City of Lowell

Claypit Brook

Climate Resilience Stormwater Management Capital Improvement Plan

THE CITY OF LOWELL
THERE'S A LOT TO *like*

MVP
Municipal Vulnerability Preparedness

Weston & Sampson℠

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Weston & Sampson

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A special thanks to the interviewees who shared their local expertise and input

- Lisa Demeo
- Deb Forgione
- John Hamblin
- Mark Young

Thank you to the Lowell Sustainability Council and the Pawtucketville Citizens Council for their engagement in this effort. **Thank you also the community members** who shared their experiences and provided feedback on the project.

Executive Summary

The City of Lowell is dedicated to reducing the impacts of climate change to the City's infrastructure, natural features, and vulnerable populations. In particular, Lowell is impacted by flooding from extreme precipitation, which is expected to worsen with climate change.

Stormwater flooding is particularly prevalent in areas with poor drainage, large amounts of impervious surfaces, and undersized culverts. Therefore, the City of Lowell sought a Municipal Vulnerability Preparedness (MVP) Action Grant to develop a Climate Resilience Stormwater Management Capital Improvement Plan (CIP) for Claypit Brook. This CIP is a roadmap to assist the City with priority setting, fiscal analysis, and efforts to obtain additional funding. The projects listed in this CIP are not guaranteed to be funded or implemented. This CIP should be updated annually as priorities, needs, and funding opportunities evolve.

Chronic stormwater flooding caused by drainage deficiencies plagues Pawtucketville, an Environmental Justice neighborhood near Claypit Brook. The proposed plan comprehensively assessed the watershed's drainage, culvert conditions, and known flooding conditions. The project team completed preliminary design of the highly vulnerable Stockbridge Avenue culvert, and identified nature based solutions to supply drainage to handle future extreme precipitation events in the Claypit Brook Watershed. This project increases the resilience of the City's infrastructural, environmental, and societal features through proactive stormwater management and equitable public engagement.

Massachusetts Municipal Vulnerability Preparedness

Lowell completed an MVP Planning Grant that accomplished the following:

- Defined the City's climate hazards
- Identifed community vulnerabilities and strengths
- Developed a plan to increase resilience

The MVP Action Grant included:

- Identifying priority adaptation actions for implementation
- Continuing outreach and engagement with the public
- Advancing the City's understanding of its climate vulnerability

Project Components

1 Equitable Community Engagement

2 Field Conditions and Stream Assessment

3 Hydraulic & Hydrologic Model of Current and Future Flood Conditions

4 Identification & Prioritization of Green Infrastructure Opportunities

5 25% Design of Culvert at Stockbridge Avenue

6 Development of Stormwater Capital Improvement Plan (CIP)

Image from the stream assessment in March 2021

Image from the stream assessment in March 2021

Project Goals

The City of Lowell is already experiencing the impacts of climate change. Extreme rain events are becoming increasingly intense and frequent, particularly in the Northeast region of the country. Historically, **precipitation during heavy events in the Northeast increased by more than 70% between 1958 and 2010.** This project aims to reduce the negative impacts of climate change on the Claypit Brook Watershed and neighborhood. Project goals include those listed below.

Identify nature-based solutions to handle future extreme precipitation events in the Claypit Brook Watershed

Complete a preliminary design of the Stockbridge Avenue culvert

Stormwater Assessment

This plan comprehensively assessed the watershed's:

1. **Drainage conditions**
2. **Stream conditions**
3. **Culvert condition**
4. **Current and future flood conditions**

The Claypit Brook Watershed

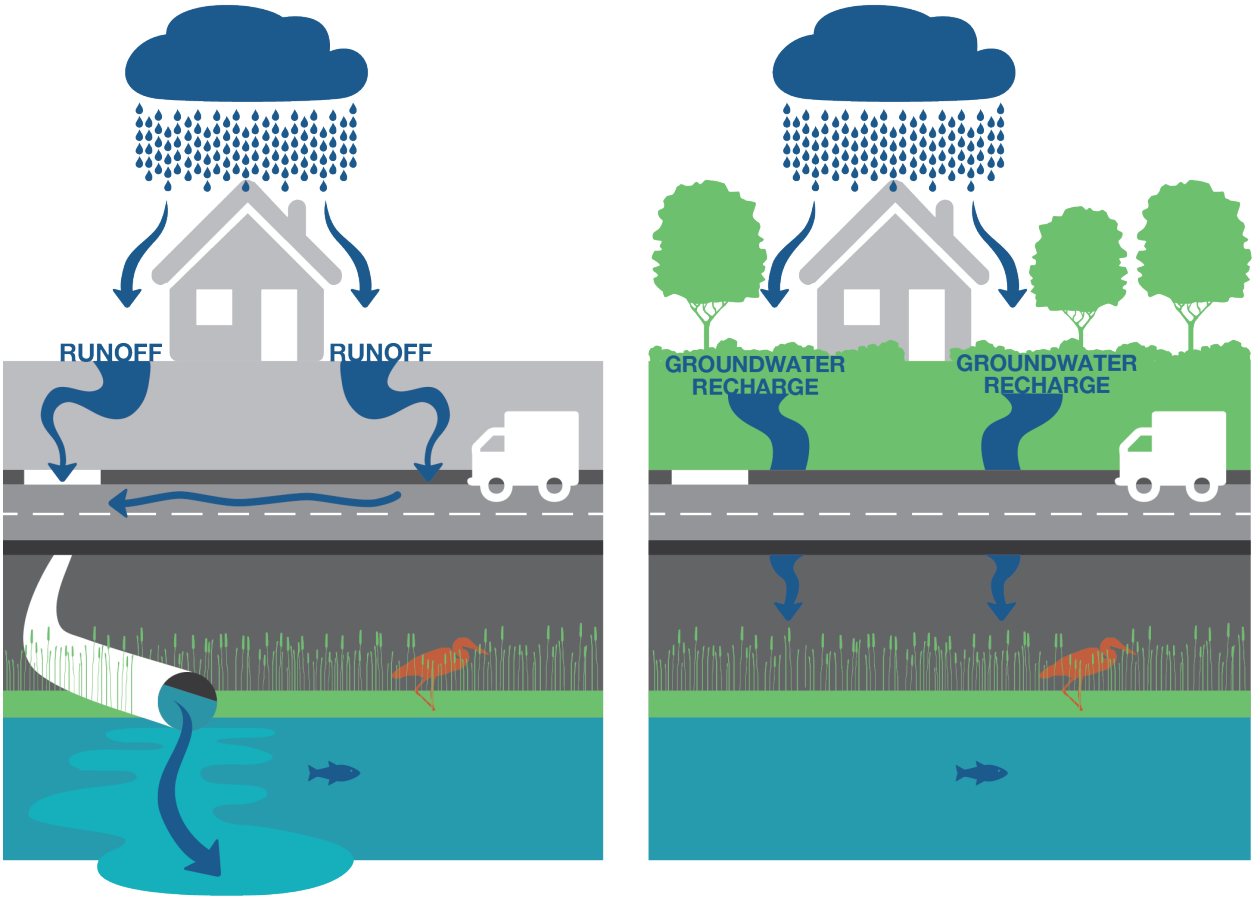
Claypit Brook is a partially urban waterbody system that courses through the historic Pawtucketville neighborhood of Lowell. Its headwaters originate in the Lowell-Dracut-Tyngsborough State Forest flowing south through a series of streams, forested wetlands, and ponds caused by natural impoundments and roadway culverts. After passing under Varnum Ave near Totman Road, the brook crosses several residential neighborhoods before outfalling into the Merrimack River near Lowell General Hospital. At a lower elevation than the River, the Brook floods before the riverbank, causing flooding throughout the low-lying neighborhoods. Due to the saturated water table, many residents experience perpetual groundwater flooding. One resident stated that, while one sump pump adequately handled standing water in their basement years ago, they need three pumps working simultaneously to handle the water in 2021.

Nuisance flooding is not the only type of flooding to impact the community. Two consecutive stormwater floods severely impacted the neighborhood in 2006 and 2007. During the 2006 flood, nearly 200 homes were impacted. Even more severe was the flood of 1936, which caused 153 deaths and over $200 million in damages.

8%
Increase in extreme precipitation events by midcentury

13%
Increase in extreme precipitation events by end of century

The map to the left illustrates the extents of the Claypit Brook Watershed and its subcatchment delineations.The brook is indicated in blue.



What is stormwater?

Stormwater is rain or snowmelt that soaks into the ground, drains into nearby waterbodies, or is conveyed through a series of pipes and released into a waterbody.

What is stormwater flooding?

Stormwater flooding occurs in areas with poor drainage, large amounts of impervious surfaces, and undersized culverts when the amount of stormwater overwhelms the existing system.

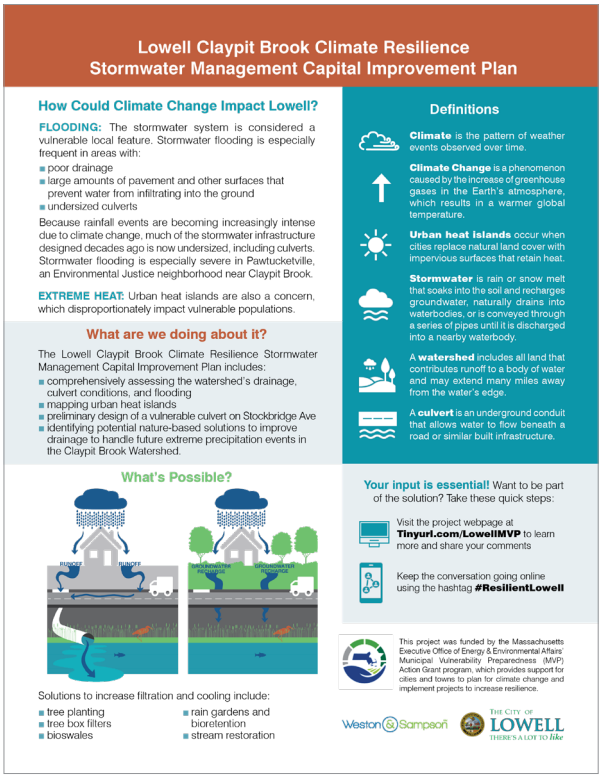
Photos of the 2006 Mother's Day Flood and evacuation in the Pawtucketville neighborhood

Community Engagement

Many residents in the Pawtucketville area have already experienced severe and repetitive flood events. Understanding their concerns and priorities contributed to the development of the Capital Improvement Plan. Engagement conducted during this project included:

- **community meetings**
- **a public survey in four languages**
- **a fact sheet in four languages**
- **in-depth interviews with local stakeholders**

> "In 2006 and 2007, floods damaged more than 70 homes in my neighborhood. Residents were forced to evacuate in the middle of the night and were relocated for up to a month after the flood."
>
> *- Survey respondent*



Lowell Claypit Brook Climate Resilience
Stormwater Management Capital Improvement Plan

How Could Climate Change Impact Lowell?

FLOODING: The stormwater system is considered a vulnerable local feature. Stormwater flooding is especially frequent in areas with:

- poor drainage
- large amounts of pavement and other surfaces that prevent water from infiltrating into the ground
- undersized culverts

Because rainfall events are becoming increasingly intense due to climate change, much of the stormwater infrastructure designed decades ago is now undersized, including culverts. Stormwater flooding is especially severe in Pawtucketville, an Environmental Justice neighborhood near Claypit Brook.

EXTREME HEAT: Urban heat islands are also a concern, which disproportionately impact vulnerable populations.

What are we doing about it?

The Lowell Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan includes:

- comprehensively assessing the watershed's drainage, culvert conditions, and flooding
- mapping urban heat islands
- preliminary design of a vulnerable culvert on Stockbridge Ave
- identifying potential nature-based solutions to improve drainage to handle future extreme precipitation events in the Claypit Brook Watershed.

What's Possible?

Solutions to increase filtration and cooling include:

- tree planting
- tree box filters
- bioswales
- rain gardens and bioretention
- stream restoration

Definitions

Climate is the pattern of weather events observed over time.

Climate Change is a phenomenon caused by the increase of greenhouse gases in the Earth's atmosphere, which results in a warmer global temperature.

Urban heat islands occur when cities replace natural land cover with impervious surfaces that retain heat.

Stormwater is rain or snow melt that soaks into the soil and recharges groundwater, naturally drains into waterbodies, or is conveyed through a series of pipes until it is discharged into a nearby waterbody.

A **watershed** includes all land that contributes runoff to a body of water and may extend many miles away from the water's edge.

A **culvert** is an underground conduit that allows water to flow beneath a road or similar built infrastructure.

Your input is essential! Want to be part of the solution? Take these quick steps:

Visit the project webpage at **Tinyurl.com/LowellMVP** to learn more and share your comments

Keep the conversation going online using the hashtag **#ResilientLowell**

This project was funded by the Massachusetts Executive Office of Energy & Environmental Affairs' Municipal Vulnerability Preparedness (MVP) Action Grant program, which provides support for cities and towns to plan for climate change and implement projects to increase resilience.

Weston & Sampson

The City of LOWELL There's a lot to like

What we heard from survey participants:

- **71%** of survey respondents live in Pawtucketville
- **65%** of resondents own a home in Lowell
- **Almost one-third (28%)** of respondents have experienced flooding on their street
- **75%** of respondents would like to see stream restoration in Claypit Brook

Interviewees were concerned with:

- Property damage and displacement after flood events
- Cost of flood insurance premiums. Many residents do not have flood insurance
- Groundwater flooding and the need for residents to continually run sump pumps
- Public health risks post-flooding, including mold and impacts to foundations
- Having adequate flood protection measures at a neighborhoood and regional scale

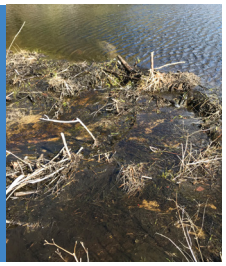
Stream Assessment

To reduce the impacts of climate change in and around Claypit Brook, an assessment of the existing conditions of the brook was conducted. Understanding existing conditions provided a basis for recommending improvements to the stream for current and future climates. Weston & Sampson performed a stream and culvert assessment along Claypit Brook on March 29th and 30th, 2021. The goal of this assessment was to document the existing conditions of Claypit Brook, and to identify deficiencies that can be used to inform a list of recommended improvements. The stream was assessed for the following conditions, shown below, which each impact the health and flow of the stream.

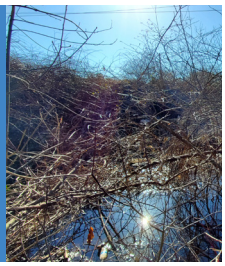
Stream Improvement	Quantity
Bank stabilization	300 linear feet
Beaver dam evaluation and mitigation	16 beaver dams
Debris removal	20 fallen trees
Overgrowth removal	1,764 linear feet
Sediment removal	10,720 cubic feet

Findings from the 2.5 mile stream assessment

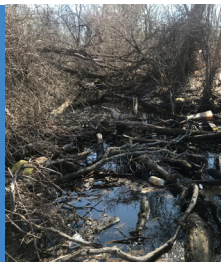
sediment build-up



vegetative overgrowth

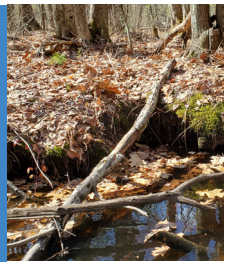


debris in stream



culvert conditions

bank erosion



beaver dams

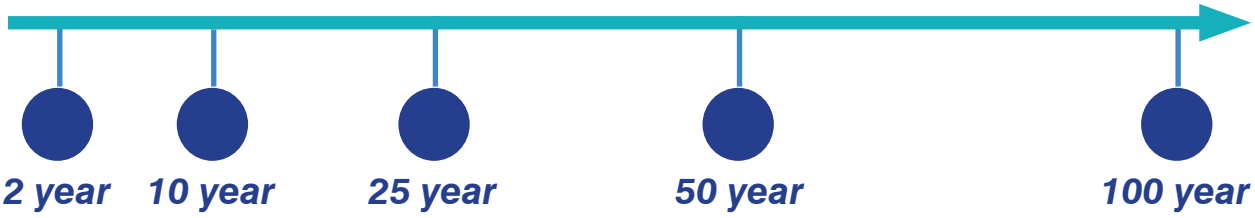
Hydraulic and Hydrologic Model

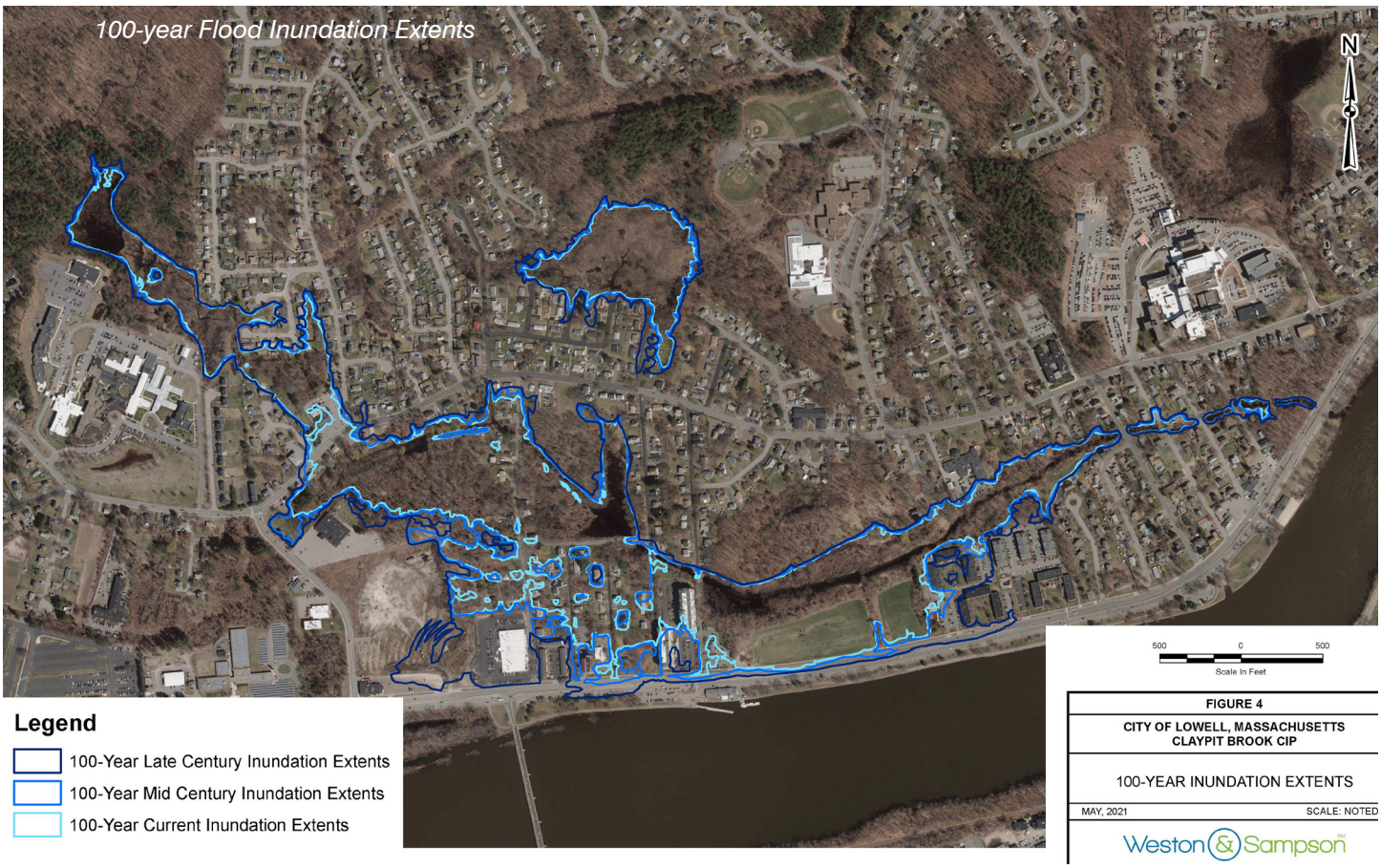
An H&H model is a computer model that simulates how rainfall runoff flows through the piped and natural stormwater system.

The H&H model developed for this project identified:

- **Current stormwater conditions**
- **Future stormwater conditions**
- **How green infrastructure strategies can reduce stormwater run-off**

Three scenarios were modeled, including current conditions, mid-century, and late-century conditions. Additionally, the storm events shown in the timeline diagram below were assessed.





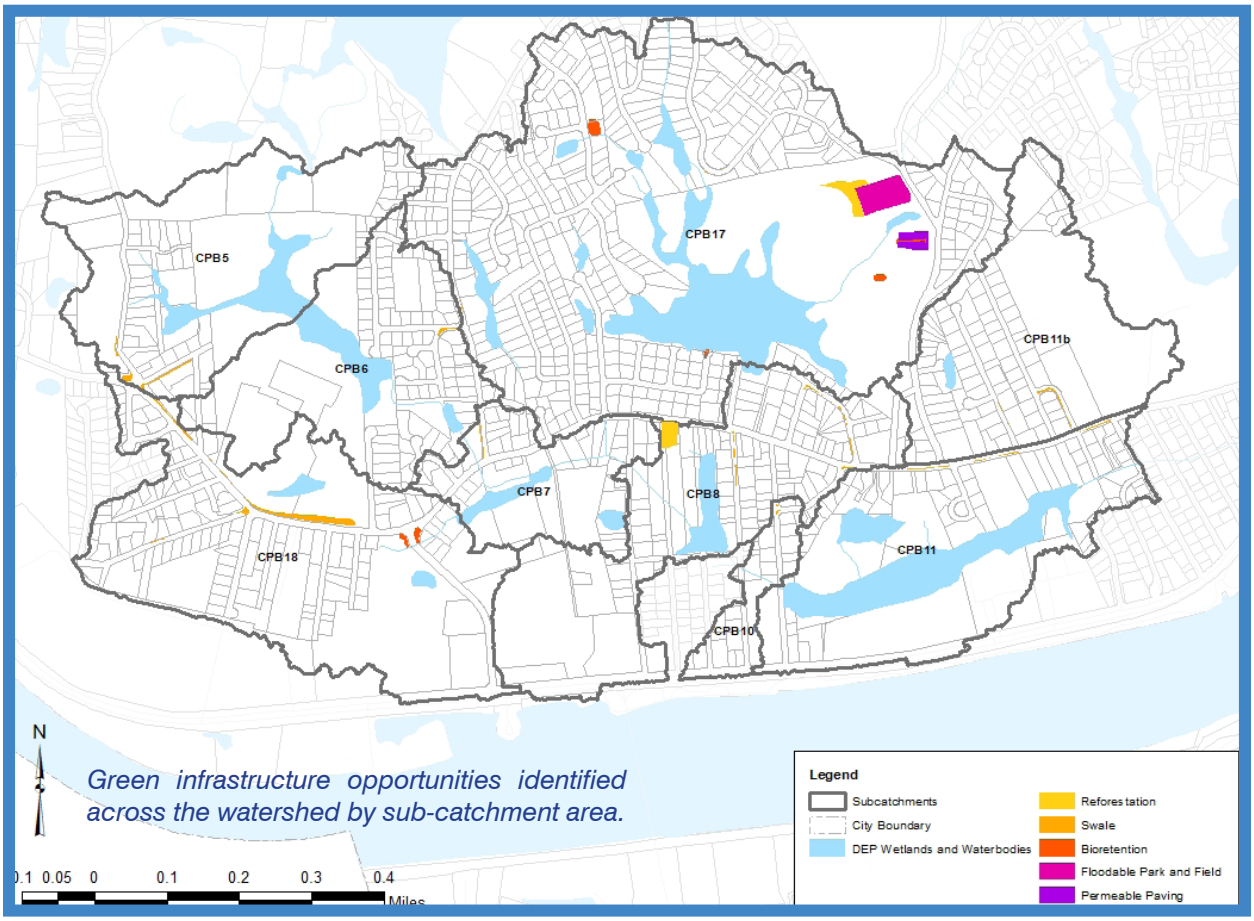
Green Infrastructure Identification

What is green infrastructure?

A range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters.
- Clean Water Act

There are two types of stormwater drainage – grey infrastructure and green infrastructure. **Grey infrastructure** consists of inlets, gutters, drains, and underground pipes that whisk water away to the nearest waterbody. **Green infrastructure** opportunities were identified considering the topography of the neighborhood, water flow, flood probability and depth, property ownership, and feasibility of implementation.

The opportunities identified represent various types of projects that can function independently or work together as a surface system of stormwater management. These types of smaller nature-based interventions also provide co-benefits to the community, like contributions to the public realm and placemaking, creating healthier spaces, and broadening ecosystem services and biodiversity. The impacts of the identified projects were modeled as part of the larger Hydraulic & Hydrologic (H&H) model and based on increased storage capacity and reduced impervious area within subcatchments. The effect of green infrastructure on urban heat reduction was also measured based on reduced impervious surfaces and increased canopy coverage.



Green infrastructure opportunities identified across the watershed by sub-catchment area.

Capital Improvement Plan Example Schedules

The Department of Public Works regularly completes capital improvements and operation and maintenance of the City's stormwater infrastructure. Financial planning and the creation of this capital improvement plan will allow for the allocation of internal resources to complete projects by providing a roadmap to focus efforts on high priority actions. This capital improvement plan is a living document and should be periodically reviewed and updated as new project priorities arise and as new information becomes available. The CIP serves as a roadmap for informing implementation when feasible for the City to do so and is not a set commitment to a particular timeframe for completing implementation of the priority actions.

The project team has identified immediate and long-term needs, solutions, and implementation cost. The priority projects in this capital improvement plan includes those related to green infrastructure, reforestation and tree planting, increased flood storage, culvert improvements, and stream improvements.

The following tables lay out the first two years of the Capital Improvement Plan over a five- and fifteen-year schedule. The five-year schedule depicts approximately one million in capital improvements annually, while the 15-year schedule depicts approximately 250,000-500,000 annual spending. The full five-year and fifteen-year CIP schedules can be found in Appendix C.

15-year Capital Improvement Plan

Year	Category	Action	Cost
1	Culvert Project	Varnum Ave	$10,000
1	Culvert Project	Stockbridge Ave	$534,000
Year 1 Total			$544,000
2	Green Infrastructure	Detention - Varnum Ave (Subcatchment: CPB8)	$150,000
2	Green Infrastructure	UHI - Increase Canopy (Subcatchment: CPB17)	$150,000
2	Flood Storage	Scenario 3	$30,000
Year 2 Total			$330,000
3	Culvert Project	Lexington Ave	$500,000
Year 3 Total			**$500,000**

5-year Capital Improvement Plan

Year	Category	Action	Cost
1	Green Infrastructure	Detention - Varnum Ave (Subcatchment: CPB8)	150,000
1	Green Infrastructure	Reforestation (Subcatchment: CPB17)	150,000
1	Flood Storage	Scenario 3	30,000
1	Culvert Project	Varnum Ave	10,000
1	Culvert Project	Stockbridge Ave	534,000
1	Culvert Project	Lexington Ave	500,000
Year 1 Total			**1,374,000**
2	Green Infrastructure	Detention Basin - Newbridge Road (Subcatchment: CPB17)	150,000
2	Green Infrastructure	Floodable Field - Gumpus Road (Subcatchment: CPB17)	150,000
2	Green Infrastructure	Swale - Retirement Community (Sub-catchment: CPB18)	150,000
2	Green Infrastructure	Swale - Varnum Ave (Sub-catchment: CPB18)	100,000
2	Green Infrastructure	Detention Basin - Dr. An Wang Middle School (Subcatchment: CPB17)	150,000
2	Culvert Project	Embankment at end of Avalon St	20,000
2	Culvert Project	Malden Ave	500,000
Year 2 Total			**1,220,000**
3	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11b)	100,000
3	Green Infrastructure	Swale - Old Ferry Road (Subcatchement: CPB18)	100,000
3	Green Infrastructure	Swale - Meadowview Dr (Subcatchment: CPB8)	30,000
3	Green Infrastructure	Swale - Jennifer Road (Subcatchment: CPB8)	20,000
3	Green Infrastructure	Swale - Meadowview Drive (Subcatchment: CPB8)	20,000
3	Green Infrastructure	Swale - Meadowview Drive (Subcatchment: CPB8)	20,000
3	Green Infrastructure	Swale - Meadowview Dr (Subcatchment: CPB8)	20,000
3	Green Infrastructure	Swale - Lexington Ave (Subcatchment: CPB8)	100,000
3	Flood Storage	Scenario 1	20,000
3	Flood Storage	Scenario 2	20,000
3	Culvert Project	Magnolia St	500,000
Year 3 Total			950,000

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1.0 Introduction

Project Background

The City of Lowell is already experiencing the impacts of climate change. Heavy precipitation and flooding were among the four main hazards discussed by stakeholders during Lowell's virtual Community Resilience Building (CRB) Workshop webinars as part of the preparation of the 2020 Municipal Vulnerability Preparedness and Hazard Mitigation Plan (MVP-HMP). Changes in precipitation can cause several impacts locally, including flooding, property damage, and increased road pollutants in waterbodies. There are two types of flooding experienced in Lowell that are intricately related: riverine flooding and stormwater flooding. Both are expected to worsen with climate change. Riverine flooding naturally occurs when waterbodies overtop their banks. This is natural and expected during large rain events such as the 100-year and 500-year flood. A 100-year flood has a 1% annual chance of occurring, while a 500-year flood has a 0.2% annual chance of occurring. It is anticipated that the annual occurrence percentage will increase overtime because of climate change.

Stormwater is rain or snowmelt that soaks into the soil and recharges groundwater, drains into a waterbody, or is channeled through a series of pipes until being released into a nearby waterbody. Therefore, stormwater flooding occurs when the piped system becomes overwhelmed or when water is too quickly released into waterbodies rather than retained onsite. This causes waterbodies to overtop their banks. Increased rates of streamflow from stormwater may also cause streambank erosion. Stormwater flooding can be caused by high amounts of impervious surfaces, insufficient stormwater detention and drainage, poor grading, or retaining walls and culverts in poor condition.

The health of Lowell's waterbodies can also play a role in flooding. When sediment builds up or vegetative debris collects, the functionality of the stream deteriorates and can contribute to localized stormwater flooding. Beaver dams can also cause flooding when dams create backwater effect.

Figure 1. FEMA FIRM Panels showing extent of floodplains near the confluence of Claypit Brook and the Merrimack River. Project boundary and brook are in yellow.

The City of Lowell is dedicated to reducing the impacts of climate change to the City's infrastructure, natural features, and vulnerable populations. Addressing the flood conditions in the Pawtucketville neighborhood and improving the area's resiliency was identified as a high priority in the 2020 MVP-HMP. Pawtucketville, an Environmental Justice neighborhood near Claypit Brook, chronically floods because of its the location within the floodplain and the drainage deficiencies of an aging system. Much of the low-lying neighborhood is within the Merrimack River 100-year and 500-year floodplains (see Figure 1). Because the neighborhood is at a lower elevation than the riverbank, the area suffers riverine flooding as well from overtopping. However, modeling indicates that flooding may also occur during the more frequent 10-year flood event, which may be caused by the stormwater system's deficiencies and land use patterns in the neighborhood.

Through this project, a stream assessment was conducted to better understand the health of the watershed and areas that could be improved or maintained to support water quality, flow, and mitigate flood impacts. Additionally, a hydrologic and hydraulic model was used to better understand current and future flood conditions in the watershed.

The project also analyzed urban heat island impacts citywide. Urban heat island refers to areas of the city which have a higher land surface temperature due to impervious and dark colored artificial surfaces, such as asphalt and land use patterns with significant amounts of development.

This project culminated in a Capital Improvement Plan (CIP) which was informed by the investigation of flooding in the neighborhood and lays out a framework for implementing climate resiliency projects throughout the Claypit Brook watershed. Recommendations include opportunities to implement new green infrastructure strategies and upgrade existing grey infrastructure.

There are two types of stormwater drainage – grey infrastructure and green infrastructure.

Grey infrastructure consists of inlets, gutters, drains, and underground pipes that whisk water away to the nearest waterbody. Grey infrastructure has been commonly used in the past, but many of the older systems have been designed with historic rainfall data that is no longer accurate.

Green infrastructure consists of nature-based and pervious solutions that allow stormwater to soak into the ground. Green infrastructure leads to better stormwater management and less flooding which contributes to the protection of residents without disrupting residential development patterns or requiring that homeowners make cost prohibitive adaptations to their properties.

This project was funded by the Massachusetts Municipal Vulnerability Preparedness Program (MVP). The MVP program funds planning grants, which focus on climate vulnerability assessments and goal setting, and actions grants, which focus on more detailed analysis and implementation of resilience projects. An MVP planning project was previously completed for Lowell. This project was funded with an action grant and moves the City closer to fulfilling its resilience goals by setting up a road map for future stormwater improvements grounded in real cost estimates and a detailed timeline for project completion.

Capital Improvement Plan Goals

The Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan set out to:

- Provide a clear understanding of the Claypit Brook stormwater drainage system under existing and future conditions
- Develop an action plan focused on the equitable implementation of climate resilience measures.
- Incorporate climate resiliency into the Stormwater Capital Improvement Plan and assess where green infrastructure and nature-base solutions can mitigate localized flooding.
- Provide benefits to the City through the avoided costs of flood damage and emergency repairs.
- Provide needed air temperature cooling in an urbanized community whose urban heat island effect is expected to intensify under climate change.

The CIP is a planning resource for the City informed by extensive analysis of the watershed. The CIP is living document which will likely evolve based on the City's ability to secure funding and build capacity for project implementation. The development of this document was an important first step for setting tangible goals and exploring project opportunities. Although the implementation of the CIP recommendations may not meet the timeline put forth, it is an important roadmap for the prioritization of projects when the City is capable.

Claypit Brook Overview

Claypit Brook is a, partially urban, waterbody system that runs for approximately 2.3 miles. Claypit Brook originates in a large wetlands complex within the Lowell-Dracut-Tyngsborough State Forest. The brook then courses through the historic Pawtucketville neighborhood before discharging into the Merrimack River near Lowell General Hospital. There are several pond-like areas throughout the watershed caused by natural impoundments and roadway culverts. The Claypit Brook watershed covers 1,344 acres or 9.5% of Lowell. (Figure 2).

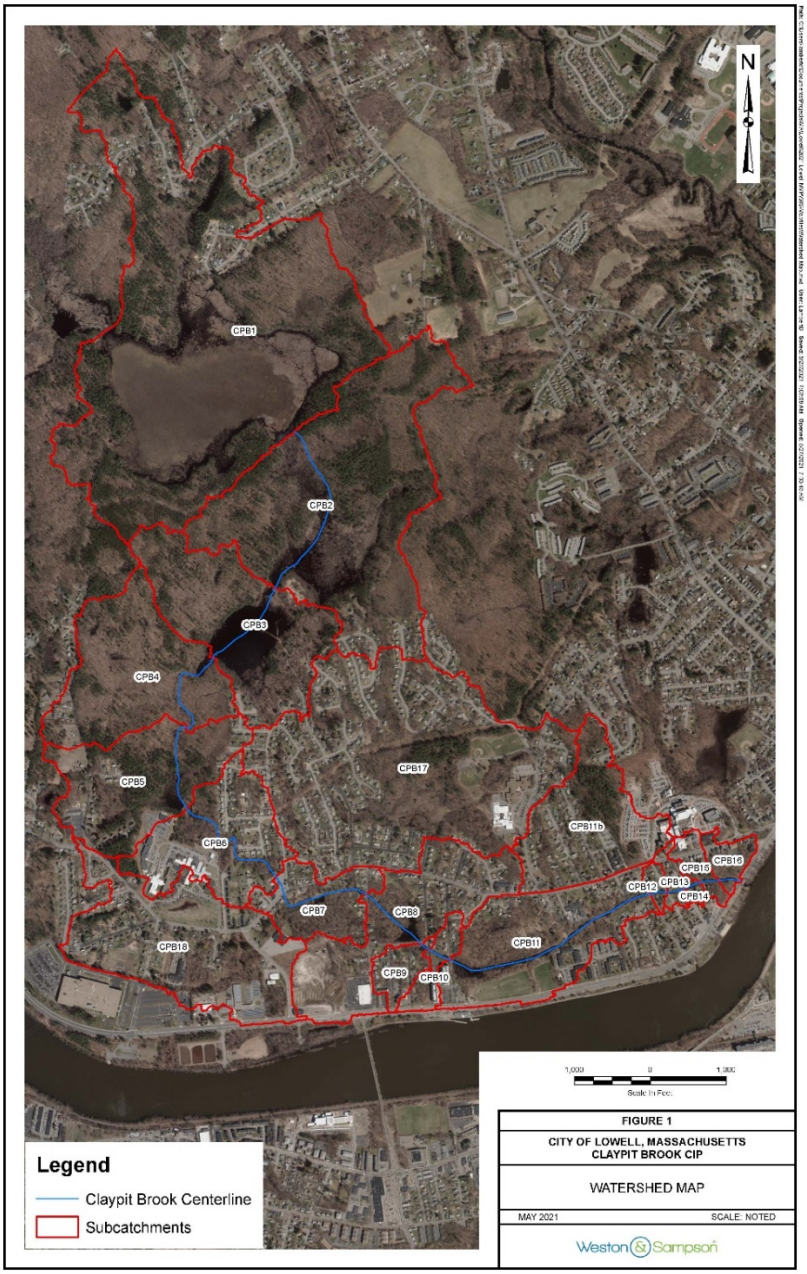


Figure 2. Extents of Claypit Brook Watershed. Source: Weston & Sampson

Neighborhood History

The Pawtucketville neighborhood and the Claypit Brook area are cherished by citizens of Lowell due to the residential/suburban nature, close-knit community, and proximity to the river walk and Lowell State Forest. The river walk is a great place for walking, biking, and enjoying nature and attracts visitors from around the region.

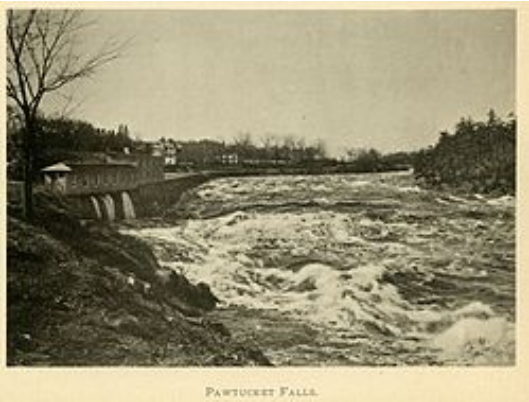


Figure 3. Historic Photo of Pawtucket Falls downstream of Claypit Brook

Pawtucketville is in the floodplain of the Merrimack River and the Claypit Brook tributary. Residents experience nuisance flooding in addition to severe repetitive flooding from these features. Two consecutive stormwater floods severely impacted the neighborhood in 2006 and 2007. During the 2006 flood, nearly 200 homes were impacted. Even more severe was the flood of 1936 which caused 153 deaths and over 200 million dollars in damages.[1] Due to the saturated water table, many residents experience perpetual groundwater flooding. One resident stated that while years ago one sump pump adequately handled standing water in their basement, as of 2021, they need three pumps working simultaneously to handle the water.

There is a strong community network in the neighborhood, and residents look out for one another when preparing for and recovering from a flood event. During the 2006 flood, Deb Forgione, the leader of the Pawtucketville Citizen's Council and longtime resident of the neighborhood, said the fire department knocked on her door at 2 am telling her that she must evacuate. Many residents were displaced from their homes over a month or more due to the substantial damages to their foundations and first floors. Those without another place to stay, stayed in their second stories until

Figure 4. 2006 Mother's Day flood and evacuation in Pawtucketville

[1] Mayer-Hohdahl, A. (2006, May 16). Folks who were there say '36 flood was worse. The Lowell Sun. Retrieved from https://www.lowellsun.com

the repairs were complete. Deb said that the neighborhood came together to support one another through the recovery process. However, many residents were still financially burdened by the event. There are many multi-generational residents in Pawtucketville who have owned their homes for many years, and no longer have a mortgage. Only homes with mortgages are required to have insurance through FEMA's National Flood Insurance Program. Due to the significant cost of insurance premiums, many residents were left without financial support to cover the cost of damages.

Land use patterns and the age and capacity of the stormwater system also impact flooding in the neighborhood. Pawtucketville has a significant amount of development and impervious surfaces that contribute to higher runoff volumes that are conveyed through traditional stormwater drainage to protect streets, residents, and businesses from flooding. To best manage the increase of stormwater a combination of drainage solutions should be utilized. Green infrastructure can reduce flooding by intercepting stormwater runoff, helping to reduce peak flows and alleviating stresses on existing grey infrastructure systems.

The residential nature of the Pawtucketville neighborhood does not necessarily negatively impact the stormwater conditions of the area. However, regional development trends contribute to the introduction of more impervious surfaces. A regional analysis of land use was not within the scope of this project. However, land use within the neighborhood was considered when identifying new green infrastructure opportunities.

General Methods

The following steps were taken to develop the Claypit Brook Climate Resilience Capital Improvement Plan:

- Conducted stream and drainage system condition assessments in Claypit Brook which included assessing ten existing culverts
- Developed a hydrologic and hydraulic model to better understand the stormwater flows during current and future climate conditions.
- Created an urban heat island model to show summer temperatures under current and future conditions impacted by climate change.
- Assessed flood scenarios and how green infrastructure projects can contribute to flood mitigation and urban heat island reduction.
- Prioritized stream restoration, stormwater upgrades, flood mitigation scenarios, and green infrastructure projects and developed costs for each.
- Conducted community and stakeholder outreach.
- Compiled findings into a capital improvement plan.

As a part of this project, the project team also developed a preliminary replacement design of the highly vulnerable Stockbridge Avenue culvert and a permitting strategy to facilitate future implementation. Appendix D includes the design drawings and associated permitting documents for the culvert.

2.0 Climate Impacts in Claypit Brook

Introduction

The goal of this project was to address both current and future climate risks of the Pawtucketville neighborhood which is in the Claypit Brook Watershed. This section of the report discusses the modeling efforts that helped the City better understand future flood and heat conditions. Climate change contributes to the increase of both flooding and heat which poses a threat to the life safety and the public health of residents. Past flood events have jeopardized the safety of residents due to high flood levels that inundated the ground levels of residences causing the need for emergency evacuation. This type of severe flood event causes post-event health issues such as mold within the flooded homes and housing displacement. Increased heat will impact young children and older adults, individuals with underlying health issues, and those with outside occupations, such as construction, most severely. The modeling efforts, and subsequent results, explained in this section provide geographic specificity regarding the extents of future flooding and urban heat island impacts.

The project's assessment not only focused on known localized flood areas, but also on the watershed system. Upstream green infrastructure solutions and grey infrastructure upgrades can slow stormwater runoff, allowing the system to function at or below its designed volume, thus reducing flooding in all areas of the watershed. Weston & Sampson developed a hydrologic and hydraulic (H&H) model of Claypit Brook and its watershed to identify the potential impacts of climate change on the depth and extents of flooding along the brook. The model was also used to evaluate the potential benefits of more than two dozen Green Infrastructure (GI) projects as well as several hypothetical flood storage projects. The results of this analysis are available in Section 4 and Section 5 respectively. The key findings of the H&H analysis on the current conditions are:

- Claypit Brook is prone to flooding multiple road crossings, which are expected to be overtopped and/or inundated during events as frequent as the 10-year flood.
- Climate change is expected to significantly increase the frequency and magnitude of roadway overtopping, and associated flooding of nearby buildings and infrastructure. Flood depths are expected to increase 0.1 to 0.6 feet by mid-century and 0.3 to 1.4 feet by late-century.

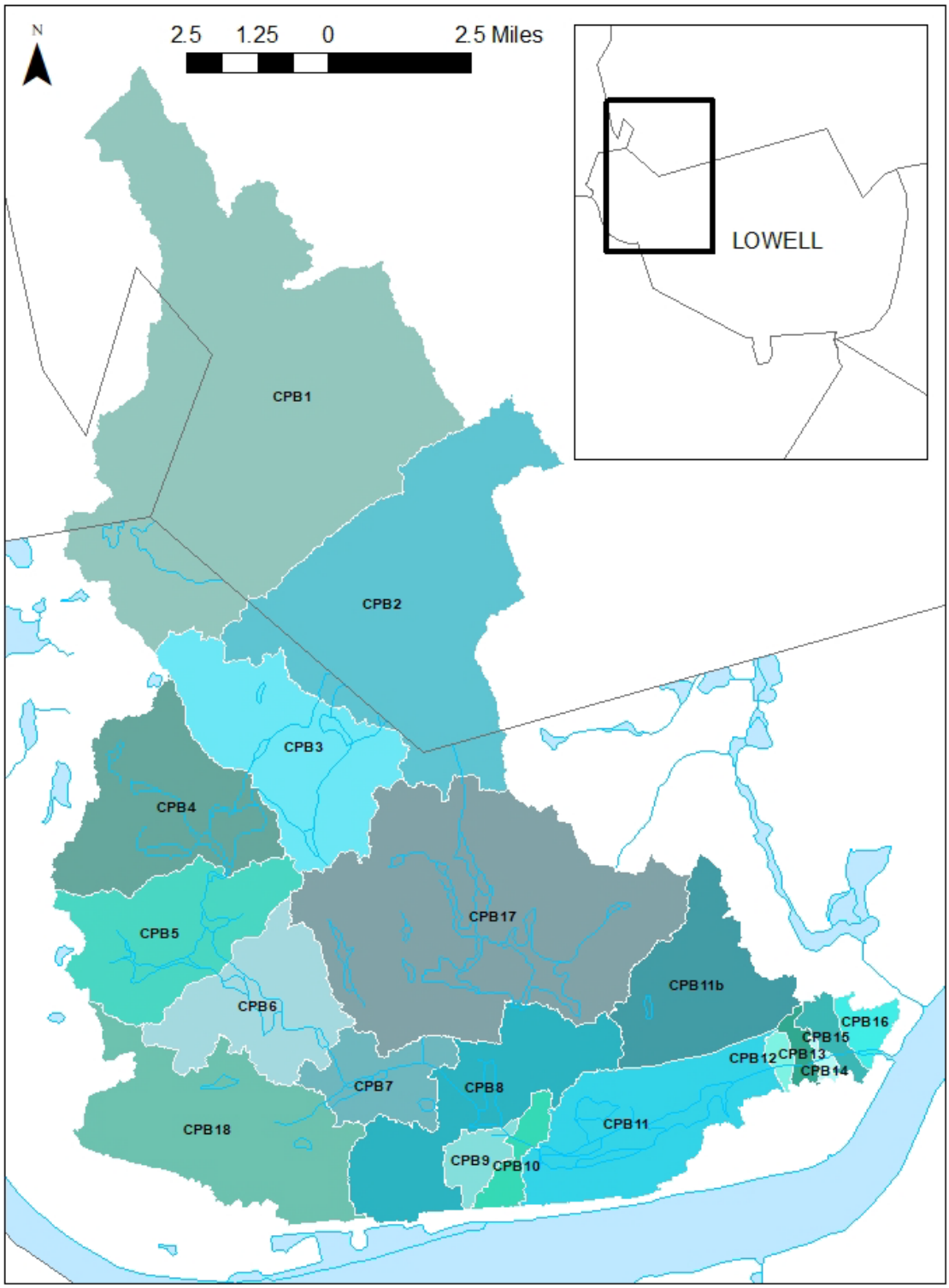


Figure 5. Claypit Brook Watershed and Delineated Subbasins.
Source: Weston & Sampson

Hydrologic and Hydraulic Model Development

Claypit Brook crosses underneath 11 roadways along the 1.5 miles of its southern extents. Previous hydraulic analyses of Claypit Brook[2] indicate that this portion of the brook functions hydraulically as a series of pools due to the peak discharge of the brook below the culverts and bridges.

Given the hydraulics of the brook, it was modeled as a series of impoundments using the HydroCAD computer program. The 2.1-square mile watershed was delineated into 19 sub-basins as shown in Figure 6. Sub-basins were incorporated into the model using the SCS unit hydrograph method, which determines runoff rates for a given drainage area over a specified duration of time. The parameters required for this method include the drainage area, curve number, and time of concentration, rainfall depth, and dimensions of any hydraulic structures such as bridges, culverts, and dams.

Drainage areas for sub-basins were measured using ArcGIS after each sub-basin was delineated using the latest LiDAR data available from MassGIS. Sub-basins ranged in size from 2 to 320 acres. A sub-basin's Curve Number (CN) represents its ability to infiltrate a storm event's initial rainfall. CNs are based on a combination of land cover and soil type. The most up-to-date land cover data was taken from the 2011 NRCS National Land Cover Database; hydrologic soil group data was derived from the from the 2012 NRCS SSURGO2 soil survey. Lastly, time of concentration indicates the length of time it takes for a single raindrop to move from the furthest reaches of a watershed to its mouth. The times of concentration for the Claypit Brook sub-basins were estimated, as described in the NRCS National Engineering Handbook, using the 1973 Mockus Lag equation, which defines time of concentration as a function of its average slope and CN.

The "pools" behind each road crossing were represented by a stage-storage curve, which defined how much water is stored behind the roadway at a given elevation, as developed from LiDAR. The elevation and dimensions of bridge openings and culverts were copied from survey data gathered in support of the current project and the 2015 Backwater Study of the brook. The shape of the roadway surface at each crossing, which was envisioned as a broad-crested weir, was copied, where possible, from a hydraulic model developed for the 2015 study, otherwise from LiDAR.

Together, these 19 pools and their associated drainage areas were subjected to a series of design rainfall events, including the 2-, 10-, 25-, 50-, and 100-year storms. The design rainfall depths were derived from the NOAA14 Hydrometeorological Atlas. To evaluate the potential impact of climate change on flooding in Claypit Brook, those same five events were also evaluated with greater design

[2] "Claypit Brook Backwater Study," Green International Affiliates, August 18, 2015.

rainfall depths based on the State's Resilient MA Action Team (RMAT) guidance for both mid-century (2030/2050) and late-century (2070/2090) time horizons, totaling 15 model simulations.

Design Event	Precipitation Depths (inches)		
	Current	Mid-Century	Late-Century
2-year	3.15	3.40	3.78
10-year	4.88	5.27	5.86
25-year	5.96	6.44	7.15
50-year	6.76	7.30	8.11
100-year	7.63	8.47	9.69

Table 1. Precipitation Depths (inches) for (5) Selected Design Events.

Table 1 illustrates how flooding depth is projected to increase overtime. Of the various model outputs, perhaps the most illustrative of the potential impacts of climate change, however, are the depths of overtopping expected at each of the many road crossings of the lowest 1.5 miles of Claypit Brook.

The impact of climate change on overtopping depth at each crossing is described below. Crossings are organized beginning upstream at Varnum Avenue.

Varnum Avenue

Varnum Avenue remains relatively dry compared to several of the crossings downstream. Currently, Varnum Avenue is expected to overtop during events larger than the 75-year recurrence interval with moderate flooding during the 100-year event. The frequency and severity of flooding is expected to worsen during future climate scenarios. The roadway is expected to be overtopped by the 45-year event during mid-century climate conditions and by the 25-year event by late-century. Roadway overtopping during the 50- and 100-year events becomes more severe during the mid-century and late-century, reaching overtopping depths of approximately one foot during the late-century 100-year event.

Figure 6. Aerial image of Varnum Avenue

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-5.07	-4.79	-4.37
10-year	-2.66	-2.15	-1.38
25-year	-1.27	-0.75	-0.01
50-year	-0.41	0.14	0.58
100-year	0.36	0.70	1.02

Table 2. Overtopping Depths at Varnum Avenue.

Townsend Avenue

Townsend Avenue is relatively flood prone. Overtopping of the roadway occurs during storms as small as the 8-year event under current climate conditions, which is expected to be reduced to the 6-year event by mid-century and the 4-year event by late-century. Flooding depths can be quite significant as well, with flood depths of more than a foot as frequently as every 25 years under current conditions. Flood depths are generally expected to increase by 0.5 to 1.5 feet by the end of the century.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-1.11	-0.82	-0.38
10-year	0.41	0.73	1.12
25-year	1.15	1.28	1.43
50-year	1.35	1.50	1.97
100-year	1.67	2.20	2.99

Table 3. Overtopping depths at Townsend Avenue

Figure 7. Aerial image of Townsend Avenue

Meadow Drive Wetland

Overland flooding is expected to occur quite frequently within Meadow Drive and some of the neighborhoods parallel to it as a result of overtopping of a wetland to the north. Flood depths in that area range from a little more than half a foot during the 10-year event to over one foot during the 100-year event. Flood depths are only expected to increase modestly, generally less than 50%, under mid- or even late-century climate conditions, although street flooding may become quite common.

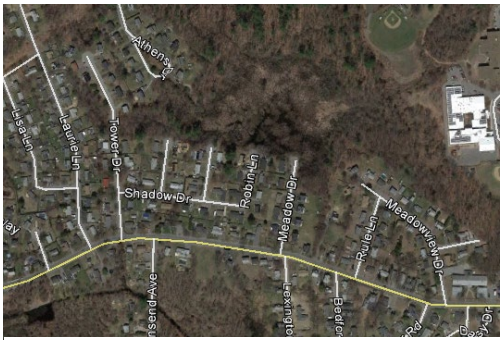


Figure 8. Aerial image of Meadow Drive Wetland.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-0.29	-0.09	0.18
10-year	0.62	0.74	0.90
25-year	0.93	1.04	1.19
50-year	1.11	1.22	1.35
100-year	1.28	1.40	1.54

Table 4. Overtopping depths at Meadow Drive Wetland

Malden Avenue

Malden Avenue experiences moderate flooding during the 10-year event and significant flooding during the 25-year and larger events under current climate conditions. Currently, the roadway begins to overtop around the 7-year event. The frequency and severity of flooding is expected to worsen during future climate scenarios. The road is expected to be overtopped by the 5-year event during mid-century and the 4-year event by late-century. Flood depths are likely to increase by up to 1.3 feet.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-1.03	-0.78	-0.41
10-year	0.66	1.00	1.38
25-year	1.42	1.54	1.70
50-year	1.62	1.76	2.23
100-year	1.94	2.47	3.26

Table 5. Overtopping depths at Malden Avenue

Figure 9. Aerial image of Malden Avenue

Lexington Avenue

Lexington Avenue experiences limited to moderate flooding during the 25-year and larger events under both current and mid-century climates with relatively little difference in peak flood depths between those two climate conditions. By late century, however, the frequency and magnitude of roadway flooding is expected to increase significantly, with limited overtopping experienced by the 10-year event and significant overtopping of more than a foot during the 50-year and more than two feet during the 100-year events.

Figure 10. Aerial image of Lexington Avenue

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-2.64	-2.40	-2.05
10-year	-0.59	-0.22	0.17
25-year	0.21	0.33	0.49
50-year	0.40	0.56	1.03
100-year	0.74	1.27	2.06

Table 6 Overtopping depths at Lexington Avenue

Bedford Avenue

Bedford Avenue currently experiences overtopping by the 16-year event with significant flooding of more than one foot during the 50- and 100-year events. Under mid-century conditions, roadway flooding can be expected by the 9-year event with significant flooding by the 40-year event. By late-century, flooding can be expected by the 8-year event with significant flooding by the 20-year event.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-1.90	-1.69	-1.38
10-year	-0.23	0.05	0.29
25-year	0.33	0.72	1.35
50-year	1.02	1.46	2.03
100-year	1.70	2.28	3.09

Table 7 Overtopping depths at Bedford Avenue

Figure 11. Aerial image of Bedford Avenue

Delaware Avenue

Delaware Avenue experiences relatively limited flooding during the 25-year event under current climate conditions with significant flooding of a foot or more during the 50-year and larger events. Flood depths are expected to worsen by 0.3 to 0.5 feet by mid-century with overtopping expected during the 13-year event. By late-century, the roadway is expected to overtop during the 9-year event with significant flood depths of a foot or more expected approximately during floods greater than or equal to the 20-year event.

Figure 12 Aerial image of Delaware Avenue

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-1.71	-1.54	-1.30
10-year	-0.42	-0.19	0.26
25-year	0.34	0.73	1.22
50-year	0.97	1.31	1.75
100-year	1.49	1.94	2.53

Table 8 Overtopping depths at Delaware Avenue

Dunbar Avenue

Dunbar Avenue is not expected to overtop during the 2-, 10-, 25-, 50-, or 100-year events under any of the three climate scenarios. The road will maintain a minimum of 0.8 feet of freeboard during each event.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-6.16	-5.97	-5.70
10-year	-4.74	-4.47	-3.91
25-year	-3.79	-3.26	-2.60
50-year	-2.94	-2.49	-1.91
100-year	-2.25	-1.66	-0.84

Table 9 Overtopping depths at Dunbar Avenue

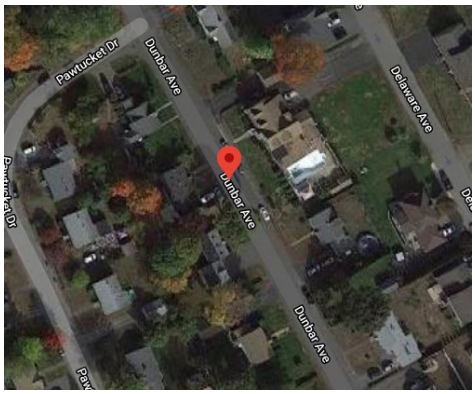


Figure 13 Aerial of Dunbar Avenue

Magnolia Street

Magnolia Street is not expected to overtop during the 2-, 10-, 25-, 50-, or 100-year events under any of the three climate scenarios. The road will maintain a minimum of 0.4 feet of freeboard during each event.

Figure 14 Aerial image of Magnolia Street

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-4.70	-4.56	-4.35
10-year	-3.62	-3.43	-2.98
25-year	-2.87	-2.36	-1.77
50-year	-2.07	-1.67	-1.19
100-year	-1.47	-0.98	-0.37

Table 10 Overtopping depths at Magnolia Street

Stockbridge Avenue

Stockbridge Avenue is not expected to overtop during current or mid-century climate scenarios. The road is expected to flood during the 100-year event by late-century. The roadway will flood, on average, every 68 years.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-2.77	-2.65	-2.49
10-year	-1.95	-1.81	-1.48
25-year	-1.40	-1.03	-0.61
50-year	-0.82	-0.54	-0.19
100-year	-0.39	-0.04	0.34

Table 11 Overtopping depths at Stockbridge Avenue

Figure 15. Aerial image of Stockbridge Avenue

Avalon Street

Avalon Street is not expected to overtop during the 2-, 10-, 25-, 50-, or 100-year events under any of the three climate scenarios. The road will maintain a minimum of 1 foot of freeboard during each event.

Figure 16 Aerial image of Avalon Street

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-3.14	-3.06	-2.94
10-year	-2.56	-2.47	-2.27
25-year	-2.22	-1.99	-1.72
50-year	-1.85	-1.67	-1.46
100-year	-1.58	-1.36	-0.99

Table 12 Overtopping depths at Avalon Street.

Pawtucket Boulevard

Pawtucket Boulevard is not expected to overtop during the 2-, 10-, 25-, 50-, or 100-year events under any of the three climate scenarios. The road will maintain a minimum of 2 feet of freeboard during each event.

Design Event	Overtopping Depth (feet)		
	Current	Mid-Century	Late-Century
2-year	-2.99	-2.94	-2.88
10-year	-2.70	-2.65	-2.55
25-year	-2.53	-2.42	-2.30
50-year	-2.36	-2.28	-2.19
100-year	-2.24	-2.15	-2.00

Table 13 Overtopping depths at Pawtucket Boulevard

Figure 17 Aerial at Pawtucket Boulevard

Urban Heat Island

City of Lowell is projected to experience both warmer average temperatures, as well as intensification of extreme temperatures in summer because of climate change. Based on temperature projections published on resilientMA.org, the number of days per year in Lowell with temperatures greater than 90°F can be as high as approximately 35 days by 2050, 53 days by 2070, and 68 days by 2090. Urban areas like Lowell, particularly sections of the city that lack vegetation, will experience heat vulnerability exacerbated due to the Urban Heat Island (UHI) effect. According to the EPA definition, "urban heat islands" occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat.[3] These types of hardscaped surfaces result in increased energy costs (e.g., for air conditioning), higher air pollution levels, increased stormwater runoffs, and heat-related illness and mortality. Many residents in Lowell are exposed to heat regularly through walking, biking, and public transit use. Therefore, it is crucial for public health to minimize the heat island effect by increasing tree canopies and decreasing impervious covers in parts of the city.

