Grant, RFR ENV 20 MVP 02, administered by the Massachusetts Executive Office of Energy and Environmental Affairs (EEA).

1.1 STOUGHTON MVP PROJECT PLANNING

The Town of Stoughton ("Town") completed the Massachusetts MVP Planning process and summary in March 2020. Through its MVP Planning grant and Community Resilience Building (CRB) process, Town staff and stakeholders identified and built consensus around flooding as a primary concern and top climate-related hazard.

As summarized in the 2020 Report[1], Town staff and community stakeholders identified the following as the Town's top four hazards:

- Flooding
- Extreme Temperatures
- Severe Storms
- Invasive Species

"The Municipal Vulnerability Preparedness (MVP) grant program created in 2017 as part of Governor Baker's Executive Order 569 provides support for cities and towns in Massachusetts to identify climate hazards, assess vulnerabilities, and develop action plans to improve resilience to climate change. Communities that complete the MVP Planning Grant process become designated as an MVP Community and are eligible for MVP Action Grant funding to implement the priority actions identified through the planning process" (https://resilientma.org/mvp/)

Workshop participants compiled locations of known flood concerns on a flood risk map (Figure 1-1) and several recommended actions to address vulnerabilities and enhance resiliency. **"Drain Capacity, BMP and Culvert Study"** emerged as one of the highest-priority actions. Other "high-priority actions" identified in the CRB Summary of Findings emerging from the small group discussions and are the following:

- Address culverts and stormwater systems; Culvert and Drainage Study/Evaluation Program
- Construct Stormwater Improvements and BMPs
- Red Wing Brook Restoration Study, design, and implementation

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- Public Outreach
- Improve translated communication with non-English speakers
- Create Resource Network to reach vulnerable populations
- Recreational Facility improvements and improve drainage and health and safety of sites

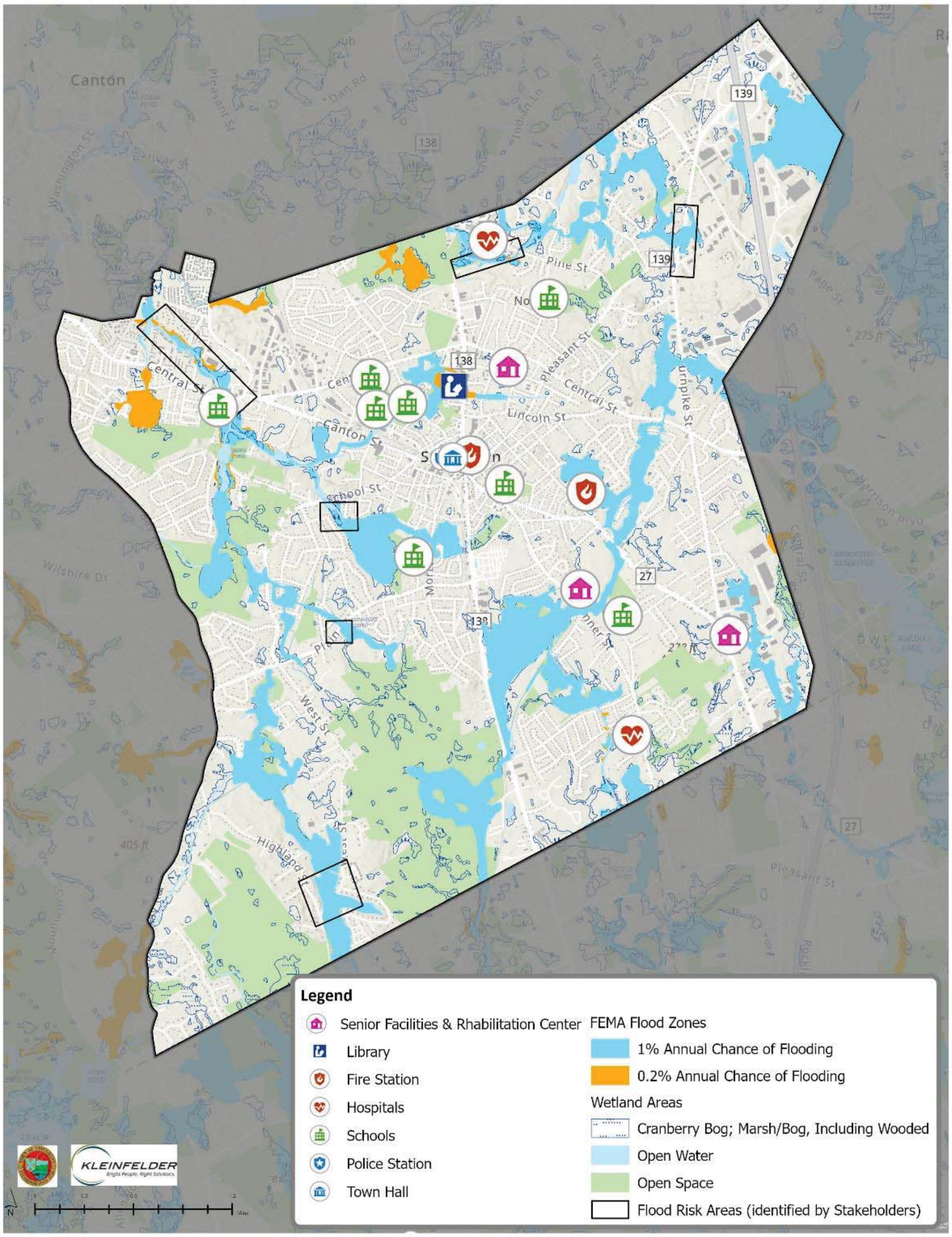

Figure 1-1: Stoughton flood risk map

1.2 CLIMATE CHANGE VULNERABILITY

A major takeaway from the 2020 MVP Planning Report identified flooding as the community's highest priority hazard. In response, the Town prioritized assessing climate change impacts on flooding and potential adaptation and resiliency measures. This formed the basis for the current MVP Action Grant project detailed in this report.

MVP Program 9 Core Principles:

- *Furthering a community identified priority action to address climate change impacts*
- *Utilizing climate change data for proactive solution*
- *Employing nature-based solutions (EBS)*
- *Increasing equitable outcomes for and supporting strong partnerships with Environmental Justic Populations and Climate Vulnerable populations*
- *Conducting robust community engagement*
- *Achieving broad and multiple community benefits*
- *Committing to monitoring project success and maintain the project into the future*
- *Utilizing regional solutions toward regional benefit*
- *Pursuing innovative, transferrable approaches*

The current project, **"Stoughton Town-wide Drainage Model, Vulnerability Assessment, and Adaptation Strategies to Mitigate Future Flooding" (FY22 Action Grant)**, includes many of the core principles set out in the MVP program. The main objective of the FY22 Action Grant has been to perform a town-wide evaluation of flooding and risk vulnerability assessment of critical infrastructure that would inform the identification of potential mitigation and/or resiliency strategies to address flood risks. The specific project scope for the FY22 MVP Action Grant included the following:

- Develop a detailed Town-wide two-dimensional drainage model (hydrologic and hydraulic model);
- Use model results and flood exposure maps to identify vulnerable critical infrastructure and community assets, as well as the Town's storm drain system;
- Develop recommended actions and strategies to reduce flood risk to vulnerable areas, promoting equitable solutions, inclusive of nature-based solutions and green infrastucture;
- Conduct public outreach and education on flooding risks as well as to share study results with the residents.

This project was completed by the Town of Stoughton between September 2022 and June 2024 in collaboration with Kleinfelder. Project Team members included:

Town of Stoughton, MA

- Marc Tisdelle, PE, Director of Development Services / Town Engineer
- Craig Horsfall, PE, Assistant Town Engineer
- Laurence Langlois, GIS Coordinator
- Nick Dufresne, Project Engineer

Kleinfelder

- Dave Peterson, P.E., Project Manager
- Kyle Johnson, Climate Resiliency/Green Infrastructure Engineer
- Greg Avenia, Technical Advisor
- Mike Sanders, Technical Advisor
- Seth Bryant, PE, Hydrologic and Hydraulic Modeler
- Ariel Patterson, Resiliency Planner
- Sadia Khan, Hydrologic and Hydraulic Modeler

Neponset River Watershed Association (NepRWA)

- Ian Cooke, Executive Director
- Kerry Snyder, Managing Director of Community Resilience
- Jeff Frisch, Watershed Resiliency Planner

2 DATA COLLECTION PROGRAM

The purpose of the field program was to understand the characteristics of the Town's drainage infrastructure including its physical layout, wet weather flow rates and depths. The physical layout of the drainage system in the Town's Geographic Information System (GIS) was evaluated for accuracy to ensure that the computer model matched real-world conditions.

The field program included inspection of stormwater culverts to verify their sizing and their condition as well as collection of invert elevation data and pipe diameter throughout the Town of Stoughton's stormwater system to verify system connectivity and direction of flow. The collected field data was used to update the Town's stormwater GIS database. This stormwater database was then used to develop a calibrated hydraulic model of the Town's stormwater system which informed the vulnerability assessment of the system to future climate conditions, specifically related to flooding.

A detailed summary of the field data collection is included in a memorandum provided to the Town *MVP Field Data Collection in the Town of Stoughton*, dated November 2023 (Appendix A).

2.1 STORMWATER GIS

The Town maintains a GIS database of stormwater assets that includes all known stormwater infrastructure, collected through a mix of field investigations and record plans. The database contains a variety of asset types, including:

- Stormwater outfalls
- Drainage manholes
- Drain pipes
- Catch basins
- Culverts
- Swales
- Structural best-management practices (BMPs)

The GIS database was reviewed by Kleinfelder to determine the level of completeness and readiness for use within the town-wide hydrologic/hydraulic ("H&H") model. The GIS was screened for connectivity (clear connections between manholes, catch basins, and drainpipes), availability of invert elevations, and availability of pipe and culvert dimensions.

The asset information included within the Town's GIS database was used as the basis for the 1-dimensional hydraulic portion of the town-wide H&H model. A 1-dimensional (1D) model was selected for the piped infrastructure in town because the drainage network is largely comprised of known cross-sectional areas and a clear flow path, meaning modeling flow in 1D along the drain lines is an appropriate representation.

An overview of the town's GIS stormwater database is shown in Figure 2-1. The stormwater database attributes include 2,393 manholes, 3,350 catch basins, and over 86 miles of drainage pipes. For the purposes of this study, the GIS review focused on drainpipes at least 12" in diameter and larger and their connected features and excluded laterals in all areas except for the downtown district. This simplification was done for modeling efficiency, while still maintaining major drain lines and key infrastructure for assessing the system capacity. Following the review, a plan for field investigation was created to fill in data gaps that were necessary for adequately modeling the hydraulic network. Field investigations are discussed further in Section 2.2.

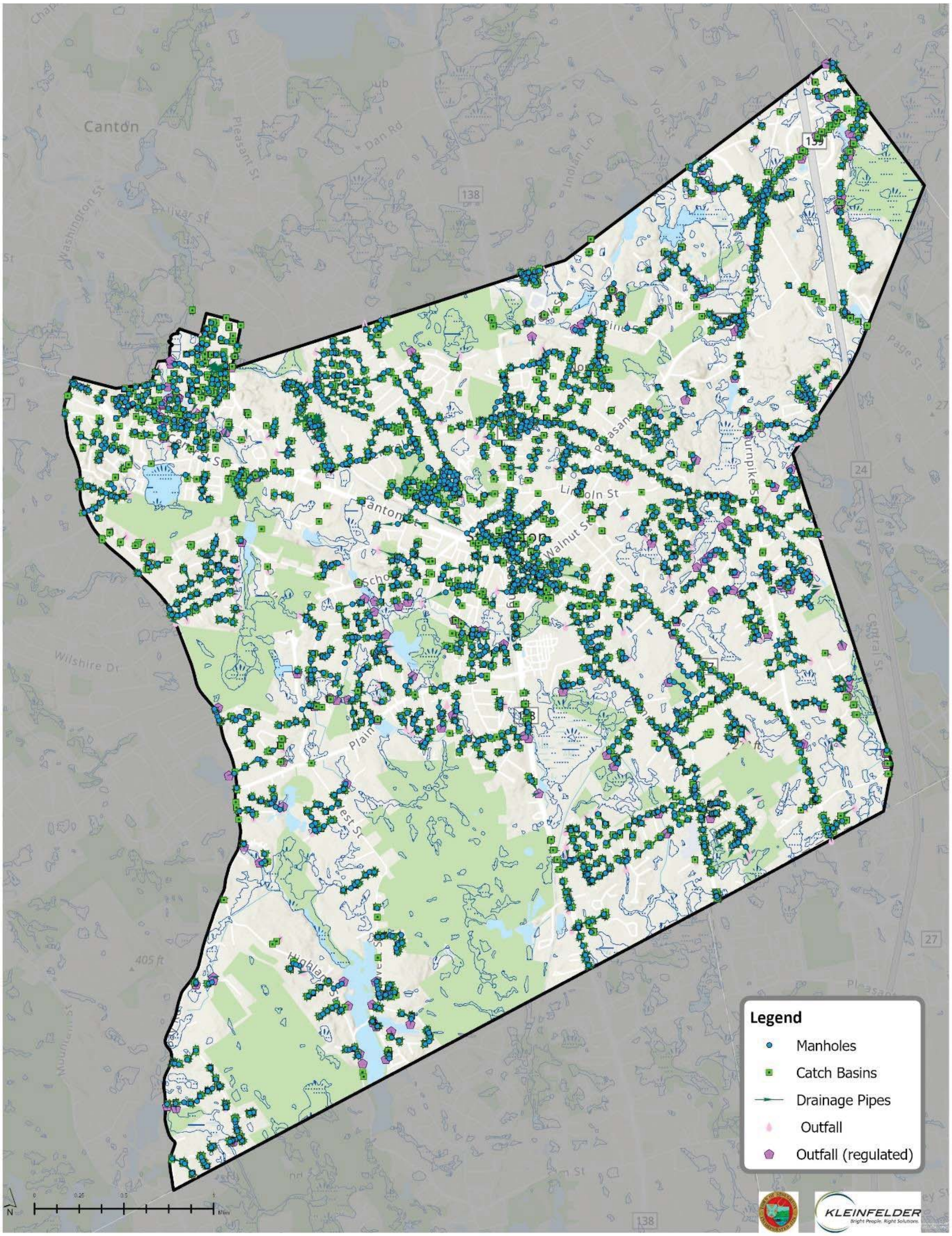

Figure 2-1: Town GIS stormwater database

2.2 FIELD INVESTIGATION

Kleinfelder field staff with support from Town staff conducted three field investigations to verify system connectivity and direction of flow, as well as to gather critical culvert measurements and conditions throughout the Town of Stoughton. In Fall 2022, one wet weather site visit and data collection were completed. Later, two field investigations were completed: one on Spring 2023, and another on Summer 2023 with a purpose to collect field data to update the Town's stormwater GIS database and, subsequently, the calibrated hydraulic model of the Town's stormwater system.

- **Initial Wet Weather Site Visit:** During the first wet weather field investigation on Fall, 2022, the team identified fourteen (14) locations to observe the flooding at areas reported by different sources as well as some key Federal Emergency Management Agency Flood Insurance Study (FEMA FIS) Modeling study locations. The objective was to identify potential flow monitoring locations, collect information on culvert dimensions and shape and gather spot water surface elevation for preliminary model validation.
- **Initial Model Validation Site Visit:** In the Spring 2023 validation field inspection, the team measured the dimensions, headwall elevation of the six (6) key culverts and used a GPS unit to survey the inverts of these culverts. The data collected from this visit was shared with the Town for updating their stormwater system database.
- **Follow-up Model Validation Site Visit:** To initiate the second validation field inspection (Summer 2023), a desktop analysis was conducted to identify the field visit locations of critical importance for connectivity within the modeled system. Twelve (12) locations were visited during the field investigation which was used to improve the completeness of the Town's stormwater system GIS database.

  In the second validation field inspection, the Team focused on confirming the drainage infrastructure characteristics where there were gaps in the existing GIS stormwater system data that would have been critical for model connectivity. The survey locations were also chosen to validate that the model matched real-world conditions. During this visit, investigation of culverts was completed to determine culvert properties for locations where dimensions, inverts, and other critical pieces of information were missing in the available GIS data used as the basis for the town-wide model. At each culvert location information on - culvert shape, characteristic dimensions, depth to channel / culvert bottom, water depth (for baseflow estimates) were collected. For all areas of interest within the drainage system that were not culverts, drainage manholes were opened and inspected using a survey rod and visual inspection for collecting information on pipe connection diameters, depth from invert to rim, and pipe offsets.

In addition to the 12 locations proposed for the field investigations, Kleinfelder also conducted a wet weather site investigation of a culvert located where Steep Hill Brook passed under Erin Road. The location was prioritized after early model validation showed disagreement between monitoring and modeled data for the location across a range of storm events.

Once the GIS database was updated with all collected relevant field information, the GIS database was integrated into PCSWMM, the hydraulic modelling program that was used to predict performance of the Town's stormwater infrastructure system during present day and future climate scenarios. After initial calibration of the model, the team determined that sufficient field data had been collected to adequately calibrate the model.

2.3 FLOW AND RAINFALL MONITORING

Flow monitoring was completed at six culverts located throughout Stoughton to measure streamflow and depth at strategic locations. Monitoring data is key to creating a calibrated model, providing a point of comparison at each monitoring location to check that the model is accurately representing the measured conditions. The culverts selected represent key drainage areas within the Town identified as flood-prone during the public survey as part of the public engagement process (Section 3.1). Flow monitoring locations and their respective contributing drainage areas are shown in Figure 2-2, with a full list of flow monitoring locations in Table 2-1.

Table 2-1: Flow monitoring location key

Monitoring Location Map ID	Street Name (Culvert Location)	Watershed
1	Erin Road	Steep Hill Brook
2	York Street	Redwing Brook
3	Turnpike Street	Beaver Brook
4	Washington Street	Whitman Brook
5	School Street	Steep Hill Brook
6	West Street	Steep Hill Brook

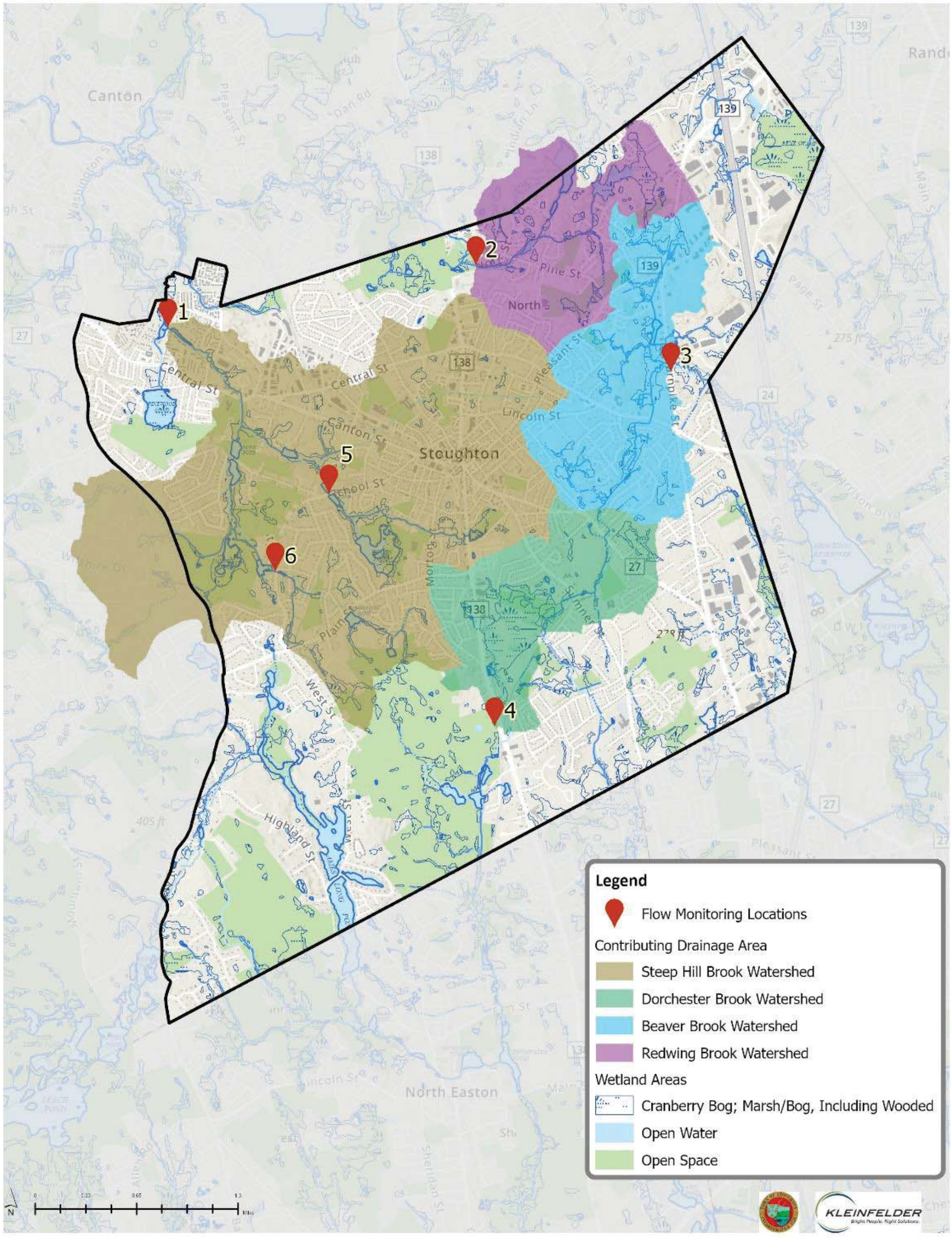

Figure 2-2: Flow monitoring locations and contributing drainage areas

At each culvert, a combination of velocity meters and level sensors were installed to gauge velocity and stage (depth) on a 15-minute basis (Figure 2-4). Each cross-sectional area was surveyed during a field visit by EST associates in order to provide a depth-to-area relationship for the stream cross-section, and this was in turn used to calculate volumetric flow rate as the product of area and velocity at each time step.

Precipitation was measured using tipping-bucket rain gauges at two locations within Stoughton to provide rainfall volume and intensity for use during calibration. Two locations were chosen to provide redundancy, corroborate rainfall readings, and provide insight into geographic differences in rainfall across the town. Gauges were located in the southwest of the town near Ames-Long Pond (1600 West Street - Figure 2-3), as well as in the northeast at 6 Carson Drive.

Figure 2-3: Example monitoring stations for flow (Left) and rainfall (Right) at Steep Hill Brook and Ames-Long Pond, respectively.

Monitoring occurred between 3/10/2023 and 5/17/2023. A total of 26 distinct rain events were observed during the monitoring period, using an event definition as any measurable rainfall that occurred with an inter-event dry period of at least 6 hours. Two large storm events in excess of 2 inches were measured, and overall, 7 events resulted in rainfall in excess of 0.25 inches (**Figure 2-4**).

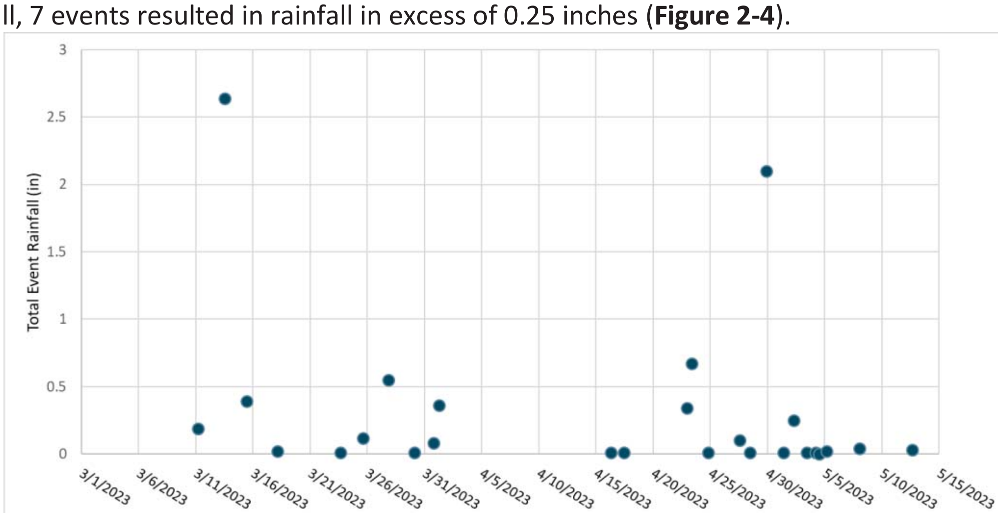

Figure 2-4: Measured Rainfall Event Totals during Monitoring Period

Time series results of stream flow and depth were compiled for the largest four storm events to be used during model calibration and validation. Table describes summary statistics for each of these four storm events.

Table 2-2: Summary statistics for largest measured rainfall events

Start Date	Duration *(hours)*	Total Rainfall *(in)*	Peak Intensity *(in/hr)*
3/13/2023	27	2.64	0.32
4/29/2023	29	2.10	0.60
4/23/2023	12	0.67	0.28
3/27/2023	17	0.55	0.12

The four largest storm events were selected for calibration and validation because the model is targeted at simulating flooding during flood events. In these storm events, the proportion of rainfall that becomes runoff rather than infiltrating or being lost is greater. Because runoff is the primary component being used to assess flood risk, these larger storms carry a greater importance to the objectives of the model and overall study.

3 PUBLIC OUTREACH

In addition to the data collection discussed in Section 2, information was solicited from the public to inform the model development, ground truth results of the modeling, and provide feedback in later stages of the study. The Town of Stoughton has a growing environmental justice (EJ) community, particularly a growing Portuguese language population. The 2000 and 2020 census show that in the past several decades, the percentage of Stoughton residents that identify as White and non-Hispanic has dropped from 87.5% to 61.0%, demonstrating the increasing diversity in Town. Because of historic challenges with including and informing EJ populations, including this growing EJ community throughout this data gathering process was made a priority for the study. Efforts were made to ensure that language and access were not barriers for involving any member of the public in the process.

Kleinfelder worked closely with the Neponset River Watershed Association (NepRWA) who coordinated public outreach for the project. Included as part of the public outreach program was:

- Town-wide survey to crowd source flood information
- A series of community meetings to provide updates and solicit feedback on the project
- Creation of a climate task-committee
- 5th grade classroom visits to present on climate change and flooding

3.1 FLOOD IMPACTS TOWN-WIDE SURVEY

Direct mail postcards were sent to all Stoughton residential and business addresses, including P.O. boxes, to ensure that information regarding the survey was made available to all Stoughton residents. Additionally bilingual fliers were installed at key community locations to provide an overview of the project, promote the survey and other public outreach activities, and provide a QR code for digital access to the survey.

The survey itself was made available in English and Portuguese to ensure access for Stoughton's Portuguese speaking community. The survey was created using Survey123 and included questions that targeted the following information:

- Location of historic flooding in Stoughton
- Source of flooding
- Impact of flooding

Results of the survey were used in tandem with preliminary modeling results to identify flood hotspots in Stoughton and provide guidance for where to focus model validation and additional field work. The results were comprehensive across the town, yielding results from geographically diverse areas of Stoughton. The survey indicated that some flood hotspots existed in the downtown area, the York Street neighborhood, the northeast of Stoughton, and the northwest corner of town. A map of survey results identifying locations of historic flooding is shown in Figure 3-1.

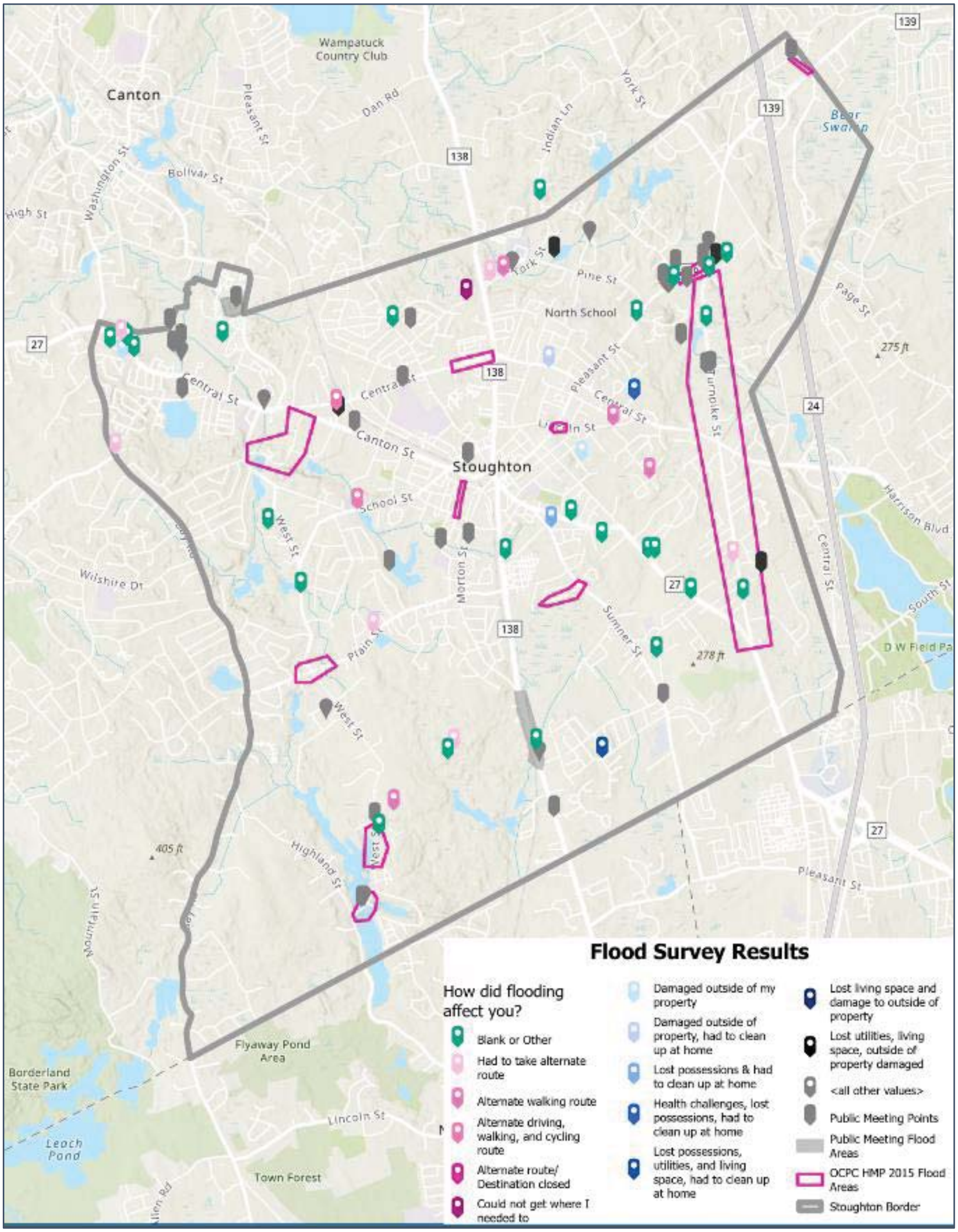

Figure 3-1: Flood locations identified in town-wide survey and public meetings

3.2 PUBLIC OUTREACH MEETINGS

A series of public outreach meetings were held to ensure that the community was well informed of the project and had an opportunity to provide input on next steps in the study. Table describes the purpose for each meeting, date held, and outcomes for the project. For both meetings, translation services were offered to encourage attendance from Stoughton's Portuguese speaking community and for the in-person meeting, food and child-care services were offered. The presentation used during these outreach meetings are included with this document as Appendix B.

Table 3-1: Summary of public outreach meetings

Meeting	Purpose	Venue	Results
Public Meeting 1 (12/15/2022)	Solicit information on flooding in the town; provide an overview of the study; get feedback on general flood mitigation strategies	Hybrid (Stoughton YMCA and virtual)	Added locations to known flood location map (Figure 3-1)
Public Meeting 2 (2/13/2024)	Present results of town-wide flood study; share potential flood-mitigation concepts; solicit feedback on concepts and ground-truth model results.	Virtual	Feeback on alternatives for York St, Downtown, and Ames-Long Pond

3.3 CLIMATE TASK-COMMITTEE

As part of the public outreach program, NepRWA recruited members of the Stoughton community to be involved in a focus group centered around climate change issues affecting the Town. The individuals were primarily recruited from community-based organizations representing or working with environmental justice residents in town. The Committee focused on climate change impacts, consequences, and discussed resilience-building opportunities in town. The members of the committee were compensated for their time and childcare services were offered as needed. The climate task-committee will serve as a group of interested stakeholders for future efforts to provide input on the concerns of residents with impending climate risks.

4 TOWN-WIDE FLOOD MODEL DEVELOPMENT

4.1 1D HYDRAULIC & HYDROLOGIC MODEL

A Town-wide 1-Dimensional (1D)/2-Dimensional (2D) hydrologic + hydraulic (H&H) stormwater model was developed using PCSWMM based software to evaluate potential future flood impacts within the Town's boundary. The model was used to evaluate system performance to understand baseline flooding under current and future climate conditions as well as explore the potential flood reduction that might be realized with proposed mitigation strategies.

The Town-wide model began with a 1D base that explicitly modeled hydraulics such as open channels, culverted flows, and the major drainage pipes from the major tributaries to the town's waterways. These components represent areas where defined flow paths existed, so modeling the direction of flow in 1D was appropriate. This includes Red Wing Brook, Steep Hill, and Dorchester Brook, among others. The Town's 1D-2D integrated H&H model also includes major ponds and reservoirs, such as Ames Pond, Pinewood Pond, Town Pond, Woods Pond, and Glen Echo Pond, as well as Reservoir Pond and its upstream tributaries (i.e., Beaver Meadow Brooks). To incorporate the Town's piped infrastructure, a simplified network of the Town's drainage system was represented by a combination of drainpipes and open channels. Stormwater drainage pipes larger than or equal to 12-inch in diameter were modeled (Figure 4-1).

For hydrology, the model incorporates parameters such as impervious cover percentage, land use type, slope, native soil types, and other catchment characteristics. The Green and Ampt infiltration method was employed to calculate infiltration, and runoff was estimated using the Kinematic Wave method. Both methods are incorporated directly into the PCSWMM model and were applied based on land use, imperviousness, slope, and underlying soils. Catchment areas were delineated to calculate inflow into each drainage network node included in the model, as well as direct runoff to waterways throughout the Town.

4.2 2D SURFACE MESH

The base 1D model was then improved to a 1D-2D integrated H&H model to help visualize surface flooding on a model mesh, the mesh was developed using LiDAR terrain data[2] to represent surface terrain at a resolution approximately 25 to 50 feet. Modeled stormwater runoff was then linked to a gridded 2D surface mesh, representing gravity flow, head loss, and surcharge throughout river-, stream-, and piped-

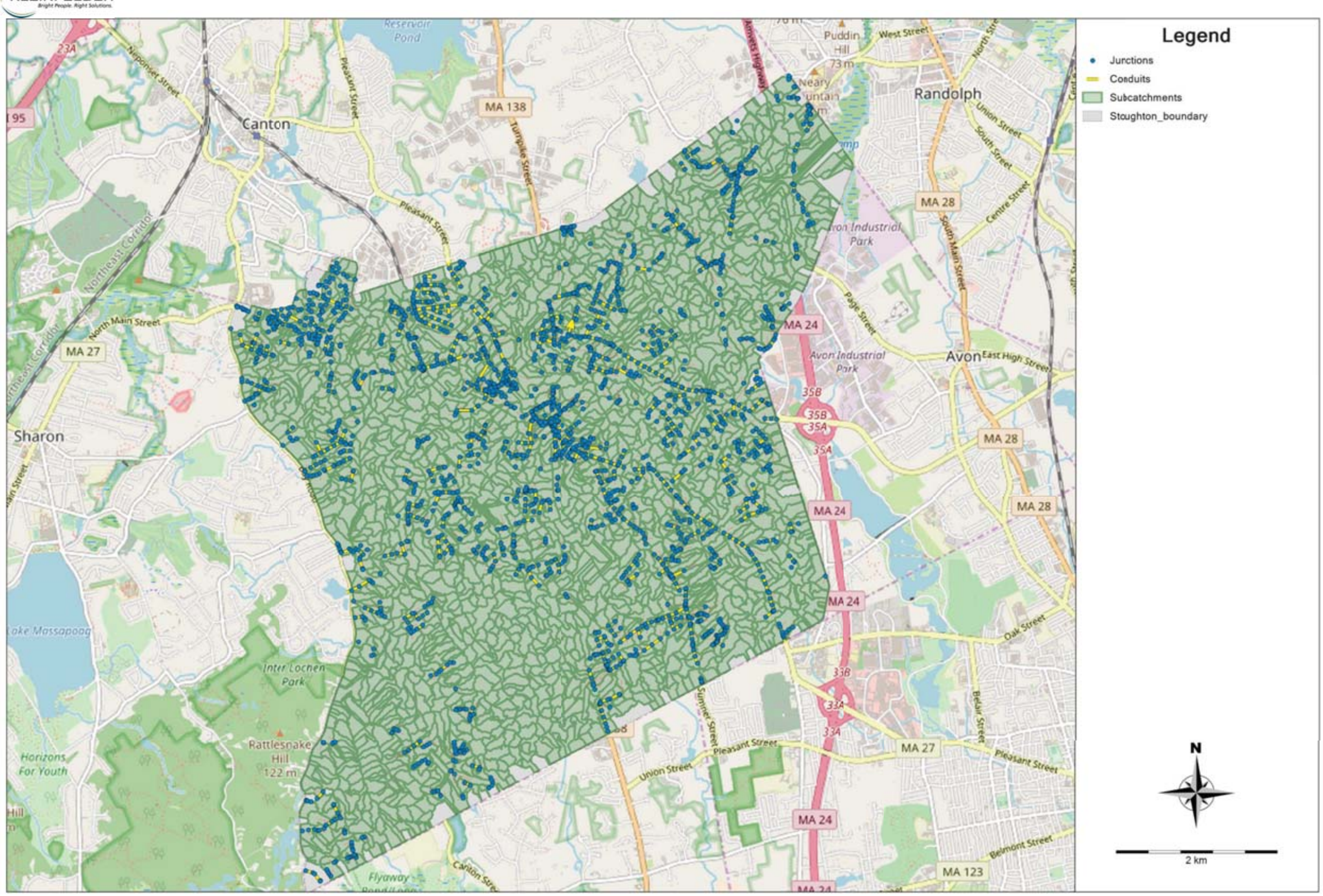

Figure 4-1: A simplified graphic representation of Town of Stoughton PCSWMM 2D H+H Model

infrastructure networks. The 2D H&H model allows for detailed analysis, identifying where surcharge conditions may result in overbank flooding, urbanized infrastructure flooding (i.e., infrastructure capacity-driven flooding), and/or groundwater flooding.

The Town-wide H&H model includes 2,875 sub-catchments connected to the simplified network, which simulates the hydrology in the watershed. Most of these catchments are between 0.01 and 16 acres in size, with a median sub-catchment size of 4 acres. In specific areas identified during the model calibration process, additional resolution was added to the 2D surface mesh to correct overland flow paths, in proximity to recent development projects where fill conditions were not accurately captured by the LiDAR data.

To perform short-duration high intensity storm evaluation, 2D surface mesh of 10 feet resolution was used in specific locations (identified based on town-wide model result and Town input) to utilize "rain-on-grid" catchment routing.

4.3 CLIMATE CHANGE SCENARIOS AND DESIGN STORM DEVELOPMENT

Design storms were developed using a combination of NOAA Atlas 14 values and the Resilient Massachusetts Action Team (RMAT) Climate Resilience Design Standards. To reflect the increased flood risk associated with climate change, design storms ranging from 10-year to 100-year were included with time horizons of present-day conditions, 2030 climate projections, and 2070 climate projections. Figure 4-2 below shows the total rainfall volumes for 24-hour storms under the various scenarios. The total rainfall volumes determined using NOAA Atlas 14 and RMAT were applied to the SCS-Type III rainfall distribution to create rainfall time series in PCSWMM.

