December 2020

Watershed-Wide Analysis to Optimize and Coordinate Regional Stormwater Management in the Upper Mystic River

MVP Municipal Vulnerability Preparedness

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Mystic River Watershed Association

Weston & Sampson

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cbi Consensus Building Institute

Prepared For:

Resilient Mystic Collaborative

In Coordination With

Upper Mystic River Watershed communities:
Town of Arlington, Town of Belmont,
Town of Burlington, City of Cambridge,
City of Everett, Town of Lexington,
City of Malden, City of Medford, City of Melrose,
Town of Reading, Town of Stoneham,
Town of Wilmington, Town of Winchester,
City of Woburn

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workshop facilitated by

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Preparedness Program,
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City of Cambridge

Financial assistance provided by the Executive Office of Energy & Environmental Affairs (EEA), under the FY19 Municipal Vulnerability Preparedness Grant Program. This program provides support for cities and towns in Massachusetts to begin the process of planning for climate change resiliency and implementing priority projects. The program helps these communities to utilize the latest science and data, and identify opportunities to take action to reduce risk and build resilience.

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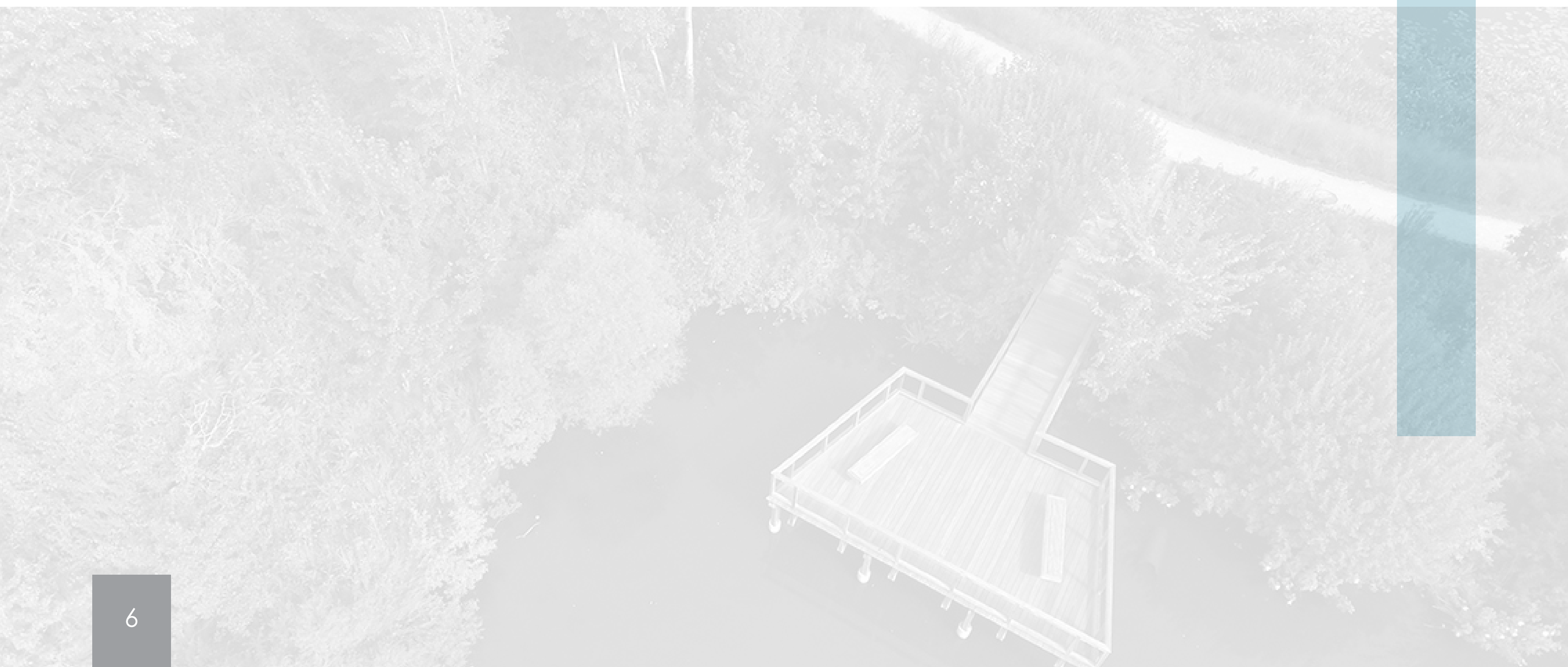

EXECUTIVE SUMMARY

Regional Stormwater Management

Extreme precipitation, such as increased or modified intensity, duration, and frequency of storm events, is one of the impacts of our changing climate. Managing the results of extreme precipitation events, and the stress it places on stormwater infrastructure, is a major challenge for municipalities, and suggests the need for regional-scale solutions. Such regional-scale solutions are exciting opportunities for collaboration and result in projects with multiple benefits. With guidance from the City of Cambridge and the Mystic River Watershed Association (MyRWA), a multi-disciplinary team of consultants worked with the Resilient Mystic Collaborative's (RMC) Upper Mystic Stormwater Working Group (UMSWG) to collect data and feedback from 17 municipalities in the Upper Mystic Watershed. The objective was to collaborate, identify, and act upon opportunities of watershed-scale flood mitigation. This collaborative project is the essential first step for RMC communities to make the case for economic, environmental, and social benefits of collective action.

Phase 1 Project Background and Approach

This report summarizes Phase I of the Upper Mystic River Watershed Regional Stormwater Management Project, which was initiated in August 2019 and completed in December 2020.

The project received grant funding from the MA Municipal Vulnerability Preparedness (MVP) Program, as well as financial support from the Barr Foundation, with grant management support from the City of Cambridge. The project scope included data collection, stakeholder engagement, hydrologic and hydraulic (H+H) modeling and analysis, desktop screening of hundreds of sites, field investigations, consensus-building, and conceptual design. Project deliverables include an updated regional watershed H+H model, a list of preferred sites for installation of constructed stormwater wetland green infrastructure (GI), 10% conceptual design of the constructed wetlands at the selected sites, and recommendations for Active Reservoir Management (ARM) at select sites in the watershed to address precipitation-based flooding. Participating municipalities benefitted from the project process, assessment of best available scientific data at the regional scale, mutual effort and collaboration, and project deliverables which provide tools and a framework for identifying near-term and future flood mitigation opportunities.

Phase 1 included extensive stakeholder outreach throughout the watershed and incorporated feedback at multiple stages. The RMC served as a uniting space for the 17 communities to share data, allowing integration of individual municipalities' storm system data into a calibrated regional InfoWorks Integrated Catchment Modeling 2-Dimensional (ICM-2D) flood model. The UMSWG and consultant team, henceforth referred to as the Project Team, conducted a GIS-based desktop screening analysis to identify viable GI sites. These sites were vetted by the RMC communities, leading to consensus-building for specific GI opportunities for regional stormwater management. These efforts resulted in ranked, mapped, and characterized descriptions for each of these significant regional GI opportunities, along with an understanding of the remaining need for other flood management strategies.

Phase 1 Results

The 10% proposed conceptual designs of constructed stormwater wetlands at the top 6 GI sites in the watershed were integrated into the watershed wide regional ICM-2D model (hereafter referred to as the "2020 regional stormwater model" or "regional stormwater model"). The regional stormwater model was run for a total of ten (10) storm and tide combinations, considering both present and future climate conditions. In addition to running the regional stormwater model for the top 6 GI sites and ARM at select sites, a watershed-wide reduction of 30% directly connected impervious area (DCIA) was also simulated. Results from these model simulations indicate the need for additional flood mitigation strategies beyond the addition or restoration of distributed watershed storage. The mapping tools developed for the project- which include the revised Mystic Viewer, a web visualization tool – may be used in the future to inform flood mitigation planning in the watershed by providing new baseline data, such as for storm events, such as 1-, 2-, 5-, and 10-year precipitation events. This is an important achievement of this project since these data were not previously generated or available at the regional watershed scale.

Key deliverables created through Phase I of this project allowed RMC member municipalities to build consensus around six priority wetland-scale project sites to advance to 10% concept design, while also building a larger portfolio of future GI and ARM opportunities to be prioritized for implementation in future phases for regional stormwater management. The six GI concepts include over 13 acres of stormwater wetlands that manage over 1,000 acres of upstream drainage, creating over 14 million gallons (MG) of new flood storage and cumulatively reducing phosphorus on the order of 600 lbs./year. To the authors' knowledge, the Mystic Viewer mapping tool, which made modeled flood scenario maps accessible to all Upper Mystic municipalities, is the first application that specifically incorporates the operational procedures at the Amelia Earhart Dam (AED).

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PROJECT CONTEXT

Upper Mystic River Watershed

The Mystic River Watershed is a network of streams, rivers, and lakes, all draining into the Mystic River. The watershed has been an integral part in the development of the 21 Greater Boston communities it connects.

The Mystic River Watershed covers 76 square miles or roughly 1% of the land area of Massachusetts. It includes all the land area that drains into the Mystic River. Its headwaters begin in Reading, MA and form the Aberjona River, then flow into the Upper Mystic Lake in Winchester. From the Lower Mystic Lake, the Mystic River flows through Arlington, Somerville, Medford, Everett, Chelsea, Charlestown, and East Boston before emptying into Boston Harbor.

The Upper Mystic is a geographic entity defined as the freshwater portion of the watershed above the Amelia Earhart Dam (see **Figure 1**).

This project, the Upper Mystic River Watershed Regional Stormwater Management Project, is one of several concurrent projects to address climate change vulnerabilities to flooding in the Mystic River watershed, as identified in see **Figure 1**. The other two RMC regional projects include assessing the infrastructure and social vulnerability of the Lower Mystic (MVP grant) and incorporating green infrastructure into Hazard Mitigation Plans and municipal Capital Investment Plans (EPA grant).

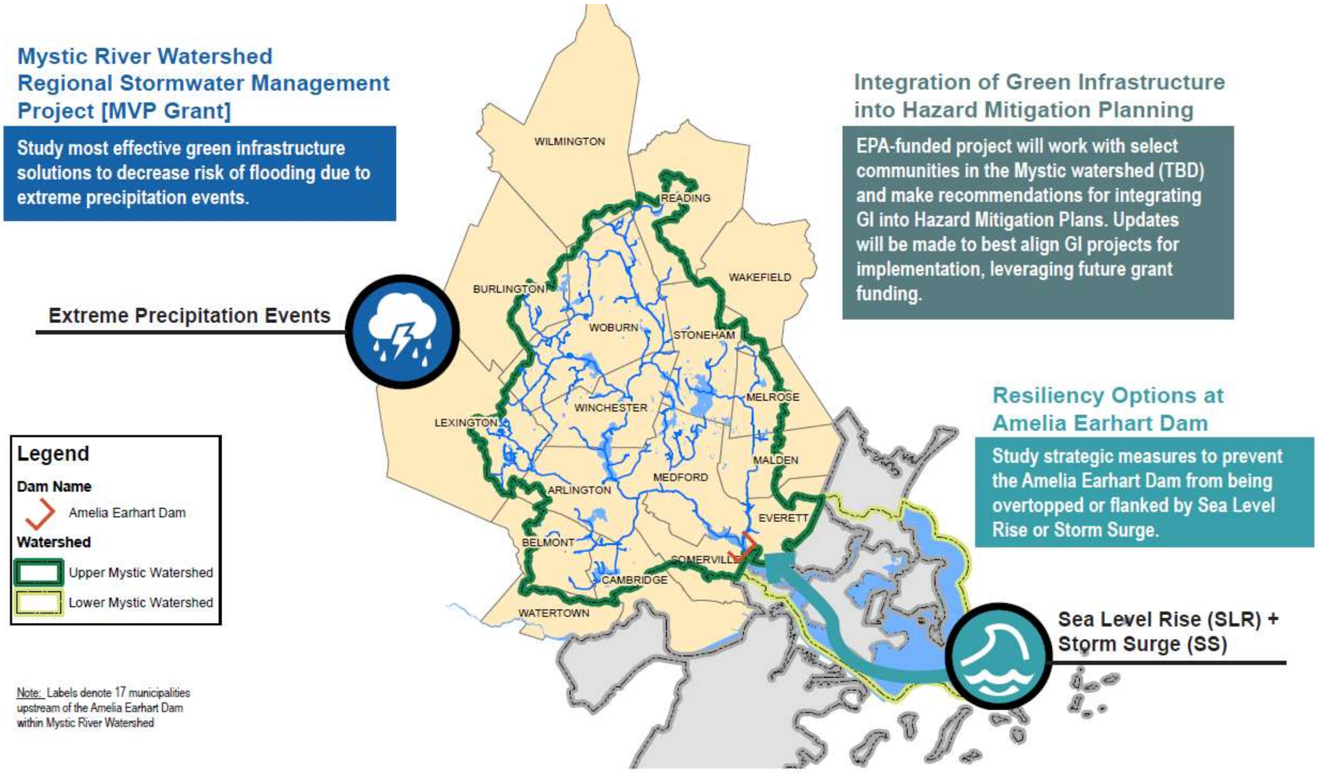

Figure 1: Related Regional Projects and Initiatives in the Mystic River Watershed

Resilient Mystic Collaborative

The Resilient Mystic Collaborative is a partnership among neighboring communities in Greater Boston's Mystic River Watershed working to protect the people and places within the watershed from climate-intensified risks[1]. The RMC includes both Upper and Lower Mystic River communities and multiple working groups, one of which is the Upper Mystic Stormwater Working Group (UMSWG). RMC communities include Arlington, Belmont, Boston, Burlington, Cambridge, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Reading, Revere, Somerville, Stoneham, Wakefield, Watertown, Winchester, Winthrop, and Woburn. The 17 Upper Mystic watershed municipalities are a subset of the RMC that coordinated the submission of this MVP regional stormwater management project and are also completing (or are in the process of completing) their individual MVP planning reports. Many of these communities are planning or implementing additional local actions to address flooding, and are pursuing subsequent MVP grant opportunities informed by this Project. This group recognizes that by working regionally, downstream communities benefit from regional flood and drought management while upstream communities get more funding for improved open space.

1 https://resilient.mysticriver.org/

In January 2019, RMC municipalities unanimously approved the following vision statement:

- We are data-driven, using cost-effective, watershed-wide, ground-truthed analyses to understand and prioritize our collaborative work.
- We are action-oriented. We prioritize, facilitate funding for, and implement cost-effective, multiple-benefit solutions that benefit the watershed as a whole through collective actions and/or site-specific interventions.
- We share a pragmatic, optimistic vision that recognizes the Mystic River as a tremendous asset that connects our 21 watershed municipalities.
- We are mutually supportive, sharing knowledge and resources across municipal boundaries to increase the resilience of our most vulnerable people and places.
- We have the collaborative structure, trust, and participation to maximize our influence and effectiveness in completing impactful projects and sharing our lessons learned.

The RMC consists of multiple working groups, including the Upper Mystic Stormwater Working Group (UMSWG). The other working groups include Social Resilience, Lower Mystic, and Advocacy and Outreach. The goal of the Upper Mystic Stormwater Working Group is to coordinate regionally stormwater projects and policies to reduce flooding and improve stormwater quality. As part of this project, the Barr Foundation has generously provided funding support for day-to-day activities of the RMC, in the form of support provided to the UMSWG. This support covered time and expense for RMC facilitators, and a dedicated social resiliency organizer.

Problem Statement

Inland (Precipitation-based) Flooding in the Upper Mystic Watershed

Nearly half of the land in the Upper Mystic Watershed has been built on or paved over. This prevents heavy rain or rapid snowmelt from soaking into the ground and puts Mystic River Watershed communities at risk of freshwater flooding. The Upper Mystic is already currently experiencing experiences chronic flooding annually, resulting in infrastructure, property, and economic damages. Rainfall projections produced by municipalities and regional entities describe significant increases in the average 10-year, 24-hour design storm, thereby increasing flooding risk. There is growing concern for more damaging and more frequent intense rainfall events (i.e., short duration, but higher intensity storms) that quickly can overwhelm existing stormwater systems and cause substantial damage to built and natural environments. Substantial damage includes contaminated stormwater/sewage inundation of basements and streets, flood damage to private and public property, riverbank erosion, acute toxin and nutrient pollution from surface flooding, and combined sewer overflows.

In March 2010, the Mystic River Watershed experienced a 25-year precipitation event during a Nor'easter that caused the Mystic River and its tributaries to flood significantly in multiple communities. Memories of that storm, along with increasingly frequent smaller flood events, have made stormwater management a top priority for

RMC communities. A major challenge, however, is developing consensus on the creation of affordable regional solutions within the watershed. For example, the more urbanized, downstream communities lack affordable options or physical opportunities to create a meaningful number of green infrastructure projects while upstream communities lack the local drivers and financial resources to create stormwater wetlands or other stormwater storage/infiltration projects that benefit downstream neighbors. Traditional engineering practices that convey water quickly via stormwater systems to the Mystic River may address upper municipalities' flooding while exacerbating downstream flooding. While there is a large amount of topographic relief between the upper watershed and the basin just upstream of Amelia Earhart Dam (AED), there are many hydraulic restrictions throughout the watershed that impact the location and magnitude of inland stormwater flooding. These include large ponds/reservoirs with flow control structures (e.g., dams, embankments, gates, weirs, stoplogs), buried/culverted streams, and other built infrastructure and channel constrictions (e.g., bridge crossings, floodplain development). These outstanding issues highlight the need for finding regional solutions that can benefit all municipalities.

Coastal Flooding, Sea-level Rise, and Downstream Conditions at the Amelia Earhart Dam

While not a focus of this project, concurrent efforts are underway led by the City of Cambridge and the Massachusetts Department of Conservation and Recreation (DCR) to better understand coastal flood risks in the Mystic River watershed from sea level rise and storm surge. These concurrent efforts have informed the present and future tidal and coastal boundary conditions that were used to inform the downstream boundary conditions at the Amelia Earhart Dam of the regional stormwater model as part of this project.

In the previous version of the regional model, pumping operations at the Dam simulated processes by which the lower parts of the Upper Mystic basin are drained during major storm events. By 2070, high tide conditions exacerbate impacts of precipitation-based flooding, as gravity-based drainage (through the Dam into Boston Harbor) is hindered by sea level rise. While coastal storm events are not modeled as part of this analysis, downstream tailwater conditions for tidal and sea-level rise scenarios greatly impact lower basin drainage upstream of the Dam.

PROJECT GOALS AND SCOPE

Objectives and Primary Goals

The primary goals of this project were to: 1) improve watershed planning tools and data sharing, 2) identify opportunities to scale up nature-based solutions, and 3) explore innovative technologies such as Active Reservoir Management (ARM). These goals are further described in the following paragraphs.

Improve Watershed Planning Tools and Data Sharing

While some communities in the Upper Mystic River Watershed have their own hydraulic models, many do not and are benefiting now from a ***regional model*** for the Upper Mystic River Watershed (hereafter the "regional model"). In the absence of local or regional flood mapping to inform public infrastructure investment, these communities often rely on flood mapping products from the Federal Emergency Management Agency (FEMA), which were established for flood insurance purposes and not planning. Significant limitations exist with these flood mapping products. For example, FEMA's Flood Information Rate Map (FIRM) mapping scenarios are limited to large and infrequent historic events (i.e., 100- and 500-year recurrence) which are not the most practical for flood mitigation planning for urban infrastructure solutions. Further, FEMA's flood mapping was developed based on stochastic data methods and does not account for the changing nature of flood risk through increased precipitation frequency and volumes with future climate change. Also, FEMA's flood risks maps do not factor the effects of piped infrastructure flooding.

Data sharing between communities (via the RMC and UMSWG) was also central to achieving the project goals. The mutually shared data allowed upgrades to the regional flood model, pioneering an approach for a ***shared watershed planning database***. This regional participation resulted in a tool that allows communities to better understand present day and future flooding, independent of municipal boundaries. The regional flood model and associated flood maps are beneficial resources, supplementing the FEMA maps, and provide the communities a better understanding of future flood risks using similar datasets, assumptions and scenarios.

Scale Up Nature-Based Solutions

It was also a key goal of this project to identify feasible sites for implementing **regionally-significant green infrastructure projects**. This project identified six (6) near-term priority sites for constructed wetland-scale GI and compared modeled flood impacts between before and after implementation of wetlands at these sites and ARM pilot projects. Modeling was performed for several precipitation-based flooding scenarios (e.g., present-day 2- and 10-year recurrence events and 2070 10- and 100-year recurrence events).

Explore Innovative Technologies

The final primary goal of this analysis was to determine the residual flooding from a significant storm event such as the 2070 10-year storm event (i.e., a future storm event with 10% recurrence, or 10% probability of occurring in any given year beyond 2070) that requires more significant expenditures and management. Such management strategies include innovative technologies such as ARM, and other adaptations and non-structural solutions. Initial analysis, completed prior to the project, indicated that it would not be possible to fully manage flooding during a 2070 10-year storm event (much less a 100--year storm event) through green infrastructure alone. ARM needs to be considered on a regional basis, across multiple dam operators (e.g., DCR, individual municipalities) in managing regional damage from riverine flooding.

Secondary Goals

The five secondary goals of this project included:

- Encourage coordination between municipalities and foster co-production and co-learning
- Model realistic, achievable solutions
- Identify specific barriers to implement and improve long-term readiness of future sites
- Identify projects that maximize co-benefits (e.g. improved water quality, social equity)
- Provide replicability and transferability

I. Encourage coordination between municipalities and foster co-production and co-learning

To achieve the best outcomes, coordination between municipalities was encouraged. The technical team worked with the Resilient Mystic

Collaborative's municipal staff to identify high-readiness projects, and foster co-production of key deliverables and co-learning outcomes. This was done by creating a collaborative workflow, engaging municipal staff directly during the project site identification and screening effort.

II. Model realistic, achievable solutions

In developing GI and ARM model simulation scenarios, efforts were made to identify specific, realistic project opportunities that could be implemented in the near future and inform future grant applications. This co-production step (working directly with the municipal staff to assess near-term project readiness) was included to best model achievable outcomes that may be realized in the near term and over the next few decades.

III. Identify specific barriers to implementation and improve long-term readiness of future sites

Work directly with communities to identify specific barriers to implementation and gauge near- and long-term readiness of potential project sites. Working with communities from the start of the project improves the likelihood of future implementation and prioritization. Some of these potential project sites may take more than a decade to develop for implementation.