Urban Heat Island (UHI) modeling and mapping is a raster-based approach and uses geographical information system (GIS) software to produce UHI maps for existing and proposed land cover conditions. UHI effect for Lowell Claypit Brook Watershed Area was analyzed by first estimating the ambient air temperature data from the land surface temperature data. The temperature of the ground

[3] United States Environmental Protection Agency. "Green Infrastructure: Reduce Urban Heat Island Effect". https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect

surface, referred to as "land surface temperature" is warmer than the ambient air temperature, which is felt by humans. Therefore, it is important to estimate ambient air temperature from land surface temperature data for the purpose of UHI modeling. The land surface temperature data for Lowell Claypit Brook Watershed Area was downloaded from the "Earth explorer" by USGS[4]. The land surface temperature data is based on using Landsat satellite imagery of the greater Boston area taken on July 13, 2016, at around 3:25 pm and processed using thermal remote sensing tools. The ambient air temperature data was downloaded for the same time frame (July 13, 2016, at around 3:25) from nearby weather stations located in the greater Lowell Area. A linear regression relationship (correlation coefficient r^2 was determined to be 0.94) was established between the land surface temperature and measured ambient air temperature for each corresponding weather station location.

Ambient air temperature variability due to UHI effect in the future was estimated based on the ratio between average ambient air temperature for existing conditions and average ambient air temperature for projected future scenarios. For this project, projected future temperature scenarios of 90°F, 95°F and 100°F were selected since these are the extreme temperature scenarios that are being recommended for Massachusetts as part of the State Hazard Mitigation and Climate Adaptation Plan (MEMA, EOEAA, 2018)[5]. The ambient air temperature variability in Lowell correspond to 90°F, 95°F and 100°F are illustrated in Figure 1. It can be seen in these figures that areas of the city that have higher impervious surfaces, heavy concentrations of buildings, and lack tree canopy cover correspond to the UHI "hot spots" in the city where localized temperatures can be as high as up to 2 – 4°F more than the average air temperatures over greener or more pervious spaces. University of Massachusetts, Downtown area, Highlands, Ayers City, South Lowell are densely populated, 'hot spots" areas.

[4] Landsat C1 Analysis Ready Data (ARD) from U.S Landsat 4-8 ARD: courtesy of the U.S. Geological Survey. https://earthexplorer.usgs.gov/

[5] Commonwealth of Massachusetts, Massachusetts Emergency Management Agency (MEMA), and Massachusetts Executive Office of Energy & Environmental Affairs (EOEEA). "Massachusetts State Hazard Mitigation and Climate Adaptation Plan," September 2018. https://www.mass.gov/service-details/massachusetts-integrated-state-hazard-mitigation-and-climate-adaptation-plan

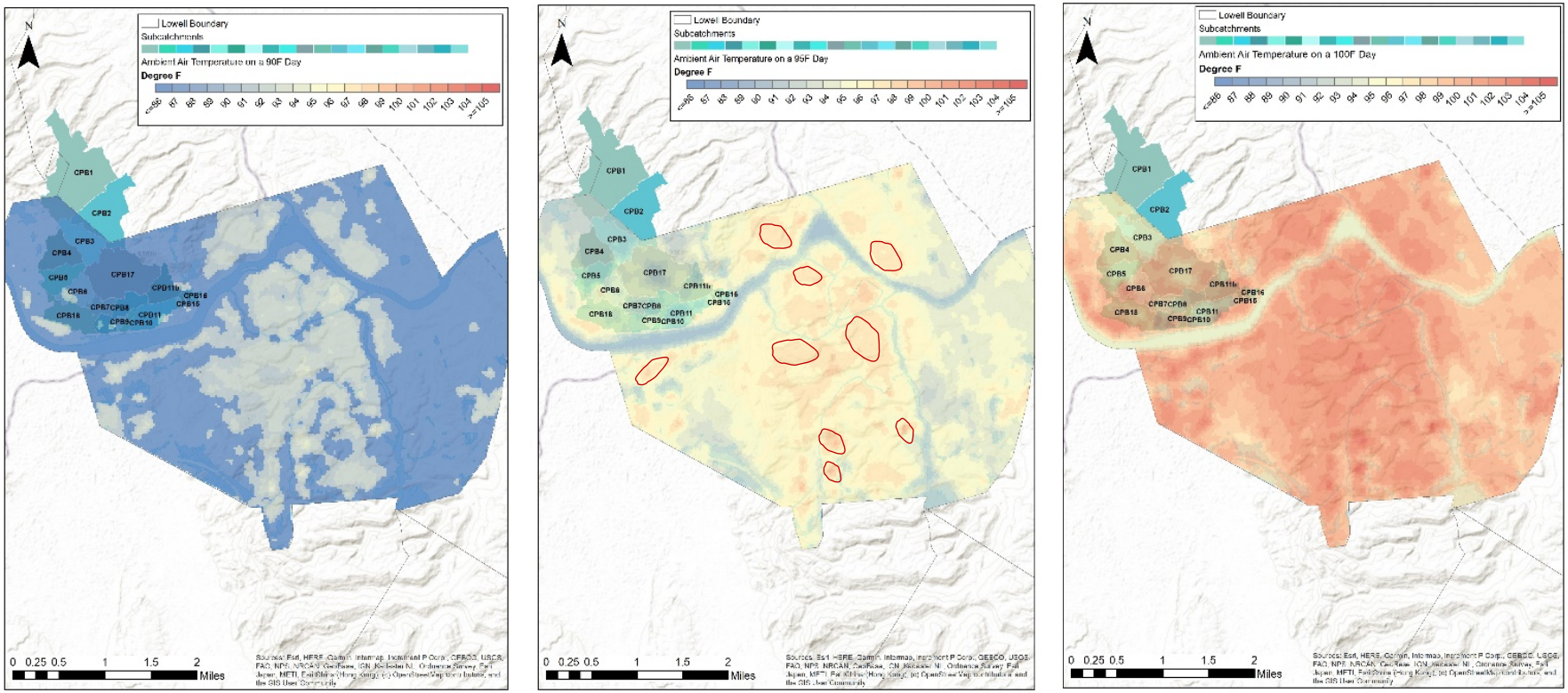
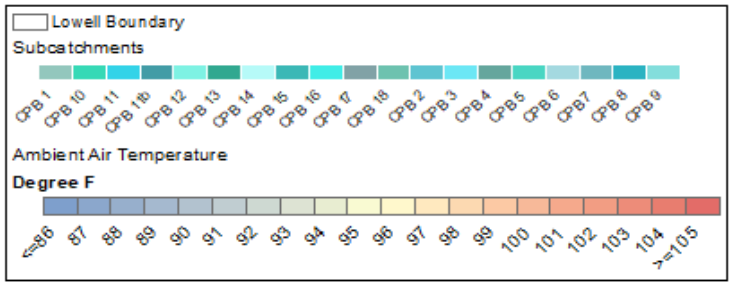


Figure 18. Urban Heat Island (UHI) effect based on estimated ambient air temperature in the City of Lowell on an average 90oF, 95oF, and 100oF day (left to right). The "hot spots" areas are marked with red boundaries. Source: Weston & Sampson



The ambient air temperature UHI map for Lowell was then used to evaluate the cooling benefits of green infrastructure implementation in the Claypit Brook watershed area. The cooling impact of green infrastructure on urban heat island effect was determined by comparing the change in ambient air temperature as a function of change in impervious cover and tree canopy in the watershed area. A spatial relationship was established between existing land cover (percent impervious surface and percent canopy cover) and ambient air temperature within the sub-catchments of the Claypit Brook watershed. The statistically averaged slope derived from these two spatial relationships exhibits a positive slope, which confirms that UHI corresponding to ambient air temperature decreases with decreasing percent impervious surface and increasing percent tree canopy. This also implies that ambient air temperature is expected to decrease as impervious area is reduced with the implementation of green infrastructure, such as swales, bioretention basins, rain gardens, and light-colored permeable pavers and as treey canopy increases with planting more trees. The cooling relationships developed for Lowell did not yield a good correlation with existing land cover. Therefore, the relationships developed by Wang et al. (2017) were used to estimate cooling benefits due to increase in canopy and decrease in impervious surfaces[6].

- For every 10% decrease in impervious surface, approximately 0.4°F of cooling can be achieved.
- For every 10% increase in tree canopy, approximately 0.4°F of cooling can be achieved.

Figures 20 and 21 demonstrate that with the proposed conditions, including an inrease in canopy and decrease in impervious areas in the southern subcatchments of the Claypitbrook watersheds, a cooling of up to 3.4°F can be achieved. Additionally, a cooling of up to 3.2°F can be achieved due to increases in tree canopy. The highest amount of cooling is achieved in subcatchment CPB17 due to a reduction of proposed impervious areas. Cooling impacts due to proposed increase in tree canopy are greatest in subcatchments CPB17 and CPB8.

[6] Wang, J.A., L.R. Hutyra, D. Li, and M.A. Friedl, 2017: Gradients of Atmospheric Temperature and Humidity Controlled by Local Urban Land-Use Intensity in Boston. Journal of Applied Meteorology and Climatology, 56, doi: 0.1175/JAMC-D-16-0325.1

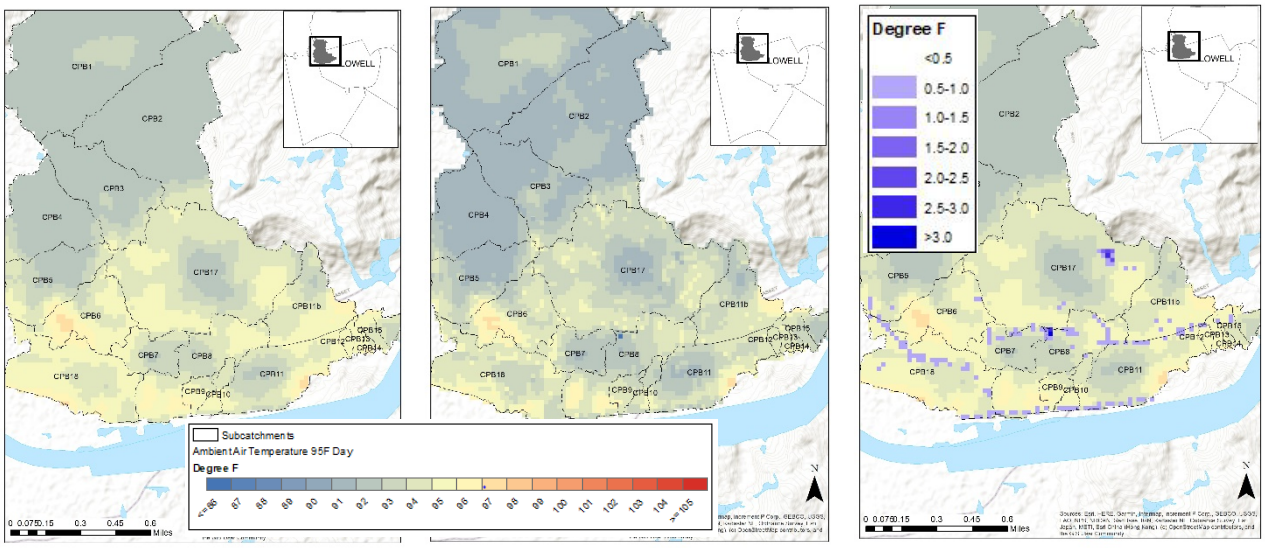


Figure 19. Estimated UHI in Claypit Brook watershed area under existing conditions on a 95°F Day (left), proposed canopy increase (center), and estimated increase in temperature due to increased canopy overlayed on top of existing conditions(right).

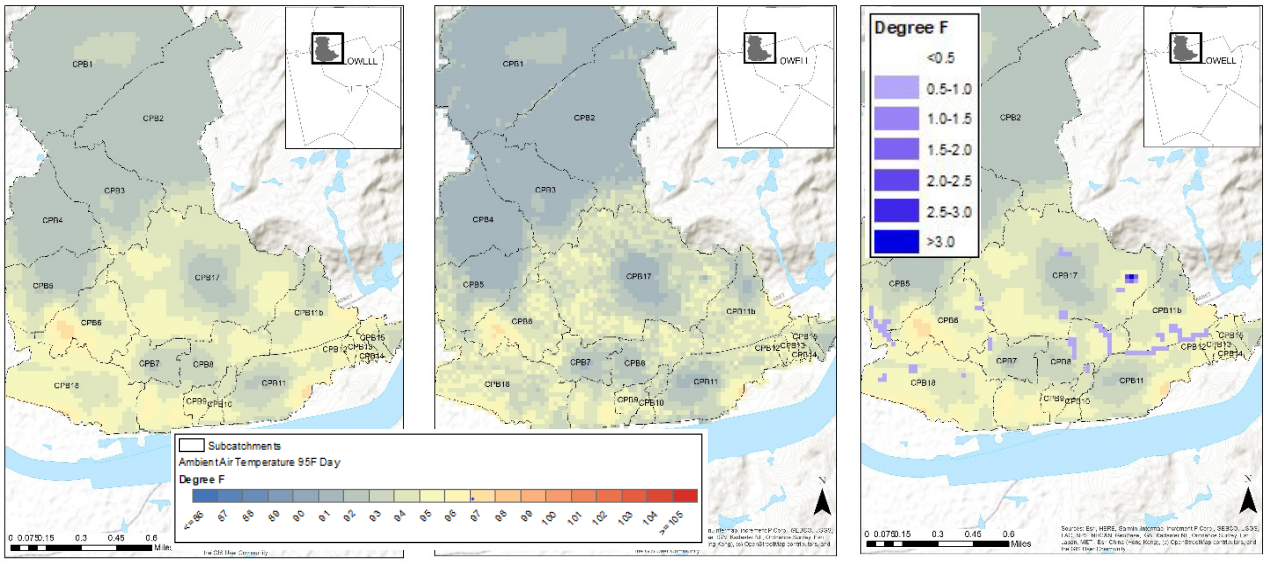


Figure 20. Estimated UHI in Claypit Brook watershed area under existing conditions on a 95°F Day (left), proposed decrease in impervious area (center), and estimated decrease in temperature due to decreased impervious area overlayed on top of existing conditions.

3.0 Stream Assessment

A stream assessment informed the actions identified in the Capital Improvement Plan. Understanding the conditions of the Brook contributes to informed decision making regarding potential improvements. While many of the conditions observed are attributed to natural processes, there are still instances in which maintenance could contribute to better health and water flow and reduce potential flooding. For example, fallen trees are a natural component of the watershed ecosystem, and do not always need to be removed because they will naturally decay and contribute to soil nutrients and bank structure. However, when trees fall across the stream, they can dam the stream and cause flooding. The following assessment focused on 'problem areas' or 'areas for improvement' along the 2.5 miles of the stream.

Streams are an important part of the stormwater system. Sediment build-up, debris, beaver dams, and culverts in poor condition can all be problematic and contribute to localized flooding. Using the stream assessment data, the functionality of the stream can be analyzed. The stream assessment team walked the centerline of the stream and documented the following conditions, as identified in Figure 22. The field crew did not document the condition or location of retaining walls along the accessible reach. The team collected data using Trimble GPS units, marking each defect in the stream as a separate GPS point. See Appendix A for a map of the deficiencies. The data points and geolocated photos will be provided under a separate cover, however, we have provided example images with locations in Appendix A. The team took an upstream and a downstream photo at various stream points to provide a future frame of reference. All data is available in GIS to serve as a future resource for the City in prioritizing needs and conducting stream maintenance, in addition to assessing opportunities for stormwater detention and flood mitigation.

To reduce the impacts of climate change in and around Claypit Brook, an assessment of the existing conditions of the brook was conducted. Understanding existing conditions provides a basis for recommending improvements to the stream for current and future climates. Weston & Sampson performed a stream and culvert assessment along Claypit Brook within Lowell's city boundary on March 29th and 30th, and June 28th, 2021.The goal of this assessment was to document the existing conditions of Claypit Brook and to identify deficiencies that can be used to inform a list of recommended improvements, which may include:

- Removal of debris within the stream channel and from embankments;
- Removal of sediment within the stream channel to improve flow;
- Structural evaluation, rehabilitation, replacement and/or maintenance at culverts;
- Addressing streambank erosion using nature-based solutions; and
- Beaver dam assessment and mitigation.

The Claypit Brook subbasin was assessed utilizing the methods described above, and the following section provides details regarding the findings. Claypit Brook flows south/southeast near the center of Pawtucketville through the Lowell-Dracut-Tyngsborough State Forest and then follows the general alignment of Varnum Street. The field crew assessed the approximately two and a half miles of Claypit Brook within the Lowell city limits. The Brook primarily runs through wooded and wetland

areas near the headwaters and through residential areas near the tailwaters. There is an extensive wetland system near the Lowell-Dracut border that is thick with sedimentation, vegetation, and beaver activity. A large beaver dam is present near the Dracut border in this area. Another large wetland is present between Bedford Avenue and Dunbar Avenue. This wetland is littered with dense, overgrown vegetation and beaver activity. The team could not access much of this wetland system because of the muck, deep pockets of impounded water, and thick vegetation, resulting in difficultly locating the Brook.

During the stream assessment, the field crew documented 13 culverts and 16 beaver dams.

Figure 21. Stream Data Collected

The field team assessed the culverts along Claypit Brook and measured the dimensions of each culvert. Thirteen culverts within or near the stream assessment area were inspected. One culvert upstream of the site (in Dracut) was inspected for modeling purposes and another inspected at the intersection of Varnum Ave and Marbles Brook was inspected upon request from the City. Each of the culverts had two barrels, except for the culvert near Elizia Circle, which has one barrel. The culverts were generally in fair condition, with only a few requiring repairs and six requiring replacement, although sediment and/or debris was observed in eight of the culverts. Sediment

depths within culverts ranged from 2 to 15 inches. Water was flowing within each culvert with sediment and debris present. At culverts with debris present, the debris was generally blocking between 20 and 50% of the pipe.

Each culvert was observed, and the condition of each culvert, as well as the area immediately upstream and downstream of each culvert was recorded. The dimensions, material, and invert elevations were also recorded for each culvert. The roadway surface elevations were collected from the latest LiDAR dataset. All of the culverts are corrugated metal pipes, with the exception of the culverts at Pawtucket Boulevard (MA Rte. 113) and the Varnum/Marbles Brook crossing, which were concrete culverts.

Of the culverts along Claypit Brook, approximately nine culverts are in need of maintenance/repair, replacement, or removal. See Attachment C for culvert location, description, and associated recommendation. The culverts at Malden Ave, Stockbridge Ave, Delaware Ave, Magnolia St, Lexington Ave, and Townsend Ave were in poor condition and in need of replacement. These culverts were severely corroded below the flow line. There is a culvert in the embankment at the end of Avalon Street that appears to no longer be in use and should be removed. The culverts in the neighborhood near Elizia Drive, Bedford Avenue, and Dunbar Avenue are in need of maintenance, including debris and sediment removal. The headwall on the south side of Varnum Avenue needs repair. The dry-set stone blocks at the headwall appear to be shifting with the potential for blocks or retained sediment to fall into the brook.

The brook's largest impediments are fallen trees, areas of moderate to severe overgrowth, and beaver dams. Much of the brook is littered with fallen trees from 6-inches to 24-inches in diameter. There were 16 beaver dams observed throughout the watershed with heights ranging from 14-inches to 4-feet. No live beavers were observed during the stream assessment; however, several beaver dams may have been active or recently active within the last year. The larger dams appeared to be preventing flow within the brook. Nearly all the observed beaver dams were north of Varnum Avenue. It is likely that there are more beaver dams located in the wetland between Bedford Avenue and Dunbar Avenue. However, this area was overgrown and difficult to access during the field investigation. Moderate to severe bank erosion (upwards of 8 and 12 inches of vertical erosion) appeared to be limited to two locations, that were up to 250 feet in length.

Potential Projects

The information in Table 14 was gathered while conducting the stream assessments. This data was compiled to identify some of the types of maintenance projects required to improve the brook. These projects include bank stabilization, culvert repair, further beaver dam evaluation and mitigation, debris removal, overgrowth removal, or sediment removal. Much of the areas that appeared to have sediment build-up were near beaver dams so the sediment removal volume was approximated from field measurements in these areas and from the few culverts with sediment depths greater than 6-inches. Each project type could improve stormwater conveyance and storage capacity in the subbasin, thereby reducing flooding in adjacent areas. These projects may also reduce contaminants and sediment entering downstream receiving waters.

Table 14. Potential Flood Mitigation Projects					
Bank Stabilization	Beaver Dam Evaluation and Mitigation	Culvert Maintenance[1] or Replacement	Debris Removal	Overgrowth Removal	Sediment Removal
300 linear feet	16 beaver dams	Maintenance is required at seven culverts, six of these culverts need to be replaced.	20 fallen trees	1,764 linear feet	10,720 cubic feet

[1]Maintenance includes structural maintenance on the culvert and/or headwall

Prioritization

Stream assessment and maintenance actions were not ranked. Ideally, these improvement actions would be completed in tandem throughout the watershed to provide maximum benefits. Alternatively, these actions could be completed in combination with other projects, for example, removing sediment near a culvert when the culvert is being upgraded. However, the team did calculate anticipated project costs as one metric with which to compare these actions. The table below provides additional detail.

Table 15. Stream Assessment and Maintenance Costs								
		Total Construction/ Cleaning Cost:	Design/ Permitting[1]	Construction Oversight[2]	Environmental Controls[3]	Total Project Cost	20% Contingency	Total Project Cost[4]
Sediment Removal	397	$148,875	$29,775	$7,444	$14,888	$200,981	$40,196	$241,178
Debris Removal	10	$14,990	$2,998	$750	$1,499	$20,237	$4,047	$24,284
Cut Back Overgrowth	1764	$44,100	$8,820	$2,205	$4,410	$59,535	$11,907	$71,442
Bank Stabilization	300	$300,000	$60,000	$15,000	$30,000	$405,000	$81,000	$486,000

[1]Assume 20%

[2]Assume 5%

[3]10%

[4]w/ 20% Contingency

Culverts were ranked by condition, cost, and level of hydraulic adequacy. Hydraulic adequacy was defined as the anticipated increase in flow if culvert upgrades were made. Higher cost upgrades were ranked lower. Culverts in poor condition and in need of urgent replacement were ranked higher. The conditions of three culverts were not able to be assessed at the time of report writing and are therefore listed as "Not Applicable (N/A)." A full table listing the average rank of each culvert and rank by prioritization criteria is included in Appendix A.

4.0 Green Infrastructure Assessment

Green infrastructure can contribute to the management of stormwater in the Claypit Brook Watershed. Upstream opportunities to introduce nature-based solutions and pervious areas contributes to the conveyance, water quality, and discharge of stormwater, decreasing loads on the grey infrastructure system. Identifying opportunities for creating new green infrastructure projects was a key component of the Capital Improvement Plan. Not only does green infrastructure contribute to flood mitigation, it also provides public health and quality of life benefits by cooling surface temperatures, providing shade, and beautifying the public realm. As discussed in the Climate

Green infrastructure opportunities were identified considering the topography of the neighborhood, water flow, flood probability and depth, property ownership, and feasibility of implementation. The opportunities represent various types of projects that can function independently or work together as a surface system of stormwater management. These types of smaller nature-based interventions also provide co-benefits to the community like contributions to the public realm and placemaking, creating healthier spaces, and broadening of ecosystem services and biodiversity. The impacts of the identified projects were modeled as part of are larger Hydraulic & Hydrologic (H&H) model and based on increased storage capacity and reduced impervious area within sub-catchments. The effect of green infrastructure on urban heath reduction was also measured based on reduced impervious surfaces and increased canopy coverage.

To better understand areas within the Claypit Brook watershed that will have the greatest impact on flood reduction, the City first looked at locations prone to flooding. Site investigations were conducted to evaluate existing drainage infrastructure and water bodies. Information gathered during this initial investigation included stream assessments, culvert locations and sizes, and field surveys to validate and supplement city drainage data. Anecdotal information was gathered from knowledgeable residents and stakeholders about existing flooding in Lowell. They also provided feedback to the City about green infrastructure designs and locations.

Types Of Green Infrastructure Opportunities

There are numerous types of Green Infrastructure (GI), each with their own subset of functions and forms. Given the context of Claypit Brook, the functions best suited for the watershed include urban heat reduction, stormwater conveyance, treatment, temporary storage, and infiltration. The list below represents types of opportunities that can be implemented given site conditions including rights-of-ways, property ownership, protected ecosystems, floodplains, and ability to intercept meaningful runoff volumes.

Although some parcels that were assessed for green infrastructure may be contaminated, they can still be reforested, or additional vegetation planted. Contaminated sites can also be used for bioretention, bioswales, and detention if an impermeable membrane or cap is installed that isolates the contaminated soils. Contaminated sites should not be used for floodable fields.

1) Reforestation – Reforestation or concentrated increases in tree canopy help reduce urban heat, improve air quality, and mitigate air pollution through carbon uptake and sequestration.

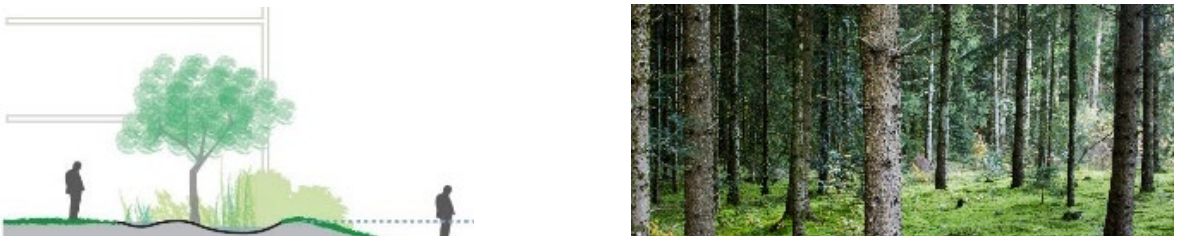


Figure 22. Section drawing of a reforested area and a photo example of a reforested area.

Reforestation can occur in empty lots, within existing parks, or interstitial spaces between roads or properties.

2) Swales – The primary function of swales is to intercept stormwater runoff before it enters the existing drainage system and convey runoff to other GI features. In many instances swales can temporarily store runoff and even allow some degree of infiltration. Swales are very useful because they can fit along narrow stretches along roads and reconnect separated surface flows.

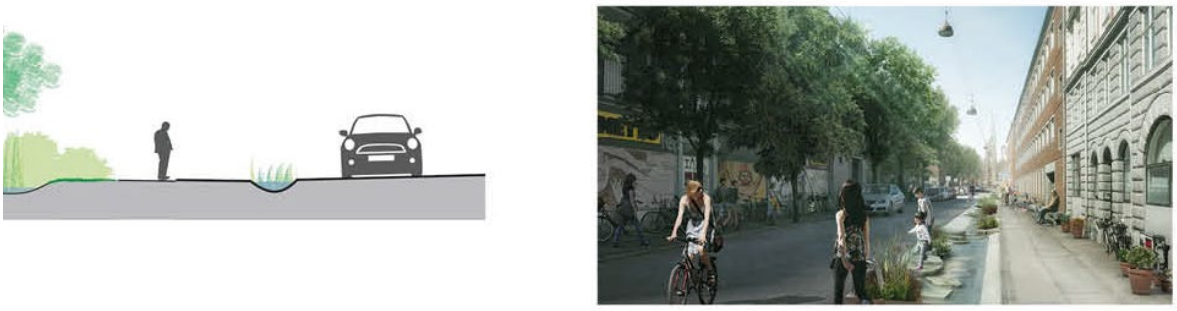


Figure 23. Section drawing of a swale and photo example of a swale.

3) Bioretention – Bioretention areas capture and hold stormwater runoff and allow it to slowly infiltrate through soil media, thus reducing flooding. Roots uptake water as well as nutrients in the runoff. These systems provide water quality benefits by removing pollutants. They can be installed along sidewalks, in medians, and parking lot edges to directly treat runoff from surrounding impervious surfaces. These components can retain stormwater for future uses or detain it before it flows back into the drainage system after the storm event.

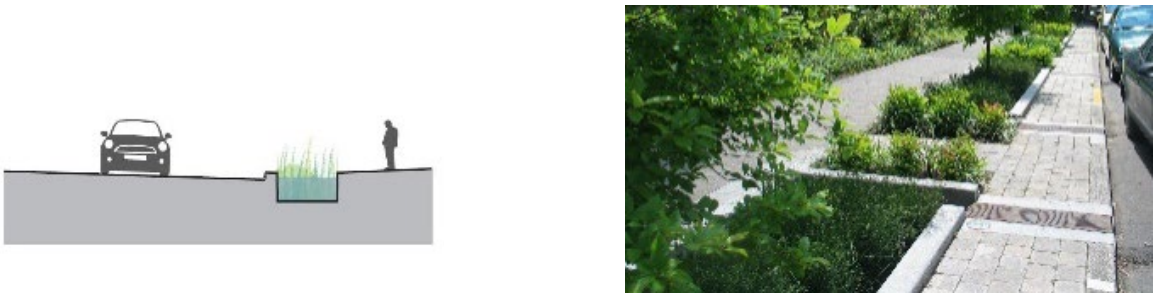


Figure 24. Section drawing of biorention and a photo example of bioretention.

4) Floodable parks – Floodable parks and recreation spaces represent the greatest opportunity for large retention spaces within urban areas. They can be located throughout the watershed and receive stormwater via conveyance systems or adjacent water bodies. They can provide a combination of hydrological services including water quality improvements via retention, detention, and infiltration.

Figure 25. Section drawing of a floodable park and a photo example of a floodable park.

5) Permeable Paving - Roadways and sidewalks are big contributors to stormwater runoff. Replacing impervious surfaces with permeable pavement allows for reduced runoff and slower infiltration back into the ground or stormwater system. Permeable pavement can be used where stable, hard surfaces are needed along streets, sidewalks and in parking areas and can be used in conjunction with underground storage.

Figure 26 Section drawing of permeable paving and a photo example of permeable paving.

Scenarios

Through our H&H analysis, nineteen sub-catchments were delineated and identified within Lowell's Claypit Brook Subbasin (Figure 2). These sub-catchments are a mixture of forested and residential land with varying degrees of impervious surfaces. Before developing green infrastructure scenarios within the watershed, sub-catchments were analyzed to determine where green infrastructure implementation would be most impactful. Sub-catchments CPB1, CPB2, CPB3, and CPB4 are all located within DCR land, which is primarily covered by forests and wetlands. Due to their existing flood mitigation capacities, these sub-catchments were not considered further in the GI opportunities analysis, though they were still included as part of a separate culvert improvements analysis. Sub-

catchments CPB9, CPB12, CPB13, CPB14, CPB15, and CPB16 are all located within the Merrimack River 100-year flood zone. These sub-catchments were excluded from the analysis as well because of the limited impact they would have on Claypit Brook flood reduction under near-term extreme storm scenarios.

Ultimately, thirty-six green infrastructure features within nine sub-catchments, referred to as scenarios, were evaluated to understand their impact on flood resilience and stormwater management in the Claypit Brook Watershed. Scenarios can be understood by their sub-catchment area and the impact green infrastructure has on that area. Strategies were determined based on feasibility and optimal impact. Each scenario described below is accompanied by a map illustrating the location, type of strategy, area, and whether it is a public or private parcel. The 'Watershed-wide Snapshot' shows the location of all strategies across the watershed and provides volumetric information regarding the effects of implementation (Figure 28).

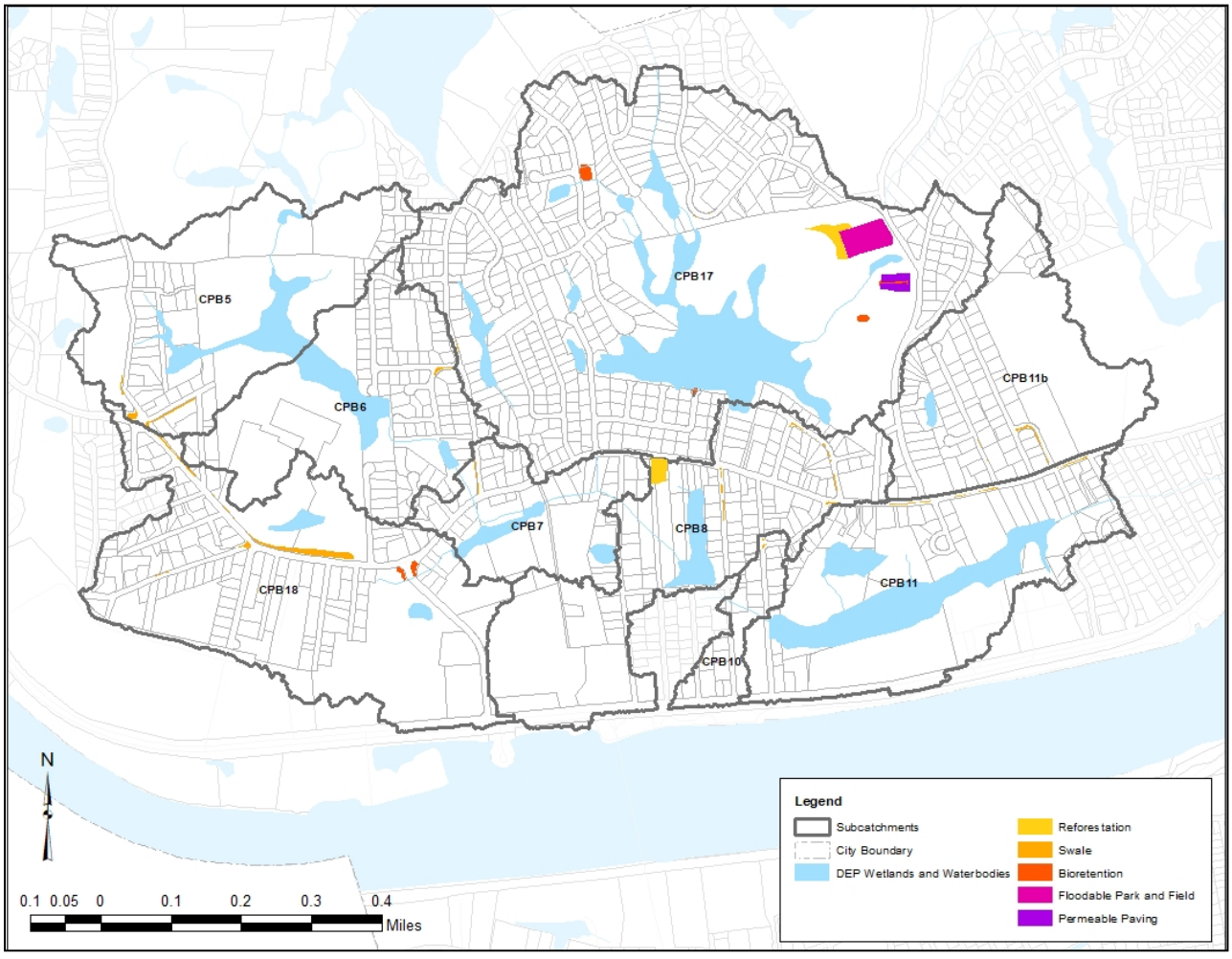


Figure 27. Green Infrastructure Opportunities throughout Claypit Brook Watershed Subcatchments

More than two dozen GI projects, grouped into nine difference scenarios, were evaluated for their flood reduction potential. Scenarios 1, 4, 7, 8, and 9 produced the greatest benefits, between 10-

30% reduction in total runoff from their respective sub-basins within the larger watershed. The GI projects would have little impact on peak discharge in Claypit Brook itself, and only Scenarios 1 and 8 would impactfully reduce flooding of road crossings; generally reductions were less than 0.2 feet.

Scenario 1: CPB5 is primarily covered by DCR forest with some residential and commercial land uses. This subcatchment is located on the western side of the Claypit Brook subbasin. There is a large wetland system in this subcatchment which flows southeast into CPB6 and feeds into Claypit Brook.

This scenario includes three swales in the southern portion of the subcatchment, along the intersection of Trotting Park Road, Anson Street, and Varnum Avenue. This area is known to experience flooding from the Lowell First Church of the Nazarene Parking lot. The existing catch basin on Trotting Park Road does not capture all the runoff from the parking lot, causing the neighboring properties to experience flooding. The proposed stormwater swales will intercept the stormwater before it reaches the road. These swales have a combined area of approximately 11,600 square feet.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	22%	18%	14%
10-year	9%	7%	6%

Table 16 Reduction in Total Runoff Volume for CPB5 scenario

GI projects in this scenario are expected to reduce impervious cover by 0.05 acres and attenuate up to 34,900 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB5 as shown in the table above.

As precipitation and runoff volumes increase with larger design events and climate change, the benefit associated with the proposed GI scenario decreases. This scenario is expected to reduce runoff during the 2-year event by 22%. However, it is reduced to 18% and 14% under mid- and late-century climates, respectively, and it is reduced to 9% during the larger 10-year event.

While this scenario will likely produce notable reductions in total runoff volumes, the proposed GI projects are not expected to significantly reduce peak runoff rates.

Downstream crossings experience a small reduction in flood depths because of lower total runoff volumes given the pool-drop nature of the lower reach of Claypit Brook. Those benefits are presented in the table below.

Roadway	Event	Flood Depth Reductions (feet)		
		Current	*Mid-Century*	*Late-Century*
Varnum Ave	2-year	0.25	0.16	0.01
	10-year	0.02	0.01	0.01
Townsend Ave	2-year	0.03	0.03	0.03
	10-year	0.02	0.02	0.00

**Gray cells indicate design storms and climate conditions where the roadway is not expected to overtop.*

Table 17 Flood Depth Reductions at Varnum Ave and Townsend Ave

The greatest reduction at Varnum Street, 0.25 feet, naturally occurs during the 2-year event under current climate conditions. However, it is reduced to 0.16 and 0.01 feet under mid- and late-century climates, respectively, and it is reduced to only 0.02 feet during the larger 10-year event. In this case, while reductions in flood depth are always beneficial, Varnum Avenue is not expected to overtop during any of the six design event-climate conditions combinations presented. In contrast, Townsend Avenue is expected to overtop during the 10-year event, although not the 2-year. Unfortunately, it is far enough downstream where the flood level reduction benefits are muted to 0.03 feet or less.

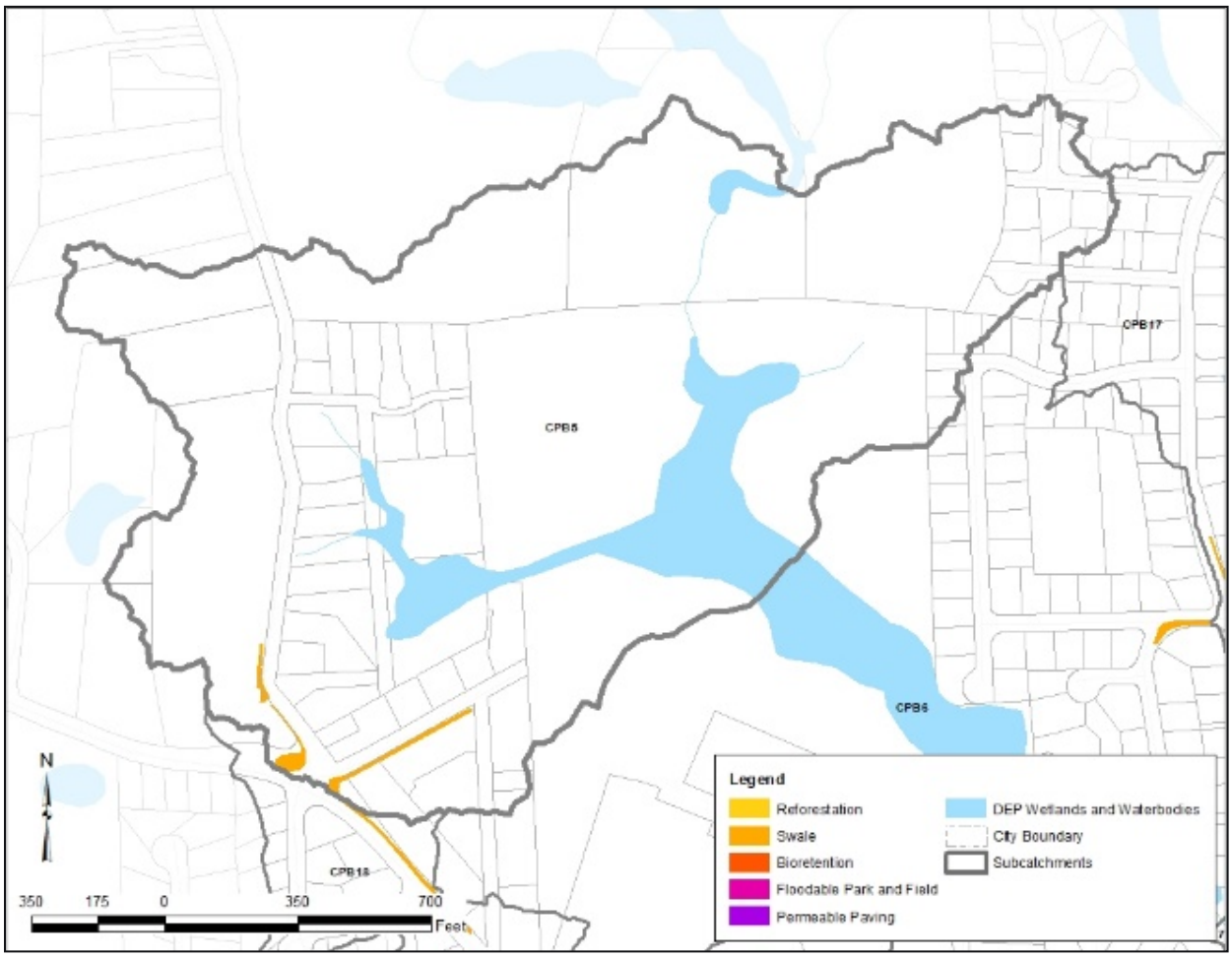


Figure 28. Green infrastructure scenario CPB5.

Scenario 2: Subcatchment CPB6 is covered by an equal distribution of open space, residential, and commercial land use. The wetland system from CPB5 begins to narrow in this subcatchment, and transitions into a stream without adjacent wetlands. The stream flows around neighborhoods and enters a culvert that passes beneath a parking lot which creates a bottleneck and ponding upstream. Most of this subcatchment is privately owned, thus limiting the locations where the City could easily install green infrastructure.

CPB6 consists of a single swale, proposed at the corner of Eleanor Drive and Cidalia Drive, an area that sees a high amount of sheet flow. The stormwater swale will intercept the flow traveling along the street and reduce localized flooding. This project/scenario is expected to reduce impervious cover by 0.06 acres and attenuate up to 9,600 cubic feet of runoff. This swale is just over 3,000 square feet. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB5 as shown in the table below.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	4%	3%	3%
10-year	2%	2%	1%

Table 18 Reduction in Total Runoff Volume in CPB6

This scenario is expected to reduce runoff volumes rather mildly, with a maximum reduction of 4% during the 2-year event under the current climate. As precipitation, and therefore runoff volumes, increase with both larger design events and with advancing climate change, the benefit associated with the proposed GI scenario decreases accordingly.

This scenario is not expected to significantly reduce peak runoff rates. Nor is it expected to reduce flood levels at the next two downstream crossings, Varnum Avenue and Townsend Avenue, by more than 0.01 feet.

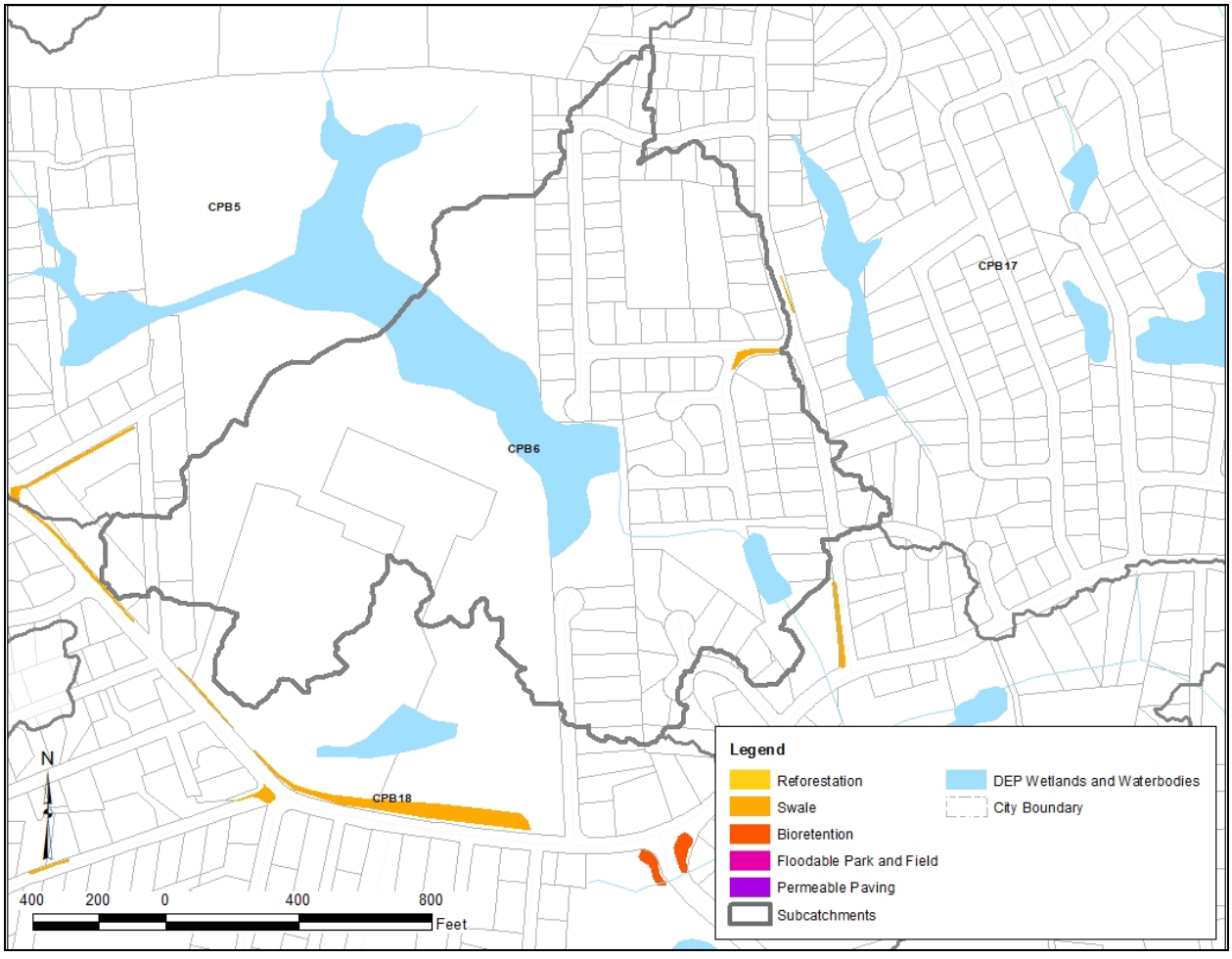


Figure 29. Green infrastructure scenario CPB6

Scenario 3: Subcatchment CPB7 is characterized primarily by forested land and some residential development. Claypit Brook flows from CPB6, through a culvert that passes south beneath a parking lot, and beneath Varnum Avenue, before it daylights on the south side of Varnum Avenue into a wetland system. The Brook then narrows and travels east. There is also a stream channel that enters the wetland system from the west that originates in CPB18.

CPB7 consists of a single swale along the eastern edge of the parking lot on the corner of Totman Road and Varnum Avenue, the parking lot that Claypit Brook flows beneath. Sheet flow can be collected off of the roadways and parking lot and directed into the swale before reaching Claypit Brook or the City's stormwater system. This swale would cover an area of just over 4,000 square feet. GI projects in this scenario are expected to reduce impervious cover by 0.07 acres and attenuate up to 11,750 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB7 as shown in the table below.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	12%	10%	8%
10-year	5%	5%	4%

Table 19 Reduction in Total Runoff Volume in CPB7

As precipitation, and therefore runoff volumes, increase with both larger design events and with advancing climate change, the benefit associated with the proposed GI scenario decreases accordingly. This scenario is expected to reduce runoff during the 2-year event by 12%. However, it is reduced to 10% and 8% under mid- and late-century climates, respectively, and it is reduced to 5% during the larger 10-year event. While this scenario will produce some reductions in total runoff volumes, it is unlikely to significantly reduce peak runoff rates or to reduce flood levels at Townsend or Malden Avenues by an appreciable amount.

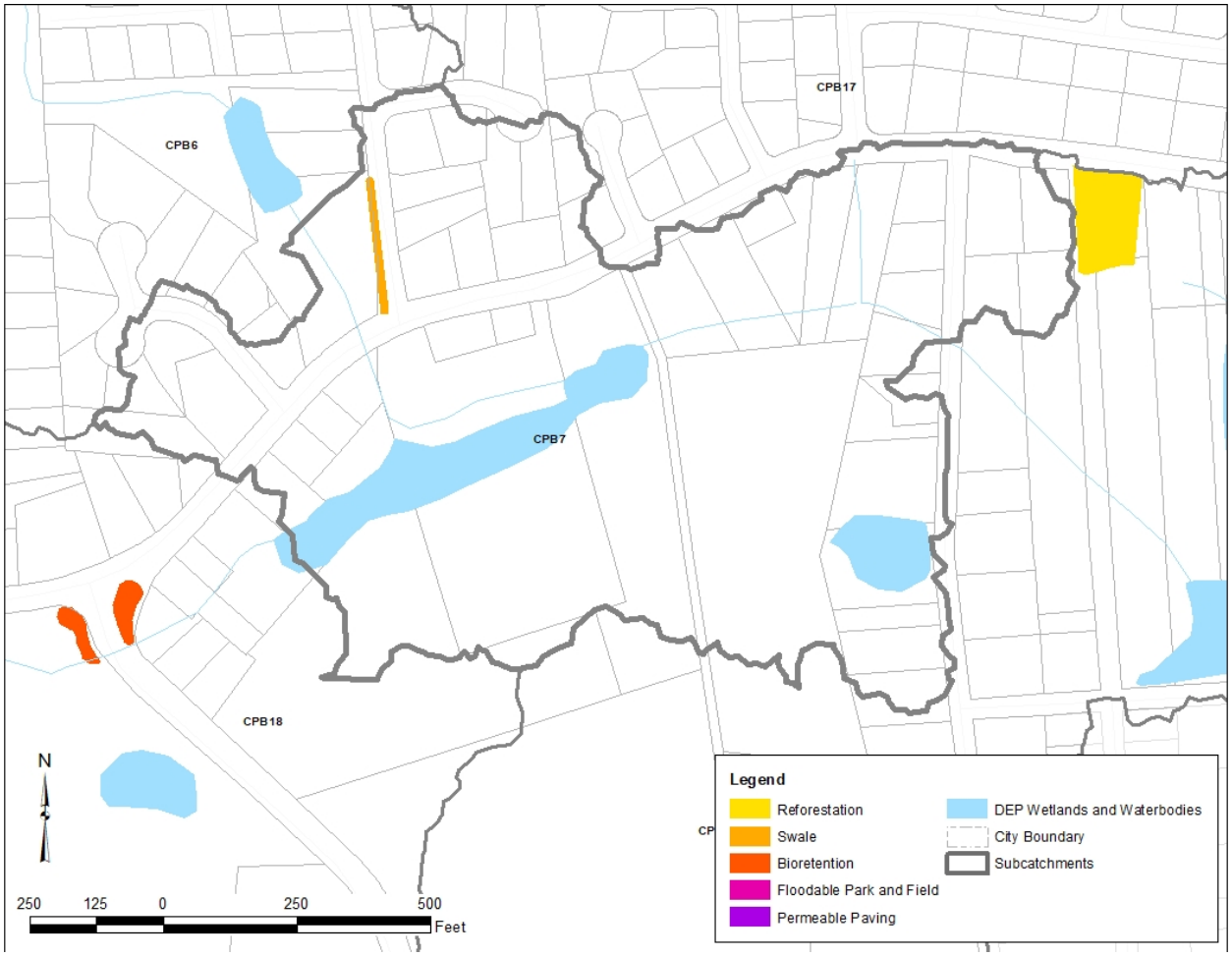


Figure 30. Green Infrastructure Scenario CPB7

Scenario 4: Subcatchment CPB8 covers a section of Route 113 along the Merrimack River, the Market Basket along Route 113, and residential development and open space north and south of Varnum Avenue. Claypit Brook flows through forested parcels owned by the City, and then enters a culvert that passes beneath a road. A wetland system exists at the upstream end of the culvert. Since the lower section of CPB8 is located within the Merrimack River 100-year flood zone, no green flood reduction opportunities were proposed in that area. Within the upper portion of the subcatchment, this scenario includes installing swales along Meadowview Drive, Jennifer Road, and Lexington Avenue. A reforestation and stormwater detention area is also prosed along Varnum Avenue. In total, the stormwater swales cover an area of 7,789 square feet, or 0.003% of the subcatchment area. The reforestation and stormwater detention area covers 21,655 square feet, or approximately half an acre.

700 Varnum Avenue is a property that consists of a 1/3 acre residential-zoned undeveloped lot. In 1951 the City of Lowell acquired the lot as a tax taking. In 2004 Lowell attempted to develop the property for an affordable housing unit. Once excavation started the site was determined to

contain contaminated soils (PAHs, VOCs, PCBs) that were attributed to disposal that occurred prior to the City obtaining ownership. The plans to develop the property were abandoned and current conditions are unknown. The site is tracked under the Massachusetts Contingency Plan (MCP) under three separate Release Tracking Numbers.

To use this site for stormwater management purposes, the current permeable cap that isolates contaminated soil would need to be replaced with an impermeable membrane/cap. A cost-effectiveness assessment would need to be conducted to all for any further consideration of this site for stormwater management and flood control in Clay Pit Brook.

GI projects in this scenario are expected to reduce impervious cover by 0.18 acres and attenuate up to 88,330 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB8 as shown in the table below.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	25%	22%	19%
10-year	13%	11%	10%

Table 20 Reduction in Total Runoff Volume in CPB8

As precipitation, and therefore runoff volumes, increase with both larger design events and with advancing climate change, the benefit associated with the proposed GI scenario decreases accordingly. This scenario is expected to reduce runoff during the 2-year event by 25%. That benefit is reduced to 22% and 19% under mid- and late-century climates, respectively, and it is reduced to 13% during the larger 10-year event.

While this scenario will produce some reductions in total runoff volumes, it is unlikely to significantly reduce peak runoff rates or to reduce flood levels at Malden or Lexington Avenues, the next two downstream crossings, by an appreciable amount.

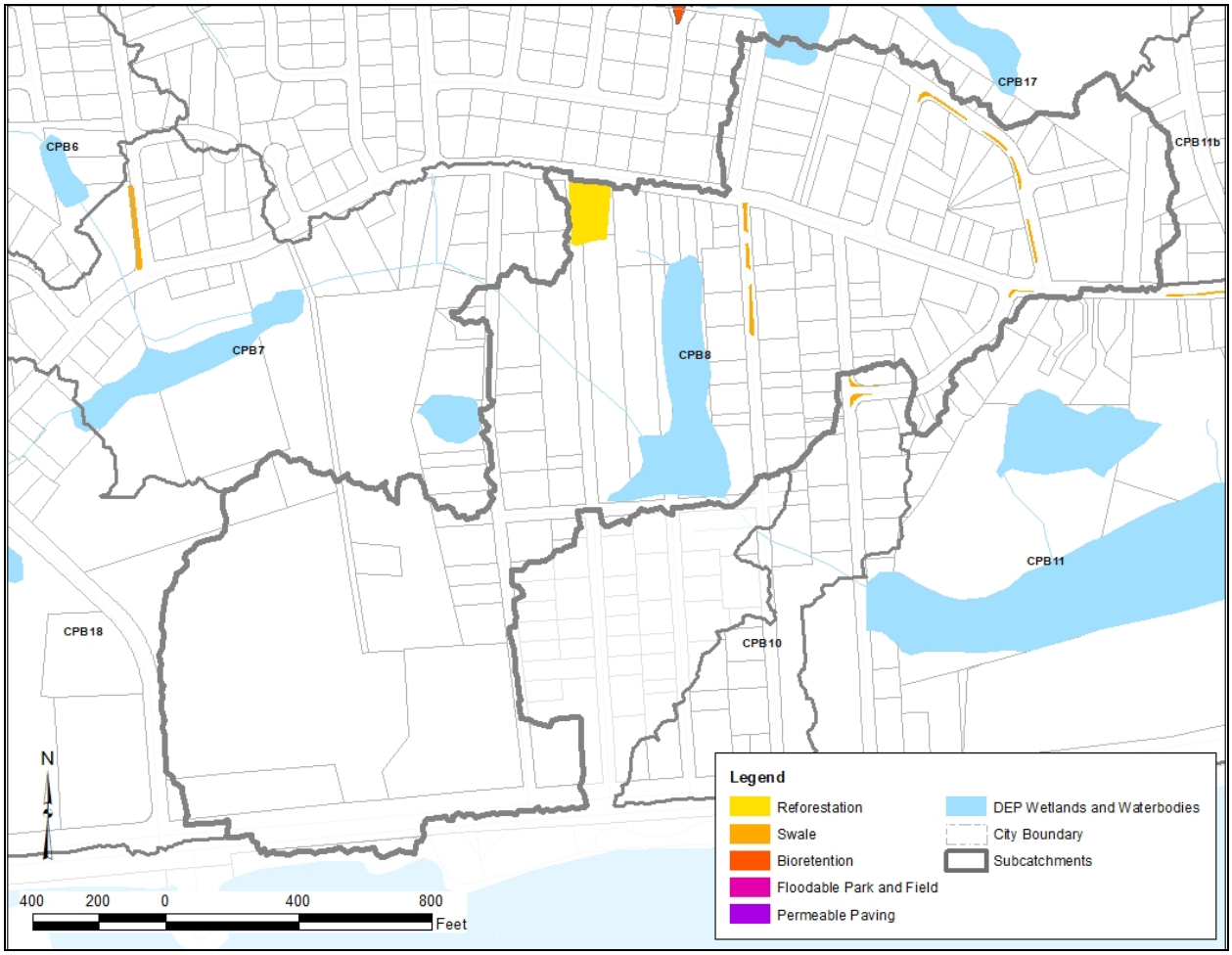


Figure 31. Green Infrastructure Scenario CPB8

Scenario 5: Subcatchment CPB10 is a narrow subcatchment that extend from Route 113 along the Merrimack River and north to Jennifer Road. Claypit Brook bisects the subcatchment, and the land use is made up of primarily residential. Two swales are proposed in the northern section of CPB10, at the corner of Jennifer Road and Bedford Avenue. These swales would intercept flow travelling down both roads towards Claypit Brook and would be connected beneath the road for additional storage and increased connectivity. The total area of the stormwater swales combined is 1,540 square feet.

GI projects in this scenario are expected to reduce impervious cover by 0.03 acres and attenuate up to 4,620 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB10 as shown in the table below.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	7%	7%	6%
10-year	4%	4%	3%

Table 21 Reduction in Total Runoff Volume in CPB10

This scenario is expected to reduce runoff during the 2-year event by 7%, a reduction that remains relatively steady under mid- and late-century conditions. It is, however, reduced to 4% during the larger 10-year event.