In addition to the 24-hour storm events used to model high-volume extreme precipitation events, several short-duration storms were modeled in SWMM to assess risk associated with high intensity storms that typically cause flash flooding. Volumes used in the short-duration storms are as follows:

10-year, 2-hour, Present Day: 2.35 inches
10-year, 2-hour, 2070: 2.82 inches

Due to the limitations of the SCS rainfall distributions (published distributions are only available for 24-hour and 6-hour durations), a more conservative rainfall distribution as developed for the 2-hour storms to offer realistic peak rainfall intensities. The distribution was developed as part of the Resilient Cambridge study completed in 2021 and is a custom distribution appropriate for high intensity, short duration storms likely to cause flash flooding[3].

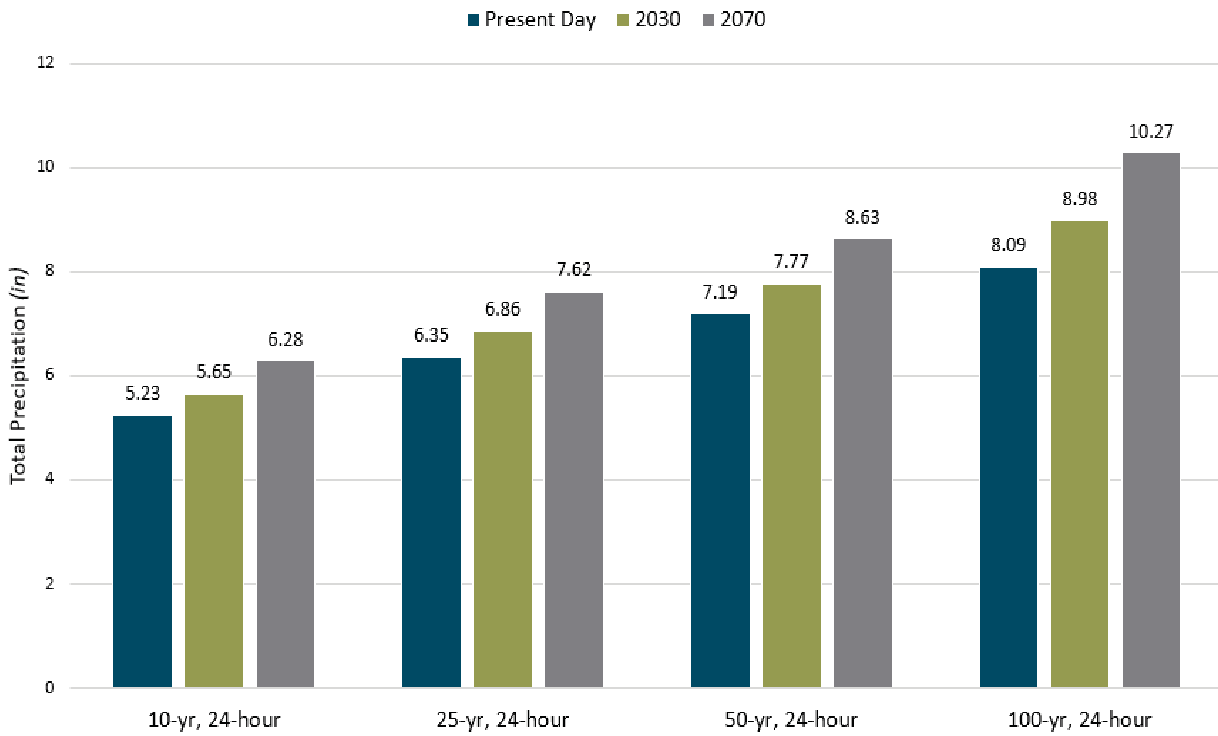

Figure 4-2: 24-hour duration design storms for various climate horizons – Stoughton, MA

4.4 CALIBRATION AND VALDATION

Stream flow, stream depth, and rainfall data collected during the monitoring phase of the project (Section 2.3) was used to calibrate and validate the town-wide model. At each of the six monitoring locations, measured 15-minute interval data was compared to modeling results to determine the accuracy of the model. Model parameters including infiltration rates, surface roughness values, and imperviousness, were adjusted until the peak flow for each monitoring location was modeled within 10% of the measured values. Figures 4-3 and 4-4 show results of calibration and validation, respectively, for sample monitoring locations, demonstrating the strong correlation between modeled and measured data developed.

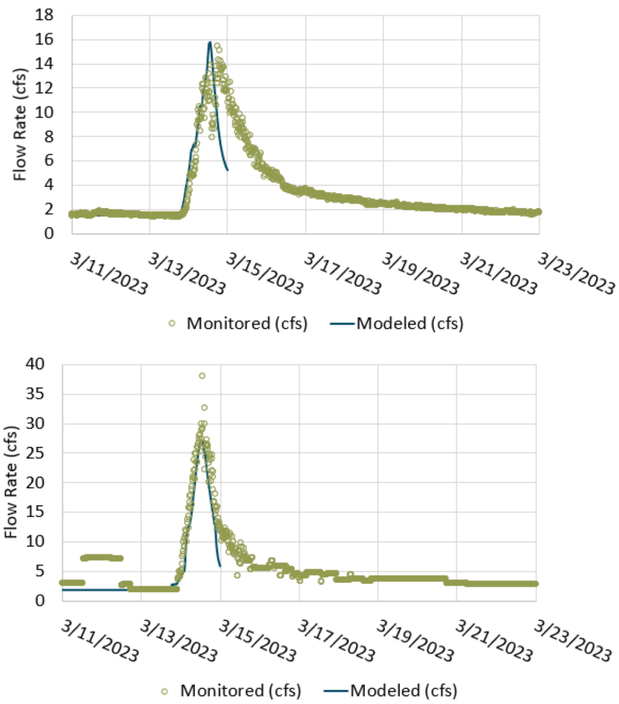

Figure 4-3: Sample calibration data for monitoring locations 4 (Top - Washington St) and 5 (Bottom - School St). The left graph demonstrates a side-by-side comparison of time-series data for modeled and monitored data, while the right graph displays a 1:1 comparison of flow magnitude at each point in time.

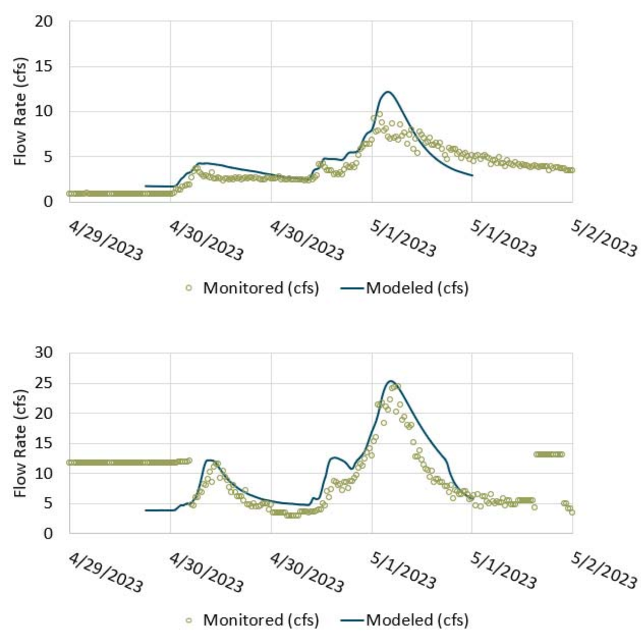

Figure 4-4: Sample validation data for monitoring locations 4 (Top - Washington St) and 5 (Bottom - School St). The left graph demonstrates a side-by-side comparison of time-series data for modeled and monitored data, while the right graph displays a 1:1 comparison of flow magnitude at each point in time.

5 RESULTS AND VULNERABILITY ASSESSMENT

5.1 FLOOD RESULTS

Following the completion of the town-wide H&H model, town-wide and neighborhood scale flood maps were created with the results of the model to portray flood risk across a variety of storm sizes and durations, representing a range of probabilities and climate change scenarios (Table). Preliminary flood modeling results for the eight (8) scenarios described in the Table were compiled and reviewed by the project team. Town officials provided initial feedback on the modeled flooding for the Present Day 10-year and 100-year flood extents, based on past observations by different Town department staff. These preliminary results were further validated against known flooding hotspots identified by the residents during the public engagement program and past reports. Full flood maps for all scenarios are available in Appendix C of this document. The paired 1D-2D H&H model was used for assessing all 24-hour storms and applied across the entirety of the town, while the detailed rain-on-grid model was used to assess the short duration (2 hour) storm events at select locations within the town.

These flood map projections formed the foundation for the remaining work of the study, as detailed in the following sections. When overlaid with critical community infrastructure and assets, these projections helped identify key areas for analyzing potential flood mitigation measures.

Table 5-1**:** Mapped storm durations, return periods, and climate horizons

Storm Duration *(hours)*	**Return Period** ***(years)***	**Climate Horizon**	**Modeling Extent**
24	10, 100	• Present Day • 2030 • 2070	Town-wide
2	10	• Present Day • 2070	Downtown, Pleasant St (northeast of Stoughton), Central St (northwest of Stoughton)

5.2 VULNERABILITY ASSESSMENT

A vulnerability assessment was completed using the results of the town-wide flood model. The goal of the assessment was to determine the overlap between flood risk in Stoughton and community assets that are

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essential for both the Town and its residents, particularly its EJ community. A review of community assets was completed using a mix of MassMapper state-wide databases and information provided by Stoughton's GIS coordinator. Assets incorporated into the assessment include:

- Municipal buildings
- Public schools
- Public safety buildings (police, fire, EMS)
- Public libraries
- Hospitals
- Senior care facilities
- Rehabilitation facilities
- Stoughton Housing Authority properties
- MBTA commuter rail and bus stops
- Pharmacies
- Food access

At each location, expected flood impacts were calculated for the 2070 100-yr, 24-hr storm event. The flood impacts were assessed based on both the flood impact directly at the facility, as well as flood impacts to the network of roads providing access to the facility. This was done to ensure that access to critical facilities was considered when assessing how flooding could impact residents under future climate conditions. Calculated metrics included:

- Peak flood depth on asset tax parcel
- Total flood volume
- Peak flood depth on access roads (defined using a 0.25 mile radius around each facility)
- Total flood volume on facility access roads

Full results of the vulnerability assessment are shown in Figure 5-1, displaying the overlap between critical facility locations and flood impacts modeled under 2070 conditions. The flood metrics calculated for each facility were used as part of a prioritization within the town on where to address flooding in the near-term, as described in Section 5.3.

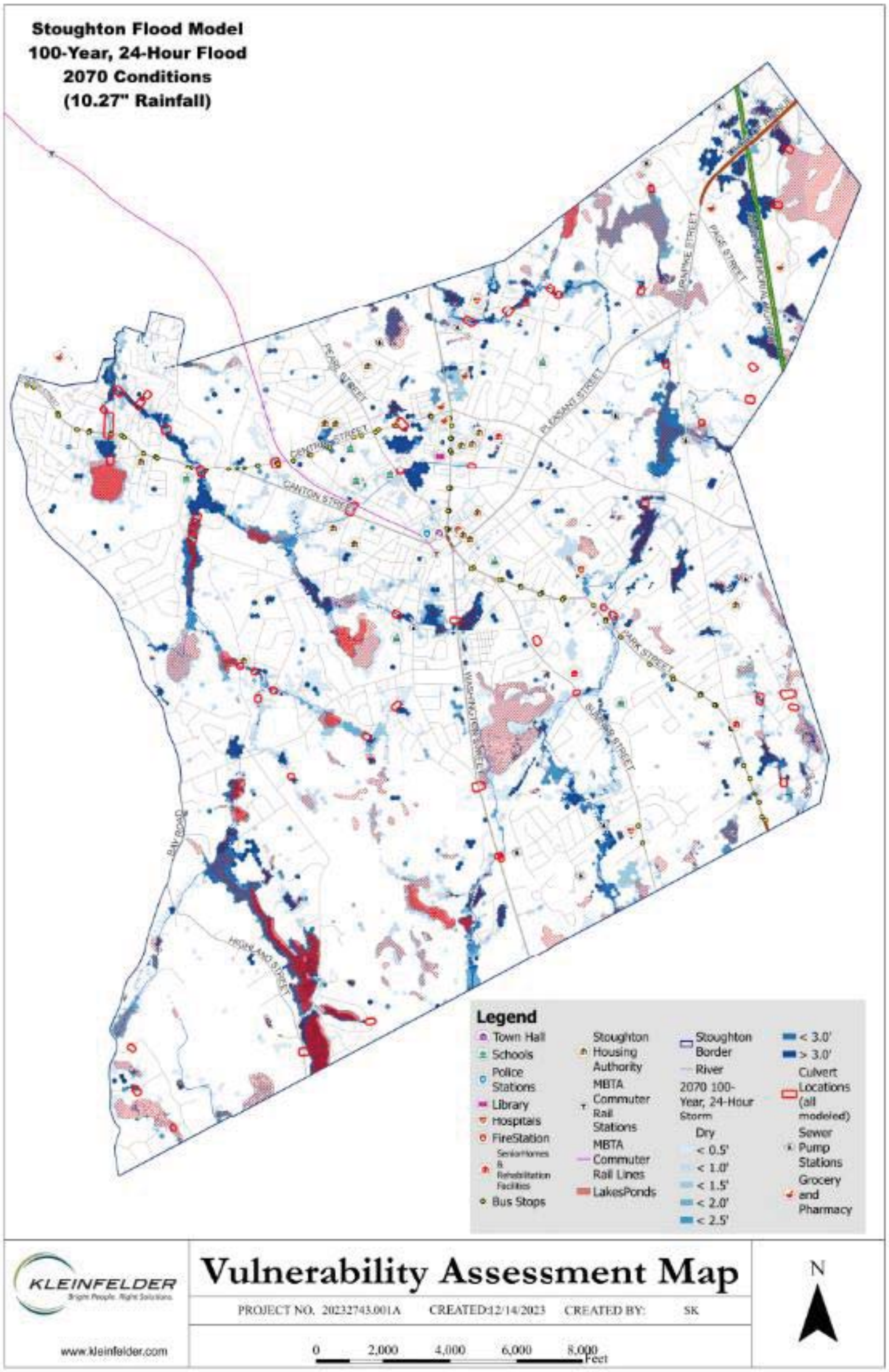

Figure 5-1: Vulnerability assessment results

5.3 PRIORITIZATION FOR ALTERNATIVE ANALYSIS

Results of the vulnerability assessment were used to select three locations to further study and propose flood mitigation solutions. The three priority locations were intended to represent places in the town that both served as important community resources and also presented a flood risk under either present day or future (climate change) conditions. The types of strategies used to resolve flooding at these three locations serve as examples of flood mitigation approaches that may be applicable to other vulnerable locations that were not studied in this report.

To determine the priority locations, assets from Section 5.2 were assigned a score based on both the potential for flooding at the asset and the criticality of the asset to Stoughton. Weights for each flood impact were used to sum up a total score for flood risk at each facility, and then the score was multiplied by the facility criticality weight in order to get the overall prioritization score. Figure 5-2 below illustrates the priority calculation.

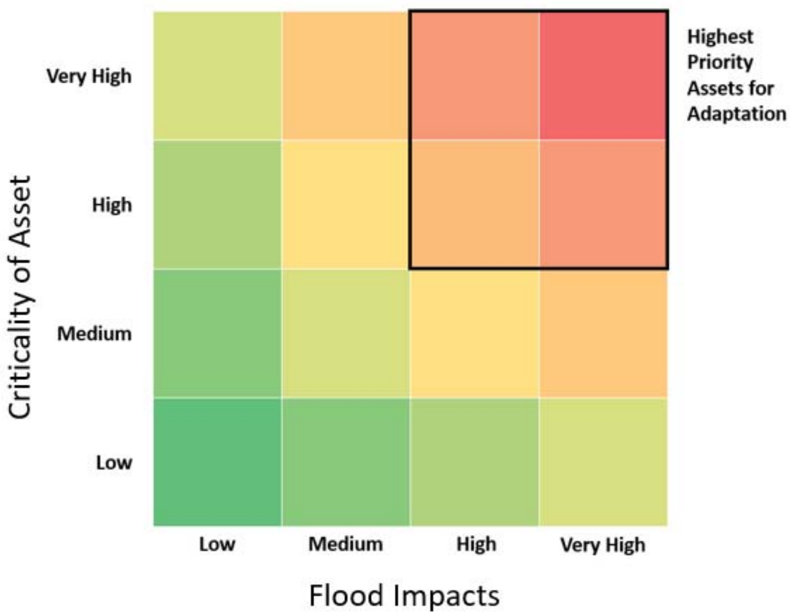

Figure 5-2: Asset prioritization matrix

Flood impacts were calculated using weighted values for each of the following criteria:

- Road flooding – peak depth
- Road flooding – average depth
- Road flooding – total volume
- Parcel flooding – average depth

Assets were assigned criticality based on the function of the facility. Assets were grouped into one of the following categories of facilities, and each was assigned a weighting score which was multiplied by the total flood impact score to determine the overall priority:

- Schools
- Municipal buildings
- Public safety
- Public housing
- Critical infrastructure (pump stations, treatment, etc.)
- Health Care
- Key routes

An overall score was calculated to represent the priority of each facility using the following equation:

$$\text{Priority Score} = (\text{Facility Criticality Weight}) \times \sum (\text{Impact Weight}) (\text{Impact Ranking})$$

Weights were developed with the Stoughton Engineering Department, and a variety of prioritization scenarios were created to run a sensitivity analysis and identify how the priority was affected by assigning different weights to facilities and flood parameters (full results included in Appendix D). Results of the prioritizations were mapped to show where hot spots of flooding and vulnerability were located. An example prioritization map is shown in Figure 5-1. Across all the prioritizations completed, a trend emerged showing that the flooding in the Downtown area of Stoughton, as well as along York St in the northern part of Town were consistently scoring higher under the priority. These two locations, along with a culvert on West St between Ames-Long Pond, were selected as priority areas by the town for further investigation and the development of flood mitigation concepts. Priority locations identified by this analysis were also cross-checked against results of the public outreach program to corroborate that the areas were of concern to residents and had accounts of historic flooding. Furthermore, the second public meeting was used to present the priority areas to the public and get feedback on their selection.

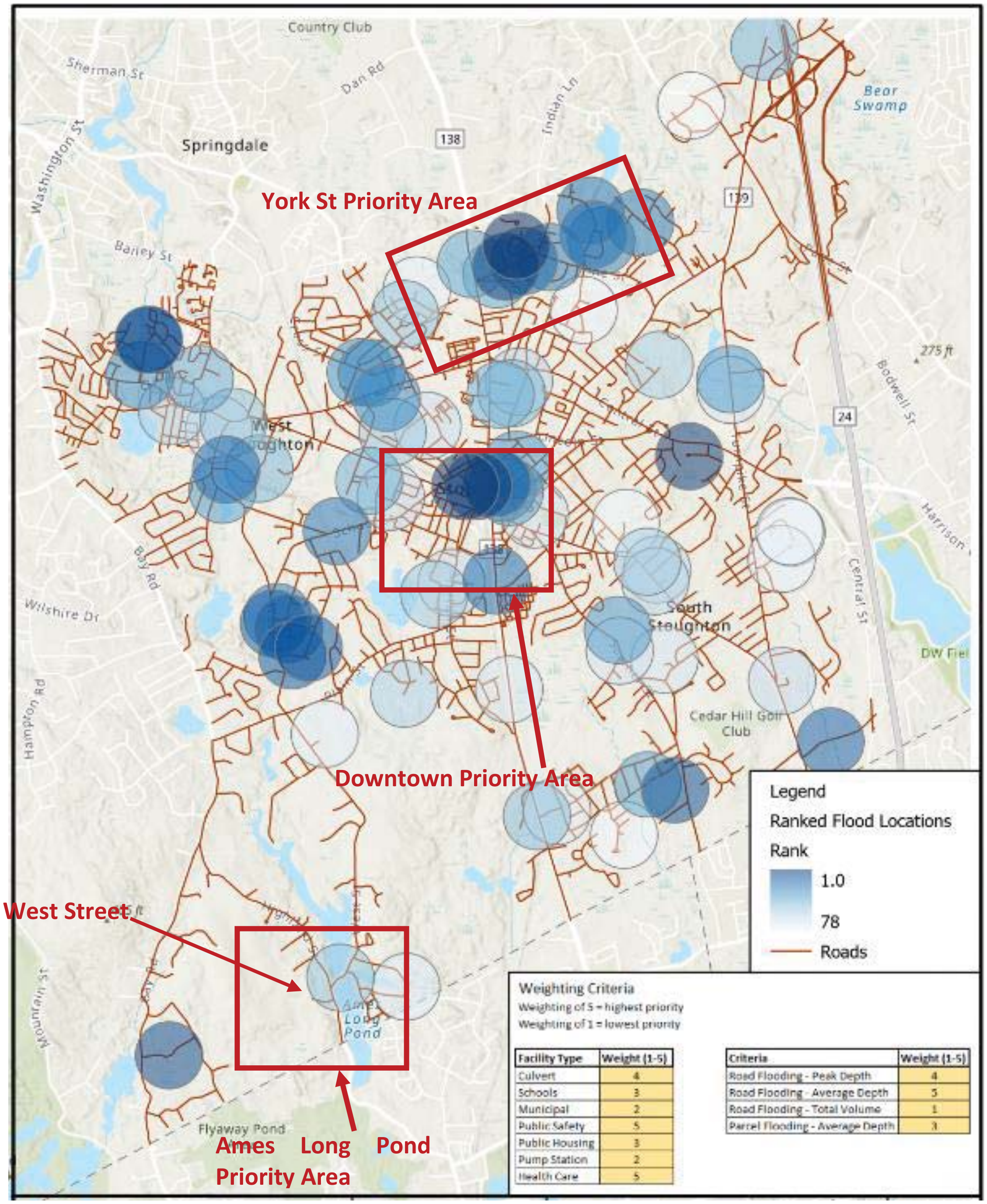

Figure 5-3: Sample prioritization map showing Downtown and York Street priority areas

At each priority location, flood mitigation strategies were assessed and modeled to provide Stoughton with next steps for addressing the most critical flooding in the town.

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6 PRIORITY AREA FLOOD MITIGATION STRATEGIES

Following the vulnerability assessment, a series of flood mitigation strategies were considered to mitigate flooding in the top priority areas identified. A combination of both gray and green infrastructure was considered, including green stormwater infrastructure, stormwater wetlands, culvert and drainage capacity improvements, and detention storage. Section 6.1 provides an overview of the general flood mitigation strategies considered, while Section 6.2 gives specific flood mitigation alternatives for each of the priority areas identified.

6.1 FLOOD MITIGATION STRATEGIES - GENERAL

6.1.1 Distributed Green Stormwater Infrastructure (GSI)

Green infrastructure, as defined by the Clean Water Act, encompasses a range of measures designed to manage stormwater using natural systems like plants and soils, permeable pavements, stormwater harvesting and reuse, and strategic landscaping. Examples include rain gardens, detention ponds, infiltration trenches, permeable pavements, and rainwater harvesting systems (Figure 6-1). This approach provides multiple benefits, including effective stormwater management, habitat creation, and beautification, although it often necessitates specialized maintenance by municipalities and large footprint to make meaningful impacts to flood reduction.

Figure 6-1: Green stormwater infrastructure -rain garden diagram *(Source: Philadelphia Water Department)*

6.1.2 Stormwater Wetlands

Wetlands are depressions in the landscape that hold water either year-round (permanent wetlands) or for part of the year (seasonal wetlands), supporting a variety of vegetation (**Figure 6-2**). Wetlands play a crucial role in flood protection by storing water and preventing rapid runoff during storms. Their ability to retain water minimizes the risk of damaging floods, as water stored in wetlands is gradually released into the groundwater or through surface outflow, helping to maintain more constant water levels in streams. This storage capacity is especially vital in low-lying areas and regions where rainwater collects, or groundwater is near the surface.

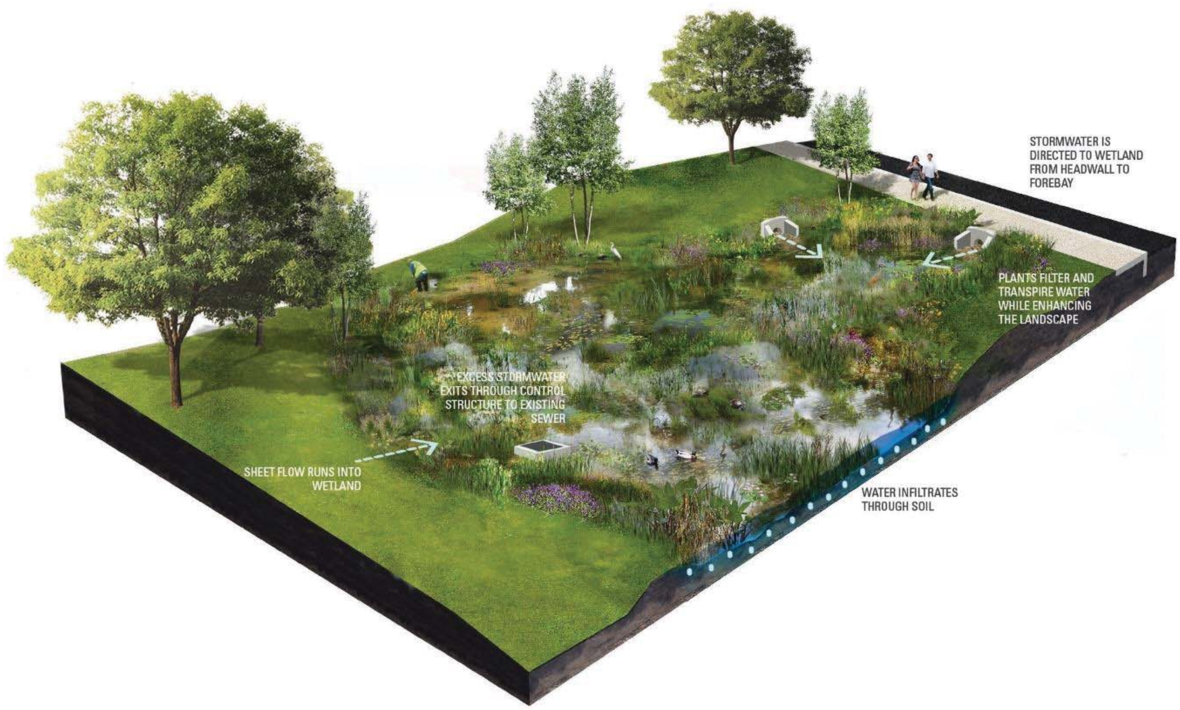

Figure 6-2: Conceptual diagram of stormwater wetland *(Source: Philadelphia Water Department)*

By acting as natural sponges, wetlands reduce the volume and speed of runoff, which helps to lower the peak flow of water entering streams and rivers during heavy rains. This function is indispensable for flood control, making wetlands an integral part of natural stormwater management systems.

6.1.3 Detention Storage

Several detention storage alternatives were considered including underground detention and above-ground detention basins (Figure 6-3). In both cases, detention storage helps mitigate flooding by providing additional storage capacity to store flood waters and slowly release through low-flow outlets. For underground storage, many proprietary modular storage options exist that allow for storage to be deployed under parking lots, fields, or other open spaces with mixed uses above.

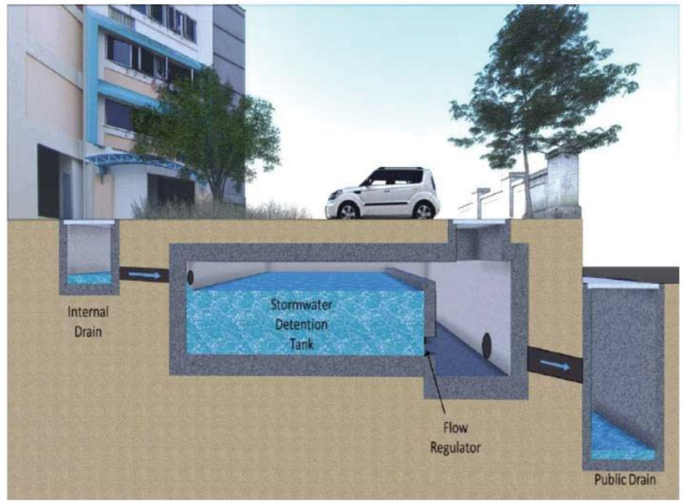

Figure 6-3: Underground detention storage conceptual design *(Source: Stormwater Sydney)*

6.1.4 Gray Infrastructure Improvements

In the context of stormwater and flooding solutions, gray infrastructure refers to man-made structures such as pipes, pumps, culverts, and dams. These systems are designed to capture and transport stormwater away from impervious surfaces to control flooding. Gray infrastructure embodies a traditional approach to stormwater management, typically focusing on a single function—stormwater control—that most municipalities are prepared to design, construct and maintain (**Figure 6-4**).

Figure 6-4: Culvert replacement example *(Source: MVP)*

6.2 FLOOD MITIGATION ANALYSIS IN PRIORITY AREAS

For each priority location selected, a sub-area model was created using the base town-wide model discussed in Section 4. Up to three flood mitigation alternatives, as discussed in Section 6.1, were modeled for each priority location to provide the Town with flood mitigation options moving forward. Alternatives were selected based on conversations with the Town and the applicability of each flood mitigation strategy for the subarea being assessed.

In addition to modeling flood impacts of each alternative, cost estimates were developed for the top feasible alternatives. The top alternatives were selected based on flood impact and discussions with the Town, as discussed further in this section. Cost estimates are Class 5 estimates per ASTM Standard E2516-11 and are based on a combination of MassDOT weighted average costs, bid costs from comparable projects, and judgement. A full breakdown of cost estimate calculations is included in Appendix E.

6.2.1 Red Wing Brook – York Street Area

Redwing Brook presents a significant flood risk to York Street and the surrounding neighborhoods and was identified as a priority area for mitigation as part of the town-wide vulnerability assessment. Under modeled conditions for future storm events, multiple culverts along the brook appear to be undersized and cause roadway flooding. The flooding along York Street presents a significant vulnerability due to the road's use as an access point to the New England Sinai Hospital, as well as the surrounding neighborhood -which houses a significant EJ population. Figure 6-5 shows flooding along York Street projected for the 2070 100-year, 24-hour storm event.

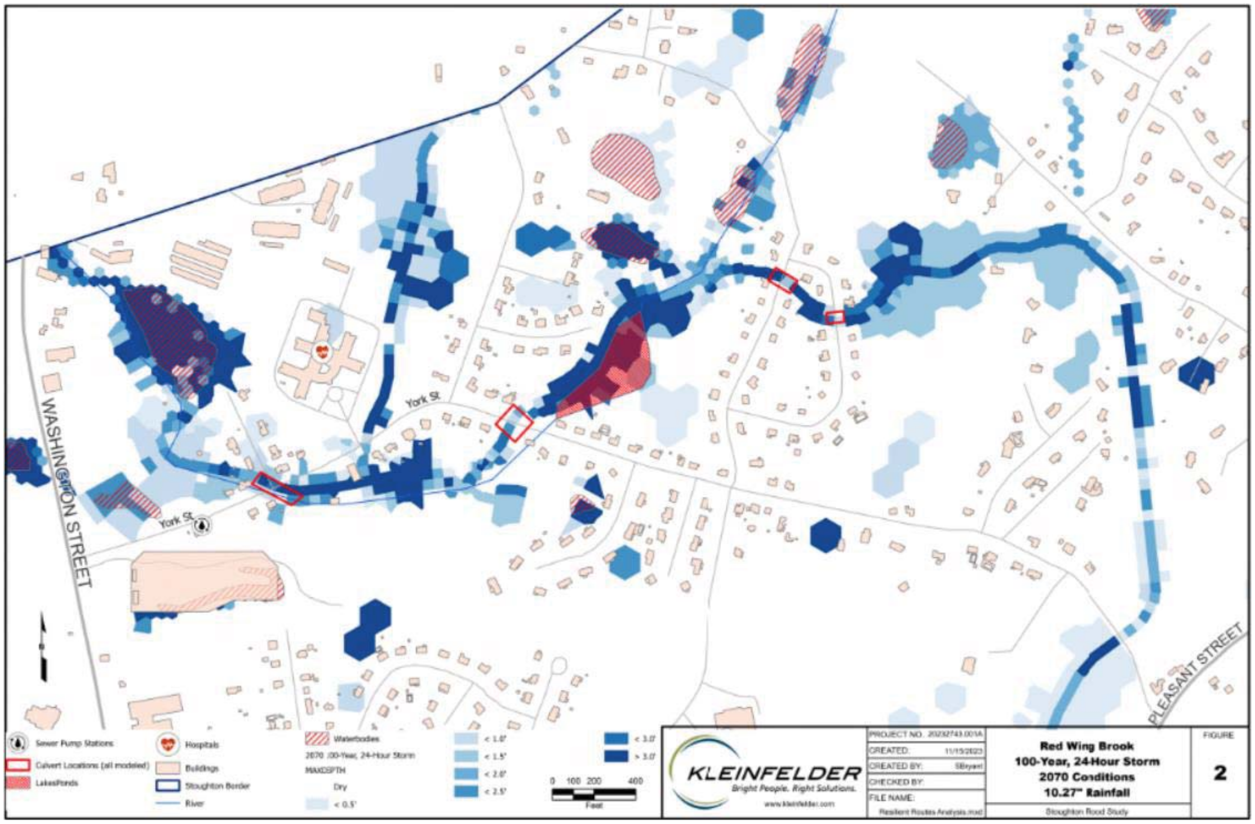

Figure 6-5: 2070 100-year, 24-hour flood results for York Street subarea under baseline conditions.

6.2.1.1 Alternative Flood Management Strategies

Three distinct flood strategies were assessed for the York St subarea: Culvert upsizing, detention basins, and floodplain wetland storage along York Brook. For each alternative, the effectiveness was assessed by comparing the peak downstream flow rate, the peak flood depth on York St, and the overall flood volume modeled. Because the Redwing Brook watershed drains to neighboring Canton, an emphasis was placed on not increasing downstream peak flows to ensure no negative downstream impacts would be experienced in Canton.

Alternative 1: Culvert Upsizing:

Two culverts presented hydraulic restrictions along Redwing Brook when considering climate-change scenarios. The two culverts are located at the York Street intersection Meadowbrook Lane and Pine St (marked in Figure 6-6). Modeling of the Redwing Brook watershed was completed, and culverts were sized to fully pass the 2070 100-year, 24-hour storm. Both culverts were sized to be 6 ft x 4 ft box culverts at the existing invert elevations of the current culverts at both stream crossings.

Figure 6-6: Location of enlarged culverts (L) and culvert under Meadowbrook Lane (R)

Alternative 2: Detention Basin:

The Town currently owns property that abuts York St near the peak flooding location at the intersection with Meadowbrook Lane (Figure 6-7). To make use of the town-owned parcels, a detention basin to provide flood storage was assessed as an alternative. The detention basin would primarily collect runoff from the abutting Ewing Drive, a significant drainage network that ultimately outlets to Redwing Brook. A low-flow outlet from the detention basin as well as an emergency spillway would outlet directly to Redwing Brook.

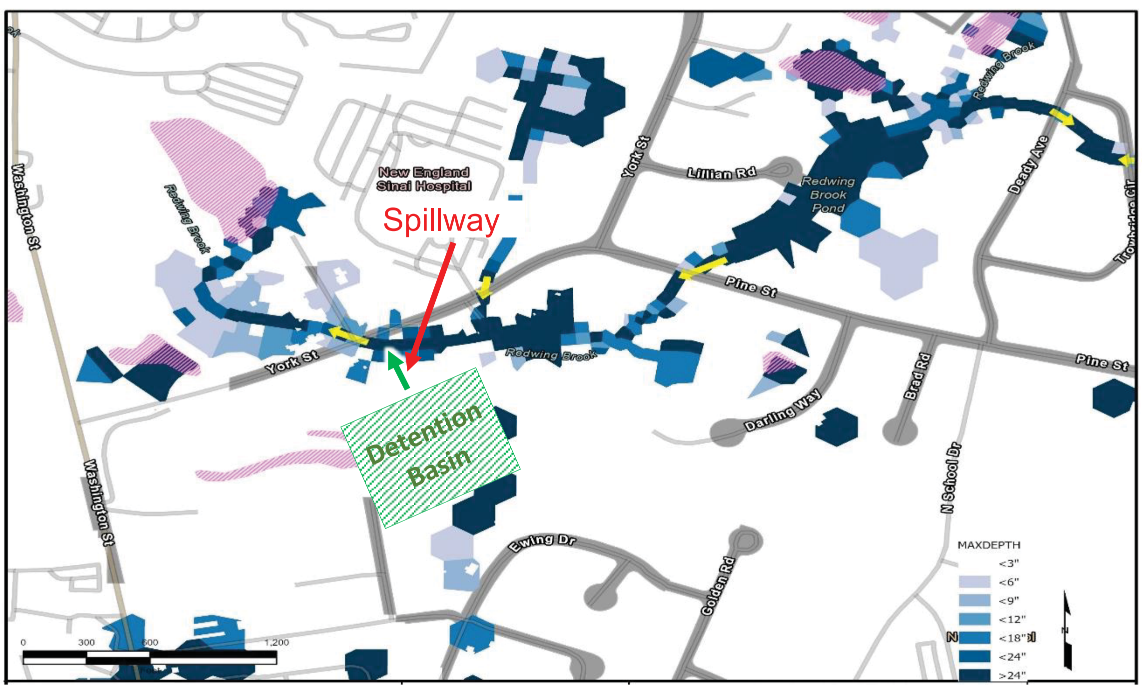

Figure 6-7: York St detention basin conceptual layout

Alternative 3: Floodplain Storage:

Additional municipal-owned parcels exist along the upper section of Redwing Brook, between Deady Ave and Glen Echo Boulevard. The property is currently undeveloped and forested and provides an opportunity for a constructed stormwater wetland and optimized flood storage in the brook's floodplain. However, the potential to require deforestation of the area for floodplain storage is likely to be unpopular a face significant challenges to move forward.

To understand the magnitude of floodplain storage needed to improve downstream flooding within the Redwing Brook area, a scenario was modeled with storage built along both sides of Redwing Brook to provide offline overflow capacity for major flood events. It was determined that a total storage capacity of approximately 30 acre-feet was necessary for containing the 100-year, 24-hour storm event.

In addition to the three mitigation strategies discussed above, a combination alternative was modeled to demonstrate the combined effect of all flood mitigation strategies. Results of the alternative for flood and peak flow mitigation are shown in Table 6-1.

Table 6-1: York Street alternatives comparison

Scenario	Peak Roadway Flood Depth *(in)*	York St Flood Volume *(acre-ft)*	Peak Downstream Discharge *(cfs)*	Peak Culvert Flow *(cfs)*
Existing Conditions	14	0.32	1092	79
Culvert Upsizing along York St	5.6	0.25	977	243
Detention Basin for Ewing Ave Runoff	9.6	0.29	943	77
Storage Along Floodplain / Wetlands	5.4	0.10	560	61
Combination	4.0	0.06	530	173

6.2.1.2 Preferred Approach

Following a review of the flood mitigation strategies with the Town, the following alternatives were selected as viable options for the town:

- Culvert upsizing
- Detention storage
- Combination of culvert upsizing and detention

From discussion with the town and the second public meeting, floodplain storage areas were determined to not be viable due to the amount of land and tree removal required in order to provide sufficient flood storage. For the alternatives being considered, ASTM Class 5 cost estimates were completed to provide

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preliminary cost estimates in 2024 dollars to the town for future planning (Table 6-2). For the immediate future, culvert upsizing provides the town with the most cost-effective method for mitigating flooding along York St, with a combination with detention storage being a long-term option to further mitigate expected flooding under increased precipitation conditions of long-term climate projections.