IV. Identify projects that maximize co-benefits

The desktop screening analysis was tailored to prioritize potential projects that maximize co-benefit opportunities, including:

- Projects that improve water quality, contributing to desired outcomes for the Alternate Mystic River Total Maximum Daily Load (TMDL) for phosphorus control (*Mystic River Watershed Alternative TMDL Development for Phosphorus Management*[2], 2020) and individual municipal separate storm sewer system (MS4) and/or combined sewer overflow (CSO) program objectives.

- Projects that integrate and achieve equity-based outcomes, such as improving recreational access for underserved communities and environmental justice communities, reducing flood risk for socially-vulnerable populations, and promote equitable investment across watershed communities.

- Projects that improve regional connectivity via trail networks, linkage between public open spaces, and projects that fit within greenway, waterfront, and open space plans.

V. Replicability and transferability

One of the RMC's key objectives is to intentionally learn from its own activities and efforts and to share those insights with others who might be interested in watershed-scale resilience. As the communities engage in conversations about managing stormwater in a way that optimizes local and regional co-benefits, the RMC is learning about the challenges and opportunities

2 https://www.epa.gov/sites/production/files/2020-06/documents/mystic-river-tmdl-report.pdf

that arise when trying to do both. The project also aimed at increasing replicable outcomes beyond the watershed, creating a workflow and new data tools that can be used by other communities. For example, a key outcome of this project was that it resulted in an affordable and replicable methodology and workflow for a watershed-wide screening analysis that can be used to create a prioritized list of alternatives that decrease stormwater flooding. The project has produced several new tools that can be easily replicated and repurposed for similar projects in other watersheds, including:

- GIS-based desktop screening analyses utilizing pre-programmed (automated) scripts, which can batch-process analyses for 16 independent criteria across hundreds of parcels in under 20 minutes
- Multicriteria Prioritization Ranking Tool (used in the May 2020 virtual workshop) that can be adapted to include other criteria, and serves as a live, interactive tool that can be easily used for similar workshops

TASK 1.

Data Collection, Municipal Staff Interviews, and Updates to Regional H+H Model

Background / Initial Regional Model

The Upper Mystic regional stormwater model was built off the modeling efforts that the City of Cambridge has engaged in over the last several years, particularly originating from the flood modeling of the Alewife sub-basin that was developed as part of the City's *Climate Change Vulnerability Assessment* (CCVA)[3] published in 2015 and updated in 2017. While it is located far inland from the coast, the CCVA analysis identified the Alewife sub-basin as particularly vulnerable to flooding. Due to its low-lying topography, this sub-basin has significant flood risk from both coastal flooding (from future sea-level rise, storm surge, and potential flanking at the Amelia Earhart Dam (AED), as well as precipitation-based flooding of inland areas upstream of the AED.

3 https://www.cambridgema.gov/-/media/Files/CDD/Climate/vulnerabilityassessment/finalreport_ccvapart2_mar2017_final2_web.pdf

Over the last two decades, the City of Cambridge has built a city-wide hydraulic sewer model that has been used to evaluate the combined sewer system performance and to assist with planning for capital projects in the City. The model was built using InfoWorks ICM by Innovyze™. This platform has the capability to use rain-on-catchment hydrology with a 2-dimensional (2D) terrain grid / surface mesh (2D mesh) for finer spatial resolution of overland flow. To better represent receiving water conditions and urban flood risk, the City of Cambridge added a 2D model mesh within its City limits to better characterize flooding.

For the City of Cambridge to explore future scenarios (such as the 2070 10-year storm event or coastal flood impacts in Alewife sub-basin), a paired 1D-2D model was developed to better capture upper watershed flow routing and watershed response. This paired model integrated two previous models (an upstream one-dimensional (1D) model and a detailed downstream 2D model) into the Initial Regional Model, and was used for analysis of the Alewife sub-basin in the 2017 CCVA report[3].

For initial purposes, the resolution of the upper basin features in the regional model was limited to a 1D riverine H+H model, with simplified 300+ acre upper watershed catchments. Simulated runoff was routed via point hydrographs to a 1D, linear river channel version that did not contain bathymetric cross-sections or transect data.

Cambridge's model integration process – which resulted in the Initial Regional Model (2019) - paired a riverine model (adapted from FEMA's Mystic River Flood Insurance Study, which used Hydrologic Engineering Center's River Analysis System (HEC-RAS) model), and the City's detailed pipe infrastructure model. The Initial Regional Model (2019) also imported elements from the Massachusetts Water Resources Authority (MWRA) regional sewer model (see **Appendix B**, supplemental materials). The 2D portion of this model (i.e., the Alewife sub-basin floodplain) was generated with a high resolution 2D grid, including flow path obstacles (see **Figure 2**).

As understanding of upstream-downstream hydraulics improved, so did the ability to explore the potential benefits of flood mitigation solutions, including structural measures (e.g., green and grey infrastructure, wetland and floodplain restoration, surface and subsurface storage) and operational solutions (e.g., dam operations, ARM).

The Initial Regional Model, completed in 2019, was used to better characterize flooding within Cambridge based on detailed hydraulic/ hydrologic processes, and was also used to perform a watershed-wide "bathtub" analysis to identify areas across the watershed that were likely prone to flooding based generally on river stage and topography (see **Figure 3**).

In early 2019, the RMC's UMSWG - with financial support from Cambridge and the Barr Foundation - used the Initial Region Model (2019) to complete simplified sensitivity analyses. These analyses involved modeling reduction of DCIA (via disconnection), as well as modeling new stormwater wetlands, and ARM to quantify the extent to which each action would contribute to reduced river flooding on a regional scale. It was also updated to simulate operations of the AED, including the pumping operations, using

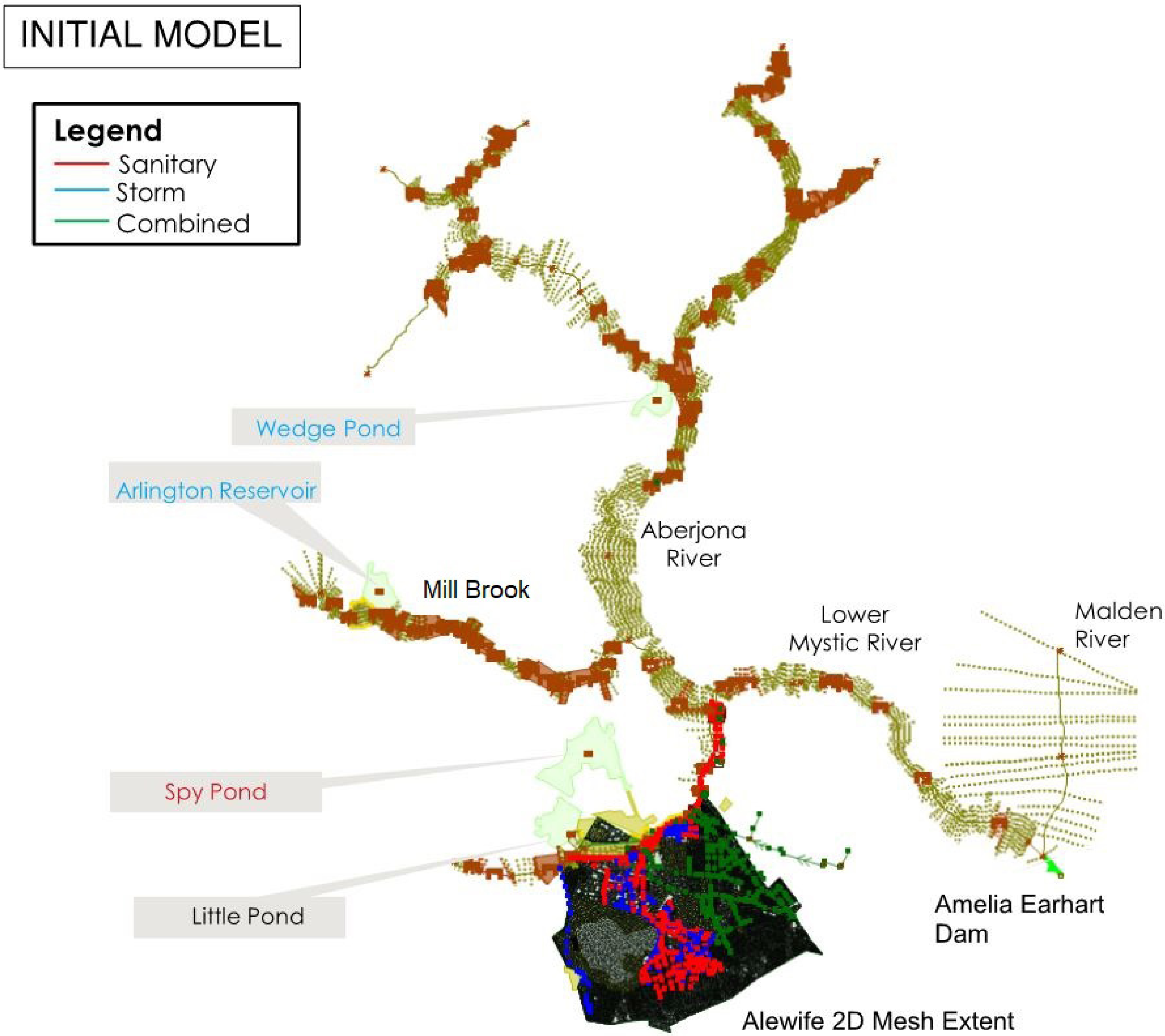

Figure 2 – Initial Regional Model (Paired 1D-2D model)

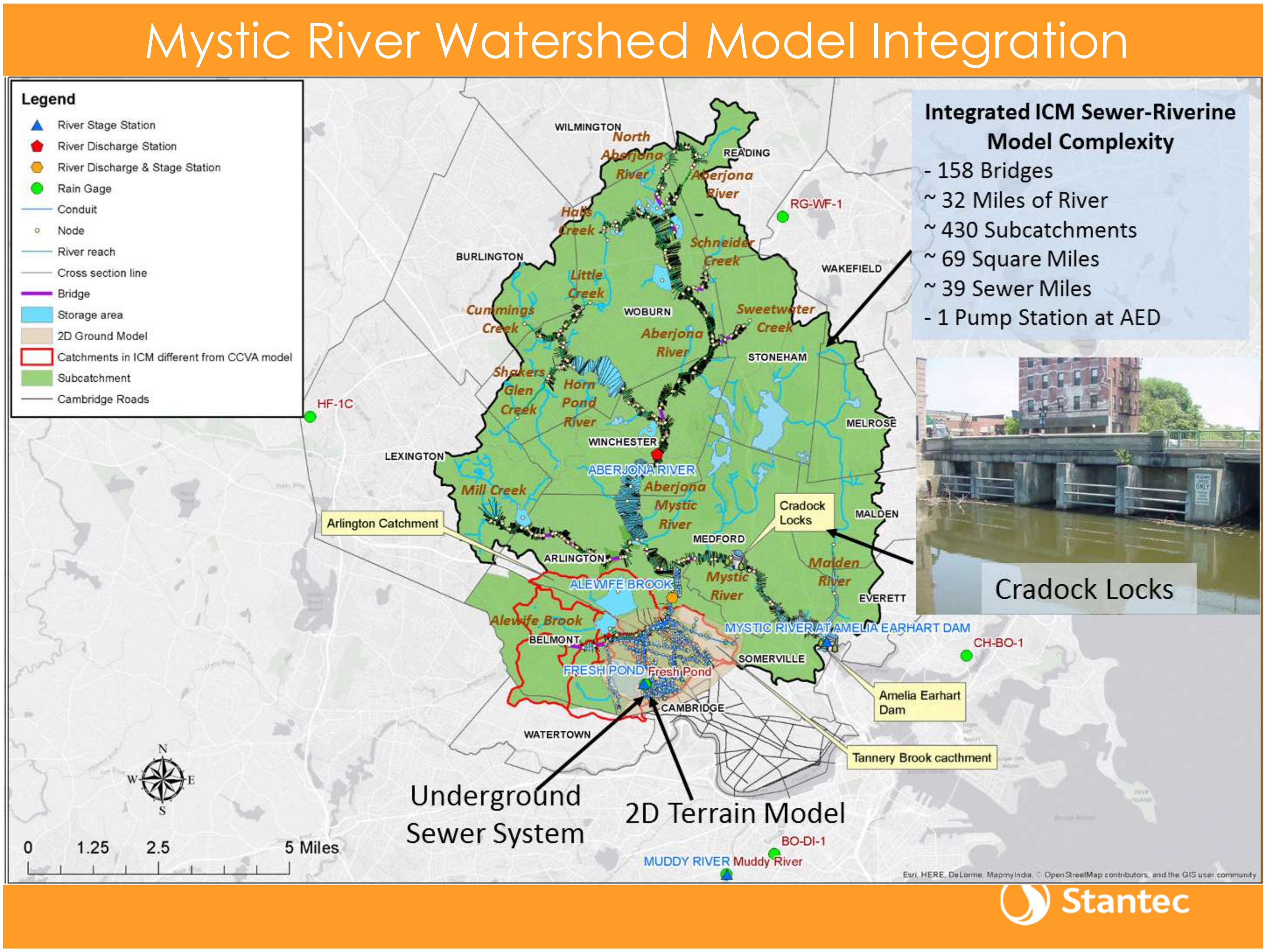

Figure 3 – Mystic River Watershed Model Integration into ICM Initial Regional Model

assumptions that differed from the FEMA model and were based on communications with DCR and subsequent model calibration.

To map flood extents, riverine overbank flooding was plotted alongside two flood proxy GIS layers that were developed by combining GIS terrain data and modeled river elevations. Together these mapped areas approximated the following:

- Areas where rivers would be expected to overtop their banks (modeled overbank flooding)
- Areas disconnected from the river/stream channel (areas situated at a lower elevation than modeled river surface elevations, but not hydrologically connected to the river). These areas were identified by an approximate analysis that considered stormwater drain

connectivity to the river and assumed propagated/backing-up through the stormwater system/network (based on nearby river transect data from the FEMA FIS).

- Low-lying areas where localized stormwater flooding may surcharge (i.e., localized low points in upland storm sewer systems that may experience flooding from inlet and conveyance capacity issues during high-intensity shorter duration storm events). These areas were identified by an approximate analysis based on terrain.

Watershed response was modeled by analyzing flood volumes and flood depths at six key reaches: Alewife Brook, Mill Brook, Lower Aberjona (near Upper Mystic Lake), Mid-Aberjona (north of Winchester town center), West Aberjona (along Horn Pond Brook), and the lower basin (downstream of Lower Mystic Lake).

Purpose of Model Updates (2019-2020)

The purpose of updating the Initial Regional Model (2019) was to have a tool that was not limited by municipal boundaries and could better characterize present and future flooding throughout the watershed. The tool could also evaluate regional solutions for flood resilience. This involved incorporating available data from municipalities, validating/calibrating the model, and producing watershed-wide spatial flooding results that were displayed in a GIS-based web-based application.

The development of a regional (watershed-based) flood model is a unique approach to work across municipal borders, tackling surface water management and piped infrastructure at a watershed scale and integrating individual H+H models from Cambridge, Somerville, Belmont, and Medford, and a 2D model mesh that includes portions of 13 of the 17 upper watershed municipalities.

Data Requests and Outreach

Data collection began with outreach to the 17 municipalities in the Upper Mystic watershed: Arlington, Belmont, Burlington, Cambridge, Everett, Lexington, Malden, Medford, Melrose, Reading, Somerville, Stoneham, Wakefield, Watertown, Wilmington, Winchester, and Woburn. Outreach occurred between September and December of 2019 and consisted of in-person interviews with MyRWA, the consultant team, and staff from each municipality, followed by email communications to finalize the data requests. **Appendix A** contains the Community Data Request form. Primary items requested included any existing H+H models and/or attribute data of the municipality's collection system, streams, reservoirs, assets and bridges not already included in the 2019 Initial Regional Model, and any additional GIS layers the municipality manages beyond the public MassGIS dataset.

Appendix A includes supporting materials for this outreach component, including map markups and feedback received from each municipality to update the regional flood model.

Regional HandH Model Updates (2020)

Table 1 and **Figure 4** show the features that were explicitly added or revised in the updated Mystic River Regional Model (excluding the 2D surface mesh, which is too dense to represent in the table). The subsections below describe the processes by which the model was updated.

Piped Networks and Subcatchment Resolution

Existing local H+H models showing storm drains, drainage channels, combined and/or sanitary sewers, key network structures, and outfalls were imported into the Regional H+H Model for Cambridge, Somerville, and Medford. In specific areas, assets from the MWRA regional sewer were also added for continuity between municipalities. The majority of the communities did not have an existing storm sewer system model; therefore, representative data from piped infrastructure GIS layers was utilized to develop the regional model. Pipe networks (primarily interceptor pipes) were imported and connected to the hydrology features (see **Appendix B**). The model connectivity was reviewed and some of the isolated subsurface storm drains at the periphery of the watershed were removed because they were either located in areas that did not interact with the Mystic River Watershed or because the full drainage path to the River could not be determined. Therefore, GIS data collected from some municipalities were not incorporated into the model. Specifically, the following areas were not included:

- The City of Watertown and the Town of Burlington did not have significant area contributing to the Mystic River Watershed to be modeled explicitly.
- Hydraulic and hydrologic features in the City of Melrose and small portions of Malden had insufficient data for the open-channel network and/or the sub-surface drainage network. These data gaps prevented connecting flows on/through the surface mesh, waterways, and underground infrastructure to the rest of the watershed model and were, therefore, excluded.

Table 2 summarizes the collection system data that was imported into the 2020 regional model update from each municipality.

When H+H models were imported directly (as for Belmont, Medford, and Somerville), subcatchments were automatically incorporated. Where pipe networks were added based on GIS data, larger subcatchments were subsequently subdivided and modeled runoff was conveyed to the pipe network rather than directly to the water bodies. These smaller subcatchments more accurately represent the modeled time of concentration for stormwater traveling through the municipal drainage network. For detailed information regarding which storm sewer pipes were added explicitly to the model, refer to the maps provided in **Appendix B**. The total number and average area of subcatchments of the 2020 model versus the 2019 model are shown in **Table 3**.

River Transects

River channel transects were updated from the Initial Regional Model (2019) to reflect actual riverbank locations. Riverbank elevations were added and/or adjusted to align vertically and horizontally with the 2D surface mesh. During

Table 1 – Features in Mystic River Regional Model by Municipality

Town	H+H Model	Sewer System GIS	Stormwater GIS	Modeled Streams and Reservoirs	Observed Stream Data Source(s)
Arlington		X	X	Mill Brook; Lower Mystic Lake; Arlington Reservoir; Spy Pond	
Belmont	X (Sanitary)	X	X	Little Pond; Clay Pit Pond and Brook	
Cambridge	X (Storm / Sanitary)	X	X	Fresh Pond; Alewife Brook	
Everett		X	X	Malden River; Amelia Earhart Dam	
Lexington		X	X	Arlington Reservoir; Mill Brook	
Malden		X	X	Malden River; Fellsway Pond	
Medford	X (Storm)			Lower Mystic Lake; Mystic River; Malden River; Wright's Pond	
Reading		X	X	N/A	
Somerville	X (Storm / Sanitary)	X	X	Alewife Brook; Mystic River; Amelia Earhart Dam	Alewife Brook @ Broadway; Amelia Earhart Dam; Boston Harbor
Stoneham		X		N/A	
Wakefield		X		N/A	
Wilmington		X	X	N/A	
Winchester		X		Aberjona River; Horn Pond Brook; Upper Mystic Lake	Aberjona River; DPW Operations for Upper Mystic Lake
Woburn		X	X	Aberjona River; Horn Pond and Brook; Cumming's Brook	

Note: The City of Watertown and the Town of Burlington did not have significant area contributing to the Mystic River Watershed to be modeled explicitly. H+H features in the City of Melrose had insufficient data for the open-channel network and/or the sub-surface drainage network to be modeled explicitly.

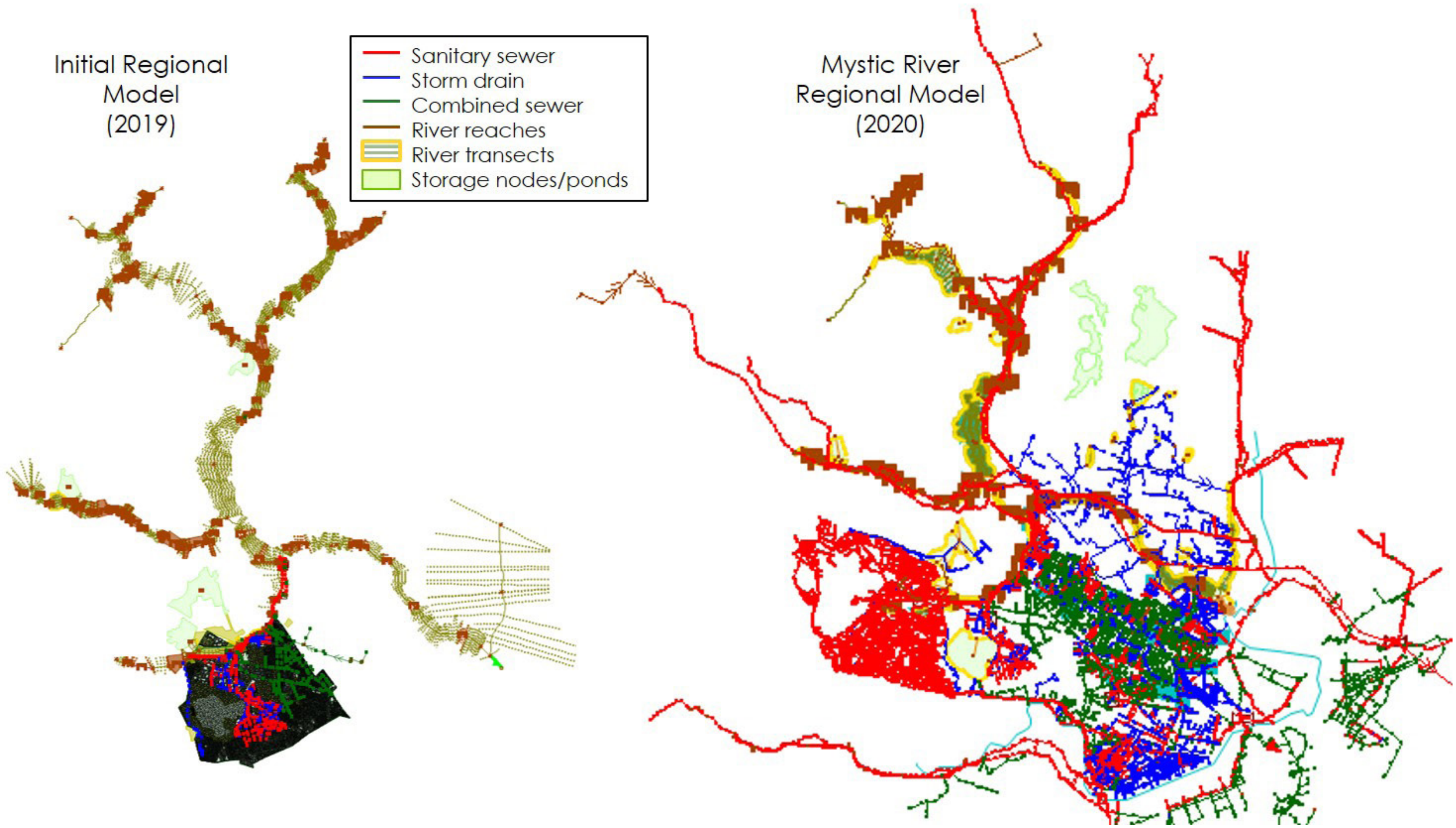

Figure 4 – Extent of Mystic River Regional Model (2020) versus Initial Regional Model (2019)

Table 2 – Stormwater System Data Imported in Regional Model Update (2020)

	Number of Assets Imported			
Town	**Storm Drain**	**Storm Manholes**	**Outfalls**	**Data Source**
Arlington	302	295	15	Town GIS
Belmont	130	139	4	Town GIS / Infoworks CS Model (sanitary)
Cambridge	3,258	3,235	37	ICM Model
Everett	162	163	7	Town GIS
Lexington	58	66	4	Town GIS
Malden	41	41	0	Town GIS
Medford	489	518	7	PCSWMM Model (storm sewers)
Reading	116	112	6	Town GIS
Somerville	3,189	3,159	5	Refined ICM Model
Stoneham	54	61	3	Town GIS
Wakefield	14	16	0	Town GIS
Wilmington	23	27	0	Town GIS
Winchester	135	146	11	Town GIS
Woburn	75	58	26	Town GIS

Table 3 – Subcatchment Summary Comparison: Before-and-After Model Updates (2020)

	Subcatchment Quantity (number)	Mean Subcatchment Size (acres)
Initial Regional Model (2019)	4,761	555
Mystic River Regional Model (2020)	6,033	284

flood conditions, the model simulated water from the river waterbodies to "spill" onto the mesh, simulating riverine floodplain storage and overbank flooding, before draining back into the waterways when flood conditions recede.Bridges were also updated to reflect actual locations - trimmed to riverbank lines - and adjusted as needed to align with the 2D surface mesh. Specific upgrades to river bathymetry were also applied to the Mystic River and Malden River main channels upstream of the AED using data provided by AECOM (2019) from a recent DCR project near the Dam.