While this scenario will produce some reductions in total runoff volumes, it is unlikely to significantly reduce peak runoff rates or to reduce flood levels at Bedford or Dunbar Avenues, the next two downstream crossings, by an appreciable amount.

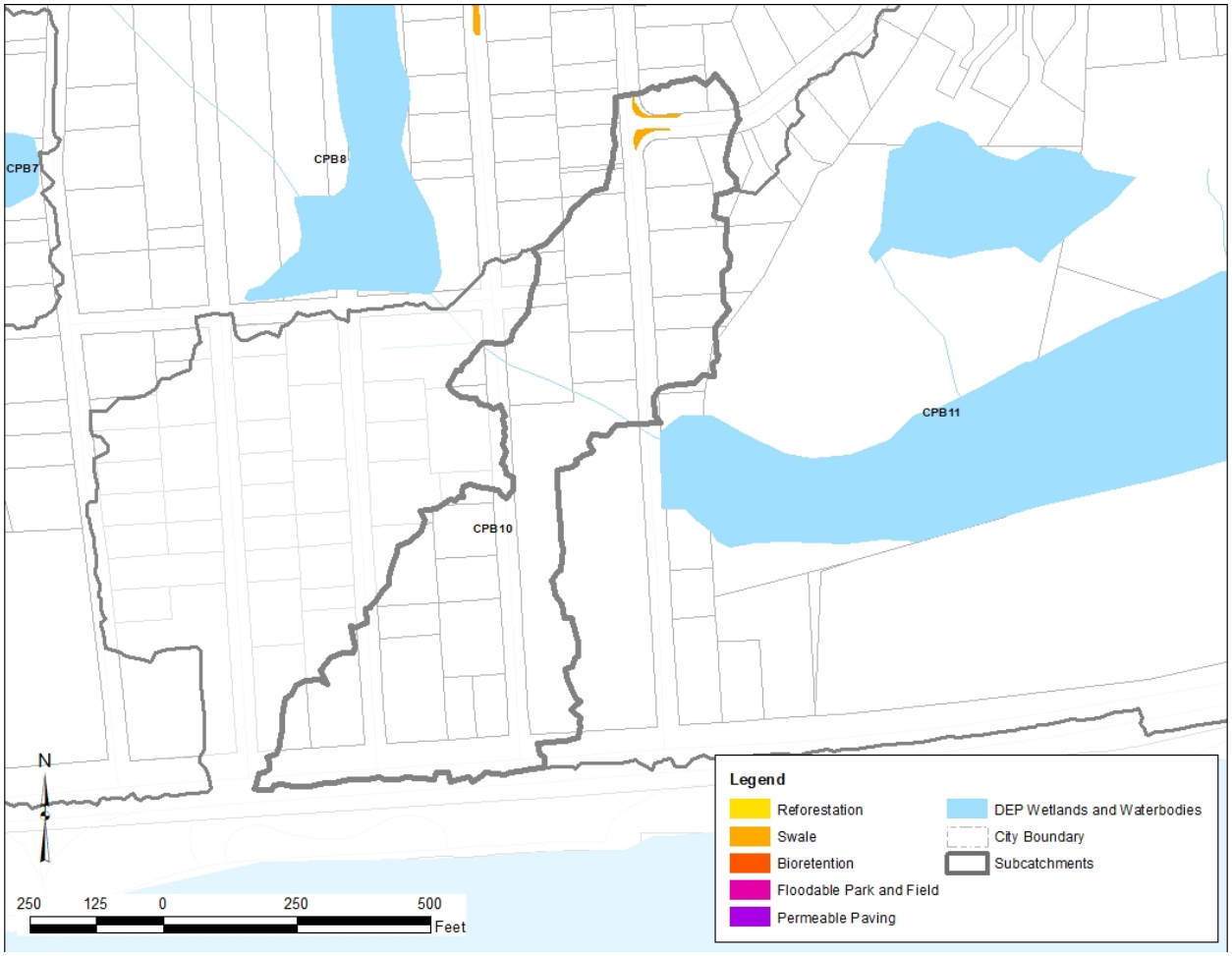


Figure 32. Green Infrastructure Scenario CPB10

Scenario 6: Subcatchment CPB11 exists between Varnum Avenue and Route 113. There is a large wetland system that extends through the subcatchment. Much of the areas is forested and grassed open space among residential and commercial development. The lower part of this subcatchment is in the Merrimack River 100-year flood plain. This scenario included stormwater swales along the south side of Varnum Road along the right-of-way to collect stormwater from the road. In total, the swales would cover just over 5,000 square feet.

GI projects in this scenario are expected to reduce impervious cover by 0.12 acres and attenuate up to 15,160 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes from sub-basin CPB11 as shown in the table below.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	5%	4%	3%
10-year	2%	2%	2%

Table 22 Reduction in Total Runoff Volume in CPB11a

This scenario is expected to reduce runoff volumes rather mildly, with a maximum reduction of 5% during the 2-year event under the current climate. As precipitation, and therefore runoff volumes, increase with both larger design events and with advancing climate change, the benefit associated with the proposed GI scenario decreases accordingly.

This scenario is not expected to significantly reduce peak runoff rates. Nor is it expected to reduce flood levels at the next two downstream crossings, Dunbar Avenue and Delaware Avenue, by more than 0.01 feet.

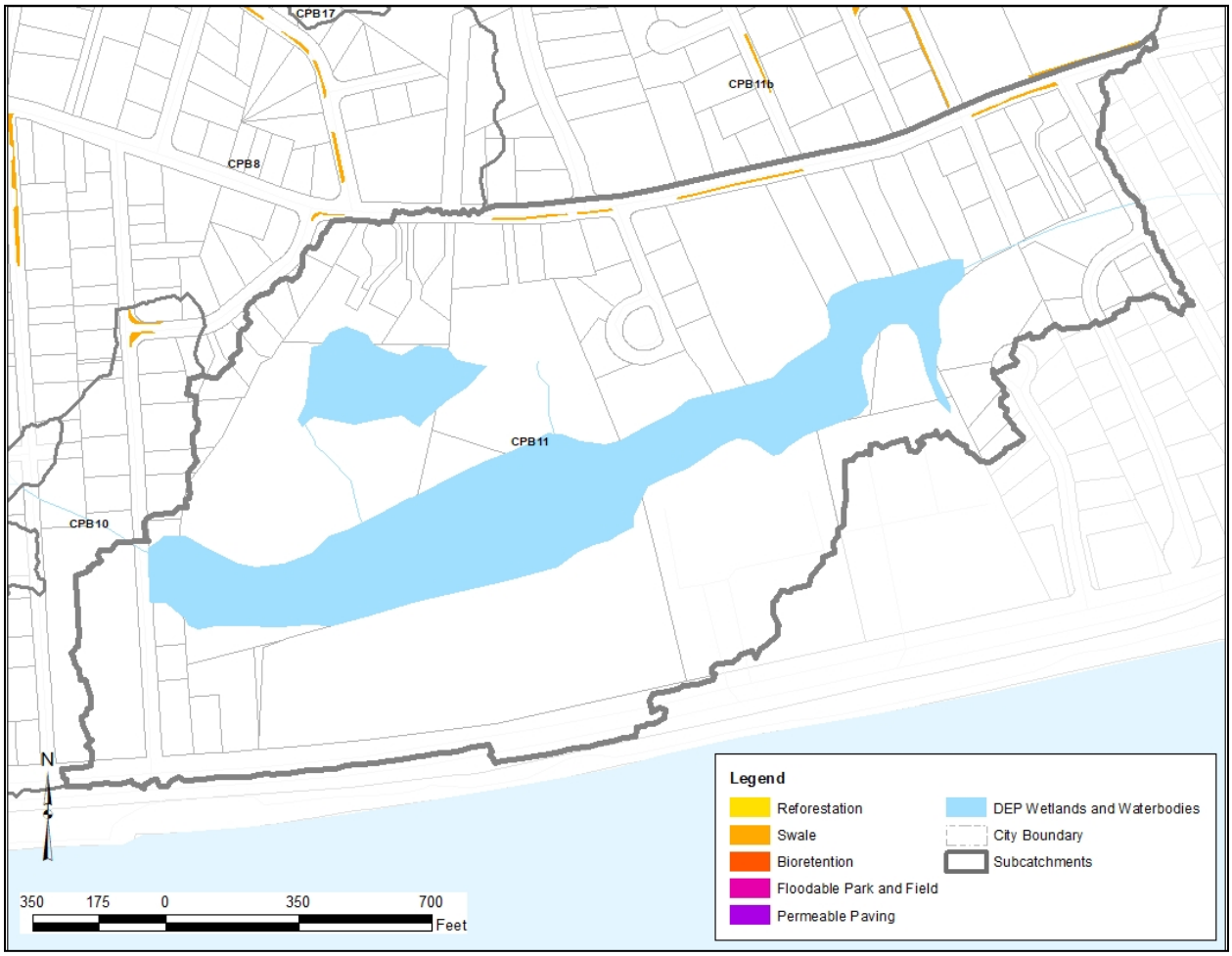


Figure 33. Green Infrastructure Scenario CPB11a

Scenario 7: Subcatchment CPB11b is located adjacent to CPB11 on the northern side of Varnum Avenue. The subcatchment is covered primarily by residential development, as well as some forested area and commercial development.

Two stormwater swales are proposed in CPB11b along Barbara Terrace and Ursula Street. These swales would collect stormwater flowing along both streets before they reach the stormwater system and Claypit Brook. In total the swales cover just over 8,300 square feet. GI projects in this scenario are expected to reduce impervious cover by 0.11 acres and attenuate up to 28,400 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB11B as shown in the table below.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	20%	17%	13%
10-year	8%	7%	6%

Table 23 Reduction in Total Runoff Volume in CPB11b

As precipitation, and therefore runoff volumes, increase with both larger design events and with advancing climate change, the benefit associated with the proposed GI scenario decreases accordingly. This scenario is expected to reduce runoff during the 2-year event by 20%. However, it is reduced to 17% and 13% under mid- and late-century climates, respectively, and it is reduced to 8% during the larger 10-year event.

While this scenario will produce some reductions in total runoff volumes, it is unlikely to significantly reduce peak runoff rates or to reduce flood levels at Dunbar or Delaware Avenues by an appreciable amount.

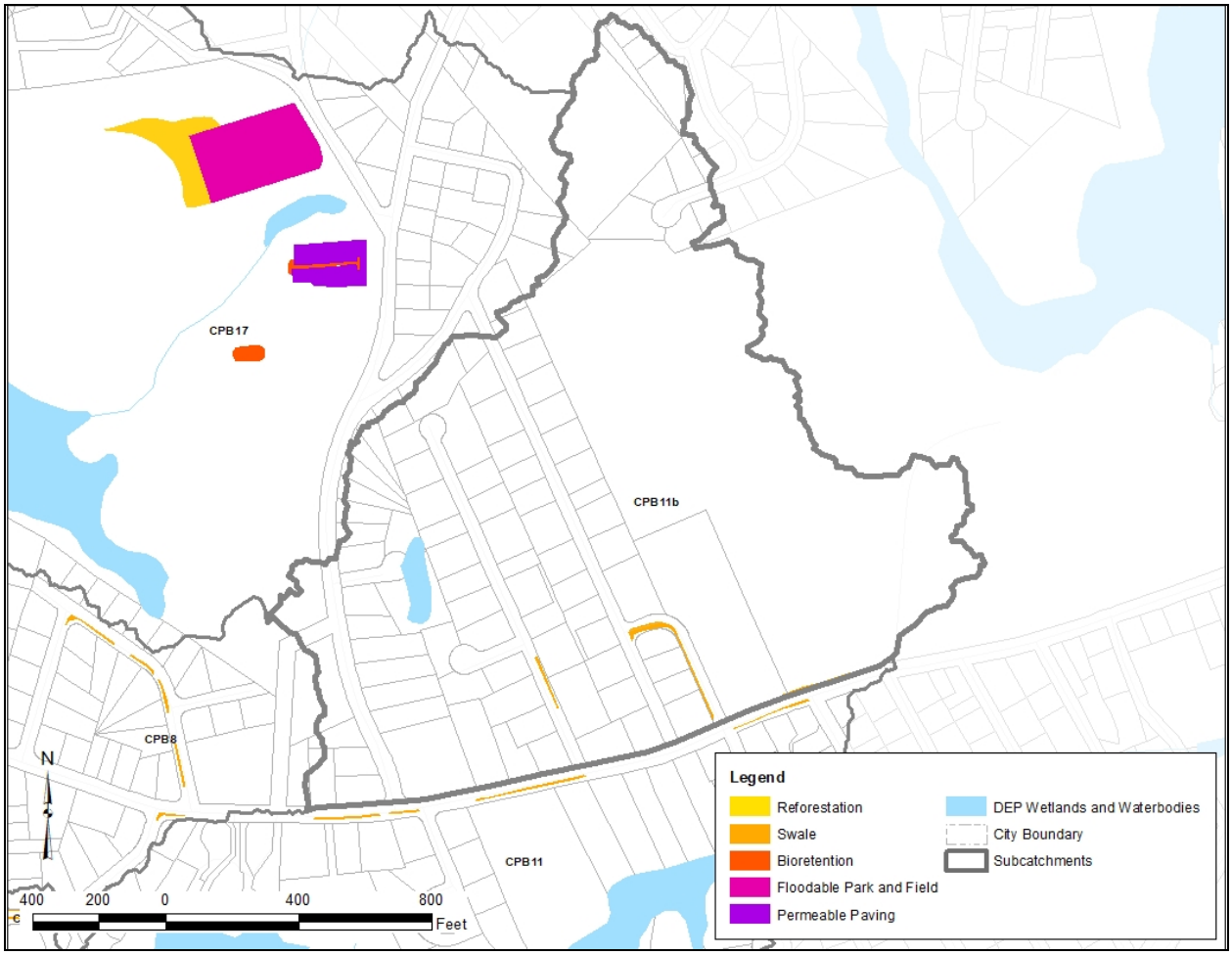


Figure 34. Green Infrastructure Scenario CPB11b

Scenario 8: Subcatchment CPB17 mostly consists of residential development. There is a large wetland system in the center of the subcatchment covering much of the open space in this subcatchment. There is a school on the eastern side of the subcatchment, built on a highpoint above the wetland.

The wetland in CPB17 collects runoff from Dr. Ann Wang Middle School. The edge of the wetland is close to the adjacent residential homes, most of which are in the 100 year flood zone. A heavy rain event could cause damage for the residents in this neighborhood. By collecting stormwater at the school, this reduces runoff into the wetland. This scenario includes the installation of a permeable pavement parking lot at the school, along with a depressed planter in the parking lot median. Additionally, by turning the field into a floodable field and adding a detention basin adjacent to the school, the City could store large volumes of water and reduce the flooding downstream. In total, these flood reduction solutions would cover 108,025 square feet within the subbasin.

Additionally, a reforestation project is identified between two playing school fields which can increase canopy over a 31,289 square foot area. An approximately 9,500 square foot detention basin is

proposed along Newbridge Road, and a swale at Totman Road. Two stormwater swales are also proposed at the bend in Acropolis Road.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	10%	9%	8%
10-year	5%	5%	4%

Table 24 Reduction in Total Runoff Volume in CPB17

GI projects in this scenario are expected to reduce impervious cover by 0.78 acres and attenuate up to 121,500 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB17 as shown in the table below.

This scenario is expected to reduce runoff during the 2-year event by 10%, a benefit that remains relatively steady under mid- and late-century climate conditions. During the larger 10-year event, however, that relative reduction in total runoff from CPB17 drops to 5%.

While this scenario will likely produce notable reductions in total runoff volumes, the proposed GI projects are not expected to significantly reduce peak runoff rates, although downstream crossings experience a small reduction in flood depths because of lower total runoff volumes given the pool-drop nature of the lower reach of Claypit Brook. Those benefits are presented in the table below.

Roadway	Event	Flood Depth Reductions (feet)		
		Current	*Mid-Century*	*Late-Century*
Meadow Drive (Wetland Overtopping)	2-year	0.19	0.18	0.14
	10-year	0.07	0.06	0.05
Malden Ave	2-year	0.03	0.03	0.04
	10-year	0.05	0.04	0.02

**Gray cells indicate design storms and climate conditions where the roadway is not expected to overtop.*

Table 25 Flood Reduction Scenarios at Meadow Drive and Malden Avenue

The greatest reduction in overland flooding, 0.19 feet at the downstream end of CPB17, in the cul-de-sac at the end of Meadow Drive, naturally occurs during the 2-year event under current climate conditions. That benefit is reduced to 0.18 and 0.14 feet under mid- and late-century climates, respectively. However, in this case, while reductions in flood depth are always beneficial, overland flooding is not expected to occur during the 2-year event under existing conditions. Flooding is expected during the 10-year event though, during which the proposed GI scenario is expected to reduce flood depths by up to 0.07 feet. Further downstream, at Malden Avenue, flood depth reductions are expected to be 0.05 feet or less.

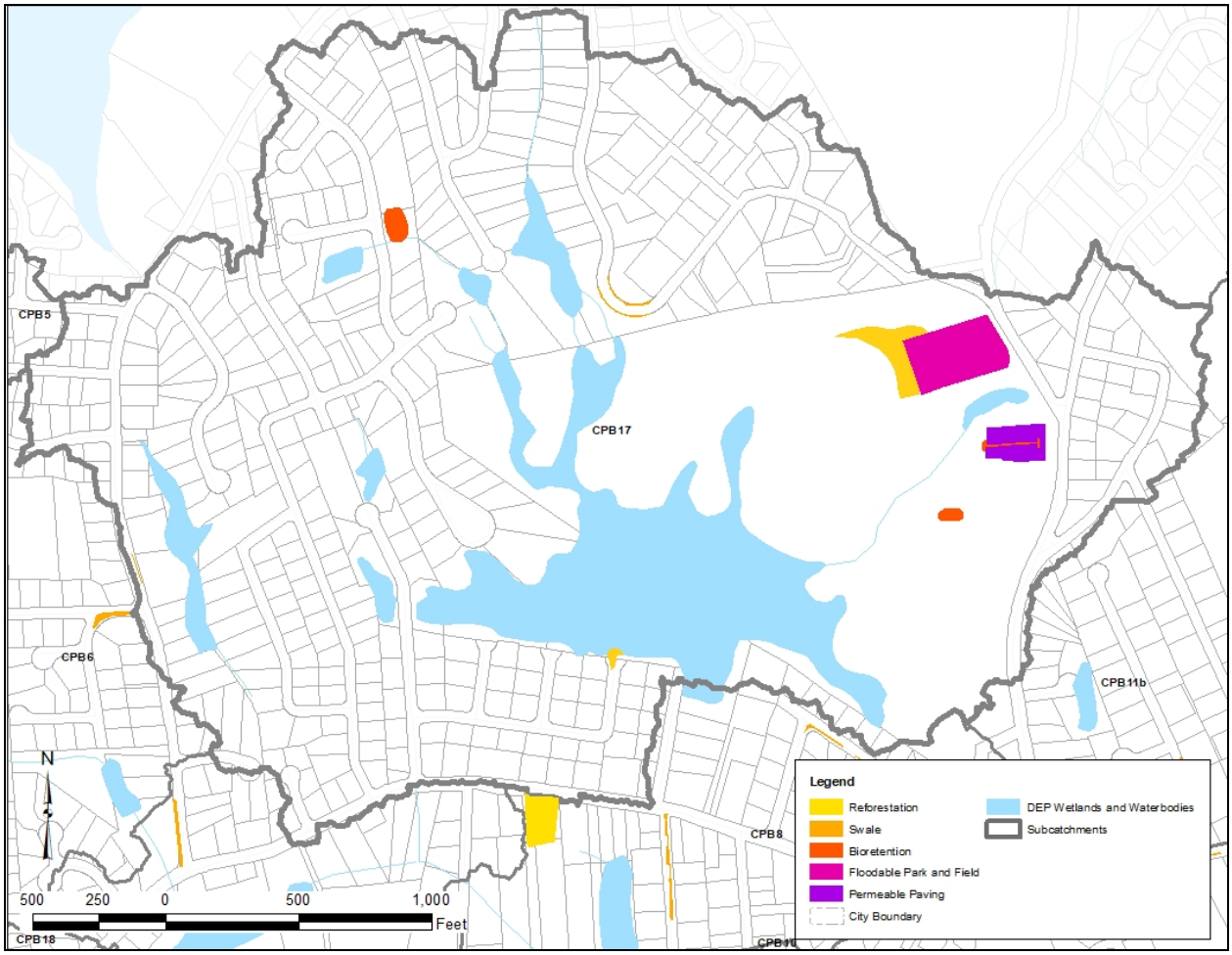


Figure 35. Green Infrastructure Scenario CPB17

Scenario 9: Subcatchment CPB18 is split by Varnum Avenue. Development in this subcatchment consists of residential and commercial development, with a small amount of open space. The subcatchment is also partially located within the Merrimack River 100-year flood plain. The long stretch of Varnum Road through CPB18 allows for the placement of multiple stormwater swales, covering 34,900 square feet. However, the placement of these swales is contingent upon approval from a private landowner, as it would be located outside of the right-of-way. Smaller swales are also proposed along Fowler Road and Old Ferry Road with a total area of 11,300 square feet.

Event	Reduction in Total Runoff Volume (%)		
	Current	*Mid-Century*	*Late-Century*
2-year	30%	26%	22%
10-year	15%	13%	11%

Table 26 Reduction in Total Runoff Volume CPB18

GI projects in this scenario are expected to reduce impervious cover by 0.1 acres and attenuate up to 138,600 cubic feet of runoff. These changes in land cover and flood storage will reduce total runoff volumes generated from sub-basin CPB18 as shown in the table below.

As precipitation, and therefore runoff volumes, increase with both larger design events and with advancing climate change, the benefit associated with the proposed GI scenario decreases accordingly. This scenario is expected to reduce runoff during the 2-year event by 30%. Reductions under mid- and late-century climate conditions, 26% and 22%, respectively, are smaller but still significant. Even during the 10-year event, this scenario would reduce total runoff by up to 15%.

While this scenario will produce significant reductions in total runoff volumes, it is unlikely to significantly reduce peak runoff rates or to reduce flood levels at Townsend or Malden Avenues by an appreciable amount.

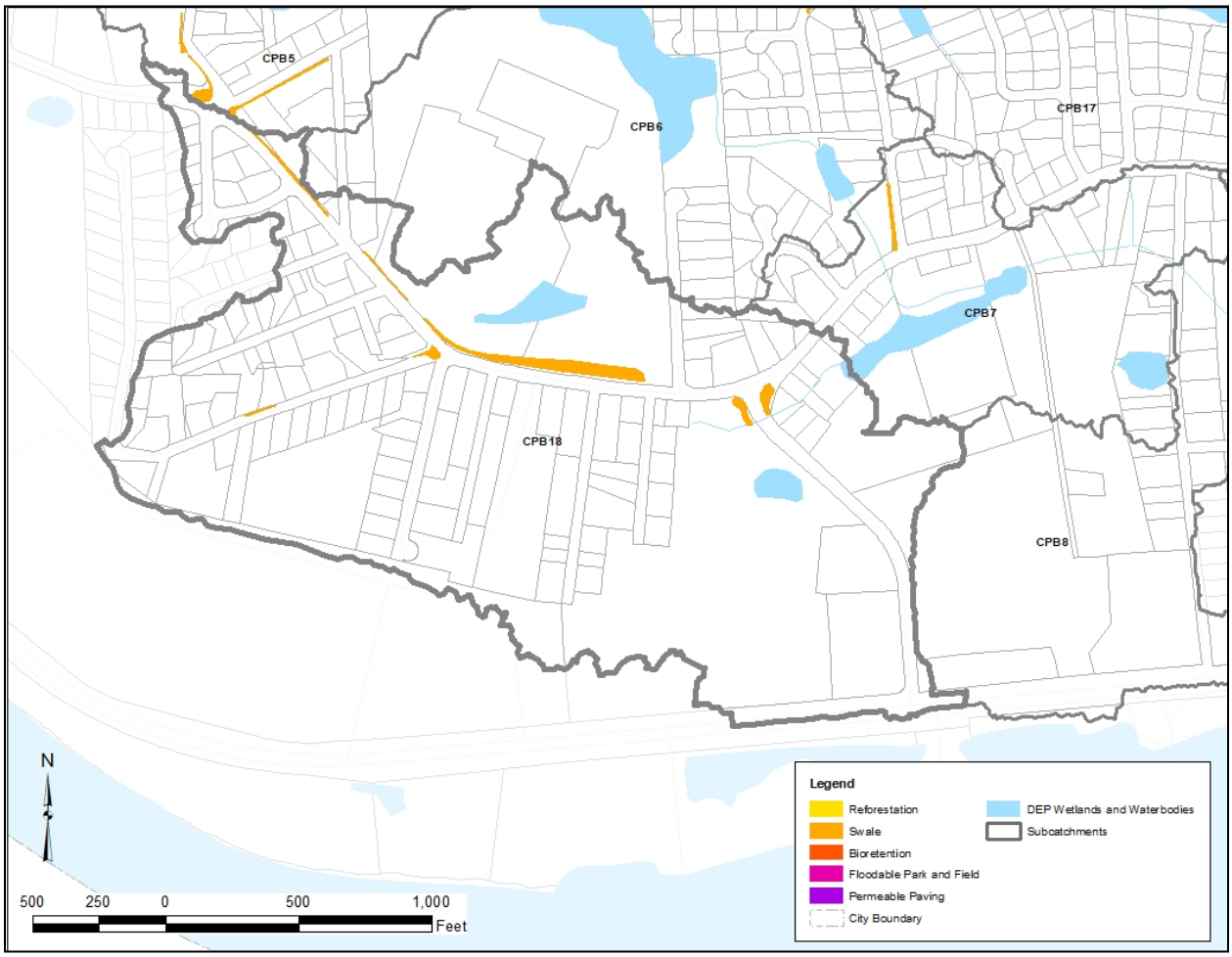


Figure 36. Green Infrastructure Scenario CPB18

Prioritization

The green infrastructure scenarios were organized by sub-catchment area and prioritized through an evaluation of Impact of Flooding (IoF) multiplied by the Feasibility and Benefit of Implementation (See table 27).

$$\text{Prioritization Score (S)} = \text{Impact of Flooding (IoF)} \times (\text{Feasibility} * \text{Benefit})$$

Impact of Flooding is defined by the delta, or reduction of water volume provided by the green infrastructure strategy, which was determined by the Hydraulic and Hydrologic modeling effort.

PRIORITIZATION DEFINITION									
SCORE 1-5	IMPACT ON FLOOD REDUCTION	COST	PROJECT SIZE	PARCEL OWNERSHIP	MAINTENANCE REQS	CONTRIBUTES TO PLACEMAKING	USES NATURE-BASED SOLUTIONS	LOCATION IN EJ COMMUNITY	URBAN HEAT ISLAND IMPROVEMENT
1	>20%	<20k	LARGE	PUBLIC LOT	YEARLY	YES - NEW PLACE	YES	YES	LARGE TREES
2	15-20%	20k-30k		PROW	TWICE YEARLY				SMALL TREES
3	10-15%	30k-50k	MED	EASEMENT	MONTHLY	CONTRIBUTES	MIX	ADJACENT	SHRUBS
4	5-10%	50k-80k		PRIVATE COLLAB	WEEKLY				GRASSES
5	0-5%	>80k	SMALL	PRIVATE	DAILY/EXTENSIVE	NO	NO	NO	NO VEGETATION

Table 27 Scoring Legend for GI Prioritization. Score of 1 is high priority; Score of 5 is low priority.

The "feasibility of implementation" is defined by following attributes:

- Cost – whether or not the strategy is cost prohibitive to implement.
- Project size (area) – Large projects contribute to more stormwater management, public realm improvements, and reduction of UHI and are prioritized over smaller projects.
- Parcel ownership – public land is easier for the City to implement on because there is no need to provide incentives, compensation, or purchase land; public right of way is within the City's jurisdiction but can be more difficult to implement on due to utilities and size constraints; private property is possible if the City has a collaborative relationship with the owner; private property without a relationship with the City is the most difficult.
- Maintenance requirements – the maintenance requirements of the strategy were evaluated based on the frequency (time) of the maintenance cycle.

The benefit of implementation is defined by following attributes:

- Contribution to place-making – whether or not the strategy improves the public realm through new planting or physically creates a new place residents can enjoy, such as a park, plaza, or field.
- Use of nature-based solutions – green infrastructure that uses vegetation provides environmental benefits and contributes to the quality of the public realm through greening, shading, and temperature reduction.
- Location in an environmental justice community – Green infrastructure can provide benefits to populations that have historically experienced negative environmental impacts due to discriminatory practices that impact economic and housing opportunity and poorly impact health.

- Urban Heat Island (UHI) improvements – Green infrastructure can contribute to the reduction of urban heat island and provide shading to the public realm. Depending on the size and type of species, the amount of urban heat island reduction varies. For example, a large tree that is planted as a component of reforestation contributes to 35-45 degree (F) of temperature reduction, while smaller shrubs also provide benefit but not as substantially.

Green Infrastructure Prioritization

			(S) = Impact on Flooding (IoF) x (Feasibilty * Benefit)											
					Impact on Flooding		Feasibility				Benefit			
ID	Green Infrastructure Strategy	Sub-Catchment Area	Rank	Overall Prioritization Score (S)	Reduction of Impervious Area	Reduction of Total Runoff	Cost	Project Size (Area ft²)	Parcel Ownership	Maintenance Requirements	Contributes to Placemaking	Uses Nature-Based Solutions	Location within EEA EJ population (Y/N)	Urban Heat Island Improvements
6	Detention - Varnum Ave	CPB8	1	1.90	2	1	5	1	1	3	2	2	1	1
28	UHI - Increase Canopy	CPB17	2	2.10	1	4	5	1	1	3	3	1	1	1
23	Detention Basin - Newbridge Road	CPB17	3	2.20	1	4	5	1	1	3	3	2	1	1
27	Floodable Field - Gumpus Road	CPB17	3	2.20	1	4	5	1	1	2	2	1	1	4
30	Swale - Retirement Community	CPB18	3	2.20	3	1	5	1	2	2	2	3	1	2
32	Swale - Varnum Ave	CPB18	3	2.20	3	1	4	2	2	2	2	3	1	2
7	Swale - Meadowview Dr	CPB8	7	2.30	2	1	2	4	2	2	3	3	1	3
8	Swale - Jennifer Road	CPB8	7	2.30	2	1	1	5	2	2	3	3	1	3
9	Swale - Meadowview Drive	CPB8	7	2.30	2	1	1	5	2	2	3	3	1	3
10	Swale - Meadowview Drive	CPB8	7	2.30	2	1	1	5	2	2	3	3	1	3
11	Swale - Meadowview Dr	CPB8	7	2.30	2	1	1	5	2	2	3	3	1	3
19	Swale - Varnum Ave	CPB11b	7	2.30	3	2	4	2	2	2	2	3	1	2
22	Detention Basin - Dr. An Wang Middle School	CPB17	7	2.30	1	4	5	2	1	3	3	2	1	1
35	Swale - Old Ferry Road	CPB18	7	2.30	3	1	4	2	2	2	3	3	1	2
12	Swale - Lexington Ave	CPB8	15	2.40	2	1	4	3	2	2	3	3	1	3
17	Swale - Barbara Terrace	CPB11b	15	2.40	3	2	4	2	2	2	3	3	1	2
33	Swale -Fowler Road	CPB18	15	2.40	3	1	3	3	2	2	3	3	1	3
34	Swale - Old Ferry Road	CPB18	15	2.40	3	1	4	3	1	2	3	3	1	3
29	Swale - Robin Lane	CPB17	19	2.44	1	4	3	3	2	2		3	1	3
2	Swale / Detention Basin - Trotting Park Road	CPB5	20	2.50	5	2	3	2	2	3	3	2	1	2
3	Swale / Detention Basin 2 - Trotting Park Road	CPB5	20	2.50	5	2	1	4	2	3	3	2	1	2
5	Swale - Varnum Road @ Totman Road	CPB7	20	2.50	4	3	4	2	2	2	2	3	1	2
14	Swale - Varnum Ave	CPB11	20	2.50	2	5	2	3	2	2	2	3	1	3
21	Depressed Planter - Dr. An Wang Middle School	CPB17	20	2.50	1	4	4	3	1	3	4	3	1	1
25	Swale - Acropolis Road	CPB17	20	2.50	1	4	2	4	2	2	4	3	1	2
26	Swale - Acropolis Road	CPB17	20	2.50	1	4	2	4	2	2	4	3	1	2
31	Swale - Varnam @ Retirement Community	CPB18	20	2.50	3	1	2	4	4	2	2	3	1	3
36	Swale Fowler Road	CPB18	20	2.50	3	1	1	5	2	2	4	3	1	3
1	Swale - Anson St	CPB5	29	2.60	5	2	5	1	2	2	3	3	1	2
15	Swale - Varnum Ave	CPB11	29	2.60	2	5	2	4	2	2	2	3	1	3
16	Swale - Varnum Ave	CPB11	29	2.60	2	5	1	5	2	2	2	3	1	3
18	Swale - Ursula St	CPB11b	29	2.60	3	2	1	5	2	2	4	3	1	3
24	Swale - Totman Road	CPB17	29	2.60	1	4	1	5	2	2	4	3	1	3
20	Porous Pavement - Dr. An Wang Middle School	CPB17	34	2.80	1	4	5	1	1	1	4	5	1	5
4	Swale - Cidalia Dr & Eleanor Dr	CPB6	35	2.90	4	5	3	3	2	2	3	3	1	3
13	Swales- Jennifer Road @ Bedford Ave	CPB10	35	2.90	5	4	2	4	2	2	3	3	1	3

Table 28 Green Infrastructure Prioritization Matrix

Table 28 lists the top 36 green infrastructure projects per subcatchment and ranks them based on the scores established using the criteria listed in Table 27. The green cells indicate higher ranking, with lower rankings in orange. The darkest green cells indicate projects that scored well across all the considerations and represent projects that should be prioritized in terms of phasing and implementation.

Scenario Recommendations

The proposed GI projects identified within Claypit Brook were modeled together as scenarios for the H&H modeling. The ranking of the scenarios in terms of greatest reduction of flooding is shown in Table 29. For example, the table and modeling suggest if all 7 GI projects in Subcatchment Scenario CPB18 were to be implemented, the total runoff within the watershed could be reduced by 26%.

Rank	Subcatchment Scenario	Percent Reduction of Total Runoff
1	CPB18	26%
2	CPB8	22%
3	CPB5	18%
4	CPB11B	17%
5	CPB7	10%
6	CPB17	9%
7	CPB10	7%
8	CPB11A	4%
9	CPB6	3%

Table 29 – Scenario Rankings in terms of Modeled Impacts on Flooding

Although the scenario approach to ranking highlights the importance of GI working together as a system of projects for stormwater management, ranking of individual projects better captures the feasibility of implementation and targeting the co-benefits of the GI.

The top 6 projects that rank highest represent a range of strategies, locations and sized of green infrastructure. They represent feasible projects that not only mitigate the impacts of flooding, but also resilient strategies to help the neighborhoods around Claypit Brook cope with future climate scenarios.

1. CPB8 - The large stormwater detention area along Varnum Road.
2. CPB17 – The stormwater detention area near Dr. An Wang Middle School
3. CPB17 – The Reforestation area between the sports fields at Dr. An Wang Middle School
4. CPB17 – The stormwater detention area along Newbridge St
5. CPB17 – The floodable field next to Dr. An Wand Middle School
6. CPB18 – The large swale along Varnum Avenue

5.0 Additional Flood Storage

In addition to the GI scenarios considered above, Weston & Sampson also evaluated the potential benefits of creating additional flood storage in the upper reaches of Claypit Brook to reduce flood volumes and peak flows in the lower, more vulnerable reaches of the brook. The additional flood storage was generally envisioned to be created by the construction of a small, non-jurisdictional dam structure. In total, three flood storage opportunities were identified and evaluated as discussed here.

Three flood storage projects were evaluated in the upper half of the watershed. All of them produced significant flood depth reductions in the more developed, lower half of the brook. Scenario S3 produced particularly significant reductions of roughly 0.5 feet (or more) throughout much of the lower half of the watershed. Note that while these storage projects were effective, the permitting hurdles associated with them, will be significant, and were not evaluated in detail under this scope of work.

Scenario S1 entails of the creation of a small, non-jurisdictional dam or flood retention structure in Claypit Brook just north of the Summit Elder Care facility. The area is currently partially impounded, as shown in the figure at the right, by beaver dams, to an elevation of approximately El. 99. The proposed structure would include a small outlet at that same elevation to maintain traditional water levels upstream and normal streamflow downstream under non-flood conditions. Otherwise, the dam structure would have a crest at El. 104, creating up to five feet or 5.1 acre-feet of storage during flood events.

Figure 37 Scenario 1 flood storage area

Approximately 54% of the watershed is located upstream of this site. The attenuation of up to 5.1 acre-feet of runoff from the brook's headwaters would reduce both total volume and peak discharge downstream, resulting in flood depth reductions at many downstream crossings, as shown in the table.

Roadway	Flood Depth Reductions (feet)					
	2-year Event			10-year Event		
	Current	*Mid-Century*	*Late-Century*	*Current*	*Mid-Century*	*Late-Century*
Varnum Ave	0.32	0.41	0.56	0.85	0.84	0.84
Townsend Ave	0.33	0.45	0.64	0.25	0.29	0.14
Malden Ave	0.34	0.42	0.50	0.31	0.29	0.14
Lexington Ave	0.33	0.39	0.45	0.39	0.31	0.14
Bedford Ave	0.28	0.34	0.38	0.30	**0.18**	0.13
Dunbar Ave	0.23	0.27	0.33	0.25	0.22	0.30
Delaware Ave	0.19	0.23	0.30	0.22	0.19	0.22
Magnolia St	0.17	0.21	0.25	0.19	0.15	0.28
Stockbridge Ave	0.14	0.15	0.20	0.14	0.11	0.20
Avalon St	0.09	0.11	0.14	0.08	0.07	0.13
Pawtucket Blvd	0.04	0.06	0.07	0.04	0.03	0.07

Table 15 Flood depth reduction from Scenario 1 proposed storage

**Gray cells indicate design storms and climate conditions where the roadway is not expected to overtop under existing, no-action conditions. Bolded red values indicate roadways that are expected to flood under no-action conditions, but that would remain dry as a result of the proposed scenario.*

As shown in the table above, the proposed flood storage project would reduce flood depths considerably during both the 2- and 10-year events. No road crossings are expected to overtop during the 2-year event under existing, no-action conditions, although the proposed flood storage project would still increase freeboard by between 0.3 to 0.6 feet in many areas. During the 10-year event, several crossings are expected to be vulnerable to flooding. The proposed project would be expected to reduce flood depths at those crossings by 0.1 to 0.3 feet although only one, Bedford Avenue during the mid-century 10-year event, would be expected to go from overtopped to dry because of the proposed flood storage project.

Scenario S2 entails the creation of a small, non-jurisdictional dam or flood retention structure in Claypit Brook west of Carly Way. The area is currently only marginally impounded by a natural narrows or pinch point immediately downstream of where two channels converge, as shown in the figure at the right. This confluence is relatively low lying and contains modest flood storage potential. The proposed structure would include a small outlet at that

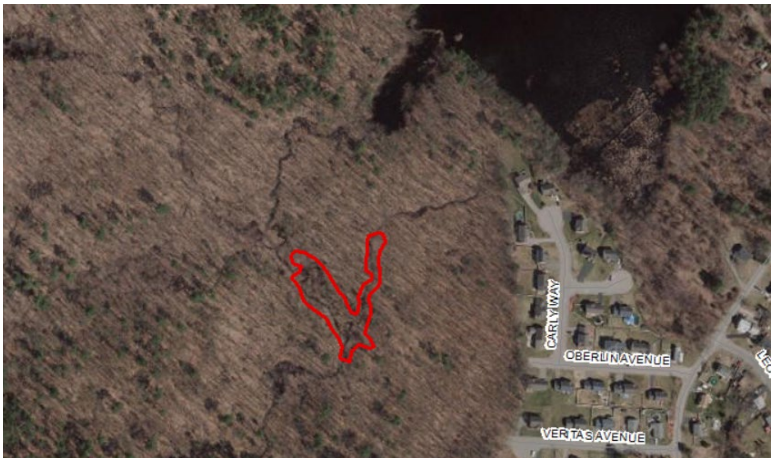


Figure 38. Scenario 2 flood storage area

existing channel thalweg, El. 129, to maintain traditional water levels upstream and normal streamflow downstream under non-flood conditions. Otherwise, the dam structure would have a crest elevation at El. 134, creating up to five feet or 3.3 acre-feet of storage during flood events.

Approximately 49% of the watershed is located upstream of this site. The attenuation of up to 3.3 acre-feet of runoff from the brook's headwaters would reduce both total runoff and peak discharge downstream, resulting in flood depth reductions at many downstream crossings, as shown in the table below.

As shown in the table, the proposed flood storage project would reduce flood depths considerably during both the 2- and 10-year events. No road crossings are expected to overtop during the 2-year event under existing, no-action conditions, although the proposed flood storage project would still increase freeboard by 0.1 to 0.3 feet in many areas. During the 10-year event, several crossings are expected to be vulnerable to flooding. The proposed project would be expected to reduce flood depths at those crossings by 0.1 to 0.3 feet although only one, Bedford Avenue during the mid-century 10-year event, would be expected to go from overtopped to dry as a result of the proposed flood storage project.

Roadway	Flood Depth Reductions (feet)					
	2-year Event			10-year Event		
	Current	*Mid-Century*	*Late-Century*	*Current*	*Mid-Century*	*Late-Century*
Varnum Ave	0.01	0.02	0.10	0.80	0.76	0.71
Townsend Ave	0.20	0.30	0.37	0.17	0.17	0.07
Malden Ave	0.24	0.31	0.27	0.19	0.17	0.07
Lexington Ave	0.24	0.29	0.24	0.22	0.18	0.07
Bedford Ave	0.21	0.24	0.20	0.16	**0.08**	0.08
Dunbar Ave	0.17	0.20	0.17	0.13	0.13	0.17
Delaware Ave	0.14	0.17	0.16	0.12	0.11	0.13
Magnolia St	0.13	0.15	0.13	0.10	0.09	0.17
Stockbridge Ave	0.11	0.11	0.10	0.08	0.06	0.12
Avalon St	0.06	0.08	0.07	0.04	0.04	0.08
Pawtucket Blvd	0.03	0.05	0.04	0.02	0.02	0.04

Table 31 Scenario 2 Flood depth reduction from Scenario 2 proposed storage

**Gray cells indicate design storms and climate conditions where the roadway is not expected to overtop under existing, no-action conditions. Bolded red values indicate roadways that are expected to flood under no-action conditions, but that would remain dry as a result of the proposed scenario.*

Scenario S3 entails the creation of a small, ideally non-jurisdictional dam or flood retention structure in Claypit Brook near the end of Carly Way and near the WCAP radio facility. The area is already significantly impounded, as shown in the figure at the right, by beaver dams, to an elevation of approximately El. 142. The proposed structure would include a small outlet at that same elevation to maintain traditional water levels upstream and normal streamflow downstream under non-flood conditions. Otherwise, the dam structure would have a spillway at El. 145 and a dam crest at El. 147, creating up to five feet or 24.3 acre-feet of storage during flood events.

Figure 39. Scenario 3 flood storage area

Approximately 43% of the watershed is located upstream of this site. The attenuation of up to 24.3 acre-feet of runoff from the brook's headwaters would reduce both total runoff and peak discharge downstream, resulting in flood depth reductions at many downstream crossings, as shown in the table below.

Roadway	Flood Depth Reductions (feet)					
	2-year Event			10-year Event		
	Current	*Mid-Century*	*Late-Century*	*Current*	*Mid-Century*	*Late-Century*
Varnum Ave	0.01	0.02	0.10	0.98	1.25	1.67
Townsend Ave	0.21	0.30	0.46	**0.45**	0.63	0.64
Malden Ave	0.25	0.32	0.42	0.62	0.69	0.64
Lexington Ave	0.25	0.30	0.40	0.98	0.83	**0.66**
Bedford Ave	0.23	0.27	0.34	0.70	**0.57**	**0.35**
Dunbar Ave	0.18	0.22	0.27	0.54	0.52	0.72
Delaware Ave	0.16	0.19	0.25	0.49	0.45	**0.56**
Magnolia St	0.14	0.17	0.20	0.41	0.36	0.58
Stockbridge Ave	0.11	0.12	0.16	0.31	0.26	0.42
Avalon St	0.07	0.09	0.11	0.18	0.17	0.27
Pawtucket Blvd	0.03	0.05	0.06	0.09	0.08	0.14

Table 32 Flood depth reduction from Scenario 3 proposed storage

**Gray cells indicate design storms and climate conditions where the roadway is not expected to overtop under existing, no-action conditions. Bolded red values indicate roadways that are expected to flood under no-action conditions, but that would remain dry as a result of the proposed scenario.*

As shown in the table above, the proposed flood storage project would reduce flood depths considerably during both the 2- and 10-year events. No road crossings are expected to overtop during the 2-year event under existing, no-action conditions, although the proposed flood storage

project would still increase freeboard by between ¼ and ½ of a foot in many areas. During the 10-year event, several crossings are expected to be vulnerable to flooding. The proposed project would be expected to eliminate overtopping at some of those crossings under current (1 of 2), mid-century (1 of 3), and late-century climates (3 of 5) while others will have increased freeboard and factors of safety.

Prioritization

Additional flood storage actions were prioritized based on potential for flood reduction, cost, and amount of flood storage provided. The table below provides additional detail on how strategies were scored and ranked using these three considerations.

Table 33. Prioritization Definition

Score 1-5	Impact on Flood Reduction	Cost	Storage (Acre-Feet)
1	>20%	<20k	>20
2	15-20%	20k-30k	15-20
3	10-15%	30k-50k	10-15
4	5-10%	50k-80k	5-10
5	0-5%	>80k	0-5

Based on these metrics, the prioritization process identified Scenario 3 as the top priority action, Scenario 1 as the second priority, and Scenario 2 as the third priority. The table below provides additional detail on the ranking of these three scenarios.

Table 34. Additional Flood Storage Actions Ranked

				Impact on Flooding	Feasibility	
ID	Description	Rank	Overall Prioritization Score (S)	Flood Depth Reduction (Mid-Century 10-year Event)	Cost	Storage (Acre-feet)
S3	Flood retention through proposed outlet control structure near Carly Way and WCAP Radio Facility	1	1.3	1	2	1
S1	Flood retention through proposed outlet control structure near Summit Elder Car Facility	2	2.3	2	1	4
S2	Flood retention through proposed outlet control structure near Carly Way	3	3.0	3	1	5

6.0 Community Engagement

The community engagement process sought to build on the work completed during the HMP-MVP Planning phase and collect feedback from residents related to the flood and heat impacts they have experienced and their preferred strategies for increased climate resiliency in the Claypit Brook Watershed. The team incorporated equitable engagement modifiers into the process to address barriers to participation, including offering technical support for virtual engagement such as step-by-step instructions and multiple options for joining Zoom meetings, contact information for questions, and starting meetings early to assist participants in joining. Translation and interpretation support was also offered in Spanish, Portuguese, and Khmer. More information on specific outreach and engagement formats is included in the sections below.

Project Webpage

The team created a new section on the webpage built during the HMP-MVP Planning phase to ensure continuity and establish the online location as an evolving depository of information about MVP work in Lowell. The new webpage section included an overview of the project, historic information on flooding in Pawtucketville, information on stormwater flooding, educational resources such as a visual fact sheet available in four languages, and a comment form for residents to submit questions and feedback at any time. The webpage was also used to share calls to action throughout the project, such as taking an online survey, registering for a public meeting, and keeping the conversation going online by using #ResilientLowell. Additionally, the Lowell webpage includes an embedded site tool that allows any webpage content to be translated automatically through Google Translate.

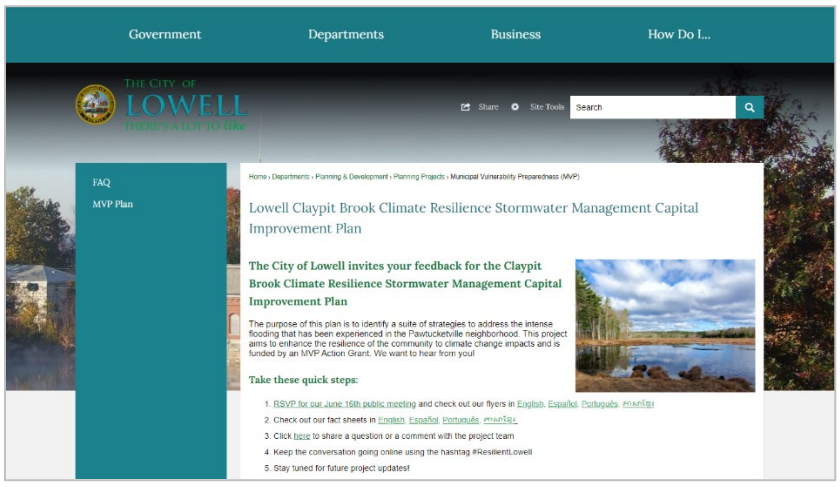


Figure 40. A screenshot of the Claypit Brook project webpage

Social Media

The project team created social media posts for Facebook and Twitter throughout the project, paired with the hashtag #ResilientLowell, which was also used during the HMP-MVP planning phase. Social

media posts were used to promote the public survey and the public meeting. Each social media post was paired with an image to draw attention and encourage engagement.

Figure 41. At left, a Twitter post from May 24th promoting the survey. At right, a Facebook post from June 7th advertising the public meeting.

Interviews

The project team conducted interviews via Microsoft Teams with stakeholders who had been impacted by flooding and extreme heat in Pawtucketville and the area surrounding the Stockbridge Avenue culvert. Interviewees discussed historic climate impacts that they had experienced, local recovery efforts, their preferred adaptation actions to increase resilience, and their recommendations on how adaptation actions should be prioritized. The input received informed the development and prioritization of recommendations.

Common themes of discussion included the property damage and displacement resulting from the severe flooding in 2006 and 2007. Interviewees also discussed the high cost of flood insurance and stated that many Pawtucketville residents do not have flood insurance for that reason. Participants also mentioned concerns about groundwater flooding and public health risks posed by flood impacts, including mold. Interviewees listed actions that residents have taken to increase their personal resilience, such as using sump pumps in basements, described public open spaces as a local asset and strength, and cited the neighborhoods strong community resilience and history of assisting neighbors after extreme events. Proposed actions to increase resilience included large-scale flood mitigation, relocating the water gauge to the top of the falls, culvert assessment and upsizing, green infrastructure, and regular stream maintenance.

Fact Sheet

The project team created a highly visual fact sheet, paired with an online survey, to get the word out about the project and collect input. The 1-page fact sheet was available in four languages and was designed to be accessible in both digital and printed formats. The fact sheet included information on flood and heat impacts in Lowell, definitions for key climate change-related terms, information on the MVP Action Grant program, and an overview of the Lowell Claypit Brook Climate Resilience Stormwater Management CIP project. The fact sheet also directed readers towards the City's MVP webpage for the most up to date information and can therefore continue to be used as a handout and educational resource during future phases of work.

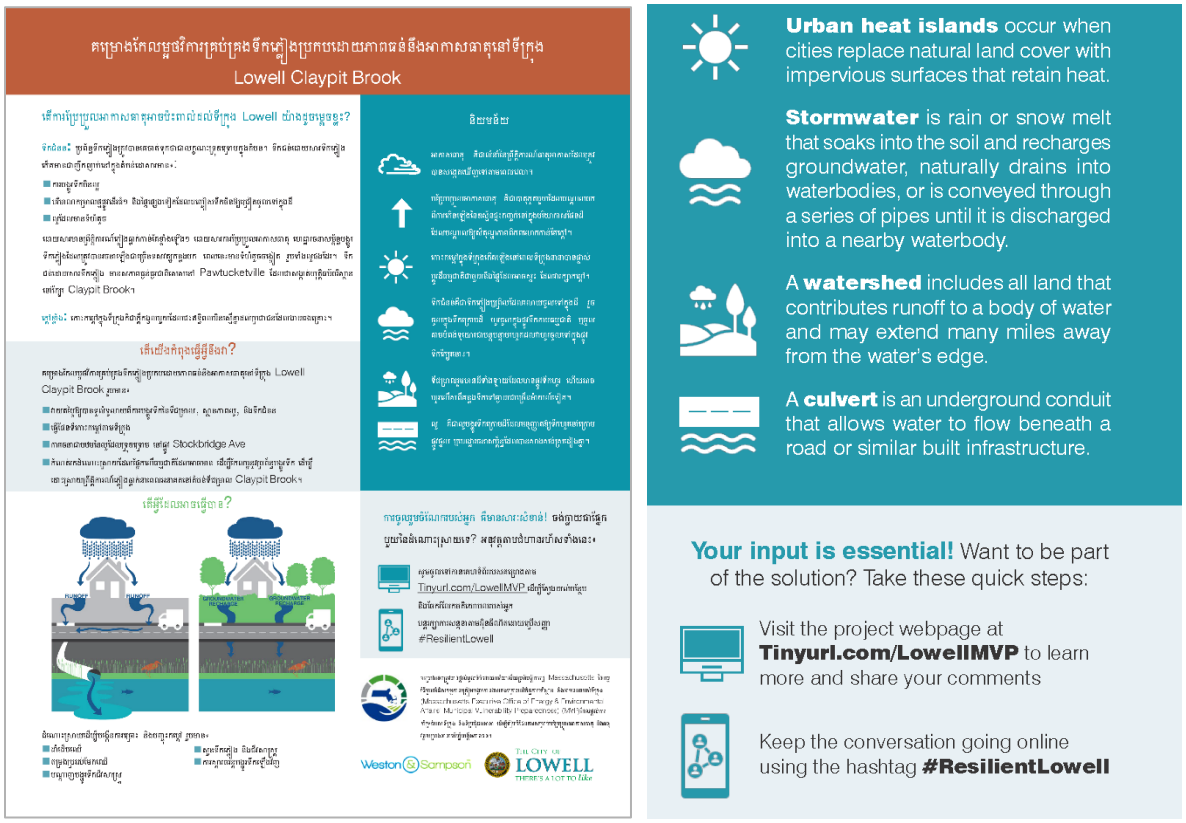


Figure 42 At left: a fact sheet in Khmer. At right: an excerpt of definitions and a call to action included in the fact sheet

Survey Results

The project team shared an online survey to collect public feedback on the assessment. The survey was accessible on the Microsoft Forms website from May 24, 2021, to June 11, 2021, and received 28 responses. The survey was shared and promoted through the following means:

- Posted on the project webpage
- An e-blast sent by the City to the stakeholder list developed during the HMP-MVP Planning Phase
- Social media posts on the City's Facebook and Twitter pages
- Survey link shared during a meeting with the Pawtucketville Citizens Council
- Survey link included as an announcement on the front page of the City's website

"In 2006 & 2007 floods damaged more than 70 homes in my neighborhood. Residents were forces to evacuate in the middle of the night and were relocated for up to a month after the flood." - Survey respondent

Most survey respondents (71%) live in Pawtucketville and most (65%) own a home in Lowell, demonstrating that the participation was highly local. Almost one-third (28%) of respondents have experienced flooding on their street and shared stories describing the impacts and aftermath of extreme events. The top three considerations to prioritize nature-based solutions to address climate impacts included the amount of flood mitigation provided, stormwater infiltration and water quality improvements, and benefits to Environmental Justice or socially vulnerable populations. Stream restoration in the Claypit Brook Watershed was the highest-ranked adaptation action item, with 75% of responses. Tree planting and upstream flood storage were the second and third-ranked options, with 57% and 50% of responses respectively. Additionally, most survey respondents (61%) would like to receive information about future climate change and resiliency projects in Lowell through PDFs available online, such as fact sheets. A full summary of the survey results and related attachments is included in the Appendix B.

Figure 43: At left: the landing page of the branching survey, offering four language options. At right: the survey in Portuguese

Meetings

Meetings were conducted virtually due to the COVID-19 pandemic. More information on four key stakeholder and public meetings held during the process is summarized in the sections below.

Lowell Sustainability Council

The City met with the Lowell Sustainability Council during their monthly meetings in January 2021 and June 2021. During both meetings, the City shared an update on the project and coordinated with the Council on how the Claypit Brook assessment fits within Lowell's larger climate change adaptation efforts.

Pawtucketville Citizens Council Meeting

The project team joined an existing Pawtucketville Citizens Council (PCC) meeting on June 7, 2021. The team shared information on the MVP program, stormwater flooding and urban heat island risks, a project overview, specific results from the stream assessment and hydraulic and hydrologic modeling, and opportunities for green infrastructure projects to increase infiltration. The Council recommended increased regulations related to onsite stormwater storage and increased buffer area along waterbodies of greater than 100 feet, and cited concerns related to the impact of new development on impervious surfaces and stormwater runoff. Resiliency strategies mentioned during the group discussion included backflow valves near residential properties and a possible future pumping system, although these solutions would be technically challenging and therefore likely infeasible at this time.

Public Meeting

The project team hosted a public meeting on Zoom on June 16, 2021, which was advertised through the following means:

- An e-blast sent by the City to the stakeholder list developed during the HMP-MVP Planning phase
- Social media posts on Facebook and Twitter
- Posted on the project webpage
- Visual promotional flyers available in four languages

Registrations were collected through an RSVP form that included translated language. Translation and interpretation support was also offered in Spanish, Portuguese, and Khmer but was ultimately not requested. The meeting was also recorded and posted on the project webpage for those who were not able to attend.

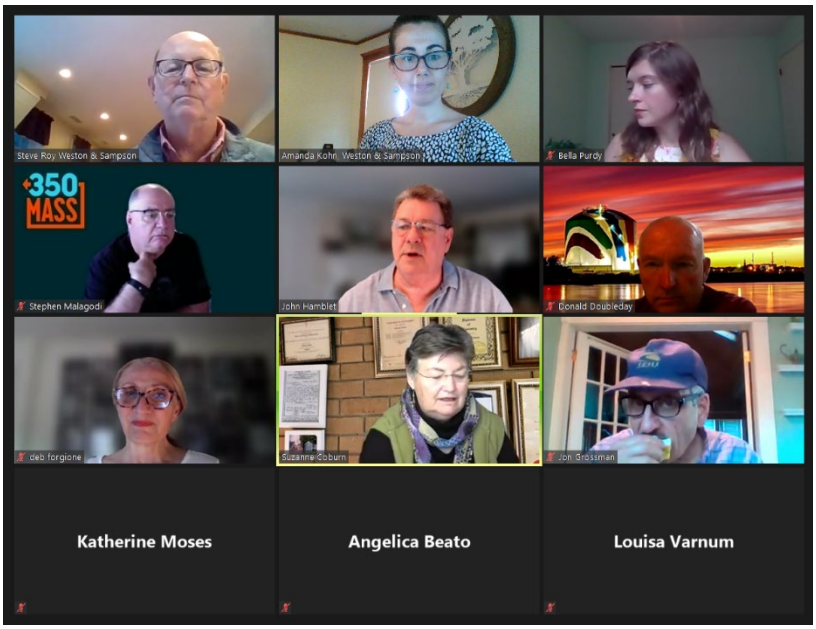


Figure 44: a screenshot of the public meeting

Question and answer sessions throughout the meeting included a discussion of context, process, and resiliency strategies. The discussion related to context included questions about the FEMA Flood Insurance Rates Maps (FIRM) and the new Risk Rating 2.0 Pricing methodology. Participants also shared a local fun fact, that water for Moxie was originally drawn from a spring behind the Wang school. The discussion related to process included information on why the Stockbridge Avenue was prioritized, due to its partial failure and the deteriorating steel plate. The team also emphasized that many upgrades, including nature-based solutions, should be completed together throughout the watershed to have the largest impact. In addition, the team emphasized the importance of addressing flooding upstream and potential locations for increased flood storage upstream. Many participants had questions about future impacts to their specific property. The group also discussed the data that was used in the assessment, including downscaled data from IPCC available on ResilientMA.org, using the methodology in the Resilient Massachusetts Action Team Climate Resilient Design Standards and Guidelines.