Table 6-2: York Street preferred approach comparison (ENR Index = 13,546.80)

Alternative	Description	Cost Estimate ($)
1. Culvert Upsizing	2 culvert replacements with 6'x4' box culverts	$1,750,000
2. Detention Storage	Detention basin along York St to collect runoff from Ewing Drive	$2,460,000
3. Combination	Culvert upsizing and detention storage	$4,210,000

6.2.2 Downtown

As the Town center, Stoughton downtown has numerous facilities frequently used by the public including the Stoughton Police Department, Fire Department, Town Hall, the post office, and the only MBTA station in the Town. To keep the entire Town connected to these emergency facilities, the Downtown area was selected as one of the priority areas based on the vulnerability assessment.

For the purpose of this study, the 100-year condition (1% Probability Storm) was used to show the more significant potential benefits of the food mitigation strategies considered. Moreover, one of the top hazard concerns identified during MVP Community Resilience Program, flash flooding in the highly impervious Downtown area, which has warranted the need to investigate the performance of the proposed flood mitigation alternatives during short-duration intense storm (2070 10-year 2-hour event). Recent observations of the devastating impact caused by a 200-year event (10 inches of rain in six hours) in Massachusetts have further emphasized the need for the Town to seek for alternatives to combat the changing climate pattern. Therefore, the modeling analysis was conducted for both short duration (10-year 2 hour) and long duration (100-year 24 hour) 2070 storm conditions and compared with baseline (i.e., existing condition). Figure 6-8 shows flooding in Downtown area projected for the 2070 10-year, 2-hour storm event.

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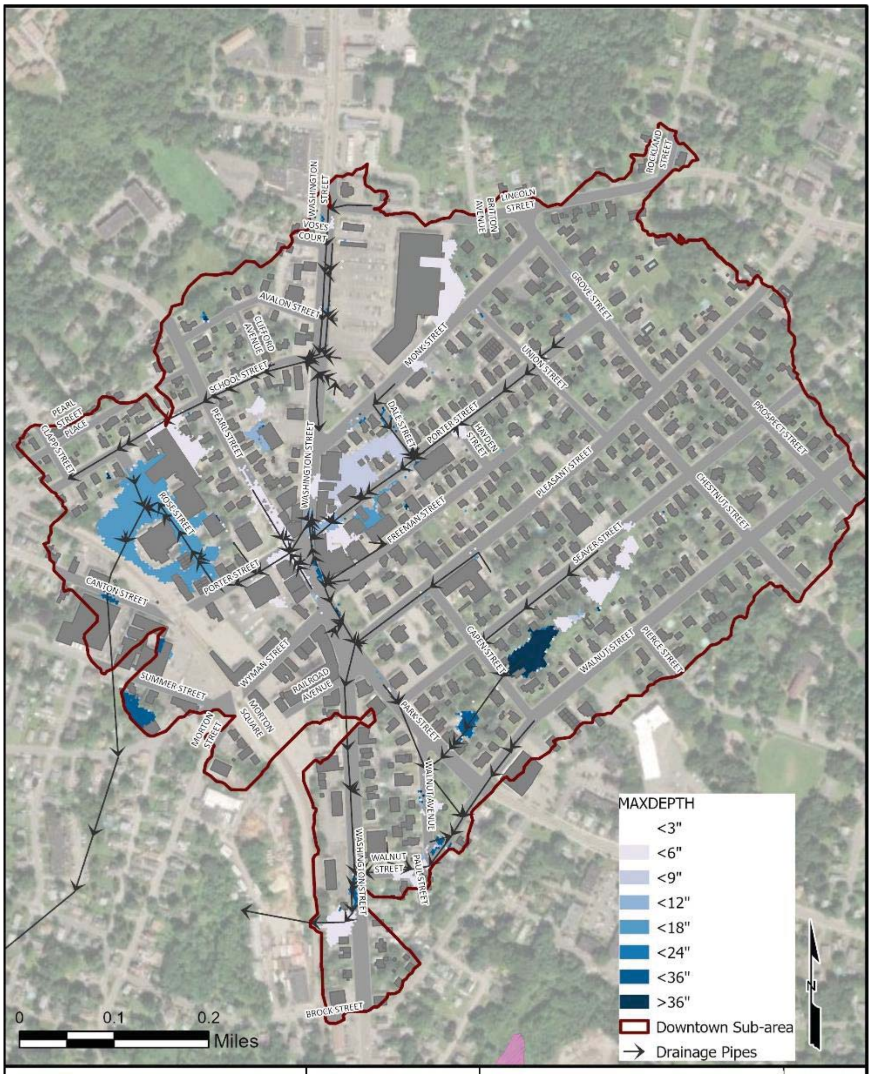

Figure 6-8: 2070 10-year, 2-hour flood results for Downtown subarea under baseline conditions

6.2.2.1 Alternative Flood Management Strategies

Three different flood mitigation strategies were assessed for the Downtown area: 1) distributed green infrastructure system, 2) stormwater pipe capacity improvements and 3) underground storage systems.

For each alternative mitigation strategy considered in the Downtown area (except distributed green infrastructure system), the effectiveness of the strategy was assessed by comparing the peak downstream flow rate at Woods Pond and the peak flood depth on Rose Street both pre- and post-mitigation. Because the Downtown area watershed drains to the Woods Pond, an emphasis was placed on not increasing downstream peak flows to ensure no negative downstream impacts would be experienced in the Woods

Pond area. Table 6-3 summarizes proposed modeled alternatives and corresponding flood mitigation strategies in the Stoughton Downtown area.

Alternative 1: Distributed Green Infrastructure System:

The distributed green infrastructure system alternative analysis assumed that about 20% of the catch basins in the Downtown area would be upgraded to bio-cells to provide additional storage and recharge to the ground (Figure 6-9).

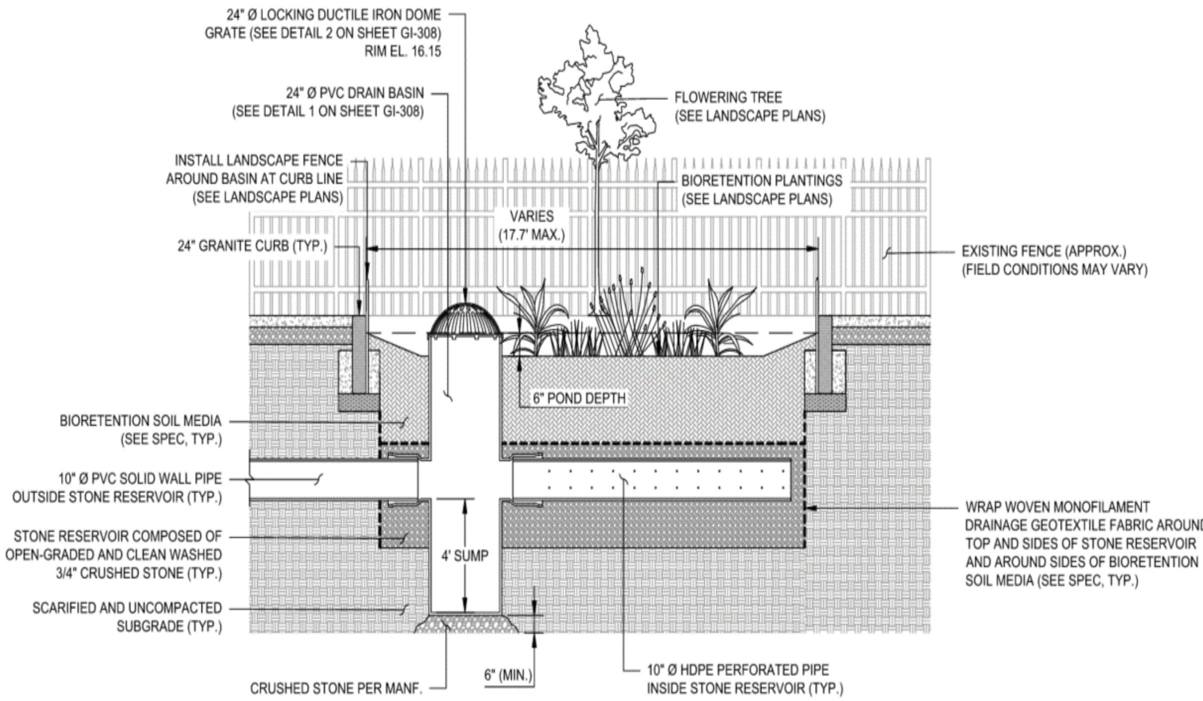

Figure 6-9: Conceptual design of catch basin inserts (modified bioretention cells)

Alternative 2: Pipe Capacity Improvement:

For the pipe capacity improvement alternative analysis, about 1,800 linear feet drainage line in the downtown area was assumed to be upsized. Existing drainage pipes along Rose Street and Porter Street would be upsized to 18” to 36” from the existing size of 10” to 22”. Figure 6-10 illustrates the stormwater pipes recommended for upsizing in the Downtown area.

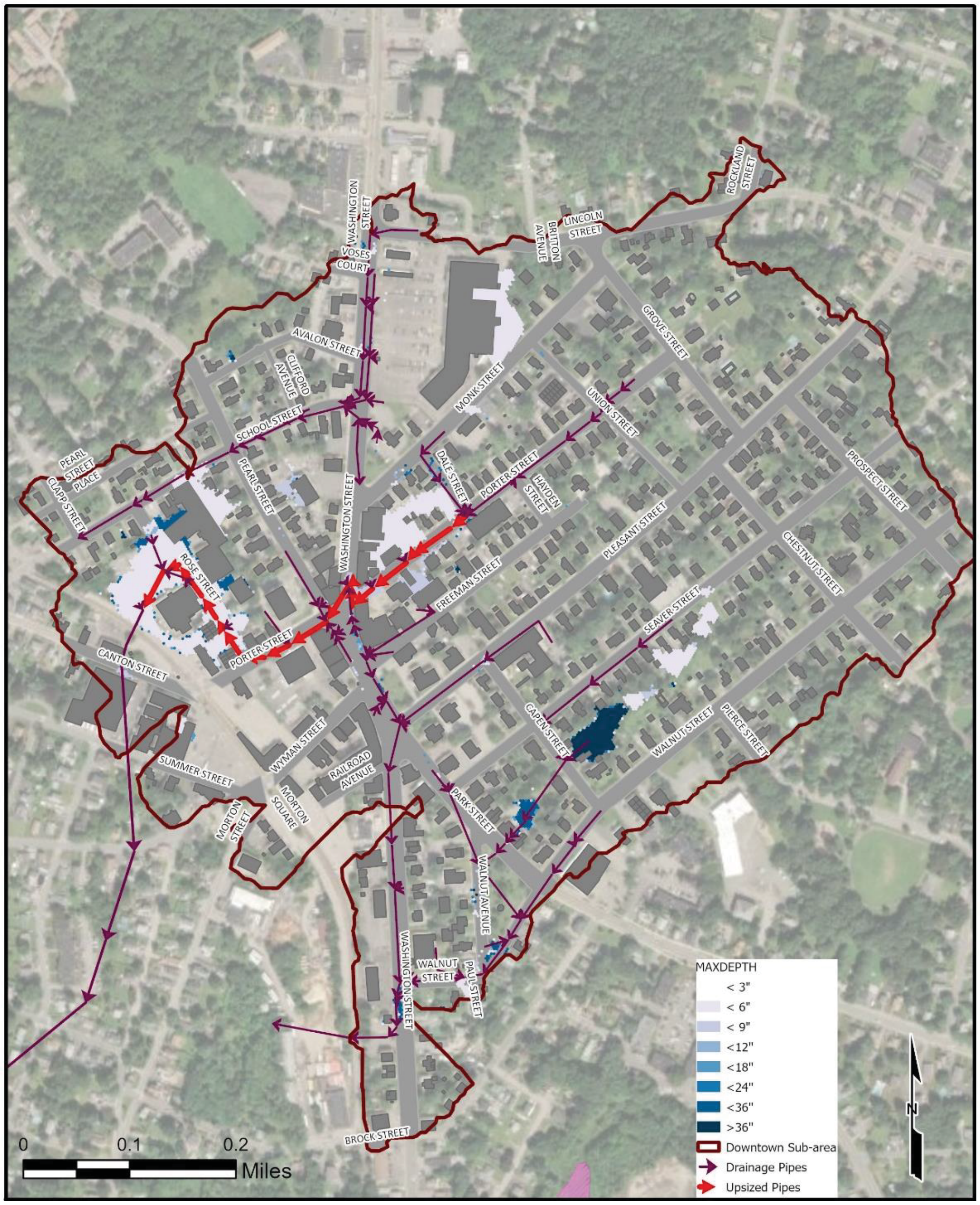

Figure 6-10: Downtown pipe capacity improvement flood mitigation strategy

<u>Alternative 3: Underground Storage System:</u>

The underground storage system alternative explores the impact of sub-surface detention systems to store the increased runoff volume. Town-owned parking lots in the Downtown area were considered for this purpose, with the Police Station parking lot and Post Office parking lot identified as one of the potential sites for an underground detention system. However, the planned expansion of the Police Station will reduce the available parking lot area. Consequently, an alternative approach was explored, involving the use of two connected underground storage systems with a combined capacity of approximately 1 million gallons (MG) (Figure 6-11). These systems would be located beneath the Police Station parking lot and the Town Hall rear parking lot to achieve the desired flood mitigation.

Another alternative considered was utilizing the Post Office parking lot to construct an additional 1 million-gallon (~1 MG) underground detention system. This would be combined with the 1 million-gallon (~1 MG) system beneath the Police Station and Town Hall parking lots, resulting in a total capacity of approximately 2 million gallons (~2 MG).

In both scenarios, the detention storage depth was expressly sized so that flows will empty out by gravity into the storm drain system without requiring any pump.

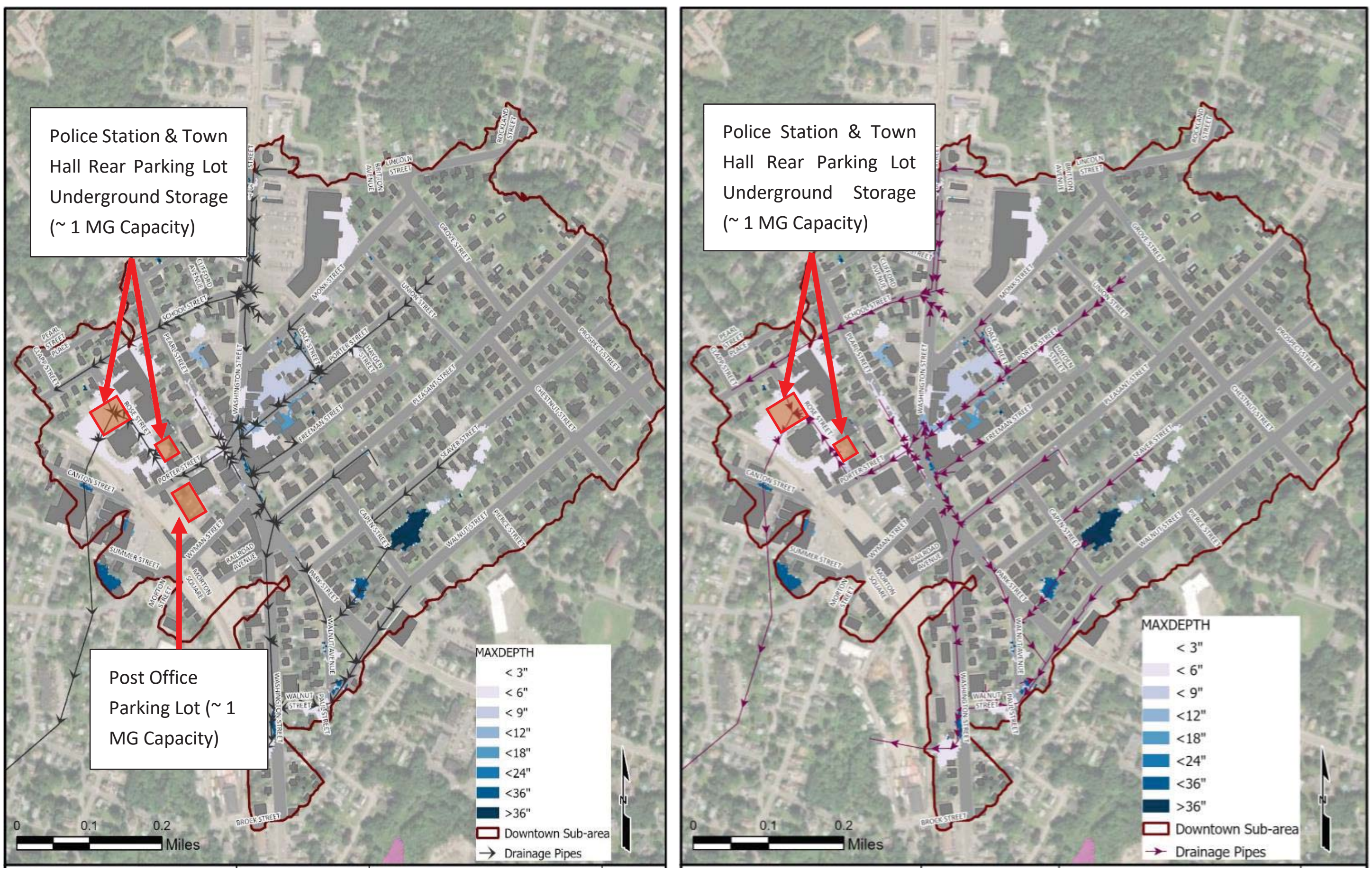

Figure 6-11: Underground storage system for flood mitigation ~2 MG storage (left), ~1 MG storage (right)

Alternative Comparison:

In addition to the three mitigation strategies discussed above, a combination of Alternative 2 (pipe capacity improvement) & Alternative 3 (underground detention storage) was modeled to demonstrate the combined effect of all flood mitigation strategies (Figure 6-12). Initially, the Post Office parking lot was identified as a potential location for underground storage because it represents a significant opportunity for storage. However, following conversations with the Town, the Post Office detention storage opportunity was deemed not feasible as the land is not currently owned by the Town. The results of these comprehensive approach for flood and peak flow mitigation are presented in Table 6-3.

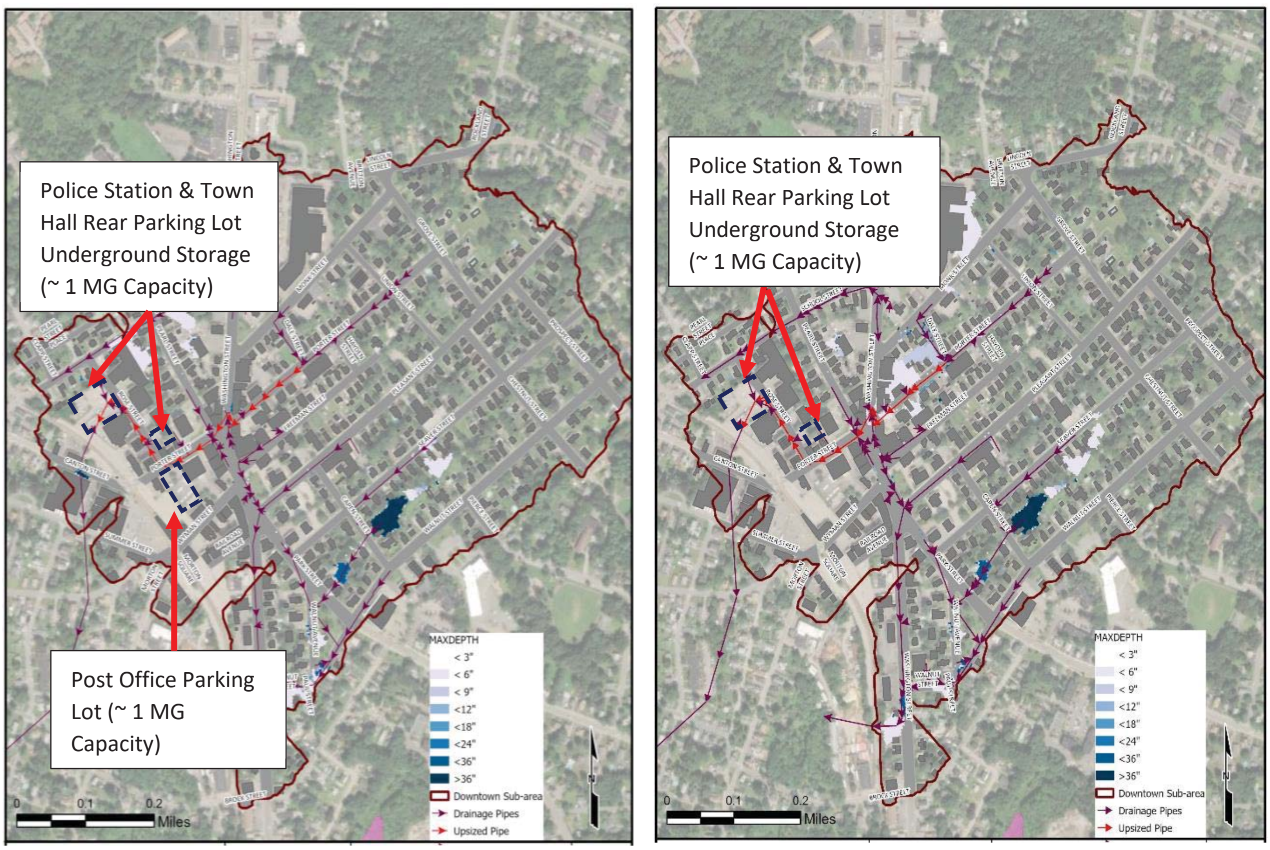

Figure 6-12: Combination of pipe capacity improvement and underground storage tank alternative; with ~2 MG underground detention storage (left) and ~1MG underground detention storage (right)

Table 6-3: Downtown area flood mitigation alternative analysis comparison

Scenario	2070 10-year 2 hour (Short Duration – Rain on Grid Model)		2070 100-year 24 hour (1% Probability storm -Townwide Model)		
	Peak Flood Depth at Rose Street *(in)*	Peak Downstream Discharge *(cfs)*	Peak Flood Depth at Rose Street *(in)*	Peak Downstream Discharge *(cfs)*	Peak Discharge at Outlet from Woods Pond (cfs)
Existing Conditions	17.3	35.8	5.3	116	119.1
Distributed Green Infrastructure at 20% of Catch Basins	14.9	35.5	-	-	-
Pipe Capacity Improvements	11.8	79.3	4.8	139	119.3
Storage at Police Station and Post Office Lots	5.9	32.8	4.6	115	117.9
Storage at Police Station	6.8	33.1	5.2	115	118.7
Combination 1 (~2 MG UG Storage + Pipe Capacity Improvement)	2.3	43	1.8	115	117.4
Combination 2 (~1 MG UG Storage + Pipe Capacity Improvement)	2.5	58	2.0	115	118.0

6.2.2.2 Preferred Approach

Compared to the other alternatives, the distributed green infrastructure provided negligible storage (about 5% of the total flood volume in the downtown area). Therefore, this alternative deemed insufficient for flood mitigation, despite the co-benefits realized by green infrastructure such as water quality improvements. As such, the following alternatives were determined to be further studies to understand their costs:

- Pipe Capacity Improvement
- Underground Storage Tank
- Combination of Pipe Capacity Improvement and Underground Storage Tank

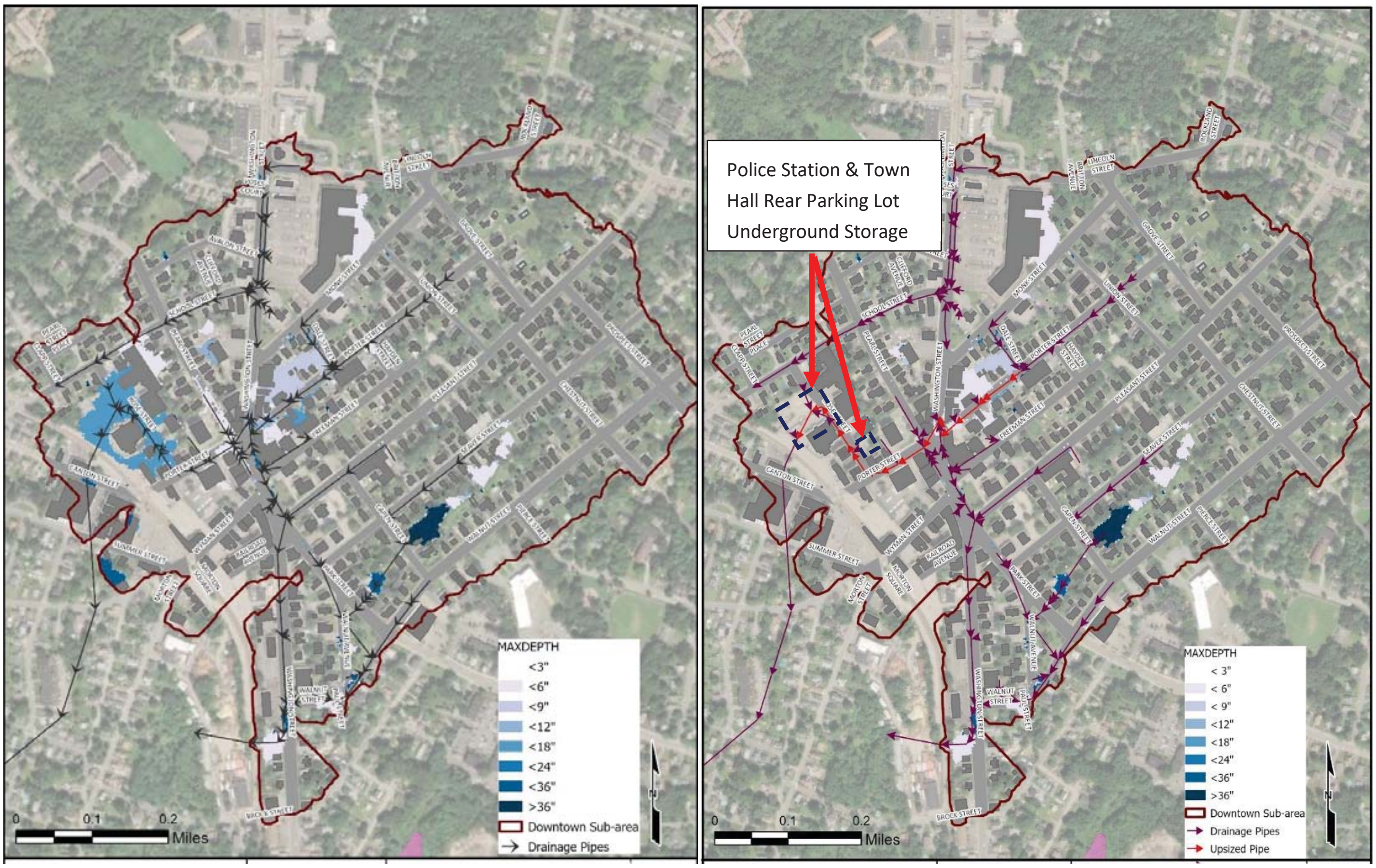

Figure 6-13: Baseline condition (left) vs combination of pipe capacity improvement and 1 MG underground storage tank alternative (right)

Figure 6-13 shows the flood mitigation potential for the combination approach (pipe capacity improvement and 1MG underground detention storage) compared to the baseline condition under 2070 10-year 2-hour storm event.

For the alternatives being considered, cost estimates were completed to provide ASTM Class 5 cost estimates in 2024 dollars to the town for future planning (Table 6-4). For the immediate future, pipe capacity improvement provides the town with the most cost-effective method for mitigating flooding in the Downtown area, with a combination with underground detention storage being a long-term option to further mitigate expected flooding under increased precipitation conditions of long-term climate projections.

Table 6-4: Downtown Area Preferred Approach Comparison (ENR Index = 13,546.80)

Alternative		Description	Cost Estimate ($)
1.	Pipe Capacity Improvements	Upsizing drainage pipe to increase system's capacity	$2,170,000
2.	Detention Storage	Underground storage in the Police Station Parking Lot to collect runoff from highly impervious Downtown area	$3,255,000
3.	Combination	Pipe Capacity improvement and detention storage (~1MG)	$5,425,000

6.2.3 Ames Pond – West Street Causeway

Ames Long Pond, an 86-acre pond located west of Route 183 on the Stoughton/Easton town line, is separated into two basins by West Street. This pond possesses significant flooding risk to the West Street. This area was identified as flood-prone through the Public Outreach program and corroborated by the modeling. Figure 6-14 shows the flooding along the West Street for 2070 100-year 24 Hour storm scenario.

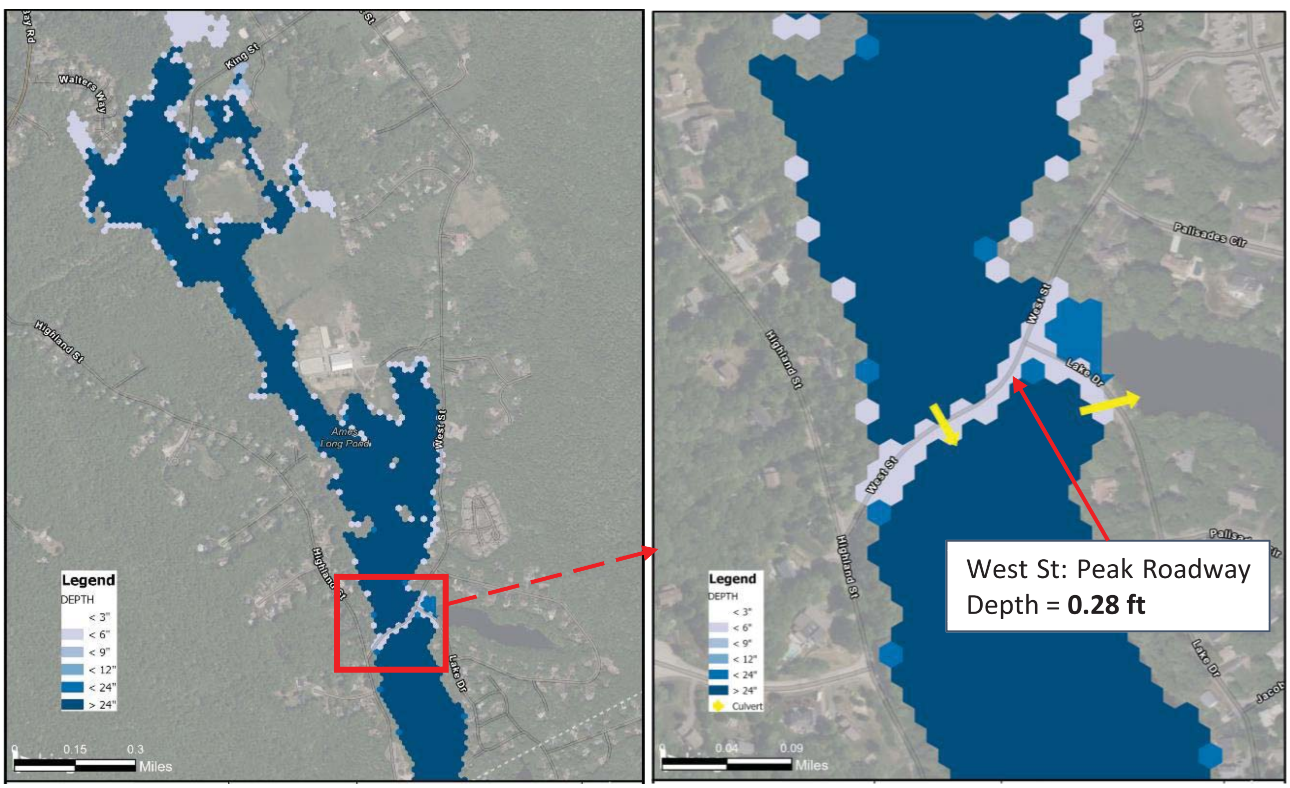

Figure 6-14: 2070 100-year, 24-hour flood results for Ames Long Pond subarea under baseline conditions

6.2.3.1 Alternative Flood Management Strategies

In the Ames Long Pond sub-area, two alternatives were analyzed: 1) culvert upsizing and 2) causeway raising. The modeling analysis conducted for 100-year 24-hour 2070 storm conditions was then compared back to baseline (i.e., existing condition). The results of these comprehensive approach for flood flow mitigation are presented in Table 6-5.

Table 6-5: Ames Long Pond flood mitigation alternative analysis

Scenario	Peak Roadway Flood Depth *(in)*
Existing Conditions	3.4
Culvert Upsizing along West St	0.0
West Street Causeway Raising above model WSE	0.0

Alternative 1: Culvert Upsizing:

During the field visit for choosing the flow metering location, Kleinfelder team found that the West Street culvert (48-inch RCP) is partially submerged. Model analysis was performed by upsizing the existing culvert to two 8ft (W) x 4ft (H) box culvert to completely pass the 2070 100-year, 24- hour storm (Figure 6-15).

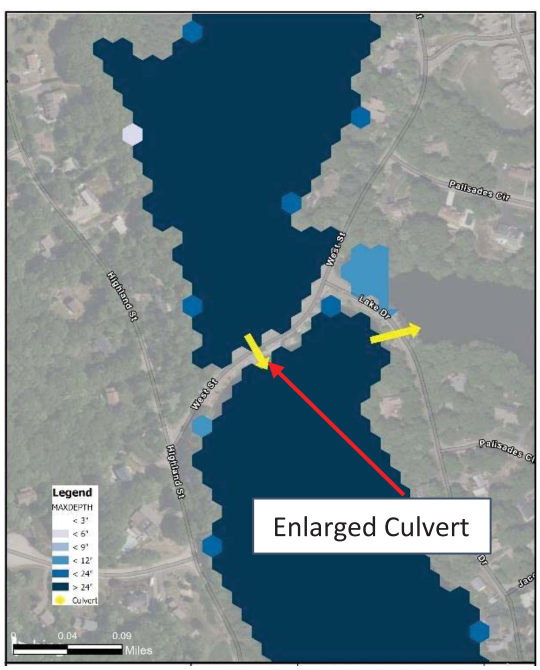

Figure 6-15: West Street culvert upsizing alternative analysis.

Alternative 2: West Street Causeway Raising:

The other alternative approach to mitigate flooding along the West Street could be the raising of the roadway elevation just above the 2070, 100-year storm event water surface elevation.

6.2.3.2 Preferred Approach

For the alternatives being considered, ASTM Class 5 cost estimates were completed to provide preliminary estimates in 2024 dollars to the town for future planning (Table 6-6). For the immediate future, culvert upsizing provides the town with the most cost-effective method for mitigating flooding along West Street.

Table 6-6: Ames Long Pond preferred approach comparison (ENR Index = 13,546.80)

Alternative	Description	Cost Estimate ($)
1. Culvert Upsizing along West St	Culvert replacement with 8’x4’ box culverts (2 barrels)	$2,445,000
2. West Street Causeway Raising	Raise West Street Causeway above modeled WSE to protect from 2070 10-year 2 Hour event	$7,515,000

7 RECOMMENDATIONS AND NEXT STEPS

Based on the vulnerability analysis, hydraulic and hydrologic modeling, and mitigation strategy identification, Kleinfelder coordinated with the Town to develop recommendations summarized in Table 7-1. Through this study, Kleinfelder identified areas and opportunities that could be explored further to better understand the specific needs and benefits of potential flood reduction/mitigation strategies.

Table 7-1: Prioritized recommendations for food mitigation strategies reviewed with the Town

Priority	Location	Description/Location	Category	2024 Cost Estimate
Near Term (0-10 years)	York Street Area	Two culvert replacements with 6'x4' box culverts	Infrastructure Improvement	$1,750,000
	Downtown Area	Pipe capacity improvements- along Porter Street, Rose Street and Washington Street	Infrastructure Improvement	$2,170,000
	Ames-Long Pond Area	Culvert replacement with 8'x4' box culverts (2 barrels) along West Street	Infrastructure Improvement	$2,445,000
	Townwide	Prioritize assessment of culvert conditions in high-risk flood areas	Infrastructure Improvement	$325,000
Long Term (Beyond 10 years)	York Street Area	Combination of culvert upsizing with detention storage	Nature based improvement in combination with Infrastructure Improvement	$2,460,000
	Downtown Area	Combination of pipe capacity improvement with underground detention storage	Infrastructure Improvement	$3,255,000

It is recommended that in the near-term, culvert and stormwater asset condition be assessed in the areas that ranked high according to the vulnerability analysis (see Figure 5-3). Any pipe segments or culverts needing repairs or replacement based on physical condition should also be checked against high-ranked areas from the vulnerability analysis. If there is overlap, future gray infrastructure upgrades (e.g., repairs/replacement/retrofits) should consider ways to simultaneously increase performance and improve localized flood mitigation outcomes, such as pipe/culvert upsizing (instead of replacement in-kind) or bundling subsurface repairs with surface improvements.

This project's extensive data collection, vulnerability assessment, and hydrologic and hydraulic modeling effort - robustly informed by Town staff and public stakeholder feedback - has resulted in a diverse portfolio of strategies that Stoughton can implement to build climate/flood resiliency over the coming decades. In consultation with Town staff, the project team has prioritized specific strategies and has recommended target phasing for implementation.

It is anticipated that future projects can be supported by grant funding for resiliency. Specific near-term opportunities that the Town can take advantage of and align with existing priorities include, but are not limited to:

- MVP Action Grant funding
- Southeast New England Program (SNEP) grant funding
- US EPA Section 319 Nonpoint Source Competitive Grants Program (or similar funding streams) for detention storage BMPs at Police Station and Town Hall Rear Parking Lot
- MassDER Culvert Replacement Municipal Assistance Grant Program

8 REFERENCES

1. Town of Stoughton CRB Summary of Findings / MVP Planning Report (Town of Stoughton and BETA Group, 2020)- https://www.mass.gov/doc/stoughton-report/download

2. LIDAR data source: MassGIS Data: Lidar Terrain Data | Mass.gov

3. Cambridge Climate Change Preparedness and Resiliency – Flood Mitigation Alternatives for The Port Neighborhood: Appendix C1, The Port Short-Duration Storms

Appendix A: Field Data Collection Memorandum

MEMORANDUM

TO: Marc Tisdelle | Town of Stoughton Engineering Department

FROM: Seth Bryant, Sadia Khan | Kleinfelder

CC: Craig Horsfall, Laurence Langlois | Town of Stoughton Engineering Department
David Peterson, Kyle Johnson, Ariel Patterson | Kleinfelder

DATE : November 13, 2023

SUBJECT: MVP Field Data Collection in the Town of Stoughton

PURPOSE

In accordance with Municipal Vulnerability Preparedness (MVP) 2023 Action Grant scope, this memorandum provides a summary of the field program conducted to verify system connectivity and direction of flow, as well as to gather critical culvert measurements and conditions throughout the Town of Stoughton. The collected field data will be used to update the Town's stormwater GIS database. This stormwater database will be used to develop a calibrated hydraulic model of the Town's stormwater system which will inform a vulnerability assessment of the system to future climate conditions, specifically related to flooding.

FIELD INVESTIGATION AND SITE SELECTION

Field investigation and data collection was completed by Kleinfelder field staff with support from Town staff between August 25, 2023, and August 31, 2023. In the field inspection, the Team focused on confirming the drainage infrastructure characteristics where there were gaps in the existing GIS stormwater system data that would have been critical for model connectivity. The survey locations were also chosen to validate that the model matched real-world conditions. A desktop analysis was conducted to identify the field visit locations of critical importance for connectivity within the modeled system. Twelve (12) locations were visited during the field investigation which was used to improve the completeness of the Town's stormwater system GIS database. For a map of the field visit locations, see in **Figure 1.**

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Of the 12 locations identified, Kleinfelder staff visited 7 during wet weather in order to help determine flow direction and connectivity in the system. Sites where wet weather was prioritized for field investigations are shown in purple in Figure 1 below.