2D Mesh Improvements

Publicly available data from MassGIS were used to create and integrate the 2D surface mesh that governs overland flow. Data incorporated into model updates includes:

- A digital elevation model (DEM) that includes the entire Mystic River Watershed and has a 1-meter horizontal resolution and vertical accuracy of approximately 7 inches. These data are available through MassGIS and are based on LiDAR data captured in 2013-2014[4]. These were used to create the 2D mesh of the ground topography.
- The buildings shapefile was also available through MassGIS and represents data aggregated from numerous local and regional governmental sources. This shapefile was used to create voids in the surface mesh spanning building footprints. The void area acts as a barrier that water is forced to flow around. In locations where a building void intersected or extended beyond a stream bank, the stream bank was adjusted to avoid model instabilities.
- Permanent water body information was downloaded from the United States Geologic Survey (USGS) as part of the National Hydrography Dataset (NHD). This layer is displayed as reference in some maps. The corresponding extents of these water bodies were subtracted from calculations in **Task 6b** to determine flooded land area extents in the watershed.

Figure 5 on the next page shows a sample neighborhood to demonstrate the interactions between surface mesh, building footprints, stream bank elevations, and waterways.

Rainfall-runoff response was simulated using rain-on-subcatchment hydrology, and runoff was subsequently conveyed to pipelines or directly to water bodies. The 2D surface mesh was used to model overland flow (where subsurface pipe flow surcharges to the ground surface) or where river overbanking would occur within the extents of the model network. The boundary of contiguous 2D mesh is shown in **Figure 6**.

Amelia Earhart Dam Updates

The AED spans the Mystic River near the City of Somerville and Everett. The dam includes three locks to control marine traffic and regulate tide levels. In the Initial Regional Model, the dam was simulated with three pumps but did not include

4 https://www.mass.gov/files/documents/2016/07/wr/lidar-projects-table.pdf

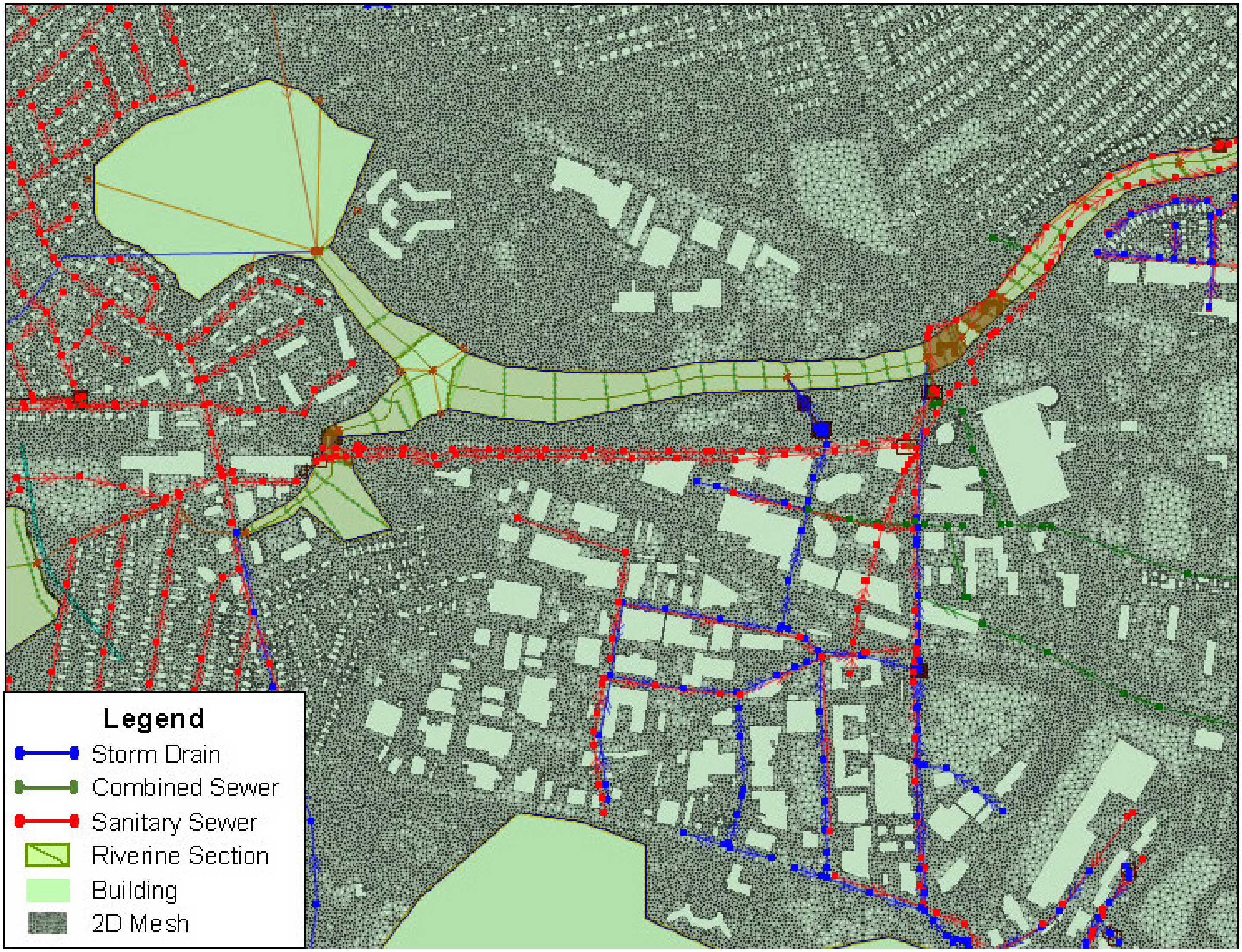

Figure 5 – Example of Interactions Between Surface Mesh, Building Footprints, and Waterways

the lock operations (i.e., detailed sluice gate operations).

As part of ongoing coordination with DCR, the City of Cambridge funded a modeling effort to better represent the operations of the AED in the model. The locks were modeled explicitly, and lock operation controls were developed in the model in conjunction with DCR. The addition of lock operations had significant impacts on modeled river levels, particularly during 24-hour storm events, since the locks at the AED are effective in draining the watershed during the low tide cycles along with pumps and even when the pumps are turned off, as long as the Harbor is at low tide.

Mystic Lakes Dam Updates

The Initial Regional Model (2019) represented

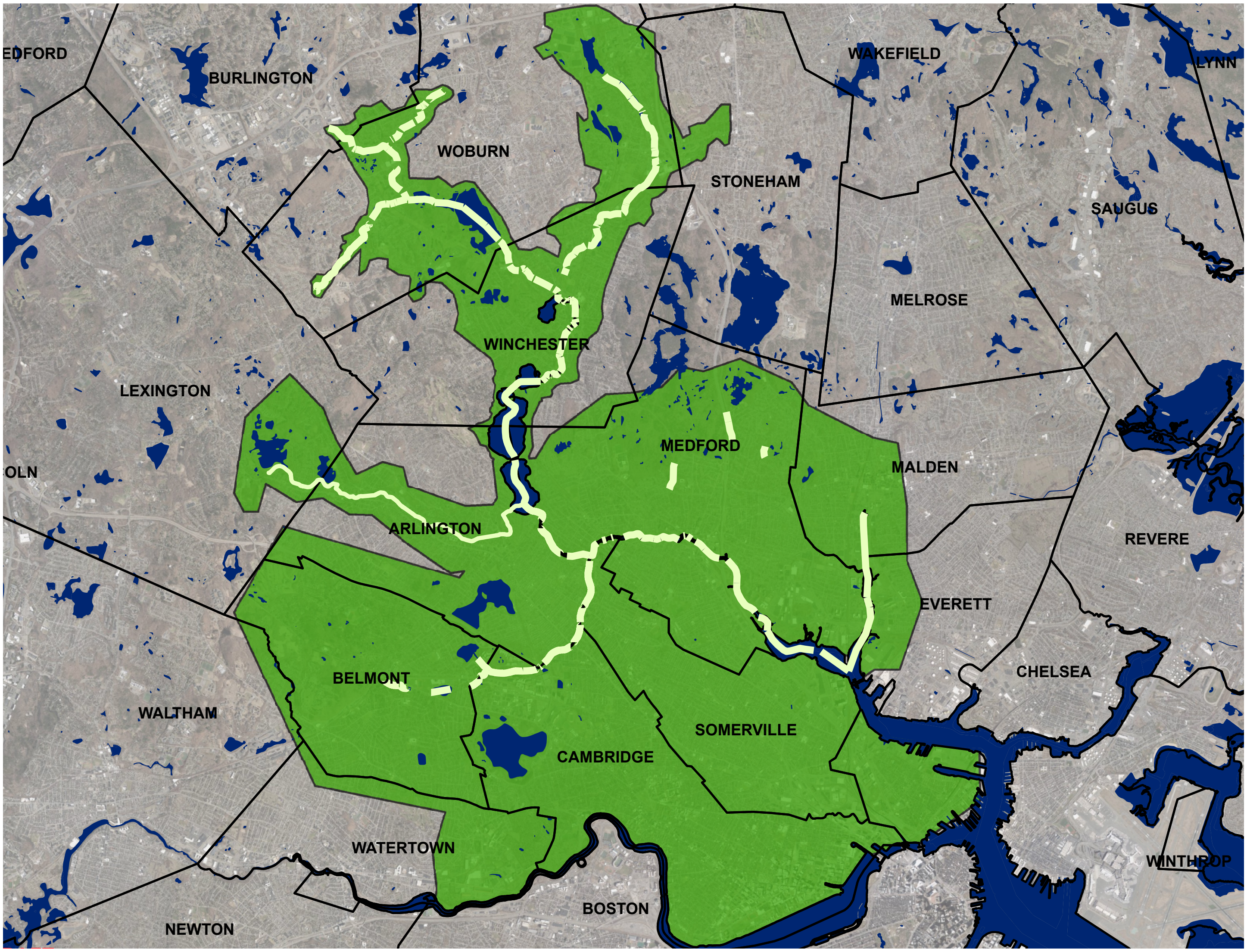

Figure 6 – Extent of 2D Mesh in Mystic River 2020 Regional Model

the Mystic Lakes Dam, located between the Upper and Lower Mystic Lakes, as a simplified (artificial) river cross section to achieve steady state flow conditions. In April 2020, MyRWA and the consultant team held a virtual call with staff from DCR to discuss details for this structure and its operations. DCR provided a presentation with photos of the Mystic Lakes Dam, accompanied by verbal confirmation of elevations, geometry, and other details. As a result, the Mystic Lakes Dam was updated in the model to include representations of the fixed emergency spillway and the operable spillway modeled with static stop logs.

Other Model Updates

Other modifications to the model were made based on available information, such as incorporating bridges, bathymetry data and reservoir information as follows:

- Bridges. 15 bridges were added to the model, six (6) of which pass over the Alewife Brook and nine (9) of which are between the convergence of Alewife Brook and the AED.
- Arlington Reservoir. An emergency spillway, built in 2006, was added to the Arlington Reservoir model element. The emergency spillway geometry was based on the 2018 Arlington Reservoir Master Plan[5].
- Fellsmere Pond. The Fellsmere Pond in the City of Malden was added to the model. The pond is hydraulically connected to the drainages for the City of Medford and Malden along Fellsway.

Excluded Waterways

Some waterways and features were not incorporated or were removed from the model for reasons noted below. These exclusions are not anticipated to impact the model's hydrologic response, which was validated through calibration. These waterways include the following:

- Sweetwater Brook (eastern tributary to the Aberjona River in south Stoneham) is hydrologically and hydraulically insignificant to water surface elevations on the Aberjona River; therefore, it was not considered an essential component to be modeled.
- North Reservoir, located in Winchester, does not have available data on the subsurface or open channel network between the Aberjona River and the North Reservoir. The available HydroCAD model provided would have been prohibitively time-intensive to import to the 2020 Regional Model and would have required major assumptions on the conveyance features downstream of the outlet structure.
- Middle/South Reservoir, also in Winchester, discharges to Smelt Brook, which then passes through the subsurface drainage network in Medford before discharging into the Mystic River. Adding the Middle/South Reservoirs would require adjusting the hydrologic representations of subcatchments in the City of Medford's calibrated model, which was imported into the 2020 Regional Model. The City of Medford's model already accounts for the hydrologic response from the Middle/South Reservoir through its calibration.
- Spot Pond, located in Stoneham, discharges flow through Melrose, Stoneham, and Malden. There was insufficient data on subsurface infrastructure from the pond outlet through these areas to explicitly incorporate Spot Pond.

Modeling Assumptions

Assumptions: Downstream Tidal Conditions

The model runs use a dynamic tide at downstream of AED (across the 2-day simulation) to model the lingering hydrologic response following a major precipitation event. The peak tide conditions are set to coincide with peak river flow (representing maximum or worst-case flooding).

5 https://arlingtonreservoir.org/reservoir-master-plan/

Two tide elevations were used for the analysis, existing tide elevations (see **Figure 7**) and future 2070 tide elevations (see **Figure 8**), both of which were derived from the Massachusetts Department of Transportation (MassDOT) Massachusetts Coast Flood Risk Model (MC-FRM). Existing tide elevations include high tide peak value of 4.77 feet NAVD88 (or 16.43 feet above City of Cambridge Base (CCB) datum). Future 2070 tide elevations include a high tide peak value of 11.40 feet NAVD88 (23.06-feet CCB). Tidal time series are shown in **Figures 7** and **8** below.

Assumptions: Rainfall

Vulnerability to precipitation-based flooding exists in many sub-basins and river reaches across the urbanized Upper Mystic River Watershed. This is true for the present-day condition where precipitation events as frequent as the 2-year,

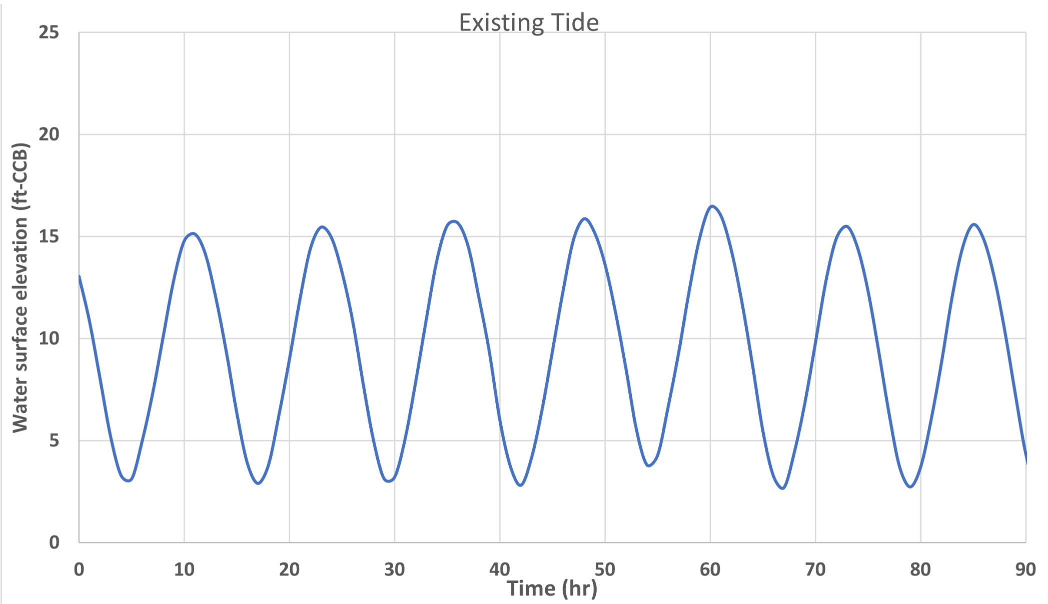

Figure 7 – Existing Tidal Conditions at Amelia Earhart Dam Used in the Model

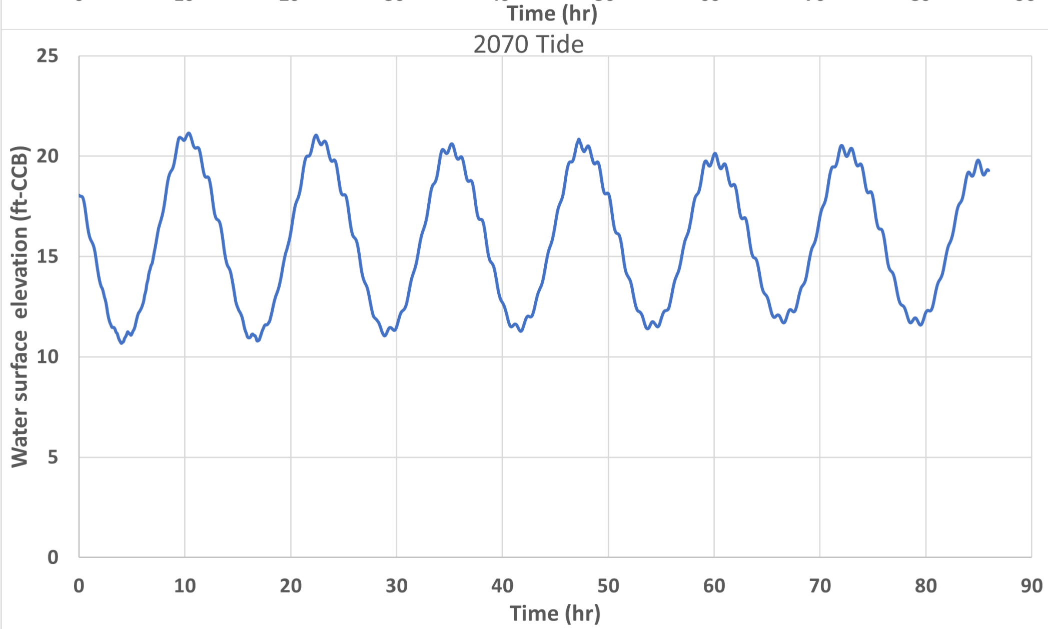

Figure 8 – Future 2070 Tidal Conditions at Amelia Earhart Dam Used in the Model (adapted from MC-FRM)

Table 4 – Rainfall Event Characteristics

Event	Storm Horizon	Peak Intensity (in/hr)	Total Rainfall (in)	Tide
1yr	Present Day	0.66	2.33	Existing
2yr	Present Day	0.80	3.20	Existing
5yr	Present Day	1.05	4.00	Existing
10yr	Present Day	1.23	4.91	Existing
100yr	Present Day	2.22	8.88	Existing
10yr	2070	1.60	6.38	2070
100yr	2070	2.93	11.70	2070

24-hour recurrence event can cause flooding in multiple watershed flooding hotspots. This vulnerability is projected to significantly increase with climate change. For example, the total amount of precipitation (P) for the 10-year, 24-hour recurrence event is projected to increase from 4.91 total inches in 2020 to 6.38 total inches in 2070.This increase in precipitation is expected to significantly increase inland flooding throughout the Upper Mystic Watershed.

The regional model was employed to analyze various storm events including the 100-year, 10-year, 5-year, 2-year and 1-year storm events. All modeled rain events were 24-hour duration and used a Soil Conservation Service (SCS) Type III rainfall distribution for the storm event profile. **Table 4** shows the characteristics for each rainfall event modeled.

Calibration and Validation

The regional model (2020) was calibrated using an historic rain event in March 2010 and validated using a historic rain event in May 2006. For the March 2010 and May 2006 storms, data were obtained at the following locations:

- Rain data recorded at the Fresh Pond Water Intake Facility
- Streamflow from the USGS stations at Alewife Brook, Aberjona River in Winchester, and Amelia Earhart Dam
- Actual observed tide data in Boston Harbor
- Records of AED actual operations with respect to locks and pumping
- DCR Operations for Upper Mystic Lake

The updated model was calibrated at the same locations as during the initial (2019) regional model integration effort (refer to **Appendix A**, supplemental material).