Discussion related to strategies included information on reforestation, addressing beaver activity, repurposing brownfield sites for stormwater management, tree planting grants through DCR, and addressing anthropogenic sedimentation and erosion in streams.

The City followed up with participants after the event to share a link to the meeting recording, a copy of the presentation, links to educational resources related to key discussion points (such as low impact development and green infrastructure projects on brownfields sites), and a reminder to view the final project report once posted.

7.0 Capital Improvement Plan

The Department of Public Works regularly completes capital improvements and operation and maintenance of the City's stormwater infrastructure. Financial planning and the creation of this capital improvement plan will allow for the allocation of internal resources to complete projects by providing a roadmap to focus efforts on high priority actions. This capital improvement plan is a living document and should be periodically reviewed and updated as new project priorities arise and as new information becomes available. The CIP serves as a roadmap for informing implementation when feasible for the City to do so and is not a set commitment to a particular timeframe for completing implementation of the priority actions.

The project team has identified immediate and long-term needs, solutions, and implementation cost. The priority projects in this capital improvement plan includes those related to green infrastructure, reforestation and tree planting, increased flood storage, culvert improvements, and stream improvements. While the prioritization approach varied by project type, prioritization considerations included condition, cost, feasibility, level of hydraulic adequacy, potential for flood reduction, and amount of flood storage provided. See Sections 3, 4, and 5 for more information on prioritization by project type. More information on project types, capital improvement-related considerations, funding sources, and a proposed capital improvement plan schedule is summarized in the sections below.

The following tables lay out the first two years of the Capital Improvement Plan over a five- and fifteen-year schedule. The five-year schedule depicts approximately one million in capital improvements annually, while the 15-year schedule depicts approximately 250,000-500,000 annual spending. The full five-year and fifteen-year CIP schedules can be found in Appendix C.

Project Types

This section provides a breakdown by category of the types of projects incorporated into the capital improvement plan.

Green Infrastructure

- Reforestation, including:
  - Reforestation along Varnum Avenue in Claypit Brook Subcatchment #8 (CPB8).
  - A reforestation project in CPB17 between two school playing fields.
- Swales, including:
  - Three swales in CPB5, along the intersection of Trotting Park Road, Anson Street, and Varnum Avenue.
  - A single swale in CPB6 at the corner of Eleanor Drive and Cidalia Drive.
  - A single swale in CPB7 along the eastern edge of the parking lot on the corner of Totman Road and Varnum Avenue.
  - Multiple swales in CPB8 along Meadowview Drive, Jennifer Road, and Lexington Avenue.
  - Two swales in the northern section of CPB10, at the corner of Jennifer Road and Bedford Avenue.
  - Multiple stormwater swales in CPB11, along the south side of Varnum Road.
  - Two stormwater swales in CPB11b, along Barbara Terrace and Ursula Street
  - Two stormwater swales at the bend in Acropolis Road in CPB17.
  - Multiple stormwater swales in CPB18, including smaller swales proposed along Fowler Road and Old Ferry Road.
- Bioretention, including:
  - A stormwater detention area along Varnum Avenue in CPB8.
  - In CPB17, a detention basin adjacent to the school, a depressed planter in the parking lot median at the school, a detention basin along Newbridge Road, and a swale at Totman Road.
- Floodable parks, including turning the field at the school in CPB17 into a floodable field.
- Permeable paving, including a permeable pavement parking lot in CPB17 at the school.

Flood Storage

- Small, non-jurisdictional dam or flood retention structure north of the Summit Elder Care facility.
- Small, non-jurisdictional dam or flood retention structure west of Carly Way.
- Small, ideally non-jurisdictional dam or flood retention structure near the end of Carly Way and near the WCAP radio facility.

Culvert Improvements

- Twelve high priority culverts were identified to need headwall repair, removal, replacement, or additional assessment.

Stream Improvements

- Priority projects include bank stabilization, culvert repair, further beaver dam evaluation and mitigation, debris removal, overgrowth removal, or sediment removal. The City is already working with a beaver consultant.

Other Considerations

The following considerations are not included in the capital improvement plan but are important factors for improving climate resiliency within the Claypit Brook watershed.

Operations & Maintenance

As the City moves forward with implementation of the CIP, emphasis should be placed on proactive and routine maintenance of drainage infrastructure. The following items are recommended:

- Site-specific O&M needs and recommendations should be included in future design processes. Final design deliverables should include an associated O&M manual.
- Inspect and maintain streams regularly to ensure that flow of water is not being hindered, which can contribute to localized flooding.
- Clean sediment and debris from culverts regularly and conduct basic structural assessments to monitor for further deterioration that warrants more immediate replacement or rehabilitation.
- Inspect BMPs following proper procedures and recommended frequency of inspection and maintenance. The MS4 Permit requires annual inspection of BMPs at a minimum.
- Identify and televise critical drainage infrastructure as needed to gain a baseline condition assessment, identify potential emergencies, and schedule future improvements.

Regulations

Regulatory and land use changes can also improve climate resilience. For example, in 2018, Lowell updated a City ordinance to include a new stormwater management article to conform with the requirements of the MS4 permit.

The City of Lowell can continue to adopt and amend mechanisms that influence the way land and buildings are developed and built, such as land use ordinances and stormwater management regulations. This work will support continuity with the HMP-MVP Planning phase, when participants identified action items that included integrating the Stormwater Team standards with Planning Office regulations, continuing to encourage low impact development (including infiltration basins and rain gardens), and assessing options for regulatory mechanisms to improve stormwater management. Updating local regulations and assessing the overlap between land use patterns and flooding can also help the City mitigating flooding in Pawtucketville by addressing flooding upstream. Resources to assist communities with increasing green infrastructure are available. For example, the "Tool-Box

Approach to Wet Growth" report includes a section on policies, ordinances, regulations, and incentives.

The local wetlands ordinance plays an important role in regulating the impact of new development on the water table and on the watershed system. The wetlands ordinance requires that new development provides onsite stormwater storage. The City could examine updates to the ordinance to incorporate climate resilience measures in the future. For example, new development within the floodplain cannot always mitigate flooding substantially with the flood storage requirement alone. Public participants at the Pawtucketville Citizens Council mentioned a desire for more stringent requirements, particularly regarding providing a dimensional buffer along waterways.

Another means of regulating development to meet climate resilience goals is through zoning ordinances. Zoning ordinances can ensure new buildings and renovated buildings are adapted to climate change through rule-based building standards that require the first floor of a building be built to the 'design flood elevation'. The design flood elevation is equivalent to the 100-year flood elevation plus one foot of 'free board'. Zoning ordinances can also incorporate resilience standards through design guidelines which allow for more flexibility while still encouraging building practices which cool the urban environment and protect residents against future flooding.

Participants at the public meeting on June 16, 2021 commented on the FEMA 2.0 updated insurance standards and associated premiums. The FEMA maps for Lowell are currently being updated. Lowell is a part of the Merrimack Valley watershed region which is currently being studied and remapped by FEMA. Residents will have an opportunity to see preliminary maps when complete and provide feedback through a public process.

Beginning on October 1, 2021, all new National Flood Insurance Program policies purchased will be rated under the new system. For all policies that renew on or after October 1, 2021 and on or before March 31, 2022, NFIP policyholders will have the option to be rated under the legacy system, or under Risk Rating 2.0. Beginning April 1, 2022, all NFIP policies (new or renewed) will be rated in the new system. Under Risk Rating 2.0, only 6% of policyholders in MA are expected to have significant increases. 39% of insurance holders are expected to see immediate decreases. More information can be found about the updated pricing methodology for the FEMA Risk Rating 2.0 here: https://www.fema.gov/flood-insurance/work-with-nfip/risk-rating.

Public Education

Ongoing public education about climate change projections, local impacts, existing resources, and strategies for increasing personal resilience are key to support adaptation to climate change within the Claypit Brook watershed. Public education can also include sharing information on flood insurance. At the time of report writing, FEMA is pursuing an updated mapping study of the Merrimack Valley watershed, where Lowell is located. Residents can get involved in these update processes once the preliminary maps are posted. FEMA is also rolling out an updated pricing methodology in phases, called Risk Rating 2.0. Residents may need assistance from municipalities in navigating these updates.

Coordination

Adapting to climate change requires a coordinated response. Working with partners has been an important part of Lowell's approach during both the HMP-MVP Planning phase and the MVP Action Grant phase. Key partners for ongoing coordination are summarized below:

- Local Land Trusts, including the Lowell Parks & Conservation Trust, Westford Conservation Trust, Chelmsford Land Conservation Trust
- Neighboring communities of Chelmsford, Westford, Dracut, and Tewksbury
- Massachusetts Executive Office of Energy & Environmental Affairs (EEA)
- Massachusetts Department of Transportation (MassDOT)
- Massachusetts Emergency Management Association (MEMA)
- Department of Conservation and Recreation (DCR)

Permitting Feasibility

Permitting feasibility is a key consideration when assessing potential resiliency strategies. Permitting feasibility is especially key when considering infrastructural projects near waterbodies or sediment removal from streams. Project teams should coordinate with permitting agencies throughout the design process.

Funding Sources

Municipal Budget

The City has not completed budget projections specific to stormwater. Lowell has Water and Wastewater Enterprise Funds and can explore additional funding mechanisms such as a Stormwater Enterprise Fund to secure dedicated revenue to implement projects recommended in this CIP. Local enterprise funds can be leveraged as a cash match for grant programs such as the MVP Action Grant. Staff time and in-kind hours may also be used for match and to assist in completing recommended projects, if required tools and machinery are available. Additionally, Chapter 90 funds can be used for stormwater projects when roadway upgrades are also necessary. Please see the Grants section below for more information on possible funding sources to support the implementation of climate adaptation action items.

Grants

The following summary describes grant programs that could fund the action items recommended in this report.

Category	Grant	Description
Brownfields	**Brownfields Remediation Loan Program**	Flexible loans up to $500,000 for environmental clean-up of brownfields.
	Brownfields Site Assessment Program	Unsecured, interest-free financing up to $100,000 for environmental assessment of brownfields.

	MassDevelopment Brownfields Redevelopment Fund	Finances the environmental assessment and remediation of brownfield sites in Economically Distressed Areas (EDAs) of the Commonwealth. Lowell is considered an EDA.
	EPA Brownfields Grant Funding Program	Funding for brownfields assessment, cleanup, revolving loans, technical assistance, and more.
Culverts	**Flood Mitigation Assistance Grant Program (FMA)**	Implement cost-effective measures that reduce or eliminate the long-term risk of flood damage, including localized flood control and stormwater management.
	Building Resilient Infrastructure & Communities (BRIC)	Provides funds for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event, with a focus on infrastructure projects and "community lifelines." Replaced FEMA's Pre-Disaster Mitigation (PDM) Program.
	DER Culvert Replacement Municipal Assistance Grant Program	Grant to replace undersized, perched, and/or degraded culverts located in an area of high ecological value.
Green Infrastructure	**DER Priority Projects**	Funds projects that offer ecological value and community benefits, including river restoration. Provides support to implement climate change resiliency priority projects. Project types include planning, assessment and regulatory updates; nature-based solutions; and resilient redesigns and retrofits for critical facilities and infrastructure.
	Municipal Vulnerability Preparedness (MVP) Action Grant	
	USDA Natural Resources Conservation Services Watershed and Flood Prevention Operations Program	Financial and technical assistance for projects including erosion and sediment control and flood prevention.
Tree Planting	**DCR Greening the Gateways Program**	Tree planting program for the Massachusetts Gateway communities to increase tree canopy and reduce cooling energy use. The City of Lowell is considered a Gateway community.
	Arbor Day Foundation TD Green Space Grant	Supports green infrastructure development, tree planting, forestry stewardship, and community green space expansion as a way to advance

		environmental and economic benefits toward a low-carbon economy. $20,000 is available. The program's annual themes may vary. Applicants are encouraged to apply with community partners.
Parks & Recreation	**Massachusetts Land and Water Conservation Fund Grant Program**	Funding for the acquisition, development, and renovation of parks, trails, and conservation areas.
	EEA Gateway City Parks Program	Funds the creation and restoration of parks and recreational facilities in underserved urban neighborhoods. The City of Lowell is considered a Gateway community.
	EEA Parkland Acquisitions and Renovations for Communities (PARC) Program	Aids in acquisition and developing land for park and outdoor recreation purposes. Can be used to acquire parkland, build a new park, or renovate an existing park.
	EEA Local Acquisitions for Natural Diversity (LAND) Grant Program	Helps cities acquire land for conservation and passive recreation.
Water Quality	**Federal Clean Water Act, 604b Grant Program: Water Quality Management Planning**	Funds nonpoint source assessment and planning projects, including projects related to green infrastructure.
	Federal Clean Water Act, Section 319 Nonpoint Source (NPS) Competitive Grants Program	Funds implementation projects that address the prevention, control, and abatement of NPS pollution.

Capital Improvement Plan Schedule

We have created two potential schedules. A five-year plan and a fifteen-year plan. The five-year plan assumes 1 million dollars annually will be available and the fifteen-year plan assumes 300-500 thousand will be available. The details are included in Appendix C. The first year of both of the potential schedules are laid out below. We have not used the prioritization criteria to divide the projects between years and evenly spaced out the project types. The stream improvements have been delayed due to the permitting feasibility and low flood mitigation potential. Some of these improvements will also be made with culvert upgrades.

5-year Capital Improvement Plan: Years 1,2

Year	Category	Action	Cost
1	Green Infrastructure	Detention - Varnum Ave (Subcatchment: CPB8)	150,000
1	Green Infrastructure	Reforestation (Subcatchment: CPB17)	150,000
1	Flood Storage	Scenario 3	30,000
1	Culvert Replacement	Varnum Ave	10,000
1	Culvert Replacement	Stockbridge Ave	534,000
1	Culvert Replacement	Lexington Ave	500,000
Year 1 Total			1,374,000
2	Green Infrastructure	Detention Basin - Newbridge Road (Subcatchment: CPB17)	150,000
2	Green Infrastructure	Floodable Field - Gumpus Road (Subcatchment: CPB17)	150,000
2	Green Infrastructure	Swale - Retirement Community (Sub-catchment: CPB18)	150,000
2	Green Infrastructure	Swale - Varnum Ave (Sub-catchment: CPB18)	100,000
2	Green Infrastructure	Detention Basin - Dr. An Wang Middle School (Subcatchment: CPB17)	150,000
2	Culvert Replacement	Embankment at end of Avalon St	20,000
2	Culvert Replacement	Malden Ave	500,000
Year 2 Total			1,220,000

Table 35- 5-Year CIP Years 1,2

15-year Capital Improvement Plan: Years 1,2

Year	Category	Action	Cost
1	Culvert Replacement	Varnum Ave	$10,000
1	Culvert Replacement	Stockbridge Ave	$534,000
Year 1 Total			$544,000
2	Green Infrastructure	Detention - Varnum Ave (Subcatchment: CPB8)	$150,000
2	Green Infrastructure	UHI - Increase Canopy (Subcatchment: CPB17)	$150,000
2	Flood Storage	Scenario 3	$30,000
Year 2 Total			$330,000

Table 36- 15-Year CIP Years 1,2

Appendix A

Data Collection, Assessment, and Modeling

Lowell Claypit Brook

Data List

References and data that informed the project deliverables, particularly the modeling effort and Urban Heat Island analysis, are listed below. Please refer to the final report and appendices for more information.

MassGIS Data and GIS Data On-File

- Land use
- Impervious surface information
- Roadways
- Major ponds
- Major streams
- Subbasin outlines
- USGS rivers and streams 25k
- USGS water bodies 25k
- Open space
- Conservation/protected land
- Parcels

GIS Data Request to City of Lowell

- Locations and condition of stormwater assets (culverts, catch basins, outfalls)
- Other local drainage basin information
- Sewer and water utilities
- Assessor/parcel data
- Trees/tree canopy

Data Received from Green International

- HEC-RAS and HEC-HMS model

Background Documents Reviewed

- Claypit Brook Backwater Study (2015)
- Map of Claypit Brook
- Stockbridge Ave Culvert Inspection (2019)
- Hazard Mitigation and Municipal Vulnerability Preparedness (HM-MVP) Plan (2020)

City of Lowell, Massachusetts

Claypit Brook - Stream Assessment
Field Investigation

APRIL 2021

Data Sources:

MassGIS Parcels, MassGIS Roads, MassGIS Buildings, MassDEP Wetlands

Disclaimer:

This information is for planning purposes only and should not be considered exact. Field inspection and verification is required. This data was created from schematic maps.

Legend

- Debris
- Beaver Dams
- Overgrowth
- Bank Erosion
- Culvert
- Bank Erosion
- Overgrowth_Lines
- Culverts
- Parcels
- Buildings
- Hydrologic Connection
- Marsh/Bog
- Wooded marsh
- Open Water

MAP SHEET 1 of 5

370 0 370 740 1,110 Feet

Weston & Sampson

City of Lowell, Massachusetts

Claypit Brook - Stream Assessment
Field Investigation

APRIL 2021

Data Sources:

MassGIS Parcels, MassGIS Roads, MassGIS Buildings, MassDEP Wetlands

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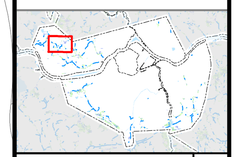

2

MAP SHEET 2 of 5

Dracut

Trotting Park Road

Pinetree Drive

Tolman Street

Ronald Lane

Toupi Lane

Newbridge Road

Carly Way

Bridget Lane

Oberlin Avenue

Veritas Avenue

Coburn Drive

Leonard Circle

Aegean Lane

Laurie Lane

1

125 0 125 250 375 Feet

Weston & Sampson

City of Lowell, Massachusetts

Claypit Brook - Stream Assessment
Field Investigation

APRIL 2021

Data Sources:

MassGIS Parcels, MassGIS Roads, MassGIS Buildings, MassDEP Wetlands

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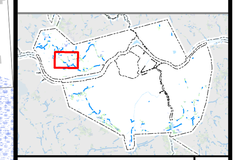

3

MAP SHEET 3 of 5

125 0 125 250 375 Feet

Weston & Sampson

City of Lowell, Massachusetts

Claypit Brook - Stream Assessment
Field Investigation

APRIL 2021

Data Sources:

MassGIS Parcels, MassGIS Roads, MassGIS Buildings, MassDEP Wetlands

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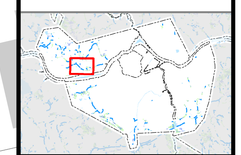
- Culvert
- Bank Erosion
- Overgrowth_Lines
- Culverts
- Parcels
- Buildings
- Hydrologic Connection
- Marsh/Bog
- Wooded marsh
- Open Water



4

MAP SHEET 4 of 5

125 0 125 250 375 Feet

Weston & Sampson

Dabby Way
Tolman Street
Lisa Lane
Laurie Lane
Tower Drive
Linda Lane
Forest Park Lane
Robin Lane
Shadow Drive
Meadow Drive
Bennington Terrace
Varnum Avenue
Ruis Lane
Meadowview Drive
Cedar Lane
West Meadow Road
Ursula Street
Daisy Drive
Jennifer Road
Varnum Terrace
Townsend Avenue
Malden Avenue
Lexington Avenue
Bedford Avenue
Shirley Avenue
Melrose Avenue
Old Ferry Road
Pawtucket Boulevard
113
3

City of Lowell, Massachusetts

Claypit Brook - Stream Assessment
Field Investigation

APRIL 2021

Data Sources:

MassGIS Parcels, MassGIS Roads, MassGIS Buildings, MassDEP Wetlands

Disclaimer:

This information is for planning purposes only and should not be considered exact. Field inspection and verification is required. This data was created from schematic maps.

Legend

- Debris
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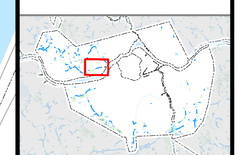
- Wooded marsh
- Open Water



5

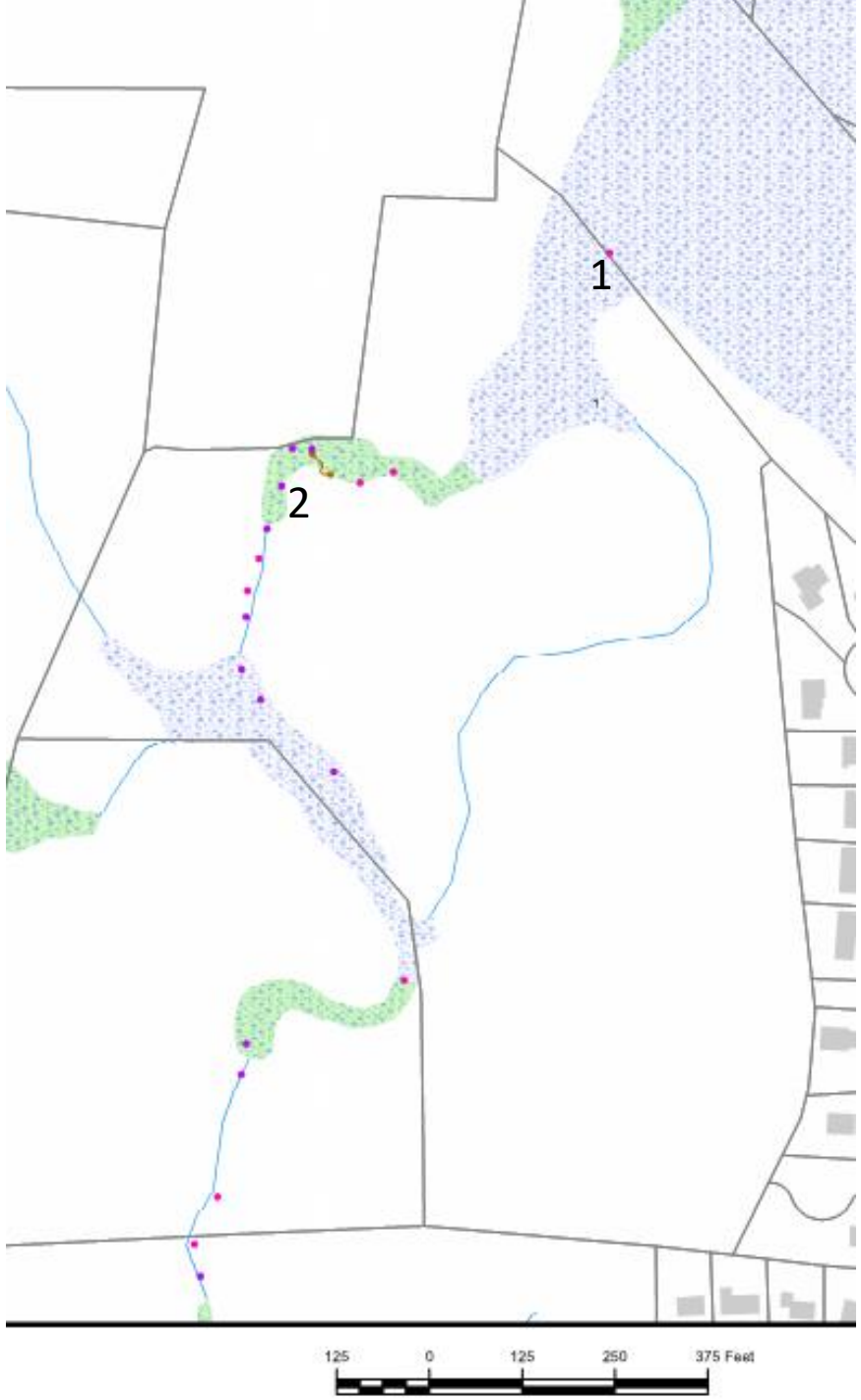
MAP SHEET 5 of 5

125 0 125 250 375 Feet

Weston & Sampson

Legend

- Debris
- Beaver Dams
- Overgrowth
- Bank Erosion
- Culvert
- Bank Erosion
- Overgrowth_Lines
- Culverts
- Parcels
- Buildings
- Hydrologic Connection
- Marsh/Bog
- Wooded marsh
- Open Water



Please see the map at left for a geographic representation of the area where Photo #1 was taken.

Please see the map at left for a geographic representation of the area where Photo #2 was taken.

Legend

- Debris
- Beaver Dams
- Overgrowth
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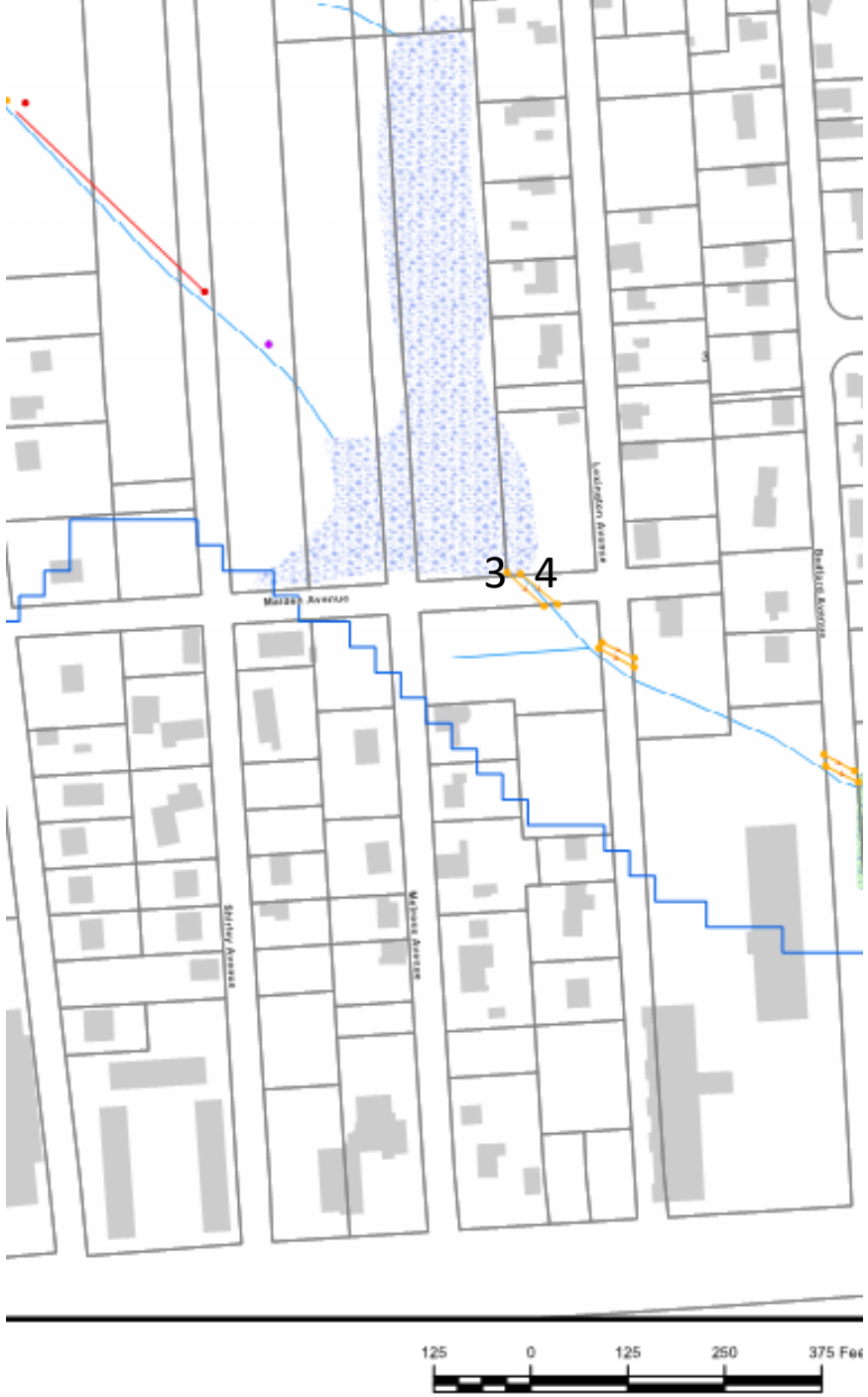
- Wooded marsh
- Open Water

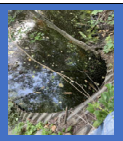
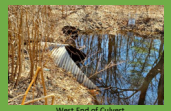


Please see the map at left for a geographic representation of the area where Photo #3 was taken.

Please see the map at left for a geographic representation of the area where Photo #4 was taken.

Attachment B. Condition Summary

CULVERT SUMMARY									
	Claypit Brook								
Project Type	Street	Culvert Description	Culvert Length	Photos	Deficiencies	Recommendations	Comments	Inspection Cost	Repair/Replacement Cost
Headwall repair/replace	Under neighborhood near Elizia Dr	36" RCP culvert beneath neighborhood at Elizia Cir and Eleanor Dr.	515 ft +/-	 North End of Culvert  South End of Culvert	South End of Culvert Blocked with Debris	Clear Debris; TV Inspect Entire Length of 36" Culvert to Evaluate Conditon; Construct Headwall at North End of Culvert and Replace Existing Headwall at South End of Culvert	Cost for Removal of Debris At South End of Culvert Included in Stream Maintenance Costs	Clean / TV Culvert - Assume $5/ft for 36" Pipe = $2,575	Labor & Material for Headwall Construction - $25,000 / Headwall = $50,000
Headwall repair/replace	Varnum Ave	5' diameter and 30" diameter lined CMPs with grates. 69" and 76"to parking lot, respectively.	340 +/-	 North End of Culvert   South End of Culvert	Sediment Build-up at Inlets; Downstream Headwall Blocks have Shifted; Lining Inside Pipes is Deteriorating.	Clear Sediment and Repair Headwall at South End of Culverts; TV Inspect Culverts to Fully Evaluate Pipe Conditon	Cost for Clearing Sediment at Inlets Included in Stream Maintenance Costs; Repair/Replacement Costs for Culvert to Be Determined Once Inspection is Complete	Clean / TV Culvert - Assume $4/ft for 30" Pipe = $1,360; Assume $5/ft for 5' diameter culvert = $1,700	Labor & Material to Repoint/Repair Headwall at South Side of Culvert = $10,000
Culvert replacement	Townsend Ave	30" diameter and 48" diameter CMPs. 44" and 54" to roadway, respectively.	50 +/-	 North End of Culvert  South End of Culvert	Some Rust Below Flowline, Mostly Backwatered	Replace Culverts with RCP; Construct Headwalls at South and North Ends			Labor & Material to Construct New 30" RCP Culvert = Assume $700/LF of 30" RCP = $45,000 Labor & Material to Construct New 48" RCP Culvert = Assume $900/LF of 48" RCP = $35,000 Labor & Material to Construct Headwalls Upstream & Downstream = $40,000/Headwall = $80,000 Assume total project cost of $500,000 with engineering design, permitting, construction oversight, construction and contingency.
Culvert replacement	Malden Ave	60" diameter and 36" diameter CMPs. 79" and 70" to roadway, respectively.	60 ft +/-	 North End of Culvert  North End of Culvert  South End of Culvert	Corroded Metal at Flow Line, Culvert is Broken in Multiple Locations	Replace Culverts with RCP; Construct Headwalls at South and North Ends			Labor & Material to Construct New 36" RCP Culvert = Assume $800/LF of 36" RCP = $48,000 Labor & Material to Construct New 60" RCP Culvert = Assume $1,200/LF of 60" RCP = $72,000 Labor & Material to Construct Headwalls Upstream & Downstream = Assume $50,000/Headwall = $100,000 Assume total project cost of $500,000 with engineering design, permitting, construction oversight, construction and contingency.
Culvert replacement	Lexington Ave	64" diameter and 36" diameter CMPs. 84" and 73" to roadway, respectively.	50 +/-	 North End of Culvert  South End of Culvert	Some Rust Below Flowline, Mostly Backwatered	Replace Culverts with RCP; Construct Headwalls at South and North Ends			Labor & Material to Construct New 36" RCP Culvert = Assume $800/LF of 36" RCP = $40,000 Labor & Material to Construct New 66" RCP Culvert = Assume $1,300/LF of 66" RCP = $65,000 Labor & Material to Construct Headwalls Upstream & Downstream = Assume $50,000/Headwall = $100,000 Assume total project cost of $500,000 with engineering design, permitting, construction oversight, construction and contingency.
Stream maintenance	Bedford Ave	40" diameter and 66" diameter CMPs. 65" and 90" to roadway, respectively.	45 ft +/-	 	Banks Overgrown Near Culverts; Sediment/Debris near Culverts	Remove Overgrown Vegetation and Debris	Cost for Removal of Overgrown Vegetation and Debris Included in Stream Maintenance Costs; Consider Future Replacement of CMP Culverts with RCP - Low Priority for Now Since Existing CMP Culverts Appear to be in Satisfactory Condition		
Stream maintenance	Dunbar Ave	Two 46" diameter CMPs. 119" to roadway.	45 ft +/-	 East End of Culvert	Banks Overgrown Near Culverts; Sediment/Debris near Culverts	Remove Overgrown Vegetation and Debris	Cost for Removal of Overgrown Vegetation and Debris Included in Stream Maintenance Costs; Consider Future Replacement of CMP Culverts with RCP - Low Priority for Now Since Existing CMP Culverts Appear to be in Satisfactory Condition		
Stream maintenance	Varnum Ave/Marbles Brook	Two 30" RCPs.	95 ft +/-	 South End of Culvert  North End of Culvert	Banks Overgrown Upstream Culverts; Sediment/Debris Upstream of Culverts	Remove Overgrown Vegetation and Debris	Cost for Removal of Overgrown Vegetation and Debris Included in Stream Maintenance Costs; Culverts Appear to be in Satisfactory Condition		
Culvert replacement	Delaware Ave	Two 60" diameter CMPs. 78" to roadway.	50 ft +/-	 East End of Culvert  East End of Culvert  East End of Culvert	Corroded Metal at Flow Line, Culvert is Broken in Multiple Locations	Replace Culverts with RCP; Construct Headwalls at East and West Ends			Labor & Material to Construct Two New 60" RCP Culverts = Assume $1,200/LF of 60" RCP = $120,000 Labor & Material to Construct Headwalls Upstream & Downstream = Assume $50,000/Headwall = $100,000 Assume total project cost of $500,000 with engineering design, permitting, construction oversight, construction and contingency.

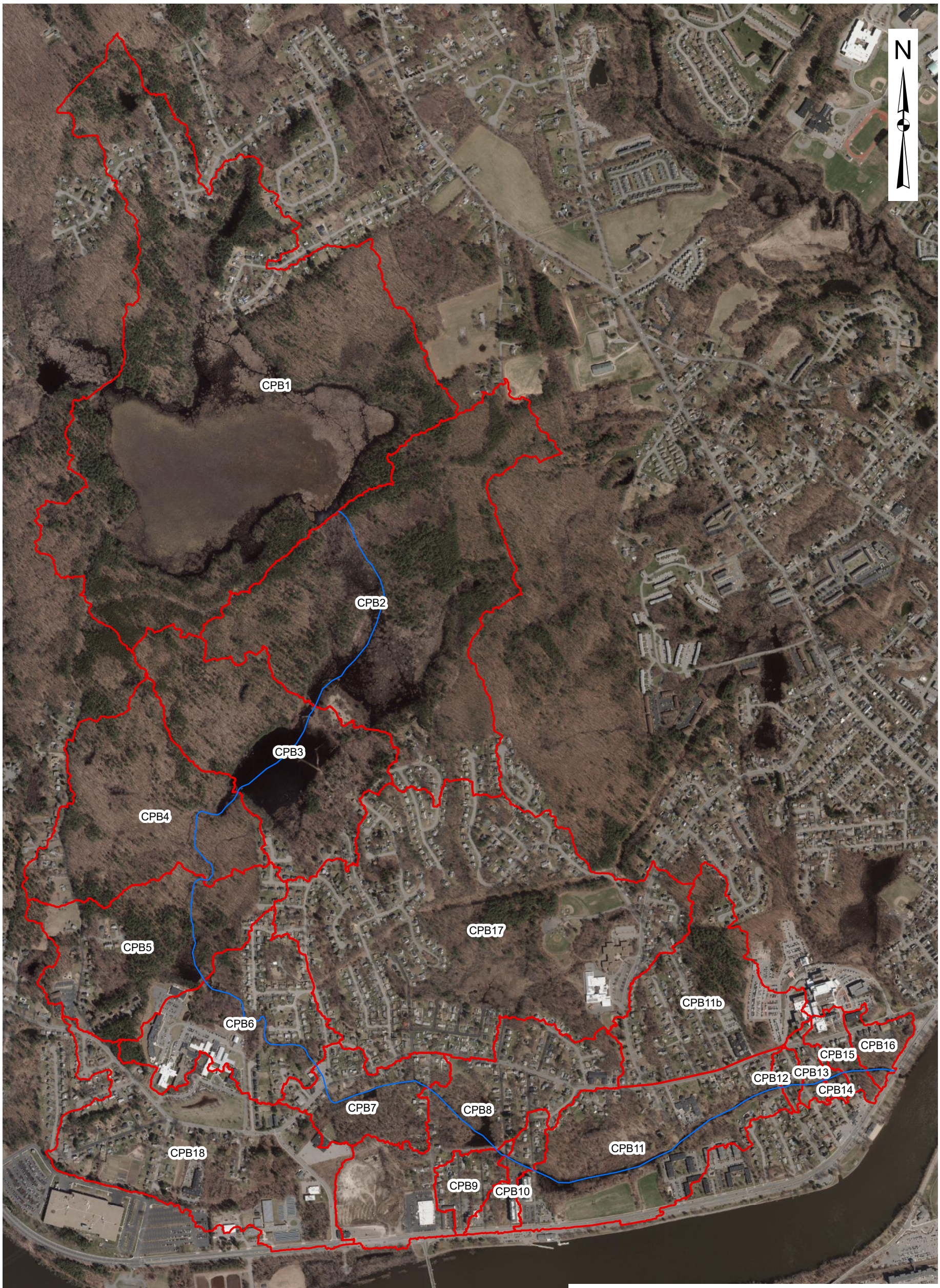
Culvert replacement	Magnolia St	Two 52" diameter CMPs. 84" to roadway.	50 ft +/-	 East End of Culvert  East End of Culvert	Corroded Metal at Flow Line	Replace Culverts with RCP; Construct Headwalls at East and West Ends			Labor & Material to Construct Two New 52" RCP Culvert = Assume $1,000/LF of 52" RCP = $100,000 Labor & Material to Construct Headwalls Upstream & Downstream = Assume $50,000/Headwall = $100,000 Assume total project cost of $500,000 with engineering design, permitting, construction oversight, construction and contingency.
Culvert replacement	Stockbridge Ave	Two 56" diameter CMPs. 77" to roadway.	50 ft +/-	 	CMP is Corroded at Flowline; Culvert is Broken in Multiple Locations	Replace Culverts with RCP; Construct Headwalls at West and East Ends			Engineering Estimate = $534,000
Remove culvert for stream restoration	Embankment at end of Avalon St	Two 48" diameter CMPs. 60" to roadway.	50 ft +/-	 West End of Culvert	Debris in Channel Upstream and Downstream	Remove Debris	These culverts do not appear to be necessary and should be considered for removal. Costs for any removal of debris included in stream maintenance costs.		Assuming one day for a crew to remove and dispose of material = $20,000
No maintenance required	Pawtucket Blvd	4' stone masonry box culvert and 54" diameter CMP. 96" and 114" to roadway, respectively.	95 ft +/-	 East End of Culvert	-	None	Consider Future Replacement of CMP Culvert with RCP - Low Priority for Now Since Existing CMP Culvert Appears to be in Satisfactory Condition		

NOTE: Costs also really don't include design or construction oversight for construction, add a contingency like we did for the stream maintenance costs

Summary of Data			
	number of culverts		
Total culverts	13	Total culverts	
remove culvert for stream restoration	1	remove culvert for stream restoration	
headwall repair/replace	2	headwall repair/replace	
culvert replacement	6	culvert replacement	
stream maintenance	3	stream maintenance	
no maintenance required	1	no maintenance required	

STREAM ASSESSMENT SUMMARY

Stream Conditions	Quantity	Notes
Sediment Removal (at culverts and beaver dams) (cy)	397	2" depth, 4" depth, 15" depth, 6" depth at culverts
Debris Removal (trees, leaves, etc) (lf)	10	1 fallen tree <6", 11 trees 6"-12", 6 trees 12"-24", 2 trees 24"-36"
Cut Back Overgrowth (lf)	1764	335' moderate, 1429' severe
Bank Stabilization (lf)	300	



1,000 0 1,000

Scale In Feet

FIGURE 1

CITY OF LOWELL, MASSACHUSETTS
CLAYPIT BROOK CIP

WATERSHED MAP

MAY 2021 SCALE: NOTED

Weston & Sampson

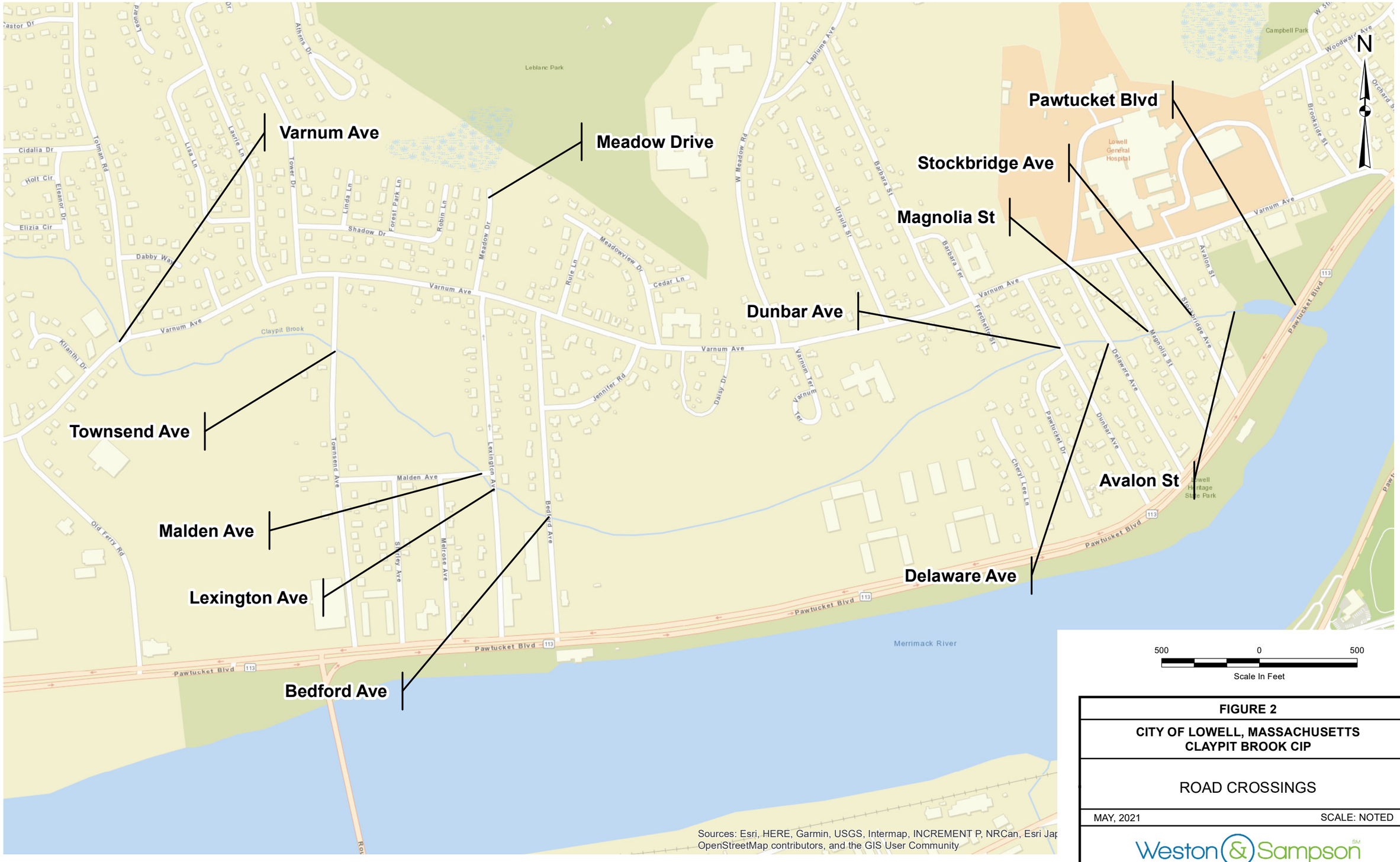


FIGURE 2

CITY OF LOWELL, MASSACHUSETTS
CLAYPIT BROOK CIP

ROAD CROSSINGS

MAY, 2021 SCALE: NOTED

Weston & Sampson

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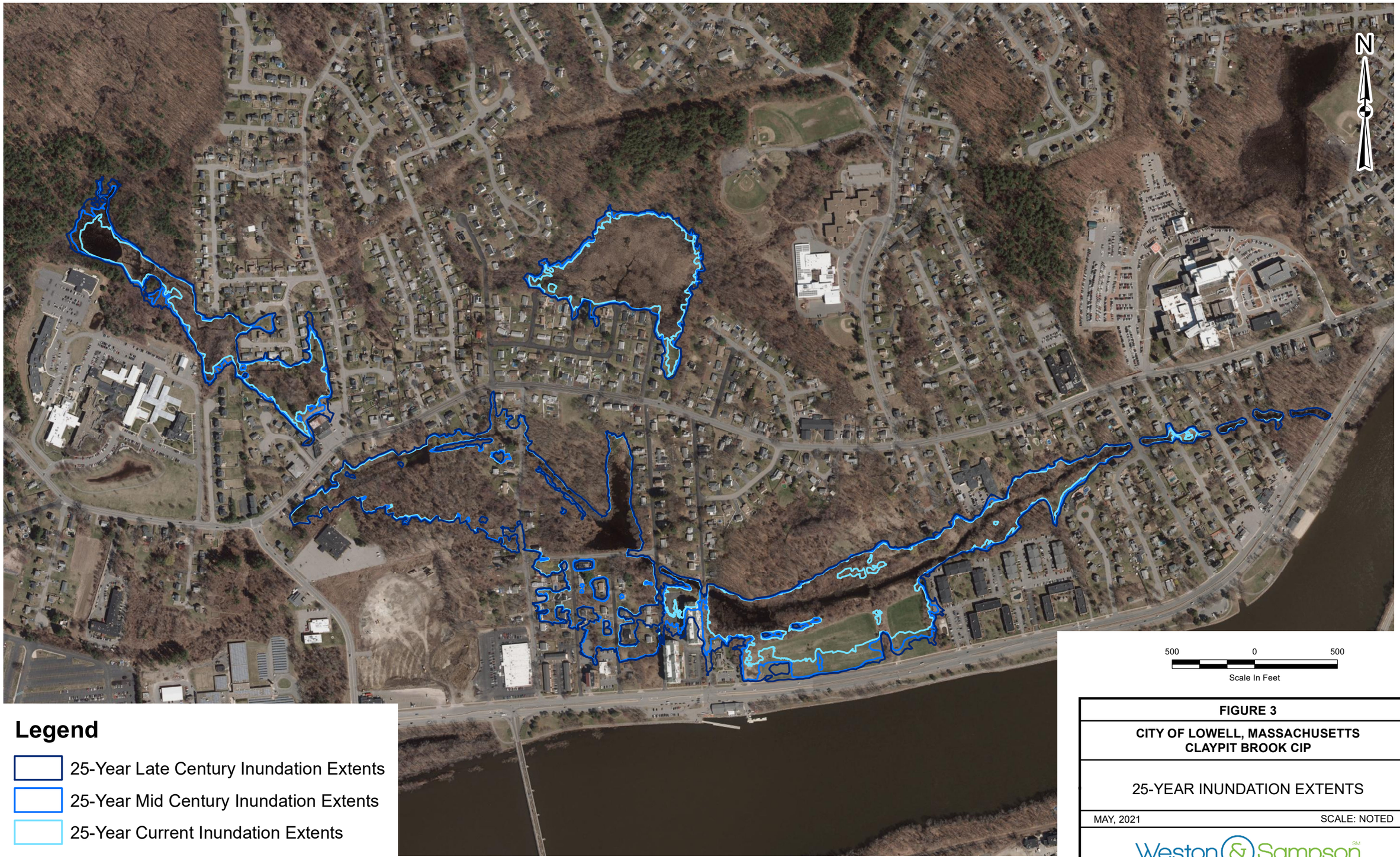


Legend

- 25-Year Late Century Inundation Extents
- 25-Year Mid Century Inundation Extents
- 25-Year Current Inundation Extents

FIGURE 3

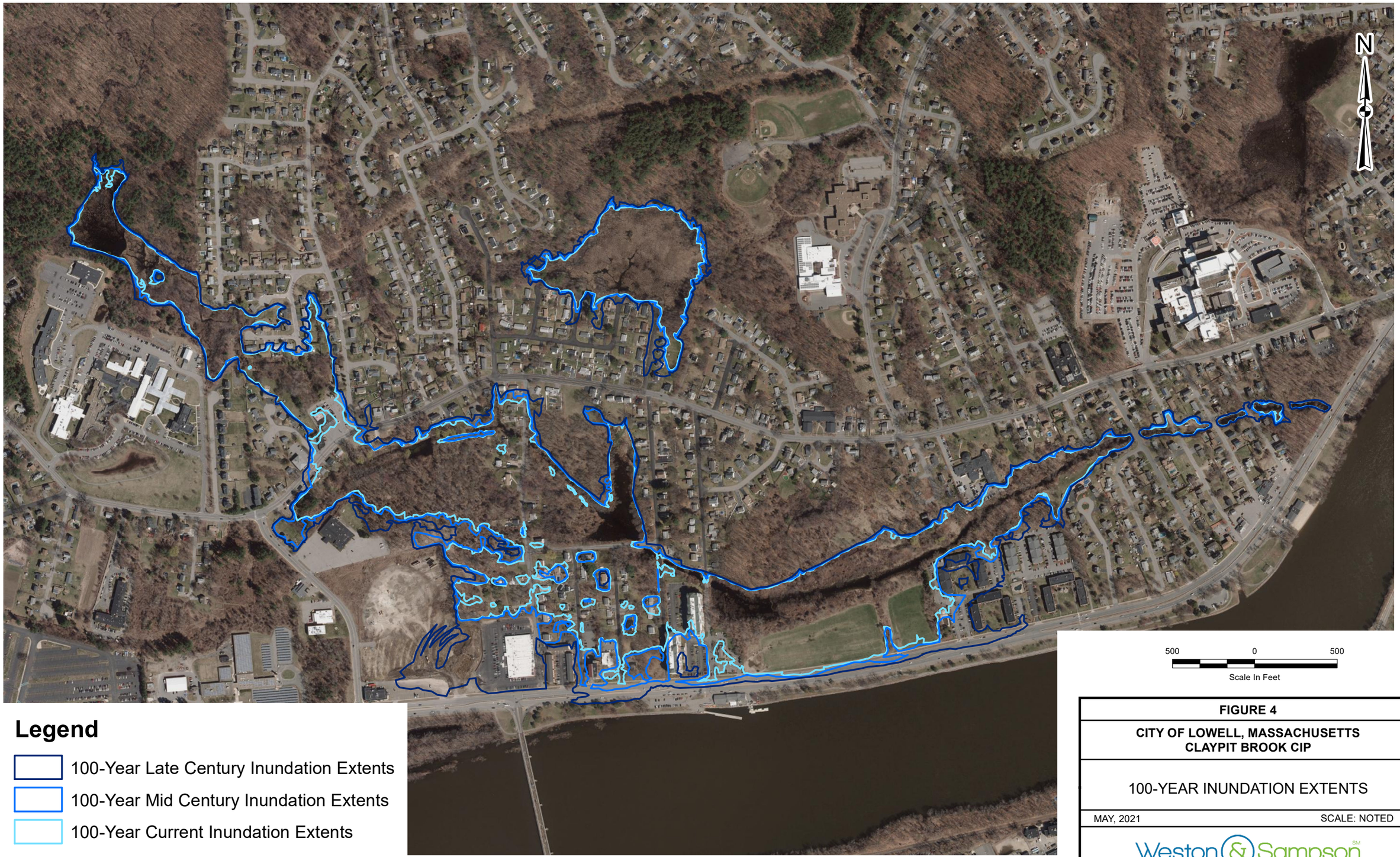
CITY OF LOWELL, MASSACHUSETTS
CLAYPIT BROOK CIP

25-YEAR INUNDATION EXTENTS

MAY, 2021 SCALE: NOTED

Weston & Sampson

Path: C:\Users\lambertd\Documents\Projects\MA\Lowell\2021 Lowell MVP\GIS\Mapfiles\25-Year Inundation Extents.mxd **User:** lambertD **Saved:** 5/27/2021 9:22:31 AM **Opened:** 5/27/2021 9:23:23 AM



Legend

- 100-Year Late Century Inundation Extents
- 100-Year Mid Century Inundation Extents
- 100-Year Current Inundation Extents

500 0 500

Scale In Feet

FIGURE 4

CITY OF LOWELL, MASSACHUSETTS
CLAYPIT BROOK CIP

100-YEAR INUNDATION EXTENTS

MAY, 2021 SCALE: NOTED

Weston & Sampson

Path: C:\Users\lambertd\Documents\Projects\MA\Lowell\2021 Lowell MVP\GIS\Mapfiles\100-Year Inundation Extents.mxd **User:** LambertD **Saved:** 5/27/2021 8:25:14 AM **Opened:** 5/27/2021 8:25:26 AM

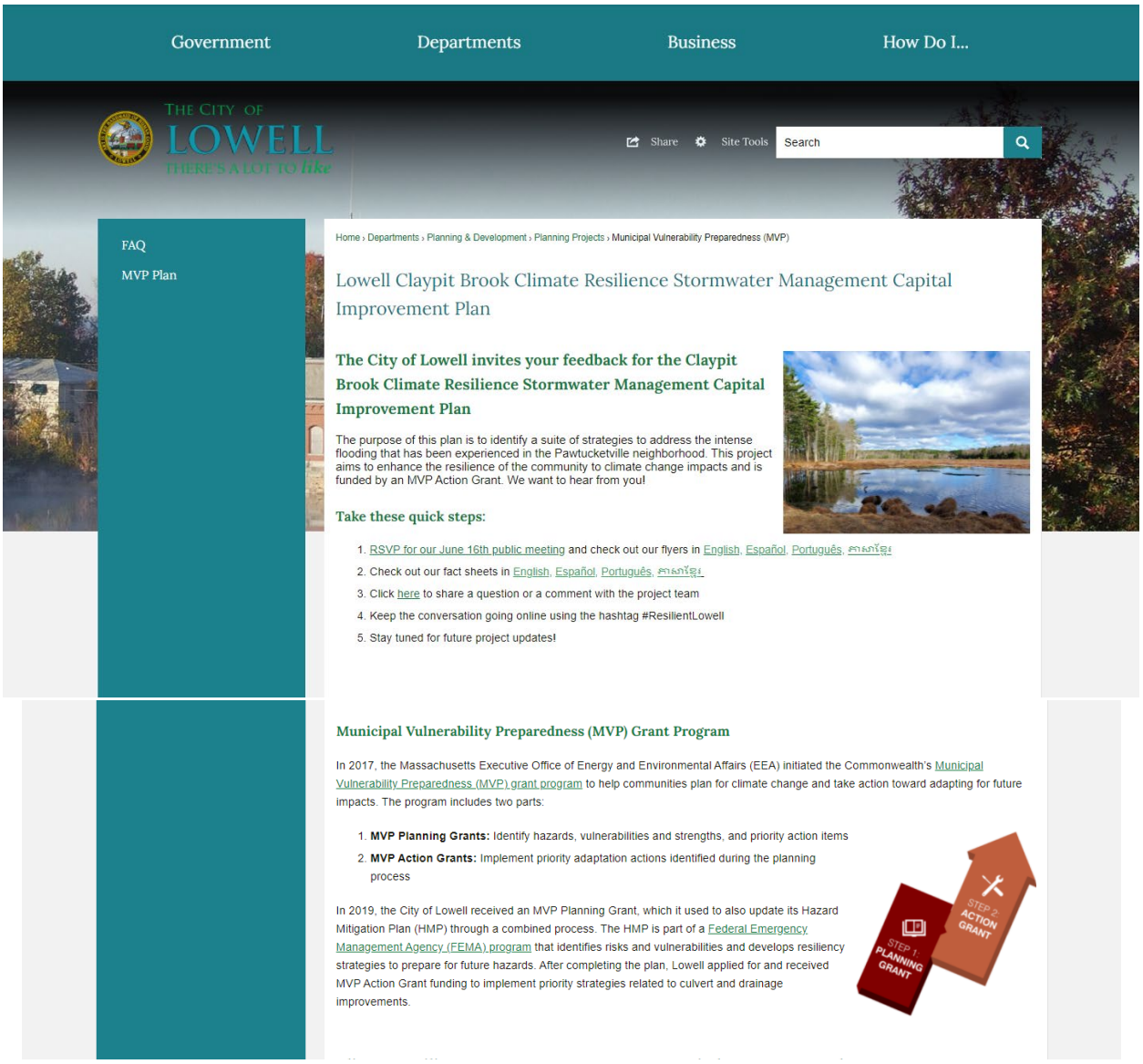
Appendix B

Public and Stakeholder Engagement Materials

Lowell Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan

Updated Project Webpage

The screenshots below show the updated project webpage. For more information, please visit the project webpage at tinyurl.com/LowellMVP.

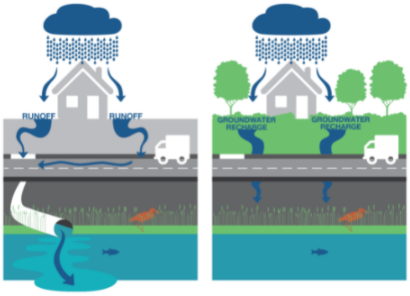


Climate Resilience Stormwater Management Capital Improvement Plan

Lowell is impacted by flooding from extreme precipitation, which is expected to worsen with climate change. Throughout Lowell's MVP Planning process, flooding was a frequently cited hazard of concern and the stormwater system was identified as a vulnerable local feature.

Stormwater is rain or snow melt that:

- soaks into the soil and recharges groundwater
- naturally drains into waterbodies
- is conveyed through a series of pipes until it is discharged into a nearby waterbody.



Stormwater flooding is particularly prevalent in:

- areas with poor drainage
- areas with large amounts of impervious surfaces
- areas with undersized culverts

Because rainfall events are becoming increasingly intense due to climate change, much of the stormwater infrastructure designed decades ago is now undersized, including culverts.

What are we doing about it?

Chronic stormwater flooding caused by drainage deficiencies plagues Pawtucketville, an Environmental Justice neighborhood near Claypit Brook. The proposed plan will comprehensively assess the watershed's drainage, culvert conditions and known flooding conditions. The project team will then:

- complete preliminary design of the highly vulnerable Stockbridge Avenue culvert
- identify nature-based solutions to supply drainage to handle future extreme precipitation events in the Claypit Brook Watershed.

Your input on this project is essential!

Lowell Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan

How Could Climate Change Impact Lowell?

FLOODING: The stormwater system is considered a vulnerable local feature. Stormwater flooding is especially frequent in areas with:

- poor drainage
- large amounts of pavement and other surfaces that prevent water from infiltrating into the ground
- undersized culverts

Because rainfall events are becoming increasingly intense due to climate change, much of the stormwater infrastructure designed decades ago is now undersized, including culverts. Stormwater flooding is especially severe in Pawtucketville, an Environmental Justice neighborhood near Claypit Brook.