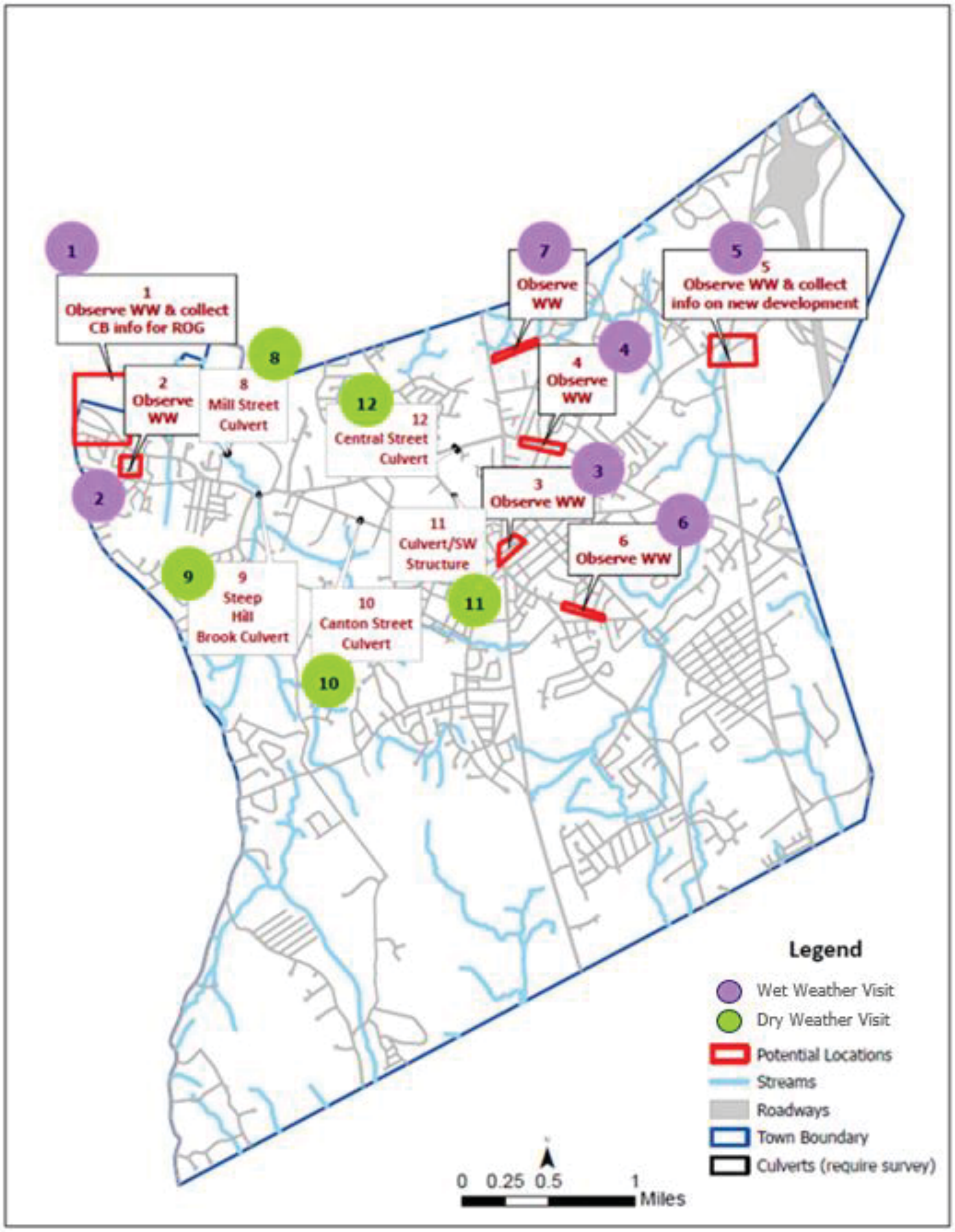

Figure 1: Priority Field Investigation Locations

FIELD DATA COLLECTION

Field investigation and data collection was completed by Kleinfelder field staff with support from Town staff between August 25, 2023, and August 31, 2023. For all areas of interest within the drainage system that were not culverts, drainage manholes were opened and inspected for the following information using a survey rod and visual inspection:

- All pipe connection diameters
- Depth from invert to rim
- Pipe offsets

Additionally, a real-time kinematics (RTK) global positioning system (GPS) survey provided by the Town was used to confirm the rim elevation at manhole locations and provide highly-accurate coordinates for the sites. Data collected was recorded on manhole inspection forms and was integrated into the Town's existing stormwater GIS database. Manhole investigation forms are included in Appendix A.

Field investigation of culverts was also completed to determine culvert properties for locations where dimensions, inverts, and other critical pieces of information were missing in the available GIS data used as the basis for the town-wide model. At each culvert location the following pieces of information were recorded:

- Culvert shape
- Characteristic dimensions
- Depth to channel / culvert bottom
- Water depth (for baseflow estimates)

All culvert information was updated in the PCSWMM town-wide model, and base flow conditions were used to develop a baseline stream condition that serves as initial conditions under all modeling scenarios.

SUMMARY OF MAJOR FIINDINGS

The findings the site investigations are compiled in field notes and digitized in the model and town GIS database. Field notes from the site investigations are included in Appendix A. At each location a variety of information was gathered to ensure that the model accurately represents the hydraulics of the drainage system and Town's hydrography. **Table 1** displays the primary objective for data gathering at each location, along with notes of major findings from each site.

Table 1: Field Investigation Results

Location	Information Gathered	Notes
1	Visual inspection of wet weather flow	Flow from the Village Shoppes was found to be flowing away from Sharon St and towards Canton stormwater system – no further information gathered / required.
2	Manhole inspections, CCTV of buried manhole and pipe section	Drainage segment included a paved-over manhole not in GIS. CCTV confirmed pipe dimensions, manhole location, and connectivity, and the model and GIS were updated accordingly.
3	Manhole inspections, connectivity	All drainage information inspected and measured for the Porter St line (previously missing information).
4	Manhole inspections, inverts and pipe dimensions	All drainage information inspected and measured along Central Ave segment of interest.
5	Manhole inspections, connectivity	Inverts and pipe dimensions collected, and the flow direction was determined for several pipe segments that appeared ambiguous in GIS database.
6	Manhole inspections, inverts and pipe dimensions	All drainage information inspected and measured along Park St segment of interest.
7	Culvert Inspection	Culvert dimensions and flow depth measured for York St. crossings along Red Wing Brook.
8	Culvert Inspection	Culvert dimensions and flow depth measured for Mill St. crossing along Steep Hill Brook
9	Culvert Inspection	Culvert dimensions and flow depth measured for Central St crossing along Steep Hill Brook.
10	Culvert Inspection	Culvert dimensions measured, and downstream outlet investigated and marked in the GIS. Several catch basins connected directly to the culvert were inspected and measured as well.
11	Culvert Inspection	Culvert dimension and flow depth measured. An upstream stone channel leading to the culvert was also identified, and all channel dimensions were measured and documented.
12	Culvert Inspection	Culvert dimensions and flow depth measured.

In addition to the 12 locations proposed for the field investigations, Kleinfelder also conducted a wet weather site investigation of a culvert located where Steep Hill Brook passed under Erin Road. The location was prioritized after early model validation showed disagreement between monitoring and modeled data for the location across a range of storm events. The stream crossing is comprised of four parallel box culverts of equal dimensions, three of which have substantial sediment buildup that has caused the main channel of Steep Hill Brook to redirect, primarily, through just one box. Information collected to accurately represent the culvert in the model includes:

- Depth of sediment in each culvert box
- Depth of flow in each culvert box
- Culvert dimensions
- Roadway depth to inverts
- Visual inspection of culverts and stream channel

Results of the site inspection indicate that under baseflow conditions and for small storm events, flow primarily flows through just one box culvert and through the main channel of Steep Hill Brook. However, during large storm events, there was evidence of flow occurring through all four box culverts and inundating the vegetated areas surrounding the main stream channel. **Figure 2** includes pictures from the site investigation for the Erin Rd culvert.

Figure 2: (Left) Main channel of Steep Hill Brook and vegetated floodplain; (Center) Evidence of high flows through floodplain and secondary box culverts; (Right) Culvert inspection of primary box culvert.

Results of the Erin Rd investigation were used to update the culvert stage-discharge curve, surrounding channel roughness values, and dimensions of each of the four boxes in the model. Updated geometry was incorporated into the Town's GIS database as well and will be provided as a separate deliverable.

STORMWATER GIS UPDATES

Once the GIS database was updated with all collected relevant field information, the GIS database was integrated into PCSWMM, the hydraulic modelling program that will be used to predict performance of the Town's stormwater infrastructure system during present day and future climate scenarios. After initial calibration of the model, the Team determined that sufficient field data had been collected to adequately calibrate the model at the established granularity of the model. Therefore, no further field data collection will be necessary. The stormwater GIS updates derived from the field investigation program associated with this project are being coordinated with the Town. The Town also continues to collect updated outfall information during their required MS4 monitoring efforts and is adding that updated information into the Town's stormwater GIS database that could be used in future modeling effort.

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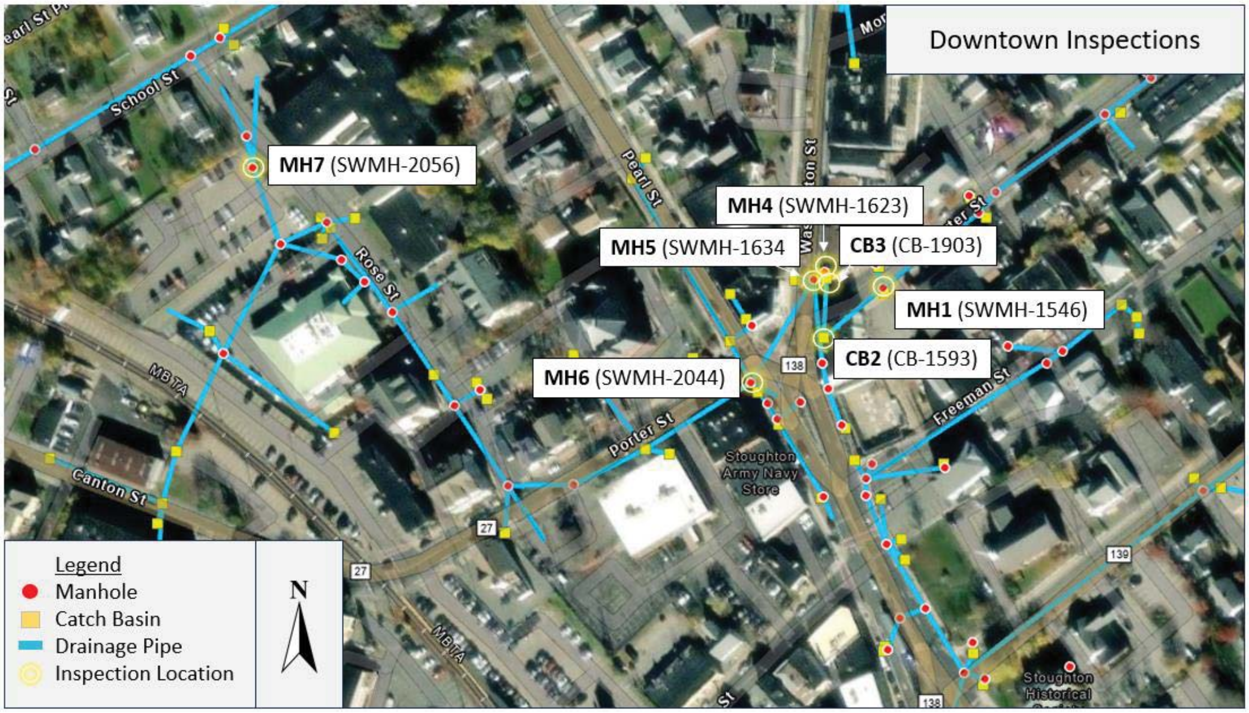
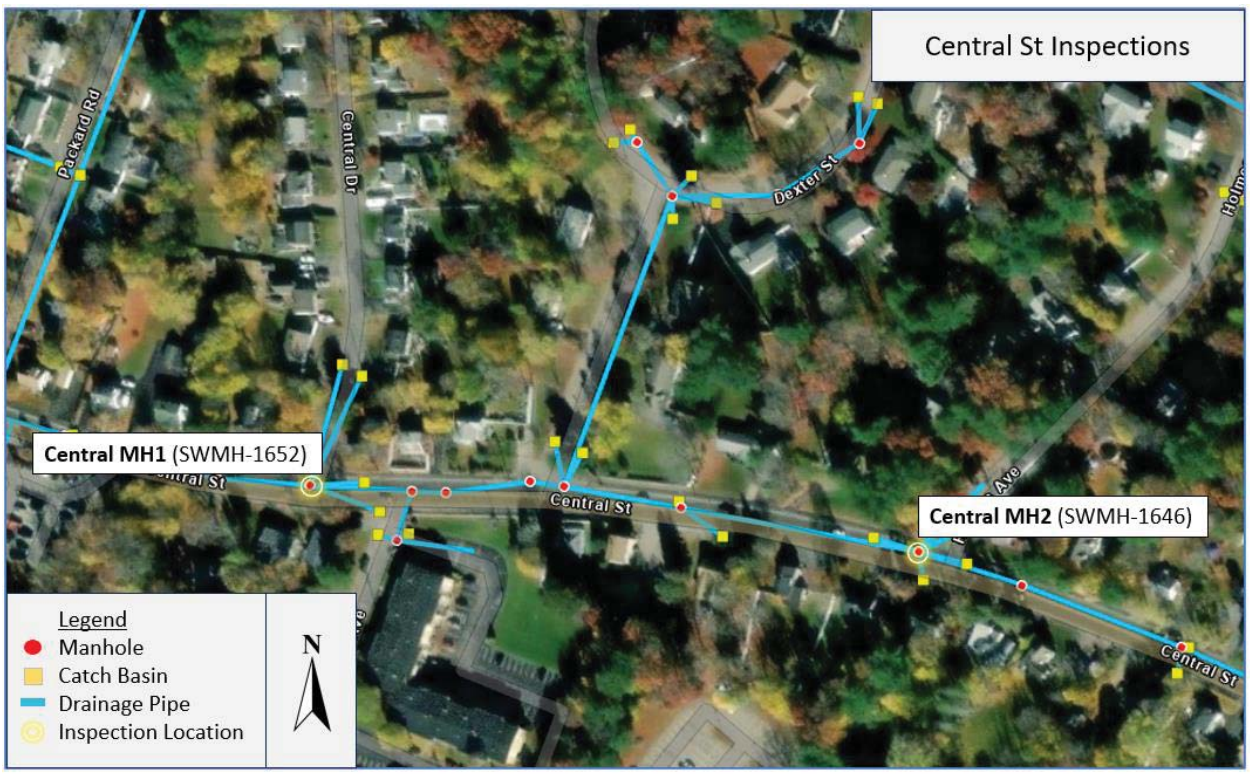
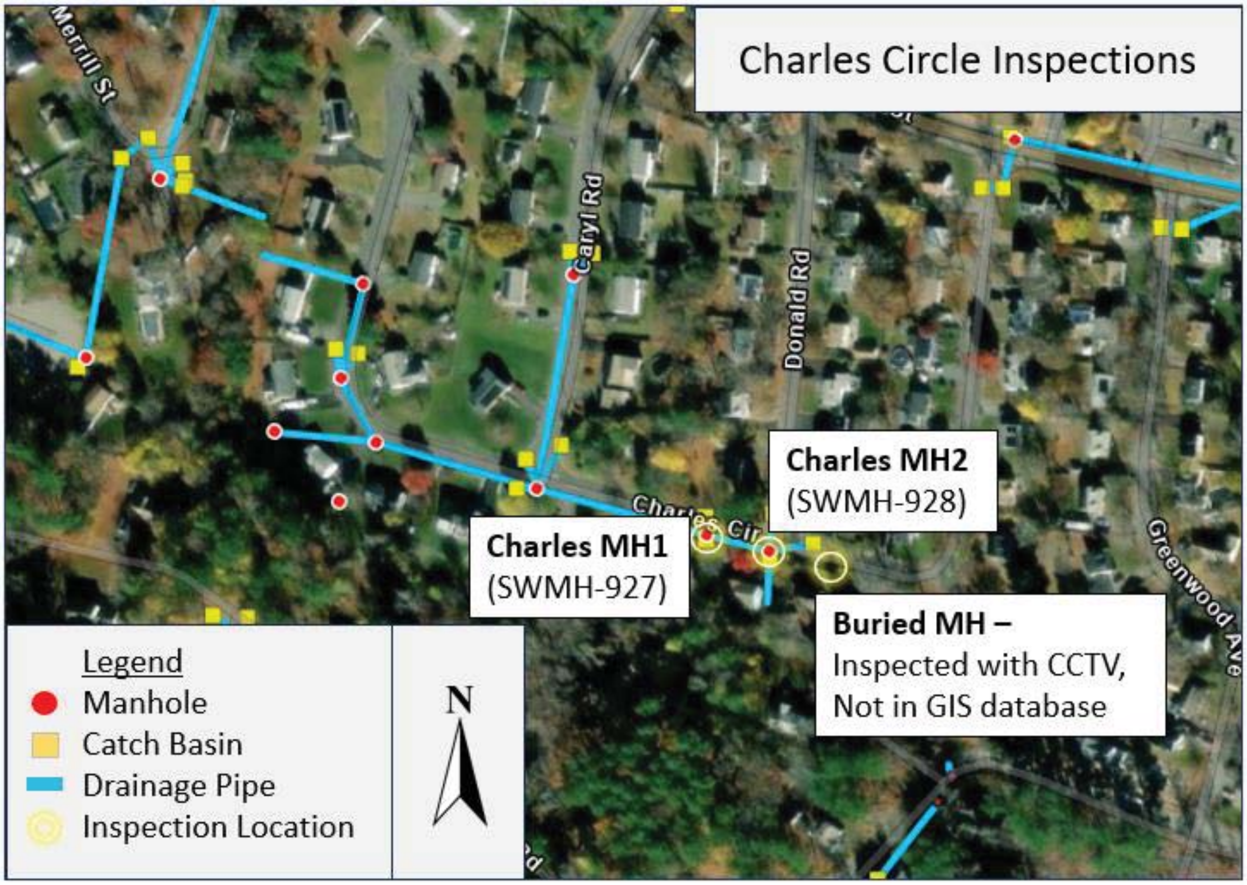
Appendix A: Field Notes and Manhole Inspection Forms

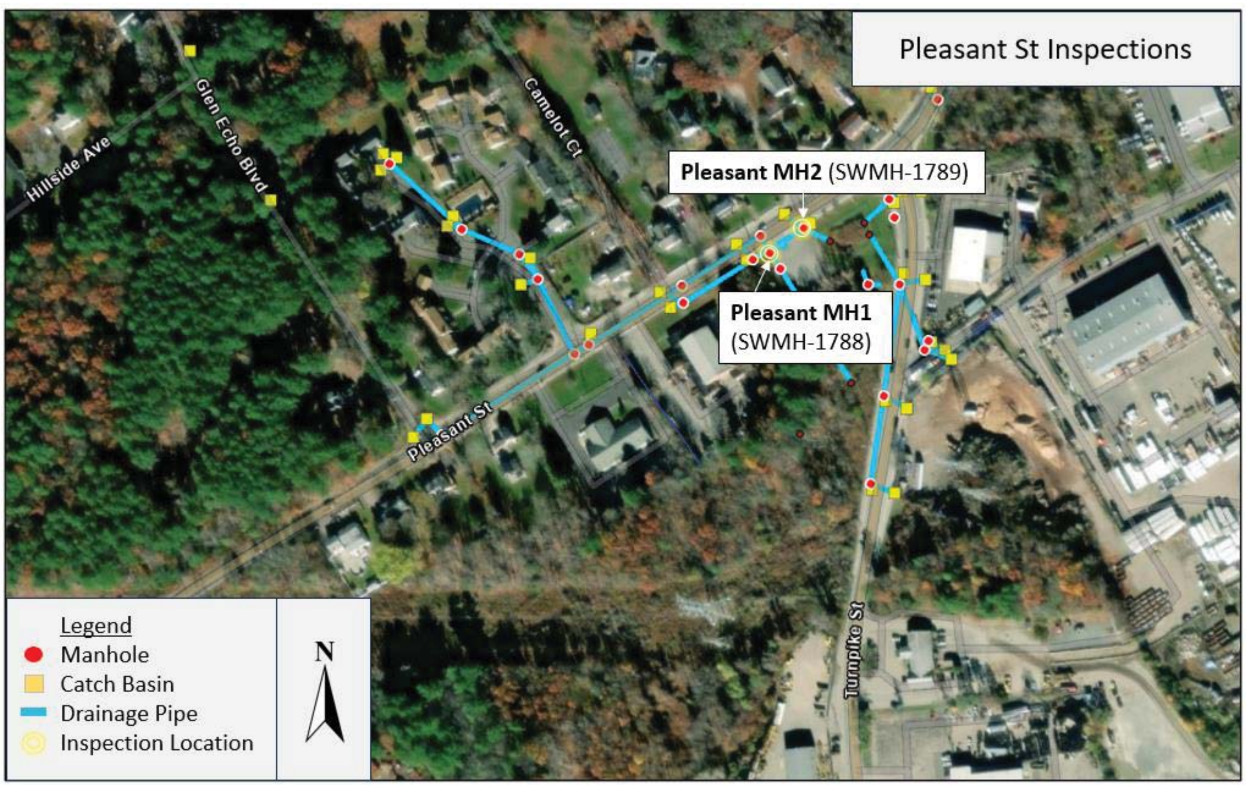


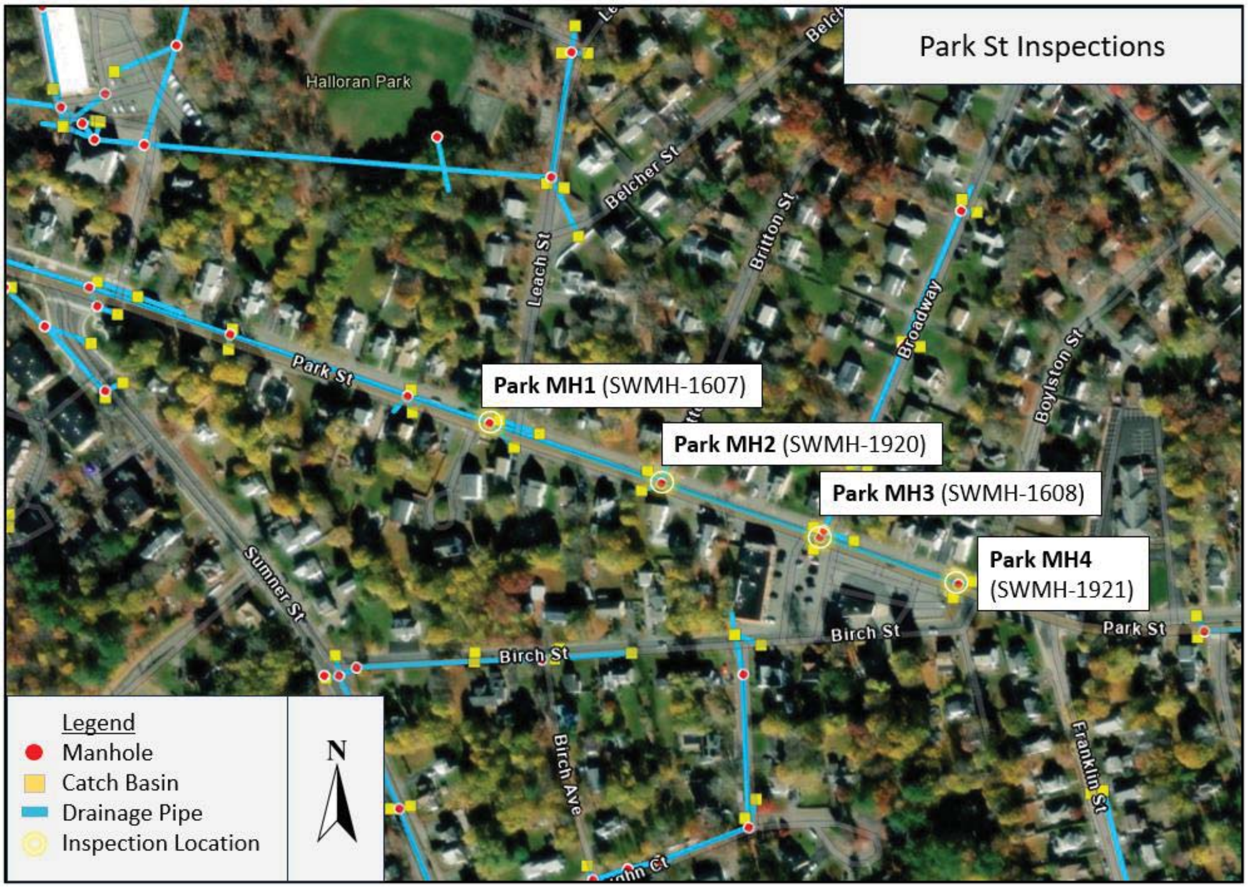
Downtown Inspections
MH7 (SWMH-2056)
MH4 (SWMH-1623)
MH5 (SWMH-1634
CB3 (CB-1903)
MH1 (SWMH-1546)
CB2 (CB-1593)
MH6 (SWMH-2044)
School St
Pearl St
Rose St
Porter St
Freeman St
Canton St
MBTA
Stoughton Army Navy Store
Stoughton Historical
Legend
Manhole
Catch Basin
Drainage Pipe
Inspection Location
N



Central St Inspections
Central MH1 (SWMH-1652)
Central MH2 (SWMH-1646)
Packard Rd
Central Dr
Dexter St
Central St
Legend
Manhole
Catch Basin
Drainage Pipe
Inspection Location
N


Charles Circle Inspections
Merrill St
Caryl Rd
Donald Rd
Charles Cir
Greenwood Ave
Charles MH2
(SWMH-928)
Charles MH1
(SWMH-927)
Buried MH –
Inspected with CCTV,
Not in GIS database
Legend
Manhole
Catch Basin
Drainage Pipe
Inspection Location
N


Pleasant St Inspections
Hillside Ave
Glen Echo Blvd
Camelot Ct
Pleasant MH2 (SWMH-1789)
Pleasant MH1
(SWMH-1788)
Pleasant St
Turnpike St
Legend
Manhole
Catch Basin
Drainage Pipe
Inspection Location
N



Park St Inspections
Halloran Park
Belcher St
Leach St
Britton St
Broadway
Boylston St
Park St
Park MH1 (SWMH-1607)
Park MH2 (SWMH-1920)
Park MH3 (SWMH-1608)
Park MH4 (SWMH-1921)
Sumner St
Birch St
Birch Ave
Franklin St
Legend
Manhole
Catch Basin
Drainage Pipe
Inspection Location
N

Manhole Inspection Field Form

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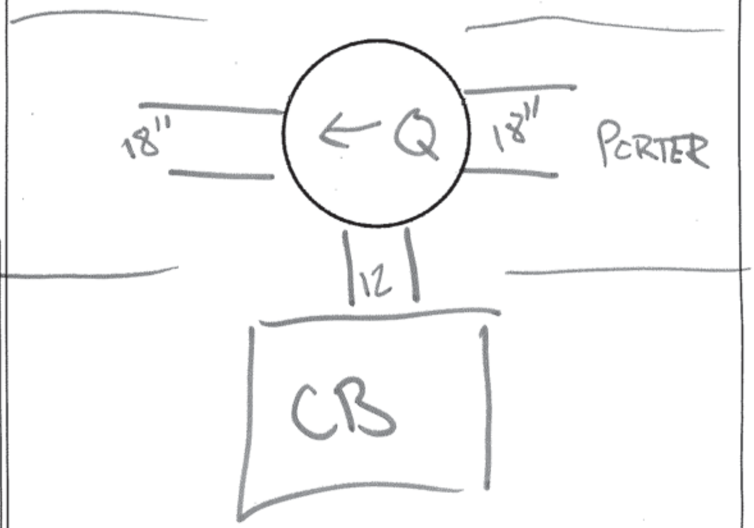
Bright People. Right Solutions.

Manhole ID: MH1 (Porter)
(SWMH-1546)
Inspector: ____
Date: ____
Weather: ____ Temp: ____
Street: ____
Inspection Type: ____ Surface Inspection ____ Entry
GPS Taken?: ____ Yes ____ No ____ Previously
Manhole Marker? ____

Schematic:



Manhole

Manhole Function: ____ Sanitary ____ Combined
____ Stormdrain ____ Common
Cover Size: ____ 24" ____ 30" ____ Other ____
Manhole Size: ____ 4' ____ 5' ____ Other ____
Depth from rim: 3.7 ft.
Depth to Wet Ring from rim: ____ ft.
Drop: ____ Yes ____ No
Manhole Material: ____
Location of Manhole: ____
Flow Condition: ____
General Notes:

Area Around Manhole

Paved: ____
Unpaved: ____

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: CB 2 (CB-1593)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

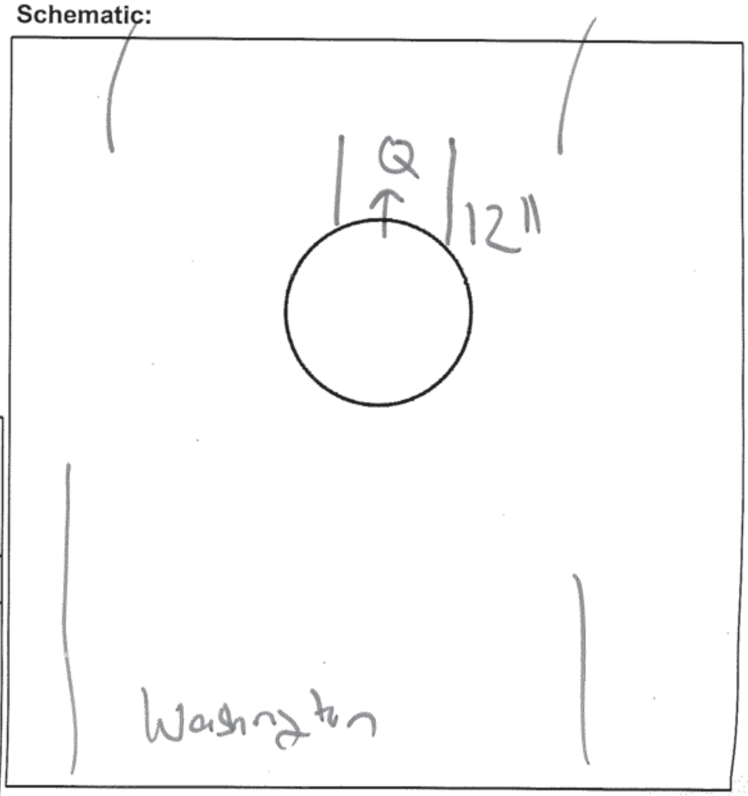
Street: ______

Inspection Type: ______ Surface Inspection ______ Entry

GPS Taken?: ______ Yes ______ No ______ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined

______ Stormdrain ______ Common

Cover Size: ______ 24" ______ 30" ______ Other ______

Manhole Size: ______ 4' ______ 5' ______ Other ______

Depth from rim: ______ ft. 6.2

Depth to Wet Ring from rim: ______ ft.

Drop: ______ Yes ______ No

Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Depth to atkt 4.5

Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: CB3 (CB-1903)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

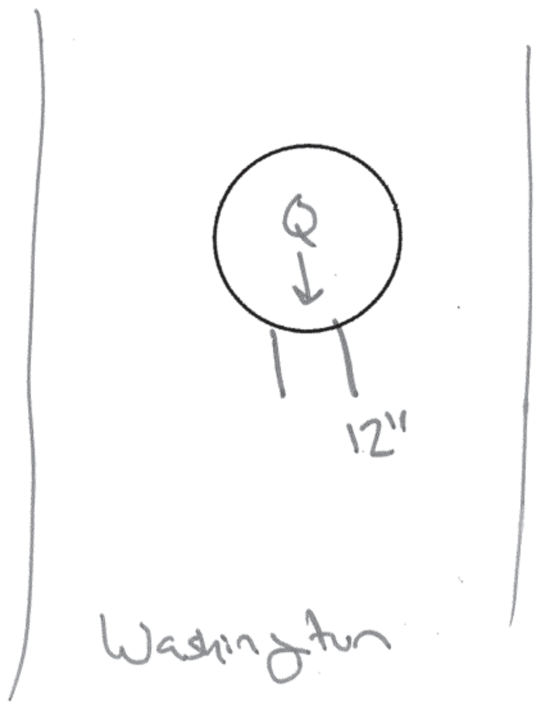
Street: ______

Inspection Type: ______ Surface Inspection ______ Entry

GPS Taken?: ______ Yes ______ No ______ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined

______ Stormdrain ______ Common

Cover Size: ______ 24" ______ 30" ______ Other ______

Manhole Size: ______ 4' ______ 5' ______ Other ______

Depth from rim: 4.8 ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ______ Yes ______ No

Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

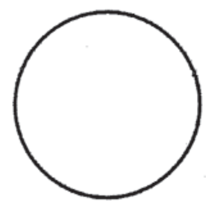
	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: MH4 (Washington)
Inspector: (SWMH-1623)
Date: ______
Weather: ______ Temp: ______
Street: ______
Inspection Type: ____ Surface Inspection ____ Entry
GPS Taken?: ____ Yes ____ No ____ Previously
Manhole Marker? ______

Schematic:



Gas manhole
L not drain

Manhole

Manhole Function: ____ Sanitary ____ Combined
____ Stormdrain ____ Common
Cover Size: ____ 24" ____ 30" ____ Other ____
Manhole Size: ____ 4' ____ 5' ____ Other ____
Depth from rim: ____ ft.
Depth to Wet Ring from rim: ____ ft.
Drop: ____ Yes ____ No
Manhole Material: ______
Location of Manhole: ______
Flow Condition: ______
General Notes:

Area Around Manhole

Paved: ______
Unpaved: ______

Pipes

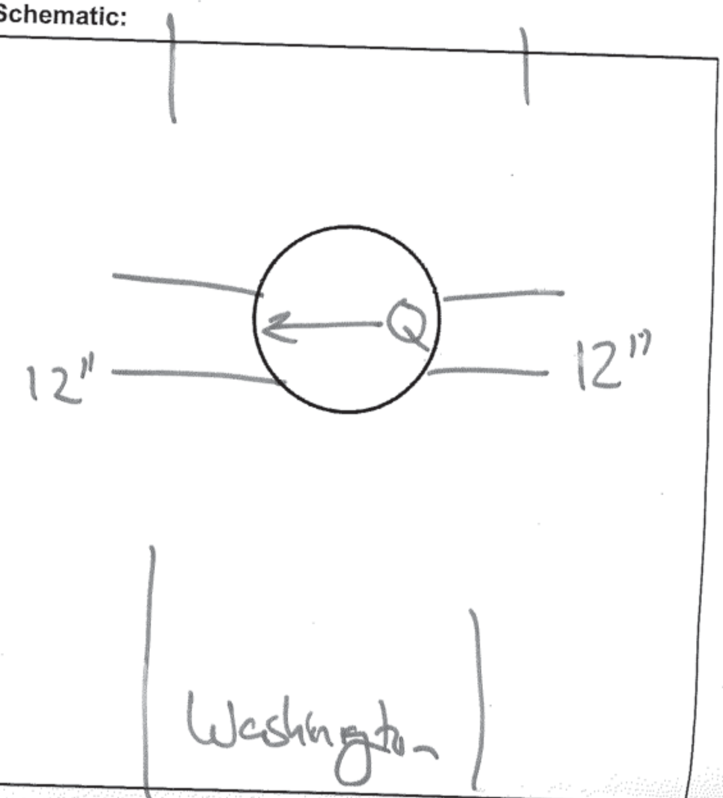
	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: MH5 (SWMH-1634)
Inspector: ______
Date: ______
Weather: ______ Temp: ______
Street: ______
Inspection Type: ___ Surface Inspection ___ Entry
GPS Taken?: ___ Yes ___ No ___ Previously
Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ___ Sanitary ___ Combined
___ Stormdrain ___ Common
Cover Size: ___ 24" ___ 30" ___ Other ______
Manhole Size: 4.5 4' ___ 5' ___ Other ______
Depth from rim: ______ ft.
Depth to Wet Ring from rim: ______ ft.
Drop: ___ Yes ___ No
Manhole Material: ______
Location of Manhole: ______
Flow Condition: ______
General Notes:

Area Around Manhole

Paved: ______
Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: MH6 (SWMH-2044)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

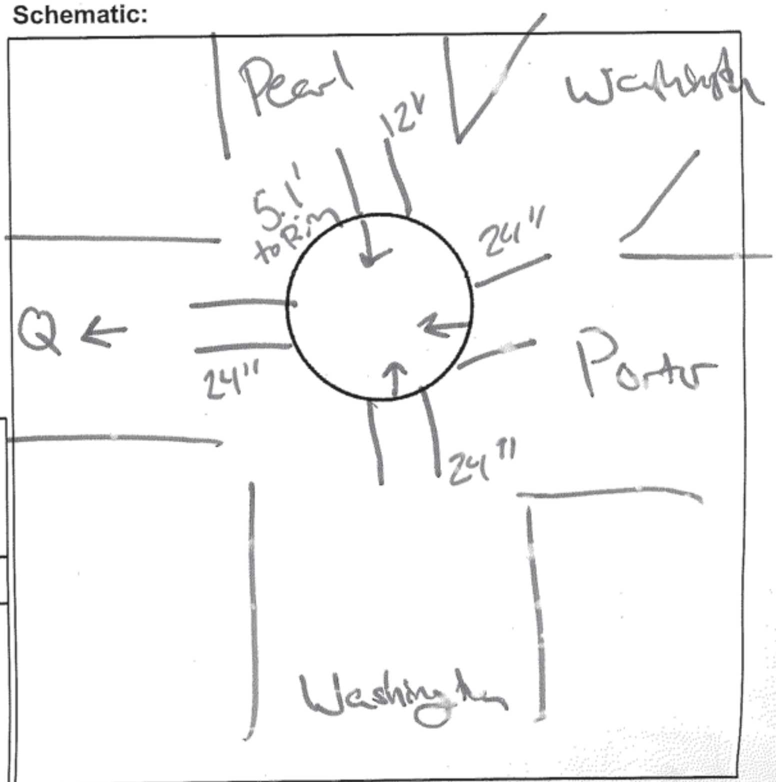
Street: ______

Inspection Type: ___ Surface Inspection ___ Entry

GPS Taken?: ___ Yes ___ No ___ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ___ Sanitary ___ Combined
___ Stormdrain ___ Common

Cover Size: ___ 24" ___ 30" ___ Other ___

Manhole Size: ___ 4' ___ 5' ___ Other ___

Depth from rim: 7.8 ft ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ___ Yes ___ No

Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
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Manhole ID: MH7 (SWMH-2056)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

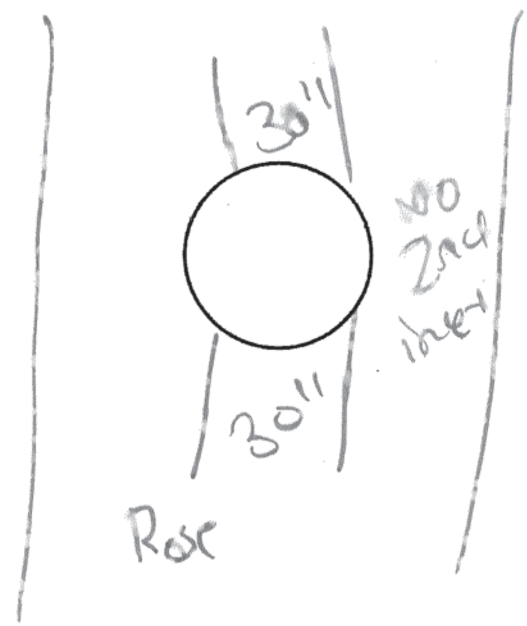
Street: ______

Inspection Type: ___ Surface Inspection ___ Entry

GPS Taken?: ___ Yes ___ No ___ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ___ Sanitary ___ Combined
___ Stormdrain ___ Common

Cover Size: ___ 24" ___ 30" ___ Other ______

Manhole Size: ___ 4' ___ 5' ___ Other ______

Depth from rim: 4.9 ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ___ Yes ___ No

Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

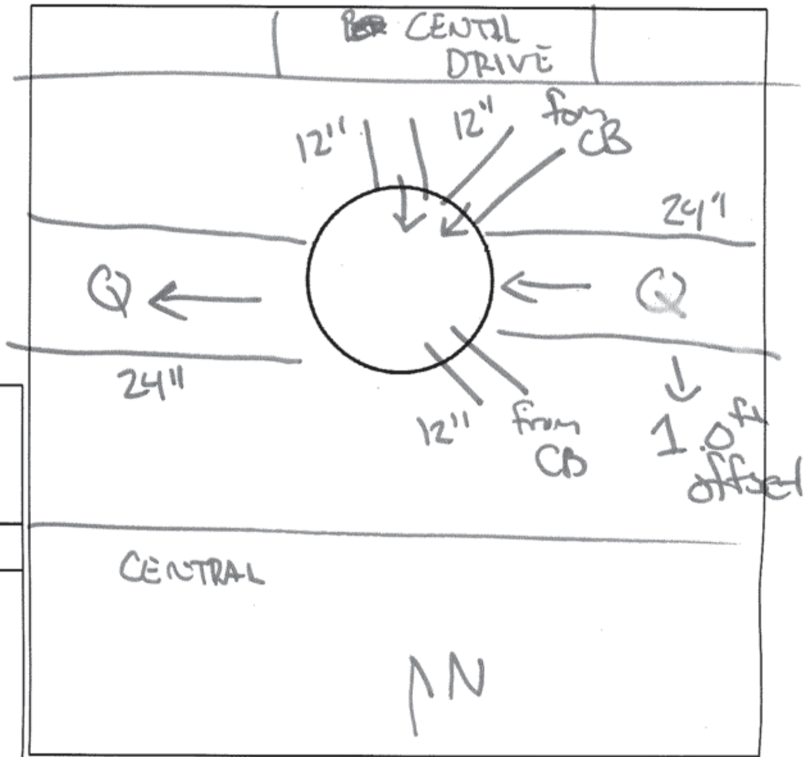
	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: CENTRAL 1 (SWMH-1652)
Inspector: ______
Date: ______
Weather: ______ Temp: ______
Street: ______
Inspection Type: ______ Surface Inspection ______ Entry
GPS Taken?: ______ Yes ______ No ______ Previously
Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined
______ Stormdrain ______ Common
Cover Size: ______ 24" ______ 30" ______ Other ______
Manhole Size: ______ 4' ______ 5' ______ Other ______
Depth from rim: 5.2 ft.
Depth to Wet Ring from rim: ______ ft.
Drop: ______ Yes ______ No
Manhole Material: ______
Location of Manhole: ______
Flow Condition: ______
General Notes:

Area Around Manhole

Paved: ______
Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
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Manhole ID: Central 2 (SWMH-1646)

Inspector: ____

Date: ____

Weather: ____ Temp: ____

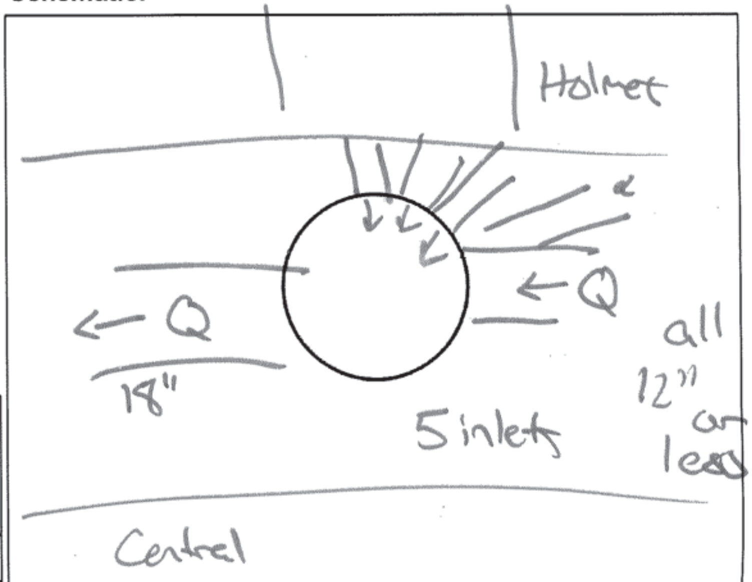
Street: ____

Inspection Type: ____ Surface Inspection ____ Entry

GPS Taken?: ____ Yes ____ No ____ Previously

Manhole Marker? ____

Schematic:



Manhole

Manhole Function: ____ Sanitary ____ Combined

____ Stormdrain ____ Common

Cover Size: ____ 24" ____ 30" ____ Other ____

Manhole Size: ____ 4' ____ 5' ____ Other ____

Depth from rim: 5.41 ft.