Mystic Viewer Tool - Flood Maps

Several key flood maps were uploaded to the web-based Mystic Viewer tool[6], including the

6 https://geo.stantec.com/MysticRiver/viewer/

Figure 9 – Mystic Viewer Tool Shows Modeled Flooding in Baseline Storms

following:

- 100-year storm (2070 storm horizon) with 2070 and existing tides
- 10-year storm (2070 storm horizon) with 2070 and existing tides
- 10-year storm (present day storms and existing tides)
- 2-year storm (present day storm horizon and existing tides

Flood extent polygons were created by selecting areas with less than a 12-inch flood depth and smoothing the edges using regional DEM. For areas outside of the 2D mesh model boundary, the flood viewer displays model results from the Initial Regional Model, which have been confirmed by the communities.

Figure 9 shows a sample screen shot from the regional flood model (2020) results. As displayed in the Mystic Viewer Tool for the 2-year, 10-year (present day and 2070 horizon), and 100-year (2070 horizon) baseline storm events, **Figure 9** shows how predicted flooding spatially increases in larger storm events and with different tidal assumptions.

A feature called Layer Swipe was also added to allow for side-by-side comparison of the Initial Regional Model (2019) and the Mystic River Regional Model (2020). The tool is accessed through the menu bar at the top level, as shown in **Figure 10**. By choosing a vertical or horizontal orientation, a slider bar (layer swipe option) appears.

Sliding the bar across the screen allows the user to see the layering more clearly. **Figure 11** shows an example of how the Layer Swipe tool works, shown for the 10-year storm. In this neighborhood, the Initial Regional Model (2019) indicated Central Avenue in Medford as a low-lying area, indicated by light orange. The updated Mystic River Regional Model (2020) incorporated the underground collection system, a better representation of the ground surface at finer resolution, and voided building footprints that do not count in the flooded area. With these factors accounted for, the model predicts more severe flooding in the 10-year storm event, indicated by dark orange. The grey bar can be toggled back and forth for ready visual comparison between the layers.

Print map versions of flood model outputs are provided in **Appendix C**.

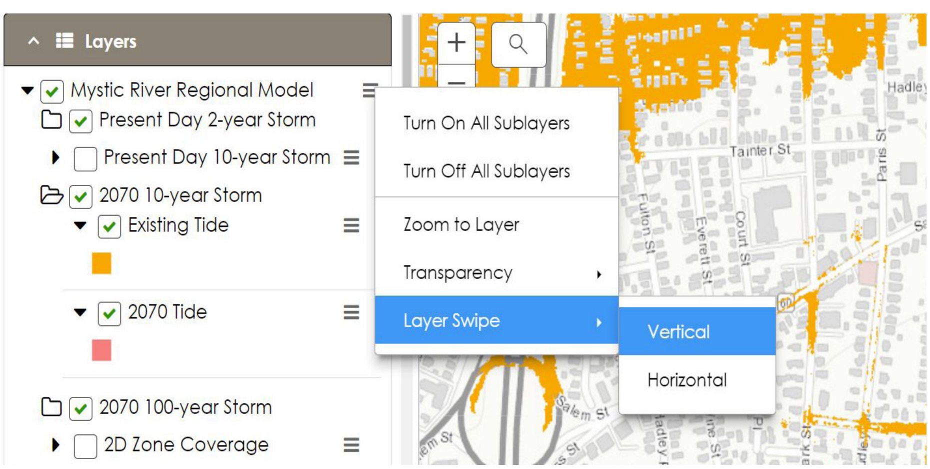

Figure 10 – Mystic Viewer Tool: Accessing Layer Swipe

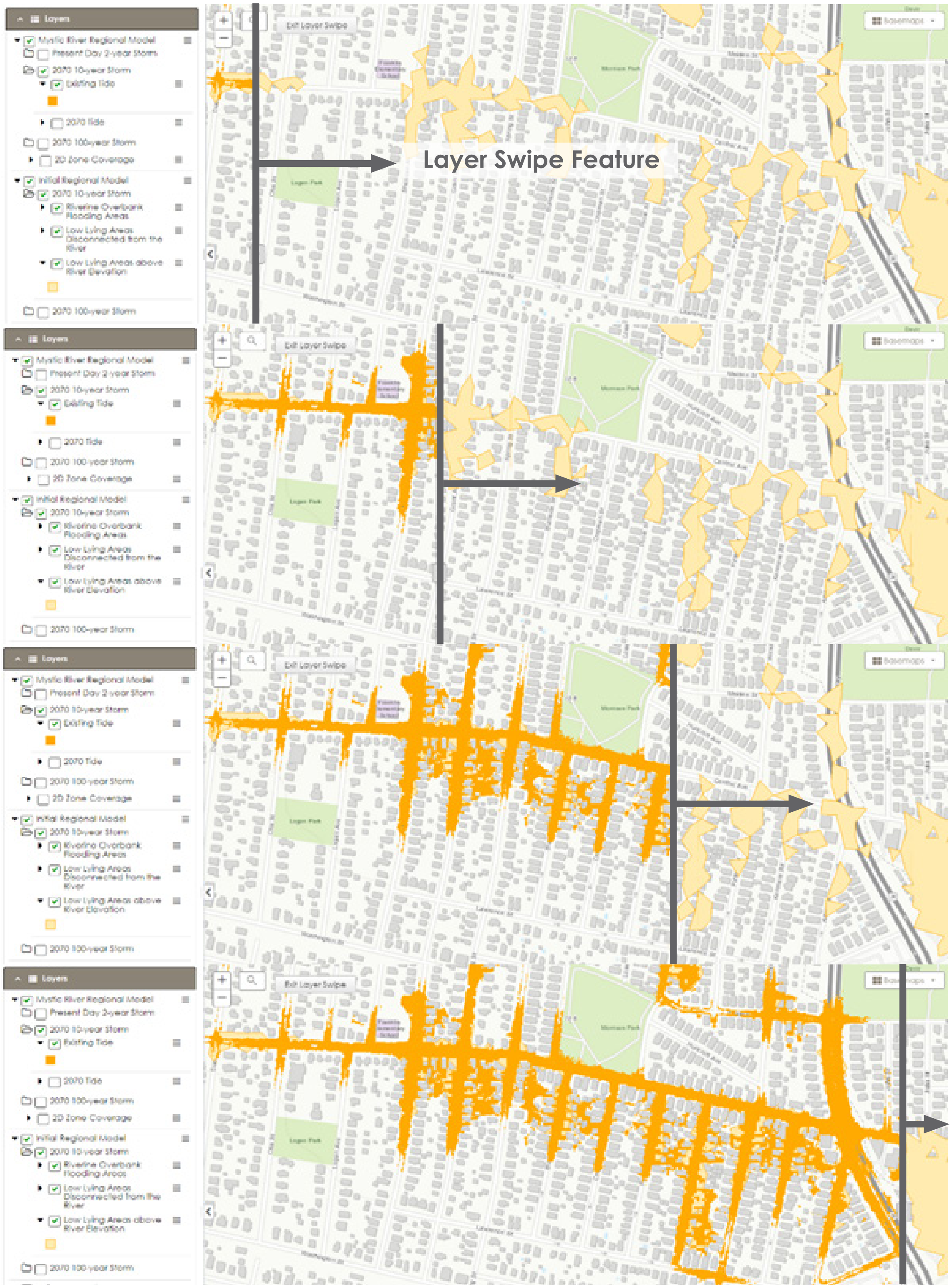

Figure 11 – Mystic Viewer Tool: Layer Swipe Feature Compares Results from the 2019 versus 2020 Model

Inquiries regarding access to the Mystic Viewer can be directed to RMC / UMSWG (contact Emily Sullivan esullivan@town.arlington.ma.us or Patrick Herron patrick@mysticriver.org).
The web-based tool can be found here: *https://geo.stantec.com/MysticRiver/viewer/*

TASK 2.

GIS-based Screening Analysis and Identification of Green Infrastructure Project Opportunities

Purpose and Goals

A GIS-based screening analysis was conducted to identify suitable locations for green infrastructure (GI) at multiple scales. The primary goal of this analysis was to identify suitable locations for large-scale green infrastructure (i.e., constructed stormwater wetlands) for flood mitigation. A secondary goal was to use the data synthesized by this effort, including updated regional modeling results, to identify locations where small- to medium-scale green infrastructure (e.g., pocket wetlands, bioretention, subsurface infiltration) may also be strategic for localized flood mitigation. In addition to identifying GI opportunities at different scales, another goal of the project and the desktop screening analysis was to collect data and identify sites that may be of more regional interest from a watershed-oriented flood mitigation planning perspective. For instance, the desktop approach was specifically tailored to perform the following screening objectives:

- Highlight regional project opportunities that do not typically come to the top of any single municipality's list of priorities, including - but not limited to the following:
    - sites where local flood impacts are not realized or not severe in present day condition but may be in the future
    - sites where flood hazard reduction benefits a neighboring municipality
    - sites with existing low-quality wetland habitat
    - existing wetland or floodplain storage areas, such as sites with significant freeboard storage for FEMA 100- or 500-year floodplain, that do not currently exhibit optimal flood mitigation for more frequent small- to medium-size storm events (such as 5- or 10-year recurrence events)
    - undevelopable parcels, demolished buildings, and/or vacant lots with limited near-term value for development or other municipal use
    - sites that are favorably situated based on municipal drainage networks. For instance, projects that may be cost-effective to achieve water quality objectives in meeting Mystic River Alternative TMDL or MS4 permitting requirements
    - sites where flood projects could contribute to improving capacity in drainage systems that are shared by multiple communities

- Prioritize project opportunities that maximize co-benefits, including:
    - Improving water quality and contributing to outcomes for the Alternative Mystic River TMDL (2020) for phosphorus control
    - Integrate and achieve equity-based outcomes, such as improving recreational access for underserved communities and environmental justice communities, reducing flood risk for socially-vulnerable populations, and equitable investment across different sub-watersheds
    - Improving regional connectivity via trail networks, linkage between public open spaces, and projects that fit within greenway, waterfront, and open space plans

Procedure

The procedure for the desktop screening analysis included both top-down and bottom-up methods for identifying suitable sites for green infrastructure. The desktop screening analysis was an iterative process leveraging both automated tools (i.e., GIS-Model Builder scripts) and direct feedback from the UMSWG. During **Task 1**, data were collected about known opportunity sites directly from participant municipal staff. These opportunity sites, which are summarized in the **Task 1** recap memo (see **Appendix A**), served as the starting point for a more top-down, comprehensive desktop screening using GIS-based analyses.

An in-person workshop, hosted by the UMSWG in October 2019, was also held to review data sources, screening criteria, and identify key data gaps for GIS-based analyses. Feedback from the UMSWG was used to re-frame screening and parsing criteria, guiding the selection of "suitable" target parcels in **Task 3**.

Target Setting

Prior to conducting the desktop analysis in GIS, the Project Team identified key target site characteristics, including parcel size and ownership. As a starting point, it was agreed that the Alewife Stormwater Wetland (located in Cambridge near Alewife Reservation) would serve as a model project for evaluating potential GI projects. This reference site was chosen primarily on the basis of its size (a nearly 3-acre constructed stormwater wetland), as it was hypothesized that regional flood mitigation benefits (i.e., reduced flood burden on downstream communities) would be realized at this scale of GI. The Alewife Stormwater Wetland also serves as a replicable model for other communities regarding achievable co-benefits, including water quality improvement, ecosystem restoration and improved habitat, and passive recreation opportunities. Since installation in 2014, the wetland park has gained broad favor from the surrounding community and is a recreational destination of many residents, as well as other neighboring communities and visitors from outside the watershed.

Methodology and Data Sources

Criteria for site selection and suitability screening

The top-down, GIS-based desktop screening analysis consisted of sixteen (16) independent analyses, assessing site suitability and performance indicators across four primary criteria: Flood Exposure and Hydrology, Cost and Ease of Implementation, Equity and Environmental Justice (EJ) indicators, and Connectivity.

To perform these screening analyses, the following data were collected or generated for each of the criteria/indicators:

Flood Exposure and Hydrology

Siting-based criteria impacting technical suitability for wetland GI at opportunity site.

Figure 12 – Alewife Stormwater Wetland and passive recreational amenities (Cambridge, MA)

- FEMA National Flood Hazard Layer (NFHL)
- Four layers were used from the 2019 Initial Regional Model (used as placeholder data until updated regional model outputs were available for 2070 10-year flooding)
    - 2070 10-year Overbank Flooding
    - 2070 10-year Low-Lying areas (GIS-based proxy layer for piped infrastructure flooding; derived from river transect data and DEM)
    - 2070 100-year Overbank Flooding
    - 2070 100-year Low-Lying areas (GIS-based proxy layer for piped infrastructure flooding; derived from river transect data and DEM)
- 2070 10-year flooding (from updated regional model; reconciles overbank and propagated infrastructure flooding into one layer within ICM-2D model mesh)
- Sub-watershed Impact

Cost and Ease of Implementation

Physical site characteristics impacting potential cost or technical suitability for wetland GI

- Soil conditions
- Slopes
- Bedrock

Equity and Environmental Justice (EJ)

Social vulnerability and flood exposure of surrounding neighborhoods

- Environmental Justice Population data developed by the Massachusetts Executive Office of Energy and Environmental Affairs
- Environmental Protection Agency (EPA) EJScreen dataset
- Center for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI)

Connectivity

Existing linkage or potential to create new "Greenway" to public open spaces and/or waterfront spaces along the Mystic River

- Proximity to existing public open space
- Proximity to Mystic River main channel / access to waterfront
- Combined connectivity (open spaces, access to waterfront)

GIS Model Builder scripts

The analysis utilized the capabilities of ArcGIS's Model Builder program to code independent scripts, allowing batch processing of large datasets. Building automated scripts allowed for the analysis to be conducted using a repeatable, scalable model that could be easily re-run with different input datasets, data sources, or criteria weightings.

Specific desktop screening analyses (e.g., assessment of an individual parcel's exposure to flooding from a 10-year recurrence event in 2070) were coded as independent scripts, which could be run simultaneously or as stand-alone analyses. Keeping these scripts independent of each other, allowed for the end user to easily integrate new or updated data that may impact specific criteria, but not others. In total, the GIS-based desktop model for this application includes 16 of these independent analysis scripts across the four primary criteria categories.

Appendix H contains the initial non-weighted scoring conditions that were developed for each of these independent GIS scripts.

In-person workshop (UMSWG workshop #1), October 2019

The first UMSWG workshop for this project was held in October 2019. The workshop was used to confirm the types of parcels to be included in the analysis, as well as overall workflow. A key takeaway from the first workshop was that the desktop screening should include private parcels, where specific opportunities could be identified by municipal staff. As pointed out by a workshop participant from Massachusetts Emergency Management Agency (MEMA), certain private parcels could be suitable candidate sites for GI. For example, private parcels located in floodplains that experience chronic flooding may not have other mechanisms for property buyouts or may otherwise be amenable to become a flood-reducing project on portions of these parcels.

Following the workshop, a set of maps was distributed to all 17 Upper Mystic watershed municipalities, to gather input on the inclusion of specific private parcels greater than 3 acres in size (see **Appendix D**).

It was also confirmed that data sources for parcel datasets should prioritize individual communities' assessor's data, as this is often more up-to-date than data available through MassGIS. These datasets also include more data regarding public open spaces (such as local parks, playgrounds, and conservation lands) that may have local protections and may not be included in the MassGIS Open Space data layer (see **Appendix E**).

Recommendations for small- to mid-size GI opportunities

In addition to identifying target opportunities for wetland-scale or regional GI, a secondary goal of this project was to use the municipal staff feedback and desktop screening analysis to identify GI opportunities at smaller scales. The purpose in identifying these small- to mid-size opportunities is to help screen near-term projects which can be prioritized and advanced independently by municipalities. While focusing on projects that may also have localized flood mitigation co-benefits, the small- to mid-scale GI opportunities identified may be prioritized for other reasons, including contributing to watershed-scale reduction of DCIA, water quality improvement, mitigation of CSOs, mitigation of other climate hazards (such as extreme heat/urban heat island), and other co-benefits.

A set of overview maps, including all GI opportunities per municipality is included in **Appendix F**. A tabular summary of these small- to mid-size GI opportunities (summarized by municipality) is also included in **Appendix J**.

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TASK 3.

Prioritization of Project Opportunities and Consensus-Building

Prioritization Process

The project was informed by a robust stakeholder engagement process. The prioritization methodology was reviewed at a stakeholder workshop held in January 2020 and feedback informed a revised methodology that was used for the GIS desktop analysis. Initial key findings were later presented at a virtual workshop in May 2020 that informed the final recommendations.

In-person workshop (UMSWG workshop #2), January 2020

The January workshop provided a forum for the UMSWG to provide feedback on the desktop screening methodology and preliminary (non-weighted) scoring to pre-rank opportunities for wetland-scale GI and ARM.

The January workshop also served as a forum to revisit primary prioritization criteria and secondary

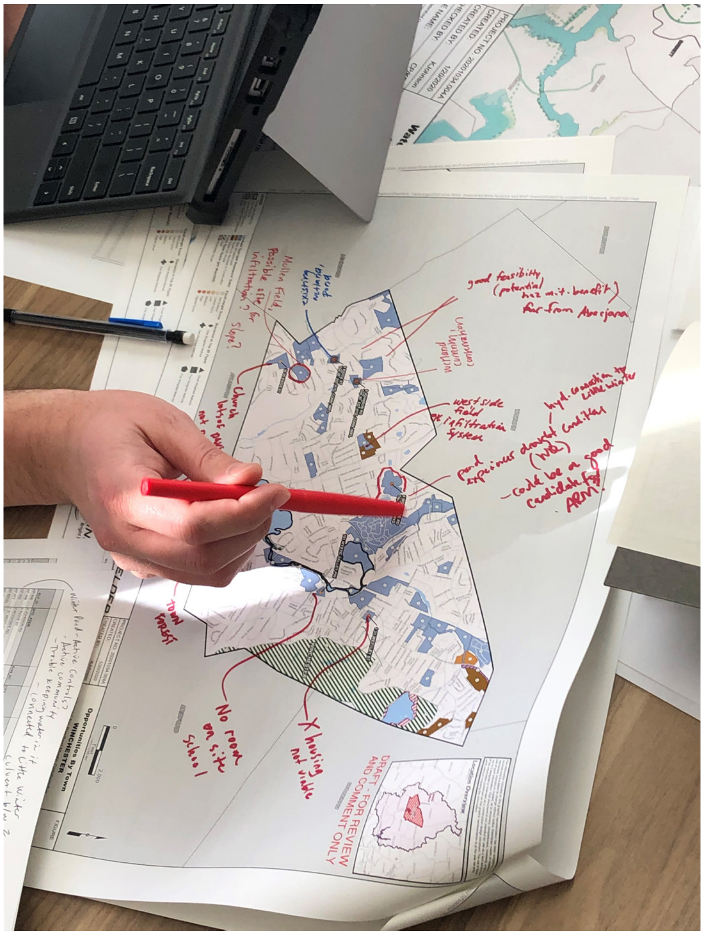

Figure 13 – Municipal staff vetting specific parcel opportunities for GI and ARM (January 2020)

Figure 14 – RMC Upper Mystic Stormwater Working Group workshop (January 2020)

criteria. In addition to the four primary criteria in the previous section, a fifth category, feedback on Public Acceptance was added because of workshop feedback during the breakout group discussions.

As summarized in **Figure 15**, the UMSWG came to a consensus that three primary criteria (hydrology, cost and ease of implementation, and Public Acceptance) should be designated as Tier I criteria, while EJ and connectivity indicators should be designated as Tier 2 (or co-benefit) criteria.

A one-page moderator guidance document, which helped facilitate the breakout group discussions at the January 2020 workshop and helped prioritize Tier 1 and Tier 2 criteria selections is included with community engagement materials in **Appendix M**.

Incorporation of Workshop Feedback (Pre-Processing of Desktop Opportunities)

Parcel Parsing of "Non-Suitable" Areas Using Automated GIS Scripts

One of the key outcomes and recommendations of the January 2020 workshop was to revisit large parcels that were previously screened out as "non-suitable" for future wetland GI. The UMSWG noted some limitations with GIS datasets, as well as methods used to screen out sites based on bedrock and slope criteria. Namely, it was difficult to score large parcels with a representative score for these criteria when conditions vary across the site.

To improve the non-weighted scoring

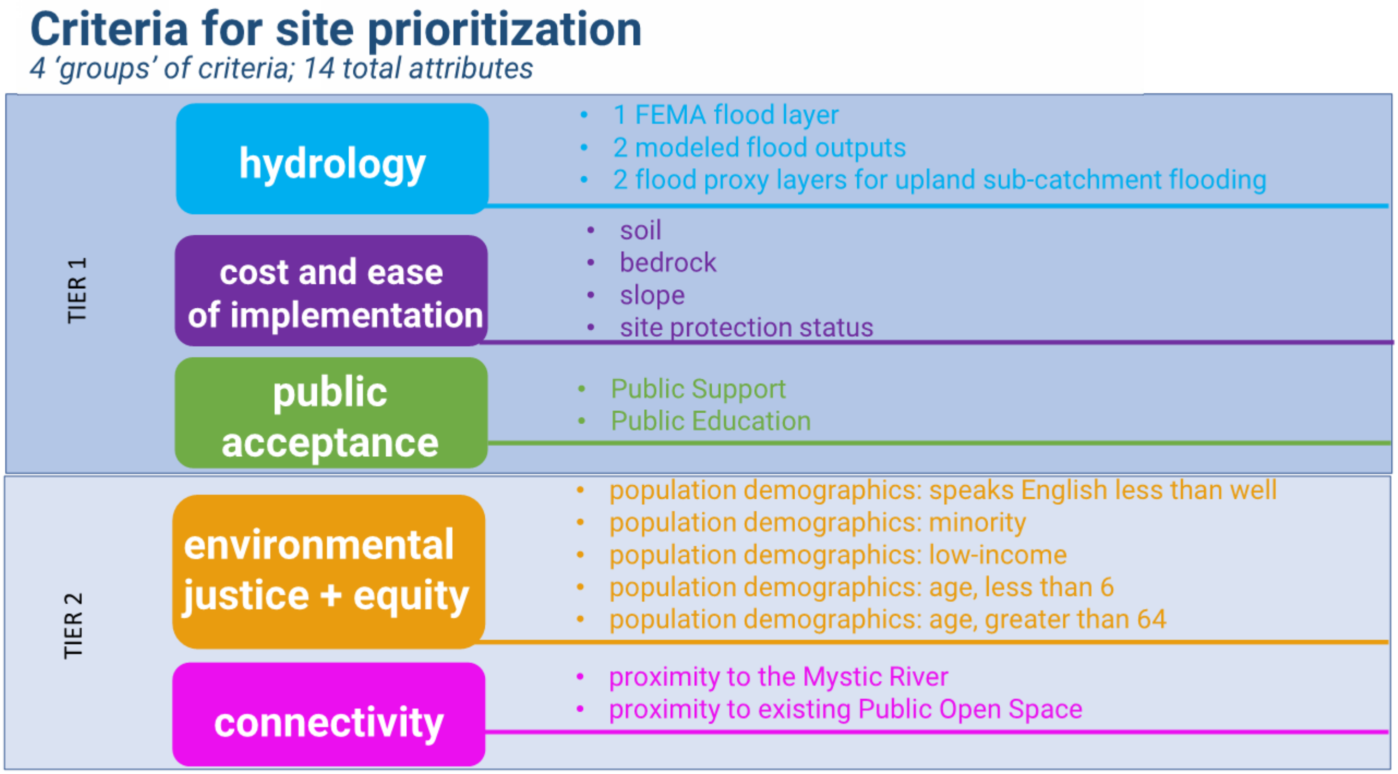

Figure 15 – Designation of Tier 1 (primary) and Tier 2 (co-benefit) Criteria (January 2020 workshop)

methodology, some pre-processing steps were needed to filter out "non-suitable" portions of parcels, without screening out the entire parcel. Applying this rationale, several additional GIS scripts were developed for pre-processing to internally trim parcel features and map only portions of these parcels that were "suitable" for wetland GI. This parcel-parsing effort was limited as follows:

- Bedrock conditions and site slopes (as other criteria such as existing site soils could be replaced as part of a future design)
- FEMA floodplain extents or modeled flooding. However, it was agreed by the UMSWG that viable candidate wetland GI sites could still exist within the 100-year or 500-year FEMA floodplains. For example, a project could favorably re-grade such sites (via dredging, or creation of new berms and off-site compensatory storage) or add active controls.