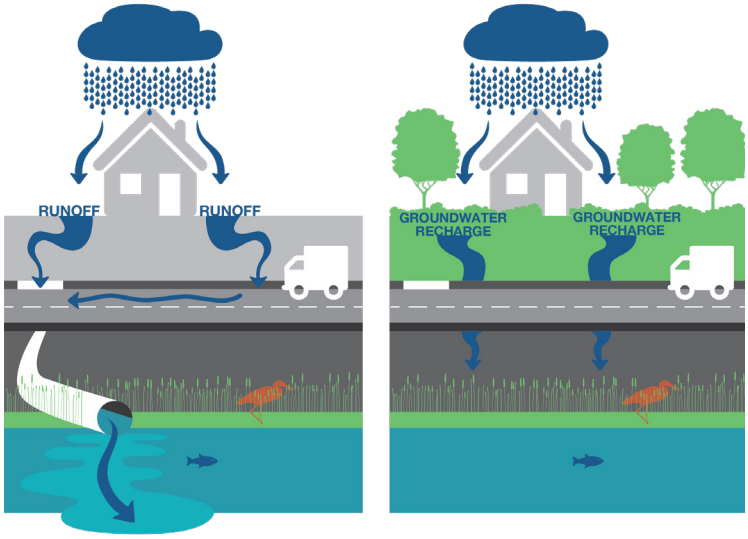
EXTREME HEAT: Urban heat islands are also a concern, which disproportionately impact vulnerable populations.

What are we doing about it?

The Lowell Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan includes:

- comprehensively assessing the watershed's drainage, culvert conditions, and flooding
- mapping urban heat islands
- preliminary design of a vulnerable culvert on Stockbridge Ave
- identifying potential nature-based solutions to improve drainage to handle future extreme precipitation events in the Claypit Brook Watershed.

What's Possible?



Solutions to increase filtration and cooling include:

- tree planting
- tree box filters
- bioswales
- rain gardens and bioretention
- stream restoration

Definitions

Climate is the pattern of weather events observed over time.

Climate Change is a phenomenon caused by the increase of greenhouse gases in the Earth's atmosphere, which results in a warmer global temperature.

Urban heat islands occur when cities replace natural land cover with impervious surfaces that retain heat.

Stormwater is rain or snow melt that soaks into the soil and recharges groundwater, naturally drains into waterbodies, or is conveyed through a series of pipes until it is discharged into a nearby waterbody.

A **watershed** includes all land that contributes runoff to a body of water and may extend many miles away from the water's edge.

A **culvert** is an underground conduit that allows water to flow beneath a road or similar built infrastructure.

Your input is essential! Want to be part of the solution? Take these quick steps:

Visit the project webpage at **Tinyurl.com/LowellMVP** to learn more and share your comments

Keep the conversation going online using the hashtag **#ResilientLowell**

This project was funded by the Massachusetts Executive Office of Energy & Environmental Affairs' Municipal Vulnerability Preparedness (MVP) Action Grant program, which provides support for cities and towns to plan for climate change and implement projects to increase resilience.

Weston & Sampson

The City of Lowell
There's a lot to *like*

គម្រោងកែលម្អថវិការគ្រប់គ្រងទឹកភ្លៀងប្រកបដោយភាពធន់នឹងអាកាសធាតុនៅទីក្រុង Lowell Claypit Brook

តើការប្រែប្រួលអាកាសធាតុអាចប៉ះពាល់ដល់ទីក្រុង Lowell យ៉ាងដូចម្តេចខ្លះ?

ទឹកជំនន់៖ ប្រព័ន្ធទឹកភ្លៀងត្រូវបានគេចាត់ទុកថាជាលក្ខណៈទ្រុឌទ្រោមក្នុងតំបន់។ ទឹកជន់ដោយសារទឹកភ្លៀងកើតមានជាញឹកញាប់នៅក្នុងតំបន់ដោសារមាន៖

- ការបង្ហូរទឹកមិនល្អ
- បរិមាណកម្រាលថ្នផ្លូវដ៏ធំ។ និងផ្ទៃផ្សេងទៀតដែលបញ្ចៀសទឹកមិនឱ្យជ្រៀតចូលទៅក្នុងដី
- លូដែលមានទំហំតូច

ដោយសារមានព្រឹត្តិការណ៍ភ្លៀងធ្លាក់កាន់តែខ្លាំងឡើង។ ដោយសារការប្រែប្រួលអាកាសធាតុ ហេដ្ឋារចនាសម្ព័ន្ធបង្ហូរទឹកភ្លៀងដែលត្រូវបានរចនាឡើងជាច្រើនទសវត្សកន្លងមក ពេលនេះមានទំហំតូចចង្អៀត រួមទាំងលូផងដែរ។ ទឹកជន់ដោយសារទឹកភ្លៀង មានសភាពធ្ងន់ធ្ងរជាពិសេសនៅ Pawtucketville ដែលជាសង្កាត់ឃុត្តិធម៌បរិស្ថាននៅតែរួ Claypit Brook។

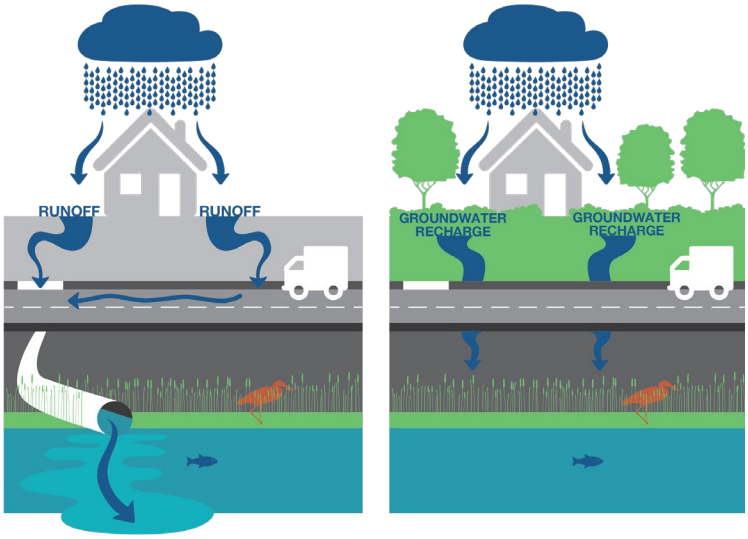
ក្តៅខ្លាំង៖ កោះកម្តៅក្នុងទីក្រុងក៏ជាក្តីកង្វល់មួយដែលជះឥទ្ធិពលមិនស្មើគ្នាដល់ប្រជាជនដែលងាយរងគ្រោះ។

តើយើងកំពុងធ្វើអ្វីនឹងវា?

គម្រោងកែលម្អថវិការគ្រប់គ្រងទឹកភ្លៀងប្រកបដោយភាពធន់នឹងអាកាសធាតុនៅទីក្រុង Lowell Claypit Brook រួមមាន៖

- វាយតម្លៃឱ្យបានទូលំទូលាយពីការបង្ហូរទឹកនៃទីជម្រាល, ស្ថានភាពលូ, និងទឹកជំនន់
- ធ្វើផែនទីកោះកម្តៅតាមទីក្រុង
- ការរចនាជាបឋមនៃលូដែលទ្រុឌទ្រោម នៅផ្លូវ Stockbridge Ave
- កំណត់រកដំណោះស្រាយដែលផ្អែកលើធម្មជាតិដែលអាចមាន ដើម្បីកែលម្អនូវប្រព័ន្ធបង្ហូរទឹក ដើម្បីដោះស្រាយព្រឹត្តិការណ៍ភ្លៀងធ្លាក់នាពេលអនាគតនៅតំបន់ទីជម្រាល Claypit Brook។

តើអ្វីដែលអាចធ្វើបាន?



ដំណោះស្រាយដើម្បីបង្កើនការច្រោះ និងបញ្ចុះកម្តៅ រួមមាន៖

- ដាំដើមឈើ
- តម្រងប្រអប់ម៉ែកឈើ
- បណ្តាញបង្ហូរទឹកជីវសាស្ត្រ
- សួនទឹកភ្លៀង និងជីវសាស្ត្រ
- ការស្តារចរន្តបង្ហូរទឹកឡើងវិញ

និយមន័យ

អាកាសធាតុ គឺជាលំនាំនៃព្រឹត្តិការណ៍ធាតុអាកាសដែលត្រូវបានសង្កេតឃើញទៅតាមពេលវេលា។

បម្រែបម្រួលអាកាសធាតុ គឺជាបាតុភូតមួយដែលបណ្តាលមកពីការកើនឡើងនៃឧស្ម័នផ្ទះកញ្ចក់នៅក្នុងបរិយាកាសផែនដី ដែលបណ្តាលឱ្យសីតុណ្ហភាពពិភពលោកកាន់តែក្តៅ។

កោះកម្តៅក្នុងទីក្រុង កើតឡើងនៅពេលទីក្រុងនានាបានផ្លាស់ប្តូរដីធម្មជាតិជាមួយនឹងផ្ទៃដែលអាចស្រះ ដែលវារក្សាកម្តៅ។

ទឹកជំនន់ គឺជាទឹកភ្លៀងប្រព្រិលដែលរលាយចូលទៅក្នុងដី រួចចូលក្នុងទឹកក្រោមដី ហូរចូលក្នុងផ្លូវទឹកតាមធម្មជាតិ ឬចូលតាមបំពង់ទុយោរជាបន្តបន្ទាប់រហូតដល់វាហូរចូលទៅក្នុងផ្លូវទឹកក្បែរនោះ។

ទីជម្រាលរួមមាន ដីទាំងឡាយដែលមានផ្លូវទឹកហូរ ហើយអាចហូរលើសពីគន្លងទឹកទៅឆ្ងាយជាច្រើនម៉ាយល៍ទៀត។

លូ គឺជាលូបង្ហូរទឹកក្រោមដីដែលអនុញ្ញាតឱ្យទឹកហូរនៅក្រោមផ្លូវថ្នល់ ឬហេដ្ឋារចនាសម្ព័ន្ធដែលបានសាងសង់ស្រដៀងគ្នា។

ការចូលរួមចំណែករបស់អ្នក គឺមានសារៈសំខាន់! ចង់ក្លាយជាផ្នែកមួយនៃដំណោះស្រាយទេ? អនុវត្តតាមជំហានរហ័សទាំងនេះ៖

សូមចូលទៅកាន់គេហទំព័ររបស់គម្រោងតាម Tinyurl.com/LowellMVP ដើម្បីស្វែងយល់បន្ថែម

និងចែករំលែកមតិយោបល់របស់អ្នក

បន្តរក្សាការសន្ទនាតាមអ៊ិនធឺណិតដោយប្រើសញ្ញា #ResilientLowell

គម្រោងនេះត្រូវបានផ្តល់មូលនិធិដោយការិយាល័យប្រតិបត្តិការរដ្ឋ Massachusetts នៃកម្មវិធីមូលនិធិសកម្មភាពត្រៀមបង្ការភាពងាយរងគ្រោះលើកិច្ចការបរិស្ថាន និងថាមពលរបស់ទីក្រុង (Massachusetts Executive Office of Energy & Environmental Affairs' Municipal Vulnerability Preparedness) (MVP)ដែលផ្តល់ការគាំទ្រចំពោះទីក្រុង និងទីប្រជុំជននានា ដើម្បីរៀបចំផែនការសម្រាប់បម្រែប្រួលអាកាសធាតុ និងអនុវត្តគម្រោងនានាដើម្បីបង្កើនភាពធន់។

Weston & Sampson

THE CITY OF LOWELL
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O plano de melhoria de capital de gestão de águas pluviais de resiliência climática Lowell Claypit Brook

Como a mudança climática pode impactar a cidade de Lowell?

INUNDAÇÃO: O sistema de águas pluviais é considerado um recurso local vulnerável. As inundações de águas pluviais são especialmente frequentes em áreas com:

- drenagem deficiente
- grandes quantidades de pavimento e outras superfícies que impedem a infiltração de água no solo
- bueiros subdimensionados

Como os eventos de chuva estão se tornando cada vez mais intensos devido à mudança climática, grande parte da infraestrutura de águas pluviais projetada décadas atrás agora é subdimensionada, incluindo bueiros. As inundações de águas pluviais são especialmente graves em Pawtucketville, um bairro de Justiça Ambiental perto de Claypit Brook.

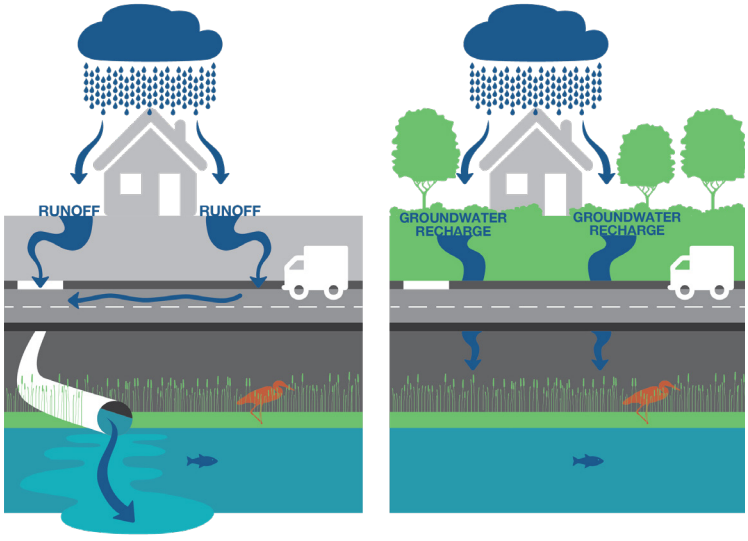
CALOR EXTREMO: As ilhas de calor urbano (ICU) também são uma preocupação, que afetam desproporcionalmente as populações vulneráveis.

O que estamos fazendo sobre isso?

O plano de melhoria de capital de gestão de águas pluviais de resiliência climática Lowell Claypit Brook inclui:

- avaliar de forma abrangente a drenagem de bacias hidrográficas, condições de bueiros e inundações
- mapeamento de ilhas de calor urbano
- projeto preliminar de um bueiro vulnerável na Stockbridge Ave
- identificação de soluções potenciais baseadas na natureza para melhorar a drenagem para lidar com futuros eventos de precipitação extrema na bacia hidrográfica de Claypit Brook.

O que é possível?



Soluções para aumentar a filtração e resfriamento incluem:

- plantação de árvores
- filtro de drenagem de berço para arborização urbana
- valetas de bioretenção
- restauração de fluxo
- jardins de chuva e sistema de bioretenção

Definições

Clima é o padrão de eventos climáticos observados ao longo do tempo.

A mudança climática é um fenômeno causado pelo aumento dos gases de efeito estufa na atmosfera terrestre, o que resulta em um aquecimento global da temperatura.

As ilhas de calor urbano (ICU) são microclimas urbanos que ocorrem quando as cidades substituem a cobertura natural do solo por superfícies impermeáveis que retêm o calor.

As águas pluviais é a chuva ou o derretimento da neve que penetra no solo e recarrega a água subterrânea, drena naturalmente para os corpos d'água ou é transportada por uma série de tubos, a rede de água pluvial, até ser descarregada em um corpo d'água próximo.

Uma bacia hidrográfica inclui todas as terras que contribuem para o escoamento de um corpo d'água e pode se estender por muitos quilômetros de distância da borda da água.

Um bueiro é um conduíte subterrâneo que permite que a água flua por baixo de uma estrada ou infraestrutura semelhante.

Sua opinião é essencial! Quer fazer parte da solução? Siga estas etapas rápidas:

Visite a página do projeto em **Tinyurl.com/LowellMVP** para saber mais e compartilhe sua opinião

Mantenha a conversa online usando a hashtag **#ResilientLowell**

Este projeto foi financiado pelo programa de Subsídio de Ação de Preparação para a Vulnerabilidade Municipal (MVP) do Escritório Executivo de Assuntos de Energia e Meio Ambiente de Massachusetts, que fornece suporte para cidades e vilas planejarem as mudanças climáticas e implementarem projetos para aumentar a resiliência.

Weston & Sampson

The City of LOWELL
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El plan de mejora de capital de gestión de aguas pluviales para la resiliencia climática de Lowell Claypit Brook

¿Cómo podría afectar el cambio climático a la ciudad de Lowell?

INUNDACIÓN: El sistema de aguas pluviales se considera un recurso local vulnerable. Las inundaciones de aguas pluviales son especialmente frecuentes en áreas con:

- drenaje deficiente
- grandes cantidades de pavimento y otras superficies que evitan que el agua se infiltre en el suelo
- alcantarillas de tamaño insuficiente

Como los eventos de lluvia se vuelven cada vez más intensos debido al cambio climático, una gran parte de la infraestructura de las aguas pluviales diseñada hace décadas ahora tiene un tamaño insuficiente, incluidas las alcantarillas. Las inundaciones de aguas pluviales son especialmente severas en Pawtucketville, un vecindario de Justicia Ambiental cerca de Claypit Brook.

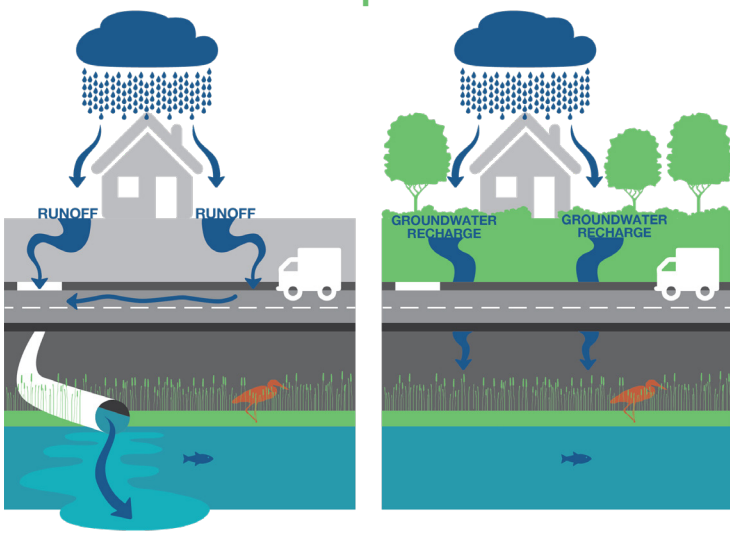
CALOR EXTREMO: Las islas de calor urbanas también son una preocupación, que impacta de manera desproporcionada a las poblaciones vulnerables.

¿Qué estamos haciendo al respecto?

El plan de mejora de capital de gestión de aguas pluviales para la resiliencia climática de Lowell Claypit Brook incluye:

- Evaluación integral del drenaje de las cuencas hidrográficas, las condiciones de las alcantarillas y las inundaciones.
- mapeo de islas de calor urbanas
- diseño preliminar de una alcantarilla vulnerable en Stockbridge Ave
- identificar posibles soluciones basadas en la naturaleza para mejorar el drenaje para manejar eventos futuros de precipitación extrema en la cuenca hidrográfica de Claypit Brook.

¿Qué es posible?



Las soluciones para aumentar la filtración y el enfriamiento incluyen:

- plantación de árboles
- filtro de drenaje de cuna para forestación urbana
- biovaleta
- restauración de las corrientes
- jardines de lluvia y celda de biorretención

Definiciones

El clima es el patrón de eventos meteorológicos observados a lo largo del tiempo.

El cambio climático es un fenómeno causado por el aumento de gases de efecto invernadero en la atmósfera terrestre, lo que resulta en un calentamiento global de la temperatura.

Las islas de calor urbanas también son una preocupación, que impacta de manera desproporcionada a las poblaciones vulnerables.

Las aguas pluviales son las aguas de lluvia o nieve derretida que penetra en el suelo y recarga las aguas subterráneas, se escurre naturalmente a los cuerpos de agua o se transporta a través de una serie de tuberías, que es la red de aguas pluviales, hasta que se descarga en un cuerpo de agua cercano.

Una cuenca hidrográfica incluye todas las tierras que contribuyen al flujo de un cuerpo de agua y pueden extenderse por muchos kilómetros lejos de la orilla del agua.

Una alcantarilla es un conducto subterráneo que permite que el agua fluya por debajo de una carretera o infraestructura similar.

¡Tu opinión es esencial! ¿Quieres ser parte de la solución? Siga estos pasos rápidos:

Visite la página web del proyecto en **Tinyurl.com/LowellMVP** para obtener más información y compartir sus comentarios

Mantenga la conversación online usando el hashtag **#ResilientLowell**

Este proyecto fue financiado por el programa de Subvenciones de Acción de Preparación para la Vulnerabilidad Municipal (MVP) de la Oficina Ejecutiva de Energía y Asuntos Ambientales de Massachusetts, que brinda apoyo a las ciudades y pueblos para planificar para el cambio climático e implementar proyectos para aumentar la resiliencia.

Weston & Sampson

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Lowell Claypit Brook MVP Action Grant Survey

Summary of Survey Results and Public Comments

Introduction

The City of Lowell was awarded a Municipal Vulnerability Preparedness (MVP) Action Grant to develop a Climate Resilience Stormwater Management Capital Improvement Plan for Claypit Brook. The plan will comprehensively assess the watershed's drainage, culvert conditions, and known flooding conditions. The project team will then complete preliminary design of the highly vulnerable Stockbridge Avenue culvert and identify nature-based solutions to supply drainage to handle future extreme precipitation events in the Claypit Brook Watershed. The project team shared an online survey to collect public feedback on this project. Key information related to the results of this survey are summarized below.

- The survey received **28 responses.**
- The survey was accessible on the Microsoft Forms website from May 24, 2021, to June 11, 2021.
- The survey was available in four languages, but only English responses were received.
- The survey was shared and promoted through the following means:
    - Posted on the project webpage, where the team shared additional educational resources such as fact sheets, and a comment form to collect questions at any time.
    - An e-blast sent by the City to the stakeholder list developed during the HM-MVP Planning Phase
    - Social media posts on the City's Facebook and Twitter pages
    - Survey link shared during a meeting with the Pawtucketville Citizens Council
    - Survey link included as an announcement on the front page of the City's website

The following summary provides an overview of the survey responses, along with key findings and recommendations for using this information. A spreadsheet of short-answer responses from survey participants, along with a copy of the original survey, are included as attachments to this document.

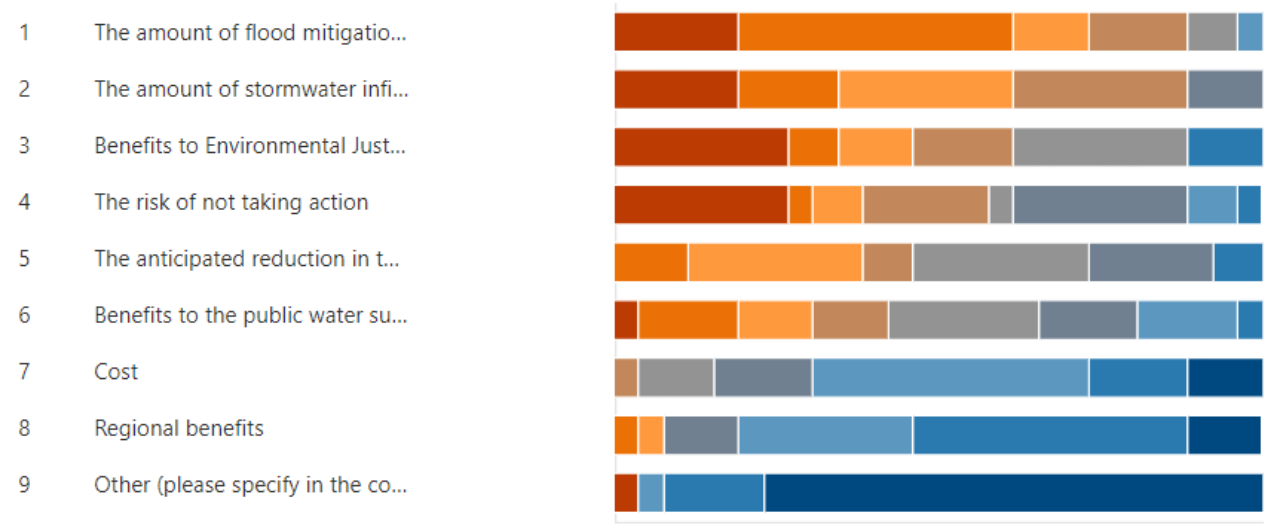
Survey Results

Which of the following climate impacts have you experienced in Lowell?

- Almost a third (28%) of respondents experienced flooding on their street
- Some people (18%) have experienced school closures due to flooding or heat, and 18% have experienced business closures due to flooding or heat
- Some people (18%) have experienced heat-related illness and 18% experienced heat-related power loss

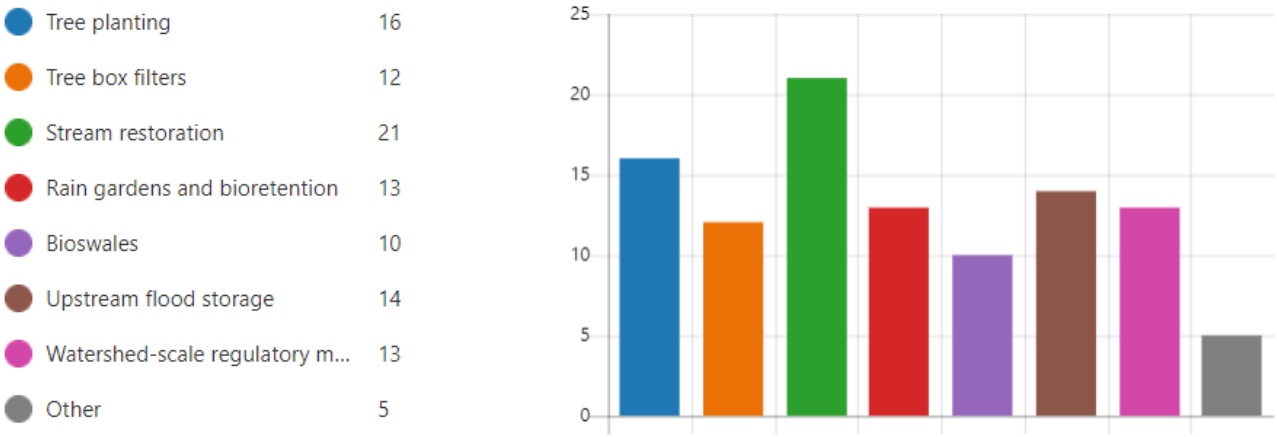
How should the City prioritize nature-based solutions using the following factors?

- Survey results suggest that the amount of flood mitigation, stormwater infiltration, and benefits to Environmental Justice populations are among the top three priorities for residents
- The risk of not taking action, reduction in the urban heat island effect, and benefits to the public water system are among residents' secondary priorities
- Cost and regional benefits were listed among the lowest priority considerations



What flood reduction strategies would you like to see assessed in the Claypit Brook Watershed?

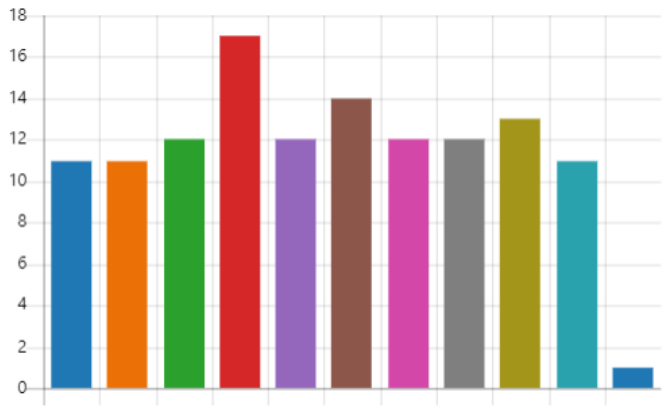
- 21 respondents would like to see stream restoration in Claypit Brook
- 16 respondents said they would like to see trees planted
- 14 respondents listed upstream flood storage



How would you like to receive information about climate change risks and resiliency projects in Lowell?

- Most residents prefer PDFs available online
- The second-choice response was information on a dedicated webpage on the City of Lowell's website
- The third-choice response was through newsletters and meetings of local groups
- The other methods were equally preferred

Interactive online webinars	11
Pre-recorded videos posted o...	11
Online surveys	12
PDFs available online, includin...	17
Printed media shared via mail,...	12
Information posted to a dedic...	14
Through social media, includi...	12
E-blasts from the City	12
Through the newsletters and ...	13
In-person events after a COVI...	11
Other	1

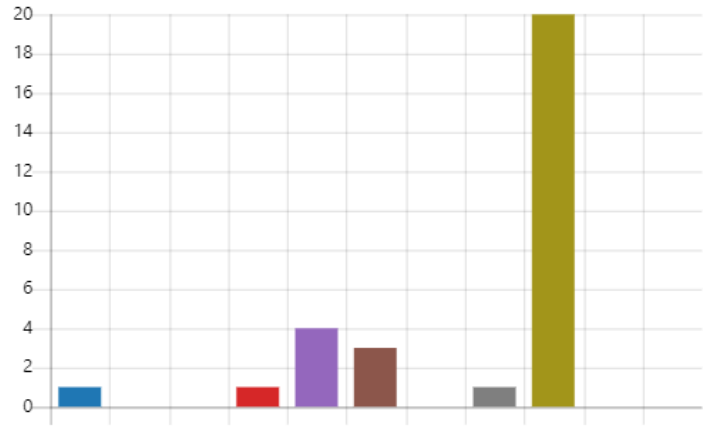


Demographics

Please select the neighborhood where you live or work:

- 71% of the participants live in Pawtucketville where most of the flooding occurs

Acre	1
Back Central	0
Belvidere	0
Centralville	1
Downtown	4
Highlands	3
Lower Belvidere	0
Lower Highlands	1
Pawtucketville	20
Sacred Heart	0
South Lowell	0



What is your connection to Lowell?

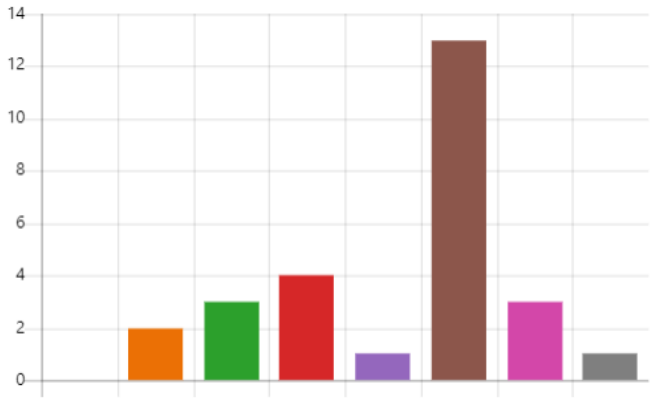
- Most of the participants (65%) own a home in Lowell
- Some rent an apartment (13%) and some (16%) work in Lowell

I rent an apartment in Lowell	4
I own a home in Lowell	20
I work in Lowell	5
I own a business in Lowell	1
Other	1

Please select your age range.

- Most respondents (61%) were over the age of 55

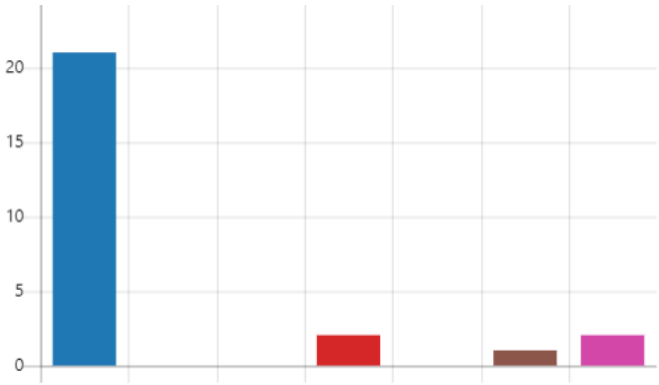
Under 18	0
18-24	2
25-35	3
36-45	4
46-55	1
56-65	13
66-75	3
Over 75	1



How would you describe yourself?

- Most respondents (75%) identified as white

White	21
Black or African-American	0
American Indian or Alaskan N...	0
Asian	2
Native Hawaiian or other Pacif...	0
Multiple races	1
Other	2



Are you of Hispanic, Latino, or of Spanish origin?

- 78% of respondents answered “no,” and 22% of respondents answered “yes”

Yes	5
No	18

Summary of short-answer responses:

Tell us more about how climate hazards have impacted you or your community. Memories of climate hazards could include flooding near Claypit Brook, flooding from beaver dams, heat waves with multiple days over 90 degrees Fahrenheit, and more.

Respondents discussed flooding of their properties and basements, power outages that lasted several days, and heat waves that required the City to open cooling stations. Flooding was linked to snowmelt, intense rainstorms, and runoff. Flooding in 2006 and 2007 was cited as particularly severe, with more than 70 homes damaged and residents forced to evacuate and relocate for a month.

Are there any additional comments or questions that you would like to share with the project team?

Comments received included discussions around the challenges of prioritizing strategies and investments in resilience, the importance of coordinating with local nonprofits and power company, and the need for increased tree canopy and shade in public outdoor spaces.

Key Findings & Next Steps

The project team should use the findings of this survey to:

- Pursue resiliency strategies including stream restoration, tree planting, and upstream flood storage.
- Prioritize nature-based solutions using factors including the amount of flood mitigation provided, the amount of stormwater infiltration provided, and benefits to Environmental Justice populations.
- Share more information through online PDFs, the City website, and coordination with local groups.
- Use the 10 email addresses collected to add to the climate resilience listserv started during the HM-MVP Planning phase. Additionally, the next public meeting should be advertised via email to respondents who shared their contact information.

Attachments

- Attachment A: Lowell Survey
- Attachment B: Short Answer Responses Spreadsheet

Lowell Claypit Brook Climate Resilience Stormwater Management Capital Improvement Plan

* Required

1

Please select one of the options below to take the survey in your preferred language! Seleccione una de las siguientes opciones para realizar la encuesta en el idioma que elija. Selecione uma das opções abaixo para responder à pesquisa em seu idioma escolhido. សូមជ្រើសរើសជម្រើសមួយក្នុងចំណោមជម្រើសខាងក្រោម ដើម្បីធ្វើការស្ទង់មតិក្នុងភាសាដែលអ្នកពេញចិត្ត! *

- ◯ English
- ◯ Español
- ◯ Portuguese
- ◯ ភាសាខ្មែរ

Introduction

Hello! We hope you are doing well during this unusual time and thank you for taking our survey. Need some background information? Read on. If not, feel free to skip to question 1.

How Could Climate Change Impact Lowell?
Flooding and extreme heat have been identified by residents and stakeholders as concerns. The stormwater system is considered to be vulnerable as the intensity and frequency of rainfall increases with climate change and may overwhelm the current aging system that we designed decades ago. Stormwater flooding in Lowell is already an issue in areas with poor drainage, large amounts of impervious surfaces, and undersized culverts. Stormwater flooding is especially severe in Pawtucketville, an Environmental Justice neighborhood near Claypit Brook. Urban heat islands are also a concern in areas with large amounts of impervious surfaces and can and disproportionately impact vulnerable populations.

What are…?
Urban heat islands occur when cities replace natural land cover with impervious surfaces that retain heat.

Stormwater is rain or snow melt that soaks into the soil and recharges groundwater, naturally drains into waterbodies, or is conveyed through a series of pipes until it is discharged into a nearby waterbody.

A watershed includes all land that contributes runoff to a body of water and may extend many miles away from the water's edge.

Impervious surfaces are pavement and other surfaces that retain heat and prevent water from infiltrating into the ground.

A culvert is an underground conduit that allows water to flow beneath a road or similar built infrastructure.

What are We Doing About It?
The Climate Resilience Stormwater Management Capital Improvement Plan for Claypit Brook will comprehensively assess the watershed's drainage, culvert conditions and flooding, and map urban heat islands. The project team will also complete preliminary design of a highly vulnerable culvert on Stockbridge Avenue, and identify nature-based solutions to improve drainage that will handle future extreme precipitation events. Your input on this project is essential!

How can I get involved?
Take this survey to tell us more about climate impacts in Lowell, your preferred nature-based solutions, and how you would like to be engaged in the future! The survey is open until June 11th.

Learn more about the project details online at tinyurl.com/LowellMVP (http://tinyurl.com/LowellMVP) and stay tuned for upcoming opportunities for participation. Keep the conversation going online using the hashtag #ResilientLowell. If you have additional input, questions, or barriers to participating, please contact Adria Boynton (Resiliency Specialist at Weston & Sampson) at boyntona@wseinc.com (mailto:boyntona@wseinc.com).

2

Which of the following climate impacts have you experienced in Lowell? Click all that apply.

- [ ] Flooding of the street my home is on
- [ ] Heat-related illness
- [ ] Heat-related power loss
- [ ] Business closures due to flooding or heat
- [ ] School closures due to flooding or heat

3

Tell us more about how climate hazards have impacted you or your community. Memories of climate hazards could include flooding near Claypit Brook, flooding from beaver dams, heat waves with multiple days over 90 degrees Fahrenheit, and more.

4

What flood reduction strategies would you like to see assessed in the Claypit Brook Watershed? Check all that apply.

- [ ] Tree planting
- [ ] Tree box filters
- [ ] Stream restoration
- [ ] Rain gardens and bioretention
- [ ] Bioswales
- [ ] Upstream flood storage
- [ ] Watershed-scale regulatory mechanisms, such as creating a stormwater overlay district
- [ ] Other

How should the City prioritize nature-based solutions using the following factors? Please rank these factors by arranging the highest priority considerations at the top of the list, and the lowest priority considerations at the bottom.

Benefits to Environmental Justice, or socially vulnerable populations

The amount of stormwater infiltration provided and water quality improvements

The amount of flood mitigation provided

The anticipated reduction in the urban heat island effect (i.e., increased cooling)

The risk of not taking action

Cost

Benefits to the public water supply and groundwater recharge

Regional benefits

Other (please specify in the comment form below)

6

How would you like to receive information about climate change risks and resiliency projects in Lowell? Check all that apply.

- [ ] Interactive online webinars
- [ ] Pre-recorded videos posted online
- [ ] Online surveys
- [ ] PDFs available online, including informational fact sheets and reports
- [ ] Printed media shared via mail, including informational fact sheets and flyers
- [ ] Information posted to a dedicated webpage on the City of Lowell website
- [ ] Through social media, including Twitter and Facebook
- [ ] E-blasts from the City
- [ ] Through the newsletters and meetings of local groups and regional organizations
- [ ] In-person events after a COVID-19 vaccine is widely available
- [ ] Other

7

Are there any additional comments or questions that you would like to share with the project team?

8

The following questions are not required. However, by answering these demographic questions, you will help us assess if our survey has broad participation. Please select all that apply:

- [ ] I rent an apartment in Lowell
- [ ] I own a home in Lowell
- [ ] I work in Lowell
- [ ] I own a business in Lowell
- [ ] Other

9

Please select the neighborhood where you live or work:

- [ ] Acre
- [ ] Back Central
- [ ] Belvidere
- [ ] Centralville
- [ ] Downtown
- [ ] Highlands
- [ ] Lower Belvidere
- [ ] Lower Highlands
- [ ] Pawtucketville
- [ ] Sacred Heart
- [ ] South Lowell

10

Please select your age range

- ◯ Under 18
- ◯ 18-24
- ◯ 25-35
- ◯ 36-45
- ◯ 46-55
- ◯ 56-65
- ◯ 66-75
- ◯ Over 75

11

How would you describe yourself?

- ◯ White
- ◯ Black or African-American
- ◯ American Indian or Alaskan Native
- ◯ Asian
- ◯ Native Hawaiian or other Pacific Islander
- ◯ Multiple races
- ◯ Other

12

Are you of Hispanic, Latino, or of Spanish origin?

- ◯ Yes
- ◯ No

13

Thank you for completing this survey. If you are interested in receiving additional updates related to climate initiatives in Lowell, please enter your email below.

Introducción

¡Hola! Esperamos que le esté yendo bien durante este momento inusual y le agradecemos su colaboración con nuestra encuesta. ¿Necesita información de antecedentes? Siga leyendo. De lo contrario, no dude en pasar a la primera pregunta.

¿Cómo podría afectar el cambio climático a la ciudad de Lowell?
Los residentes y las partes interesadas identificaron las inundaciones y el calor extremo como preocupaciones. Se considera vulnerable el sistema de aguas pluviales ya que la intensidad y frecuencia de las lluvias aumentan con el cambio climático y puede sobrecargar el sistema actual que hemos diseñado hace muchas décadas y que ya está obsoleto. La inundación de aguas pluviales en Lowell ya es un problema en áreas con drenaje deficiente, grandes cantidades de superficies impermeables y alcantarillas de tamaño insuficiente. Las inundaciones de aguas pluviales son especialmente severas en Pawtucketville, un vecindario de Justicia Ambiental cerca de Claypit Brook. Las islas de calor urbano también son una preocupación en áreas con grandes cantidades de superficies impermeables y pueden afectar de manera desproporcionada a las poblaciones mas vulnerables.

¿Qué son...?
Las islas de calor urbano se producen cuando las ciudades reemplazan la cubierta terrestre natural con superficies impermeables que retienen el calor.

Las aguas pluviales son las aguas de lluvia o nieve derretida que penetra en el suelo y recarga las aguas subterráneas, se escurre naturalmente a los cuerpos de agua o se transporta a través de una serie de tuberías, que es la red de aguas pluviales, hasta que se descarga en un cuerpo de agua cercano.

Una cuenca hidrográfica incluye todas las tierras que contribuyen al flujo de un cuerpo de agua y pueden extenderse por muchos kilómetros lejos de la orilla del agua.

Las superficies impermeables son el pavimento y otras superficies que retienen el calor y evitan que el agua se infiltre en el suelo.

Una alcantarilla es un conducto subterráneo que permite que el agua fluya por debajo de una carretera o infraestructura similar.

¿Qué estamos haciendo al respecto?
El plan de mejora de capital para la gestión de aguas pluviales de resiliencia climática de Claypit Brook evaluará de manera integral el drenaje de las cuencas, las alcantarillas y las condiciones de inundación, y mapeará las islas de calor urbano. El equipo del proyecto también completará el diseño preliminar de una boca de acceso altamente vulnerable en Stockbridge Avenue e identificará soluciones basadas en la naturaleza para mejorar el sistema de drenaje que manejará futuros eventos de precipitación extrema. ¡Tu opinión sobre este proyecto es fundamental!

¿Cómo puedo participar?
¡Participe en esta encuesta para contarnos más sobre los impactos climáticos en Lowell, sus soluciones preferidas basadas en la naturaleza y cómo le gustaría participar en el futuro!

Obtenga más información sobre los detalles del proyecto en tinyurl.com/LowellMVP

(http://tinyurl.com/LowellMVP) y esté atento a las próximas oportunidades de participación. Mantenga la conversación con el hashtag #ResilientLowell. Si tiene sugerencias, preguntas o preocupaciones adicionales para la participación, comuníquese con Adria Boynton (especialista en resiliencia de Weston & Sampson) en boyntona@wseinc.com (mailto:boyntona@wseinc.com).

14

¿Cuál de los siguientes impactos climáticos ha experimentado en Lowell? Haga clic en todas las opciones que correspondan.

- [ ] Inundación de la calle en la que está mi casa
- [ ] Enfermedad relacionada con el calor
- [ ] Fallas eléctricas relacionada con el calor
- [ ] Cierres de empresas debido a inundaciones o calor
- [ ] Cierres de escuelas debido a inundaciones o calor

15

Cuéntenos más sobre cómo los peligros climáticos lo han afectado a usted o a su comunidad. Los recuerdos de los peligros climáticos pueden incluir inundaciones cerca de Claypit Brook, inundaciones por represas de castores, olas de calor con varios días de más de 90 grados Fahrenheit y más.

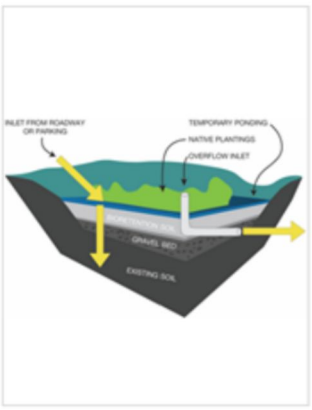
16

¿Qué estrategias de reducción de inundaciones le gustaría que se evaluaran en la cuenca de Claypit Brook? Marque todo lo que corresponda.

Plantación de árboles & Filtro de drenaje de cuna para forestación urbana


Restauración de las corrientes


Jardines de lluvia y celda de biorretención



Biovaleta

- [ ] Plantación de árboles
- [ ] Filtro de drenaje de cuna para forestación urbana
- [ ] Restauración de las corrientes
- [ ] Jardines de lluvia y celda de biorretención
- [ ] Biovaleta
- [ ] Almacenamiento de inundaciones contra corriente
- [ ] Mecanismos regulatórios en escala de cuencas hidrográficas, como la creación de un distrito de superposición de aguas pluviales
- [ ]

Other

¿Cómo debería priorizar la ciudad las soluciones basadas en la naturaleza utilizando los siguientes factores? Clasifique estos factores colocando las consideraciones de mayor prioridad en la parte superior de la lista y las consideraciones de menor prioridad en la parte inferior.

Beneficios para la justicia ambiental o poblaciones socialmente vulnerables

La cantidad de infiltración de aguas pluviales proporcionada y las mejoras en la calidad del agua

La cantidad de mitigación de inundaciones proporcionada

La reducción del efecto de la isla de calor urbano (es decir, mayor enfriamiento)

El riesgo de no tomar medidas

Los gastos

Beneficios para el suministro público de agua y la recarga de aguas subterráneas

Beneficios regionales

Otro (especifique en el formulario de comentarios a continuación)

18

¿Cómo le gustaría recibir información sobre los riesgos del cambio climático y los proyectos de resiliencia en Lowell? Marque todo lo que corresponda.

- [ ] Seminarios web interactivos
- [ ] Videos pregrabados publicados en el internet
- [ ] Encuestas en línea
- [ ] PDF disponibles en línea, incluidas hojas informativas e informes
- [ ] Medios impresos compartidos por correo, incluidas hojas informativas y folletos
- [ ] Información publicada en una página de web dedicada en el sitio web de la ciudad de Lowell
- [ ] A través de las redes sociales, incluidos Twitter y Facebook
- [ ] Correos electrónicos enviados de la ciudad
- [ ] A través de boletines y reuniones de grupos locales y organizaciones regionales
- [ ] Eventos en persona después de que una vacuna COVID-19 esté ampliamente disponible
- [ ]

Other

19

¿Hay algún comentario o pregunta adicional que le gustaría compartir con el equipo del proyecto?

20

Las siguientes preguntas no son necesarias. Sin embargo, al responder a estas preguntas demográficas, nos ayudará a evaluar si nuestra encuesta tiene una amplia participación. Por favor seleccione todas las respuestas válidas:

- [ ] Alquilo un apartamento en Lowell
- [ ] Soy dueño de una casa en Lowell
- [ ] Yo trabajo en Lowell
- [ ] Soy dueño de un negocio en Lowell
- [ ] Other

21

Seleccione el vecindario donde vive o trabaja:

- [ ] Acre
- [ ] Back Central
- [ ] Belvidere
- [ ] Centralville
- [ ] Downtown
- [ ] Highlands
- [ ] Lower Belvidere
- [ ] Lower Highlands
- [ ] Pawtucketville
- [ ] Sacred Heart
- [ ] South Lowell

22

Seleccione su rango de edad

- ◯ Menores de 18 años
- ◯ 18-24
- ◯ 25-35
- ◯ 36-45
- ◯ 46-55
- ◯ 56-65
- ◯ 66-75
- ◯ Más de 75 años

23

¿Cómo te describes?

- ◯ Blanco
- ◯ Negro o afroamericano
- ◯ Indio americano o nativo de Alaska
- ◯ Asiático
- ◯ Nativo hawaiano/otro isleño del Pacífico
- ◯ Varias razas
- ◯ Other

24

¿Es usted de origen hispano, latino o español?

- ◯ Sí
- ◯ No

25

Gracias por completar esta encuesta. Si está interesado en recibir actualizaciones adicionales relacionadas con las iniciativas climáticas en Lowell, ingrese su correo electrónico a continuación.

Introdução

Olá! Esperamos que você esteja bem considerando este período incomum que estamos passando e agradecemos por responder à nossa pesquisa. Precisa de algumas informações básicas? Continue lendo. Caso contrário, pule para a pergunta 1.

Como a mudança climática pode impactar a cidade de Lowell?
Inundações e calor extremo foram identificados pelos residentes e partes interessadas como preocupações. O sistema de águas pluviais é considerado vulnerável à medida que a intensidade e a frequência das chuvas aumentam com as mudanças climáticas e podem sobrecarregar o atual sistema que projetamos há décadas e já se encontra obsoleto. A inundação de águas pluviais em Lowell já é um problema em áreas com drenagem deficiente, grandes quantidades de superfícies impermeáveis e bueiros subdimensionados. As inundações de águas pluviais são especialmente graves em Pawtucketville, um bairro de Justiça Ambiental perto de Claypit Brook. As ilhas de calor urbanas também são uma preocupação em áreas com grandes quantidades de superfícies impermeáveis e podem impactar desproporcionalmente as populações vulneráveis.

O que são...?
As ilhas de calor urbano (ICU) são microclimas urbanos que ocorrem quando as cidades substituem a cobertura natural do solo por superfícies impermeáveis que retêm o calor.

As águas pluviais é a chuva ou o derretimento da neve que penetra no solo e recarrega a água subterrânea, drena naturalmente para os corpos d'água ou é transportada por uma série de tubos, a rede de água pluvial, até ser descarregada em um corpo d'água próximo.

Uma bacia hidrográfica inclui todas as terras que contribuem para o escoamento de um corpo d'água e pode se estender por muitos quilômetros de distância da borda da água.

As superfícies impermeáveis são pavimentos e outras superfícies que retêm o calor e evitam que a água se infiltre no solo.

Um bueiro é um conduíte subterrâneo que permite que a água flua por baixo de uma estrada ou infraestrutura semelhante.

O que estamos fazendo sobre isso?
Plano de melhoria de capital para gestão de águas pluviais para resiliência climática de Claypit Brook avaliará de forma abrangente a drenagem da bacia hidrográfica, as condições de bueiros e inundações, e mapeará ilhas de calor urbanas. A equipe do projeto também concluirá o projeto preliminar de um bueiro altamente vulnerável na Stockbridge Avenue e identificará soluções baseadas na natureza para melhorar o sistema de drenagem que irá lidar com futuros eventos de precipitação extrema. Sua opinião sobre este projeto é essencial!

Como posso participar?
Participe desta pesquisa para nos contar mais sobre os impactos climáticos em Lowell, suas soluções baseadas na natureza preferidas e como você gostaria de se engajar no futuro!

Saiba mais sobre os detalhes do projeto online em tinyurl.com/LowellMVP (http://tinyurl.com/LowellMVP) e fique atento para as próximas oportunidades de participação. Mantenha a conversa online usando a hashtag #ResilientLowell. Se você tiver sugestões adicionais,

perguntas ou barreiras para participar, entre em contato com Adria Boynton (especialista em resiliência da Weston & Sampson) em boyntona@wseinc.com (mailto:boyntona@wseinc.com).

26

Quais dos seguintes impactos climáticos você experienciou em Lowell? Clique em todas as opções que se aplicam.

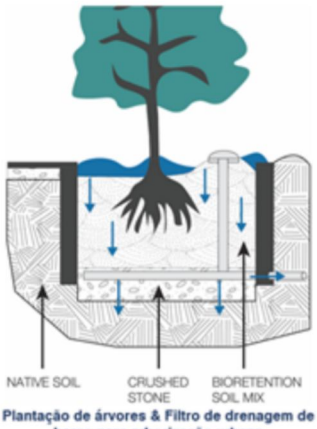
- [ ] Inundação da rua onde moro
- [ ] Doença relacionada ao calor
- [ ] Perda de energia elétrica relacionada ao calor
- [ ] Fechamentos de empresas devido a inundações ou calor
- [ ] Fechamento de escolas devido a inundações ou calor

27

Conte-nos mais sobre como os riscos climáticos afetaram você ou sua comunidade. Lembranças de riscos climáticos podem incluir enchentes perto de Claypit Brook, inundações s de barragens de castores, ondas de calor com vários dias acima de 90 graus Fahrenheit e muito mais.

28

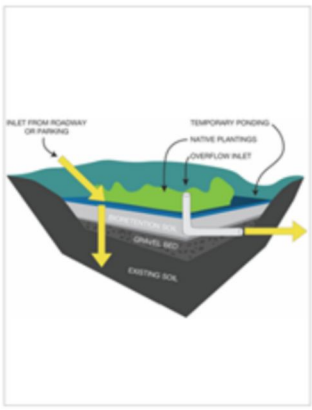
Quais estratégias de redução de enchentes você gostaria de ver avaliadas na bacia hidrográfica de Claypit Brook? Marque todas as opções aplicáveis.



Plantação de árvores & Filtro de drenagem de berço para arborização urbana


Restauração de fluxo


Jardins de chuva e bioretenção



Valetas de bioretenção

- [ ] Plantação de árvores
- [ ] Filtro de drenagem de berço para arborização urbana
- [ ] Restauração de fluxo
- [ ] Jardins de chuva e bioretenção
- [ ] Valetas de bioretenção
- [ ] Armazenamento de inundação contra a corrente
- [ ] Mecanismos regulatórios em escala de bacias hidrográficas, como a criação de um distrito de cobertura de águas pluviais
- [ ]

Other

Como a cidade deve priorizar as soluções baseadas na natureza usando os seguintes fatores? Classifique esses fatores organizando as considerações de prioridade mais alta no topo da lista e as considerações de prioridade mais baixa na parte inferior.

Benefícios de Direito Ambiental, ou populações socialmente vulneráveis

A quantidade de infiltração de águas pluviais fornecida e melhorias na qualidade da água

A quantidade de mitigação de inundação fornecida

A redução no efeito da ilha de calor urbano (ou seja, aumento do resfriamento)

O risco de não agir

Os gastos

Benefícios para abastecimento público de água e recarga de lençóis freáticos

Benefícios regionais

Outro (especifique no formulário de comentário abaixo)

30

Você gostaria de receber informações sobre os riscos das mudanças climáticas e projetos de resiliência em Lowell? Marque todas as opções aplicáveis.

- [ ] Webinars interativos online
- [ ] Vídeos pré-gravados postados online
- [ ] Pesquisas online
- [ ] PDFs disponíveis online, incluindo fichas informativas e relatórios
- [ ] Mídia impressa compartilhada por correio, incluindo folhetos informativos
- [ ] Informações postadas em uma página da web dedicada no site da cidade de Lowell
- [ ] Por meio da mídia social, incluindo Twitter e Facebook
- [ ] Emails enviados pela cidade
- [ ] Por meio de boletins e reuniões de grupos locais e organizações regionais
- [ ] Eventos pessoais após a vacina COVID-19 estar amplamente disponível
- [ ]

Other

31

Há algum comentário ou pergunta adicional que você gostaria de compartilhar com a equipe do projeto?

32

As seguintes perguntas não são obrigatórias. Porém, ao responder a essas perguntas demográficas, você nos ajudará a avaliar se nossa pesquisa tem ampla participação. Por favor selecione tudo que se aplica:

- [ ] Eu alugo um apartamento em Lowell
- [ ] Eu sou dono(a) de uma casa em Lowell
- [ ] Eu trabalho em Lowell
- [ ] Eu tenho um negócio em Lowell
- [ ] Other

33

Selecione o bairro onde você mora ou trabalha:

- [ ] Acre
- [ ] Back Central
- [ ] Belvidere
- [ ] Centralville
- [ ] Downtown
- [ ] Highlands
- [ ] Lower Belvidere
- [ ] Lower Highlands
- [ ] Pawtucketville
- [ ] Sacred Heart
- [ ] South Lowell

34

Selecione sua faixa etária

- ◯ Menores de 18
- ◯ 18-24
- ◯ 25-35
- ◯ 36-45
- ◯ 46-55
- ◯ 56-65
- ◯ 66-75
- ◯ Mais de 75

35

Como você descreveria a si mesmo?

- ◯ Braco
- ◯ Preto ou Afro-americano
- ◯ Índio americano ou nativo do Alasca
- ◯ Asiático
- ◯ Havaiano nativo ou de outra ilha do Pacífico
- ◯ Mais de uma cor ou raça
- ◯ [ ]

Other

36

Você é hispânico, latino ou de origem espanhola?

- ◯ Sim
- ◯ Não

37

Obrigado por completar esta pesquisa. Se você estiver interessado em receber atualizações adicionais relacionadas às iniciativas climáticas em Lowell, por favor, digite seu e-mail abaixo.

សេចក្តីផ្តើម

សួស្តី! យើងសង្ឃឹមថាអ្នកធ្វើបានល្អក្នុងកំឡុងពេលដ៏លំបាកនេះ ហើយសូមអរគុណចំពោះការស្ទង់មតិរបស់យើង។ តើអ្នកត្រូវការសាវតារព័ត៌មានខ្លះមែនទេ? សូមអានបន្ត។ បើមិនត្រូវការទេ សូមរំលងទៅសំណួរទី 1។

តើការប្រែប្រួលអាកាសធាតុអាចប៉ះពាល់ដល់ទីក្រុង Lowell យ៉ាងដូចម្តេចខ្លះ?
ទឹកជំនន់ និងឡើងកម្តៅត្រូវបានចាត់ទុកថាជាបញ្ហាកង្វល់ដោយប្រជាលរដ្ឋ និងភាគីពាក់ព័ន្ធផ្សេងៗ។ ប្រព័ន្ធទឹកភ្លៀង ត្រូវបានចាត់ទុកថាមានភាពងាយរងគ្រោះដោយសារអាំងតង់ស៊ីតេ និងប្រេកង់នៃទឹកភ្លៀងកើនឡើងជាមួយនឹងការប្រែប្រួលអាកាសធាតុ ហើយអាចនឹងប៉ះពាល់ដល់ប្រព័ន្ធដ៏មានភាពចំណាស់នាពេលបច្ចុប្បន្ន ដែលយើងបានរចនាឡើងជាច្រើនទសវត្សរ៍កន្លងមក។ ទឹកជន់ដោយសារទឹកភ្លៀងនៅទីក្រុង Lowell គឺជាបញ្ហាមួយរួចទៅហើយនៅក្នុងតំបន់ដែលមានប្រព័ន្ធបង្ហូរទឹកមិនល្អ បរិមាណដ៏ច្រើននៃការស្ទះផ្ទៃខាងលើ និងលូដែលមានទំហំតូចៗ។ ទឹកជន់ដោយសារទឹកភ្លៀង មានសភាពធ្ងន់ធ្ងរជាពិសេសនៅ Pawtucketville ដែលជាសង្កាត់យុត្តិធម៌បរិស្ថាននៅក្បែរ Claypit Brook។ កោះកម្តៅក្នុងទីក្រុងក៏ជាក្តីកង្វល់មួយផងដែរនៅក្នុងតំបន់ដែលមានការកកស្ទះផ្ទៃខាងលើច្រើន និងអាចធ្វើឱ្យប៉ះពាល់ដល់ប្រជាជនងាយដែលរងគ្រោះ។

អ្វីខ្លះ...?
កោះកម្តៅក្នុងទីក្រុងកើតឡើងនៅពេលទីក្រុងនានាបានផ្លាស់ប្តូរដីធម្មជាតិជាមួយនឹងផ្ទៃដែលអាចស្ទះ ដែលវារក្សាកម្តៅ។

ទឹកជំនន់គឺជាទឹកភ្លៀងឬព្រិលដែលរលាយចូលទៅក្នុងដី រួចចូលក្នុងទឹកក្រោមដី ហូរចូលក្នុងផ្លូវទឹកតាមធម្មជាតិ ឬចូលតាមបំពង់ទុយោរជាបន្តបន្ទាប់រហូតដល់វាហូរចូលទៅក្នុងផ្លូវទឹកក្បែរនោះ។

ទីជម្រាលរួមមានដីទាំងឡាយដែលមានផ្លូវទឹកហូរ ហើយអាចហូរលើសពីគន្លងទឹកទៅឆ្ងាយជាច្រើនម៉ាយល៍ទៀត។

ផ្ទៃដែលស្ទះ គឺកម្រាលផ្លូវដើរថ្ម និងផ្ទៃផ្សេងទៀតដែលរក្សាកម្តៅ និងបញ្ចៀសទឹកមិនឱ្យជ្រៀតចូលទៅក្នុងដី។

លូ គឺជាលូបង្ហូរទឹកក្រោមដីដែលអនុញ្ញាតឱ្យទឹកហូរនៅក្រោមផ្លូវថ្នល់ ឬហេដ្ឋារចនាសម្ព័ន្ធដែលបានសាងសង់ស្រដៀងគ្នា។

តើយើងកំពុងធ្វើអ្វីនឹងវា?
គម្រោងកែលម្អថវិការគ្រប់គ្រងទឹកភ្លៀងប្រកបដោយភាពធន់នឹងអាកាសធាតុទីក្រុងសម្រាប់ Claypit Brook នឹងធ្វើការវាយតម្លៃយ៉ាងទូលំទូលាយអំពីការបង្ហូរទឹកនៃទីជម្រាល ស្ថានភាពលូ ទឹកជំនន់ និងផែនទីកោះកម្តៅនៅតាមទីក្រុង។ ក្រុមការងារគម្រោងក៏នឹងបញ្ចប់ការរចនាបឋមសម្រាប់លូដែលទ្រុឌទ្រោមបំផុតនៅតាមវិថី Stockbridge Avenue និងកំណត់ដំណោះស្រាយ ដែលមានលក្ខណៈធម្មជាតិ ដើម្បីកែលម្អប្រព័ន្ធបង្ហូរទឹកដែលនឹងអាចដោះស្រាយព្រឹត្តិការណ៍ភ្លៀងធ្លាក់ខ្លាំងនាពេលអនាគត។ ការចូលរួមរបស់អ្នកលើគម្រោងនេះ គឺមានសារៈសំខាន់ណាស់!