Depth to Wet Ring from rim: ____ ft.

Drop: ____ Yes ____ No

Manhole Material: ____

Location of Manhole: ____

Flow Condition: ____

General Notes:

Area Around Manhole

Paved: ____

Unpaved: ____

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

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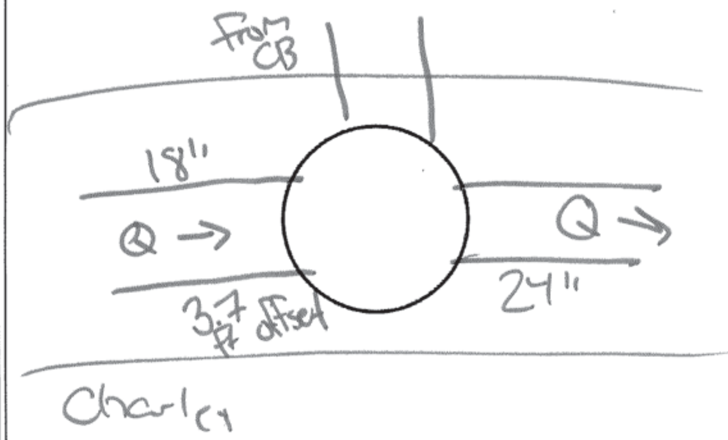
Bright People. Right Solutions.

Manhole ID: Charles 1 (SWMH-927)
Inspector: ______
Date: ______
Weather: ______ Temp: ______
Street: ______
Inspection Type: ______ Surface Inspection ______ Entry
GPS Taken?: ______ Yes ______ No ______ Previously
Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined
______ Stormdrain ______ Common
Cover Size: ______ 24" ______ 30" ______ Other ______
Manhole Size: ______ 4' ______ 5' ______ Other ______
Depth from rim: 5.6 ft ft.
Depth to Wet Ring from rim: ______ ft.
Drop: ______ Yes ______ No
Manhole Material: ______
Location of Manhole: ______
Flow Condition: ______
General Notes:

Area Around Manhole

Paved: ______
Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

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Manhole ID: Charles 2 (SWMH-928)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

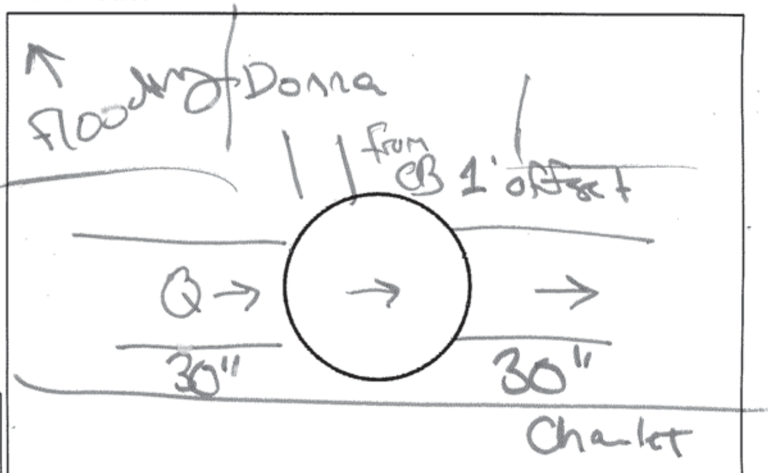
Street: ______

Inspection Type: ______ Surface Inspection ______ Entry

GPS Taken?: ______ Yes ______ No ______ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined

______ Stormdrain ______ Common

Cover Size: ______ 24" ______ 30" ______ Other ______

Manhole Size: ______ 4' ______ 5' ______ Other ______

Depth from rim: 5.1' ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ______ Yes ______ No

Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

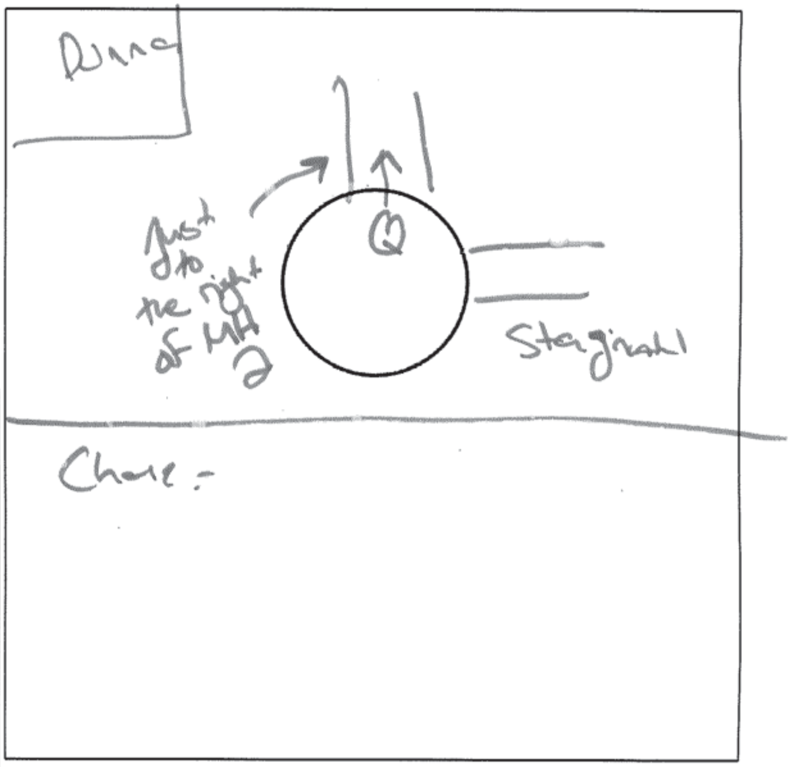
	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: Charles CB1
Inspector: ____________
Date: ____________
Weather: ____________ Temp: ____
Street: ____________
Inspection Type: ____ Surface Inspection ____ Entry
GPS Taken?: ____ Yes ____ No ____ Previously
Manhole Marker? ____

Schematic:



Manhole

Manhole Function: ____ Sanitary ____ Combined
____ Stormdrain ____ Common
Cover Size: ____ 24" ____ 30" ____ Other ____
Manhole Size: ____ 4' ____ 5' ____ Other ____
Depth from rim: ____ ft.
Depth to Wet Ring from rim: ____ ft.
Drop: ____ Yes ____ No
Manhole Material: ____________
Location of Manhole: ____________
Flow Condition: ____________
General Notes:

Area Around Manhole

Paved: ____________
Unpaved: ____________

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: Pleasant 1 (SWMH-1788)

Inspector: ____

Date: ____

Weather: ____ Temp: ____

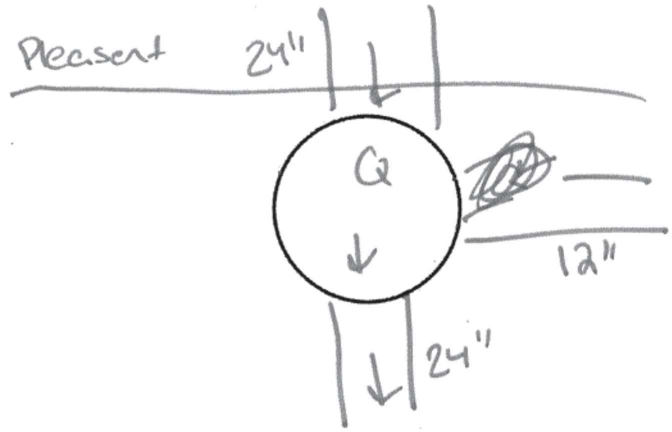
Street: ____

Inspection Type: ____ Surface Inspection ____ Entry

GPS Taken?: ____ Yes ____ No ____ Previously

Manhole Marker? ____

Schematic:



Manhole

Manhole Function: ____ Sanitary ____ Combined

____ Stormdrain ____ Common

Cover Size: ____ 24" ____ 30" ____ Other ____

Manhole Size: ____ 4' ____ 5' ____ Other ____

Depth from rim: 6.8 ft.

Depth to Wet Ring from rim: ____ ft.

Drop: ____ Yes ____ No

Manhole Material: ____

Location of Manhole: ____

Flow Condition: ____

General Notes:

Area Around Manhole

Paved: ____

Unpaved: ____

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

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Bright People. Right Solutions.

Manhole ID: Pleasant 2 (SWMH-1789)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

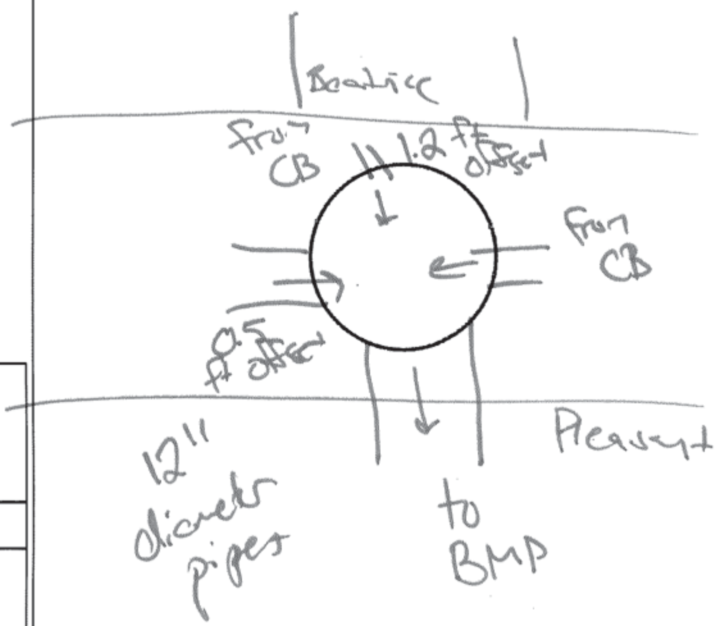
Street: ______

Inspection Type: ___ Surface Inspection ___ Entry

GPS Taken?: ___ Yes ___ No ___ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ___ Sanitary ___ Combined

___ Stormdrain ___ Common

Cover Size: ___ 24" ___ 30" ___ Other ___

Manhole Size: ___ 4' ___ 5' ___ Other ___

Depth from rim: 4.9 ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ___ Yes ___ No

Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

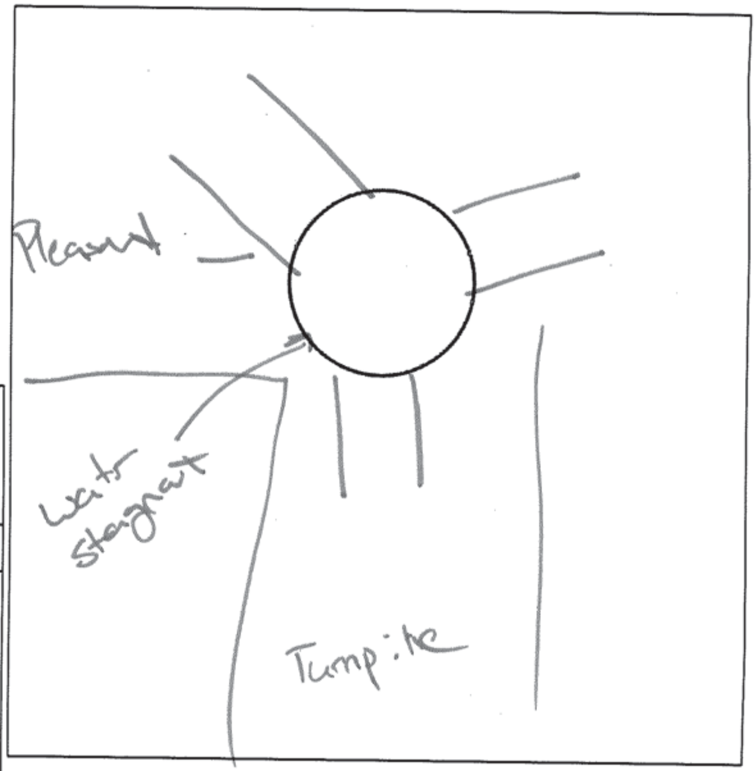
	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: Turnpike Culvert
Inspector: ______
Date: ______
Weather: ______ Temp: ______
Street: ______
Inspection Type: ______ Surface Inspection ______ Entry
GPS Taken?: ______ Yes ______ No ______ Previously
Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined
______ Stormdrain ______ Common
Cover Size: ______ 24" ______ 30" ______ Other ______
Manhole Size: ______ 4' ______ 5' ______ Other ______
Depth from rim: 5.8 ft.
Depth to Wet Ring from rim: ______ ft.
Drop: ______ Yes ______ No
Manhole Material: ______
Location of Manhole: ______
Flow Condition: ______
General Notes:

Area Around Manhole

Paved: ______
Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: PARK 2 (SWMH-1920)

Inspector: ____________

Date: ____________

Weather: ____________ Temp: ______

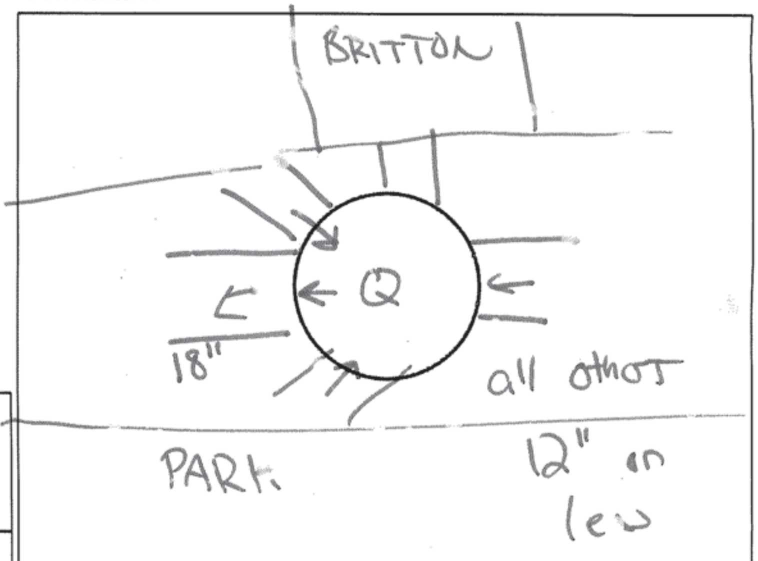
Street: ____________

Inspection Type: ______ Surface Inspection ______ Entry

GPS Taken?: ______ Yes ______ No ______ Previously

Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ______ Sanitary ______ Combined
______ Stormdrain ______ Common

Cover Size: ______ 24" ______ 30" ______ Other ______

Manhole Size: ______ 4' ______ 5' ______ Other ______

Depth from rim: 7.8 ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ______ Yes ______ No

Manhole Material: ____________

Location of Manhole: ____________

Flow Condition: ____________

General Notes:

Area Around Manhole

Paved: ____________

Unpaved: ____________

Pipes

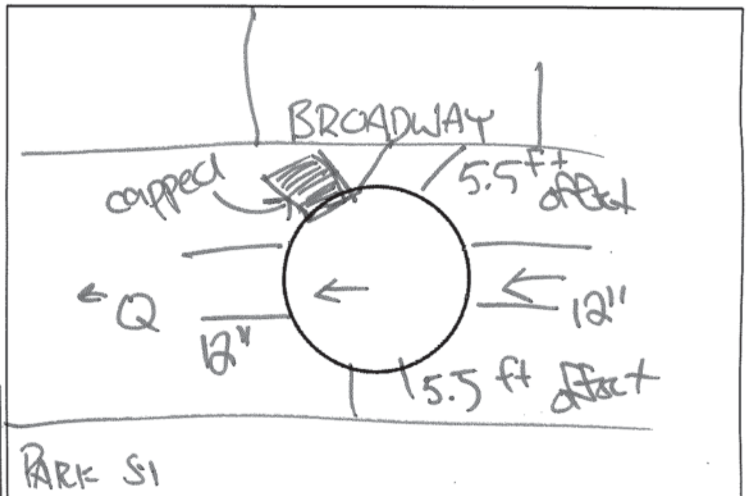
	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
Bright People. Right Solutions.

Manhole ID: PARK 3
Inspector: (SWMH-1608)
Date: ______
Weather: ______ Temp: ______
Street: ______
Inspection Type: ____ Surface Inspection ____ Entry
GPS Taken?: ____ Yes ____ No ____ Previously
Manhole Marker? ______

Schematic:



Manhole

Manhole Function: ____ Sanitary ____ Combined
____ Stormdrain ____ Common
Cover Size: ____ 24" ____ 30" ____ Other ____
Manhole Size: ____ 4' ____ 5' ____ Other ____
Depth from rim: 7.4 ft.
Depth to Wet Ring from rim: ______ ft.
Drop: ____ Yes ____ No
Manhole Material: ______
Location of Manhole: ______
Flow Condition: ______
General Notes:

Area Around Manhole

Paved: ______
Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

Manhole Inspection Field Form

KLEINFELDER
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Manhole ID: PARK 4 (SWMH-1921)

Inspector: ______

Date: ______

Weather: ______ Temp: ______

Street: ______

Inspection Type: ___ Surface Inspection ___ Entry

GPS Taken?: ___ Yes ___ No ___ Previously

Manhole Marker? ______

Manhole

Manhole Function: ___ Sanitary ___ Combined
___ Stormdrain ___ Common

Cover Size: ___ 24" ___ 30" ___ Other ___

Manhole Size: ___ 4' ___ 5' ___ Other ___

Depth from rim: 6.5 ft.

Depth to Wet Ring from rim: ______ ft.

Drop: ___ Yes ___ No

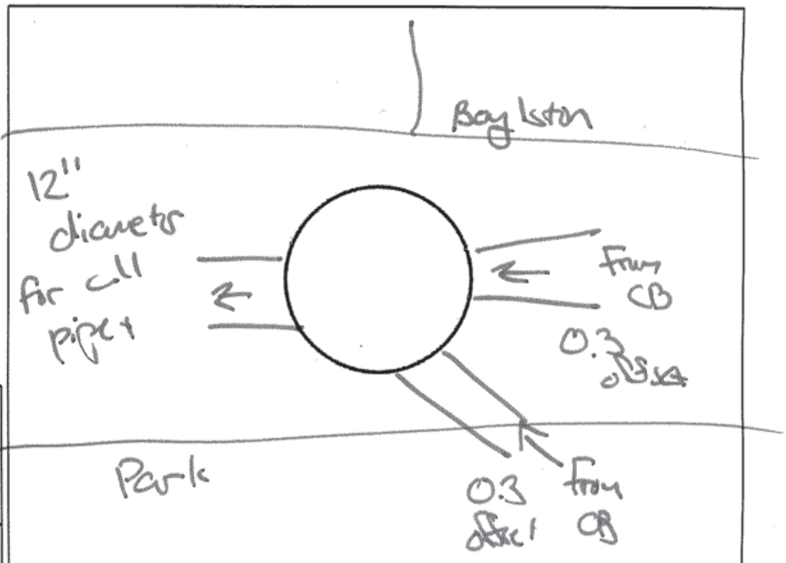
Manhole Material: ______

Location of Manhole: ______

Flow Condition: ______

General Notes:

Schematic:



Area Around Manhole

Paved: ______

Unpaved: ______

Pipes

	Pipe Asset ID	Pipe Size (in)	Material	Shape	Invert Depth from Rim (ft.)	Flow Depth from Invert (in.)	Debris Depth from Invert (in.)	Condition of Pipe

SHEET ______ OF ______

KLEINFELDER
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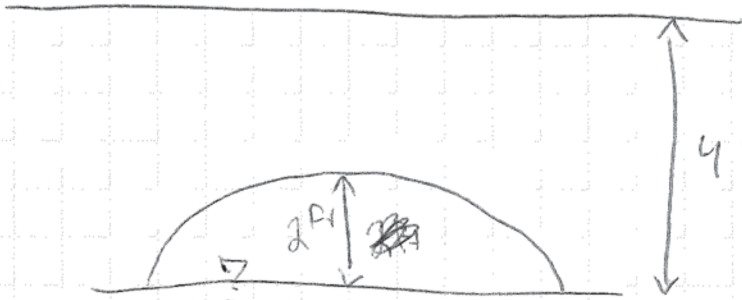
PROJECT NO. ______

PROJECT: STOUGHTON FLOOD STUDY | REVIEWED BY: ______ | DATE: ______

SUBJECT: CULVERT INVESTIGATIONS | BY: SPB | DATE: 8/3/23

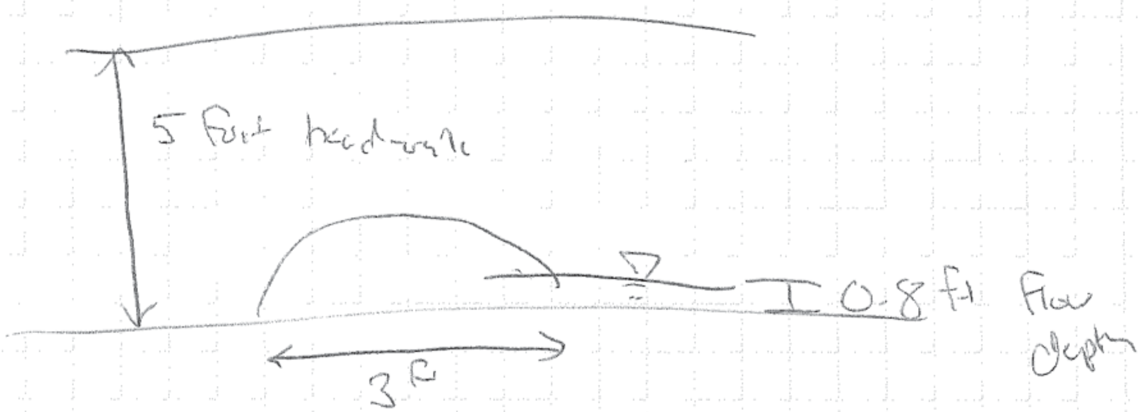
LOCATION 7: YORK ST CULVERT (HOSPITAL)

Upstream



very low baseflow

Downstream



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SHEET ____ OF ____

PROJECT NO. ____

PROJECT Stoughton Flood Study REVIEWED BY ____ DATE ____

SUBJECT Culvert Investigation BY SPB DATE 8/31/23

- Location 8: Mill St Culvert
  8/31/2023 9:00 AM

  Total Height: 8.1 ft
  Flow Depth: 0.9 ft
  Total Width: 8.0 ft
  } 8' x 8' Box Culvert
  ∟ all taken upstream

  Downstream Flow Depth: 1.0 ft

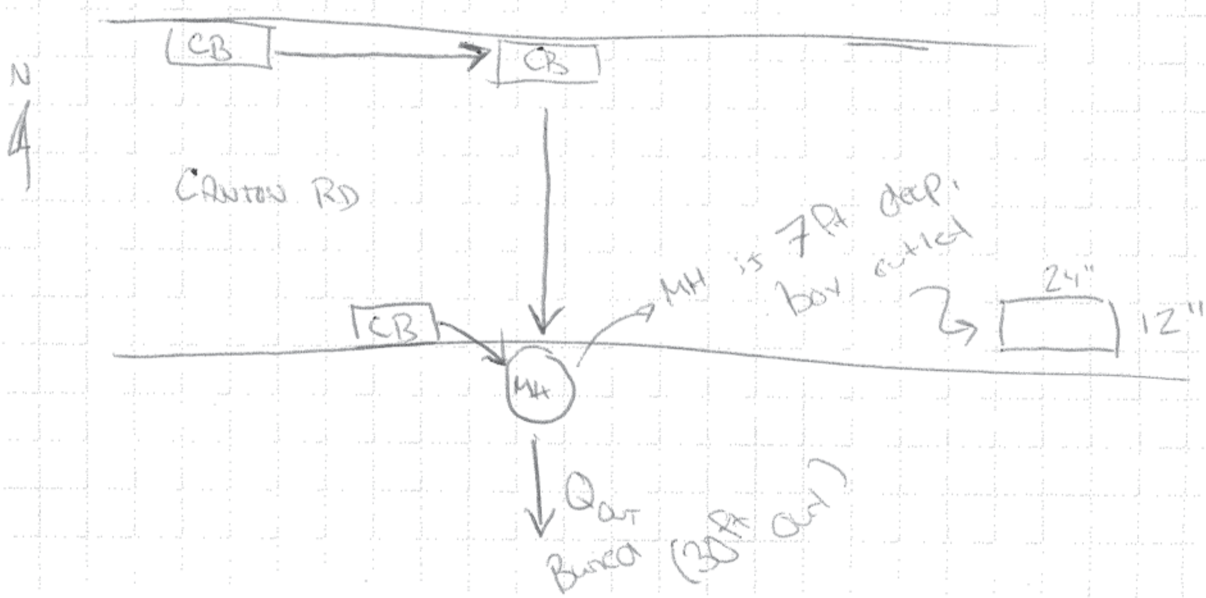
- Location 9: Central Ave / Steep Hill Brook

  Flow depth (staff gauge) 0.95 ft
  Culvert depth: 4.7 ft (5' box w/ natural bottom)
  Culvert width: 10.0 ft

- Location 10

  - Seems relatively minor - just pick up CBs from either side of the street and flows into wetland area

  - Heavily vegetated around culvert outlet



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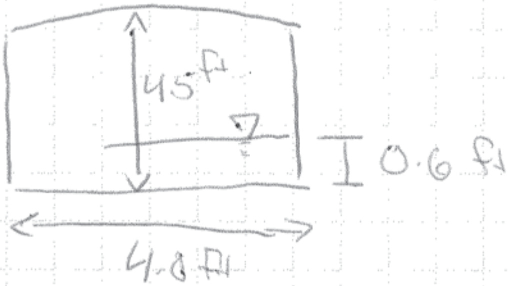
SHEET ______ OF ______

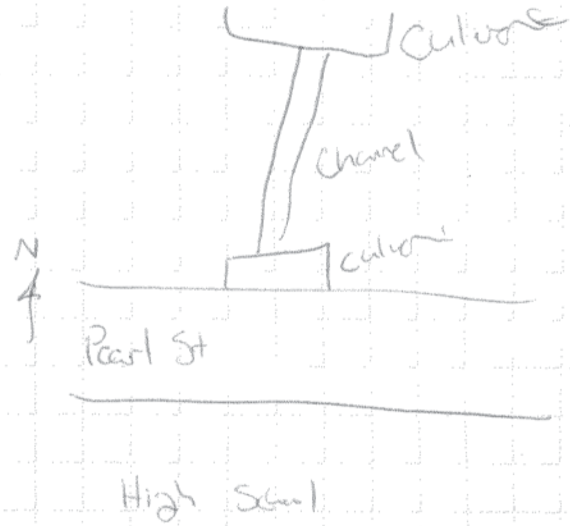
PROJECT NO. ______

PROJECT STOUGHTON FLOOD STUDY   REVIEWED BY ______   DATE ______

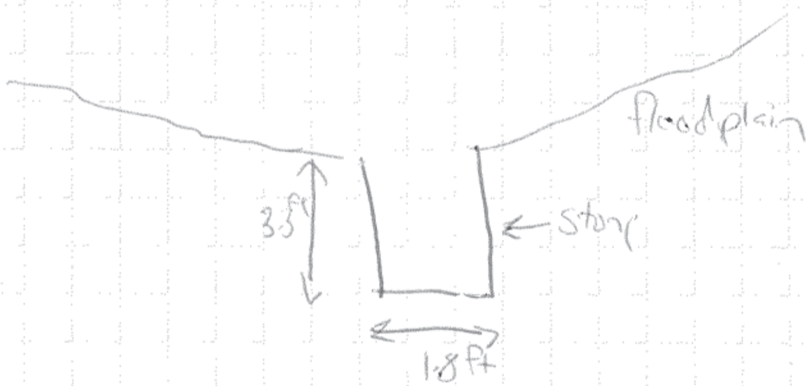
SUBJECT CULVERT INVESTIGATIONS   BY SPB   DATE 8/31/2023

Location 11: Pearl St
- old stone culvert
- flow to south

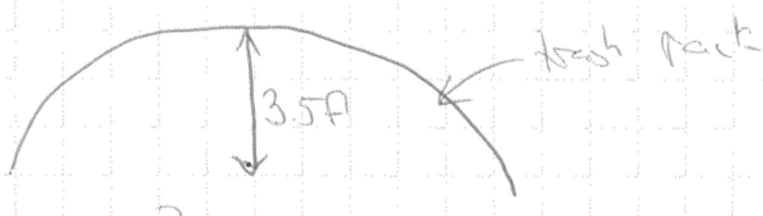




Upstream is channelized



Upstream Culvert



→ constant flow out - seems like buried stream

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SHEET ____ OF ____

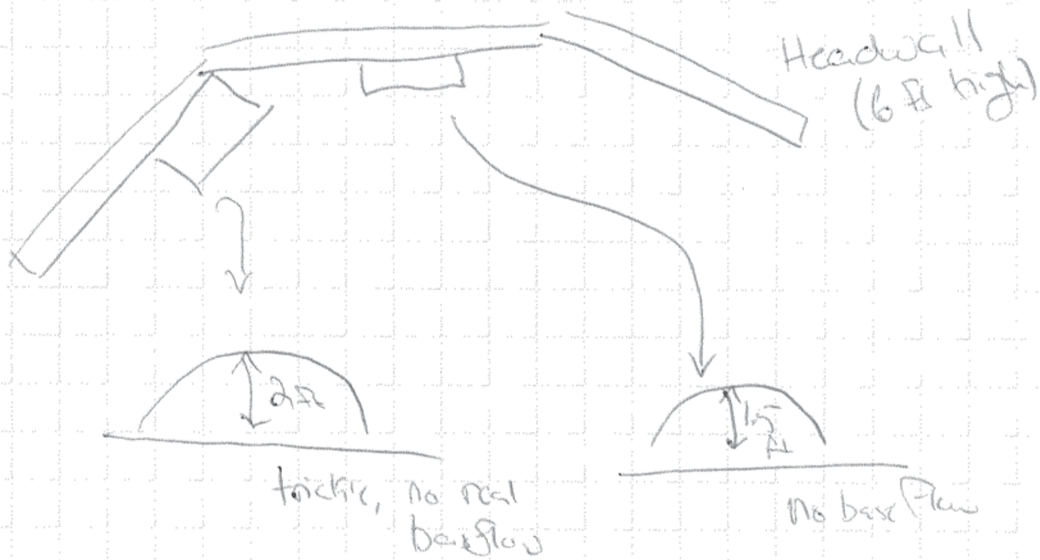
PROJECT NO. ____

PROJECT: Stoughton Flood Study | REVIEWED BY ____ DATE ____

SUBJECT: Culvert Investigations | BY SPB | DATE 8/23/23

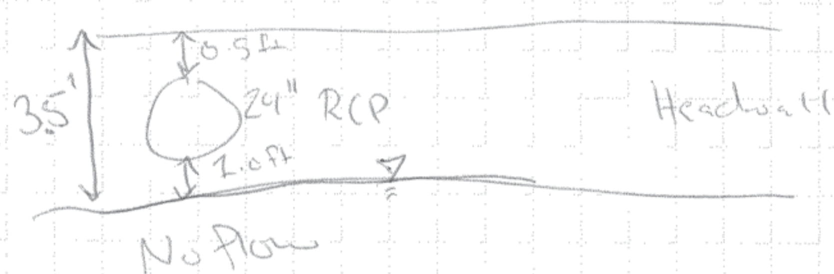
Location 12: Clotilda Rd

Downstream



Upstream:

Stagnant



Appendix B: Public Outreach Program Presentations

KLEINFELDER One Beacon Street, Suite 8100, Boston, MA 02108 p | 617.497.7800 f | 617.498.4630

Stoughton Stormwater Model and Flood Mitigation

Public Meeting

February 13, 2024 6:30PM to 8:30PM

Agenda

- Introductions
- Background
- Model Development
- Flood Vulnerabilities and Priorities
  - Case 1: York St
  - Case 2: Downtown
- Next Steps
- Discussion

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Introductions

- Town of Stoughton
  - Marc Tisdelle
  - Craig Horsfall
- Project Team (Kleinfelder)
  - Dave Peterson
  - Ariel Patterson
  - Seth Bryant
- Project Team (NepRWA)
  - Kerry Snyder
  - Jeff Frisch
  - Ian Cooke

Background

- Two-year **flood study** looking at the impact of future extreme rainfall in Stoughton
- Study stems from prior Town study to identify primary climate change related concerns
- Sponsored by the Municipal Vulnerability Preparedness program
- Study includes:
  - Model development
  - Public engagement and focus group meetings
  - Identify high-priority locations based on flood projections and community needs
  - Recommending strategies to mitigate flooding

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Audience Poll #1 (Warmup)

How does flooding impact you?

- ❑ Impacts to my job
- ❑ Impacts to my health & safety
- ❑ Impacts to my community
- ❑ Impacts to my home or property
- ❑ Impacts to my commute

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Poll #2

If you had $100 to spend on Stoughton's budget, and had to divide it between the following, how many dollars would you give to stormwater infrastructure?