In both of these cases, new storage could be better optimized for smaller, more frequent precipitation events (e.g., 5-year, 10-year, or 2070 10-year events). The pre-processing step to parse "suitable" portions of parcels, based on bedrock conditions and steep slopes, is graphically represented in **Figure 16**.

Interim mapping materials showing how the parcel-parsing was applied within each community are provided in **Appendix F**.

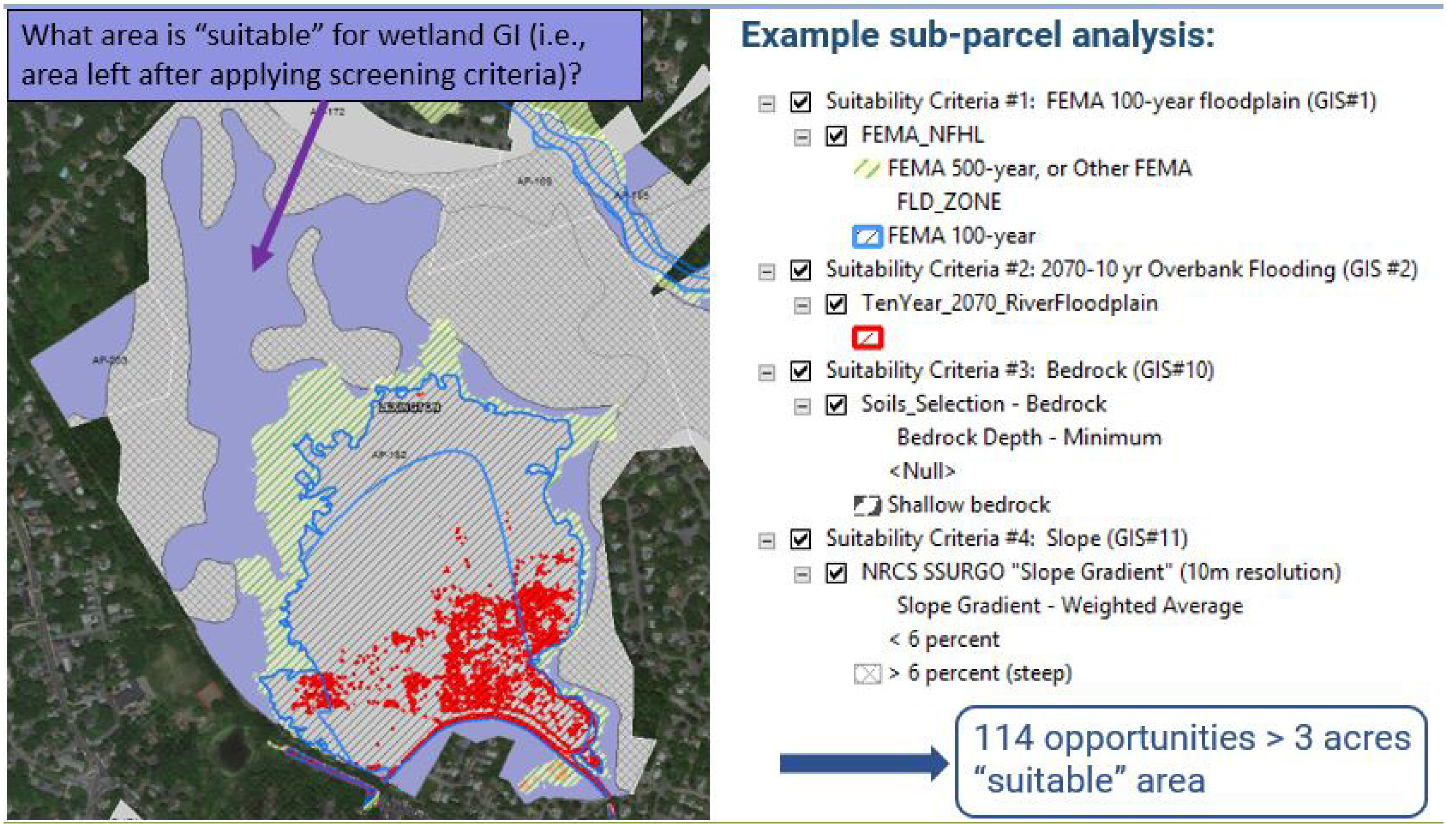

Figure 16 – Parcel Pre-Processing Step to Parse "Suitable" Portions of Parcels for Wetland GI

Additional Desktop Screening of Opportunity Sites

Existing Land Cover / Programmed Site Uses

To reduce the sample set to a more manageable size, the consultant team used Google Street view, aerial imagery, municipalities' assessor's data and other ground-truthing methods to remove unsuitable parcels. This additional step analysis helped further narrow the GI opportunity set from 465 sites to 114 sites. Parcels removed included cemeteries (such as in **Figure 17**), fully built out parcels with building and parking lots, or highly programmed open space unlikely to be converted to wetland use.

Similarly, school and park athletic fields and golf courses were hand-screened and removed from the opportunity set. While these may be great opportunities for subsurface infiltration or detention best management practices (BMPs), the Working Group determined that these sites could not be converted to wetlands.

The Project Team reduced the opportunity set of sites to 15 sites per municipality and requested feedback on each of the 15 sites.

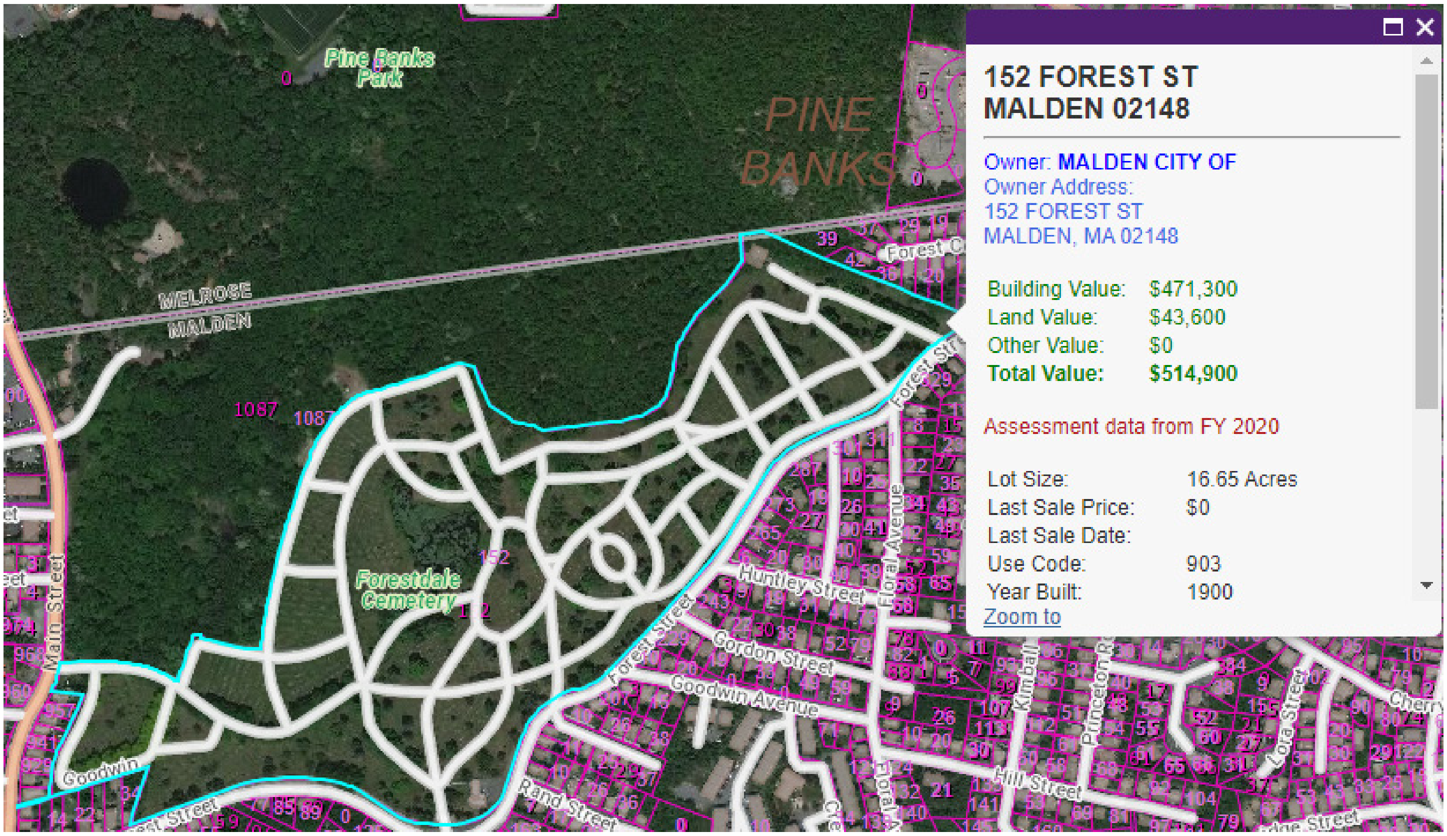

Figure 17 – Example site eliminated from parcel opportunity set due to existing cemetery use

Refinement of Tier I and Tier 2 Ranking Criteria

Desktop Screening of Priority Habitat and Site Restoration Potential

In early April 2020, the Project Team determined that on-site field investigations (as part of **Task 4**) were unlikely to happened due to the COVID-19 pandemic. In place of site visit observations, an additional criterion was added to assess ecological and habitat condition, and existing resource quality of sites.

The added criterion analyzed Priority Habitat and Site Restoration Potential using GIS-based methods. To conduct this analysis, aerial photographs were used to assess general vegetation cover types at each site. MassGIS Natural Heritage and Endangered Species Program (NHESP) Priority and Estimated Habitats of Rare Species data layers, MassGIS NHESP BioMap2 Core Habitat and Critical Natural Landscape data layers, and the MassGIS MassDEP wetlands data layers were used to rank each parcel. For each site the existing cover type(s) and area(s) were identified. An initial score was assigned based on existing cover type(s). A score of 1 to 5 was assigned to each site, 1 being the highest quality habitat and

5 being the lowest quality habitat. A higher score would constitute a site with degraded habitat, more suited for a constructed wetland and thus greater potential for habitat restoration.

Existing cover types and scores included:

- Impervious Surface – Score of 5. Preferred siting for a constructed wetland due to existing low-quality habitat.
- Turf Grassland – Score of 3. Mid-level score due to medium-quality habitat.
- Woodland and/or Wetland – Score of 1. Least preferred siting for a constructed wetland due to existing high-quality habitat (exclusive of existing invasive plant species presence).
- Combinations of Cover Types – Scores of 2 and 4 were assigned where combinations of cover types were identified.

There was a relatively small number of parcels with NHESP Priority Habitats of Rare Species, Estimated Habitats of Rare Species, BioMap2 Core Habitat, or Critical Natural Landscape areas present. In these instances, the Project Team used the cover type percentages to determine the score, and on several occasions, adjusted a score from a 2 to a 1 where these data areas were present.

The desktop analysis did not determine habitat quality based on the following parameters: habitat type (composition); species diversity; age of habitat (early-, mid, and late-successional communities); and presence/dominance of invasive plant species. Invasive plant species analysis occurred during **Task 4** when field investigations of the priority sites were conducted.

Adjustments to GIS Criteria and Non-Weighted Scoring Methodology

Prior to conducting additional outreach and gathering site-specific feedback from municipal staff, several GIS processes were consolidated or replaced. Non-weighted scoring approaches were modified, as follows:

- Three of the four intermediate flood layers (GIS-based proxy layers from the Initial Regional Model) that were used in the preliminary screening effort were removed and replaced as better data became available from the updated regional model. The 2070 10-year overbank flooding layer was maintained, as the results from the updated regional model underwent additional quality control checks.

- Existing site soil conditions (i.e., Hydrologic Soil Group conditions of existing soils) taken from the Natural Resources Conservation Service (NRCS) 2014 SSURGO dataset were removed as a scoring criterion. Although this data is generally the most detailed level of soil geographic data developed by the National Cooperative Soil Survey, and can be used to assess site suitability for infiltration-focused GI projects, this criterion was not seen as significant for scoring of wetland opportunities as on-site soils could be replaced during implementation. For wetland GI projects, design typically limits infiltration, improving water quality treatment. For example, during implementation of the Alewife Stormwater Wetland project, the well-draining soils found on-site were removed and stored for later use on projects elsewhere, and off-site soils were imported to the site and compacted to create non-infiltrating conditions.

- The census tract data from two equity/EJ sources (e.g., EEOEA EJ dataset and EPA EJScreen) were replaced with data from CDC's Social Vulnerability Index, SVI. This index-based approach simplified the analysis, controlling across multiple different vulnerability indicators.

After applying these modifications to the scoring methodology, non-weighted scores (across 9 total GIS-based criteria) was generated. Tabular data was used to help pre-rank wetland GI opportunity sites, facilitating feedback from municipalities for a targeted subset of parcels (see **Appendix G**).

Feedback from Municipalities for Specific Sites (Public Acceptance)

Another round of feedback from municipal staff was conducted in March 2020, soliciting input on specific sites. This served as an opportunity for additional co-production, since some of these were new sites not previously considered for GI,]. Feedback was performed by multiple City/Town departments (i.e., planning/community development, engineering, and conservation staff), concurrently on their own schedules.

This outreach effort also helped vet data used in the new Multicriteria Prioritization Tool, which was used in the May 2020 virtual workshop. The communities were provided with tabular lists of suitable GI parcels with preliminary (non-weighted) scoring.

Non-Weighted Scoring Using GIS Criteria and Public Acceptance Feedback

To help pre-rank sites ahead of the May 2020 virtual workshop, a total of nine (9) GIS-based criteria, along with the direct municipal feedback in the form of Public Acceptance scores were used for non-weighted scoring.

Appendix I contains the initial non-weighted scoring conditions that were developed for each of these independent GIS scripts.

Multi-Criteria Prioritization (Pre-Prioritization Feedback and New Prioritization Tool)

One-Page Summary Fact Sheets

Using the non-weighted scoring, the consultant team generated one-page summary fact sheets for the top 35 wetland GI opportunities (see **Appendix L**). These opportunities included sites that were deemed to have a high likelihood of public acceptance (i.e., scores 4 or 5), indicating near-term readiness and fewest near-term barriers to implementation.

These one-page summary fact sheets were developed and distributed ahead of the May 2020 virtual workshop. Sharing these in advance of the workshop added transparency to the GIS desktop analysis and facilitated in-depth discussion at the workshop These one-page summary fact sheets were also a way to gather data on the localized flood mitigation potential of these projects.

Local Flood Mitigation Feedback

The One-pagers were shared in advance of the workshop, as they also served as form to gather additional anecdotal data on the localized flood mitigation potential of these sites. The potential for wetland GI projects to produce localized flood mitigation benefits in areas where this type of flooding is already observed by these communities was considered a co-benefit to the larger goal of regional flood mitigation.

Data were collected from the municipalities via polling conducted prior the workshop to determine local flood mitigation potential. If proposed wetland GI solutions can help address localized flooding, municipalities could leverage future grant funding to construct the wetland GI solutions. Possible funding sources include FEMA's Flood Mitigation Assistance (FMA) or Building Resilient Infrastructure and Communities (BRIC) grants.

Table 5 – Criteria Used for Non-Weighted Scoring of Sites (April 2020)

No.	Primary Criteria/ Indicator Group	GIS criteria	GIS Criteria Description	Scoring Overview	Rationale / Assumptions	Data Source
1	**Flood Exposure and Hydrology**	FEMA flood zones	Location of GI opportunity with respect to FEMA 100- and 500-year flood zones	Highest scores prioritize areas in close proximity, but just outside FEMA 100-year floodplain; Moderate scores include areas within 100-year and 500-year flood zones; Low scores reserved for upstream areas sitting outside any floodplain (not advantageous for large DCIA disconnection by gravity flow)		FEMA NFHL
2	**Flood Exposure and Hydrology**	2070 10-year overbank flooding	Location of GI opportunity with respect to modeled flooding (2070 10-year overbank flooding)	Highest scores prioritize areas where modeled flooding is present; Moderate scores include areas within 500 feet of modeled flood areas; Low scores reserved for upstream areas > 0.5 miles from modeled flooding	Areas within flood zones (FEMA flood zones or modeled flood areas) may be suitable sites if new storage can be created; these areas are typically in advantageous locations (already in downstream areas, where piped infrastructure retrofits to get runoff to site may be more efficient)	Initial Regional Model (2019)
3	**Flood Exposure and Hydrology**	2070 10-year overbank flooding	Location of GI opportunity with respect to modeled flooding (2070 10-year flood layer)	Highest scores prioritize areas where modeled flooding is present; Moderate scores include areas within 0.5 miles of modeled flood areas; Low scores reserved for upstream areas > 0.5 miles from modeled flooding		Updated Regional Model (2020)
4	**Flood Exposure and Hydrology**	Subwatershed Impact	Sub-watershed within which the GI opportunity is located	Highest scores prioritize areas in Aberjona or Horn Pond subwatershed; Moderate scores include areas within Alewife, Mill Brook, Malden River, or Mystic Lakes subwatershed; Low scores reserved for areas within Mystic River (lower basin) subwatershed	Assumes flood storage benefits created in upstream subwatersheds can have greater impact on regional mitigation	2006 Mystic River Watershed Action Plan
5	**Cost and Ease of Implementation**	Slope (Topography)	Predominant site slope conditions present at GI opportunity site	Highest scores prioritize portions of sites with less than 3% slopes; Low scores reserved for portions of sites with greater than 6% slopes; Moderate scores include areas in between these thresholds	Assumes implementation of wetland GI is most feasible at sites with no or gradual slopes	MassGIS DEM, NRCS SSURGO
6	**Cost and Ease of Implementation**	Article 97 protection status	Protection status of land surface uses at GI opportunity site	Highest scores prioritize portions of sites without Article 97 protection status; Low scores reserved for sites with known Article 97 protection (per MassGIS); Moderate scores include parcels with unknown protection status	Existing Article 97 protections do not preclude future wetland GI, but may make implementation process more of a challenge	MassGIS Open Space

Table 5 – Criteria Used for Non-Weighted Scoring of Sites (April 2020) - Continued

No.	Primary Criteria/ Indicator Group	GIS criteria	GIS Criteria Description	Scoring Overview	Rationale / Assumptions	Data Source
7	**Equity and Environmental Justice (EJ)**	Social Vulnerability Index (SVI) and Flood Exposure	Location of GI opportunity with respect to socially vulnerable and EJ populations exposed to flooding	Highest scores prioritize area ranking high with social vulnerability index and in close proximity to modeled flooding; Moderate scores include areas ranking in middle tier in terms of social vulnerability index; Low scores reserved for areas with least vulnerable populations	Addition of wetland GI can improve access to passive recreation and waterfront spaces for socially vulnerable and EJ populations, while also reducing flood vulnerability	CDC's Social Vulnerability Index
8	**Connectivity**	Parks and Mystic River Connectivity	Location of GI opportunity with respect to public open space and Mystic River main channel	Highest scores prioritize areas within 500 feet of other public open spaces and Mystic River main channel; Low scores reserved for upstream areas > 0.5 miles from other public open spaces and Mystic River main channel; Moderate scores include areas in between these thresholds	Addition of wetland GI can improve connectivity of public open spaces or improve access to waterfront space.	MassGIS Open Space, Hydro (25k)
9	**Habitat Restoration**	Existing Habitat Quality and Restoration Potential	Predominant land cover type - or special habitat conditions - present at GI opportunity site	Highest scores prioritize areas with low quality habitat - such as impervious areas that could be retrofit to GI; Moderate scores include turf grasslands or low-quality upland areas; Low scores reserved for areas existing woodlands or wetlands, with lowest scores given to areas where existing high-quality priority habitat or critical landscape areas are present	Wetland-scale GI represents an opportunity to restore large parcels areas, and in the process improve and/or restore habitat outcomes.	NHESP Priority Habitats of Rare Species, BioMap2 Core Habitat, Critical Natural Landscape areas or Estimated Habitats of Rare Species
10	**Public Acceptance**	n/a	Feedback from municipal engineer, planning, or conservation staff, gauging the viability of wetland GI opportunity at site location	Highest scores prioritize parcels where public (and host municipality) would likely be amenable to wetland GI use on site; Moderate scores include parcels with ownership status requiring more coordination (private or conservation parcels); Low scores are reserved for parcels with existing protections (such as Article 97), abutter concerns, or other suitability concerns	Public acceptance is a good indicator of the near-term readiness of GI opportunities	Direct feedback from municipal staff (April 2020)