តើខ្ញុំអាចចូលរួមបានយ៉ាងដូចម្តេច?
ធ្វើការស្ទង់មតិនេះដើម្បីប្រាប់យើងបន្ថែមទៀតអំពីផលប៉ះពាល់អាកាសធាតុនៅ

ស្វែងយល់បន្ថែមអំពីព័ត៌មានលម្អិតរបស់គម្រោងតាមអ៊ីនធឺណិតនៅគេហទំព័រ tinyurl.com/LowellMVP (http://tinyurl.com/LowellMVP) និងរង់ចាំមើលឱកាសចូលរួមនាពេលខាងមុខ។ បន្តរក្សាការសន្ទនាតាមអ៊ិនធឺណិតដោយប្រើសញ្ញា #ResilientLowell។ ប្រសិនបើអ្នកមានព័ត៌មានបន្ថែម សំណួរ ឬឧបសគ្គក្នុងការចូលរួម សូមទាក់ទងមកកាន់ Adria Boynton (អ្នកឯកទេសខាងភាពធន់នៅ Weston & Sampson) តាមរយៈអ៊ីមែល boyntona@wseinc.com (mailto:boyntona@wseinc.com)។

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តើផលប៉ះពាល់អាកាសធាតុដូចខាងក្រោមណាខ្លះ ដែលអ្នកបានជួបប្រទះនៅទីក្រុង Lowell? ចុចទាំងអស់ដែលអ្នកគិតថាប៉ះពាល់។

- [ ] ទឹកជំនន់នៅតាមដងផ្លូវផ្ទះខ្ពស់
- [ ] ជំងឺទាក់ទងនឹងកម្តៅ
- [ ] ការបាត់បង់ថាមពលដែលទាក់ទងនឹងកម្តៅ
- [ ] ការបិទអាជីវកម្មដោយសារទឹកជំនន់ ឬកម្តៅ
- [ ] ការបិទសាលារៀនដោយសារទឹកជំនន់ ឬកម្តៅ

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សូមប្រាប់យើងបន្ថែមទៀតអំពីគ្រោះថ្នាក់អាកាសធាតុដែលបានប៉ះពាល់ដល់អ្នក ឬសហគមន៍របស់អ្នក។ ការចងចាំនៃគ្រោះថ្នាក់អាកាសធាតុ អាចរួមមានទាំងទឹកជំនន់នៅក្បែរតំបន់ Claypit Brook ទឹកជំនន់ពីទំនប់កាស្ទ័រ រលកកម្តៅដែលមានច្រើនថ្ងៃលើសពីកម្រិត 90 អង្សាហ្វារិនហៃ និងបញ្ហាផ្សេងទៀត។

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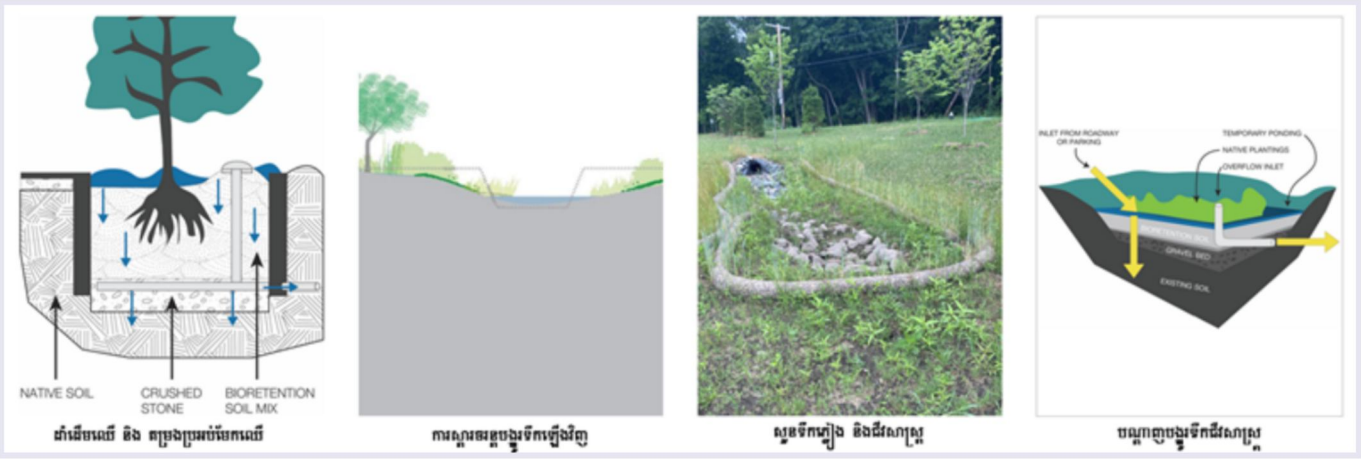
តើយុទ្ធសាស្ត្រកាត់បន្ថយទឹកជំនន់អ្វីខ្លះដែលអ្នកចង់ឃើញដើម្បីវាយតម្លៃនៅក្នុងតំបន់ទីជម្រាល Claypit Brook? គូសធីកទាំងអស់ដែលអ្នកចង់ឃើញ។



- [ ] ដាំដើមឈើ
- [ ] តម្រងប្រអប់មែកឈើ
- [ ] ការស្តារចរន្តបង្ហូរទឹកឡើងវិញ
- [ ] សួនទឹកស្ងៀង និងជីរសាស្ត្រ
- [ ] បណ្តាញបង្ហូរទឹកជីរសាស្ត្រ
- [ ] កន្លែងស្តុកទឹកជំនន់ដើមទឹក
- [ ] យន្តការបទបញ្ជាត្រីមាត្រដ្ឋានទីជម្រាល មានដូចជាការបង្កើតសង្កាត់គ្រប់ទឹកស្ងៀង
- [ ]

Other

តើទីក្រុងគួរផ្តល់អាទិភាពដល់ដំណោះស្រាយបែបធម្មជាតិដោយប្រើកត្តាដូចខាងក្រោម យ៉ាងដូចម្តេច? សូមចាត់ថ្នាក់កត្តាទាំងនេះដោយរៀបចំការចាត់ទុកអាទិភាពខ្ពស់បំផុតនៅខាងលើនៃតារាង និងការចាត់ទុកអាទិភាពទាបបំផុតនៅខាងក្រោម។

អត្ថប្រយោជន៍ចំពោះយុត្តិធម៌បរិស្ថាន ឬប្រជាជនងាយរងគ្រោះក្នុងសង្គម

បរិមាណនៃការជ្រៀតចូលនៃទឹកភ្លៀងដែលបានផ្តល់ និងការធ្វើឲ្យប្រសើរនៃគុណភាពទឹក

បរិមាណនៃការកាត់បន្ថយទឹកជំនន់ដែលបានផ្តល់

ការកាត់បន្ថយនៃផលប៉ះពាល់កោះកម្តៅក្នុងទីក្រុង (ឧទាហរណ៍ ការកើនឡើងនៃការចុះកម្តៅ)

ហានិភ័យនៃការមិនចាត់វិធានការ

ចំណាយ

អត្ថប្រយោជន៍សម្រាប់ការផ្គត់ផ្គង់ទឹកសាធារណៈ និងការបញ្ចូលទឹកក្រោមដី

អត្ថប្រយោជន៍ក្នុងតំបន់

ផ្សេងទៀត (សូមបញ្ជាក់នៅក្នុងទម្រង់មតិយោបល់ខាងក្រោម)

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តើអ្នកចង់ទទួលបានព័ត៌មានអំពីហានិភ័យនៃការប្រែប្រួលអាកាសធាតុ និងគម្រោងភាពធន់នៅទីក្រុង Lowell យ៉ាងដូចម្តេច? គូសធីកទាំងអស់ដែលអ្នកចង់ឃើញ។

- [ ] តាមរយៈការប្រជុំតាមអនឡាញ
- [ ] វីដេអូដែលបានថតទុកមុន និងបានបង្ហោះលើអ៊ីនធឺណិត
- [ ] ការស្ទង់មតិតាមអនឡាញ
- [ ] ឯកសារ PDF អាចរកបានតាមអ៊ិនធឺណិត រួមមានសន្លឹកព្រឹត្តិបត្រព័ត៌មាន និងរបាយការណ៍ផ្សេងៗ
- [ ] ប្រព័ន្ធផ្សព្វផ្សាយដែលបានបោះពុម្ពចែកចាយ តាមរយៈអ៊ីមែល រួមមានសន្លឹកព្រឹត្តិបត្រព័ត៌មាន និងប័ណ្ណផ្សព្វផ្សាយ
- [ ] ព័ត៌មានត្រូវបានផ្សព្វផ្សាយលើទំព័រ ដែលមាននៅលើគេហទំព័រនៃទីក្រុង Lowell
- [ ] តាមរយៈបណ្តាញសង្គម រួមមាន Twitter និង Facebook
- [ ] សារអេឡិចត្រូនិចពីទីក្រុង
- [ ] តាមរយៈព្រឹត្តិបត្រព័ត៌មាន និងការប្រជុំរបស់ក្រុមក្នុងមូលដ្ឋាន និងអង្គការក្នុងតំបន់
- [ ] ព្រឹត្តិការណ៍ដោយផ្ទាល់ បន្ទាប់ពីទទួលការចាក់វ៉ាក់សាំង COVID-19 អាចរកបានយ៉ាងទូលំទូលាយ
- [ ]

Other

43

តើមានយោបល់ ឬសំណួរបន្ថែមដែលអ្នកចង់ចែករំលែកជាមួយក្រុមគម្រោងទេ?

44

សំណួរខាងក្រោមជាជម្រើសស្រេចចិត្តរបស់អ្នក។ ប៉ុន្តែ តាមរយៈការឆ្លើយសំណួរប្រជាសាស្ត្រទាំងនេះ អ្នកនឹងជួយយើងក្នុងការវាយតម្លៃ ប្រសិនបើការស្នងមតិរបស់យើងមានការចូលរួមយ៉ាងទូលំទូលាយ។ សូមជ្រើសរើសចម្លើយដែលត្រូវជាមួយអ្នក៖

- [ ] ខ្ញុំជួលអាជ្ញាតមិននៅ Lowell
- [ ] ខ្ញុំមានផ្ទះនៅ Lowell
- [ ] ខ្ញុំធ្វើការនៅ Lowell
- [ ] ខ្ញុំជាម្ចាស់អាជីវកម្មនៅ Lowell
- [ ] Other

45

សូមជ្រើសរើសសង្កាត់ដែលអ្នករស់នៅ ឬធ្វើការ៖

- [ ] Acre
- [ ] Back Central
- [ ] Belvidere
- [ ] Centralville
- [ ] Downtown
- [ ] Highlands
- [ ] Lower Belvidere
- [ ] Lower Highlands
- [ ] Pawtucketville
- [ ] Sacred Heart
- [ ] South Lowell

46

សូមជ្រើសរើសចន្លោះអាយុរបស់អ្នក

- ក្រោម 18 ឆ្នាំ
- 18-24
- 25-35
- 36-45
- 46-55
- 56-65
- 66-75
- លើសពី 75 ឆ្នាំ

47

តើអ្នកនឹងពណ៌នាខ្លួនអ្នកយ៉ាងដូចម្តេច?

- ជនជាតិស្បែកស
- ជនជាតិស្បែកខ្មៅ ឬអាហ្វ្រិក-អាមេរិចកាំង
- ជនជាតិអាមេរិចដើមកំណើតឥណ្ឌា ឬអាឡាស្កា
- ជនជាតិអាស៊ី
- ជនជាតិដើមកំណើតហាវ៉ៃ ឬអ្នកកោះប៉ាស៊ីហ្វិកផ្សេងទៀត
- កូនកាត់ច្រើនជាតិសាសន៍
- Other

48

តើអ្នកជាជនជាតិអេស្ប៉ាញ, ជនជាតិអាមេរិកឡាទីន, ឬដើមកំណើតអេស្ប៉ាញមែនទេ?

- ◯ បាទ/ចាស
- ◯ មិនមែនទេ

49

សូមអរគុណដែលបានបំពេញការស្ទង់មតិនេះ។ ប្រសិនបើអ្នកចាប់អារម្មណ៍ក្នុងការទទួលបានព័ត៌មានថ្មីៗទាក់ទងនឹងគំនិតផ្តួចផ្តើមអាកាសធាតុនៅក្នុងទីក្រុង Lowell, សូមវាយបញ្ចូលអ៊ីមែលរបស់អ្នកនៅខាងក្រោម។

Attachment B: Short Answer Responses

Tell us more about how climate hazards have impacted you or your community. Memories of climate hazards could include flooding near Claypit Brook, flooding from beaver dams, heat waves.	Are there any additional comments or questions that you would like to share with the project team?
I can't speak to a heat-related outing, but 4-5 years ago we lost power in the Tyler Park neighborhood for several days due to winter storm activity.	How do we prioritize the needed investment in mitigation? This work is important but must be balanced. How best to do that?
Around 2017, Lowell experienced an extreme heat wave that led the city to open cooling stations.	
Snow quickly melting (Christmas Day 2020) and causing my basment to flood	
5+	
In 2006 & 2007 floods damaged more than 70 homes in my neighborhood. Residents were forces to evacuate in the middle of the night and were relocated for up to a month after the flood.	
My backyard was completed flooded when we had the last major flooding	Claypit Brook is in my backyard, never seen anyone cleaning it out or doing anything to help it.
Climate change is a political term for natural cycles of weather. ie: precipitation, heat and cold extremes. Must are cycles associated with cycles of heat from the sun and very little has to do with co2 in the atmosphere. The dust bowl of the 30's and thousands of others are perfect examples. Did you know it snowed regularly in July and aug during the 1600's in America? So flooding is an issue in lowell and the obvious is that they have raised the level of the dam from 2' to over 10' high over the last 150 yrs. then the dopes at ferc allowed a change to boards that used to result in them destructed for a period during spring snow melt and rains. Now the river is held for profit at high levels yr round to make more money.	Yes. Why the liberal slant to a science problem? Want to stop flooding, LOWER THE GOD DARN BLADDER BOARDS DURING SPRING MELT SEASON. JEESH. and clean and increase the culverts for draining neighborhoods and use a one way flow valve at the end of clay pit brook as it enters river during a flood.
	We are new homeowners in Pawtucketville and were surprised when we got water in the basement this spring.
Lots of down trees in Clay Pit Brook, mostly due to high winds	
	Please coordinate outreach with local non-profits promoting climate change so the work of each other can be amplified
The street that my home is on doesn't flood but my basement does, with snow melt and run off, so the addition of impervious surfaces in Pawtucketville concern me.	
Beaver Brook area in pawtucketville and centralville. Pawtucketville wide area between claypit and the river.	I believe there is one sensor for the official height of the Merrimack and that is close to Bridge St. This is of no help to the claypit pawtucketville area. The power company MUST cooperate in this issue.
Flooding in the Lexington Ave, Malden St, Townsend Ave areas	
Technically, no climate hazards. However, there may be flooding near the Merrimack River and Clay Pit Brook in the spring due to heavy rains with deep snow cover over the northern Merrimack River basin. There may also be some flooding if a tropical storm brought heavy rains to the area. One should expect 90 degree heat or higher during the summer with a heat wave or two, so, do not think this is unusual.	Please note that climate change is a natural process (it has changed in the past, is changing now, and will change in the future). Increasing greenhouse gases may have an effect on the climate but this is not certain.
There have been days were there are 90 degree days for multiple days. As well as the other extreme, of extreme cold and snow. Both these events had cancelled or made school difficult when I'd still attended school. Hot days can not only be annoying but dangerous. Snow can also be dangerous since I live next to a road with an incline, so it might be tough to get out of the street.	I really hope the city really takes action on these issues, and not kick the can down the road. I know how these projects can often take years to manifest due to funding issues and just slow bureaucracy.

not climate hazard it is the operators of the dam that add and do not mitigate flooding and also when they stopped trapping beavers our problems are man amdes	
Heat waves are made worse by impervious pavement heat sinks and lack of street shade. Sewer overflow caused by intense rain storms. The problems of climate change resilience MUST NOT be restricted to one part of the city.	I ranked benefits to environmental justice somewhat low because, while I believe that some areas should be given priority due to economic factors, we all benefit from improvement in Lowell's environment. Just as has been said repeatedly about Covid-19, we are all in this together. While flood mitigation is important, heat relief and water quality should be given top priority. For instance, pergolas over driveways should be promoted to cut down on heat radiating. While the canals are a beautiful resource, the tree canopy is paltry near them. Must public parks aside from Shed and Fort Hill seem to focus on open space instead of shade. I confess that I do not know or understand all the mechanisms.
I am lucky to live up Totman with shade in the morning and evening hours. Plan on read watching what kid of tree to plant for shade at 12 noon if there is continuous heat waves in the next decade.	
Increased populations of harmful insects such as ticks are a menace!	

Lowell - Pawtucketville Citizens Council

Meeting June 7, 2021

Attendees

- Pawtucketville Citizens Council Members
- Katherine Moses, City of Lowell
- Christine Clancy, City of Lowell
- Bella Purdy, Weston & Sampson
- Steve Roy, Weston & Sampson

Notes

- Resident commented that they are concerned about the regulation of onsite storage. They mentioned that new development both in the neighborhood and regionally contributes to more impervious surface and greater stormwater flooding. They were concerned that storage is not adequate, or that when new development is in the floodplain it does not make a substantial impact.
- Resident commented that they would like to see more stringent regulatory requirements. Particularly, the wetlands ordinance could be update to include a larger buffer area along waterbodies of ~100'
- One resident suggested that an above ground pipe/culvert system be run along the riverbed and emptied below the falls. Christine/Steve mentioned that from a permitting perspective this would be infeasible due to inability to build continuous system along the waterbody and across many properties.
- Resident commented that backflow valves near his property are impactful and asked whether more of these systems could be installed by the Claypit Brook. Steve mentioned that due to elevation these would not be effective by the Brook. However, a pumping system could be considered/and necessary in the future.

Lowell Claypit Brook

Public Meeting June 16, 2021

Attendees

1. Katherine Moses, City of Lowell
2. Bella Purdy, Weston & Sampson
3. Steve Roy, Weston & Sampson
4. Amanda Kohn, Weston & Sampson
5. John Hamblet
6. Suzanne Coburn
7. Angelica Beato
8. Deb Forgione
9. Donald Doubleday
10. Jon Grossman
11. Louisa Varnum
12. Stephen Malagodi
13. Marty Hogan
14. Rodney Elliot
15. Michelle Rowden
16. IPhone

Notes

- Discussion on FEMA flood maps and new flood insurance policies
- Question on why Stockbridge Ave was prioritized –the culvert had already partially failed and that there is a steel plate over the portion that has deteriorated.
    - A lot of these upgrades should be completed together throughout the watershed to have the largest impact, including nature-based solutions. In addition, we discussed that you need to address flooding upstream and that the answer isn't always where its flooding. This came up when we gave the example of the improvements at the Wang School. Audience didn't realize storage would be possible there.
    - Many residents are curious about what will happen to their street/home.
- Fun fact: Water for Moxie was originally drawn from a spring behind the Wang school.
- Varnum Ave reforestation example in the PowerPoint is a toxic site. Brownfields can be repurposed for environmental benefits.
- DCR has tree planting grants
- Question on what data was used – we used downscaled data from IPCC that can be found on resilientma.org using the methodology in the Climate Resilient Design Standards and Guidelines
- Backflow valves briefly mentioned. There is one on Beaver Brook. Referenced conversation at PCC that this was not feasible
- Stream clean up requires balance – some sedimentation and tree down are natural. However, anthropogenic sedimentation and erosion can make conditions worse.
- Appeal to the city from a resident to be proactive: Flooding = lowers property values = lower tax values = less funding to do project

- There is a conservation restriction at Valley Farm. Maybe some work could be completed there. The Lowell Parks and Conservation Trust may also fund reforestation projects.

Additional Resources Provided to Attendees Post-Meeting

Massachusetts' clearinghouse of climate data: https://resilientma.org/

Climate Resilience Design Standards & Guidelines: resilientma.org/rmat_home/designstandards/

FEMA NFIP Risk Rating 2.0 and Flood Insurance: FEMA's new rate structure, AKA Risk Rating 2.0, will take effect as follows:

- Beginning on October 1, 2021, all new NFIP policies purchased will be rated under the new system.
- For all policies that renew on or after October 1, 2021 and on or before March 31, 2022, NFIP policyholders will have the option to be rated under the legacy system, or under Risk Rating 2.0.
- Beginning April 1, 2022, all NFIP policies (new or renewed) will be rated in the new system.
- Current policyholders will be notified thru their insurance carrier. A letter is anticipated to go out to all policyholders at least 6 months before they are due to renew to give plenty of time to get quotes from private insurers.
- Read more about this updated methodology here.
- 39% of participants will see a decrease in cost of flood insurance. 55% percent of policy holders could see up to a $20 per month increase or no changes at all. The remaining 6% of folks will see an increase greater than $20 per month.

MVP priorities nature-based solutions (NBS) and Low Impact Development (LID): view project examples and related resources on the MVP NBS Toolkit and the LID Center website

Stormwater Management on Brownfield Sites: view an EPA report on best practices, an EPA and HUD-funded practice guide, an EPA presentation on strategies, and a presentation on lessons learned from the Franklin Regional Council of Governments.

FEMA FIRM Updates: Lowell is in FEMA's Merrimack Valley watershed, which is indeed in a FEMA mapping study/ update at this time. Local officials have been involved through the regulatory mapping process/ meetings.

MVP Regional Coordinator: Michelle Rowden, Northeast Regional Coordinator, michelle.rowden@state.ma.us, 857-343-0097

City of Lowell – Sustainability Council

Lowell Sustainability Council Agenda
Thursday, January 7, 2021, 6:30 pm
Via Zoom Meeting:
https://lowellma.zoom.us/j/89546192078?pwd=MUI5UTBqRTNHd0hsVDFXQWt5SkowQT09
Or use the dial-in number (877) 853-5247 and input the following when prompted:
Meeting ID: 895 4619 2078
Passcode: 429950

I. Minutes for Approval
November 24, 2020 (Special Meeting) and December 3, 2020

II. MVP Program
Special Guest Katherine Moses

III. Sustainability Summit
Chair Mason

IV. Gas Modernization Project
Chair Mason, Member M. Hondros-McCarthy

V. Recommendation that the City explore all available options to fund and install solar panels on the roof of Lowell High School (Update)
Chair Mason

VI. Communication Subcommittee
Member Geer

VII. LSC Subcommittee Updates as Needed
a. Recycling Subcommittee (Member Geer)
b. Electric Vehicles (Member C. Hondros-McCarthy)
c. Bicycle/Pedestrian Mobility (Member Studwell)
d. Lowell High School (Chair Mason)
e. Road to 100/Community Choice Aggregation (Member M. Hondros-McCarthy)

VIII. Further Comments and Upcoming Events from Sustainability Council Members

IX. Adjournment

City of Lowell – Sustainability Council

Lowell Sustainability Council Agenda
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Or use the dial-in number (877) 853-5247 and input the following when prompted:
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Note: These minutes are not completed verbatim. Asterisks in front of items represent action items for the LSC or others present. This meeting took place virtually via videoconference during the Massachusetts State of Emergency due to the COVID-19 pandemic.

Members Present

- Jay R. Mason
- Jonathan Geer
- Cormac Hondros-McCarthy
- Mikaela Hondros-McCarthy
- Candace Lawrence
- Carolyn McCarthy
- Greg Studwell

Others Present

- Christopher Glenn Hayes, Department of Planning and Development
- Katherine Moses, Energy Manager, Department of Planning and Development

A quorum of the Board was present. The meeting was called to order at 6:36 pm.

I. Minutes for Approval

November 24, 2020 (Special Meeting) and December 3, 2020

Member Geer offers a comment on the second page of the recycling subcommittee update. He asks to strike "curb alert" for the term "community yard sale."

Member Geer motions to accept the minutes from October 24, 2020 and December 3, 2020. Chair Mason seconds. The motion passes unanimously.

II. MVP Program

Special Guest Katherine Moses

Chair Mason introduces K. Moses.

K. Moses shares presentation on what the city is doing in terms of municipal vulnerability preparedness.

City of Lowell – Sustainability Council

Lowell Sustainability Council Agenda

Thursday, January 7, 2021, 6:30 pm

Via Zoom Meeting:

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- MVP program has various goals, but overall is a proactive approach to adaptation strategies
- MVP program consists of two grants:
    - MVP Planning grant, after you complete all steps, you receive MVP designation
    - Lowell received planning grant, contracted with Weston & Sampson, and updated its Hazard Mitigation Plan along with getting MVP designation
    - Action Grant is step two with MVP designation to implement priority actions
- To determine top hazards in Lowell, Weston & Sampson had interviews with area experts, analyzed climate data (resilientma.org)
    - Identified four hazards (extreme winter weather, wind and microbursts, flooding, extreme temperatures)
- Other analysis was discussed such as temperature changes, precipitation changes, extreme winter weather events, and impacts of extreme weather

Member M. Hondros-McCarthy asked whether the data was specific to Lowell or Massachusetts.

K. Moses stated that the data is for all of Massachusetts, as they don't have Lowell-specific data, and noted that at the bottom of each slide are sources, and additional information is in report. K. Moses continued the presentation:

- The MVP Action Grant is based on the high priority actions identified in the planning grant,
- Among other actions the MVP Action Grant can fund are assessment, outreach, management, nature based solutions, retrofits, and redesigns
- The City was awarded a $138,000 to address a high priority vulnerability through the MPV Planning Process: Clay Pit Brook Climate Relilience Stormwater Management Capital Improvement Plan
- Flooding at Clay Pit Brook Identified also by community members as an issue, with specific tasks including:
    - Model current and future climate conditions,
    - Assess flood areas and culverts,
    - Assess the complete drainage system,
    - Assess flood storage and culvert design alternatives,
    - Identify opportunities for green infrastructure and nature-based solutions, and

City of Lowell – Sustainability Council

Lowell Sustainability Council Agenda

Thursday, January 7, 2021, 6:30 pm

Via Zoom Meeting:

https://lowellma.zoom.us/j/89546192078?pwd=MUI5UTBqRTNHd0hsVDFXQWt5SkowQT09

Or use the dial-in number (877) 853-5247 and input the following when prompted:

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- Identify/prioritize projects to mitigate flooding risks in the Claypit Brook Watershed
- The LSC could help via:
  - Learn more by visiting our project webpage tinyurl.com/LowellMVP
  - Attend a virtual outreach meeting (dates TBD)
  - Help us promote the project by sharing on Facebook, Twitter, and other avenues with the hashtag #ResilientLowell

Member C. Hondros-McCarthy asks what would we expect to see implemented in the City of Lowell?

K. Moses stated that a number of tasks were identified which covered a gamut of things such as flooding-based actions, addressing with matching grants, energy types of things, things like making sure vulnerable populations taken care of in extreme events, greening the gateways initiative to create more tree coverage, a lot of individualized action items. The MVP Plan provides a lot of tools and grants. In addition, the city must report on it on an annual basis to remain eligible for MCP Action grants.

Member C. Hondros-McCarthy asks whether the identified tasks are all research-based action or physical in nature. She clarified the question: will anything be built through these plans?

K. Moses states the tasks include a little bit of both, and some of actions identified are planning-based, others are one-off capital projects.

Member C. Hondros-McCarthy asks whether this going to be tied at all with the master plan for Lowell.

K. Moses answers that she doesn't know this specifically.

Member C. Hondros-McCarthy asks whether K. Moses knows if there is going to be an updated master plan for Lowell.

C. Hayes states that there was an intent to start master planning in 2020, but the pandemic and shifting staff priorities changed that intent. He states that there is some discussion of starting master planning after the pandemic, but that it would be at direction of city manager.

Chair Mason asks if a planning grant can be used for a master plan.

K. Moses states that a city may only get one planning grant, so it could not be used for a master plan. She states a city can get multiple action grants.

Member M. Hondros-McCarthy states that he is very excited. He asks if any money has been set aside to provide relief to people in low-income housing if, for example, a flood displaces someone.

K. Moses states that was discussed during the plan. For the action plan, it's just planning, there is not money reserved for those actions. She states the City will be working with partners in the community such as housing and homelessness that can help those who are vulnerable.

Member M. Hondros-McCarthy asks whether there are any updates with the LEAP program, put in for approval with DPU.

K Moses states there are no updates and that they have started planning for the next 3 year plan, which means it is unlikely to advance. She states the City has been working closely with National Grid to find ways to take advantage of the programs that are there and connect people who are harder to reach with the grants.

III. Sustainability Summit

Chair Mason

Chair Mason states that the Summit planning committee decided on a theme of impacts of COVID-19 on climate change, and committee members did research on topics related to this. The next step is to present findings, but there is not time. The goal is to use the knowledge gained and talk about in the meeting with what we are trying to accomplish and what those steps are going to be. The next steps on the particular schedule are to fully define what the summit goals are and establish an agenda.

Chair Mason continues, from an initial review of the materials, there is a huge amount of information available. He states he believes he would like to research COVID, climate change, and the economic implications of what that has done to our means of social structure, political structure, and economic structure. He states he will pare the multipage document that was shared down and ask others to do the same.

J. Geer states he agrees, that some general, overarching themes that are going on under COVID regarding sustainability and climate change will appear in the research. He continues that he quickly read the material and while optimistic that COVID was going to refocus a lot of people on nature and environment, he was also disheartened that with lack of resources and tight budget, a lot of the climate change steps we might take are on hold. He discusses

gaps whereby more of the rainforest is being used for grazing, deforestation and that those types of themes would be helpful to percolate up.

Chair Mason suggests focusing on economics to tell a cogent story people will relate to and find supported.

Member M. Hodnros-McCarthy states that something that may be more of a bright spot would be the recent legislation the state of Massachusetts has approved, and that she thinks COVID led to Biden being elected, so there's a little more hope under that administration.

There is further discussion on national sustainability issues.

There is discussion of schedule of the next Summit subcommittee meeting, with consensus on Tuesday, 1/12, 7:00 pm. C. Hayes will set up a public meeting.

Member C. McCarthy asks that while some members will find focus on pathways out of COVID, if that's something that we're seriously looking to wrap into the theme, is there someone who is interested in gathering more resources on that?

Member Mason states that he thinks it is timely, as it just came out of legislature, and the subcommittee can talk about it, as it could lend a nice focus to the work we're doing and the message we're doing.

C. Hayes notes the LSC should consider planning a virtual event if they're targeting spring, as most people are assuming physical gathering won't occur until late summer at the earliest.

IV. Gas Modernization Project

Chair Mason, Member M. Hondros-McCarthy

Member M. Hondros-McCarthy starts the agenda item, but notes she didn't attend the Conservation Commission meeting and invites other members to share what happened and tone of meeting. She states she read the materials and that there will be a follow-up January 13th. She states National Grid answered all the LSC questions.

Member C. Hondros-McCarthy reports the group at the Conservation Commission was very insistent. The attendees noticed National Grid was not giving specific answers and asked further questions. C. Hondros-McCarthy reports that toward the end, the Conservation Commission asked National Grid to answer these questions prior to the next meeting, and it was somewhat a contingency.

Member C. Hondros-McCarthy continues that the main question he was concerned with was 'why do they have to replace the whole pipeline if there is something out there that would work for inspecting the pipes.' He states that their response was valid in that, they don't want to use the pig, because the required number of sensors causes that to be elongated, increases risk that it gets stuck.

Member C. Hondros-McCarthy continues that he doesn't know that we have, how much we can do, following this response, which is kind of decent, to say the LSC doesn't believe your risk assessment.

The LSC discusses concerns related to the lifespan of the pipeline and investment that represents compared to the five year plan to go to 100% renewable energy.

Chair Mason asks whether we write a letter of disagreement.

Member M. Hondros-McCarthy states that the only body that can stop it is the Conservation Commission. He states the City Council can't stop it.

Member C. Hondros-McCarthy states that the Conservation Commission has a pretty good grasp of environmental impact of clearing wetlands. She states she believes the only action available is to go to the meeting, listen to the meeting, and potentially have comments National Grid responds with.

C. Hayes notes the two major charges of the LSC are recommendations to City Council and the City Administration and communication and education to the public.

Member C. Hondros-McCarthy states he can post the meeting on Facebook.

There is additional discussion on possible LSC actions and impacts upon wetlands.

The LSC decides by consensus to send the National Grid answers to former member Andy Kollar. Chair Mason reports he already did.

V. Recommendation that the City explore all available options to fund and install solar panels on the roof of Lowell High School (Update)

Chair Mason

Chair Mason reports he spoke with the City Manager's office after the council referred the recommendation to that office, and that the next step is to meet with the Manager to go over the LSC items and issues. He states that if anyone would like to join, it hasn't been set up yet. He states that the LSC has had a meeting with the Manager before and that this will be a

good opportunity to reinvigorate our relationship with the manager, get answers to the status of the high school, and get something a little more productive going.

Member Geer asks whether Chair Mason has any sense of appetite to move on more solar for the High School.

Chair Mason states he has been trying to promote, champion, and continue the process for a year and has been trying to set up a meeting with the City Manager during that time.

VI. Communication Subcommittee

Member Geer

Member Geer states the need to establish a subcommittee that would develop an approach, getting the word out about the council, word about issues the LSC is interested in. He states that if we have several members that would be much like other subcommittees that would have notice of meeting, agendas, as well. He states he would be able to organize but need more help.

Member C. Hondros-McCarthy states he has been posting on Facebook and volunteers to be in the initial meeting. Members McCarthy and Lawrence volunteer. The is discussion of scheduling with consensus on Tuesday, January 19, 7:00 pm.

Chair Mason states there is a terrific set of folders that former member S. Pedersen put together, and it might be a good start to look through there.

VII. LSC Subcommittee Updates as Needed

a. *Recycling Subcommittee (Member Geer)*
   Met on December 7 and on January 4, meeting monthly again. Couple updates: We've been working on education materials to share with LPS, some have bene sent out by solid waste and recycling office. Got a report on the metrics of the recycling mobile app, gets a lot of use, work to try to expand it. When to put out barrels, that was encouraging. Solid waste is making goo duse of UML intern, intern for last 3 semesters, doing good work at the direction of the staff. It's a challenge to get a whole lot done during COVID we hear from the office, making best effort, more trash, more recycling, people stay at home generating more of each, that's a challenge, and there's less enforcement of the ordinances. Next meeting is Feb 1.

b. *Electric Vehicles (Member C. Hondros-McCarthy)*
   Call in with LRTA to get an update on their EV buses. Aside from that, no updates.

City of Lowell – Sustainability Council

Lowell Sustainability Council Agenda
Thursday, January 7, 2021, 6:30 pm
Via Zoom Meeting:
https://lowellma.zoom.us/j/89546192078?pwd=MUI5UTBqRTNHd0hsVDFXQWt5SkowQT09
Or use the dial-in number (877) 853-5247 and input the following when prompted:
Meeting ID: 895 4619 2078
Passcode: 429950

c. Bicycle/Pedestrian Mobility (Member Studwell)
No updates, but should be next meeting.

d. Lowell High School (Chair Mason)
No updates.

Member Geer asks if the Building Subcommitte is still meeting.

Chair Mason states the High School Building committee is meeting regularly. Last meeting approved construction docs, presented to MSBA, approved completion and passage of documents. The sustainability subcommittee to the committee meets once a year, with very broad based updates.

e. Road to 100/Community Choice Aggregation (Member M. Hondros-McCarthy)
No updates.

VIII. Further Comments and Upcoming Events from Sustainability Council Members

No comments are voiced by Sustainability Council Members.

There is discussion to include summit planning meeting and communication subcommittee meeting updates in the next agenda.

IX. Adjournment

Member Geer motions to adjourn the meeting. Member Cormac seconds. The motion passes unanimously. The meeting is adjourned at 8:02 pm.

City of Lowell – Sustainability Council

Lowell Sustainability Council Agenda
Thursday, June 24, 2021, 6:30 pm
Via Zoom Meeting:
https://lowellma.zoom.us/j/82701670355
Or use the dial-in number (877) 853-5247 and input the following when prompted:
Meeting ID: 827 0167 0355
Passcode: N/A

I. Introduction

II. Minutes for Approval
May 27, 2021

III. MVP Clay Pit Brook Climate Resiliency Stormwater Management Capital Improvement Plan
Katherine Moses

IV. LSC Subcommittee Updates
a. Communication Subcommittee (Member Geer)
b. Recycling Subcommittee (Member Geer)
c. Electric Vehicles (Member C. Hondros-McCarthy)
d. Bicycle/Pedestrian Mobility (Member Studwell)
e. Lowell High School (Chair Mason)
f. Road to 100/Community Choice Aggregation (Member M. Hondros-McCarthy)

V. New Business and Upcoming Events from Sustainability Council Members

***VI.* Community Choice Aggregation**
M. Hondros-McCarthy

VII. Proposed Recommendation: Inventory and Mitigation of Heat Islands
Chair Mason
350 MA

***VIII.* Lowell Sustainability Summit**
Chair Mason

***IX.* Net Zero Code Initiative**
Chair Mason

X. Adjournment

Note: official minutes for this meeting were not yet approved and posted at the end of the grant period (June 30).

Appendix C

CIP Materials

Culvert Ranking

Note: Does not include Varnum Ave and Marbles Brook as this is not within the Claypit Brook Watershed

Location	Culvert Description	Improvement	Average	Condition	High Level Hydraulic Adequacy	Price	Project Size (Length, Ft)
Varnum Ave	5' diameter and 30" diameter lined CMPs with grates. 69" and 76"to parking lot, respectively.	Headwall Repair	1.5	2	1	$10,000	340 +/-
Stockbridge Ave	Two 56" diameter CMPs. 77" to roadway.	Replace	1.9	1	2.8	$534,000	50 ft +/-
Lexington Ave	64" diameter and 36" diameter CMPs. 84" and 73" to roadway, respectively.	Replace	2.0	2	2	$500,000	50 +/-
Embankment at end of Avalon St	Two 48" diameter CMPs. 60" to roadway.	Removal	2.2	3	1.4	$20,000	50 ft +/-
Malden Ave	60" diameter and 36" diameter CMPs. 79" and 70" to roadway, respectively.	Replace	2.2	1	3.4	$500,000	60 ft +/-
Magnolia St	Two 52" diameter CMPs. 84" to roadway.	Additional Assessment	2.3	2	2.6	$500,000	50 ft +/-
Delaware Ave	Two 60" diameter CMPs. 78" to roadway.	Additional Assessment	2.7	2	3.4	$500,000	50 ft +/-
Townsend Ave	30" diameter and 48" diameter CMPs. 44" and 54" to roadway, respectively.	Replace	2.9	2	3.8	$350,000	50 +/-
Under neighborhood near Elizia Dr	36" RCP culvert beneath neighborhood at Elizia Cir and Eleanor Dr.	Headwall Repair	3.0	3	N/A	$50,000	515 ft +/-
Bedford Ave	40" diameter and 66" diameter CMPs. 65" and 90" to roadway, respectively.	Stream Improvements		N/A	2.8	See Streamm Assessment	45 ft +/-
Dunbar Ave	Two 46" diameter CMPs. 119" to roadway.	Stream Improvements		N/A	1.6	See Streamm Assessment	45 ft +/-
Pawtucket Blvd	4' stone masonry box culvert and 54" diameter CMP. 96" and 114" to roadway, respectively.	None at this time		N/A	2.2	N/A	95 ft +/-

5-year Capital Improvement Plan

Year	Category	Action	Cost
1	Green Infrastructure	Detention - Varnum Ave (Subcatchment: CPB8)	$150,000
1	Green Infrastructure	Reforestation (Subcatchment: CPB17)	$150,000
1	Flood Storage	Scenario 3	$30,000
1	Culvert Project	Varnum Ave	$10,000
1	Culvert Project	Stockbridge Ave	$534,000
1	Culvert Project	Lexington Ave	$500,000
Year 1 Total			$1,374,000
2	Green Infrastructure	Detention Basin - Newbridge Road (Subcatchment: CPB17)	$150,000
2	Green Infrastructure	Floodable Field - Gumpus Road (Subcatchment: CPB17)	$150,000
2	Green Infrastructure	Swale - Retirement Community (Sub-catchment: CPB18)	$150,000
2	Green Infrastructure	Swale - Varnum Ave (Sub-catchment: CPB18)	$100,000
2	Green Infrastructure	Detention Basin - Dr. An Wang Middle School (Subcatchment: CPB17)	$150,000
2	Culvert Project	Embankment at end of Avalon St	$20,000
2	Culvert Project	Malden Ave	$500,000
Year 2 Total			$1,220,000
3	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11b)	$100,000
3	Green Infrastructure	Swale - Old Ferry Road (Subcatchement: CPB18)	$100,000
3	Green Infrastructure	Swale - Meadowview Dr (Subcatchment: CPB8)	$30,000
3	Green Infrastructure	Swale - Jennifer Road (Subcatchment: CPB8)	$20,000
3	Green Infrastructure	Swale - Meadowview Drive (Subcatchment: CPB8)	$20,000
3	Green Infrastructure	Swale - Meadowview Drive (Subcatchment: CPB8)	$20,000
3	Green Infrastructure	Swale - Meadowview Dr (Subcatchment: CPB8)	$20,000
3	Green Infrastructure	Swale - Lexington Ave (Subcatchment: CPB8)	$100,000
3	Flood Storage	Scenario 1	$20,000
3	Flood Storage	Scenario 2	$20,000
3	Culvert Project	Magnolia St	$500,000
Year 3 Total			$950,000
4	Green Infrastructure	Swale - Barbara Terrace (Subcatchment: CPB11b)	$100,000
4	Green Infrastructure	Swale - Old Ferry Road (Subcatchment: CPB18)	$100,000
4	Green Infrastructure	Swale -Fowler Road (Subcatchment: CPB18)	$50,000
4	Green Infrastructure	Swale - Robin Lane (Subcatchment: CPB17)	$50,000

4	Green Infrastructure	Swale - Varnum Road @ Totman Road (Subcatchment: CPB7)	$100,000
4	Green Infrastructure	Depressed Planter - Dr. An Wang Middle School (Subcatchment: CPB17)	$100,000
4	Green Infrastructure	Swale / Detention Basin - Trotting Park Road (Subcatchment: CPB5)	$50,000
4	Culvert Project	Delaware Ave	$500,000
4	Culvert Project	Townsend Ave	$350,000
4	Culvert Project	Under neighborhood near Elizia Dr	$50,000
Year 4 Total			$1,450,000
5	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11)	$30,000
5	Green Infrastructure	Swale - Acropolis Road (Subcatchment: CPB17)	$30,000
5	Green Infrastructure	Swale - Acropolis Road (Subcatchment: CPB17)	$30,000
5	Green Infrastructure	Swale - Varnam @ Retirement Community (Subcatchment: CPB18)	$30,000
5	Green Infrastructure	Swale / Detention Basin 2 - Trotting Park Road (Subcatchment: CPB5)	$20,000
5	Green Infrastructure	Swale Fowler Road (Subcatchment: CPB18)	$20,000
5	Green Infrastructure	Swale - Anson St (Subcatchment: CPB5)	$150,000
5	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11)	$30,000
5	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11)	$20,000
5	Green Infrastructure	Swale - Ursula St (Subcatchment: CPB17)	$20,000
5	Green Infrastructure	Swale - Totman Road (Subcatchment: CPB17)	$20,000
5	Green Infrastructure	Porous Pavement - Dr. An Wang Middle School (Subcatchment: CPB17)	$150,000
5	Green Infrastructure	Swale - Cidalia Dr & Eleanor Dr (Subcatchment: CPB6)	$50,000
5	Green Infrastructure	Swales- Jennifer Road @ Bedford Ave (Subcatchment:CPB10)	$30,000
5	Stream Improvements		$486,000
Year 5 Total			$1,116,000
Total Costs 5 Year CIP			**$6,110,000**

15-year Capital Improvement Plan

Year	Category	Action	Cost
1	Culvert Project	Varnum Ave	$10,000
1	Culvert Project	Stockbridge Ave	$534,000
Year 1 Total			$544,000
2	Green Infrastructure	Detention - Varnum Ave (Subcatchment: CPB8)	$150,000
2	Green Infrastructure	UHI - Increase Canopy (Subcatchment: CPB17)	$150,000
2	Flood Storage	Scenario 3	$30,000
Year 2 Total			$330,000
3	Culvert Project	Lexington Ave	$500,000
Year 3 Total			$500,000
4	Green Infrastructure	Detention Basin - Newbridge Road (Subcatchment:CPB17)	$150,000
4	Green Infrastructure	Floodable Field - Gumpus Road (Subcatchment: CPB17)	$150,000
4	Flood Storage	Scenario 1	$20,000
Year 4 Total			$320,000
5	Culvert Project	Embankment at end of Avalon St	$20,000
5	Culvert Project	Malden Ave	$500,000
Year 5 Total			$520,000
6	Green Infrastructure	Swale - Retirement Community (Subcatchment: CPB18)	$150,000
6	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB18)	$100,000
6	Green Infrastructure	Detention Basin - Dr. An Wang Middle School (Subcatchment: CPB17)	$150,000
6	Flood Storage	Scenario 2	$20,000
Year 6 Total			$420,000
7	Culvert Project	Magnolia St	$500,000
Year 7 Total			$500,000
8	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11b)	$100,000
8	Green Infrastructure	Swale - Old Ferry Road (Subcatchment: CPB18)	$100,000
8	Green Infrastructure	Swale - Meadowview Dr (Subcatchment: CPB8)	$30,000
8	Green Infrastructure	Swale - Jennifer Road (Subcatchment: CPB8)	$20,000
8	Green Infrastructure	Swale - Meadowview Drive (Subcatchment: CPB8)	$20,000
8	Green Infrastructure	Swale - Meadowview Drive (Subcatchment: CPB8)	$20,000
8	Green Infrastructure	Swale - Meadowview Dr (Subcatchment: CPB8)	$20,000
Year 8 Total			$310,000
9	Culvert Project	Delaware Ave	$500,000
Year 9 Total			$500,000

10	Green Infrastructure	Swale - Lexington Ave (Subcatchment: CPB8)	100,00
10	Green Infrastructure	Swale - Barbara Terrace (Subcatchment: CPB11b)	100,00
10	Green Infrastructure	Swale - Old Ferry Road (Subcatchment: CPB18)	100,00
Year 10 Total			$300,000
11	Culvert Project	Townsend Avenue	$350,000
Year 11 Total			$350,000
12	Green Infrastructure	Swale -Fowler Road (Subcatchment: CPB18)	$50,000
12	Green Infrastructure	Swale - Robin Lane (Subcatchment: CPB17)	$50,000
12	Green Infrastructure	Swale - Varnum Road @ Totman Road (Subcatchment: CPB7)	$100,000
12	Green Infrastructure	Depressed Planter - Dr. An Wang Middle School (Subcatchment: CPB17)	$100,000
Year 12 Total			$300,000
13	Green Infrastructure	Swale / Detention Basin - Trotting Park Road (Subcatchment: CPB5)	$50,000
13	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11)	$30,000
13	Green Infrastructure	Swale - Acropolis Road (Subcatchment: CPB17)	$30,000
13	Green Infrastructure	Swale - Acropolis Road (Subcatchment: CPB17)	$30,000
13	Green Infrastructure	Swale - Varnam @ Retirement Community (Subcatchment: CPB18)	$30,000
13	Green Infrastructure	Swale / Detention Basin 2 - Trotting Park Road (Subcatchment: CPB5)	$20,000
13	Green Infrastructure	Swale Fowler Road (Subcatchment: CPB18)	$20,000
13	Green Infrastructure	Swale - Anson St (Subcatchment: CPB5)	$150,000
Year 13 Total			$360,000
14	Stream Improvements		$486,000
Year 14 Total			$486,000
15	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11)	$30,000
15	Green Infrastructure	Swale - Varnum Ave (Subcatchment: CPB11)	$20,000
15	Green Infrastructure	Swale - Ursula St (Subcatchment: CPB11b)	$20,000
15	Green Infrastructure	Swale - Totman Road (Subcatchment:CPB17)	$20,000
15	Green Infrastructure	Porous Pavement - Dr. An Wang Middle School (Subcatchment:CPB17)	$150,000

15	Green Infrastructure	Swale - Cidalia Dr & Eleanor Dr (Subcatchment: CPB6)	$50,000
15	Green Infrastructure	Swales- Jennifer Road @ Bedford Ave (Subcatchment: CPB10)	$30,000
15	Culvert Project	Under neighborhood near Elizia Dr	$50,000
Year 15 Total			$370,000

Appendix D

Stockbridge Avenue Culvert Materials

ALTERNATIVE ANALYSIS

The two existing 5.25' rise x 7.25' span elliptical culverts on Stockbridge Avenue have been selected for replacement due to corrosion below the flow line, to improve stream continuity, and to reduce flooding of Claypit Brook in the area surrounding Stockbridge Ave. The existing culverts have a combined maximum outflow capacity of 90.27 cubic feet. Resizing of the culverts is necessary to meet the increased demand in flow from increased number and severity of stormwater events brought on by climate change. Weston and Sampson conducted a hydraulic analysis, and it was found that the Claypit Brook showed a risk of overtopping Stockbridge Ave., flooding the road during a projected future 100-year storm event. Though the risk of flooding at the road is low the existing culverts serve as a bottle neck that creates ponding above and below the culvert location. Resizing the culverts allows for better management of storm flows and the chance to alleviate upstream and downstream ponding. In addition to resizing the culverts this project presents an opportunity to better meet the standards of the Massachusetts Stream Crossing Standards and provide a culvert that allows more natural and safe passage of species that utilize the Claypit Brook waterway.

Culvert sizing information is provided below. Please note that due to site restrictions noted below the recommended sizing per the Massachusetts Stream Crossing Standards have been met for a replacement crossing, but not for the criteria stipulated for a new crossing. Because of this, a size was selected to maximize the culvert size (for capacity and fish/wildlife passage) while allowing constructability within the site restrictions. For these reasons, an alternative analysis on culvert size was not performed, as the maximum culvert size was selected that would both work within the site constraints and meet the Stream Crossing Standards for sizing to the maximum extent possible. An alternative analysis on culvert types is presented later in this section.

1.1 Culvert Rise (Height)

The approximate distance between natural channel bottom (approximate elevation 88.5') and top of roadway (approximate elevation 95.9') is ~7.4'. This distance limits the rise for the proposed culvert sizing. Factoring in roadway subbase (~12 to 18-inches) and pavement thicknesses (5-inches), concrete culvert ceiling thickness (~8-inches), roadway and shoulder slopes for drainage and any proposed concrete culvert ceiling thickness, result in a maximum rise opening of 4.5-feet.

1.2 Culvert Span (Width)

Per the stream crossing standards, the optimal span for a new crossing should be 1.2 times the bankfull width of the stream/river with an openness greater than 0.82-feet. Areas upstream and downstream displaying a ponding/wetland type characterization, making a bankfull width difficult to determine and/or indeterminate. Because of this, the USGS simple regression equation for estimating bank full width in Massachusetts's streams was utilized (Bankfull width (ft) = 15.0418 [Drainage area (mi^2)]$^{0.4038}$, See excerpts from USGS document in **Appendix A**).

Using the bankfull width equation above with a drainage area of approximately 2.08 mi^2 yields an estimated bankfull width of approximately 20.2-feet. To meet the standard for a new stream crossing, the span would be just over 24-feet (24.3-feet). While a culvert of this size would allow for increased flow and wildlife passage, constructability of a culvert this size is problematic and is not appropriate for this replacement culvert.

In addition, a culvert of this size would also make the proposed culvert cross sectional area much larger than the two existing elliptical culverts. Increasing the existing culverts to this size could cause issues at both the downstream (significant additional flows during large storm events inundating downstream crossings) and the upstream (potential to drain and reduce the upstream wetland areas) by allowing significantly increased flows to pass. For replacement culverts, the stream crossing standards require this to be taken into consideration when determining sizing.

Based on hydrologic modeling and layout alternatives at the site, a 14-foot-wide culvert is the largest recommended size that would increase flow capacity and minimize any additional issues with increasing the size of the new culverts. In addition, Massachusetts Department of Transportation (MassDOT) classifies a bridge as anything over a 10-foot span. Once a culvert exceeds this span, MassDOT review and permitting is needed on the structure which may require additional roadway/area improvements. It should be noted that the culvert sizes chosen will require additional MassDOT review and permitting.

The larger effective width of the new culvert will result in lower flow velocity. The new culvert will also have openness greater than the original culverts. The lower flow velocities and increased openness should allow for better passage of fish and wildlife.

1.3 Culvert Type Alternative Analysis and Recommendation

The reviewed culvert types are as follows:

Three-Sided Concrete Box or Arch Culvert:
This culvert consists of a bottomless culvert with concrete walls and ceiling, for the box culvert, or a concrete arch that spans the culvert width. These types of culverts are beneficial due to the longer life span of concrete (vs. other materials), ease of installation for precast sections, and most importantly allows construction with limited river-bed disturbance. Disturbance would largely be limited to the footing areas at the bottom of the walls, which are required for subsurface structural/foundation support. There are increased structural requirements and added cost of construction for concrete footings required with a three-sided culvert that should be considered.

Concrete Box Culvert:
This culvert is like the three-sided version, but with a concrete bottom. The difference being that there is additional disturbance to the riverbed due to the excavation needed for the culvert bottom. The main advantage over the three-sided culvert, is the box is typically more structurally sound, and allows for a better foundation than with just footings, especially in poor subsurface soils.

We did not review/analyze metal arch types as the longevity is typically shorter than a concrete structure. While the actual structure cost may be initially less, the continued traffic on Stockbridge Ave. would reduce the lifespan of the metal culverts over time much faster than the box culverts.

Similarly, a full bridge span/crossing was not reviewed. These structures typically require longer closure times, tend to be costlier and as the selected span (14-feet) is not excessive for a precast culvert, this type of crossing is not recommended.

Recommended Culvert Type:

Though a bottomless bridge would provide natural flood and minimize disturbance to the stream, it is also the most labor and cost intensive. Since both existing elliptical culverts will need to be completely removed there will already be disturbance to the stream bed and therefore it would not create more disturbance brought on with the installation of a box culvert. It is recommended that two 7'W x 4.4'H precast concrete box culverts be installed (with applicable up- and downstream T-walls) because they will be structurally sound, allow for a better foundation, and should prevent scour and loss of soil around the floors/walls during high flow events. The culverts should be embedded in the soil and have a 24" bed of 3" river stone placed throughout the culvert as well as at the entrance and exit opening. The maximum outflow capacity of the culverts will increase from 90.27 cubic feet per second to 180.95 cubic feet per second. The Stockbridge Ave. will have a reduced risk of flooding over the road, but will reduce the more problematic ponding that is occurring both upstream and downstream of Stockbridge Ave. This is the best solution to meet the requirements and constraints of the selected site.

APPENDIX A

EXCERPTS FROM USGS

Table 6. Statistical summary of simple and multiple regression equations for estimating bankfull stream width, mean depth, cross-sectional area, and discharge for streams in and near Massachusetts.

[n, number; R^2, coefficient of determination; S_e, standard error of the estimate; S_p, standard error of the prediction; ft, foot; mi^2, square miles; ft^2, square foot; ft^3/s, cubic foot per second; log, base-10 logarithm; %, percent]

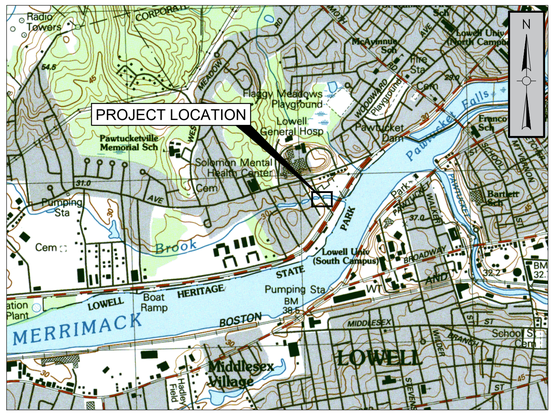
Equation number	Equation	n	R^2	Adjusted R^2	Predicted R^2	S_e (log)	S_e (%)	S_p (log)	S_p (%)
	Simple regression equation								
8	Bankfull width (ft) = 15.0418 [Drainage area (mi^2)]$^{0.4038}$	33	0.877	0.873	0.8635	0.0903	21.02	0.0950	22.14
9	Bankfull mean depth (ft) = 0.9502 [Drainage area (mi^2)]$^{0.2960}$	33	0.820	0.814	0.7995	0.0826	19.19	0.0873	20.30
10	Bankfull cross-sectional area (ft^2) = 14.1156 [Drainage area (mi^2)]$^{0.7026}$	33	0.911	0.908	0.9028	0.1308	30.81	0.1369	32.31
11	Bankfull discharge (ft^3/s) = 37.1364 [Drainage area (mi^2)]$^{0.7996}$	33	0.770	0.762	0.7428	0.2608	65.89	0.2757	70.43
	Multiple regression equation								
12	Bankfull width (ft) = 10.6640 [Drainage area (mi^2)]$^{0.3935}$ [Mean basin slope (%)]$^{0.1751}$	33	0.900	0.894	0.8780	0.0825	19.17	0.0913	21.26
13	Bankfull mean depth (ft) = 0.7295 [Drainage area (mi^2)]$^{0.2880}$ [Mean basin slope (%)]$^{0.1346}$	33	0.845	0.834	0.8159	0.0781	18.13	0.0850	19.76
14	Bankfull cross-sectional area (ft^2) = 7.6711 [Drainage area (mi^2)]$^{0.6842}$ [Mean basin slope (%)]$^{0.3105}$	33	0.937	0.932	0.9320	0.1123	26.30	0.1234	29.00
15	Bankfull discharge (ft^3/s) = 8.2490 [Drainage area (mi^2)]$^{0.7545}$ [Mean basin slope (%)]$^{0.7659}$	33	0.871	0.862	0.8366	0.1986	48.23	0.2234	55.02

CULVERT REPLACEMENT

STOCKBRIDGE AVENUE AT CLAYPIT BROOK
LOWELL, MASSACHUSETTS

Weston & Sampson

Weston & Sampson Engineers, Inc.
55 Walkers Brook Drive, Suite 100
Reading, MA 01867
978.532.1900 800.SAMPSON
www.westonandsampson.com



LOCUS MAP
NOT TO SCALE

DRAWING INDEX	
SHEET	TITLE
G000	COVER AND DRAWING INDEX
G001	ABBREVIATIONS, NOTES AND LEGEND
C100	EXISTING CONDITIONS PLAN
C101	SITE PREPARATION & EROSION AND SEDIMENT CONTROL PLAN
C102	PROPOSED CONDITIONS SITE PLAN
C103	CULVERT PROFILE
C501	CONSTRUCTION DETAILS I

05/12/2021

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811 Know what's below. Call before you dig.