- ❑ Stormwater Infrastructure
- ❑ Other Infrastructure (Roads, water, sewer)
- ❑ Schools
- ❑ Public Safety
- ❑ Parks & Recreation

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Model Development

- A computer model allows the Town to test different storms to see where flooding occurs and to what extent
- Town-wide model created through a mix of field investigations, flow monitoring in stormwater pipes, and the Town's geographic database

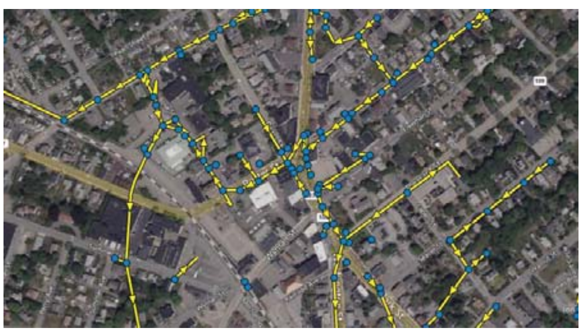

Image of the Town's underground stormwater drainage pipes using the Townwide Model

Monitoring equipment deployed throughout Town's streams

Engineers conduct field investigations

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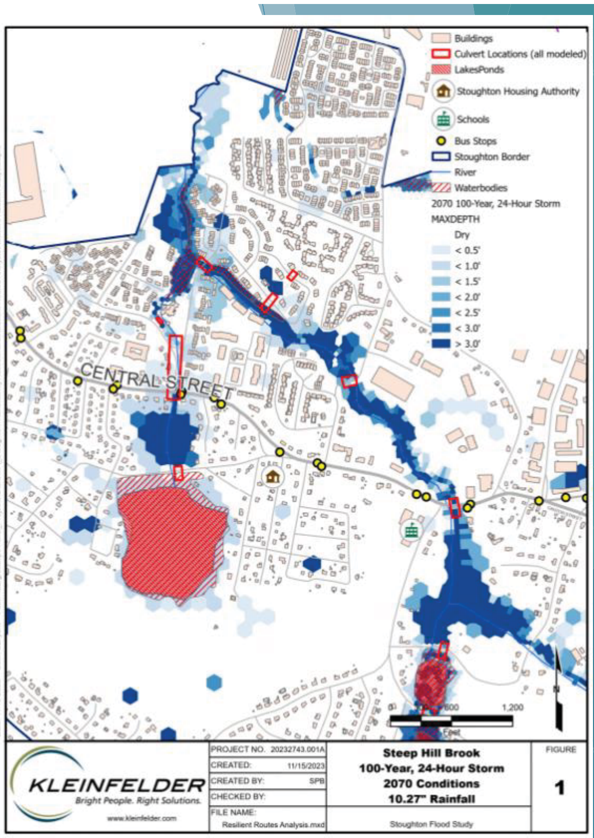
Town-Wide Modeling Results

- Available online at

https://neponset.org/stoughton-climate-resilience-project/

- Looked at multiple climate change scenarios:
  - Present-day conditions
  - 2030 climate change predictions
  - 2070 climate change predictions
- Simulated multiple rainfall types:
  - Likelihood of storm
  - Duration & intensity of storms



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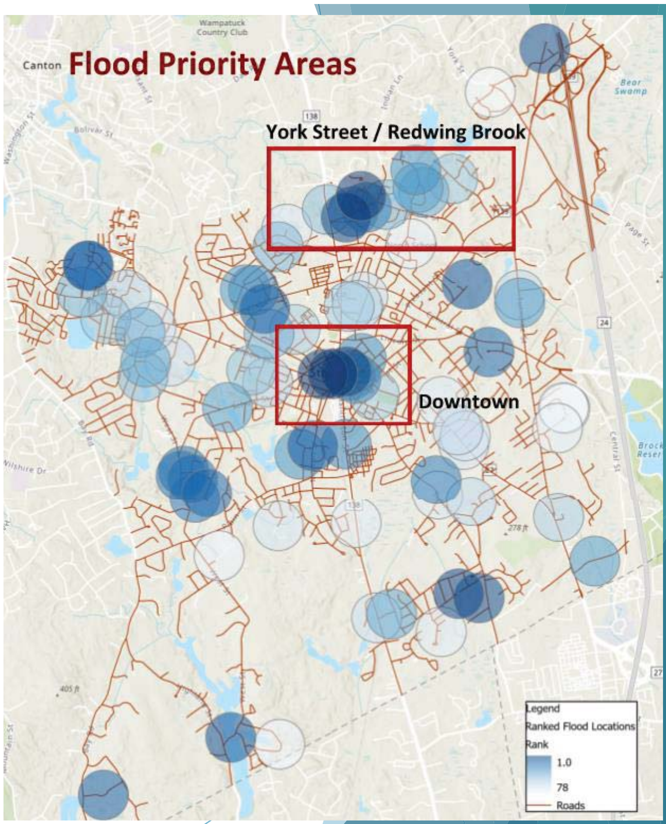
Vulnerabilities to Flooding

- Flood results were combined with community resources to see where vulnerability exists in Town
- Resources include:
  - Public safety (police, fire)
  - Schools
  - Public and Senior housing
  - Transit (major roads, bus, commuter rail)
  - Healthcare (hospitals, pharmacy)
  - Food



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Menu of Flood Solutions

Above: Gray infrastructure
Right: Green infrastructure

Source: Neponset River Watershed Association (NepRWA)

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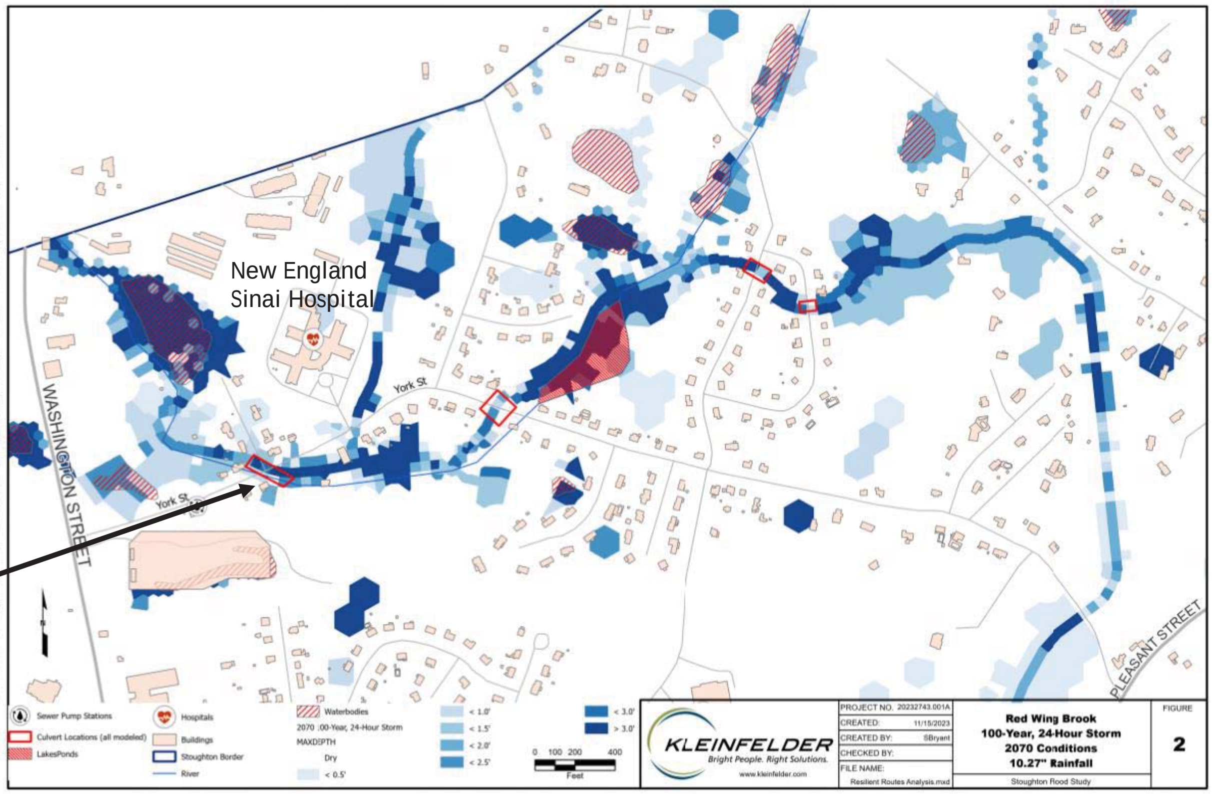
Location 1: York Street

- Flooding along Redwing Brook
- main cause of flooding is the **undersized, aging culvert**



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Potential Solution: Culvert Enhancements

Scott Jackson photo

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Potential Solution: Storage Options

Floodplain storage along natural stream

Wetland storage

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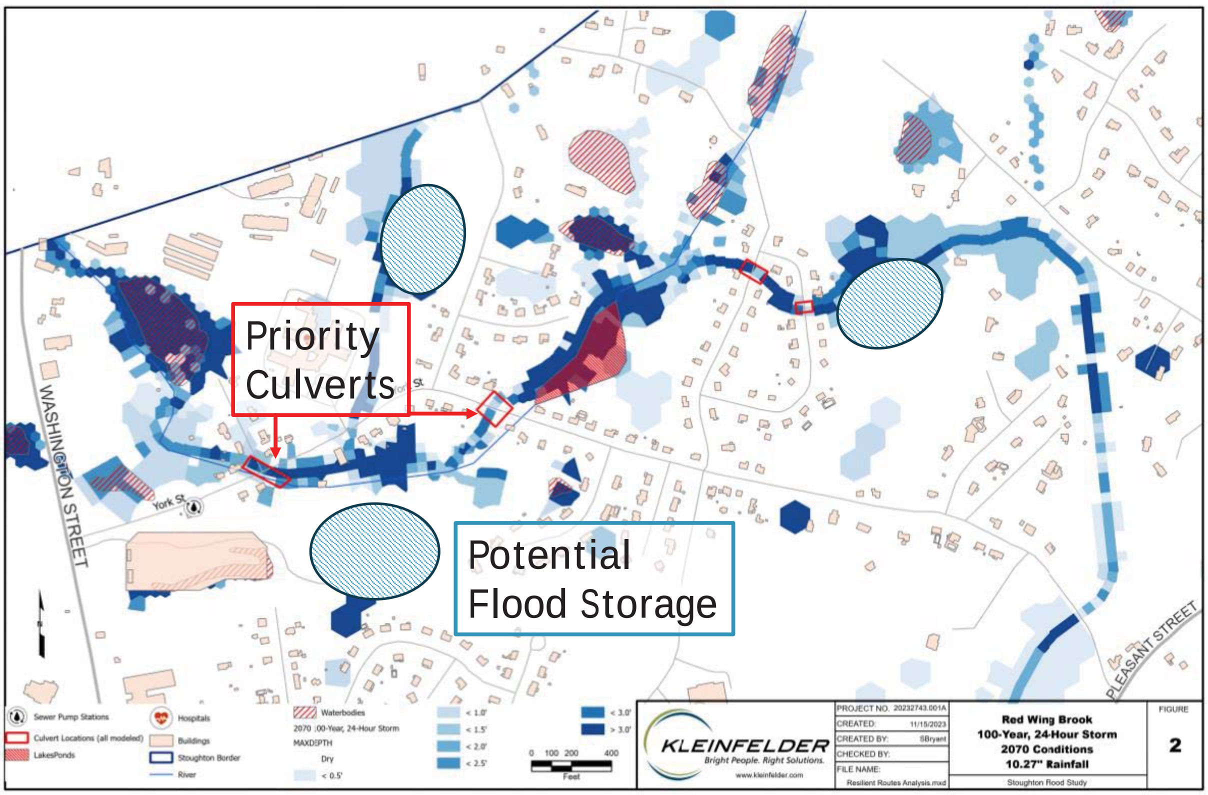

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Audience Poll #3 – York Street Solutions

We've discussed various options for addressing flooding in York Street Area. **Of the options presented, which do you prefer in the area?** Please rank them in order of preference (1 = most preferred, 3 = least preferred)

- ❑ Flood storage along streams
- ❑ Large wetland storage areas
- ❑ Culvert replacements

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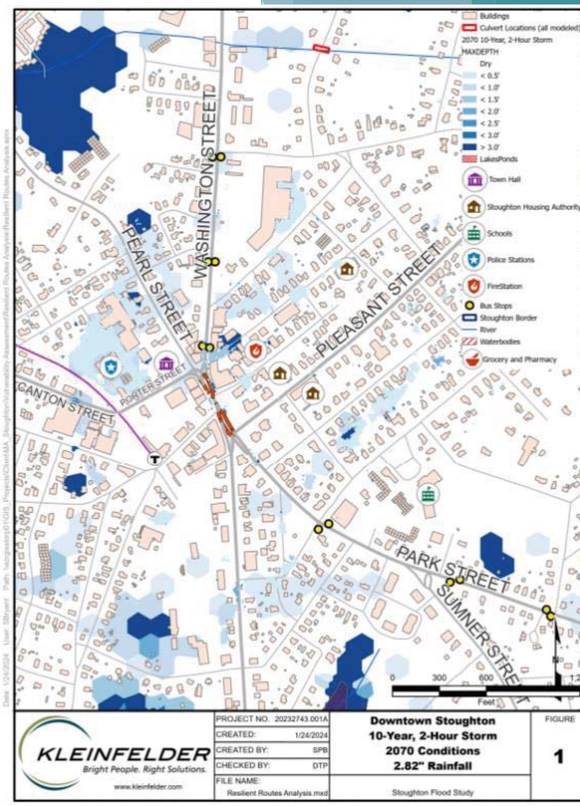
Location 2: Downtown

- Focus on short duration, high intensity storms
- Flash flooding concerns for highly paved areas
- Limited space for major infrastructure additions



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Potential Solution: Underground Storage

- Allows for large storage capacity without wasting surface space
- Opportunities with parking lots, parks, open spaces, etc.

Underground storage in Cambridge, MA parking lot

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Potential Solution: Pipe and Inlet Improvements

Catch-basin in downtown Stoughton

Undersized culvert in Stoughton

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Potential Solution: Green Infrastructure

- Many co-benefits including: Water quality, increased green space,
- Opportunistic Approach: Limited opportunities to incorporate broadly

Source: Minnesota Stormwater Manual
https://stormwater.pca.state.mn.us/index.php?title=Case_studies_for_dry_swale_(grass_swale)
Watershed Council
https://www.watershedcouncil.org/bioswale.html

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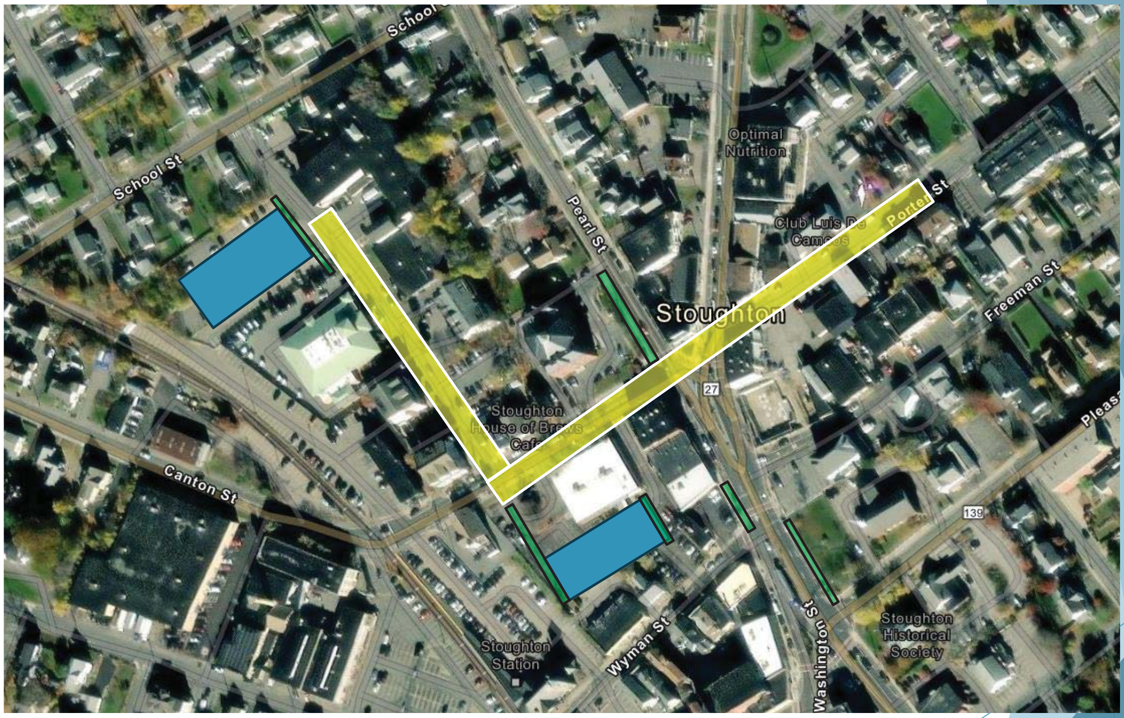
Potential Storage Areas

Potential Pipe Improvements

Potential Green Infrastructure



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Audience Poll #4 – Downtown Solutions

We've discussed various options for addressing flooding in the Downtown Area. **Of the options presented which would you like to see?** Please rank them in order of preference (1 = most preferred, 3 = least preferred)

- ❑ Green Infrastructure
- ❑ Underground Storage
- ❑ Pipe / inlet improvements

Location 3: West Street (Ames Long Pond)

Below: West St causeway over Ames Long Pond
Right: Modeled flood results

Next Steps

- Conceptual strategies for flood solutions
- Final recommendations and report
- Identify funding opportunities

Final Poll #5

If you had $100 to spend on Stoughton's budget, and had to divide it between the following, how many dollars would you give to stormwater infrastructure?

- Stormwater Infrastructure
- Other Infrastructure (Roads, water, sewer)
- Schools
- Public Safety
- Parks & Recreation

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Discussion

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Stoughton Stormwater Model and Flood Reduction

Public Meeting

December 15, 2022

Old Colony YMCA, Stoughton & Virtual

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Agenda

- Introduction
  - Project overview
  - Project team
  - Q&A on project scope
- How does flooding affect you?
- Where is the flooding?
  - Review survey responses so far
  - Flood mapping activity
- What should we do about it?
  - Overview of flood reduction measures
  - What would you like to see in Stoughton?
- Concluding remarks (and discussion)

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Project Overview

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MVP

Municipal Vulnerability Preparedness

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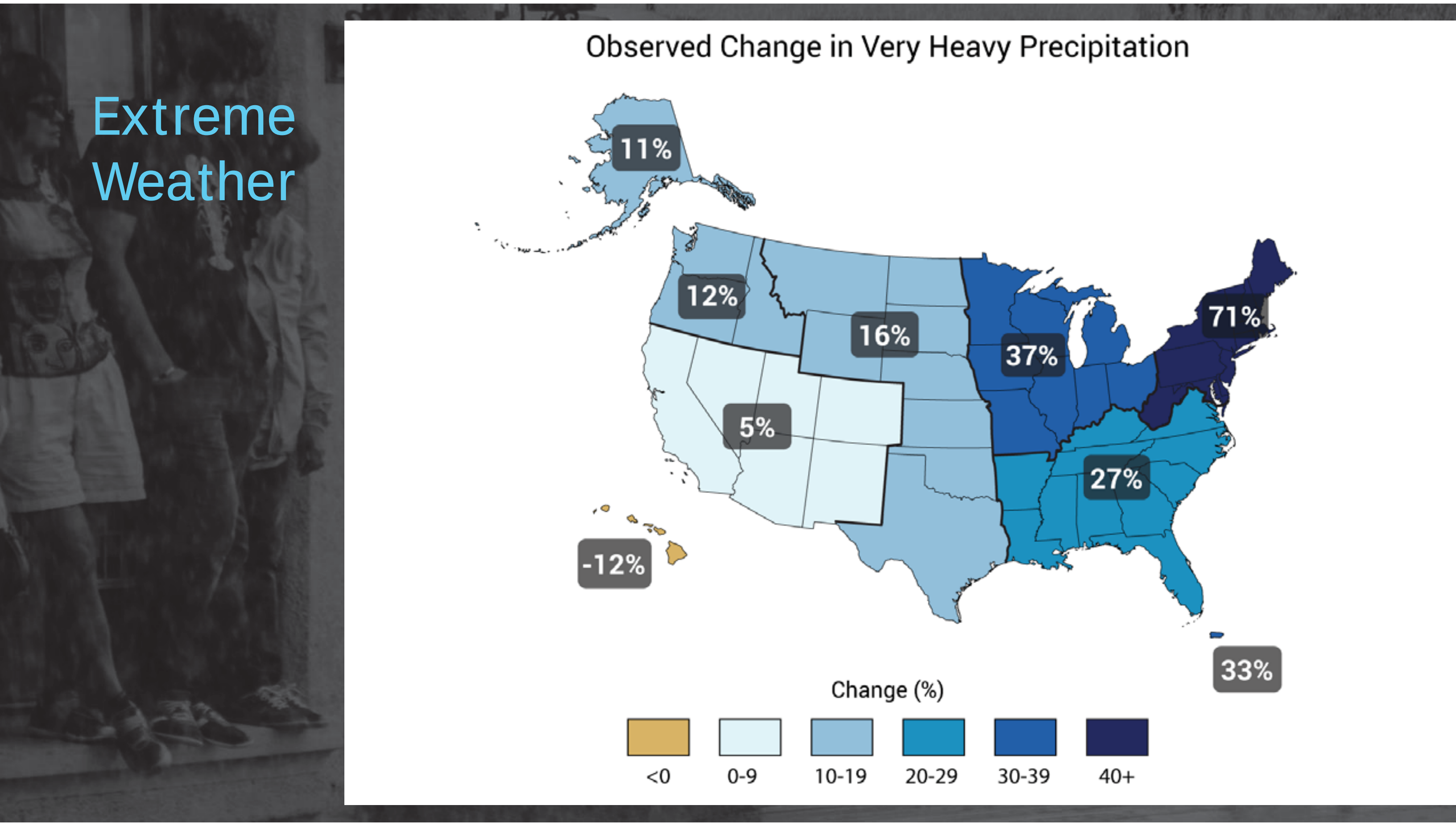
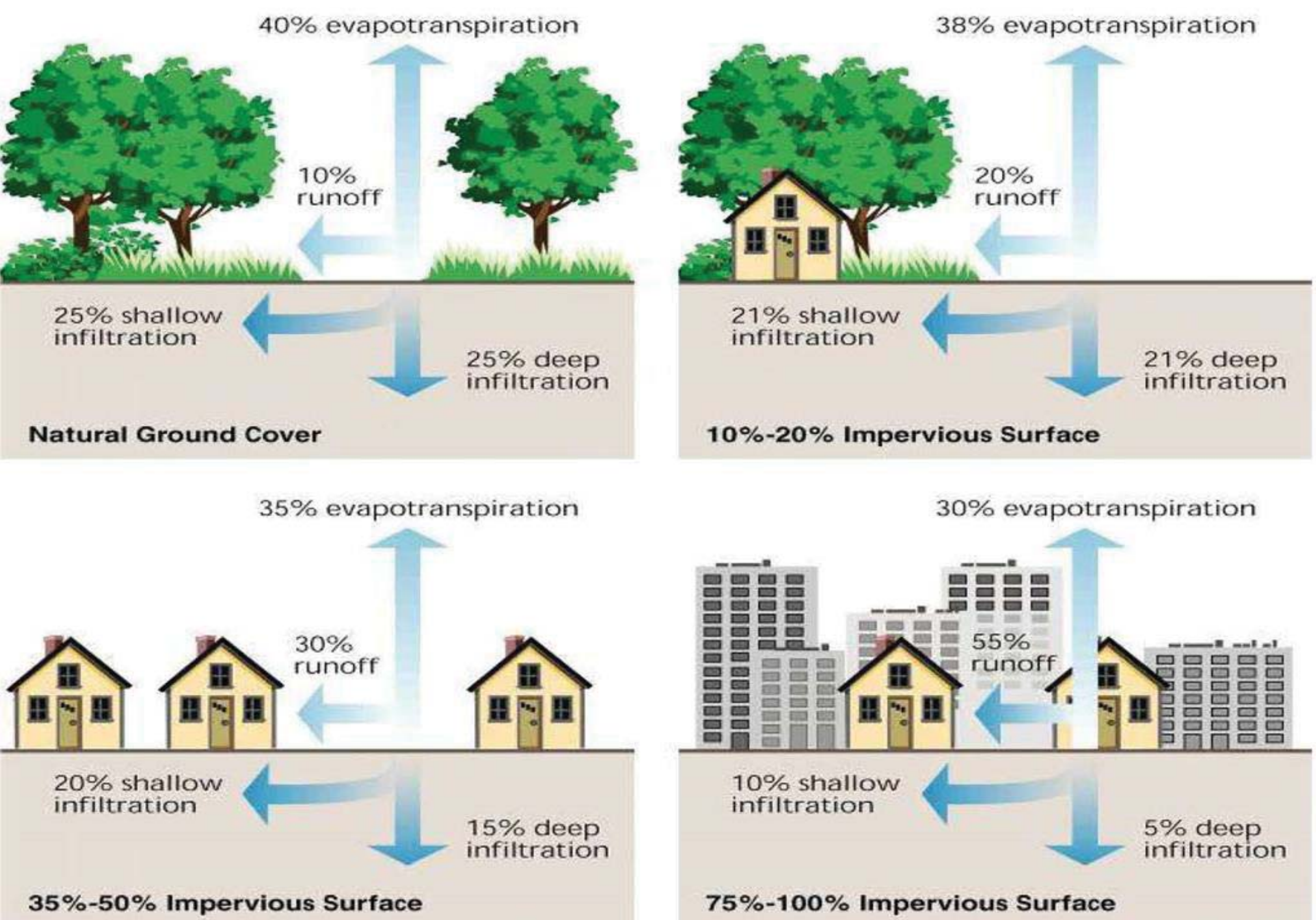


Extreme Weather
Observed Change in Very Heavy Precipitation
11%
12%
16%
5%
37%
71%
27%
-12%
33%
Change (%)
<0
0-9
10-19
20-29
30-39
40+


40% evapotranspiration
10% runoff
25% shallow infiltration
25% deep infiltration
Natural Ground Cover
38% evapotranspiration
20% runoff
21% shallow infiltration
21% deep infiltration
10%-20% Impervious Surface
35% evapotranspiration
30% runoff
20% shallow infiltration
15% deep infiltration
35%-50% Impervious Surface
30% evapotranspiration
55% runoff
10% shallow infiltration
5% deep infiltration
75%-100% Impervious Surface

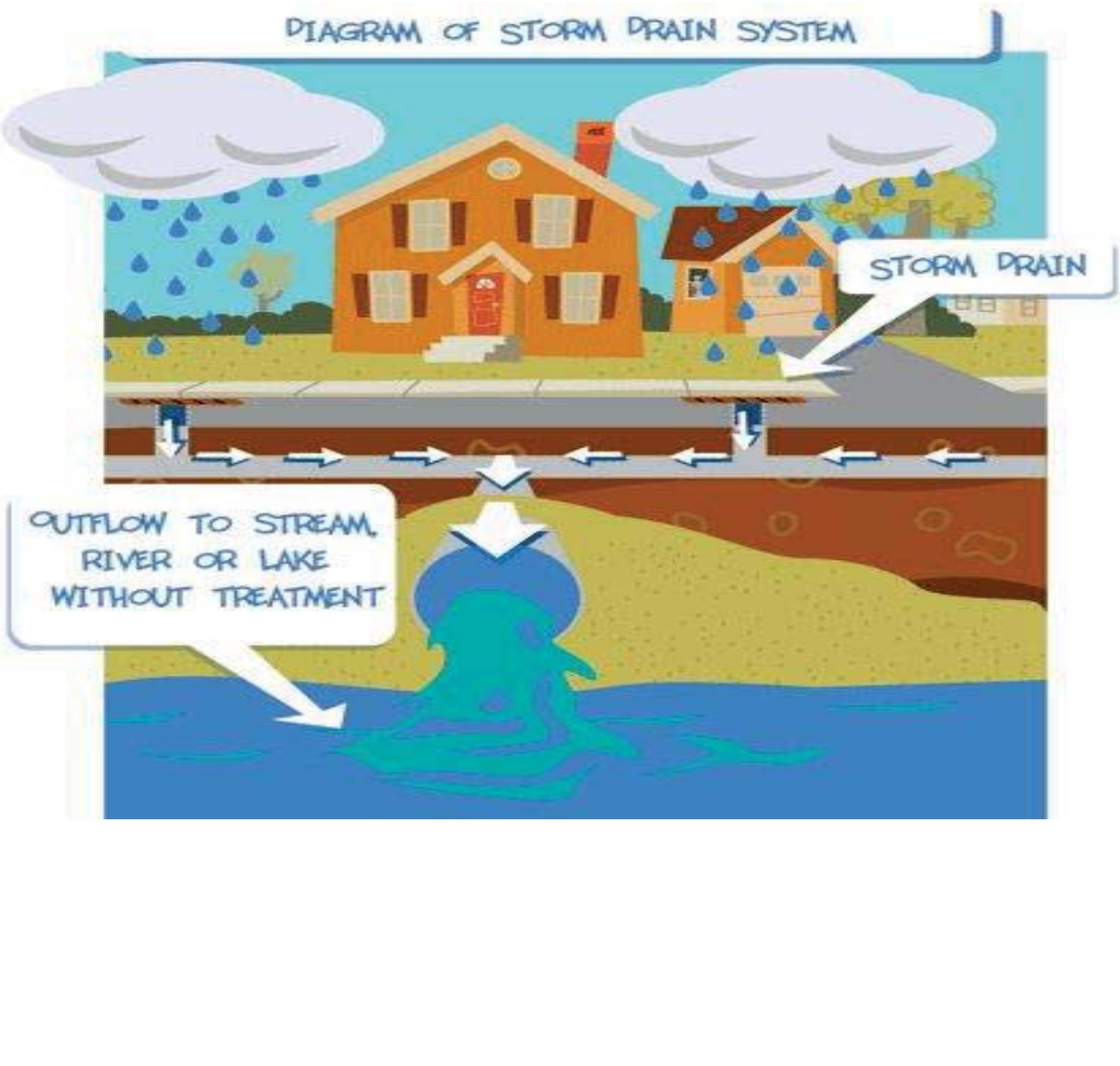


DIAGRAM OF STORM DRAIN SYSTEM
STORM DRAIN
OUTFLOW TO STREAM, RIVER OR LAKE WITHOUT TREATMENT

Storm drain system

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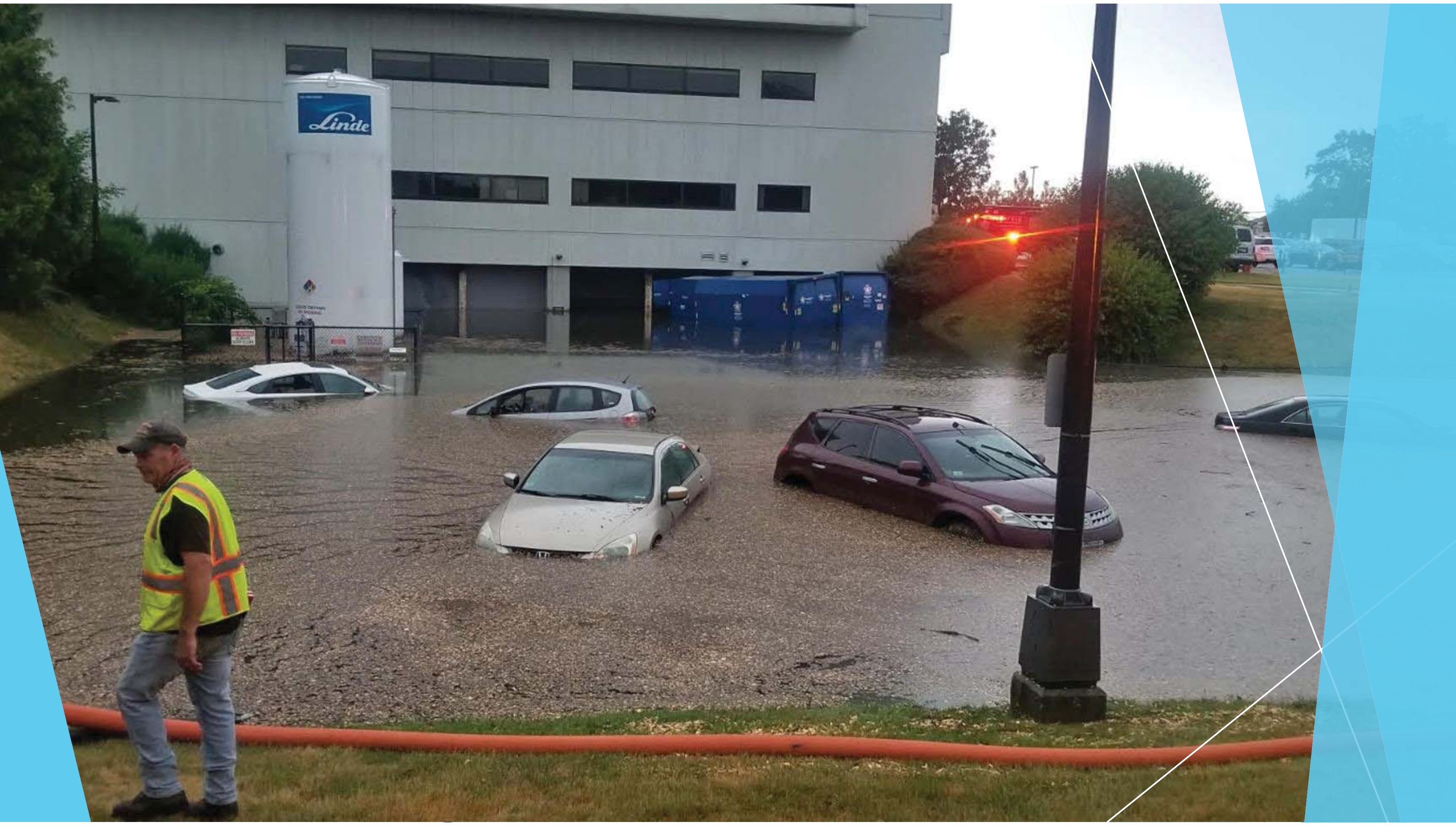
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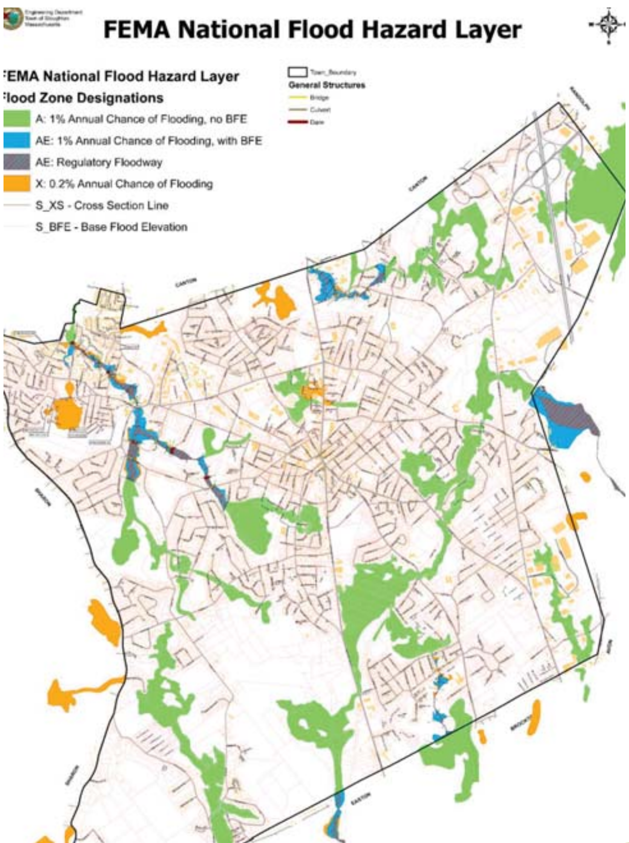

Flood Model

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Community Engagement

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Questions?

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How does flooding affect you?

Where is the flooding?

What should we do about it?

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Where have you seen flooding around Stoughton?

- Join a breakout group to put places you have seen flooding on the map!
- Facilitator will be available to assist with mapping and take notes
- Convene and share out in ~15 minutes

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Where is the flooding?

What should we do about it?

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Flood solutions

- The best flood reduction measures depends on the type of flooding… and what you want in your community!
  - “Grey” infrastructure
  - “Green” infrastructure

"Grey" Infrastructure for Flood Reduction

Source: Neponset River Watershed Association (NepRWA)

- Typically designed from hard materials like concrete; goal is to move water away from where it can do damage as quickly as possible.
- Strengths
  - With enough investment, grey infrastructure can be designed to handle very large storms
- Weaknesses
  - Grey infrastructure rapidly shifts stormwater elsewhere- potentially to another place it could cause harm.
  - Grey infrastructure allows stormwater to carry pollutants to aquatic ecosystems without any natural filtering

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"Green" Infrastructure for Flood Reduction

Source: Neponset River Watershed Association (NepRWA)

- Incorporates a mix of hard materials, porous materials like soil or gravel, and vegetation. Typically designed to store or slow stormwater before it reaches places it could harm people or property.
- Strengths
  - Green infrastructure keeps water where it is and reduces the amount of water that is flowing at one time
  - Can be designed to remove pollutants/prevent stormwater pollutants from entering water bodies
- Weaknesses
  - Green infrastructure can mitigate small-storm flooding, but extensive green infrastructure is required to reduce flooding from severe storms

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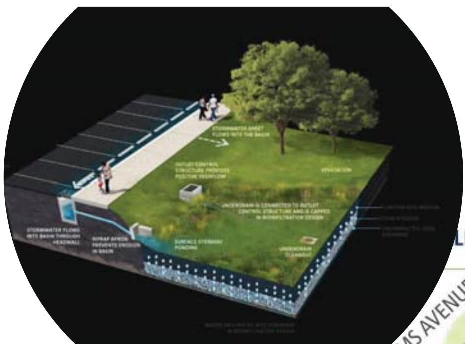
Basin-type Green Stormwater Infrastructure



Source: *Philadelphia Water Department*

- Large, shallow basin or set of pools
- Depending on design, may provide
  - Groundwater recharge
  - Reduce flooding
  - Reduce sediment in stormwater
  - Reduce other pollutants entering groundwater or water bodies

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Linear Green Stormwater Infrastructure

- Multiple types can be used in linear formats to store, slow, and infiltrate runoff from roads, sidewalks, etc.
- Examples
  - Linear constructed wetland to store stormwater before it runs off
  - Infiltration trenches which channel stormwater into the soil
  - Rain gardens designed to absorb stormwater

Source: Minnesota Stormwater Manual
https://stormwater.pca.state.mn.us/index.php?title=Case_studies_for_dry_swale_(grass_swale)
Watershed Council
https://www.watershedcouncil.org/bioswale.html

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Distributed Green Stormwater Infrastructure

- Work by storing or infiltrating a little stormwater at one place
- To reduce flooding, need to implement a lot in one area
- Examples
  - Green roofs
  - Rain barrels
  - Pervious pavement

Source: *Massachusetts Stormwater Handbook*

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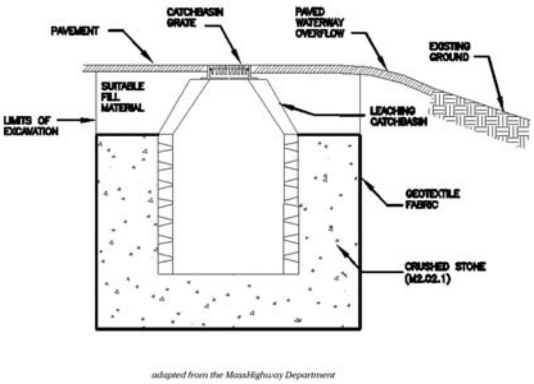
Drainage-Integrated Green Infrastructure



Source: Massachusetts Stormwater Handbook

- Works with existing drainage system (catch basins, pipes) to slow runoff and recharge groundwater
- May not be apparent once in place!
  - Leaching catch basin
  - Stormwater street planter
  - Subsurface infiltration structures

Source: Green Streets Design Manual

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What do you want to see in your community? Let's talk about it!

- Join a breakout group to discuss what kinds of flood solutions you would prefer
- Facilitator will be available to take notes, keep conversation going, and provide more information on green and grey flood solutions
- Convene and share out in ~15 minutes

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What do you want to see in your community? Let's talk about it!

- What flood reduction measures would you like to see in Stoughton?
- What are your priorities for how the Town manages flooding?
- How much do you value benefits of green infrastructure other than flood reduction?

What do you want to see in your community? Let's talk about it!

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Thank you for attending!