Ranking Criteria	Input Weights
Local Benefits to flood reduction	0%
Regional benefits to flood reduction	40%
Readiness (Ownership, Town Notes, Article 97)	25%
Equity (Social vulnerable population; proximity to existing parks)	25%
Ecosystem/Habitat restoration Potential	10%

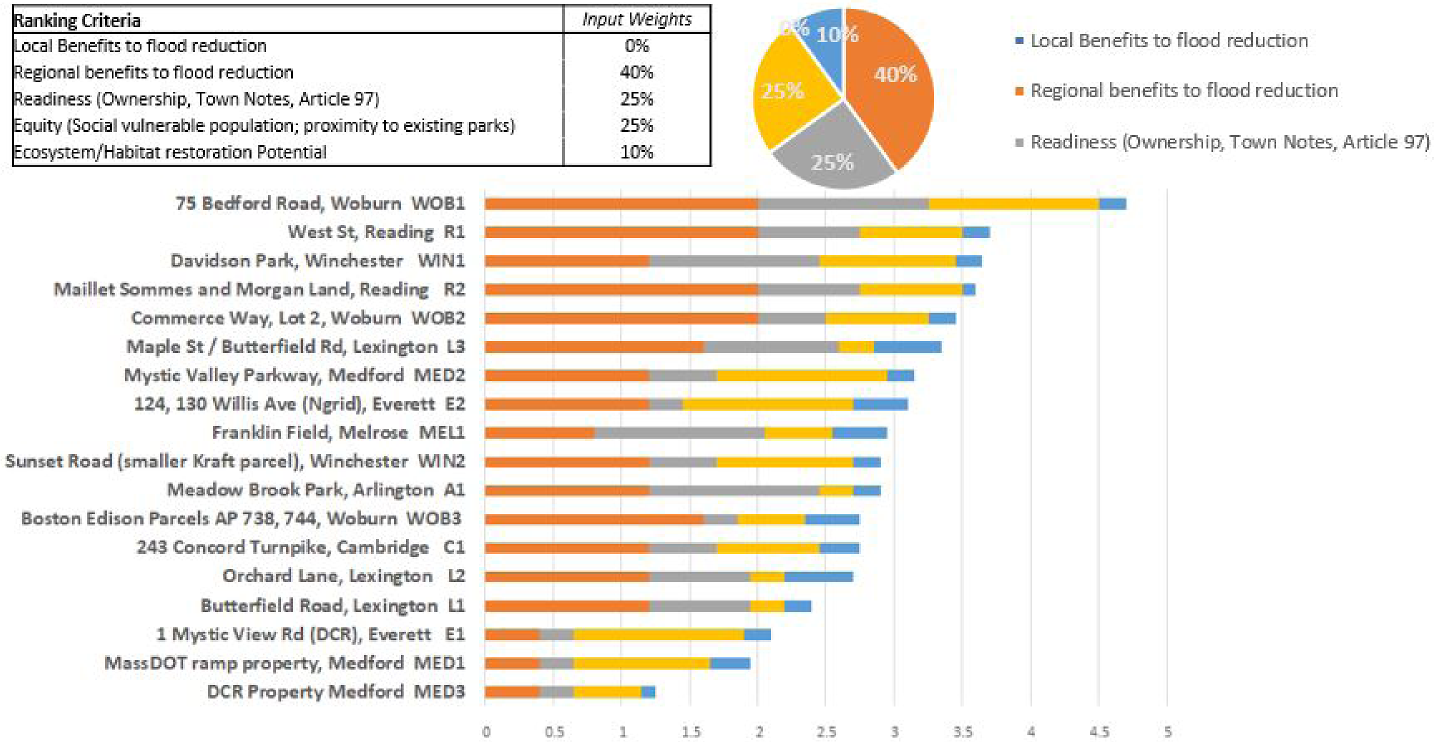

Figure 18 – Screenshot of Criteria Weighting from the Multicriteria Prioritization Tool

Multicriteria Prioritization Tool (Interactive Tool)

A new Multicriteria Prioritization Tool was created and informed by the data collected in the one-page summary fact sheets prior to the May 2020 virtual workshop. This Excel-based interactive tool was created to facilitate live feedback during the workshop and explore alternative criteria weighting across different subsets of criteria. The Multicriteria Prioritization Tool includes a user interface with pie and bar charts, visualizing how projects rank against each other when different weighting configurations are applied. The back-end tabs included in the tool allow users to modify raw scores across the ten Tier 1 and Tier 2 (non-weighted) scoring criteria (see **Appendix K**).

May 2020 virtual workshop (UMSWG)

Due to the Covid-19 pandemic, a virtual presentation was held on May 4, 2020 in place of an in-person workshop. The goal of the workshop was to build consensus around top project opportunities within the watershed.

The workshop drew over 20 attendees, representing more than a dozen municipalities, non-profits (MyRWA and The Nature Conservancy), and was facilitated by the Consensus Building Institute (CBI). The workshop was conducted in two parts, including a summary of opportunity sites, followed by virtual breakout group discussions.

To facilitate consensus-building, MyRWA and

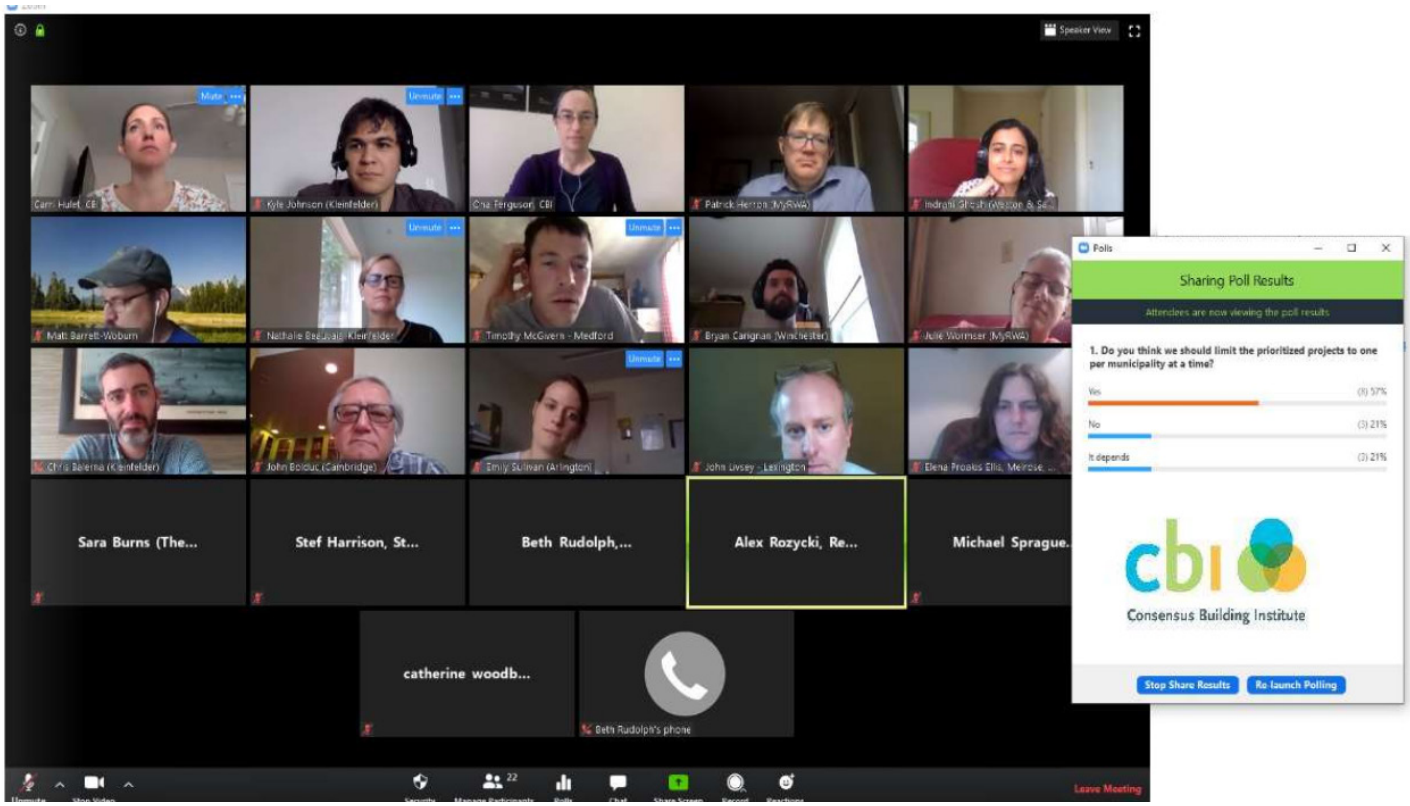

Figure 19 – Virtual Workshop Held via Zoom (May 2020)

the Project Team presented several "straw proposals," each speaking to different technical and watershed outcomes. The Multicriteria Prioritization Tool was used to showcase how specific project opportunities ranked via different weighting approaches. Through manipulation of the Tool, the team was able to demonstrate how specific opportunities could rise or fall in rank relative to other projects based on modified weighting.

Participants were then split into virtual breakout groups, where event moderators helped the attendees use the Multicriteria Prioritization Tool in a live format. The pros and cons of each potential project site were shared by communities, and CBI conducted several interactive polls to facilitate discussion. During the workshop, municipal staff and other participants built consensus around specific opportunities Municipalities also discussed other considerations, such as how to prioritize multiple opportunities within the same municipality, given that the most impactful watershed projects may not be equally distributed across political boundaries.

The virtual breakout sessions helped develop group consensus and advance 12 priority sites for follow-up field investigations and next steps.

TASK 4.

Targeted Site Investigations

Field visits of the priority sites finalized at the May 2020 Workshop were conducted on various dates from July 6 through July 21, 2020, by consultant team members and municipal and owner representatives. As time allowed, the field crew added several sites to the initial list, based on the stakeholder engagement process, municipality recommendations, and proximity to the other sites. For example, additional site visits were conducted at other high-ranking sites in Reading, Winchester, and Woburn.

Prior to the site visits, the consultant team compiled MassGIS-based maps to assist with the field investigation. These maps included contours, utilities, wetland, water, and FEMA flood data layers. Once on site, the team members walked the site to assess the general topography and elevation grades, bedrock outcrops, vegetation types, age and species diversity, presence of invasive plant species, habitat connectivity to other parcels, trails and pathways, accessibility for maintenance vehicles, streams and swales, property line encroachments, and utilities. The team asked municipal and owner representatives questions regarding the history of the site, existing use, future planned use, known stormwater flooding and drainage issues on site or in the nearby area, and information on the existing drainage network and feasibility to redirect stormwater runoff to the site.

The visited sites are listed below in **Table 6**.

Refer to **Appendix N** for additional site-specific information presented in July and August 2020 project meetings.

Figure 20 – 15 Site Investigations Performed amid the Covid-19 Pandemic

Table 6 – Criteria Visited as Part of Task 4 Field Investigations (April 2020)

Priority Site Address	City/Town	Location Description
Priority Site Address	City/Town	Location Description
Mystic Valley Parkway	Arlington	Meadowbrook Park
1-2 Mystic View Road (*Privately owned parcel*)	Everett	Gateway Park
Maple Street	Lexington	Parcel Behind Harrington School
Orchard Lane	Lexington	Conservation Area
4068 Mystic Valley Parkway (*Privately owned parcel*)	Medford	Former Radio Tower Site
Franklin Field	Melrose	Recreational Field
Willow Street	Reading	Maillet, Sommes and Morgan Land
Summer Street	Reading	Linneca Thelin Bird Sanctuary
West Street	Reading	Xavier/Aberjona River Parcel
West Street	Reading	Boyd Parcel
Longwood Road (*Additional site visited*)	Reading	Conservation Area
end of Arnold Ave. Road (*Additional site visited*)	Reading	Conservation Area
Cross Street	Winchester	Davidson Park
75 Bedford Street	Woburn	Former Hurld School
2 Commerce Way	Woburn	Existing Wetland near Target
Washington Circle (*Additional site visited*)	Woburn	Cranberry Bog Conservation Area

Table 7 – Summary of Key Tasks to Inform Field Investigations (Opportunity Screening and Prioritization Steps)

Process Stage	Description of Key Tasks	Number of Potential Sites Identified, or Prioritized	Timeframe
Initial Opportunity Screening	Site identification of municipal-owned parcels, vacant use parcels, and Open Space parcels (per MassGIS) > 3 acres	240	September – October 2019
Revised Opportunity Screening	Site identification procedure revised to use municipality-specific land use and land cover data (i.e., Assessor's database linked to municipalities' parcel datasets) as open space layer is limited to State-protected open space. Procedure modified to include conservation lands, parks, and other municipal parcels that are not protected use by State (i.e., Article 97 sites), as well as non-residential private parcels > 3 acres.	892 (↑ **652** added)	November 2020
Desktop Analysis	Per feedback from Working Group, procedure modified to reduce land use/ ownership types considered for private parcels. Select induvial private parcels (as informed by direct feedback from municipalities) were retained. Procedure was also modified to include at least 5 opportunities from each of 17 Upper Mystic municipalities (next largest qualifying parcels below 3-acre target parcel size threshold was added for municipalities without at least 5 opportunities).	465 (↓ **427** removed)	December-January 2020
Desktop Analysis	GIS-based Suitability Analysis was performed to screen parcels that may be amenable to wetland GI/flood mitigation based on suitability factors, including steep slopes, shallow bedrock, and proximity to high-risk flood areas (per FEMA and prior modeling analyses).	114 (↓ **351** removed)	December-January 2020
Desktop Analysis	Per Working Group feedback, analysis was performed at sub-parcel level (as not to screen out sites where portions of site were found unsuitable; parcels with >3 acres of total sui area within parcel were retained).	142 (↑ **28** added)	January- February 2020
Desktop Analysis	Pre-prioritization sensitivity analysis was performed (using weighting tool and informed by feedback from communities on Public Acceptance/ Feasibility scores).	35 (↓ **107** removed)	March 2020
Prioritization	One-pagers; feedback from municipalities on local flood hazard mitigation potential	Top 35	April 2020
Prioritization and Site investigations	Per feedback from May 2020 Working Group workshop, sub-set of Top 35 sites selected for site investigations	Top 15	May – June 2020
Prioritization	Per feedback from steering team and host municipalities, consensus reached for prioritization of Top 6 sites for conceptual design, immediate next steps	Top 6	July-August 2020
Conceptual Design and Scenario Modeling	10% conceptual layout and design of 6 wetland GI sites, scenario modeling within regional model	Top 6	August- November 2020
Phase II Prioritization (Next steps)	Based on results of Phase I, prioritize near-term focus sites and outcomes for Phase II	3 "high readiness" opportunities	Next Phase (Winter 2020/ Spring 2021)

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TASK 5.

Green Infrastructure – Constructed Stormwater Wetland Conceptual Designs

Concept Designs

Six (6) sites were selected for the 10% concept design development stage. The six sites are located in Arlington, Everett, Lexington, Medford, Reading and Woburn. To begin design, the Project Team gathered available site data and background information including record plans, reports, and GIS data layers from municipal and owner representatives. The Project Team developed base plans using aerial maps, contour data, parcel boundaries, utilities, and estimated resource areas and buffers.

The actual siting for each proposed constructed stormwater wetland system and amenities was determined based on review of the base plans, site visit field notes, and review of other available information. For half of the sites, there were multiple options for siting the constructed wetland system. In those cases, a simple graphic was developed with the options and a follow-up meeting was scheduled with the municipality to solicit feedback. Once a draft concept was developed, the team reached out to the municipal representatives for comments and revisions were incorporated before the concepts were finalized.

The proposed constructed stormwater wetland systems were sized based on the available area within each site taking into consideration existing approximate wetlands, streams, roads, parcel boundaries, and grade contours. Assumptions were made for the proposed elevations for the access paths, top of berm, wetland permanent pool, and overflow elevations based on surrounding GIS-based grade contours. Static storage volumes above assumed permanent pool elevations were calculated for the proposed systems based on the surface areas and assumed elevations.

An order of magnitude estimate of probable construction costs was prepared for each of the six constructed wetland concepts. General items in these cost estimates included: excavation and earthwork; paths and boardwalks, site improvements; planting; and mobilization. Wetland mitigation costs were estimated at a 2:1 ratio of lost wetland for Arlington, Reading, Everett, and Medford (no existing wetland areas were impacted by concept designs for Lexington and Woburn sites). A 25% construction contingency was used to adjust for the early design phase and future construction date. Design fees and costs associated with permitting and off-site grey infrastructure improvements were not included in these estimates, which are included in the **Figures 21**, **23**, **25**, **27**, **29**, **31**, and **Appendix O**.

Fact sheets and conceptual design layouts were developed for each of the six sites, as presented in the following pages (see **Figures 21** through **32**). The fact sheets also contain estimates for water quality co-benefits at each site, which were estimated using the approach recommended by *the 2016 Massachusetts MS4 General Permit, Appendix F*[7] for stormwater wetlands and MassGIS land cover data within the proposed upstream contributing drainage areas.

Limitations of 10% Design Concepts

There were some limitations in the data and information available for each of the six sites. As this was a 10% concept design the Project Team did not have the benefit of research field topographic surveys, field wetland delineations, existing utility investigations, environmental site assessments, historic map and use research, and soil reports. There were also challenges related to access to specific site data that could not be shared within the project's timeline, and access to multiple stakeholders and those with knowledge of the sites. In addition to municipal engineers and conservation commission agents, the Project Team was able to obtain insightful and critical information from members of the respective planning boards, facilities and public works departments, design consultants, and private developers.

7 https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-2016-ma-sms4-gp.pdf

Watershed-wide Analysis to Optimize & Coordinate Regional Stormwater Management in the Mystic River Watershed

Mystic River WATERSHED ASSOCIATION

Prepared for the Resilient Mystic Collaborative (RMC)

0 Mystic Valley Parkway (Meadowbrook Park) - Arlington, MA

Owner

Town of Arlington Park

Parcel Size

9.1 acres (site has protected site use under Article 97)

Conceptual Constructed Wetland Information

Contributing Drainage Area: 125 acres
Forebay Area: 0.36 acres
Wetland Area: 1.87 acres
Wetland Permanent Pool Area: 1.32 acres
Static Storage Volume Above Permanent Pool: 7.69 acre-ft
Existing Wetland Impacted Area: 2.62 acres

Conceptual Estimated Cost: $4,015,000*

Constructed Wetland: $2,345,000
Paths/Signage/Boardwalk: $100,000
Wetland Mitigation and Stream Restoration: $475,000
**Includes 10% Mobilization and 25% Contingency Cost,*
**Excludes Cost for Upstream Stormwater/Grey Infrastructure and Design/Permitting*

Potential Pollutant Removal Estimates

~76 lbs/year TP removal, ~365 lbs/year TN removal

Site-Specific Opportunities & Co-Benefits

- Mill Brook, an urban stream passing through the site, offers opportunity for stream restoration, flood mitigation, and ecological enhancement.
- Existing site is dominated by invasive phragmites grasses and Japanese knotweed.
- Opportunity for improved passive recreation accessibility (park has limited site access via cemetery).
- Opportunity to reduce erosion and pre-treat stormwater runoff from Town Cemetery and other upstream areas (water quality cobenefit).

Arlington GIS Map – Meadowbrook Park Property

Site Photo – Meadowbrook Park Property

Design Considerations & Challenges

- Constructed stormwater wetland could operate as a stormwater improvement separate from Mill Brook, assuming upstream runoff could be conveyed from west of site. However, MWRA sewer crossing is barrier to implementation.
- Alternative flood storage concept could utilize existing wetland area, adding active controls at downstream outlet to better detain and treat flows prior to discharging to Lower Mystic Lake.

Figure 21 – GI Fact Sheet for Meadowbrook Park Site (Arlington)

Figure 22 – Conceptual Design Layout for Meadowbrook Park Site (Arlington)

Watershed-wide Analysis to Optimize & Coordinate Regional Stormwater Management in the Mystic River Watershed

Prepared for the Resilient Mystic Collaborative (RMC)

2 Mystic View Road (Gateway Park) - Everett, MA

Owner

DDRC Gateway LLC

Parcel Size

~23 acres

Conceptual Constructed Wetland Information

Contributing Drainage Area: 225-325 acres
Forebay Area: 0.63 acres
Wetland Area: 2.96 acres
Wetland Permanent Pool Area: 2.27 acres
Static Storage Volume Above Permanent Pool: 18.17 acre-ft
Existing Wetland Impacted Area: 1.7 acres

Conceptual Estimated Cost: $4,653,000*

Constructed Wetland: $2,850,000
Paths/Signage/Boardwalk: $159,000
Wetland Mitigation: $375,000
**Includes 10% Mobilization and 25% Contingency Cost*,
**Excludes Cost for Upstream Stormwater/Grey Infrastructure and Design/Permitting*

Potential Pollutant Removal Estimates

~166 lbs/year TP removal, ~769 lbs/year TN removal

Site-Specific Opportunities & Co-Benefits

- The location of proposed wetland park is strategically aligned with the long-term visions for the City of Everett waterfront and Malden River Greenway plans. Concept would improved passive recreation and pedestrian accessibility between the Amelia Earhart Dam and Village Landing Park up to Malden Center and (proposed) Spot Pond Brook Greenway.
- Existing site vegetation is dominated by invasive phragmites grasses, which are contracted to be removed every few years by private owner to preserve viewpoints.
- Concept builds off previous site visioning process with Shadley Associates, and has potential tie-in to proposed Spring Street Diversion Alternative in the City's Integrated (Water) Plan.

Everett MuniMapper – 2 Mystic View Rd Property

Site Photo – 2 Mystic View Rd Property

Design Considerations & Challenges

- Property is privately owned by DDRC Gateway LLC with activity and use limitations (AULs). Although proposed concept site uses are in line with AULs, further analysis of to determine if any required soil remediation is required.