GENERAL NOTES

1. TOPOGRAPHICAL INFORMATION BASED UPON A FIELD SURVEY CONDUCTED BY WESTON & SAMPSON SURVEYORS IN MARCH, 2021.
2. ALL BIDDERS ARE REQUIRED TO INSPECT THE PROJECT SITE IN ITS ENTIRETY PRIOR TO SUBMITTING THEIR BID, AND BECOME FAMILIAR WITH ALL CONDITIONS AS THEY MAY AFFECT THEIR BID. CONTRACTOR AND SUB-CONTRACTOR SHALL BE FAMILIAR WITH ALL DRAWINGS AND SPECIFICATIONS PRIOR TO COMMENCING THE CONSTRUCTION.
3. LOCATIONS OF ANY UTILITIES SHOWN ON THESE PLANS ARE APPROXIMATE ONLY. CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFYING THE LOCATION OF SUCH UTILITIES, PROTECTING ALL EXISTING UTILITIES AND REPAIRING ANY DAMAGE DONE DURING CONSTRUCTION. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL ON-SITE COORDINATION WITH UTILITY COMPANIES AND PUBLIC AGENCIES AND FOR OBTAINING ALL REQUIRED PERMITS AND PAYING ALL REQUIRED FEES. IN ACCORDANCE WITH M.G.L. CHAPTER 82, SECTION 40, INCLUDING AMENDMENTS, CONTRACTORS SHALL NOTIFY ALL UTILITY COMPANIES AND GOVERNMENT AGENCIES IN WRITING PRIOR TO EXCAVATION.
4. WHERE AN EXISTING UTILITY IS FOUND TO CONFLICT WITH THE PROPOSED WORK, THE LOCATION, ELEVATION AND SIZE OF THE UTILITY SHALL BE ACCURATELY DETERMINED WITHOUT DELAY BY THE CONTRACTOR AND THE INFORMATION FURNISHED TO THE ENGINEER FOR RESOLUTION OF THE CONFLICT.
5. THE CONTRACTOR SHALL MAKE ALL ARRANGEMENTS FOR THE ALTERATION AND ADJUSTMENT OF GAS, ELECTRIC, TELEPHONE AND ANY OTHER PRIVATE UTILITIES BY THE UTILITY OWNER AT NO ADDITIONAL COST TO THE OWNER.
6. CONTRACTOR SHALL BE RESPONSIBLE FOR REVIEWING ALL DRAWINGS AND SPECIFICATIONS TO DETERMINE THE EXTENT OF EXCAVATION AND DEMOLITION REQUIRED TO RECEIVE SITE IMPROVEMENTS.
7. ANY DISCREPANCIES OR CONFLICTS BETWEEN THE DRAWINGS AND EXISTING CONDITIONS, EXISTING CONDITIONS TO REMAIN, TEMPORARY CONSTRUCTION, PERMANENT CONSTRUCTION AND WORK OF ADJACENT CONTRACTS SHALL BE BROUGHT TO THE ATTENTION OF THE OWNER BEFORE PROCEEDING. ITEMS ENCOUNTERED IN AREAS OF EXCAVATION THAT ARE NOT INDICATED ON THE DRAWINGS, BUT ARE VISIBLE ON SURFACE, SHALL BE THE CONTRACTOR'S RESPONSIBILITY AND SHALL BE REMOVED AT NO ADDITIONAL COST TO THE OWNER.
8. ANY ALTERATIONS TO THESE DRAWINGS MADE IN THE FIELD DURING CONSTRUCTION SHALL BE RECORDED BY THE GENERAL CONTRACTOR ON "AS-BUILT" DRAWINGS.
9. ALL AREAS DISTURBED BY THE CONTRACTOR'S OPERATIONS OUTSIDE THE PROJECT LIMITS, SHALL BE RESTORED TO THE ORIGINAL CONDITION BY THE CONTRACTOR AT NO ADDITIONAL COST AND TO THE SATISFACTION OF THE OWNER.
10. ALL WORK SHOWN ON THE PLANS AS BOLD SHALL REPRESENT PROPOSED WORK. THE TERM "PROPOSED (PROP)" INDICATES WORK TO BE CONSTRUCTED USING NEW MATERIALS OR, WHERE APPLICABLE, RE-USING EXISTING MATERIALS IDENTIFIED AS "REMOVE AND RESET (R&R)", OR REMOVE, RELOCATE, RESET, (R,R&R).
11. ALL KNOWN EXISTING STATE, COUNTY AND CITY LOCATION LINES AND PRIVATE PROPERTY LINES HAVE BEEN ESTABLISHED FROM AVAILABLE INFORMATION AND ARE INDICATED ON THE PLANS.
12. THE CONTRACTOR SHALL TAKE ALL NECESSARY PRECAUTIONS TO PROTECT HIS EMPLOYEES, AS WELL AS PUBLIC USERS FROM INJURY DURING THE ENTIRE CONSTRUCTION PERIOD USING ALL NECESSARY SAFEGUARDS, INCLUDING BUT NOT LIMITED TO, THE ERECTION OF TEMPORARY WALKS, STRUCTURES, PROTECTIVE BARRIERS, COVERING, OR FENCES AS NEEDED.
13. THE CONTRACTOR SHALL SUPPLY THE OWNER WITH THE NAME OF THE OSHA "COMPETENT PERSON" PRIOR TO CONSTRUCTION.
14. FILLING OF EXCAVATED AREAS SHALL NOT TAKE PLACE WITHOUT THE PRESENCE OR PERMISSION OF THE OWNER.
15. EXISTING TREES TO REMAIN SHALL BE PROTECTED FROM CONSTRUCTION ACTIVITIES. NO STOCKPILING OF MATERIAL, EQUIPMENT OR VEHICULAR TRAFFIC SHALL BE ALLOWED WITHIN THE DRIP LINE OF TREES TO REMAIN. NO GUYS SHALL BE ATTACHED TO ANY TREE TO REMAIN. WHEN NECESSARY OR AS DIRECTED BY THE ENGINEER, THE CONTRACTOR SHALL ERECT TEMPORARY BARRIERS FOR THE PROTECTION OF EXISTING TREES DURING CONSTRUCTION.
16. THE CONTRACTOR SHALL CALL DIGSAFE AT 811 AT LEAST 72 HOURS, SATURDAYS, AND HOLIDAYS EXCLUDED, PRIOR TO EXCAVATING AT ANY LOCATION. A COPY OF THE DIGSAFE PROJECT REFERENCE NUMBER(S) SHALL BE GIVEN TO THE OWNER PRIOR TO EXCAVATION.
17. ALL FILL BELOW THE PROPOSED BUILDINGS SHALL CONFORM TO STRUCTURAL FILL IN ACCORDANCE WITH RECOMMENDATIONS PROVIDED BY A GEOTECHNICAL ENGINEER.
18. CONTRACTOR IS RESPONSIBLE FOR STAKING CONSTRUCTION BASELINES, BLDG, STRUCTURES, ETC WITH A LICENSED SURVEYOR IN FIELD. NO CONSTRUCTION WILL BE PERFORMED WITHOUT THE PROPOSED BASELINES AND LAYOUTS APPROVED BY THE ENGINEER.
19. NO FILL SHALL CONTAIN HAZARDOUS MATERIALS.
20. CONTRACTOR SHALL PROVIDE TEMPORARY FENCING AROUND PERIMETER OF WORK AREA (LIMIT OF WORK). FENCE SHALL NOT IMPEDE TRAVEL WAYS.
21. ANY QUANTITIES SHOWN ON PLANS ARE FOR COMPARATIVE BIDDING PURPOSES ONLY. IT IS THE CONTRACTOR'S RESPONSIBILITY TO VISIT THE PROJECT SITE TO VERIFY ALL QUANTITIES AND CONDITIONS PRIOR TO SUBMITTING BID.
22. ALL EXISTING DRAINAGE FACILITIES TO REMAIN SHALL BE MAINTAINED FREE OF DEBRIS, SOIL, SEDIMENT, AND FOREIGN MATERIAL AND OPERATIONAL THROUGHOUT THE LIFE OF THE CONTRACT. REMOVE ALL SOIL, SEDIMENT, DEBRIS AND FOREIGN MATERIAL FROM ALL DRAINAGE STRUCTURES, INCLUDING BUT NOT LIMITED TO, DRAINAGE INLETS, MANHOLES AND CATCH BASINS WITHIN THE LIMIT OF WORK AND DRAINAGE STRUCTURES OUTSIDE THE LIMIT OF WORK THAT ARE IMPACTED BY THE WORK FOR THE ENTIRE DURATION OF CONSTRUCTION.
23. CONTRACTOR'S STAGING AREA MUST BE WITHIN THE CONTRACT LIMIT LINE (LIMIT OF WORK AS IDENTIFIED ON THE PLANS).
24. THE CONTRACTOR SHALL KEEP ALL STREETS, PARKING LOTS AND WALKS THAT ARE NOT RESTRICTED FROM PUBLIC USE DURING CONSTRUCTION BROOM CLEAN AT ALL TIMES. THE CONTRACTOR SHALL USE ACCEPTABLE METHODS AND MATERIALS TO MAINTAIN ADEQUATE DUST CONTROL THROUGHOUT CONSTRUCTION.
25. CONTRACTOR SHALL COORDINATE ALL WORK WITH THE OWNER.
26. THE LIMIT OF WORK SHALL BE DELINEATED IN THE FIELD PRIOR TO THE START OF SITE CLEARING OR CONSTRUCTION.
27. HAULING OF EARTH MATERIALS TO AND FROM THE SITE SHALL BE RESTRICTED TO THE HOURS OF 7:00 AM TO 5:00 PM MONDAY THROUGH FRIDAY. HAULING SHALL ALSO BE PROHIBITED ON STATE AND FEDERAL HOLIDAYS.
28. ANY BOULDERS 3 CY OR SMALLER SHALL BE CONSIDERED UNDOCUMENTED FILL AND SHALL BE DISPOSED OF AT NO ADDITIONAL COST TO THE OWNER.
29. THE TERM "AS DIRECTED" AS USED IN THE CONTRACT DRAWINGS SHALL BE REPLACED WITH "AS REQUIRED".

EROSION AND SEDIMENT CONTROL NOTES

1. ALL SEDIMENT AND EROSION CONTROL DEVICES SHALL BE PUT INTO PLACE BY G.C. PRIOR TO BEGINNING ANY CONSTRUCTION OR DEMOLITION. REFER TO PLAN FOR APPROXIMATE LOCATION OF EROSION AND SEDIMENT CONTROL. REFER TO SPECS AND DETAILS FOR TYPE OF EROSION AND SEDIMENT CONTROL.
2. THE G.C. SHALL BE RESPONSIBLE FOR THE CONTINUAL MAINTENANCE OF ALL CONTROL DEVICES THROUGHOUT THE DURATION OF THE PROJECT.
3. CONTRACTOR SHALL MEET ALL OF THE STATE OF MASSACHUSETTS D.E.P. WETLAND ORDINANCE REGULATIONS FOR SEDIMENT AND EROSION CONTROL.
4. EXCAVATED MATERIAL STOCKPILED ON THE SITE SHALL BE SURROUNDED BY A RING OF UNBROKEN SEDIMENT AND EROSION CONTROL FENCE. THE LIMITS OF ALL GRADING AND DISTURBANCE SHALL BE KEPT TO A MINIMUM WITHIN THE APPROVED AREA OF CONSTRUCTION. ALL AREAS OUTSIDE OF THE LIMIT OF CONTRACT SHALL REMAIN TOTALLY UNDISTURBED UNLESS OTHERWISE APPROVED BY OWNER'S REPRESENTATIVE.
5. ALL CATCH BASINS AND DRAIN GRATES WITHIN LIMIT OF CONTRACT SHALL BE PROTECTED WITH FILTER FABRIC DURING THE ENTIRE DURATION OF CONSTRUCTION.
6. EROSION CONTROL BARRIERS TO BE INSTALLED AT THE TOE OF SLOPES. SEE SITE PREPARATION PLAN, NOTES, DETAILS AND SPECIFICATIONS.
7. ANY AREA OUTSIDE THE PROJECT LIMIT THAT IS DISTURBED SHALL BE RESTORED TO ITS ORIGINAL CONDITION AT NO COST TO THE OWNER.
8. THE CONTRACTOR SHALL PROVIDE DUST CONTROL FOR CONSTRUCTION OPERATIONS AS APPROVED BY OWNER.
9. ALL POINTS OF CONSTRUCTION EGRESS OR INGRESS SHALL BE MAINTAINED TO PREVENT TRACKING OR FLOWING OF SEDIMENT ON TO PUBLIC/PRIVATE ROADS.

DEMOLITION & SITE PREPARATION NOTES

1. THE CONTRACTOR SHALL INCLUDE IN THE BID THE COST OF REMOVING ANY EXISTING SITE FEATURES AND APPURTENANCES NECESSARY TO ACCOMPLISH THE CONSTRUCTION OF THE PROPOSED SITE IMPROVEMENTS. THE CONTRACTOR SHALL ALSO INCLUDE IN THE BID THE COST NECESSARY TO RESTORE SUCH ITEMS IF THEY ARE SCHEDULED TO REMAIN AS PART OF THE FINAL SITE IMPROVEMENTS. REFER TO PLANS TO DETERMINE EXCAVATION, DEMOLITION AND TO DETERMINE THE LOCATION OF THE PROPOSED SITE IMPROVEMENTS.
2. THE OWNER RESERVES THE RIGHT TO REVIEW ALL MATERIALS DESIGNATED FOR REMOVAL AND TO RETAIN OWNERSHIP OF SUCH MATERIALS. IF THE OWNER RETAINS ANY MATERIAL THE CONTRACTOR SHALL ALLOW ARRANGEMENTS WITH THE OWNER TO HAVE THOSE MATERIALS REMOVED OFF SITE AT NO ADDITIONAL COST.
3. UNLESS SPECIFICALLY NOTED TO BE SAVED / STOCKPILED (R&S) OR REUSED / RELOCATED (R&R), ALL SITE FEATURES CALLED FOR REMOVAL (REM) SHALL BE REMOVED WITH THEIR FOOTINGS, ATTACHMENTS, BASE MATERIAL, ETC, TRANSPORTED FROM THE SITE TO BE DISPOSED OF IN A LAWFUL MANNER AT AN ACCEPTABLE DISPOSAL SITE AND AT NO COST TO THE OWNER.
4. ALL EXISTING SITE FEATURES TO REMAIN SHALL BE PROTECTED THROUGHOUT THE CONSTRUCTION PERIOD. ANY FEATURES DAMAGED DURING CONSTRUCTION OPERATIONS SHALL BE REPAIRED OR REPLACED TO THE SATISFACTION OF THE OWNER'S REPRESENTATIVE AT NO ADDITIONAL COST.
5. DURING EARTHWORK OPERATIONS, CONTRACTOR SHALL TAKE CARE TO NOT DISTURB EXISTING MATERIALS TO REMAIN, OUTSIDE THE LIMITS OF EXCAVATION AND BACKFILL AND SHALL TAKE WHATEVER MEASURES NECESSARY, AT THE CONTRACTOR'S EXPENSE, TO PREVENT ANY EXCAVATED MATERIAL FROM COLLAPSING. ALL BACKFILL MATERIALS SHALL BE PLACED AND COMPACTED AS SPECIFIED TO THE SUBGRADE REQUIRED FOR THE INSTALLATION OF THE REMAINDER OF THE CONTRACT WORK.
6. IT SHALL BE THE CONTRACTOR'S OPTION, WITH CONCURRENCE OF THE OWNER, TO REUSE EXISTING GRAVEL IF IT MEETS THE REQUIREMENTS OF THE SPECIFICATIONS FOR GRAVEL BORROW.
7. ALL ITEMS CALLED FOR REMOVAL SHALL BE REMOVED TO FULL DEPTH INCLUDING ALL FOOTINGS, FOUNDATIONS, AND OTHER APPURTENANCES, EXCEPT AS SPECIFICALLY NOTED OTHERWISE.
8. THE STORAGE OF MATERIALS AND EQUIPMENT WILL BE PERMITTED AT LOCATIONS DESIGNATED BY OWNER OR OWNER'S REPRESENTATIVE. PROTECTION OF STORED MATERIALS AND EQUIPMENT SHALL BE THE SOLE RESPONSIBILITY OF THE CONTRACTOR.

LAYOUT & MATERIALS NOTES

1. REFER TO EXISTING CONDITIONS PLANS FOR SURVEY INFORMATION SHEET C100.
2. COORDINATE ALL LAYOUT ACTIVITIES WITH THE SCOPE OF WORK CALLED FOR BY DEMOLITION, GRADING AND UTILITIES OPERATIONS ENCOMPASSED BY THIS CONTRACT. SET, PROTECT AND REPLACE REFERENCE STAKES AS NECESSARY OR AS REQUIRED BY THE OWNER'S REPRESENTATIVE.
3. ALL WORK SHALL BE PERFORMED BY CONTRACTOR UNLESS SPECIFICALLY INDICATED THAT THE WORK WILL BE PERFORMED "BY OTHERS".
4. TO FACILITATE LAYOUT OF PROPOSED SITE FEATURES AND FACILITIES, LAYOUT INFORMATION FOR CERTAIN FUTURE WORK, WHICH IS NOT INCLUDED WITHIN THE SCOPE OF THIS CONTRACT HAS BEEN PROVIDED ON THE LAYOUT AND MATERIALS PLAN FOR INFORMATION ONLY. THE LAYOUT OF SITE AMENITIES AND FENCES MUST BE APPROVED BY THE OWNER'S REPRESENTATIVE PRIOR TO INSTALLATION. SOME ITEMS ARE "NOT IN CONTRACT" (NIC) AND SHOWN FOR REFERENCE ONLY.
5. THE LAYOUT OF SITE AMENITIES AND FENCES MUST BE APPROVED BY THE OWNER'S REPRESENTATIVE PRIOR TO INSTALLATION.
6. THE LAYOUT OF ALL NEW PATHWAYS / WALKWAYS AND THE GRADING OF ALL SLOPES AND CROSS SLOPES SHALL CONFORM TO THE COMMONWEALTH OF MASSACHUSETTS RULES AND REGULATIONS FOR HANDICAP ACCESS CMR 521, AND THE AMERICANS WITH DISABILITIES ACT (ADA), TITLE 3. THE CONTRACTOR SHALL NOTIFY THE OWNER IMMEDIATELY OF ANY DISCREPANCIES BETWEEN ACTUAL CONDITIONS AND THOSE REQUIRED.
7. ALL LAYOUT LINES, OFFSETS, OR REFERENCES TO LOCATING OBJECTS ARE EITHER PARALLEL OR PERPENDICULAR UNLESS OTHERWISE DESIGNATED WITH ANGLE OFFSETS NOTED.
8. ALL PROPOSED SITE FEATURES SHALL BE LAID OUT AND STAKED FOR REVIEW AND APPROVAL BY THE OWNER'S REPRESENTATIVE PRIOR TO COMMENCEMENT OF INSTALLATION. ANY REQUIRED ADJUSTMENTS TO THE LAYOUT SHALL BE UNDERTAKEN AS REQUIRED, AT NO ADDITIONAL COST TO THE OWNER.
9. ALL PROPOSED PAVEMENTS SHALL MEET THE LINE AND GRADE OF EXISTING ADJACENT PAVEMENT SURFACES AND SHALL BE TREATED WITH AN RS-1 TACK COAT AT POINT OF CONNECTION. ALL PATHWAY WIDTHS SHALL BE AS NOTED ON THE LAYOUT AND MATERIALS PLAN.
10. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND GRADES ON THE GROUND AND REPORT ANY DISCREPANCIES IMMEDIATELY TO THE OWNER.
11. THE CONTRACTOR SHALL BE RESPONSIBLE FOR FIELD MEASUREMENT OF ALL PROPOSED FENCES AND GATES.
12. ALL REFERENCES TO LOAM AND SEED (L&S) REFER TO HYDROMULCH SEEDED LAWN, UNLESS NOTED OTHERWISE.
13. REFER TO DETAIL DRAWINGS FOR CONSTRUCTION DETAILS.
14. CONTRACTOR SHALL PERFORM ALL EARTHWORK IN CONFORMANCE WITH PROJECT GEOTECHNICAL RECOMMENDATIONS AND SPECIFICATIONS.
15. EXCESS FILL MATERIAL SHALL BE REMOVED & DISPOSED OF BY THE CONTRACTOR AT NO ADDITIONAL COST.

GRADING, UTILITIES & DRAINAGE NOTES

1. ALL WORK RELATING TO INSTALLATION, RENOVATION OR MODIFICATION OF WATER, DRAINAGE AND/OR SEWER SERVICES SHALL BE PERFORMED IN ACCORDANCE WITH THE STANDARDS OF THE TOWN OF LOWELL. THE CONTRACTOR SHALL NOTIFY THE STONEHAM DEPARTMENT OF PUBLIC WORKS AND MASSDOT PRIOR TO PERFORMING ANY PAVEMENT CUTS OR MAKING CONNECTIONS TO ANY TOWN UTILITIES.
2. THE CONTRACTOR SHALL OBTAIN A STREET OPENING PERMIT FROM THE STONEHAM DEPARTMENT OF PUBLIC WORKS AND MASSDOT PRIOR TO PERFORMING ANY EXCAVATION WITHIN PUBLIC RIGHT OF WAY.
3. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND GRADES ON THE GROUND AND REPORT ANY DISCREPANCIES IMMEDIATELY TO THE OWNER.
4. ALL GRADING IS TO BE SMOOTH AND CONTINUOUS WHERE PROPOSED GRAVEL SURFACE MEETS EXISTING SURFACE, BLEND THE TWO PAVEMENTS AND ELIMINATE ROUGH SPOTS AND ABRUPT GRADE CHANGES AND MEET LINE AND GRADE OF EXISTING CONDITIONS WITH NEW IMPROVEMENTS.
5. CONTRACTOR SHALL MAINTAIN POSITIVE DRAINAGE (1.5% MINIMUM) AWAY FROM ALL BUILDING FOUNDATIONS AND STRUCTURES.
6. CONTRACTOR SHALL ENSURE ALL AREAS ARE PROPERLY PITCHED TO DRAIN, WITH NO SURFACE WATER PONDING OR PUDDLING.
7. ALL NEW WALKWAYS / ACCESS PATHS MUST CONFORM TO CURRENT AMERICANS WITH DISABILITIES ACT (ADA) REGULATIONS: WALKWAYS SHALL MAINTAIN A CROSS PITCH OF NOT MORE THAN TWO PERCENT (2%) AND THE RUNNING SLOPE (PARALLEL TO THE DIRECTION OF TRAVEL) BETWEEN 1% MIN. AND 5% MAX.
8. MINIMUM SLOPE ON ALL WALKWAYS WILL BE 1:100 OR 1% TO PROVIDE POSITIVE DRAINAGE. ANY DISCREPANCIES NOT ALLOWING THIS TO OCCUR SHALL BE REPORTED TO THE OWNER PRIOR TO CONTINUING WORK.
9. ALL UTILITY GRATES, COVERS OR OTHER SURFACE ELEMENTS INTENDED TO BE EXPOSED AT GRADE SHALL BE FLUSH WITH THE ADJACENT FINISHED GRADE AND ADJUSTED TO PROVIDE A SMOOTH TRANSITION AT ALL EDGES.
10. THE CONTRACTOR SHALL SET SUBGRADE ELEVATIONS TO ALLOW FOR POSITIVE DRAINAGE AND PROVIDE EROSION CONTROL DEVICES, STRUCTURES, MATERIALS AND CONSTRUCTION METHODS TO DIRECT SILT MIGRATION AWAY FROM DRAINAGE AND OTHER UTILITY SYSTEMS, PUBLIC/PRIVATE STREETS AND WORK AREAS. CLEAN BASINS REGULARLY AND AT THE END OF THE PROJECT.
11. EXCAVATION REQUIRED WITHIN PROXIMITY OF KNOWN EXISTING UTILITY LINES SHALL BE DONE BY HAND. CONTRACTOR SHALL REPAIR ANY DAMAGE TO EXISTING UTILITY LINES OR STRUCTURES INCURRED DURING CONSTRUCTION OPERATIONS AT NO COST TO THE OWNER.
12. WHERE NEW EARTHWORK MEETS EXISTING EARTHWORK, CONTRACTOR SHALL BLEND NEW EARTHWORK SMOOTHLY INTO EXISTING, PROVIDING VERTICAL CURVES OR ROUNDS AT ALL TOP AND BOTTOM OF SLOPES.
13. ALL FILL SHALL BE PLACED IN LIFTS & COMPACTED IN ACCORDANCE WITH THE EARTH WORK SPEC.
14. WHERE A SPECIFIC LIMIT OF WORK LINE IS NOT OBVIOUS OR IMPLIED, BLEND GRADES TO EXISTING CONDITIONS WITHIN 5 FEET OF PROPOSED CONTOURS.
15. RESTORE ALL DISTURBED AREAS AND LIMITS OF ALL REMOVALS TO LOAM AND SEED (L&S) UNLESS OTHERWISE NOTED.
16. SEE EARTHWORK SECTION OF SPECIFICATIONS FOR SPECIFIC EXCAVATION AND FILLING PROCEDURES.
17. PIPELINE AND UTILITY TRENCHES ON STEEP SLOPES SHALL BE PROVIDED WITH BENTONITE TRENCH DAMS AS SHOW IN PLAN DETAILS.
18. ALL PRECAST STRUCTURES SHALL BE RATED FOR H-20 LOADING.

ABBREVIATIONS

GENERAL

PROP	PROPOSED
ADJ	ADJUST
BIT. CONC.	BITUMINOUS CONCRETE
CEM. CONC.	CEMENT CONCRETE
℄	BASELINE
N.T.S.	NOT TO SCALE
B.M.	BENCH MARK
ABAN	ABANDON
MB	MAIL BOX
GRAN. CURB	GRANITE CURB
EXIST. (OR EX.)	EXISTING
FDN	FOUNDATION
F.L. (OR F)	FLOW LINE
P	PROPERTY LINE
PVMT	PAVEMENT
P.W.W.	PAVED WATERWAY
RC	REINFORCED CONCRETE
M.H.B.	MASSACHUSETTS HIGHWAY BOUND
REM	REMOVE
REMOD	REMODEL
RET	RETAIN
R.O.W.	RIGHT-OF-WAY
R&R	REMOVE AND RESET
R,R&R	REMOVE, RELOCATED AND RESET
R&S	REMOVE AND STACK
R&D	REMOVE AND DISPOSE
SB	STONE BOUND
NIC	NOT IN CONTRACT
H.C.	HANDICAP
WCR	WHEELCHAIR RAMP
FF	FINISHED FLOOR
HMA	HOT MIX ASPHALT
G.C.	GENERAL CONTRACTOR
E.C.	ELECTRICAL CONTRACTOR
P.C.	PLUMBING CONTRACTOR
SWEL	SOLID WHITE EDGE LINE
BWLL	BROKEN WHITE LANE LINE
SYEL	SOLID YELLOW EDGE LINE
SB/DH	STONE BOUND/ DRILL HOLE
CLF	CHAIN LINK FENCE
TEMP.	TEMPORARY
TYP.	TYPICAL
EQ	EQUIPMENT
H.C.	HANDICAP
EOP	EDGE OF PAVEMENT
PROT	PROTECT
CTE	CONNECT TO EXISTING
RL	ROOF LEADER
L.O.W.	LIMIT OF WORK
VIF	VERIFY IN FIELD
APPROX.	APPROXIMATE
TBM	TEMPORARY BENCHMARK
ALT.	ALTERNATE
BVW	BORDERING VEGETATED WETLAND

UTILITIES

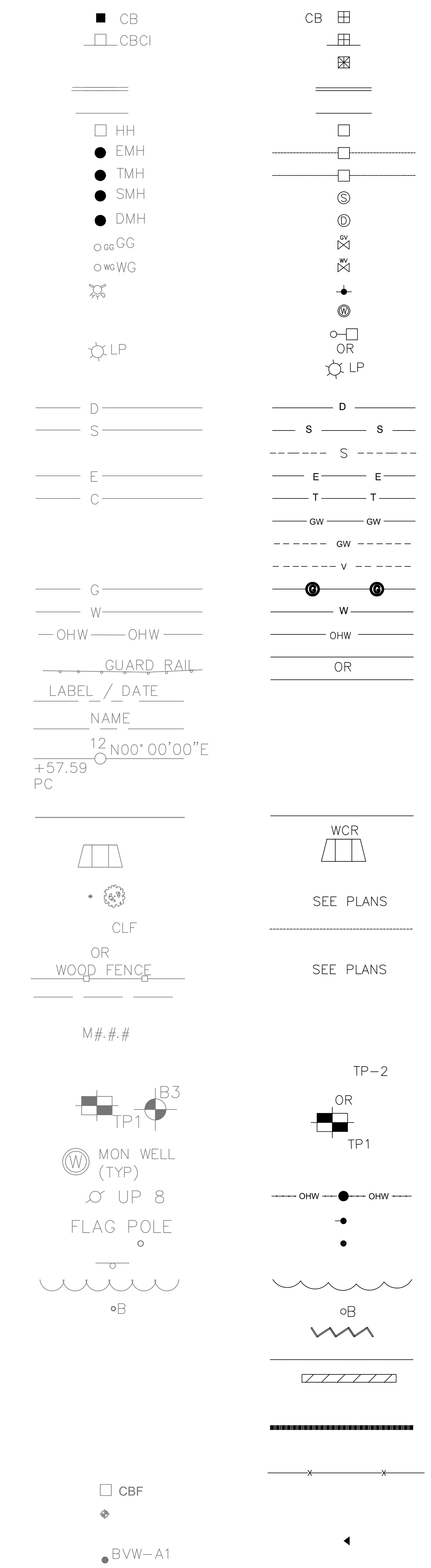
GICI	GUTTER INLET W/ CURB INLET
CBCI	CATCH BASIN W/ CURB INLET
CB	CATCH BASIN
C.I.T.	CHANGE IN TYPE
CTE	CONNECT TO EXISTING
F&G	FRAME AND GRATE
F&C	FRAME AND COVER
CI	CURB INLET
CIP	CAST IRON PIPE
CMP	CORRUGATED METAL PIPE
DI	DUCTILE IRON PIPE
GI	GUTTER INLET
ACCM PIPE	ASPHALT COATED CORRUGATED METAL PIPE
HYD	HYDRANT
INV. ELEV.	INVERT ELEVATION
UP	UTILITY POLE
SMH	SEWER MANHOLE
WG	WATER GATE
DS	DOWN SPOUT
HDPE	HIGH DENSITY POLYETHYLENE PIPE
PVC	POLYVINYL CHLORIDE
RCP	REINFORCED CONCRETE PIPE
DMH	DRAIN MANHOLE
LB	LEACHING BASIN
LG	LEACHING GALLEY
CI	CAST IRON
OCS	OUTLET CONTROL STRUCTURE
OGT	OIL AND GRIT TRAP
VC	VITRIFIED CLAY PIPE
LP	LIGHT POLE
OHW	OVERHEAD WIRE
UPLP	UTILITY POLE WITH LIGHT
SWTU	STORM WATER TREATMENT UNIT
HH	HANDHOLE
GW	GARAGE WASTE
CO	CLEANOUT
LC	LEACHING CHAMBER
GV	GATE VALVE

ALIGNMENT/GRADING

BW	BOTTOM OF WALL
BC	BOTTOM OF CURB
PI	POINT OF INTERSECTION
PC	POINT OF CURVATURE
PT	POINT OF TANGENCY
PRC	POINT OF REVERSE CURVATURE
PCC	POINT OF COMPOUND CURVATURE
PVI	POINT OF VERTICAL INTERSECTION
PVC	POINT OF VERTICAL CURVATURE
PVT	POINT OF VERTICAL TANGENCY
ELEV	ELEVATION
CC	CENTER OF CURVE
H.P.	HIGH POINT
L.P.	LOW POINT
R	RADIUS OF CURVATURE
STA	STATION
S.S.D.	STOPPING SIGHT DISTANCE
TC	TOP OF CURB
TW	TOP OF WALL

GENERAL SYMBOLS

EXISTING | PROPOSED



- CATCH BASIN
- CATCH BASIN CURB INLET
- LEACHING GALLEY
- CURB (OR BERM)-TYPE NOTED
- EDGE OF ROAD
- HANDHOLE (NUMBER AS NOTED)
- ELECTRIC MANHOLE
- TELEPHONE MANHOLE
- SEWER MANHOLE
- DRAINAGE MANHOLE
- GAS GATE
- WATER GATE VALVE
- HYDRANT
- WELL
- LIGHTPOLE
- DRAIN PIPE
- SEWER MAIN
- SEWER MAIN BY P.C.
- ELECTRIC DUCT
- TELEPHONE/COMMUNICATIONS/FIRE ALARM
- GARAGE WASTE LINE
- GARAGE WASTE LINE BY P.C.
- VENTS BY P.C.
- GAS MAIN
- WATER MAIN
- OVERHEAD WIRES
- GUARD RAIL (SIZE AND TYPE NOTED)
- HIGHWAY / PROPERTY BOUND (TYPE NOTED)
- CITY OR CITY OR COUNTY LAYOUT LINE
- CITY,CITY OR COUNTY BOUNDARY
- BASE OR SURVEY LINE
- CENTERLINE OF CONSTRUCTION
- PROPERTY LINE
- WHEELCHAIR RAMP (WCR)
- TREE (SIZE AND TYPE NOTED)
- FENCE (SIZE AND TYPE NOTED)
- EASEMENT LINE/ FUTURE CITY PROPERTY LINE
- MASSHIGHWAY STANDARD SPECIFICATION REFERENCE NUMBER
- TEST PIT/BORINGS
- MONITORING WELL
- UTILITY POLE
- GUY POLE
- FLAG POLE
- SIGN
- TREE LINE
- BOLLARD
- BIKE RACK
- SAWCUT
- EROSION CONTROL (SPECIFIED ON PLANS)
- OBSERVATION WELL
- LIMIT OF WORK
- TEMPORARY FENCE
- CONCRETE BOUND FOUND
- TEMPORARY BENCHMARK (TBM)
- DI WATER REDUCER
- WETLAND FLAG

Project:

CITY OF LOWELL, MA

STOCKBRIDGE AVE. CULVERTS REPLACEMENT PROJECT

STOCKBRIDGE AVE.
LOWELL, MA 01852

Weston & Sampson
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Consultants:

Revisions:

No.	Date	Description

Seal:

Issued For:

25% DESIGN

Scale:	NO SCALE
Date:	5/12/2021
Drawn By:	BDR
Reviewed By:	JIP
Approved By:	JIP
W&S Project No.:	ENG20-1044
W&S File No.:	---

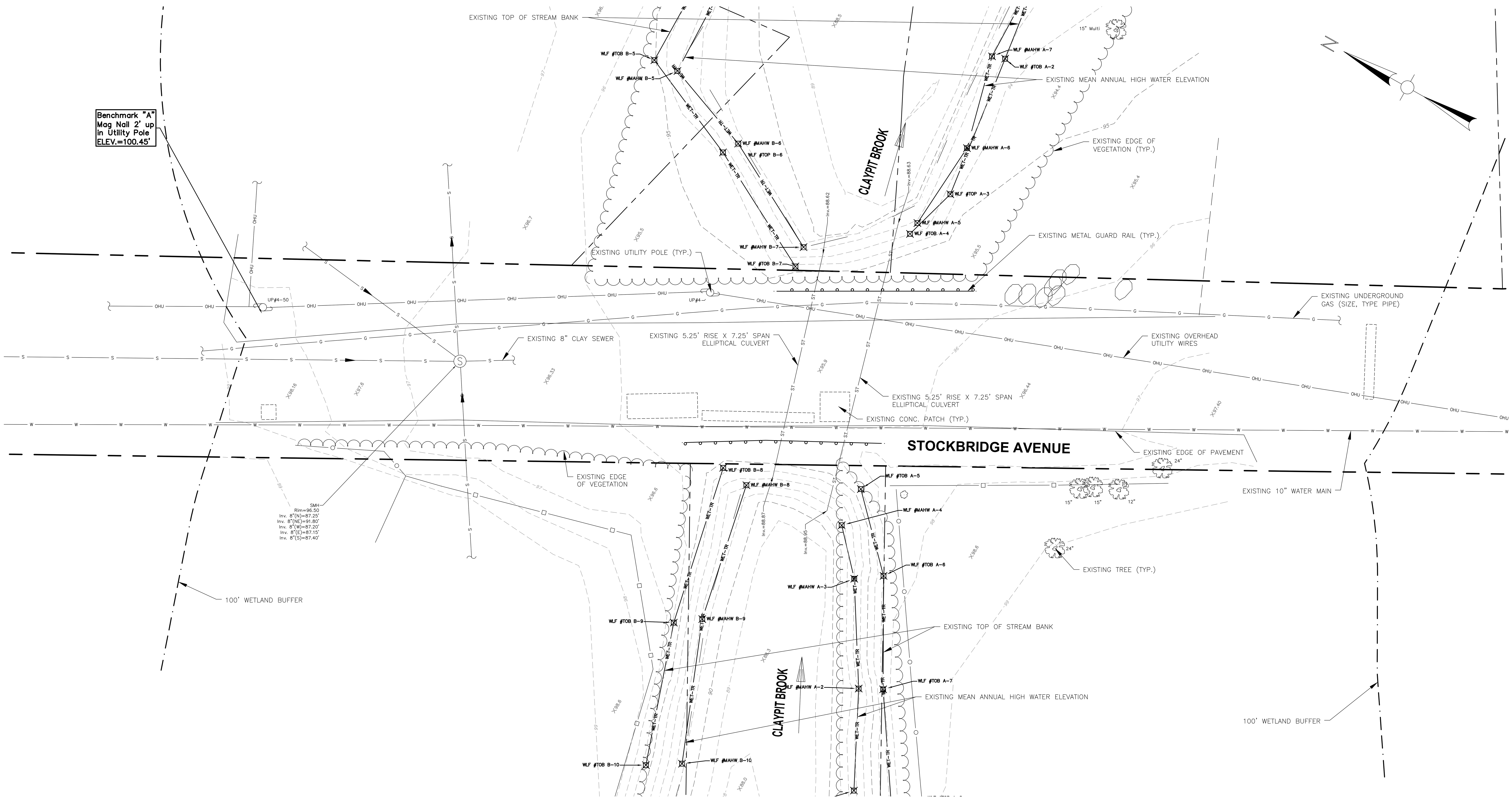
Drawing Title:

ABBREVIATIONS, NOTES AND LEGEND

Sheet Number:

G002

Rev: 1.8 Date: 10/24/2019



PLAN
SCALE: 1" = 10'

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10 5 0 10 20
SCALE: 1"=10'

Project:

CITY OF LOWELL, MA

STOCKBRIDGE AVE. CULVERTS REPLACEMENT PROJECT

STOCKBRIDGE AVE.
LOWELL, MA 01852

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Consultants:

Revisions:

No.	Date	Description

Seal:

Issued For:

25% DESIGN

Scale:	1"=10'
Date:	05/12/2021
Drawn By:	BDR
Reviewed By:	JIP
Approved By:	JIP
W&S Project No.:	ENG20-1044
W&S File No.:	---

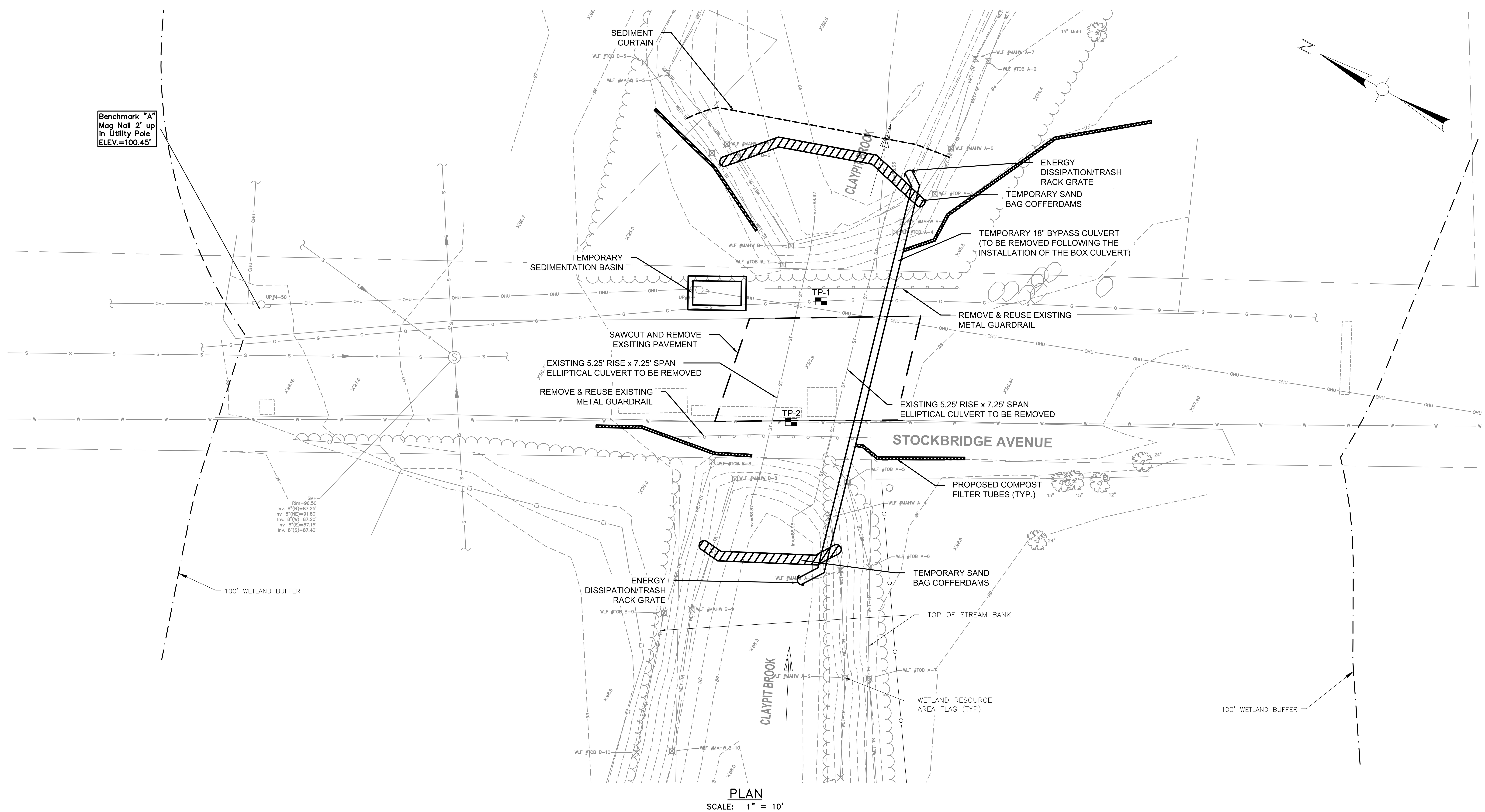
Drawing Title:

EXISTING CONDITIONS

Sheet Number:

C100

Rev. 1.8 Date: 10/24/2019



PLAN

SCALE: 1" = 10'

FOR REVIEW ONLY
NOT FOR CONSTRUCTION

SCALE: 1"=10'

Project:

CITY OF LOWELL, MA

STOCKBRIDGE AVE. CULVERTS REPLACEMENT PROJECT

STOCKBRIDGE AVE.
LOWELL, MA 01852

Weston & Sampson

Weston & Sampson Engineers, Inc.
55 Walkers Brook Drive, Suite 100
Reading, MA 01867
978.532.1900 800.SAMPSON
www.westonandsampson.com

Consultants:

Revisions:

No.	Date	Description

Seal:

Issued For:

25% DESIGN

Scale:	1"=10'
Date:	5/12/2021
Drawn By:	BDR
Reviewed By:	JIP
Approved By:	JIP
W&S Project No.:	ENG20-1044
W&S File No.:	---

Drawing Title:

SITE PREPARATION & EROSION AND SEDIMENT CONTROL PLAN

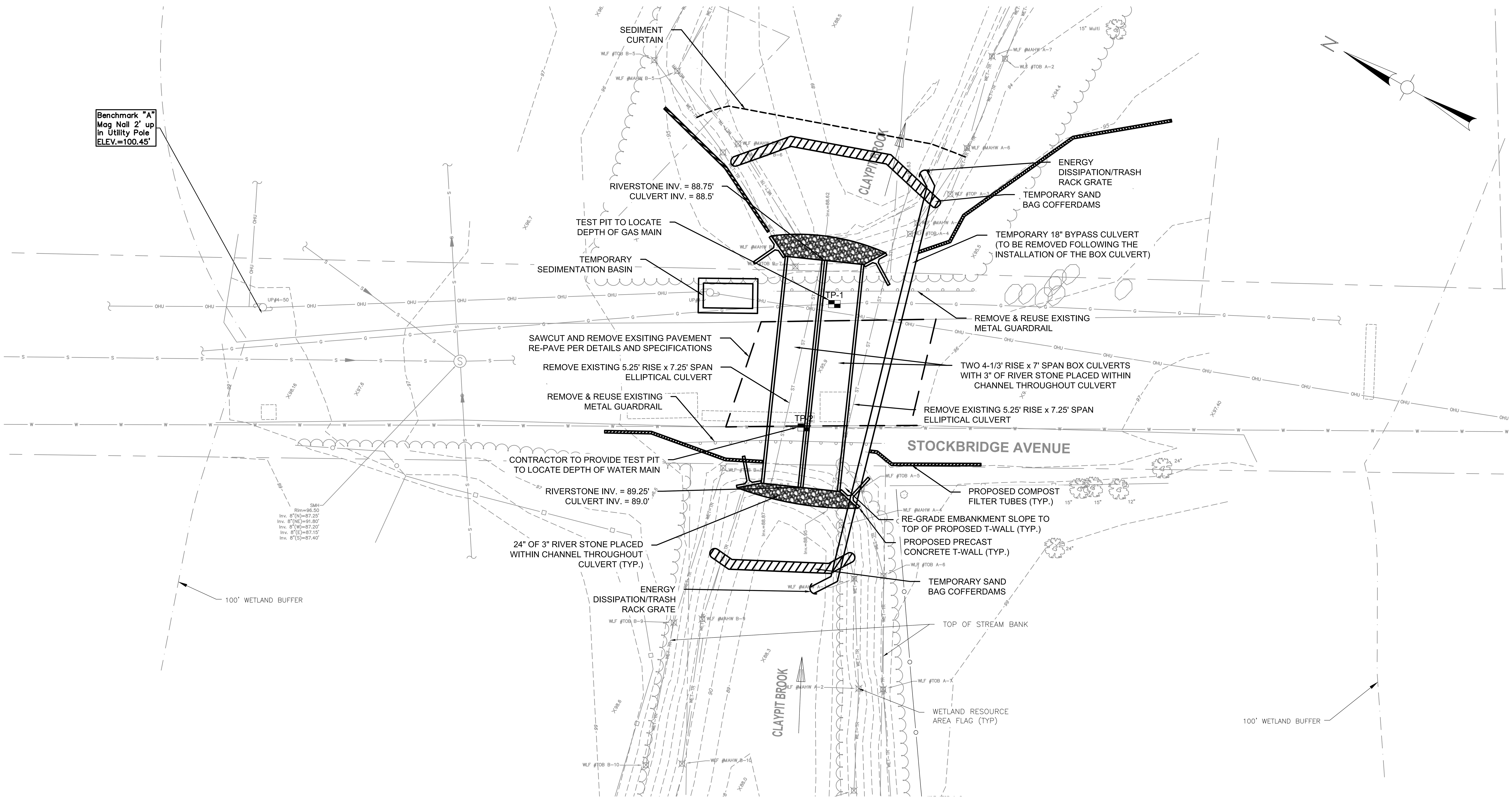
Sheet Number:

C101

Rev. 1.8 Date: 10/24/2019

NOTES

1. CONTRACTOR SHALL SUBMIT SHOP DRAWINGS FOR PRECAST CULVERT AND WINGWALL COMPONENTS STAMPED BY A REGISTERED PROFESSIONAL STRUCTURAL ENGINEER.
2. THE CONTRACTOR SHALL BE REQUIRED TO PERFORM A TEST PIT TO VERIFY UTILITY DEPTHS AT ALL THE LOCATIONS INDICATED ON THIS PLAN PRIOR TO CONSTRUCTION.



PLAN
SCALE: 1" = 10'

FOR REVIEW ONLY
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SCALE: 1"=10'

Project:
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Revisions:

No.	Date	Description

Seal:

Issued For:
25% DESIGN

Scale: 1"=10'
Date: 5/12/2021
Drawn By: BDR
Reviewed By: JIP
Approved By: JIP
W&S Project No.: ENG20-1044
W&S File No.: ---

Drawing Title:
PROPOSED CONDITIONS SITE PLAN

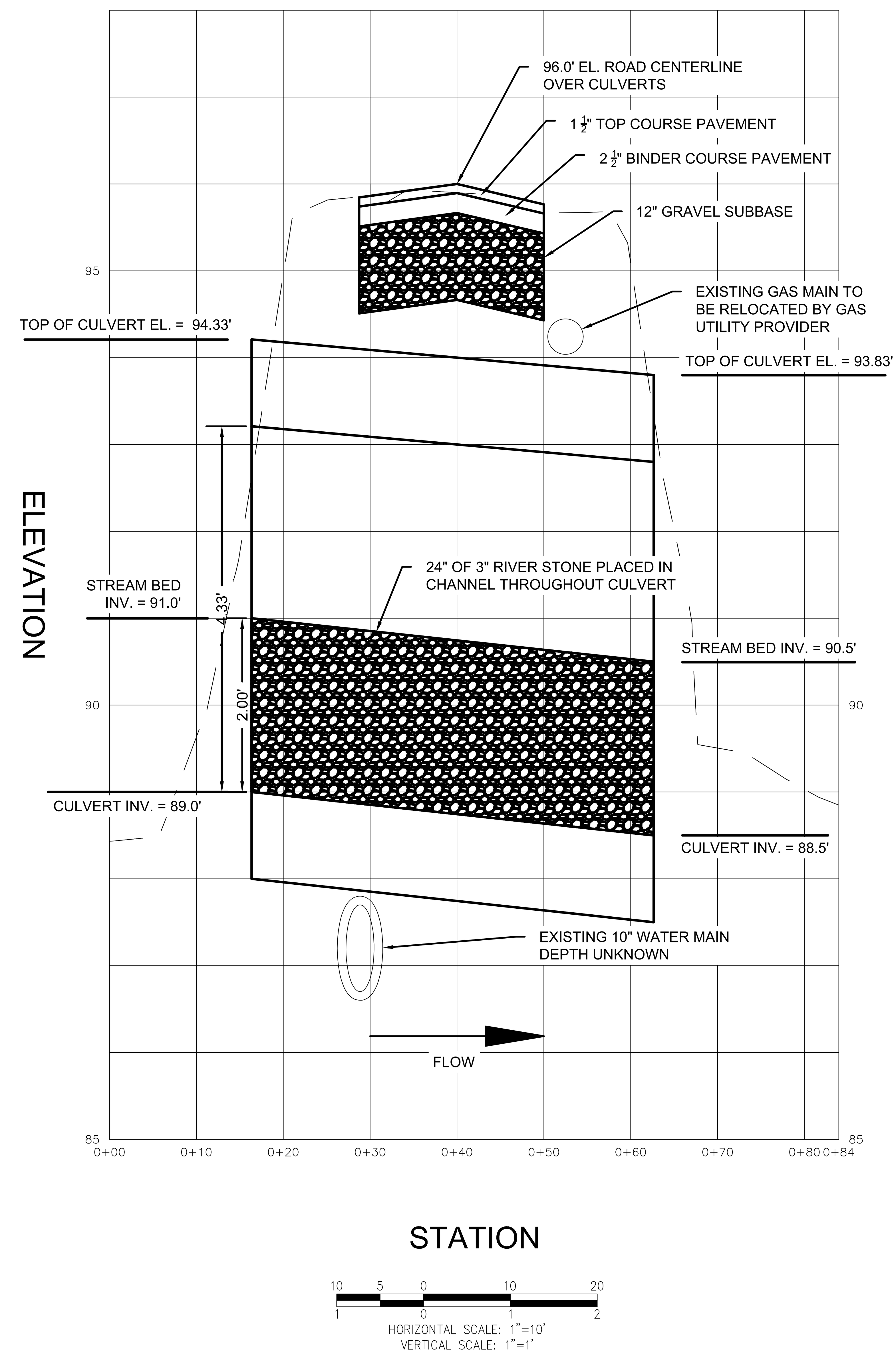
Sheet Number:
C102

Rev. 1.8 Date: 10/24/2019

NOTES

1. CONTRACTOR SHALL SUBMIT SHOP DRAWINGS FOR PRECAST CULVERT AND WINGWALL COMPONENTS STAMPED BY A REGISTERED PROFESSIONAL STRUCTURAL ENGINEER.
2. THE CONTRACTOR SHALL BE REQUIRED TO PERFORM A TEST PIT TO VERIFY UTILITY DEPTHS AT ALL THE LOCATIONS INDICATED ON THIS PLAN PRIOR TO CONSTRUCTION.