You can learn more, check progress, and fill out the survey here:
https://arcg.is/1jCS9O

Sign up for email notifications about the project here:
https://www.neponset.org/stoughton-climate-resilience-project/

Appendix C: Town-Wide Flood Model Maps

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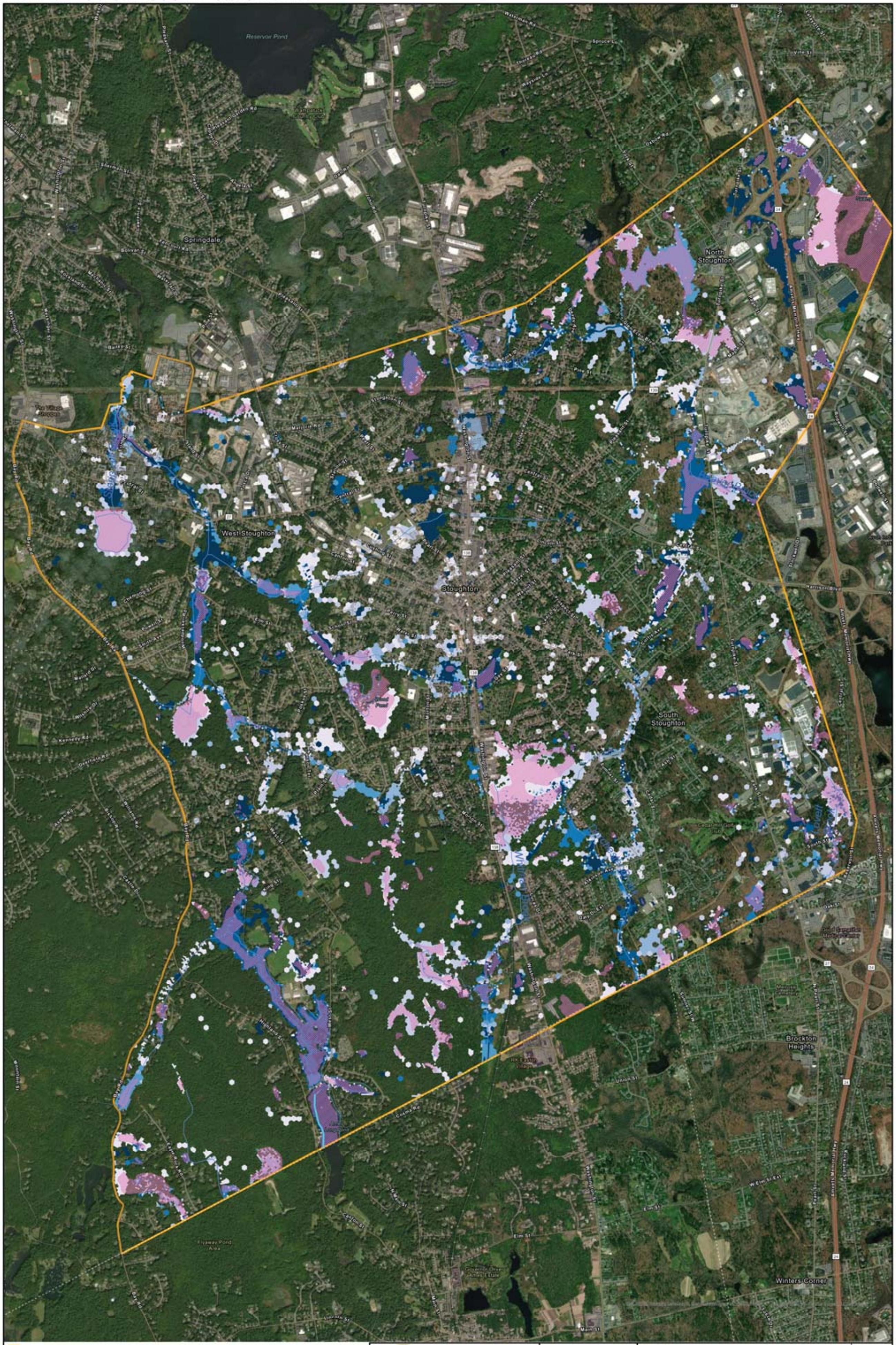

Stoughton Border	0.500001 - 1.000000
Water Bodies	1.000001 - 1.500000
USGS Rivers and Streams	1.500001 - 2.000000
2070 100-Year, 24-Hours Storm	2.000001 - 2.500000
0.000000 - 0.250000	2.500001 - 3.000000
0.250001 - 0.500000	3.000001 - 29.740000

0 0.25 0.5 1
Miles

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CREATED BY:	SPB
CHECKED BY:	DTP
FILE NAME:	Year 2 Maps.mxd

Stoughton Flood Model
2070 100-Year, 24-Hour Storm
(10.27" Rainfall)

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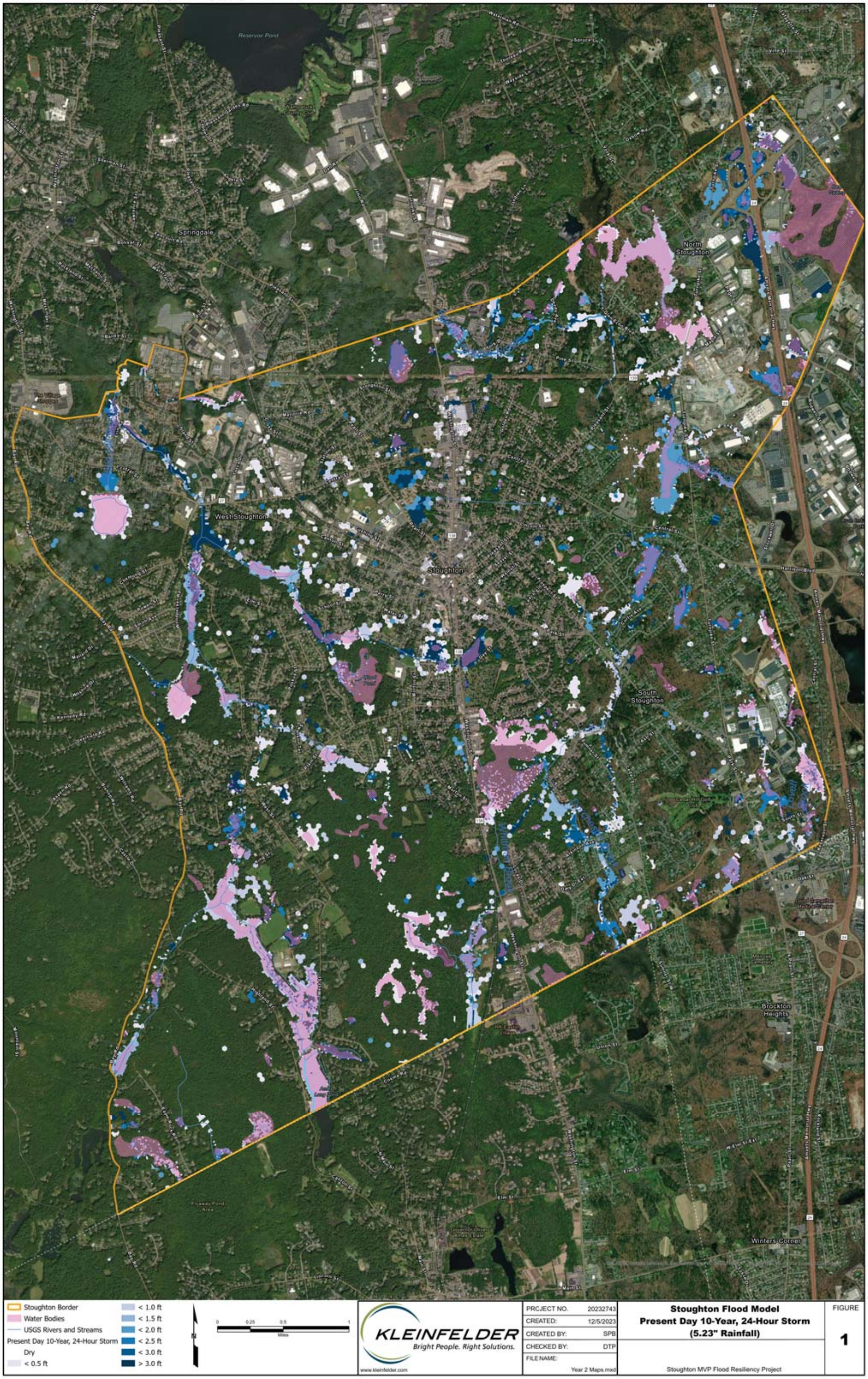
FIGURE
6



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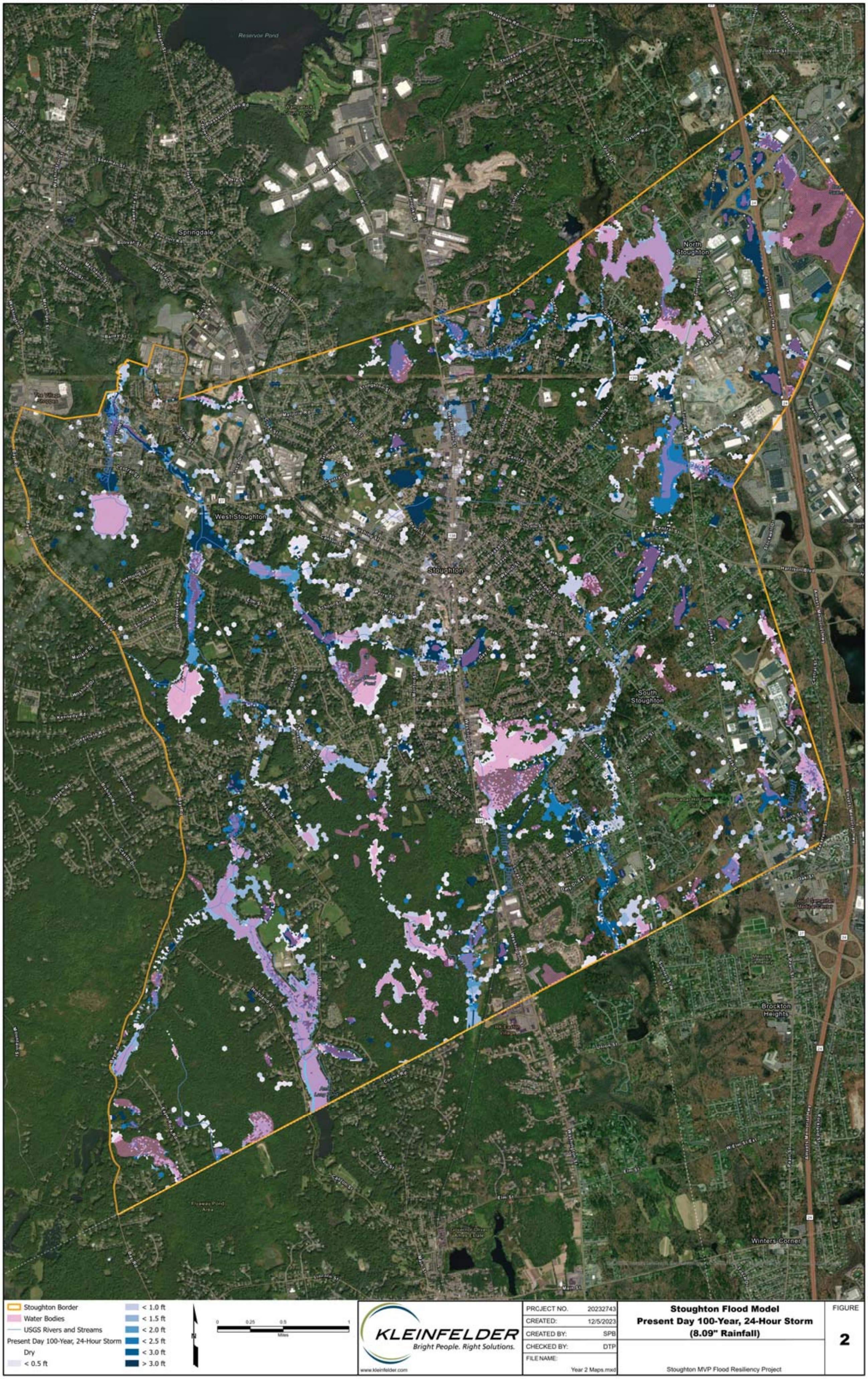
FILE NAME:	Year 2 Maps.mxd

Stoughton Flood Model
Present Day 10-Year, 24-Hour Storm
(5.23" Rainfall)

Stoughton MVP Flood Resiliency Project

FIGURE **1**



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Stoughton Flood Model
Present Day 100-Year, 24-Hour Storm
(8.09" Rainfall)

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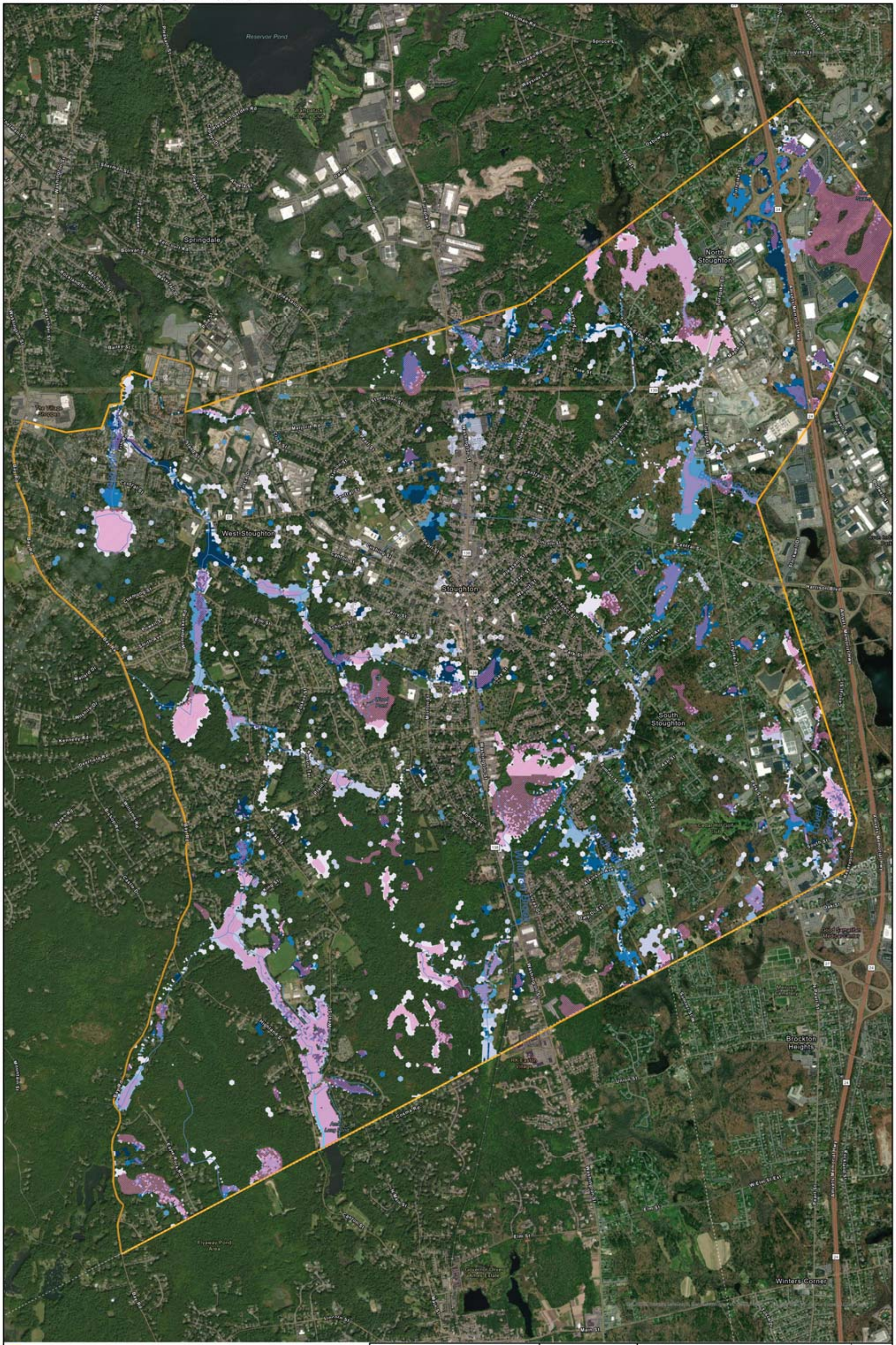
FIGURE
2



Stoughton Border
Water Bodies
USGS Rivers and Streams
2030 10-Year, 24-Hour Storm
Dry
< 0.5 ft
< 1.0 ft
< 1.5 ft
< 2.0 ft
< 2.5 ft
< 3.0 ft
> 3.0 ft

N

0 0.25 0.5 1
Miles

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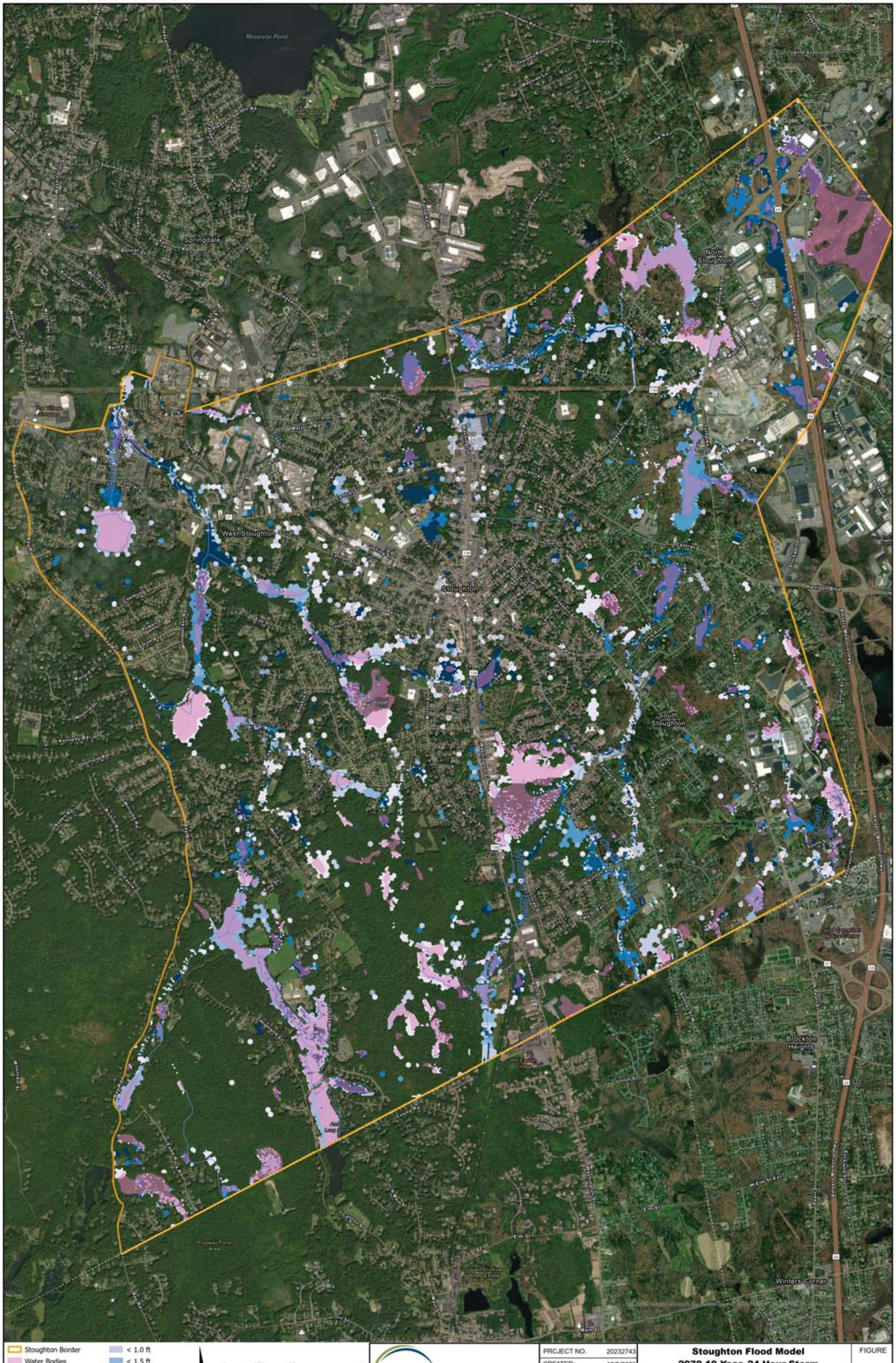
Stoughton Flood Model
2030 10-Year, 24-Hour Storm
(5.65" Rainfall)

Stoughton MVP Flood Resiliency Project

FIGURE
3



Stoughton Border	< 1.0 ft
Water Bodies	< 1.5 ft
USGS Rivers and Streams	< 2.0 ft
2070 10-Year, 24-Hour Storm	< 2.5 ft
Dry	< 3.0 ft
< 0.5 ft	> 3.0 ft

0 0.25 0.5 1
Miles

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FILE NAME:	Year 2 Maps.mxd

Stoughton Flood Model
2070 10-Year, 24-Hour Storm
(6.28" Rainfall)

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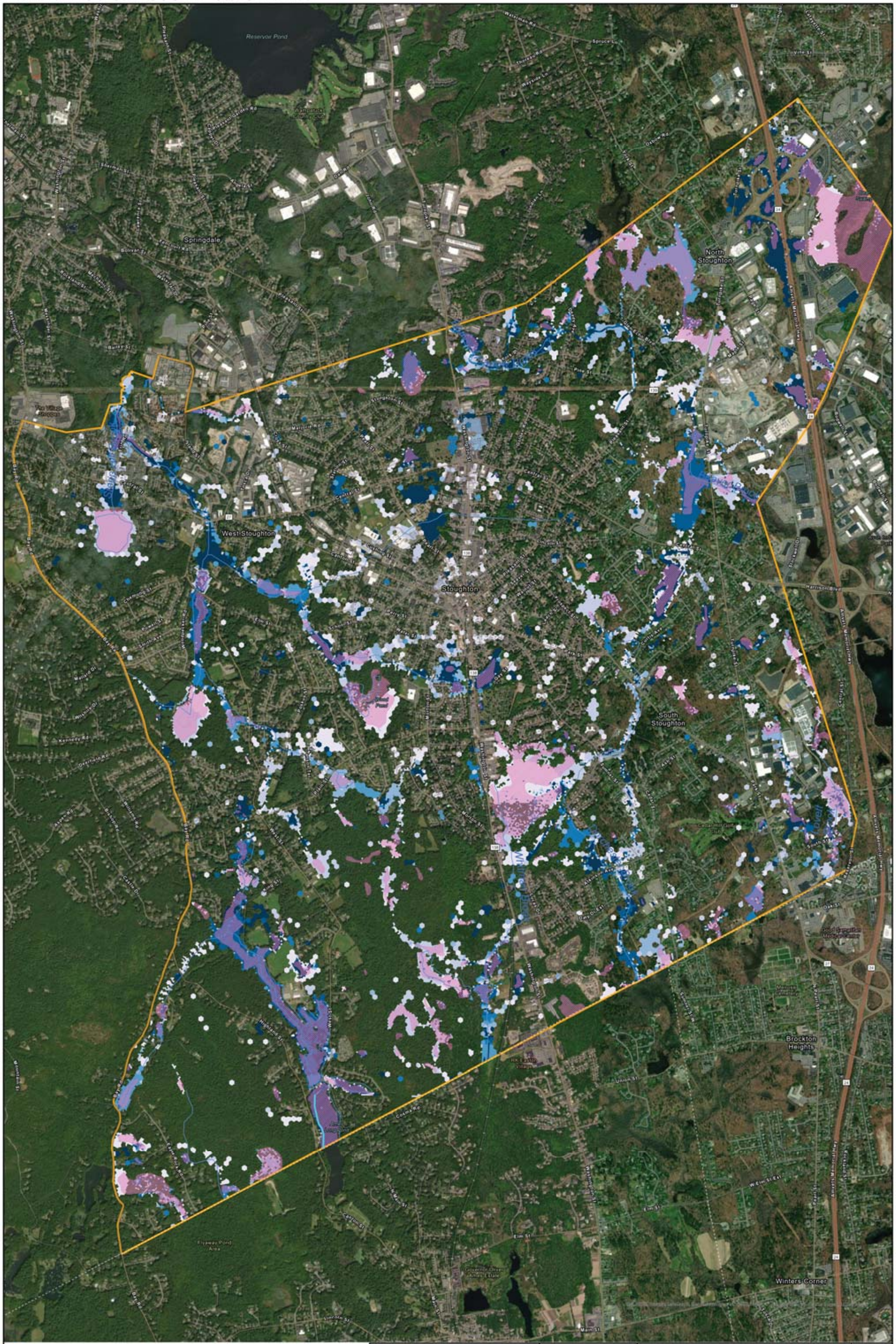
FIGURE
5



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CREATED BY:	SPB
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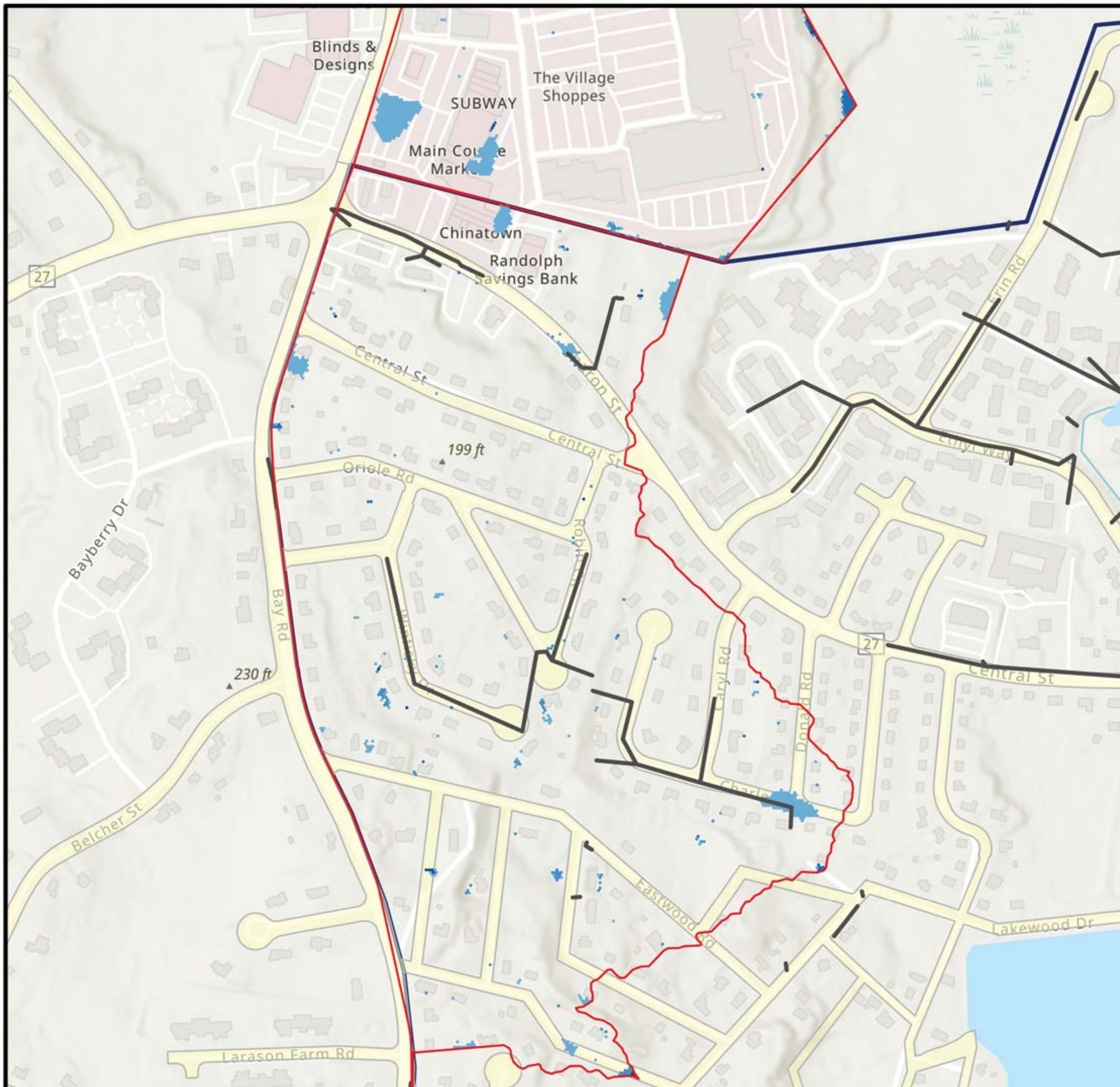
FILE NAME:	Year 2 Maps.mxd

Stoughton Flood Model
2030 100-Year, 24-Hour Storm
(8.98" Rainfall)

Stoughton MVP Flood Resiliency Project

FIGURE
4



Date: 6/28/2023 User: SBryant Path: \\azrgisstorp01\GIS_Projects\Client\MA_Stoughton\StormwaterMVP\Year 1 Flood Maps\Stoughton Year 1 Maps.aprx

Legend

- Drainage Pipes
- Key Locations
- 2-Hour, 10-Year Present Day MAXDEPTH
  - Dry
  - < 1.0 ft
  - < 2.0 ft
  - < 3.0 ft
  - > 3.0 ft
- Stoughton Border
- Road Extent

N

0 0.05 0.1 0.2 Miles

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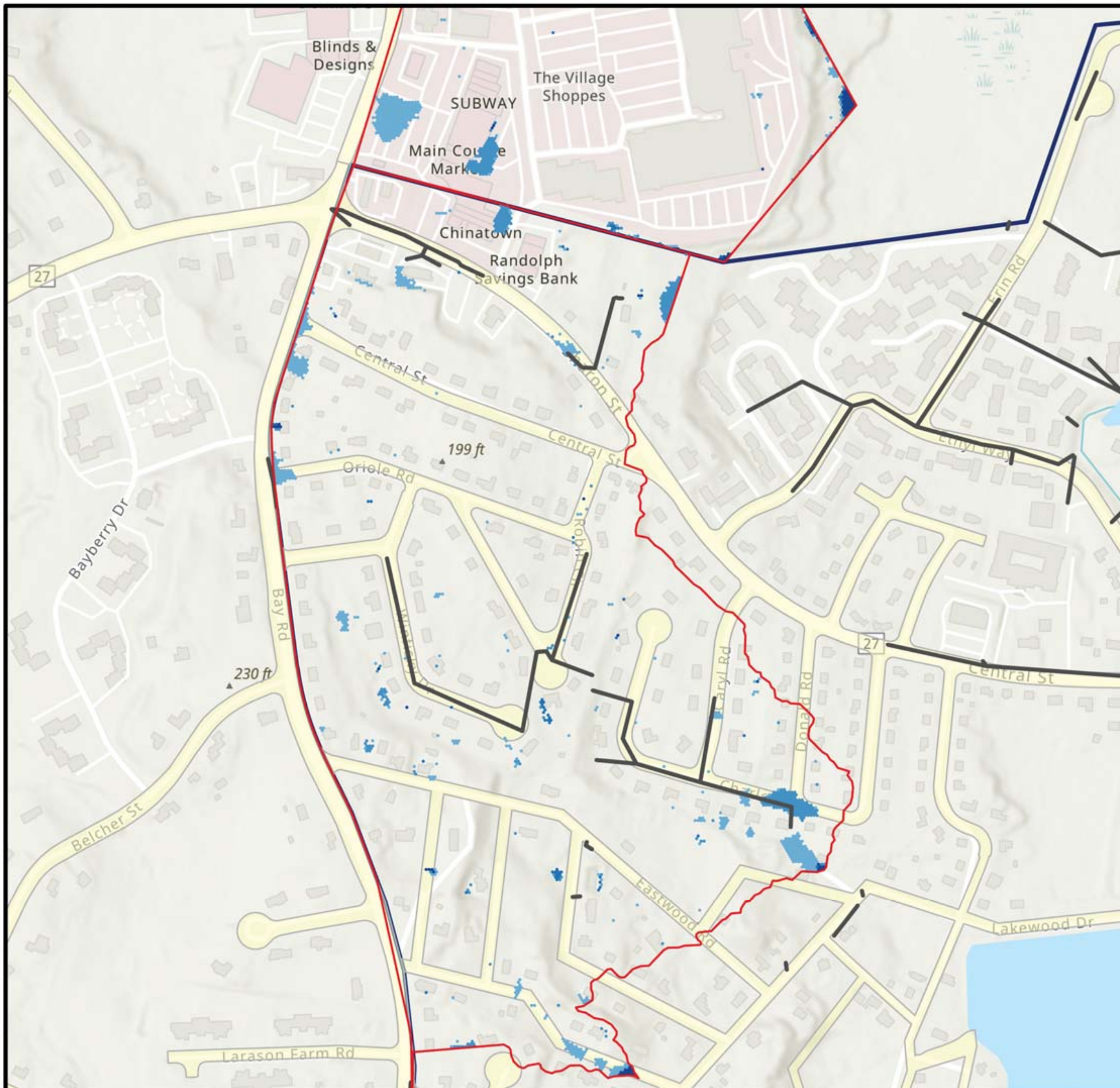
FILE NAME:	Stoughton Year 1 Maps.mxd

Stoughton Flood Model
10-Year, 2-Hour Flood
Present Conditions

Stoughton MVP Flood Resiliency Project

FIGURE

9



Date: 6/28/2023 User: SBryant Path: \\azrgisstorp01\GIS_Projects\Client\MA_Stoughton\StormwaterMVP\Year 1 Flood Maps\Stoughton Year 1 Maps\Stoughton Year 1 Maps.aprx

Legend

Drainage Pipes
Key Locations
Stoughton Border

2-Hour, 10-Year 2070 Storm
MAXDEPTH
Dry
< 1.0 ft
< 2.0 ft
< 3.0 ft
> 3.0 ft
Road Extent

N

0 0.05 0.1 0.2 Miles

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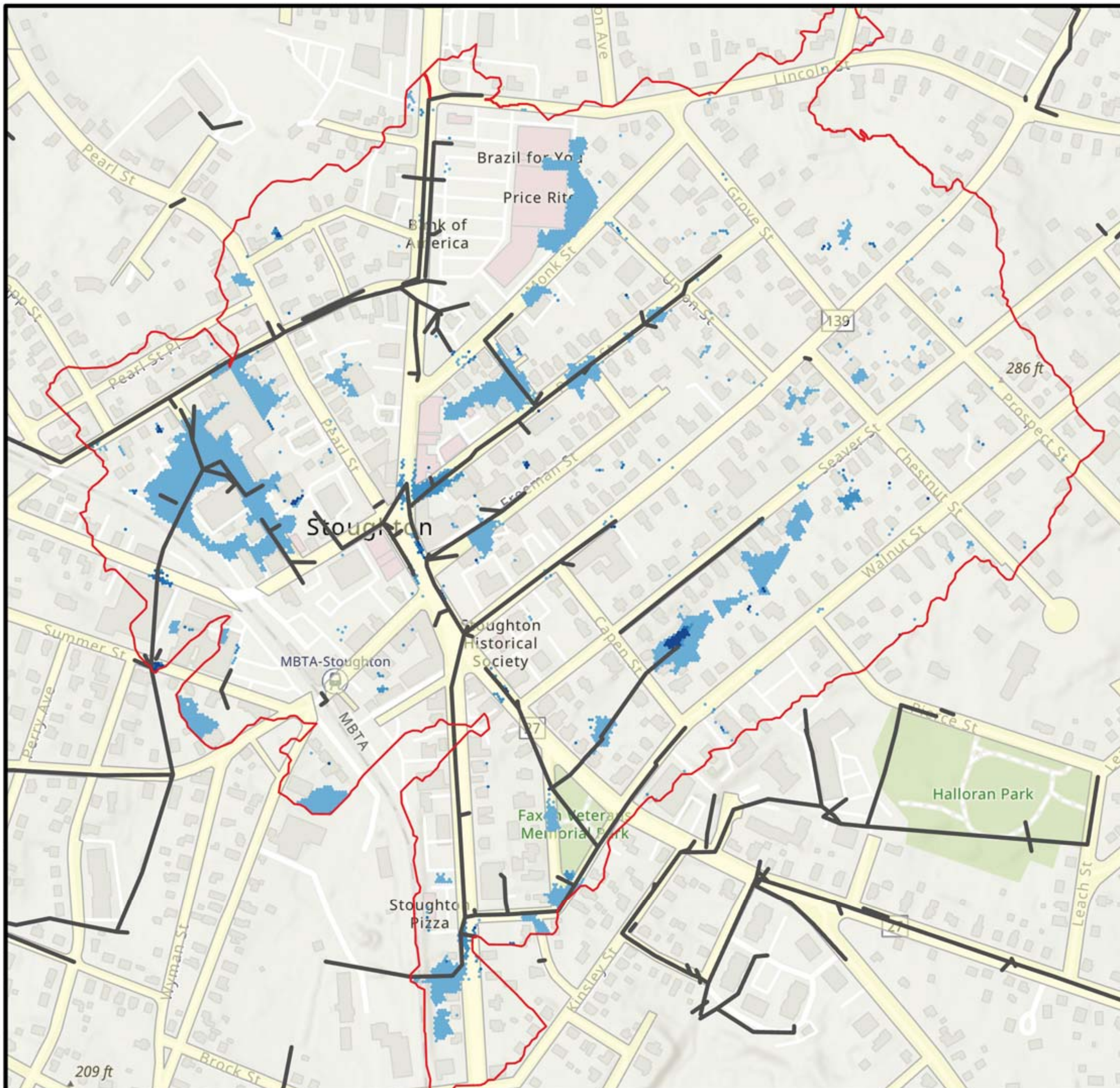
FILE NAME:	Stoughton Year 1 Maps.mxd

Stoughton Flood Model
10-Year, 2-Hour Flood
2070 Conditions

Stoughton MVP Flood Resiliency Project

FIGURE

10



Legend

Drainage Pipes	2-Hour, 10-Year 2070 Storm	< 2.0 ft	
Key Locations	MAXDEPTH	< 3.0 ft	
Stoughton Border	Dry	> 3.0 ft	N
	< 1.0 ft	Road Extent	

0 0.05 0.1 0.2 Miles

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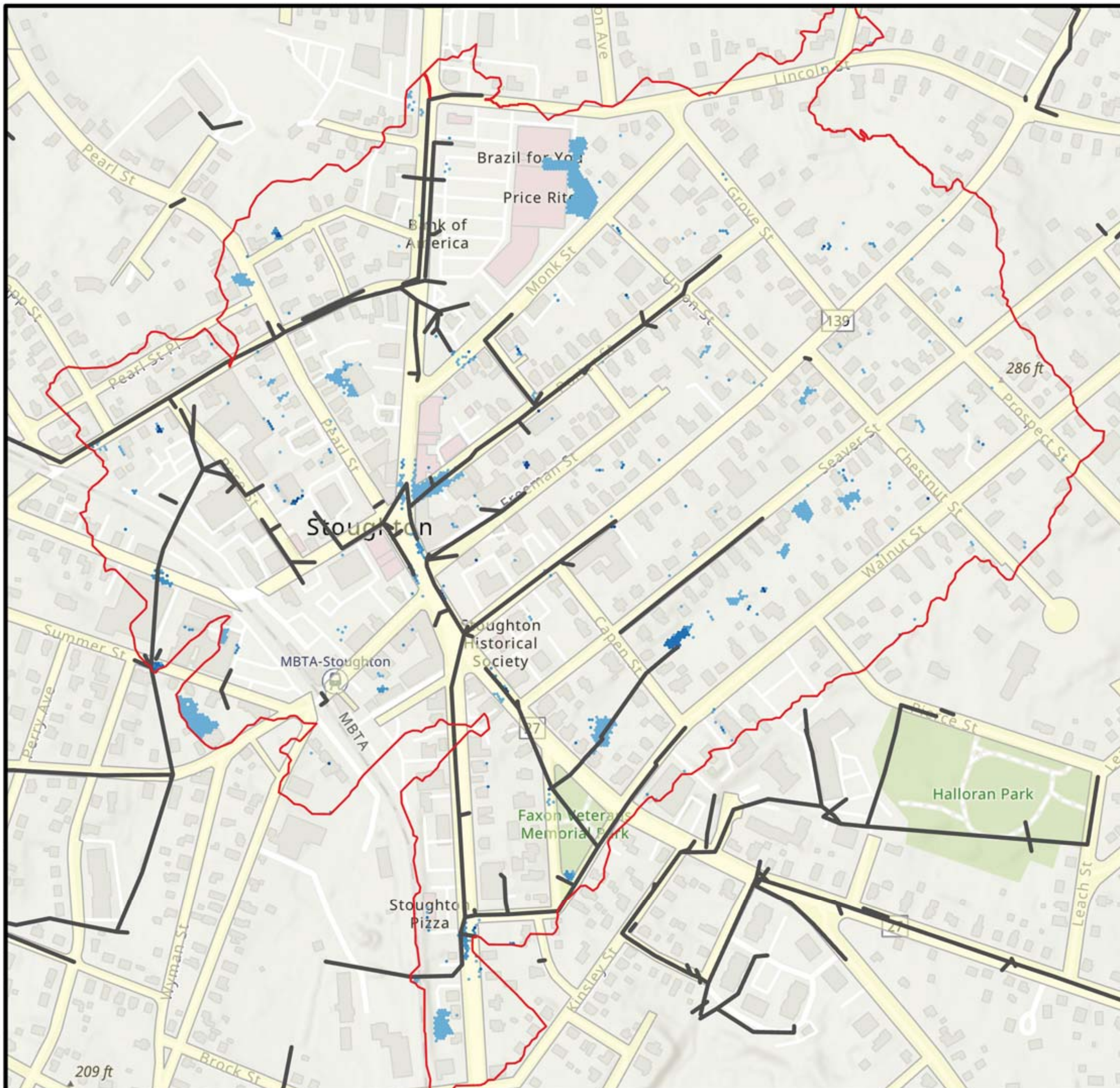
PROJECT NO. 20232743.001A	**Stoughton Flood Model**	FIGURE
CREATED: 6/28/2023	**10-Year, 2-Hour Flood**	
CREATED BY: SPB	**2070 Conditions**	**8**
CHECKED BY: DTP		
FILE NAME: Stoughton Year 1 Maps.mxd	Stoughton MVP Flood Resiliency Project	