Figure 23 – GI Fact Sheet for Gateway Park Site (Everett)

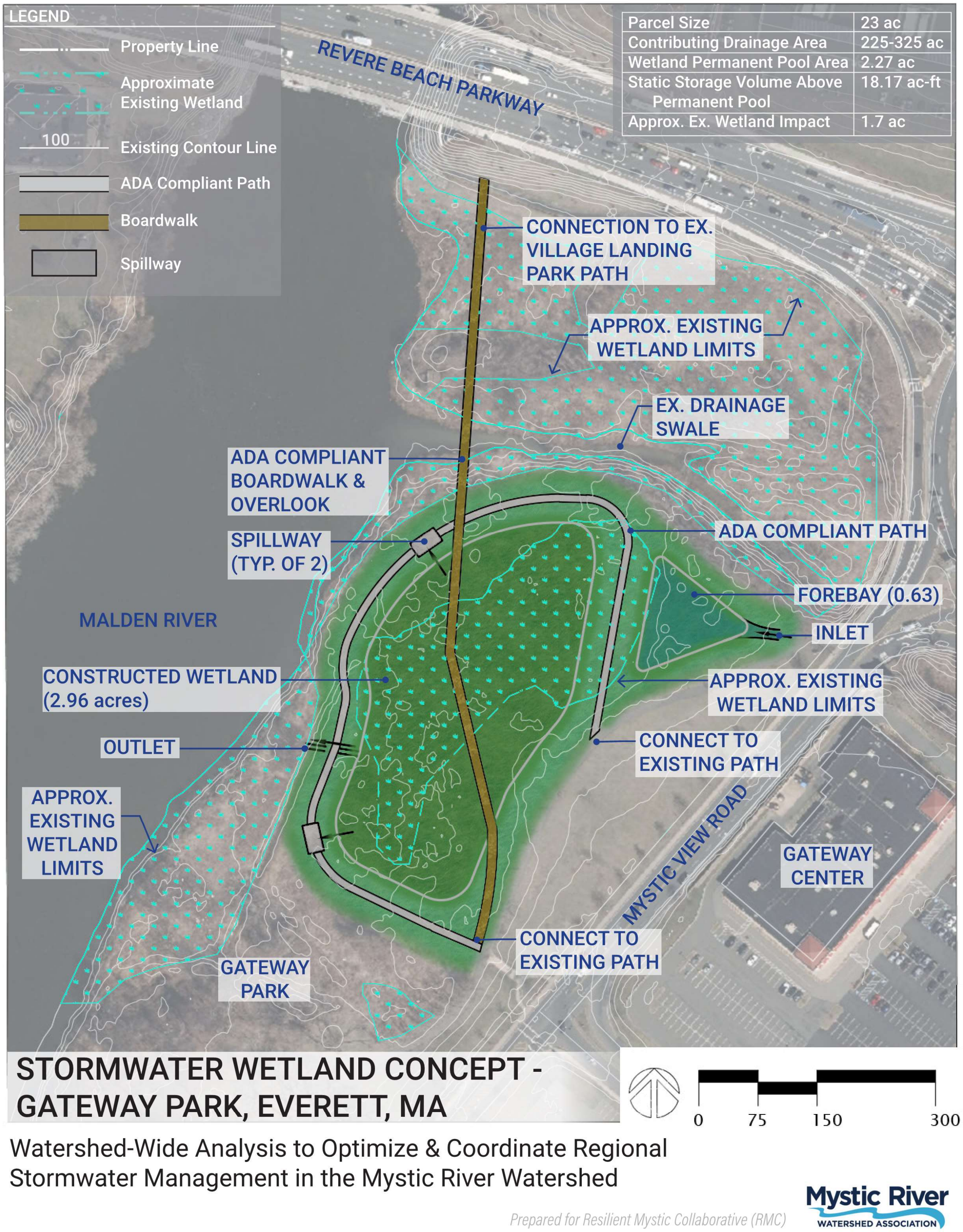


Figure 24 – Conceptual Design Layout for Gateway Park Site (Everett)

Watershed-wide Analysis to Optimize & Coordinate Regional Stormwater Management in the Mystic River Watershed

Mystic River WATERSHED ASSOCIATION

Prepared for the Resilient Mystic Collaborative (RMC)

Maple St. (behind Harrington School) - Lexington, MA

Owner

Town of Lexington

Parcel Size

27.26 acres

Conceptual Constructed Wetland Information

Contributing Drainage Area: 205 acres
Forebay Area: 0.35 acres
Wetland Area: 1.34 acres
Wetland Permanent Pool Area: 0.87 acres
Static Storage Volume Above Permanent Pool: 5.18 acre-ft

Conceptual Estimated Cost: $2,702,000*

Constructed Wetland: $1,880,000
Paths/Signage/Boardwalk: $85,000
Wetland Mitigation: $0
**Includes 10% Mobilization and 25% Contingency Cost*,
**Excludes Cost for Upstream Stormwater/Grey Infrastructure and Design/Permitting*

Potential Pollutant Removal Estimates

~127 lbs/year TP removal, ~663 lbs/year TN removal

Site-Specific Opportunities & Co-Benefits

- Wetland opportunity is contained on Town-owned land; less coordination and site access issues for construction or O&M.
- The larger upland site areas (away from the existing wetland) offers best opportunity for the constructed wetland. Constructed wetland concept can be kept separate, so as not to encroach on any existing wetland.
- Opportunity for local flood mitigation opportunity (flow can be routed from north (Woburn St). Some flooding also observed to northwest near Solomon Pierce Road.
- Site is adjacent to future (active) recreational facilities, with environmental education/Big Backyard opportunity (for Harrington Elementary School); pathways along edge of wooded area have grown in over time.

Lexington GIS Map – Maple Street Property

Site Photo – Maple Street Property

Design Considerations & Challenges

- Confirm Exxon Oil Easement (through the site per Lexington GIS) is abandoned.
- Consider coordination with MassDOT, MWRA for adjacent drainage opportunities off of Lowell St. and Maple St. to wetland to wetland (or distributed green infrastructure).

Figure 25 – GI Fact Sheet for Maple St. Site (Lexington)

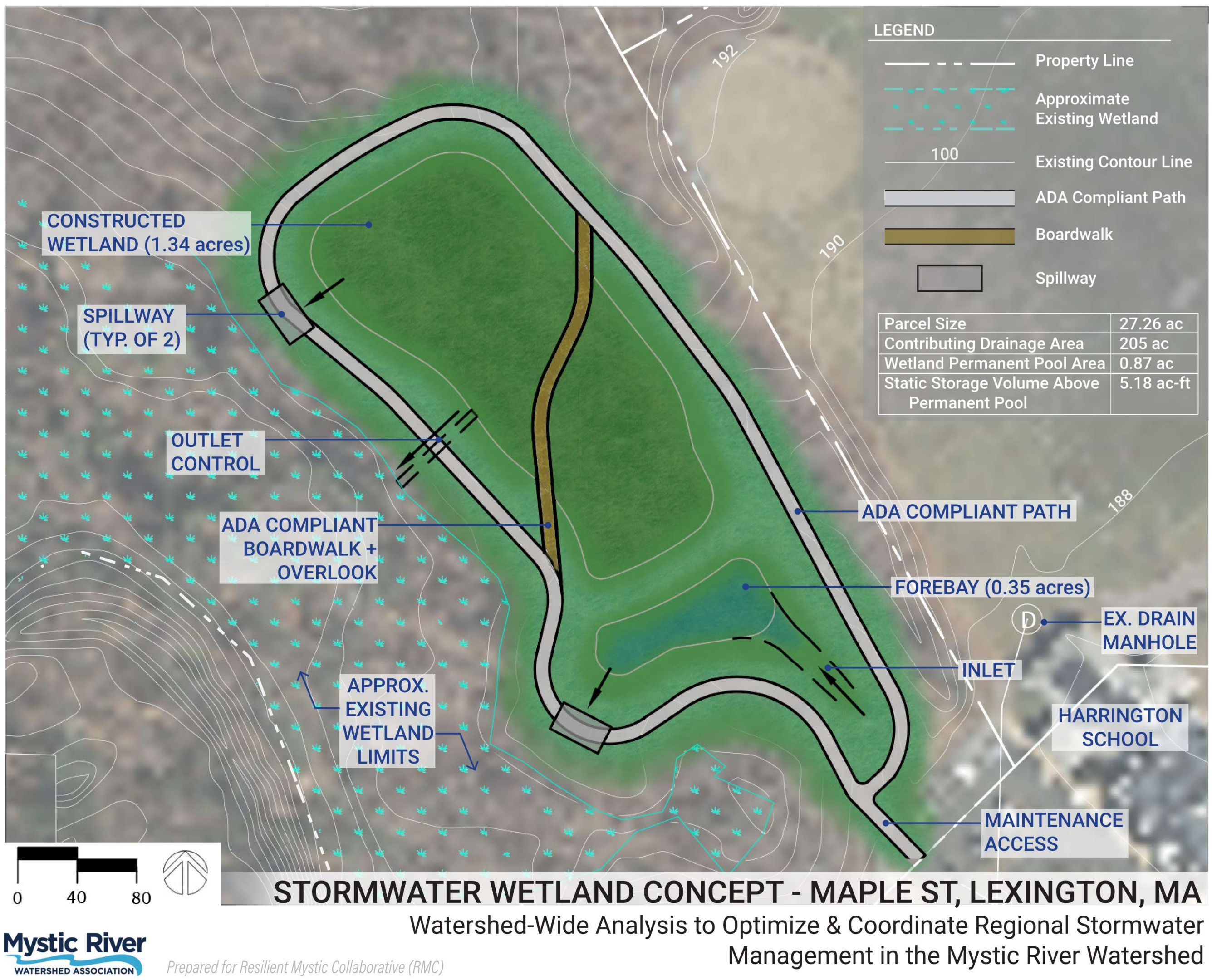


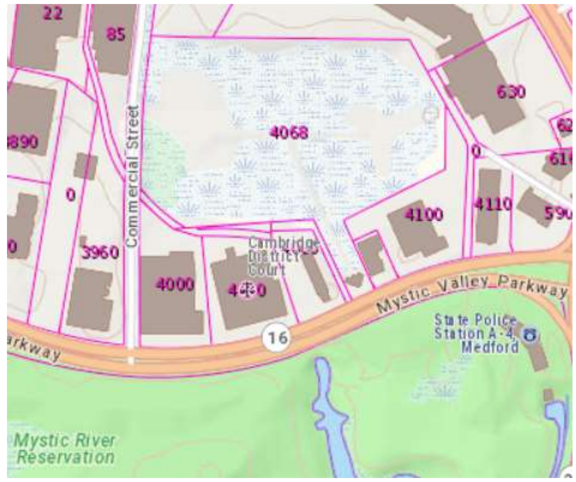
Figure 26 – Conceptual Design layout for Maple St. Site (Lexington)

Watershed-wide Analysis to Optimize & Coordinate Regional Stormwater Management in the Mystic River Watershed

Mystic River WATERSHED ASSOCIATION

Prepared for the Resilient Mystic Collaborative (RMC)

4068 Mystic Valley Parkway - Medford, MA



MuniMapper – 4068 Mystic Valley Parkway Property

Site Photo – 4068 Mystic Valley Parkway Property

Owner

Fellsway Associates LLC

Parcel Size

18 acres

Conceptual Constructed Wetland Information

Contributing Drainage Area: 190 acres
Forebay Area: 0.29 acres
Wetland Area: 2.52 acres
Wetland Permanent Pool Area: 1.56 acres
Static Storage Volume Above Permanent Pool: 5.48 acre-ft
Existing Wetland Impacted Area: 3.9 acres

Conceptual Estimated Cost: $3,944,000*

Constructed Wetland: $2,442,000
Paths/Signage/Boardwalk: $81,000
Wetland Mitigation: $345,000
**Includes 10% Mobilization and 25% Contingency Cost,*
**Excludes Cost for Upstream Stormwater/Grey Infrastructure and Design/Permitting*

Potential Pollutant Removal Estimates

~109 lbs/year TP removal, ~547 lbs/year TN removal

Site-Specific Opportunities & Co-Benefits

- Property is privately owned by Fellsway Associates LLC with development planned in the northwest upland portion of the site.
- Site has close proximity to Mystic River Reservation with potential for increased connectivity and public open space.
- Existing wetlands appear man-made. Low-quality habitat comprised almost entirely of invasive phragmites grasses.
- Existing radio tower, building, and access roads would not be impacted by concept.
- Opportunity for water quality improvement of adjacent largely-impervious commercial areas

Design Considerations & Challenges

- Extent of existing upstream drainage site needs to be confirmed. Past wet weather observation (anecdotal by MyRWA) has noted that outlet by Mystic Valley Parkway has positive flow, but not substantial.
- Site outlet elevation is not much higher than Mystic River; active outlet controls may be needed to improve performance during low- to mid-size storm events.

Figure 27 – GI Fact Sheet for Mystic Valley Parkway Site (Medford)

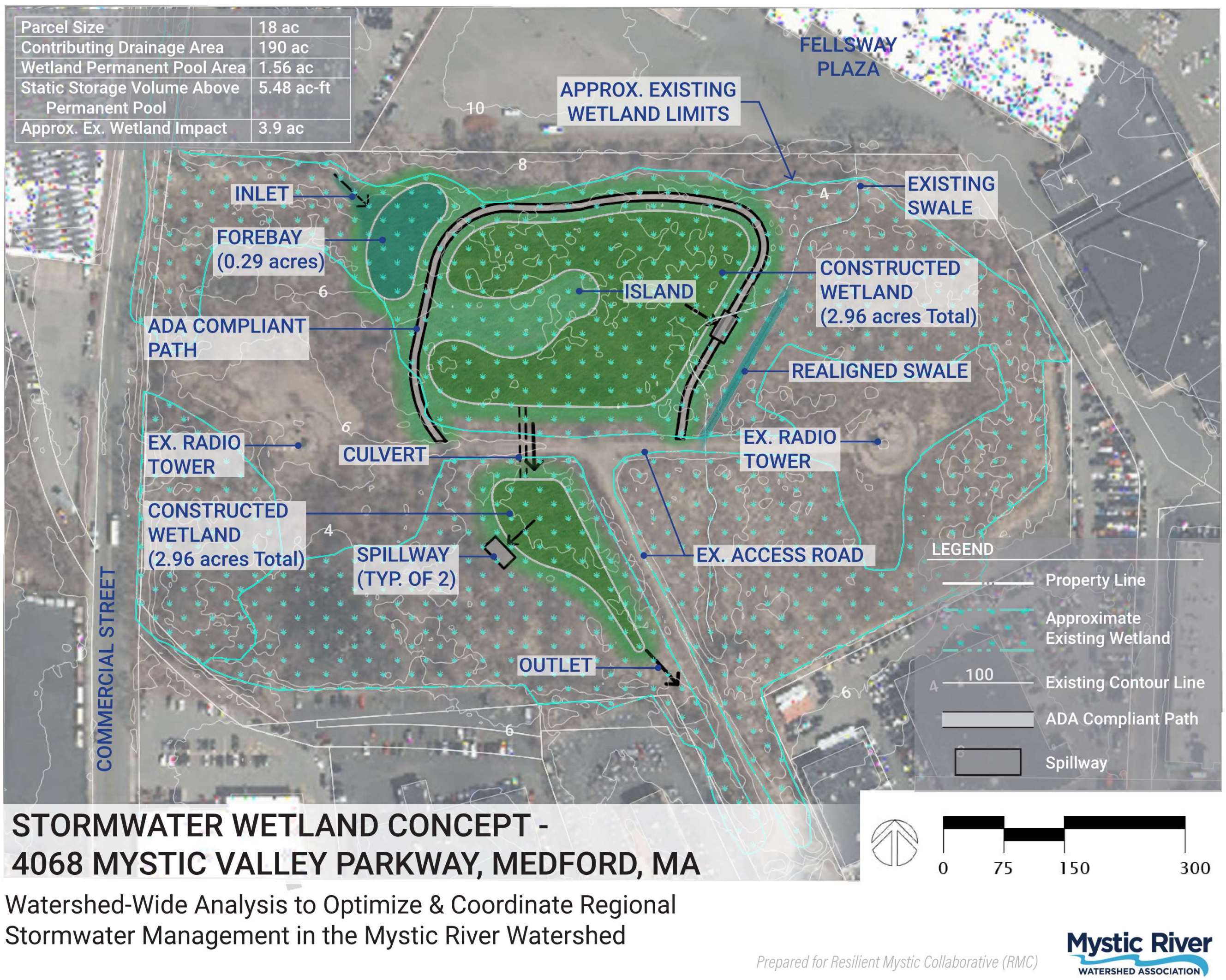


Figure 28 – Conceptual Design Layout for Mystic Valley Parkway Site (Medford)

Watershed-wide Analysis to Optimize & Coordinate Regional Stormwater Management in the Mystic River Watershed

Prepared for the Resilient Mystic Collaborative (RMC)

0 Willow Street (Maillet, Sommes & Morgan Land) - Reading, MA

Owner

Town of Reading (conservation parcel)

Parcel Size

5.48 acres; protected site use under Article 97

Conceptual Constructed Wetland Information

Contributing Drainage Area: 100-150 acres
Forebay Area: 0.29 acres
Wetland Area: 1.72 acres
Wetland Permanent Pool Area: 0.96 acres
Static Storage Volume Above Permanent Pool: 5.96 acre-ft
Existing Wetland Impacted Area: 1 acre

Conceptual Estimated Cost: $2,828,000*

Constructed Wetland: $1,880,000
Paths/Signage/Boardwalk: $97,000
Wetland Mitigation: $80,000
**Includes 10% Mobilization and 25% Contingency Cost,*
**Excludes Cost for Upstream Stormwater/Grey Infrastructure and Design/Permitting*

Potential Pollutant Removal Estimates

~79 lbs/year TP removal, ~364 lbs/year TN removal

Site-Specific Opportunities & Co-Benefits

- Concept compliments existing recreational and trail use; proposed ADA-compliant trail and boardwalk connects to existing open space circulation.
- It is envisioned that recreation/trail improvements can improve access linkage between Willow Street/Austin Preparatory School and depot/Town center (via Hunt & Vine Street).
- Wetland environmental education (co-benefit) and collaboration opportunity with Austin Preparatory School drainage improvements.
- Existing upland space at site comprised of low-quality lawn, Japanese knotweed, and oriental bittersweet invasives.
- Relocates existing sanitary sewer outside of the existing wetland.

Reading GIS Map – 0 Willow St Property

Site Photo – 0 Willow St Property

Design Considerations & Challenges

- Opportunities to mitigate flooding at Willow St, Lowell and Bond Streets, and washout sheet flow from Lee and Hunt Streets.
- Existing 12" sewer alignment cuts below advantageous areas for wetland space; may need to work around or relocate towards private parcels at north edge of site.

Figure 29 – GI Fact Sheet for Maillet, Sommes & Morgan Land Site (Reading)

Figure 30 – Conceptual Design Layout for GI Fact Sheet for Maillet, Sommes & Morgan Land Site (Reading)

Watershed-wide Analysis to Optimize & Coordinate Regional Stormwater Management in the Mystic River Watershed

Prepared for the Resilient Mystic Collaborative (RMC)

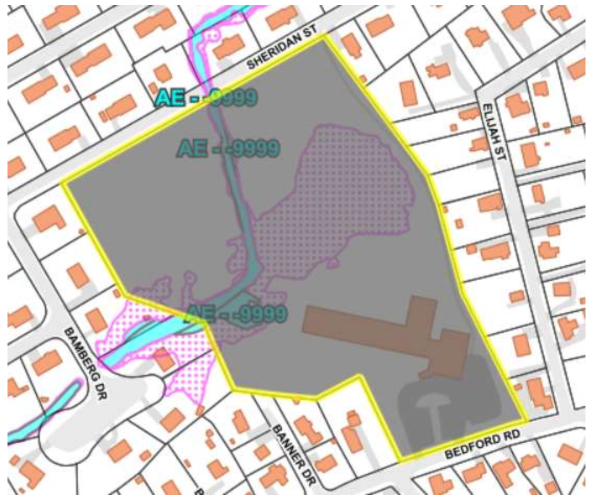
75 Bedford Road (former Hurld School)- Woburn, MA

Owner
City of Woburn

Parcel Size
- 11.27 acres (site has protected site use under Article 97)

Conceptual Constructed Wetland Information
Contributing Drainage Area: 100-150 acres
Forebay Area: 0.12 acres
Wetland Area: 0.67 acres
Wetland Permanent Pool Area: 0.43 acres
Static Storage Volume Above Permanent Pool: 2.06 acre-ft

Conceptual Estimated Cost: $1,464,000*
Constructed Wetland: $997,000
Paths/Signage/Boardwalk: $68,000
Wetland Mitigation: $0
**Includes 10% Mobilization and 25% Contingency Cost,*
**Excludes Cost for Upstream Stormwater/Grey Infrastructure and Design/Permitting*



Woburn GIS Map – 75 Bedford Road Property

Site Photo – 75 Bedford Road Property

Potential Pollutant Removal Estimates
~46 lbs/year TP removal, ~217 lbs/year TN removal

Site-Specific Opportunities & Co-Benefits
- Passive recreational opportunity with increased connectivity to the former Hurld School (building to be demolished and used for future public open space), improving site perception.
- Opportunity to connect to existing trail on east side of property connects Bedford Road and Sheridan Street. Recreation/trail opportunities are limited in this area of the City (Horn Pond areas are closest).
- The larger upland site area away from the existing wetland and Cummings Brook offer best opportunity for the constructed wetland.
- Existing upland parts of site is early successional woodland dominated by invasive tree, shrub, groundcover and vine species.