STOCKBRIDGE AVE. PROPOSED



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25% DESIGN

Scale:	1"=10'
Date:	5/12/2021
Drawn By:	BDR
Reviewed By:	JIP
Approved By:	JIP
W&S Project No.:	ENG20-1044
W&S File No.:	---

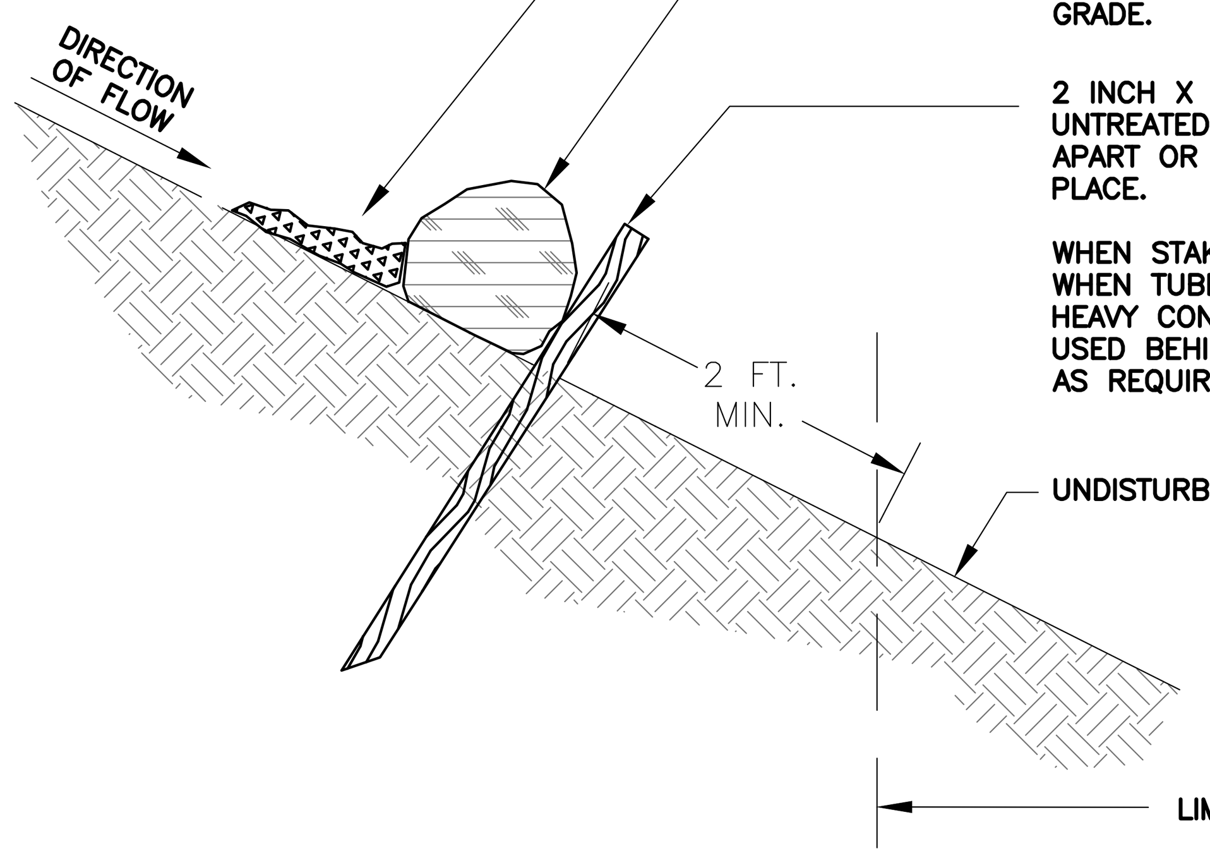
Drawing Title:

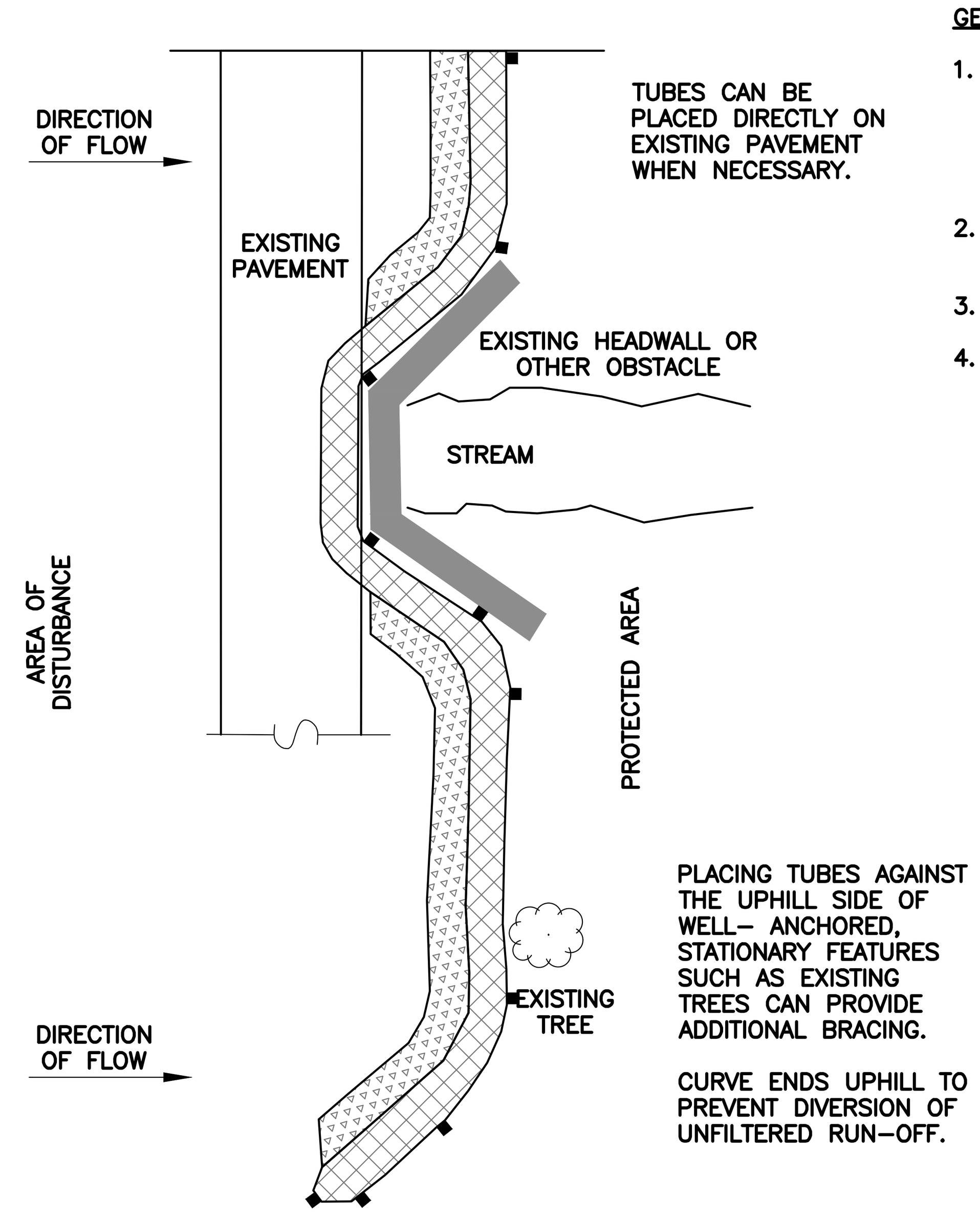
PROPOSED CULVERT PROFILE

Sheet Number:

C103

Rev. 1.8 Date: 10/24/2019

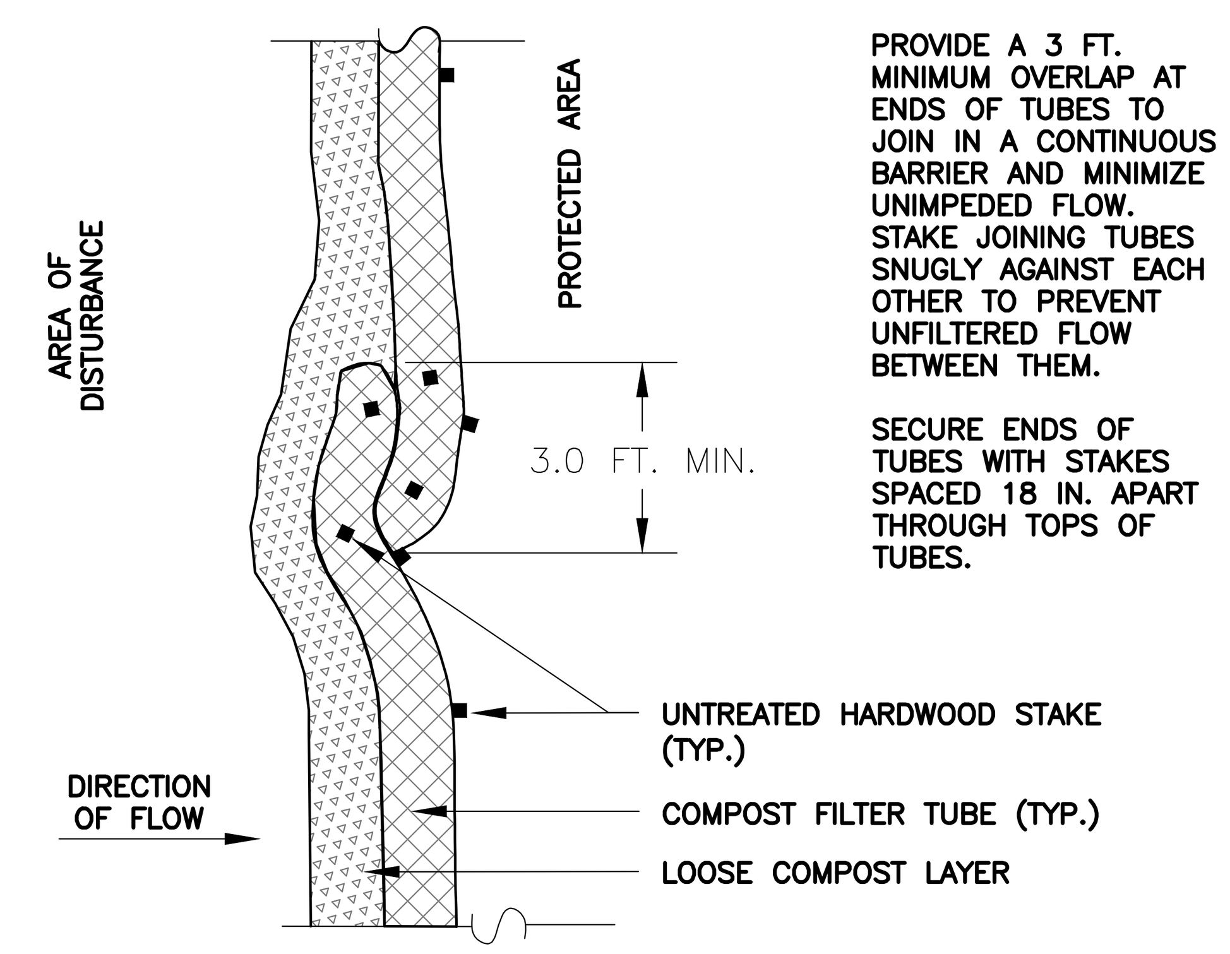

2 IN. DEEP x 12 IN. WIDE LAYER OF LOOSE COMPOST MATERIAL PLACED ON UPHILL/FLOW SIDE OF TUBES TO FILL SPACE BETWEEN SOIL SURFACE AND TUBES.
COMPOST FILTER TUBE MINIMUM 12 INCHES IN DIAMETER WITH AN EFFECTIVE HEIGHT OF 9.5 INCHES.
TUBES FOR COMPOST FILTERS SHALL BE JUTE MESH OR APPROVED BIODEGRADABLE MATERIAL. ADDITIONAL TUBES SHALL BE USED AT THE REQUIREMENT OF THE ENGINEER.
TAMP TUBES IN PLACE TO ENSURE GOOD CONTACT WITH SOIL SURFACE. IT IS NOT NECESSARY TO TRENCH TUBES INTO EXISTING GRADE.
2 INCH X 2 INCH X 3 FEET UNTREATED HARDWOOD STAKES, UP TO 5 FT. APART OR AS REQUIRED TO SECURE TUBES IN PLACE.
WHEN STAKING IS NOT POSSIBLE, SUCH AS WHEN TUBES MUST BE PLACED ON PAVEMENT, HEAVY CONCRETE OR CINDER BLOCKS CAN BE USED BEHIND TUBES UP TO 5 FT. APART OR AS REQUIRED TO SECURE TUBES IN PLACE.
DIRECTION OF FLOW
2 FT. MIN.
UNDISTURBED SUBGRADE
LIMIT OF WORK


DIRECTION OF FLOW
EXISTING PAVEMENT
TUBES CAN BE PLACED DIRECTLY ON EXISTING PAVEMENT WHEN NECESSARY.
EXISTING HEADWALL OR OTHER OBSTACLE
STREAM
AREA OF DISTURBANCE
PROTECTED AREA
PLACING TUBES AGAINST THE UPHILL SIDE OF WELL- ANCHORED, STATIONARY FEATURES SUCH AS EXISTING TREES CAN PROVIDE ADDITIONAL BRACING.
CURVE ENDS UPHILL TO PREVENT DIVERSION OF UNFILTERED RUN-OFF.
EXISTING TREE
DIRECTION OF FLOW

PLAN VIEW

GENERAL NOTES:

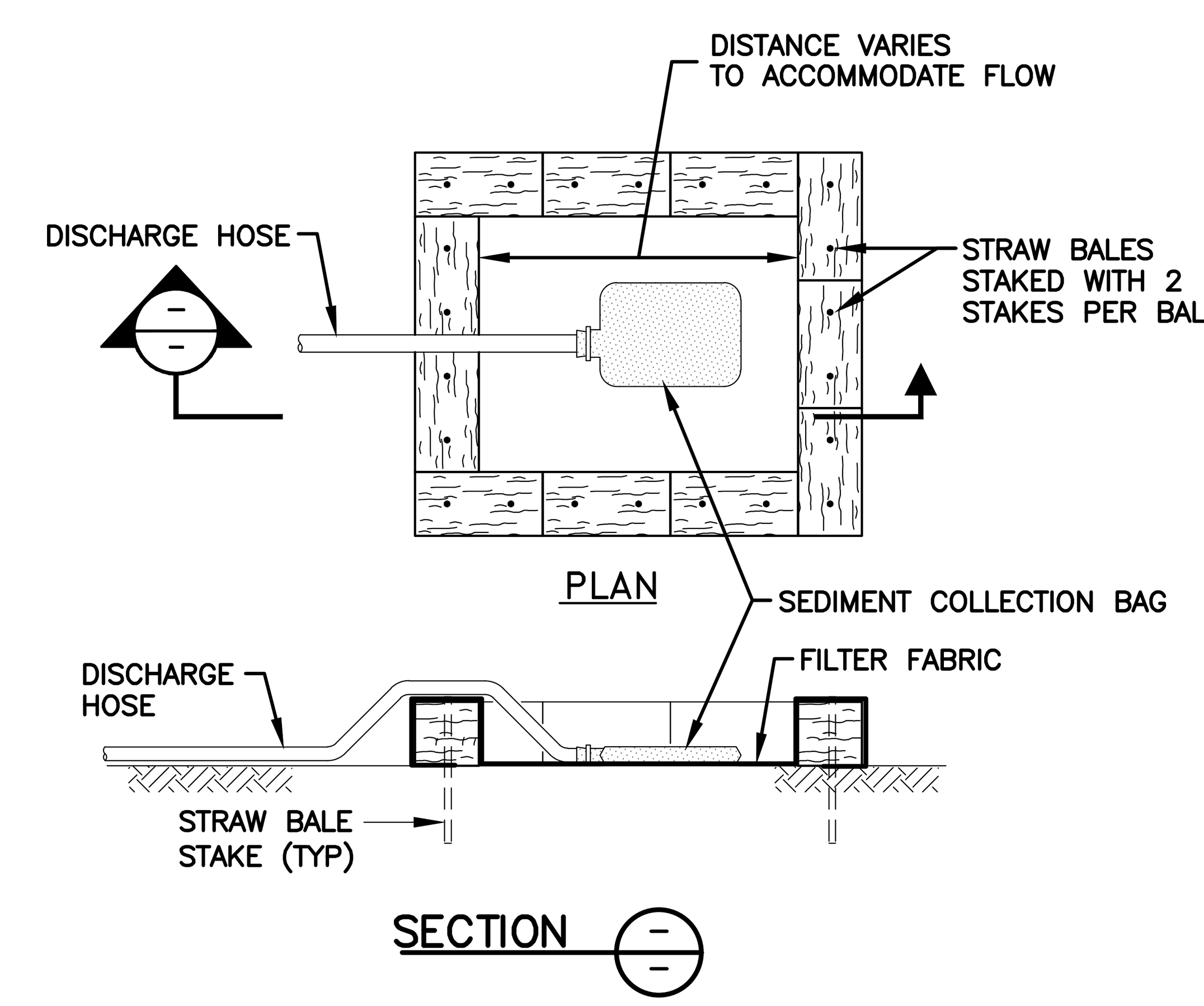
1. PROVIDE A MINIMUM TUBE DIAMETER OF 12 INCHES FOR SLOPES UP TO 50 FEET IN LENGTH WITH A SLOPE RATIO OF 3H:1V OR STEEPER. LONGER SLOPES OF 3H:1V MAY REQUIRE LARGER TUBE DIAMETER OR ADDITIONAL COURSING OF FILTER TUBES TO CREATE A FILTER BERM. REFER TO MANUFACTURER'S RECOMMENDATIONS FOR SITUATIONS WITH LONGER OR STEEPER SLOPES.
2. INSTALL TUBES ALONG CONTOURS AND PERPENDICULAR TO SHEET OR CONCENTRATED FLOW.
3. DO NOT INSTALL IN PERENNIAL, EPHEMERAL OR INTERMITTENT STREAMS.
4. CONFIGURE TUBES AROUND EXISTING SITE FEATURES TO MINIMIZE SITE DISTURBANCE AND MAXIMIZE CAPTURE AREA OF STORMWATER RUN-OFF.


AREA OF DISTURBANCE
PROTECTED AREA
PROVIDE A 3 FT. MINIMUM OVERLAP AT ENDS OF TUBES TO JOIN IN A CONTINUOUS BARRIER AND MINIMIZE UNIMPEDED FLOW. STAKE JOINING TUBES SNUGLY AGAINST EACH OTHER TO PREVENT UNFILTERED FLOW BETWEEN THEM.
SECURE ENDS OF TUBES WITH STAKES SPACED 18 IN. APART THROUGH TOPS OF TUBES.
3.0 FT. MIN.
UNTREATED HARDWOOD STAKE (TYP.)
COMPOST FILTER TUBE (TYP.)
LOOSE COMPOST LAYER
DIRECTION OF FLOW

PLAN VIEW – JOIN DETAIL

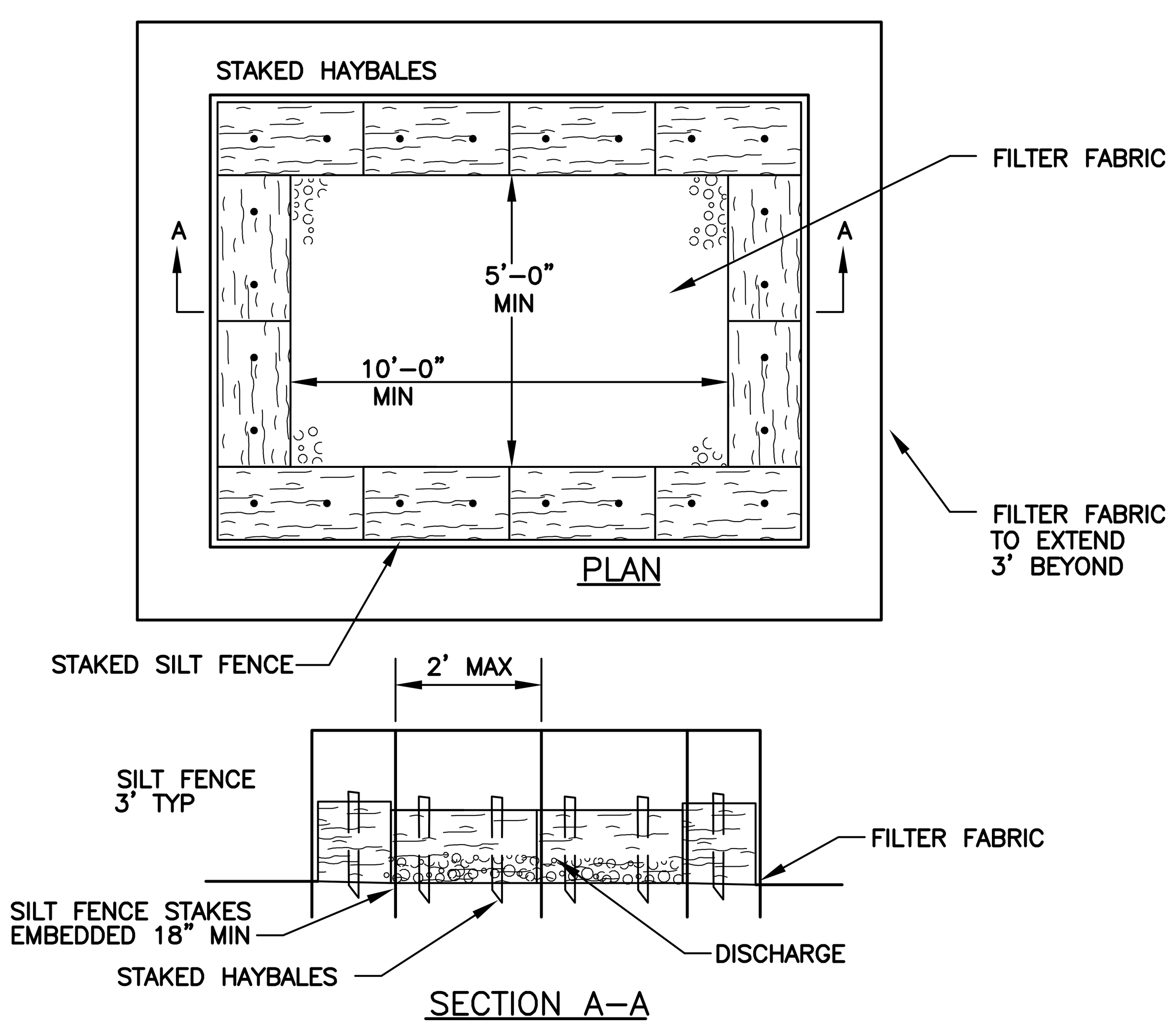
SINGLE COMPOST FILTER TUBE DETAIL

NOT TO SCALE



DEWATERING DISCHARGE DISPOSAL DETAIL

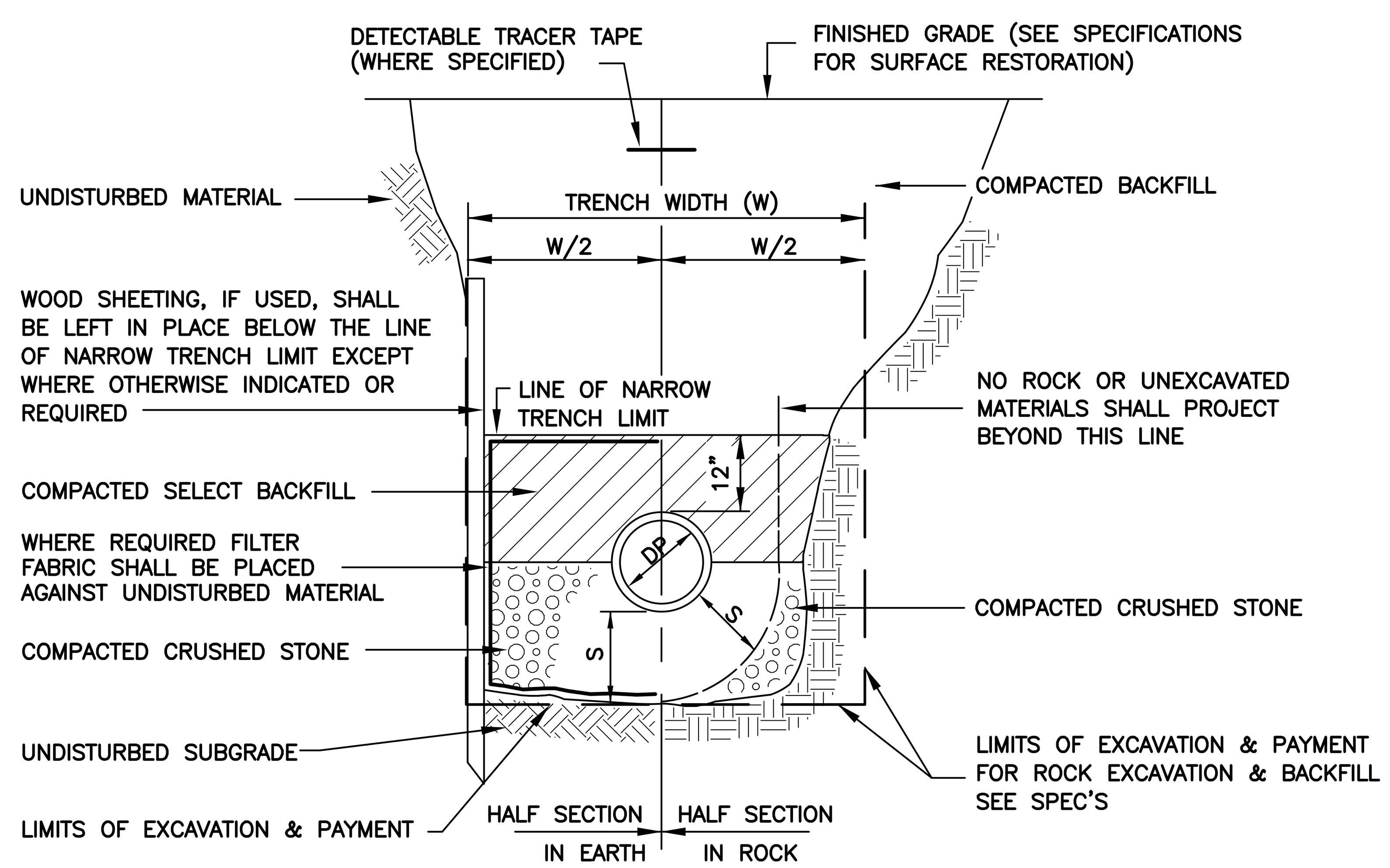
N.T.S.



NOTE: ALL DEWATERING DISCHARGES SHALL BE FILTERED THROUGH A SEDIMENTATION BASIN

SEDIMENTATION BASIN DETAIL

N.T.S.

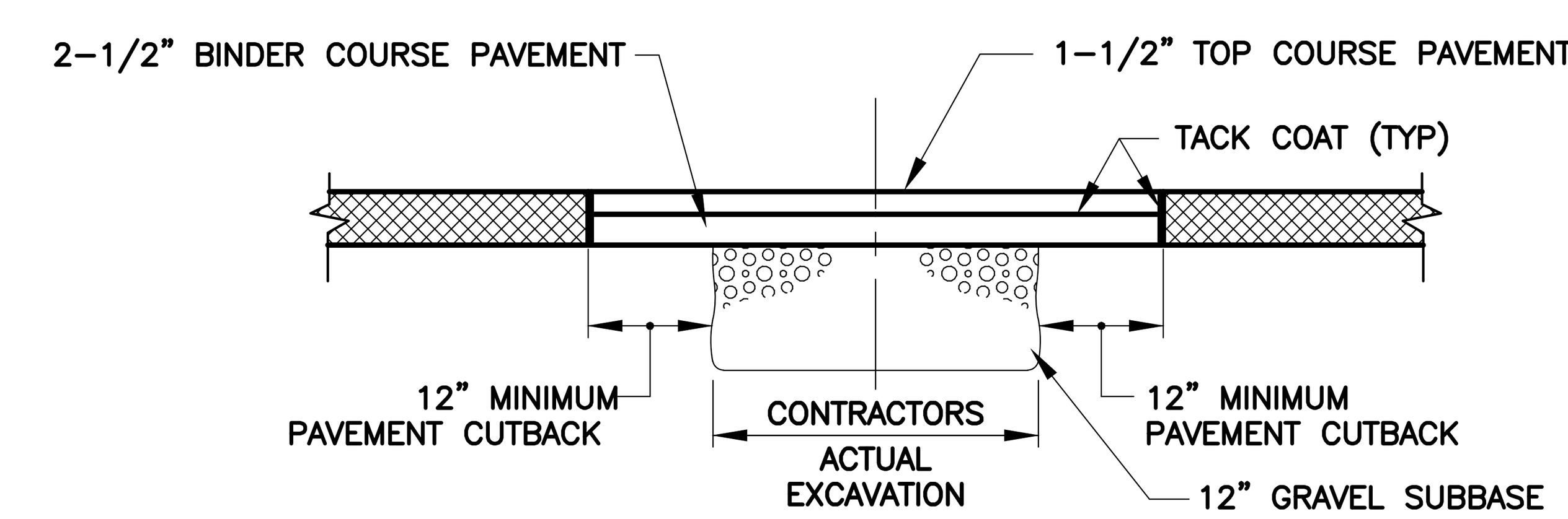

DETECTABLE TRACER TAPE (WHERE SPECIFIED)
FINISHED GRADE (SEE SPECIFICATIONS FOR SURFACE RESTORATION)
UNDISTURBED MATERIAL
TRENCH WIDTH (W)
COMPACTED BACKFILL
W/2
W/2
WOOD SHEETING, IF USED, SHALL BE LEFT IN PLACE BELOW THE LINE OF NARROW TRENCH LIMIT EXCEPT WHERE OTHERWISE INDICATED OR REQUIRED
LINE OF NARROW TRENCH LIMIT
NO ROCK OR UNEXCAVATED MATERIALS SHALL PROJECT BEYOND THIS LINE
12"
COMPACTED SELECT BACKFILL
DP
WHERE REQUIRED FILTER FABRIC SHALL BE PLACED AGAINST UNDISTURBED MATERIAL
S
S
COMPACTED CRUSHED STONE
COMPACTED CRUSHED STONE
UNDISTURBED SUBGRADE
LIMITS OF EXCAVATION & PAYMENT FOR ROCK EXCAVATION & BACKFILL SEE SPEC'S
LIMITS OF EXCAVATION & PAYMENT
HALF SECTION IN EARTH
HALF SECTION IN ROCK

NOTE:
FOR W, DP, & S, SEE TABLE A

TRENCH DETAIL

(SEWER, FORCE MAIN, STORM DRAIN)

N.T.S.



TRENCH WIDTH PAVEMENT
FULL SECTION

PAVEMENT REPLACEMENT DETAILS

N.T.S.

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Consultants:

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Issued For:
25% DESIGN

Scale:	NO SCALE
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Drawn By:	BDR
Reviewed By:	JIP
Approved By:	JIP
W&S Project No.:	ENG20-1044
W&S File No.:	---

Drawing Title:
CONSTRUCTION DETAILS I

Sheet Number:
C501

Rev: 1.8 Date: 10/24/2019

STOCKBRIDGE AVE. CULVERT REPLACEMENT PROJECT
ENGINEER'S ESTIMATE
6/17/2021

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	COST
-	COMPOST FILTER TUBE	151	LF	$ 2.50	$ 377.50
767.8	BALES OF HAY FOR EROSION CONTROL	23	EA	$ 23.50	$ 540.50
697.2	FLOATING SILT FENCE	60	FT	$ 85.00	$ 5,100.00
991.1	CONTROL OF WATER	1	LS	$ 100,000.00	$ 100,000.00
141.1	TEST PIT	20	CY	$ 125.00	$ 2,500.00
482.3	SAWCUT PAVEMENT	120	FT	$ 3.00	$ 360.00
632.2	INDIVIDUAL POST REMOVED AND RESET	8	EA	$ 100.00	$ 800.00
120	EXCAVATION	300	CY	$ 50.00	$ 15,000.00
146	DRAINAGE STRUCTURE REMOVED	2	EA	$ 886.09	$ 1,772.18
151.2	GRAVEL BORROW FOR BACKFILLING STRUCTURES	100	CY	$ 61.50	$ 6,150.00
-	PRECAST BOX CULVERT 46'x7'x4.4'	92	LF	$ 2,500.00	$ 230,000.00
-	PRECAST T-WALL	4	EA	$ 5,000.00	$ 20,000.00
-	3" RIVERSTONE BEDDING	84	TON	$ 80.00	$ 6,720.00
170	GRADING OF BANK	120	SY	$ 6.00	$ 720.00
765	SEEDING	80	SY	$ 2.79	$ 223.20
129.2	OLD PAVEMENT EXCAVATION	775	SF	$ 19.50	$ 15,112.50
156.8	CRUSHED STONE FOR SUB-BASE	29	CY	$ 45.00	$ 1,305.00
-	PAVING - BINDER	10	TONS	$ 180.00	$ 1,800.00
-	PAVING - TOP COURSE	12	TON	$ 180.00	$ 2,160.00
-	Mobilization/Demobilization	1	LS		$ 41,064.09
-	Contingency	1	LS		$ 82,128.18
				TOTAL:	**$ 533,833.14**

Weston & Sampson SM

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55 Walkers Brook Drive, Suite 100
Reading, MA 01867
tel: 978.532.1900

Permitting Feasibility Study

June 2021

STOCKBRIDGE AVENUE CULVERT REPLACEMENT

LOWELL, MASSACHUSETTS

PREPARED FOR:
CITY OF LOWELL

PREPARED BY:
WESTON & SAMPSON ENGINEERS, INC

TABLE OF CONTENTS

Page

Stockbridge Avenue Culvert Replacement

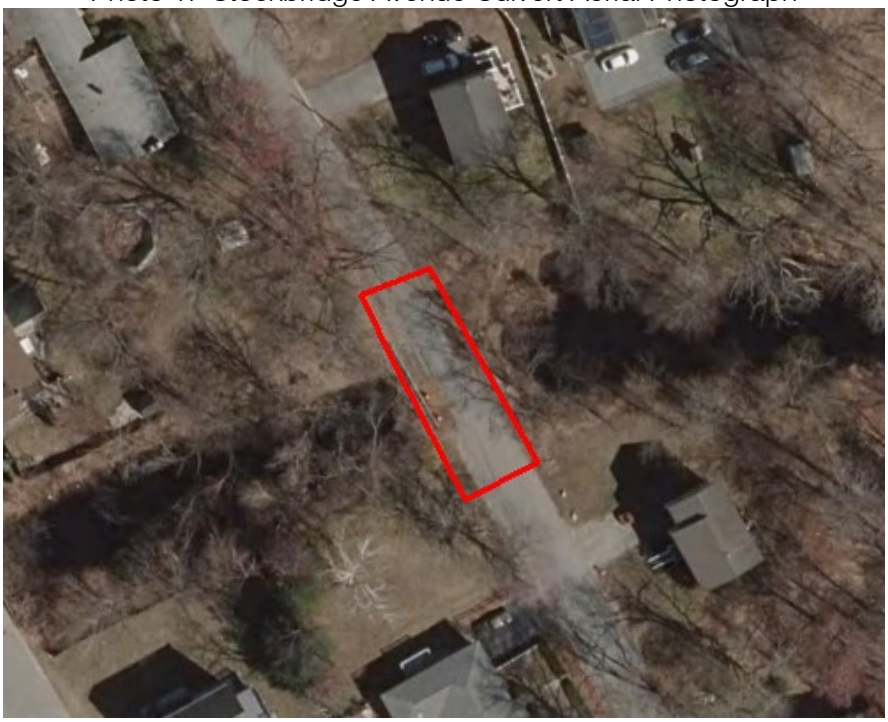
1.0 INTRODUCTION

The City of Lowell is already experiencing the impacts of climate change. Extreme rain events are becoming increasingly intense and frequent in much of the world, this is particularly the case in the Northeast region of the country. Changes in precipitation can cause a number of impacts locally, including flooding, damage from intense rainfall, and increased road pollutants in waterbodies. Stormwater flooding in particular can be caused by high amounts of impervious surfaces, undersized culverts, and insufficient stormwater detention and drainage. Therefore, stormwater infrastructure including culverts should be designed with climate change in mind to prepare these systems for the increasing flows projected during their design life.

The Stockbridge Avenue culvert was identified as a vulnerability during the MVP Planning Process and its vulnerability is well known and documented by the City. This led to its selection over other infrastructural assets as a priority action to resolve in 2021. The Stockbridge Avenue culvert failed during the devastating "Mother's Day Flood" in May 2006, which further contributed to flooding that impacted the Pawtucketville neighborhood. The May 2006 event caused the worst flooding recorded since the Hurricane of '38. The Pawtucketville neighborhood was particularly hard hit by this event, and has been identified by the City as a highly vulnerable, flood-prone area.

As part of the initial planning efforts for the Stockbridge Avenue culvert replacement project, the City of Lowell hired Weston & Sampson to conduct an environmental permitting feasibility study. This study is recommended so that the City understands local, state, and federal permits that may be associated with this project. This permitting feasibility study provides project specific permits, associated costs, and approval schedules. As project design is fine-tuned, so will be the list of required permits, costs, and timelines. Photo 1, below, provides the location of the Stockbridge Avenue culvert.

Photo 1. Stockbridge Avenue Culvert Aerial Photograph



2.0 METHODOLOGY

2.1 Resources

A number of resources were reviewed in order to inform this study of the environmental and human impacts that may occur as part of this project. Local, state, and federal regulations, and supporting documents, were reviewed to determine which permits will likely be required for the culvert replacement project. These resources include the following:

- City of Lowell Conservation Commission: Rules and Regulations
- City of Lowell Wetlands Ordinance
- City of Lowell Zoning Code
- City of Lowell Zoning Map
- City of Lowell Online GIS Maps (reviewed 3/18/21)
- Massachusetts Wetlands Protection Act (310 CMR 10.00)
- Massachusetts Environmental Policy Act (MEPA) (301 CMR 11.00)
- Massachusetts Chapter 91 regulations (310 CMR 9.00)
- Massachusetts 401 Water Quality Certification Regulations (314 CMR 9.00)
- Department of the Army – General Permits for the Commonwealth of Massachusetts (effective date 4/16/18)
- Federal Emergency Management Act (FEMA) website (data updated May 2021)
- MACRIS (State historic) online database (reviewed 3/18/21)

To determine which permits may be required for the project, environmental and human receptors maps were created to identify any constraints. Once identified, area impacts were then estimated to determine which permits would be required as many of these permits are triggered by impact areas. The additional supporting maps included:

- Figure 1 - Environmental receptors map, created by Weston & Sampson using MassGIS data layers on 3/18/21
- Figure 2 - Human receptors map, created by Weston & Sampson using MassGIS data layers on 3/18/21
- Figure 3 - FEMA flood zone map, created 3/18/21
- Figure 4 - City of Lowell Zoning map, downloaded 3/18/21

The results of the environmental and human receptor mapping are discussed in further detail in the next section.

2.2 Environmental and Human Receptors Mapping

A preliminary desktop survey of environmental and human receptors in the area was conducted in ArcView using MassGIS data layers. The environmental resources map (see Figure 1) contains the following information:

- Aerial photography
- Perennial rivers and intermittent streams (USGS 1:25,000 Topographic Quadrangle)
- Ponds, lakes, oceans, reservoirs (USGS 1:25,000 Topographic Quadrangle)

- MassDEP mapped wetlands (Stereo color infrared photography at 1:12,000 scale)
- 100-year flood zone (FEMA, 2017)
- Natural Heritage and Endangers Species Program (NHESP) Estimated and Priority habitats (NHESP, 2017)
- NHESP certified vernal pools (NHESP, 2017)
- Areas of Environmental Concern (ACECs) (EEA, 2009)
- 2-foot contours created from LiDAR data

The human resource receptors map (see Figure 2) contained the following information resources:

- State registry of historic places
- Underground storage tanks
- Tier classified sites
- Public water supplies
- Chapter 21E sites
- MassDEP major facilities (large quantity generators)
- Surface water supply protection zones
- Groundwater supply protection zones
- Landfill facilities
- Open Space / Conservation Area

The map provides information on any hazardous sites, water supply protection areas and protected open space, all of which may require additional approvals other than environmental approvals to move forward with the project.

In addition to the MassGIS 100-year flood zone mapping, a more accurate 100-year flood zone was mapped using the online Federal Emergency Management Agency (FEMA) website (https://msc.fema.gov/portal/home as of 3/18/21). See Figure 3 for the FEMA map.

Additional mapped areas that were reviewed are provided below.

2.3 Other Investigations

The City of Lowell Zoning map was reviewed (see Figure 4) to determine what zoning district the project is located within. Knowing the zoning district is important as municipalities have rules and regulations that dictate what are allowable uses and proper setbacks on properties depending on the zoning district.

A review of the MACRIS (State historic) online database did not provide any results of historic buildings, area, burial ground, object, or structure along Stockbridge Avenue.

Based on a review of the above-mentioned resources, the following sections provide discussions of project requirements at the local, state, and federal level.

3.0 FINDINGS

Results from the above-mentioned mapping efforts shows the presence of the following either at or near the culvert replacement site:

- The site is zoned as "Suburban Neighborhood Single Family (SSF)"
- Protected environmental resources include:

    - Bank
    - Land under Water
    - 25-foot Riverfront Area
    - Bordering Land Subject to Flooding (100-year flood zone)

Lowell Heritage State Park (owned and managed by Massachusetts Department of Conservation and Recreation, or DCR) is located approximately 200 feet east of the culvert. Work will not impact the state park property.

These findings were used to develop the permitting, costs and schedule discussions that are provided in the following sections.

3.1 Local Permitting discussion

A review of the City of Lowell Conservation Commission: Rules and Regulations and City of Lowell Wetlands Ordinance indicate that there are some standards that are more stringent or more inclusive when compared with the Massachusetts Wetlands Protection act. Some of these items include:

- Minor activities within the riverfront area will require filing of a Notice of Intent
- Abutters within 300-feet of property need to be notified about any public conservation commission meetings to discuss the project

When reviewing the environmental receptors map (Figure 1) it appears that the limit of work for the culvert replacement project will fall under the jurisdictional area of the Lowell conservation commission. As such, a wetlands Notice of Intent (NOI) would be required. While the NOI follows the Massachusetts Wetlands Protection Act requirements, it is considered a local permit. The Massachusetts Wetlands Protection Act (MGL c.131 § 40) (WPA) and implementing regulations (310 CMR 10.00) is a State statute administered locally. Jurisdiction under the WPA would occur for proposed removal, fill, dredge and/or alteration of a wetland resource protected under the WPA. The WPA requires the preparation of an NOI for work within a wetland resource area, work within 100 feet of certain resource areas and/or within the 100-year flood plain. The general performance standards for work or activities occurring within each wetland resource are identified in the WPA.

Assuming work would consist of just culvert replacement, a NOI submission would be required for work in the following protected resource areas:

- 25-foot riverfront area
- Bordering land subject to flooding (100-year flood zone)
- Bank

- Land under water

According to the Lowell zoning map (Figure 4), the culvert replacement work is within the Suburban Neighborhood Single Family zone. This project is not technically on a specific parcel as this is work in the roadway. Additionally, no structures will be constructed, and this is considered replacement work, so no change in use. As such, there are no zoning limitations to be concerned with for this project.

A discussion of applicable state permit follows.

3.2 State Permitting Discussion

Numerous state regulations were reviewed to determine if any state environmental permits would be required for the culvert replacement project. A discussion of state environmental permits is provided below, which includes a determination of whether each state environmental permit would be required.

Massachusetts Environmental Policy Act (MEPA) (301 CMR 11.0)

The purpose of MEPA and 301 CMR 11.00 is to provide meaningful opportunities for public review of the potential environmental impacts of a project for which a permit is required from an agency of the Commonwealth, and to assist agencies of the Commonwealth in using all feasible means to avoid damage to the environment or, to the extent damage to the environment cannot be avoided, to minimize and mitigate damage to the environment to the maximum extent practicable. MEPA's review is intended to inform the participating agencies of the project, to maximize consistency between agency actions, and to facilitate coordination of all environmental and development review and permitting processes of the Commonwealth. The MEPA process provides an opportunity for the project proponent to identify required agency actions and to describe and analyze how the project will comply with applicable regulatory standards and requirements. Through review of the MEPA documents, each participating agency can comment on aspects of the project or issues regarding its agency action that require additional description or analysis.

MEPA review is required when one or more review thresholds are met or exceeded and there is a state action (i.e., state funding or state permitting). A MEPA submission should not be required for this project because none of the thresholds, including land under water impacts > ½ acre or 500 linear feet of bank impacts, are triggered. If these impacts are increased during final design, then this permit will need to be reconsidered.

Massachusetts Waterways Regulation (310 CMR 9.00) (Ch. 91 Review)

310 CMR 9.00 was enacted for the following purposes:

(1) to protect and promote the public's interest in tidelands, Great Ponds, and non-tidal rivers and streams in accordance with the public trust doctrine,

(2) to preserve and protect the rights in tidelands of the inhabitants of the Commonwealth by ensuring that the tidelands are utilized only for water-dependent uses or otherwise serve a proper public purpose,

(3) protect the public health, safety, and general welfare as it may be affected by any project in tidelands, Great Ponds, and non-tidal rivers and streams,

(4) support public and private efforts to revitalize unproductive property along urban waterfronts in a manner that promotes public use and enjoyment of the water, and

(5) foster the right of the people to clean air and water, freedom from excessive and unnecessary noise, and the natural, scenic, and historic, and esthetic qualities of their environment.

Because the project will include work within a navigable waterway, the project will fall under Chapter 91 jurisdiction and Chapter 91 license submittal will be required.

Massachusetts 401 Water Quality Certification (314 CMR 9.00)

Projects in Massachusetts involving the discharge of dredged or fill material, dredging, or dredged material disposal activities in waters of the United States, which require federal licenses or permits are subject to 314 CMR 9.00. 314 CMR 9.07 also applies to any dredging project and the management of dredged material within the marine boundaries and at upland locations within the Commonwealth.

The purpose of the 401 Water Quality Certification (WQC) is to ensure that proposed discharges of dredged or fill material, dredging and dredged material disposal in the waters of the United States within the Commonwealth comply with the Surface Water Quality Standards and other appropriate requirements of the state law.

One of the thresholds for a 401 WQC is dredging more than 100 cubic yards (CY) of material from a stream or impacting more than 5,000 square feet (sf) of land under water (LUW). Based on the 25% design plans, it appears that an estimated 1,700 sf of LUW will be impacted with minimal dredging (<100 CF) being required. As such it does not appear that this project will trigger any 401 WQC thresholds and therefore would not require a 401 WQC submission. If these impacts are increased during final design, then this permit will need to be reconsidered.

Massachusetts Endangered Species Act (MESA) (321 CMR 10.00)

The MESA review, under the Massachusetts Endangered Species Act (MESA) (321 CMR 10.00), assists proponents with projects or activities that will take place in mapped Priority Habitat in order to avoid a take of a state-listed species. Because there is no endangered species habitat within the project site, a MESA Project Review filing is not required.

Massachusetts Historic Commission (MHC) (Section 106)

MHC Section 106 reviews are required for projects with State action, including State funding or State permits. MHC maintains an online database with historically significant locations. A search of the MACRIS online database did not show any historical results on Stockbridge Avenue. However MHC submission will be required because there will be a State action (Chapter 91 submission), for this project.

The next section, below, provides a discussion of permitting the culvert replacement project at the federal level.

3.3 Federal Permitting Discussion

US Army Corps of Engineers General Permits for the Commonwealth of Massachusetts

The U.S. Army Corps of Engineers (Corps) regulates construction and other work in navigable waterways under Section 10 of the Rivers and Harbors Act of 1899, and has authority over the discharge of dredged or fill material into "waters of the United States" (a term which includes wetlands and all other

aquatic areas) under Section 404 of the Clean Water Act. Under these laws, those who seek to carry out such work must first receive a permit from the Corps. The program considers the full public interest by balancing the favorable impacts against the detrimental impacts. This is known as the "public interest review." The program reflects the national concerns for both the protection and utilization of important resources.

In Massachusetts, regional Corps general permits can be issued for certain activities with no more than minimal adverse effects on the aquatic environment. Because there will be work within navigable waters or waters of the United States for this project, a Corps general permit submission will be required. This submission would require either a Self-Verification Notification (SVN) or Pre-Construction Notification (PCN). A SVN would be required for impacts less than 5,000 sf below ordinary high water (OHW). A PCN would be required for impacts greater than 5,000 sf below OHW. Based on the 25% design plans, it appears that an estimated 1,700 sf of area below OHW will be impacted and, therefore, a SVN will be required for this project. If these impacts are increased during final design, then this permit will need to be reconsidered.

US Environmental Protection Agency (EPA) Construction General Permit (CGP)

If more than one acre of land will be disturbed for a project, a US Environmental Protection Agency (EPA) National Pollution Discharge Elimination System (NPDES) Construction General Permit (CGP) will be required. As part of this submission, a stormwater pollution prevention plan (SWPPP) will need to be developed.

It is assumed less than 1 acre of land will be disturbed and therefore would not require an EPA CGP.

Estimated costs for local, state, and federal review are provided in the next section.

3.4 Costs

Local reviewing agencies that will likely need to be consulted include the Lowell Conservation Commission. Costs to prepare, submit and respond to up to two (2) rounds of reviewer comments for a Notice of Intent are in the $8,000 - $12,000 range.

At the state level, the following submissions (and associated costs) will likely be required:

- Chapter 91 submission: $6,000 - 8,000,
- MHC submission: $1,000 - $1,500,

At the federal level, following submissions (and associated costs) will likely be required:

- ACOE SVN – for less than 5,000 sf of impacts below Ordinary High Water: $2,000 - $3,000,

Overall permitting costs this culvert replacement project would be in the $17,000 and $24,500 range. Table 1, below, summarizes these costs.

Figure 1. Costs Summary

	Minimum	Maximum
Local Considerations		
Notice of Intent	$8,000	$12,000
State Considerations		
Chapter 91	$6,000	$8,000
MHC	$1,000	$1,500
Federal Considerations		
ACOE SVN	$2,000	$3,000
Total Costs	$17,000	$24,500

The above-mentioned costs include the following:

- Preparation of application form(s) and address all relevant elements
- Preparation of Project Narrative providing history and justification of project
- Identification of resources and methods for mitigation and restoration as well as minimization of impacts
- Incorporation of plans illustrating project limits and resource areas
- Attend and assist in presentation of project at public site meetings
- Continued communication with reviewing agencies throughout the permit review period
- Incorporation of agency and client comments from site meeting

Permitting costs do not include the following:

- Engineering design
- Stormwater Report
- Plan set development
- Additional studies

Review times for the above-mentioned permits are provided, below

3.5 Schedule

Time required to gain permit approval varies based on the permit. Below is a list of permits with general time required to gain approval once permits have been submitted:

- NOI: 1 - 3 months
- MassDEP Ch. 91: up to 9 months
- MHC: 1 month

- ACOE SVN: 1 month (formal approval is not issued)

There is not a set order that permits need to be submitted. The required permits noted above can all be submitted concurrently. The permit with the longest review time for this project is the MassDEP Chapter 91 submission, which can take up to nine (9) months to gain approval. Within the last few years, we have experienced an even longer review time for this permit. Total permitting review time should be considered between nine to twelve months.

4.0 SUMMARY AND CONCLUSIONS

4.1 Summary

As part of the initial planning efforts for the Stockbridge Avenue culvert replacement project, the City of Lowell hired Weston & Sampson to conduct an environmental permitting feasibility study for the project.

A number of resources were used to inform this study of the environmental and human impacts that may occur as part of this project. Additionally, local, state, and federal regulations were reviewed to determine which permits will likely be required for this project.

Results from the environmental resource mapping shows that the following environmental resource areas would likely be impacted:

- 25-foot Riverfront Area
- Land under water
- 100-year flood zone
- 100-foot buffer zone (off of bank)

Based on the human receptor map, it does not appear that there are any hazardous sites, water supply protection areas, or protected open space within the project area.

4.2 Conclusion

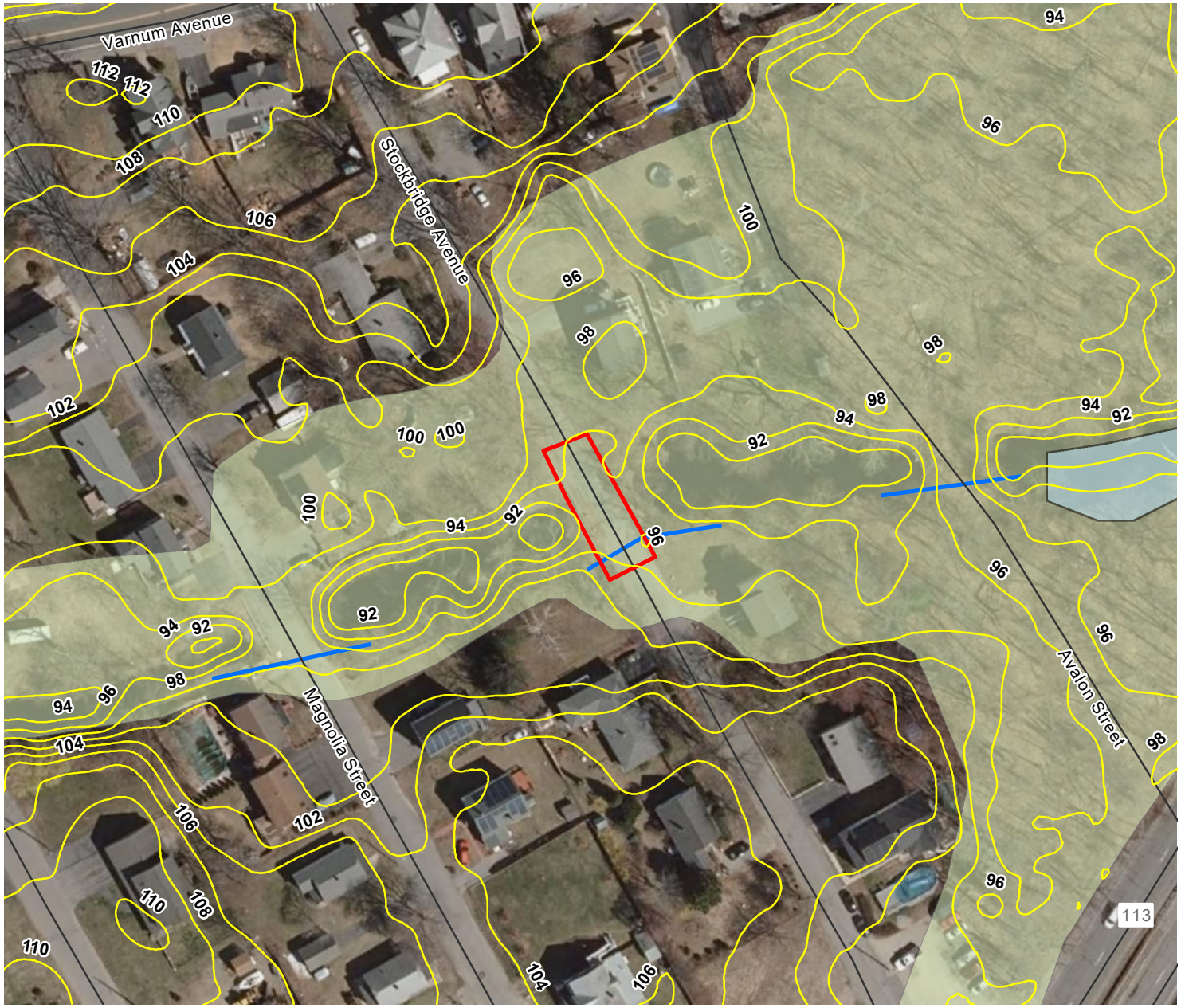
The following environmental permits will be required for this project:

- Notice of Intent
- Chapter 91
- ACOE SVN
- Section 106 MHC

This permitting effort would cost between $17,000 and $24,500 and take between nine to twelve months to gain permit approval.

Figures

Path: \\wse03.local\WSE\Projects\MA\Lowell MA\MVP Action Grant - Claypit Brook CIP\Permitting\GIS\permitting strategy\Environmental Receptor - Lowell.mxd **User:** higginsm **Saved:** 3/22/2021 8:48:43 AM **Opened:** 3/22/2021 8:49:17 AM



N
W E
S

100 50 0 100
Feet

Data Source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

Legend

- Contouors (2-foot)
- Work Area
- Perennial Stream
- Intermittent Stream
- Marsh/Bog
- Wooded marsh
- Cranberry Bog
- Salt Marsh
- Open Water
- Reservoir (with PWSID)
- Tidal Flats
- Beach/Dune

ACECs

- ACECs

NHESP Habitats

- NHESP Estimated Habitats of Rare Wildlife
- NHESP Priority Habitats of Rare Species
- NHESP Certified Vernal Pools
- NHESP Potential Vernal Pools

100-Year Flood Zone

- 100-Year Flood Zone

Outstanding Resource Waters

- Public Water Supply Contributor
- ORW for ACEC
- ORW for both Water Supply and Other

FIGURE 1

Stockbridge Avenue Culvert
Lowell, MA

Environmental Resource Map

Weston & Sampson

N
W E
S

100 50 0 100
Feet

Data Source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

Legend

- Work Area
- State Registry of Historic Places
- All Underground Storage Tanks

Tier Classified Sites

- Tier 1A
- Tier 1B
- Tier 1C
- Tier 1D
- Tier II

PUBLIC WATER SUPPLIES

- Community Ground Water
- Community Surface Water
- Surface Distribution Site
- Non-Transient Non-Community
- Transient Non-Community
- Proposed Well

CH21E AUL Sites

- CH21E AUL Sites

DEP BWP Major Facilities

Large Quantity Generators (LQG)

- EPA/RCRA-regulated Hazard. Waste
- MA-regulated Hazard. Waste
- MA and EPA/RCRA-regulated Hazard. Waste
- Solid Waste Facilities - All Landfills
- IWPAs
- Zone I
- DEP Approved Zone IIs
- Zone A
- ZONE B

Open Space / Conservation Land

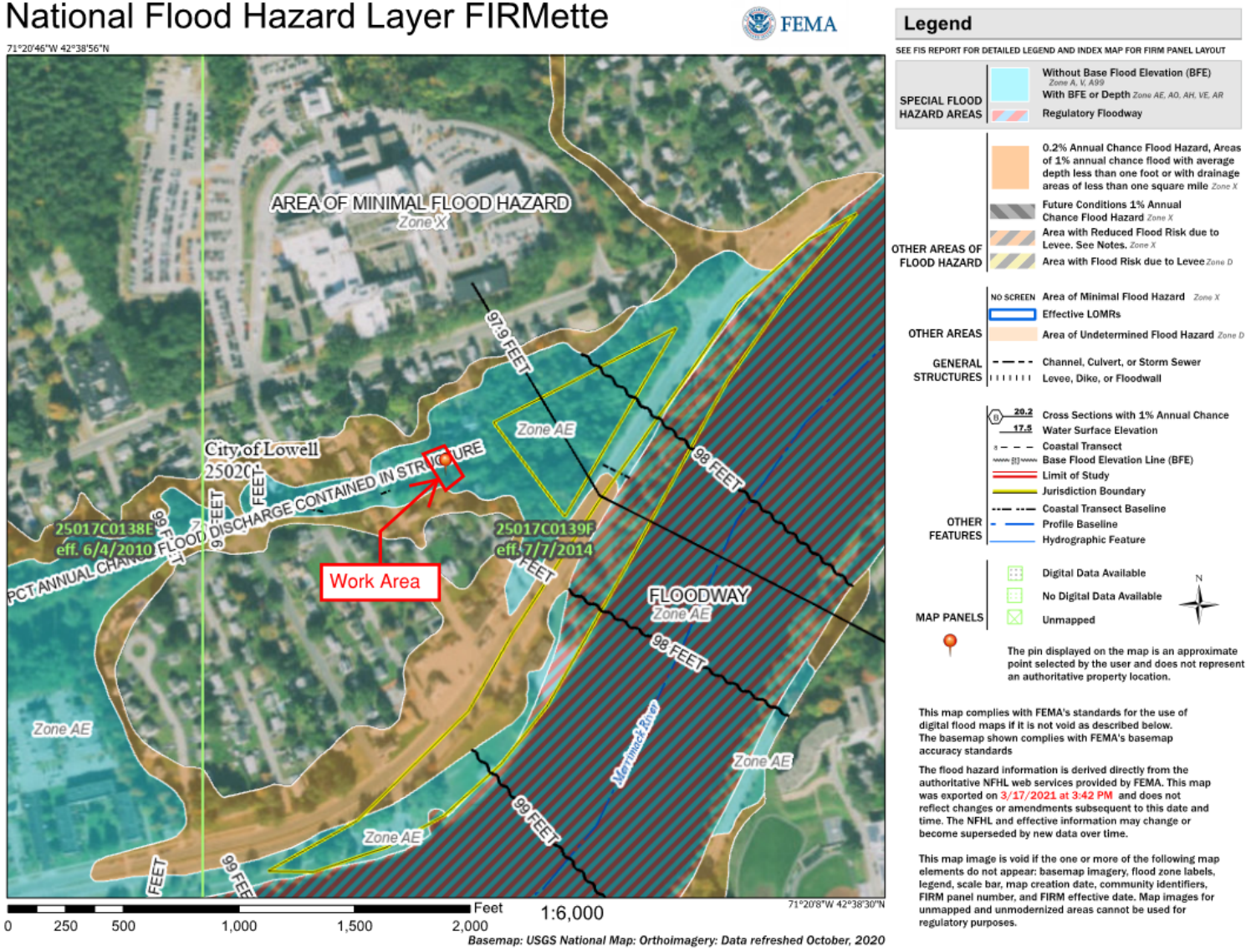
- State

FIGURE 2

Stockbridge Avenue Culvert
Lowell, MA

Human Receptor Map

Weston & Sampson



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 Cross Sections with 1% Annual Chance
- 17.5 Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 3/17/2021 at 3:42 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

FIGURE 3
Stockbridge Avenue Culvert
Lowell, MA

FEMA Map

Weston & Sampson

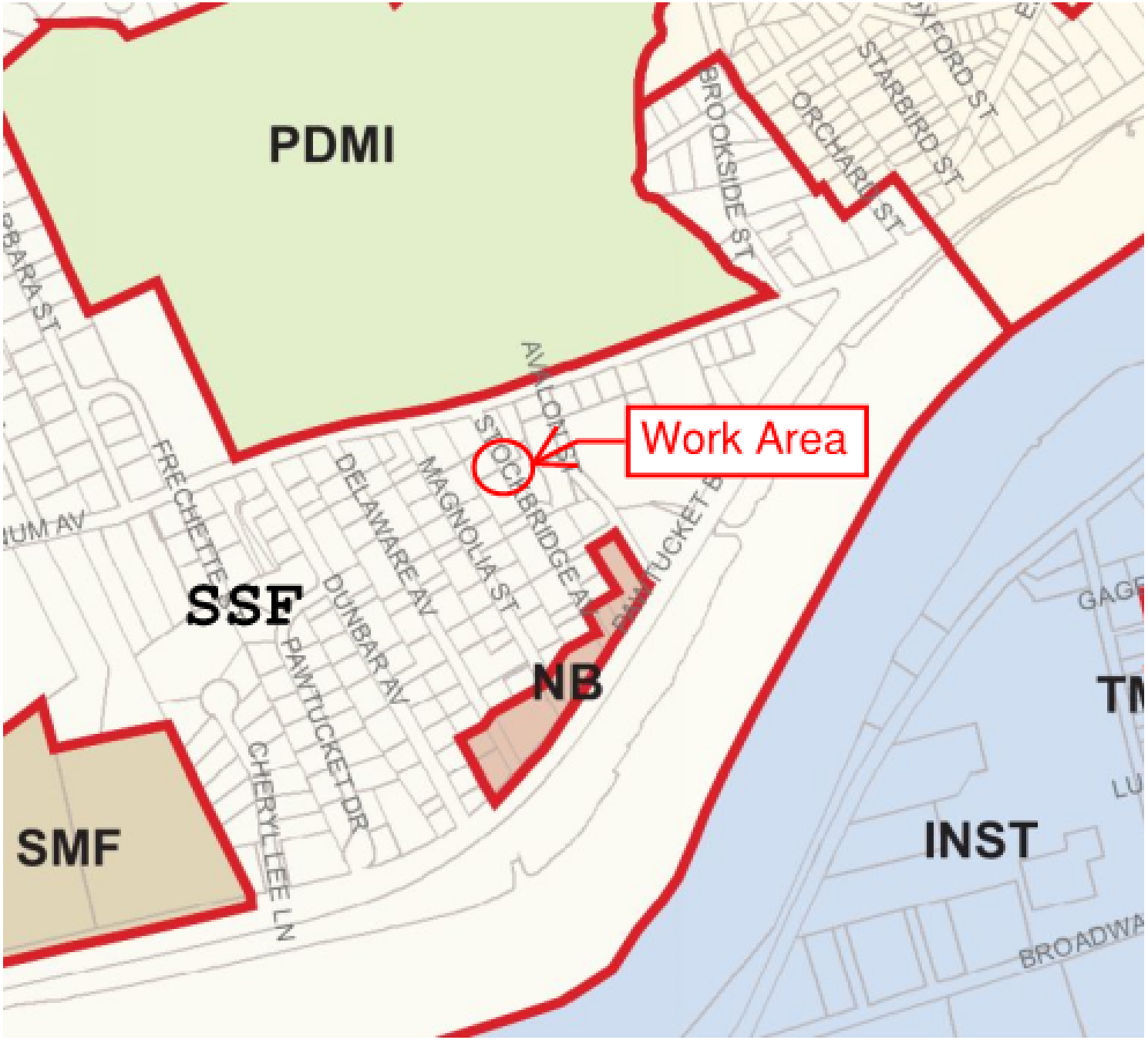


FIGURE 4
Stockbridge Avenue Culvert
Lowell, MA

Zoning Map

Weston & Sampson