Date: 6/28/2023 User: SBryant Path: \\azrgisstorp01\GIS_Projects\Client\MA_Stoughton\StormwaterMVP\Year 1 Flood Maps\Stoughton Year 1 Maps\Stoughton Year 1 Maps.aprx



Legend

Drainage Pipes
Key Locations
2-Hour, 10-Year Present Day
MAXDEPTH
Dry
< 1.0 ft
< 2.0 ft
< 3.0 ft
> 3.0 ft
Stoughton Border
Road Extent

0 0.05 0.1 0.2 Miles

N

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FILE NAME:	Stoughton Year 1 Maps.mxd

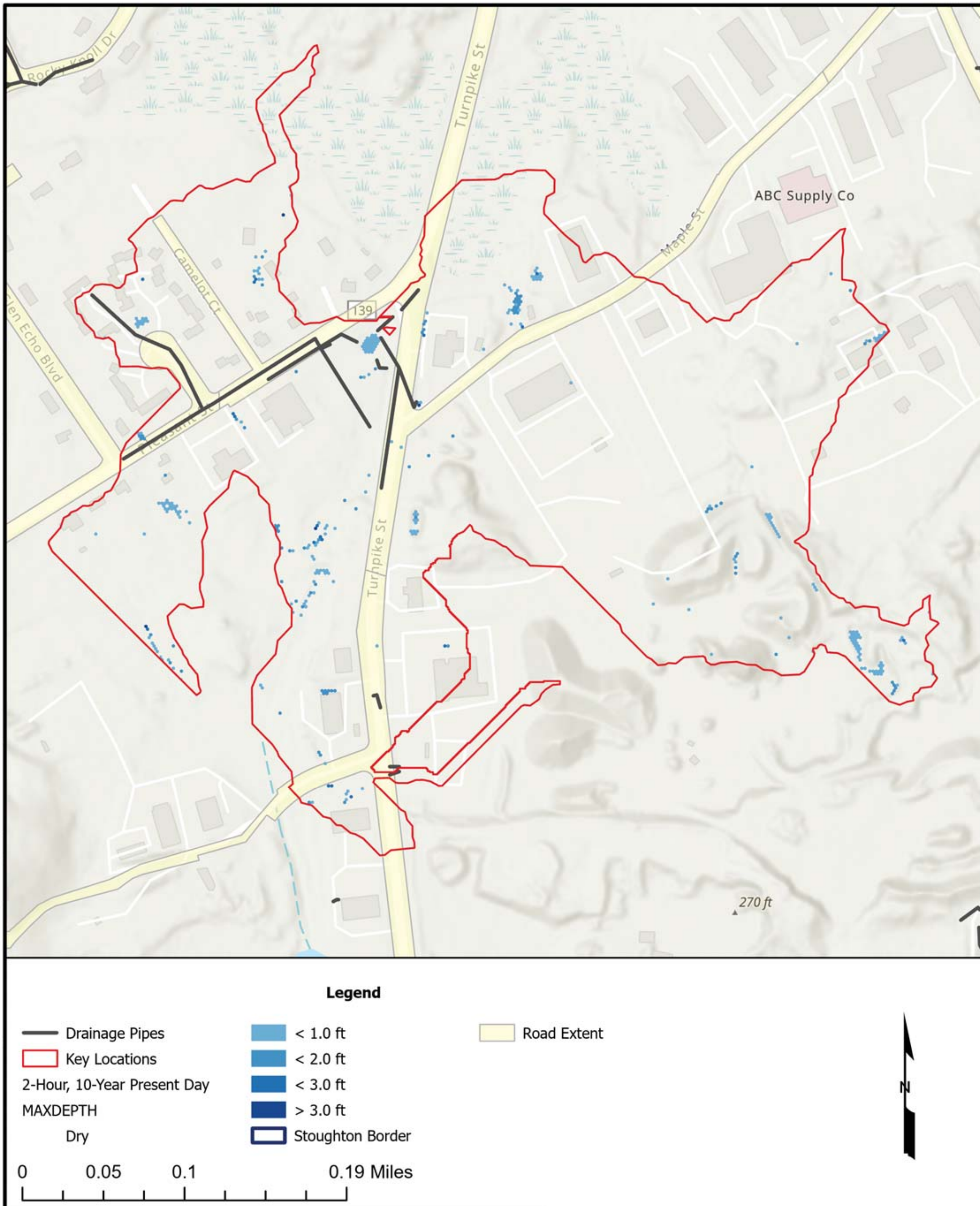
Stoughton Flood Model
10-Year, 2-Hour Flood
Present Conditions

Stoughton MVP Flood Resiliency Project

FIGURE

7

Date: 6/28/2023 User: SBryant Path: \\azrgisstorp01\GIS_Projects\Client\MA_Stoughton\StormwaterMVP\Year 1 Flood Maps\Stoughton Year 1 Maps\Stoughton Year 1 Maps.aprx



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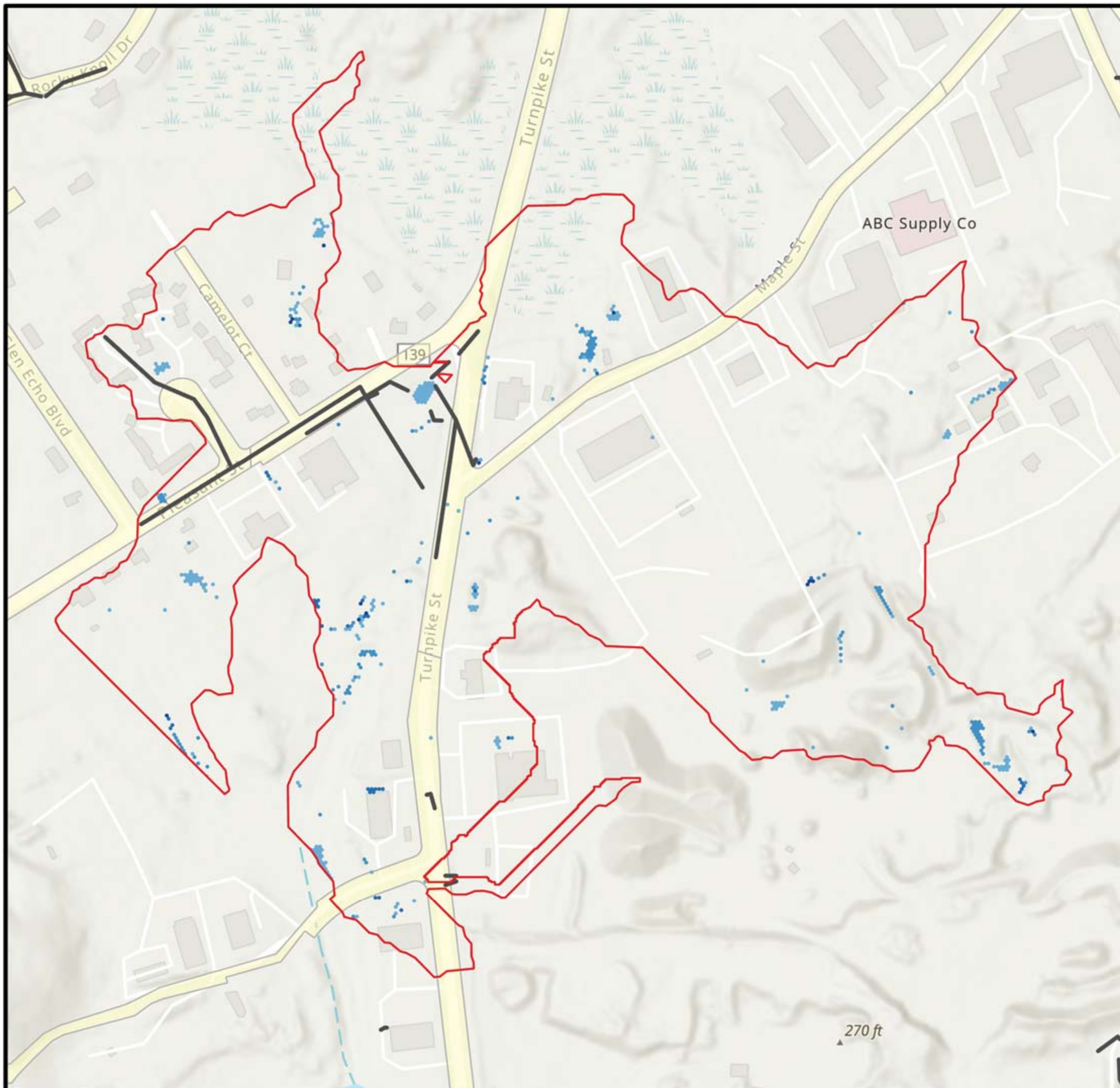
FILE NAME:	Stoughton Year 1 Maps.mxd

Stoughton Flood Model
10-Year, 2-Hour Flood
Present Conditions

Stoughton MVP Flood Resiliency Project

FIGURE

11



Legend

- Drainage Pipes
- Key Locations
- Stoughton Border

2-Hour, 10-Year 2070 Storm
MAXDEPTH
- Dry
- < 1.0 ft
- < 2.0 ft
- < 3.0 ft
- > 3.0 ft
- Road Extent

N

0 0.05 0.1 0.19 Miles

Date: 6/28/2023 User: SBryant Path: \\azrgisstorp01\GIS_Projects\Client\MA_Stoughton\StormwaterMVP\Year 1 Flood Maps\Stoughton Year 1 Maps\Stoughton Year 1 Maps.aprx

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	CREATED: 6/28/2023		**12**
	CREATED BY: SPB		
	CHECKED BY: DTP		
	FILE NAME: Stoughton Year 1 Maps.mxd	Stoughton MVP Flood Resiliency Project	

Appendix D: Alternative Analysis Prioritization Maps

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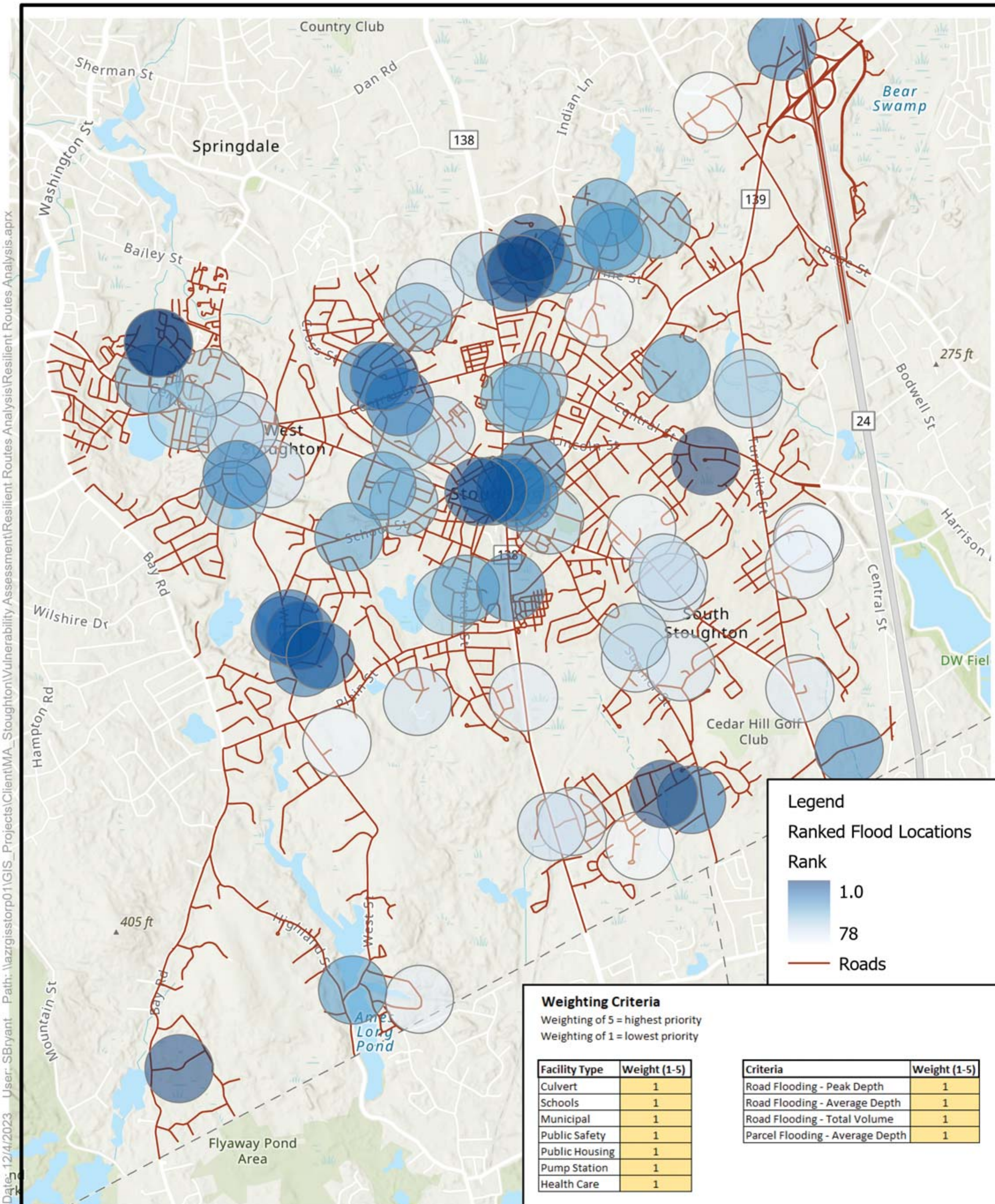

Weighting Criteria

Weighting of 5 = highest priority
Weighting of 1 = lowest priority

Facility Type	Weight (1-5)
Culvert	1
Schools	1
Municipal	1
Public Safety	1
Public Housing	1
Pump Station	1
Health Care	1

Criteria	Weight (1-5)
Road Flooding - Peak Depth	1
Road Flooding - Average Depth	1
Road Flooding - Total Volume	1
Parcel Flooding - Average Depth	1

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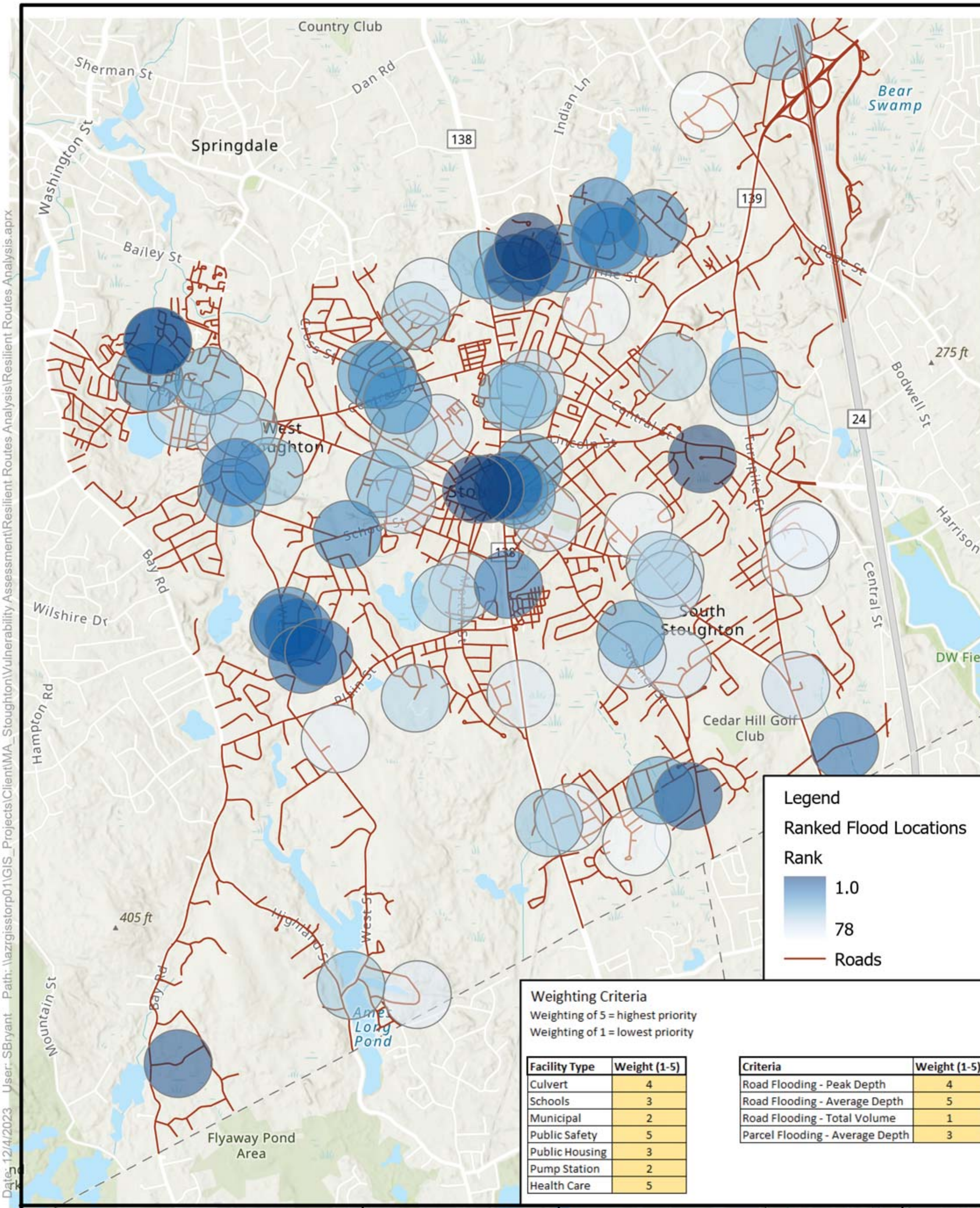
FILE NAME:	Resilient Routes Analysis.mxd

Stoughton Flood Vulnerability Critical Location Risk Assessment

0 0.25 0.5 1
Miles
N

FIGURE
1



Weighting Criteria

Weighting of 5 = highest priority
Weighting of 1 = lowest priority

Facility Type	Weight (1-5)
Culvert	4
Schools	3
Municipal	2
Public Safety	5
Public Housing	3
Pump Station	2
Health Care	5

Criteria	Weight (1-5)
Road Flooding - Peak Depth	4
Road Flooding - Average Depth	5
Road Flooding - Total Volume	1
Parcel Flooding - Average Depth	3

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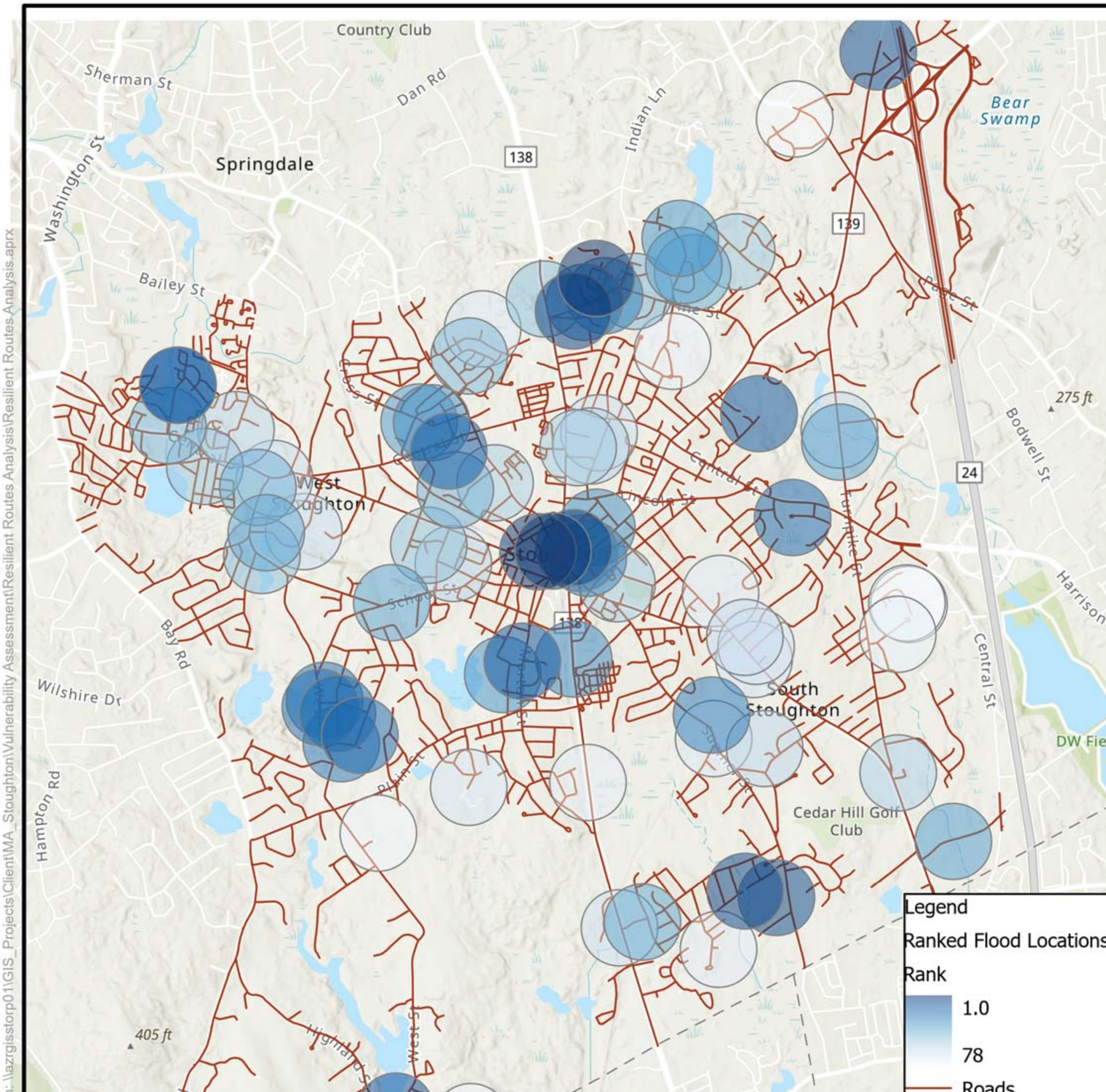
FILE NAME:	Resilient Routes Analysis.mxd

Stoughton Flood Vulnerability Critical Location Risk Assessment

0 0.25 0.5 1
Miles
N

FIGURE
1



Weighting Criteria

Weighting of 5 = highest priority

Weighting of 1 = lowest priority

Facility Type	Weight (1-5)
Culvert	2
Schools	3
Municipal	2
Public Safety	5
Public Housing	2
Pump Station	4
Health Care	5

Criteria	Weight (1-5)
Road Flooding - Peak Depth	5
Road Flooding - Average Depth	3
Road Flooding - Total Volume	3
Parcel Flooding - Average Depth	1

Date: 12/15/2023 User: SBryant Path: \\azrgisstorp01\GIS_Projects\Client\MA_Stoughton\Vulnerability Assessment\Resilient Routes Analysis\Resilient Routes Analysis.aprx

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CREATED:	12/15/2023
CREATED BY:	SPB
CHECKED BY:	DTP
FILE NAME:	Resilient Routes Analysis.mxd

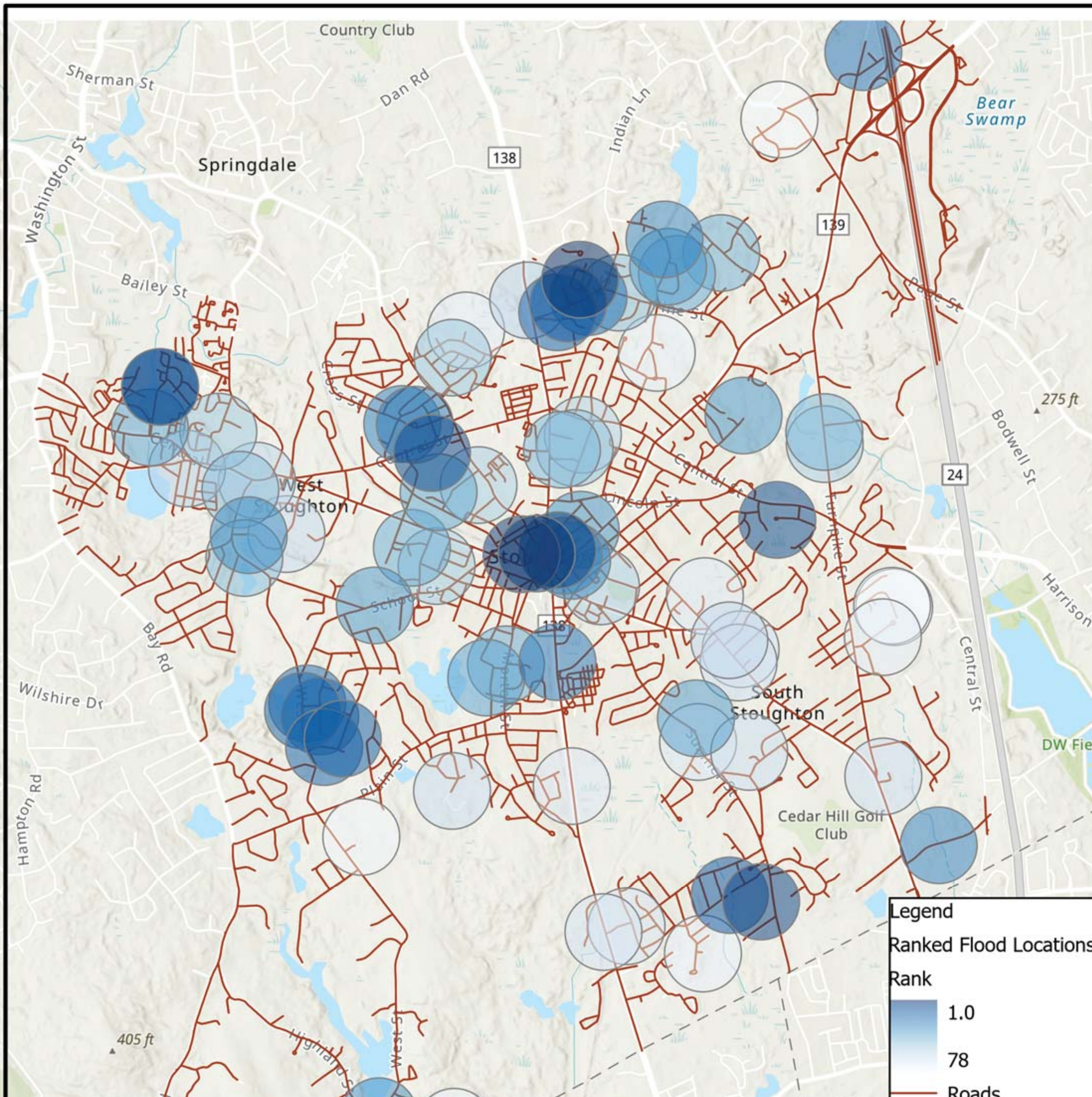
Stoughton Flood Vulnerability Critical Location Risk Assessment

0 0.25 0.5 1
Miles

N

FIGURE

1



Weighting Criteria

Weighting of 5 = highest priority
Weighting of 1 = lowest priority

Facility Type	Weight (1-5)
Culvert	3
Schools	4
Municipal	2
Public Safety	5
Public Housing	3
Pump Station	3
Health Care	5

Criteria	Weight (1-5)
Road Flooding - Peak Depth	3
Road Flooding - Average Depth	5
Road Flooding - Total Volume	2
Parcel Flooding - Average Depth	1

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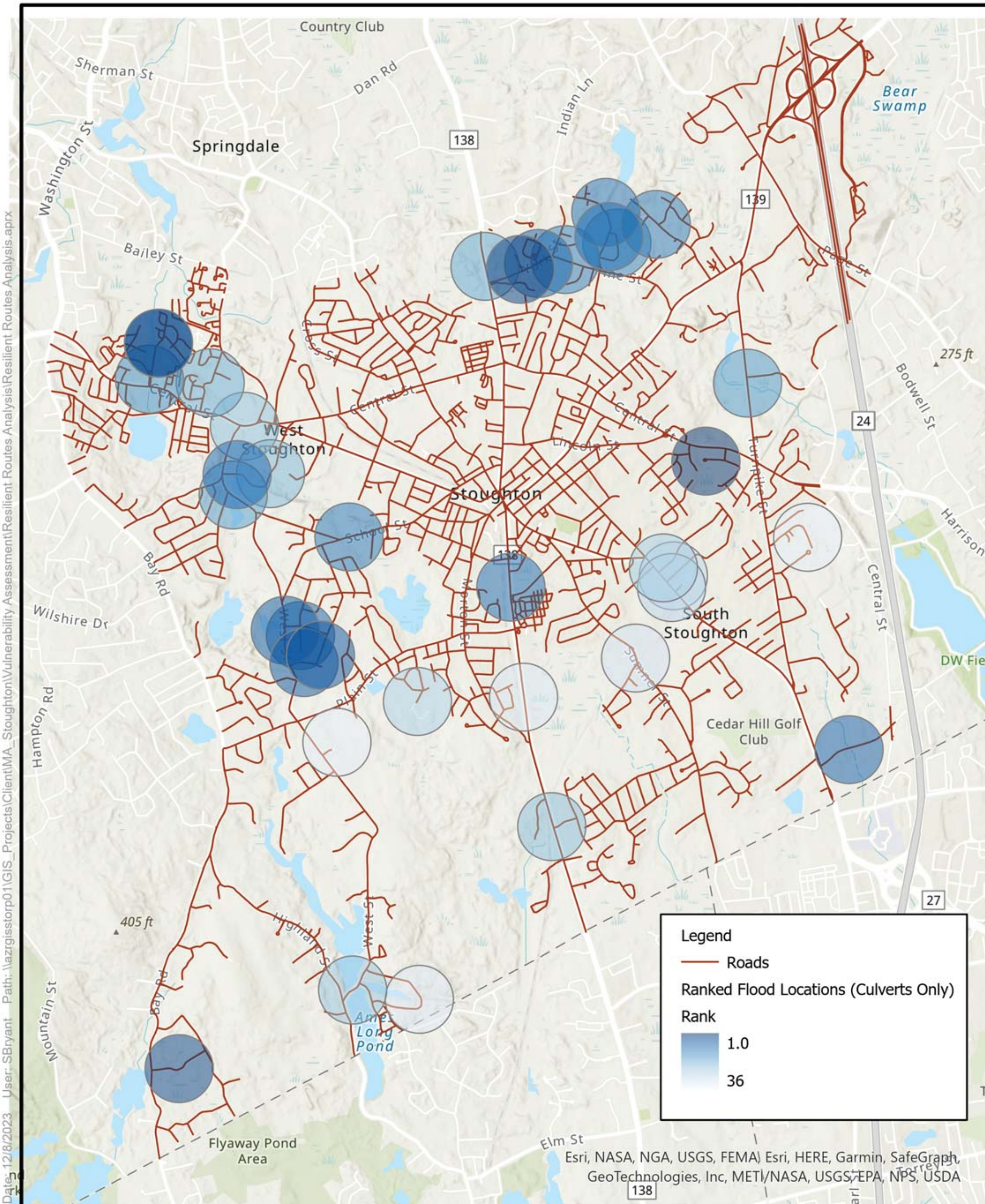
FILE NAME:	Resilient Routes Analysis.mxd

Stoughton Flood Vulnerability Critical Location Risk Assessment

0 0.25 0.5 1
Miles
N

FIGURE
1



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FILE NAME:	Resilient Routes Analysis.mxd

Stoughton Flood Vulnerability Critical Location Risk Assessment

0 0.25 0.5 1
Miles
N

FIGURE
1

Appendix E: Alternatives Cost Estimates

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York Street Alternative 1 - Culvert Replacement

ENR Index = 13,546.80

Item	Unit	Unit Price	Quantity	Cost	Notes
Pre-cast culvert	LS	$ 380,000	2	$ 760,000	Includes furnishing and installation of all materials related to structure
Sub Base	CY	$ 85.00	111	$ 9,444	
Binder Course	TON	$ 350.00	48	$ 16,917	Assumes 2.5" thickness
Surface Course	TON	$ 350.00	29	$ 10,150	Assumes 1.5" thickness
Pavement Removal	SY	$ 33.00	333	$ 11,000	
Excavation	CY	$ 75.00	889	$ 66,667	Higher cost for excavation over a waterway
Traffic Management	LS	$ 20,000	1	$ 20,000	

Subtotal	$ 894,178
Contingency (50% total)	$ 447,089
Mobilization (5% total)	$ 67,063
ESDC (15% total)	$ 201,190
Engineering (10% total)	$ 134,127
Total Cost	**$ 1,743,647**

York Street Alternative 2 - Detention Basin

ENR Index = 13,546.80

Item	Unit	Unit Price	Quantity	Cost	Notes
Excavation	CY	$ 50.00	11,852	$ 592,593	
Tree Removal	Ea	$ 2,800	20	$ 56,000	Includes full tree and stump removal
Outlet Structure	Ea	$ 30,000	1	$ 30,000	
Grading	SY	$ 20.00	8,889	$ 177,778	
Drain Line (24")	LF	$ 350.00	650	$ 227,500	Includes excavation, installation, and backfill
Surface Restoration	SY	$ 20.00	8,889	$ 177,778	Includes wetland vegetation planting

Subtotal	$ 1,261,648
Contingency (50% total)	$ 630,824
Mobilization (5% total)	$ 94,624
ESDC (15% total)	$ 283,871
Engineering (10% total)	$ 189,247
Total Cost	**$ 2,460,214**

Downtown Alternative 1 - Drainage Infrastructure Improvements

ENR Index = 13,546.80

Item	Unit	Unit Price	Quantity	Cost	Notes
18" Drainage Pipes	LF	$ 400	247	$ 98,800	Cost includes excavation, installation, and backfill
30" Drainage Pipes	LF	$ 275	1,517	$ 417,175	Cost includes excavation, installation, and backfill
Pavement Removal	SY	$ 33	855	$ 28,200	
Crushed Stone Sub Base	CY	$ 85	282	$ 23,970	
Binder Course	TON	$ 350	124	$ 43,369	Assumes 2.5" thickness
Surface Course	TON	$ 350	74	$ 26,023	Assumes 1.5" thickness
Pre-cast Manhole	Ea	$ 6,500	18	$ 117,000	
Catch Basins	Ea	$ 6,000	18	$ 108,000	

Traffic Management	LS	$ 100,000	1	$ 100,000	
Utility Coordination	LS	$ 150,000	1	$ 150,000	

Subtotal	$ 1,112,536
Contingency (50% total)	$ 556,268
Mobilization (5% total)	$ 83,440
ESDC (15% total)	$ 250,321
Engineering (10% total)	$ 166,880
Total Cost	**$ 2,169,446**

Downtown Alternative 2 - Underground Storage

ENR Index = 13,546.80

Item	Unit	Unit Price	Quantity	Cost	Notes
Pavement Removal	SY	$ 33.00	1,667	$ 55,000	
Excavation	CY	$ 50.00	4,444	$ 222,200	
Storage System	CF	$ 20.15	60,000	$ 1,209,000	Includes tank, crushed stone base, geotextiles, outlet structure, installation
Sub Base	CY	$ 85.00	556	$ 47,222	
Binder Course	TON	$ 350.00	242	$ 84,583	Assumes 2.5" thickness
Surface Course	TON	$ 350.00	145	$ 50,750	Assumes 1.5" thickness

Subtotal	$ 1,668,756
Contingency (50% total)	$ 834,378
Mobilization (5% total)	$ 125,157
ESDC (15% total)	$ 375,470
Engineering (10% total)	$ 250,313
Total Cost	**$ 3,254,073**

Ames-Long Pond Alternative 1 - Culvert Replacement

ENR Index = 13,546.80

Item	Unit	Unit Price	Quantity	Cost	Notes
Pre-cast culvert	LS	$ 495,000.00	2.0	$ 990,000.00	Includes furnishing and installation of all materials related to structure
Sub Base	CY	$ 85.00	44.44	$ 3,777.78	
Binder Course	TON	$ 350.00	19.33	$ 6,766.67	Assumes 2.5" thickness
Surface Course	TON	$ 350.00	11.60	$ 4,060.00	Assumes 1.5" thickness
Pavement Removal	SY	$ 33.00	133	$ 4,400.00	
Excavation	CY	$ 75.00	444	$ 33,333.33	Higher cost for excavation over a waterway
Traffic Management	LS	$ 10,000.00	1.0	$ 10,000.00	
Flow Management and Bypass	LS	$ 200,000.00	1.0	$ 200,000.00	Sheet piling / management of upper pond water during construction

Subtotal	$ 1,252,337.78
Contingency (50% total)	$ 626,168.89
Mobilization (5% total)	$ 93,925.33
ESDC (15% total)	$ 281,776.00
Engineering (10% total)	$ 187,850.67
Total Cost	**$ 2,442,058.67**

Ames-Long Pond Alternative 2 -Causeway Raising

ENR Index = 13,546.80

Item	Unit	Unit Price	Quantity	Cost	Notes
Causeway Fill	CY	$ 400.00	5185	$ 2,074,000.00	
Pre-cast culvert	LS	$ 495,000.00	2	$ 990,000.00	Includes furnishing and installation of all materials related to structure
Excavation	CY	$ 75.00	444	$ 33,333.33	
Sub Base	CY	$ 85.00	1481	$ 125,925.93	
Binder Course	TON	$ 350.00	483	$ 169,166.67	Assumes 2.5" thickness
Surface Course	TON	$ 350.00	290	$ 101,500.00	Assumes 1.5" thickness
Pavement Removal	SY	$ 33.00	3333	$ 110,000.00	
Traffic Management	LS	$ 50,000.00	1	$ 50,000.00	
Flow Management and Bypass	LS	$ 200,000.00	1	$ 200,000.00	Sheet piling / management of upper pond water during construction

Subtotal	$ 3,853,925.93
Contingency (50% total)	$ 1,926,962.96
Mobilization (5% total)	$ 289,044.44
ESDC (15% total)	$ 867,133.33
Engineering (10% total)	$ 578,088.89
Total Cost	**$ 7,515,155.56**