Design Considerations & Challenges
- Advantageously re-routing upstream stormwater for multiple benefits (such as Cummings Brook and Middlesex Canal low-lying areas) which have both low-flow, stagnant water issues and downstream flooding
- Other upstream drainage (near Rag Rock Hill on Bedford Rd side) may be more advantageous based on alternative siting layouts

Figure 31 – GI Fact Sheet for 75 Bedford Road Site (Woburn)

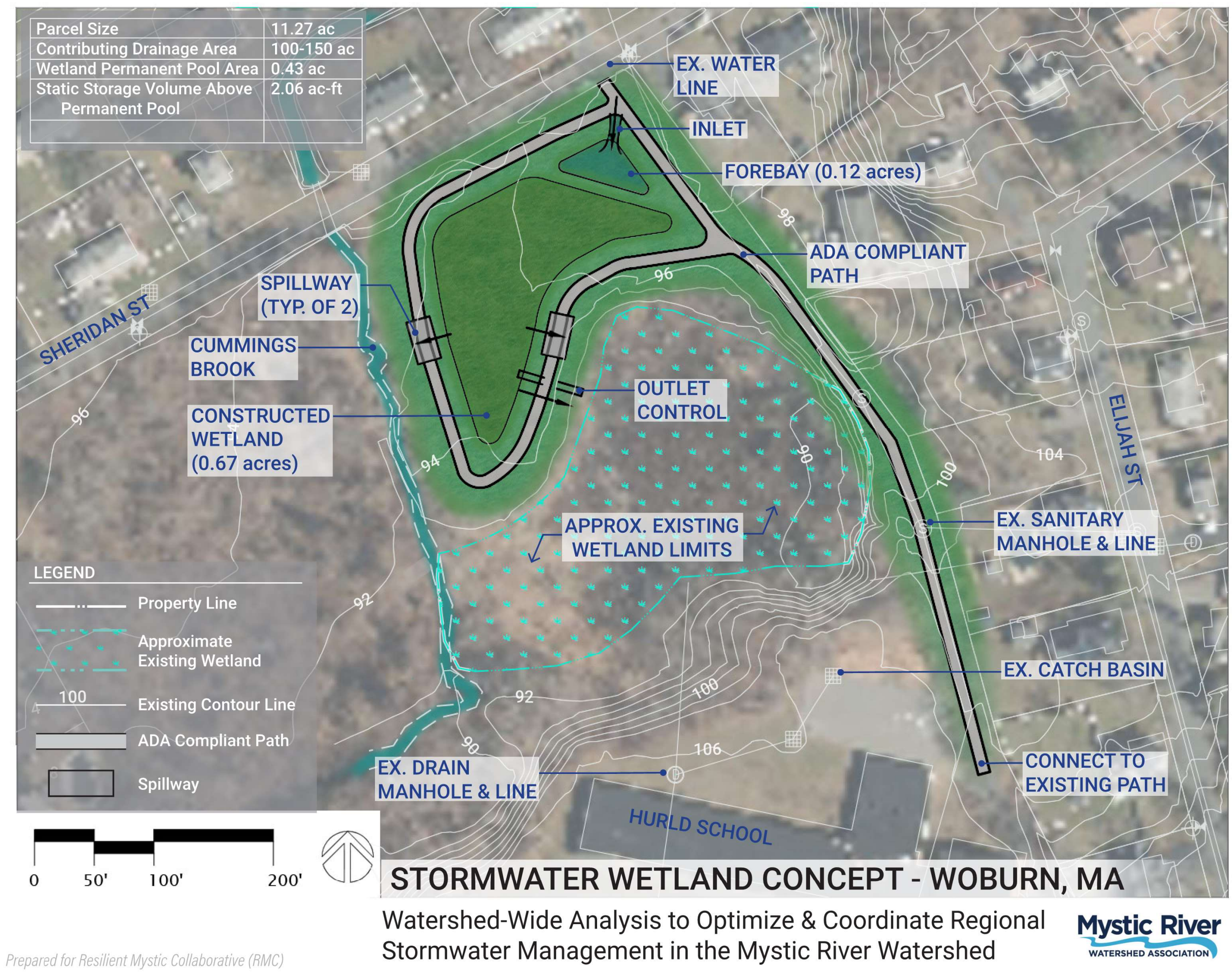


Figure 32 – Conceptual Design Layout for GI Fact Sheet for 75 Bedford Road Site (Woburn)

TASK 6a.

Active Reservoir Management

Purpose

The Mystic River Watershed is both a natural and engineered system. Throughout the watershed, there are impoundments that have become accepted parts of the landscape. For example, Horn Pond in Woburn has a dam structure, serves as a backup drinking water supply, and plays a role in replenishing groundwater supplies. Spot Pond in the Middlesex Fells is a source of water for Winchester and a backup source for MWRA. The Mystic Lakes Dam was reconstructed in 2012, and the AED serves a critical role in providing flood protection. There are a number of other surface water bodies in the watershed, which if efficiently managed, have potential to increase stormwater storage in the watershed and yield flood reduction benefits as part of a regional strategy.

Technologically "Smart" stormwater controls have the potential to reduce peak flows based on real-time monitoring and cloud-based technologies. ARM projects, which are commonly also referred to as Continuous Monitoring and Adaptive Control (CMAC) for non-reservoir sites, control the timing and rate of stormwater flow through existing and new facilities, enabling them to respond to storm events predictively. While the flood control and ecological restoration benefits of these technologies have been clearly demonstrated at multiple individual sites[8], more work is needed to understand the overall benefits at the watershed scale and to how best identify and prioritize locations for implementation in the Upper Mystic Watershed.

Opportunities – Desktop Analysis and Outreach

As part of this project, the consultant team performed a screening assessment using GIS and compiled information from outreach activities and past reports to identify potential priority locations to pursue "smart" stormwater controls. This analysis found that near-term priority sites for further investigation include: Spy Pond and Arlington Reservoir (Arlington), Wright's Pond (Medford), Clay Pit Pond (Belmont), Spot Pond (DCR), and Walker/Whittemore Pond (Woburn). The data compiled from the initial screening is summarized in tabular format in **Appendix P**.

The consultant team also compiled a map that includes key existing flow-control structures throughout the Upper Mystic River Watershed (see **Appendix Q**).

The consultant team and MyRWA conducted outreach with staff at DCR and the Town of Winchester to collect data specific to the Mystic Dam, Upper Mystic Lake, and the Winchester reservoirs in Middlesex Falls. The team also participated in a May 2020 event, hosted by the Arlington-Belmont-Cambridge Tri-Community Flood Working Group, in which the results of a preliminary feasibility assessment of ARM at Spy Pond (Arlington) were shared by Jeff Walker/ Walker Environmental Research. In August 2020, the consultant team coordinated with the Department of Public Works (DPW) staff from the City of Medford to gather data specific to existing outlet control and stop-log operations at Wright's Pond.

As informed by these outreach activities and prior study, the consultant team incorporated updated flow controls (such as key spillway elevations and current operations logic) and actual bathymetry into the regional flood model at Mystic Dam, Spy Pond, and Wright's Pond. The City of Medford's hydraulic model, which was imported into the regional model as part of earlier project updates, already accounts for the hydrologic response from Winchester's Middle/South Reservoir through its calibration.

Upper Mystic Case Study: Wright's Pond

Wright's Pond in Medford was identified as a priority opportunity in the initial screening of ARM pilot. This site was chosen as a sample case study for drafting sample control logics for forecast-based controls and scenario modeling. Wright's Pond was chosen for a number of reasons. Foremost, it is a site that resides at a higher elevation than the lower basin (near Middlesex Fells Reservation) and has a relatively large upstream contributing drainage area. The facility has been mentioned

8 https://www.wef.org/globalassets/assets-wef/3---resources/online-education/webcasts/presentation-handouts/presentation-handouts---opti-eshowcase-7-27-17.pdf

in both *the City of Medford's Climate Change Vulnerability Assessment*[9] (2019) and prior modeling analysis, funded in part through a Fiscal Year 2018 MVP Action Grant.

The City of Medford has also worked with other consultants to model existing outlet configurations at this site, related to dam safety and operations of existing stop-log features at the Wright's Pond outlet structure. Data from this and other past reports helped inform the modeling analysis, simulating active controls (see **Task 6b** – Hydraulic Modeling section).

The Wright's Pond site also makes for an interesting case study, as it is located upstream of largely urbanized area, with drainage routed to the Mystic River via a large subsurface culvert along I-93. Forecast-based discharges must also consider downstream hydraulics to not pre-emptively flood any downstream areas during basin drawdown which would typically occur ahead of a storm event that may otherwise result in flooding.

The technical team worked with OptiRTC, a vendor specializing in real-time controls and forecast-based management of reservoirs and stormwater devices, to draft sample control logic that was used to hydraulically model potential ARM interventions at Wright's Pond and Spy Pond (in Arlington). These were considered "pilot" sites for evaluation of ARM strategies.

Limitations of Draft ARM Control Logic

The draft control logic that was developed for the Wright's Pond and Spy Pond pilot ARM sites, was simplified to consider only a few key parameters (see documentation provided in **Appendix P**). However, more detailed analysis is needed at each location to better understand factors that may influence design and optimization. Such factors may include the addition of pumps to supplement gravity-based drainage during basin drawdown, sizing and key elevations of specific outlet controls such as actuated valves, or the optimization of timed releases based on live forecasts, downstream pipe capacity, or other modeling or monitoring data.

For the purposes of hydraulic modeling, the draft control logic, which was integrated into the regional model scenarios, simplifies these processes by assuming that pre-event drawdown has occurred to target water elevations. The hydraulic modeling analysis does not explicitly model pumping operations for pre-event basin drawdown, or any active controls during storm's onset which may allow additional storage capacity to be used during peak rainfall or when downstream pipes/waterways are full.

For initial modeling results for Wright's Pond, refer to the **Task 6b** – Hydraulic Modeling section.

9 https://drive.google.com/file/d/1DvxUiXpGnp8soxA3njZUgCSMBcWki_fm/view

Conclusions: ARM suitability, Barriers to Implementation in Upper Mystic Watershed

The initial modeling analysis for potential ARM at Spy Pond indicates that the flood mitigation benefits of ARM are largely dependent on basin topography. The Alewife sub-watershed is located at a low elevation, where it may be more difficult for ARM to achieve large-scale benefits. For example, it was previously reported that basin-scale flooding that occurs under large precipitation events (50-year recurrence or greater[10]) can produce backflow conditions in the Alewife Brook[11]. Thus, tailwater conditions may limit the regional benefit of individual ARM projects during large events.

In these low-lying basin areas, flood mitigation benefits may still exist for ARM designed for smaller and more frequent precipitation events but will likely require additional optimization analysis that consider dynamic performance. Dynamic performance can include dynamic tailwater conditions, and active controls initiated during a storm's onset.

Next Steps

The initial ARM screening and modeling analysis was limited by available data and budget for design/sizing/optimization of future active controls. At both the Wright's Pond and Spy Pond sites, there is significant potential to expand on this analysis and model additional scenarios that consider dynamic conditions and optimization. New literature published in the last year for ARM feasibility at Spy Pond can directly inform next steps for sizing and optimizing ARM upstream of Alewife Brook where significant flooding occurs in Arlington and Cambridge. The same type of analyses can be applied to other large ponds and reservoirs, such as at Clay Pit Pond (Belmont), Walker/Whittemore Pond (Woburn), Arlington Reservoir, Cranberry Bog Conservation Area (Woburn), and Spot Pond (DCR).

Additional coordination with DCR and MWRA is needed at Spot Pond, which contributes significant flow to a buried conduit in the Malden River sub-watershed. Upstream flooding in Melrose and Malden may be linked to sub-regional capacity of these shared drainage networks. A previous U.S. Army Corps of Engineers (USACE) study that led to a 2008 report[12] for the Malden River initially considered an ARM alternative but only on the basis of water quality and purposes of "flushing" with freshwater flows from Spot Pond. The alternative was eliminated as on option based on inadequate summertime freshwater flow but was not assessed for regional flooding purposes.

In addition to the sites mentioned above, there are numerous other opportunities for ARM to improve water quality, such as to combat algal blooms. During conversations with staff at the

10 Route 2-Alewife Brook Parkway Project, Arlington/Belmont/Cambridge: Environmental Impact Statement (1987): https://play.google.com/books/reader?id=cqM1AQAAMAAJ&hl=en&pg=GBS.PA13

11 Tri-Community Working Group Progress Report (2015): https://www.cambridgema.gov/~/media/Files/publicworksdepartment/stormwatermanagement/tricommunityworkinggroupfinalreportaugust2005.pdf?la=en

12 https://www.nae.usace.army.mil/Portals/74/docs/Topics/MaldenRiver/DPR_Final.pdf

Town of Winchester, Winchester mentioned that interventions designed for low-flow conditions and small storms may be strategic for locations such as Winter Pond, Little Winter Pond, and Wedge Pond. Although Wedge Pond is situated at an elevation that is too low to provide significant flood mitigation benefits, this pond gets "short-circuited" by flow from Horn Pond Brook during storm events, exacerbating water quality issues.

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TASK 6b.

Hydraulic Modeling

The hydraulic model was used to evaluate flood reduction benefits of GI and ARM.

Representing GI in the Regional Model

The GI conceptual designs described under **Task 5** were integrated into the regional model. The amount of depressed storage was increased in the appropriate catchments so that the target volume of runoff was intercepted before it entered the open channel system. The wetland concepts included in the model are explained as following:

- Medford: The surface area and elevation curve of the storage pond was adjusted to account for excavated area.

- Reading and Lexington: The river channel in these areas was not modeled explicitly, so the sub-catchment's hydrologic response downstream was changed using the Sustainable Urban Drainage Systems (SUDs) programming routine within the ICM-2D regional model (2020). This routine is intended to represent GI and simulate intercepting runoff from part of a parent subcatchment up to a given volume. The contributing area to the Reading wetland was estimated at approximately 5 acres. The SUDs) routine in the model intercepts the first 2.6 million gallons (MG), based on storage curves provided, from that 5 acres. The contributing area to the Lexington wetland was estimated at approximately 210 acres. The SUDS routine in the model intercepts the first 1.7 MG, based on storage curves provided, from that 210 acres.

- Everett, Woburn, and Arlington: The river cross section geometry was adjusted to represent the conceptual design. Note that all of the changes were in areas that are entirely underwater in the baseline storm models.

Because individual GI projects are not expected to have a regional flood reduction benefit, a watershed-wide scenario (Enhanced GI) was developed to represent GI implemented on a regional scale. This was done using fifty (50) potential locations identified in the desktop analyses in **Task 2**, each of which were ranked higher by municipalities in **Task 3** (sites that were assigned scores of 4 or 5 for Public Acceptance). For each location, the amount of DCIA was reduced by increasing the pervious area within the appropriate subcatchments.

DCIA is the amount of impervious surface, such as concrete or pavement, that is directly connected to storm sewer systems via catch basins and piped roof drain connections. DCIA is labeled as area 2 in **Figure 33**. Changing a portion of the DCIA to pervious area allows more rainfall to infiltrate into the ground, decreasing the overall runoff to the flow path. In moderate and heavy rainfalls, the amount of rainfall will exceed the rate at which water can infiltrate into the ground. Thus, removing DCIA will reduce, but cannot eliminate runoff from an area.

Table 8 summarizes the DCIA reductions that were incorporated into the regional model as the enhanced GI scenario (watershed-scale sensitivity analysis).

Representing ARM in the Regional Model

The ARM concepts described under **Task 6a** were also represented in the model. For large storm events, it was assumed that reservoirs would be lowered prior to the start of the storm event. This was simulated by starting model runs (initial conditions) with lower water elevations in the managed reservoirs. The initial water surface elevation for Wright's Pond was three feet lower than in the baseline run. The initial water surface elevation for Spy Pond was two feet lower than in the baseline run. Representations of the outlet structures for both reservoirs were updated within the model when these projects were incorporated.

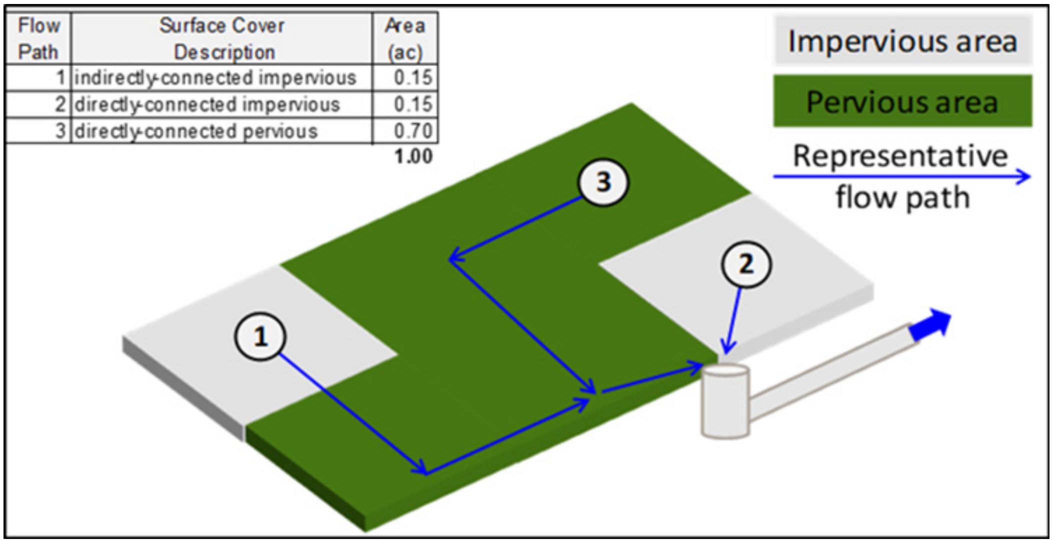


Figure 33 – Schematic Representation of DCIA (Flow Path 2)

Table 8 – Directly Connected Impervious Area (DCIA) Reductions in Enhanced GI Scenario

Location	DCIA (Acres)		
	Starting	Reduction	% Reduction
Upper Mystic Lake Watershed	2,823	1,275	45%
Mill Brook Watershed	529	529	100%
City of Belmont	710	225	32%
City of Cambridge	529	225	43%
City of Somerville	2,336	225	10%
City of Medford - South of Mystic	583	150	26%
City of Medford - North of Mystic	2,147	150	7%
City of Everett	135	135	100%
Malden River Watershed	2,021	615	30%
Total	**11813**	**3529**	**30%**

Note: This high-level sensitivity analysis approximates the distribution of priority sites from desktop screening analysis and prioritizations in **Tasks 2** *and* **3** *(i.e., 50 GI locations). The spatial distribution of DCIA reduction in this scenario was applied for sensitivity purposes and does not take into account on-the-ground conditions impacting feasibility. There are many factors that may limit DCIA reduction in any given area. However, no feasibility, cost effectiveness, or other optimization has been applied specifically to acreage/percentage values within sub-basins or municipalities.*

Table 9 – Hydraulic Model Scenarios

Event	Storm Horizon	Tide	Scenarios
100-year	Present day	Existing	Baseline
100-year	Present day	2070	Baseline + 2070 Tide only
100-year	2070	Existing	2070 Baseline (no SLR)
100-year	2070	2070	2070 Baseline
10-year	Present day	Existing	Baseline, +GI/ARM
10-year	2070	Existing	2070 Baseline (no SLR)
10-year	2070	2070	2070 Baseline
5-year	Present day	Existing	Baseline, +GI/ARM
2-year	Present day	Existing	Baseline, +GI/ARM, Enhanced GI
1-year	Present day	Existing	Baseline, Enhanced GI

"+GI/ARM"scenario includes 6 GI sites and 2 ARM sites
"Enhanced GI" scenario models watershed-wide 30% DCIA disconnection

Modeling Scenarios

Hydraulic modeling was performed under a variety of hydraulic conditions, including flooding scenarios for various large storm events. Modeling also included the GI and ARM project scenarios described in **Tasks 5** and **6a**, as well as the Enhanced GI and ARM scenario that included the watershed-scale green infrastructure with the ARM projects in **Task 6a**.

Table 9 summarizes the modeling scenarios included.

Modeling Results – Baseline Flooding

Figures 34 through **39** show how baseline flooding is distributed in the watershed in a variety of precipitation-based storm events modeled using the updated regional model (2020).

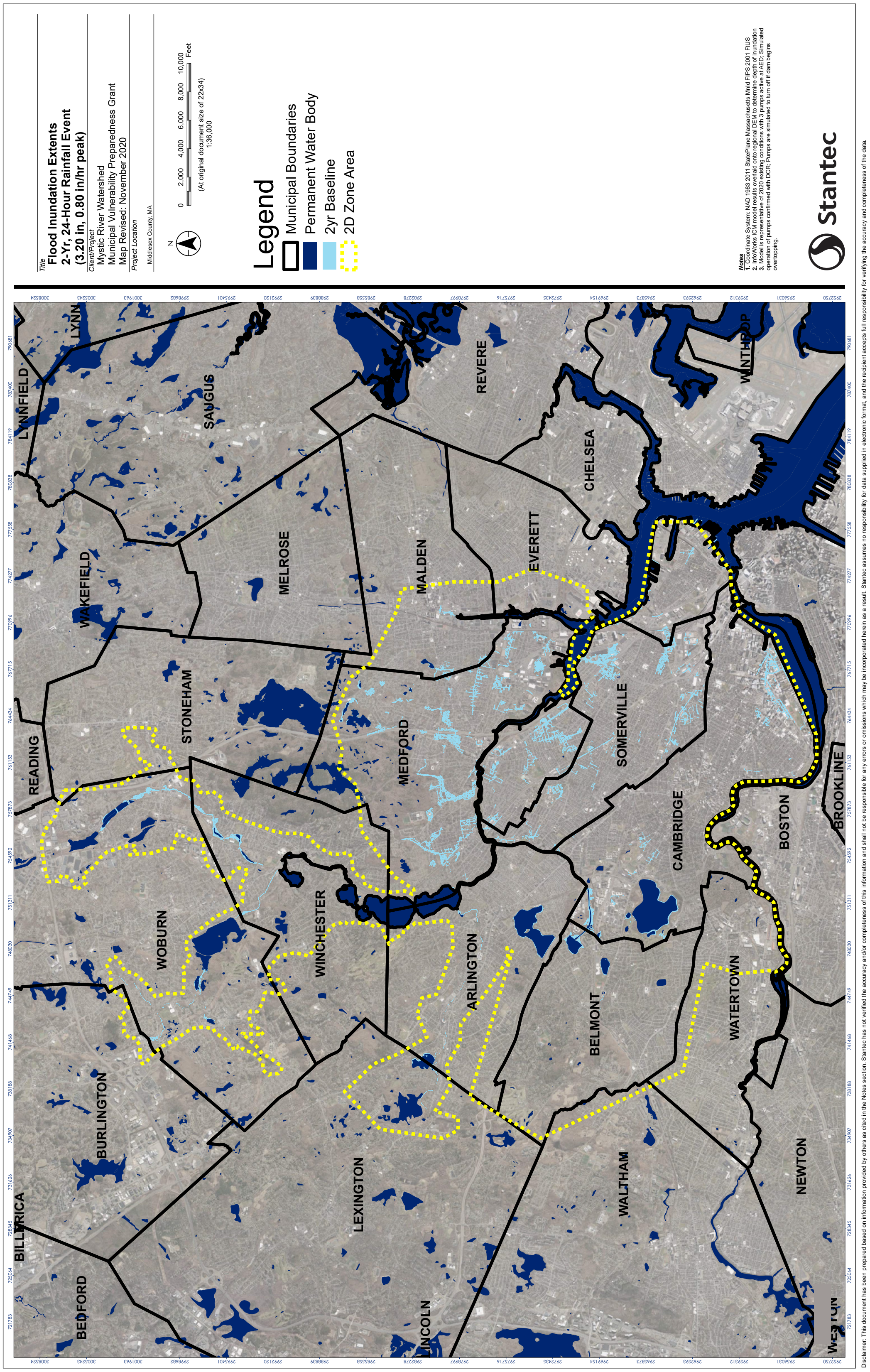


Figure 34 – Baseline Flooding: 2-year Present Day Storm, with Existing Tides

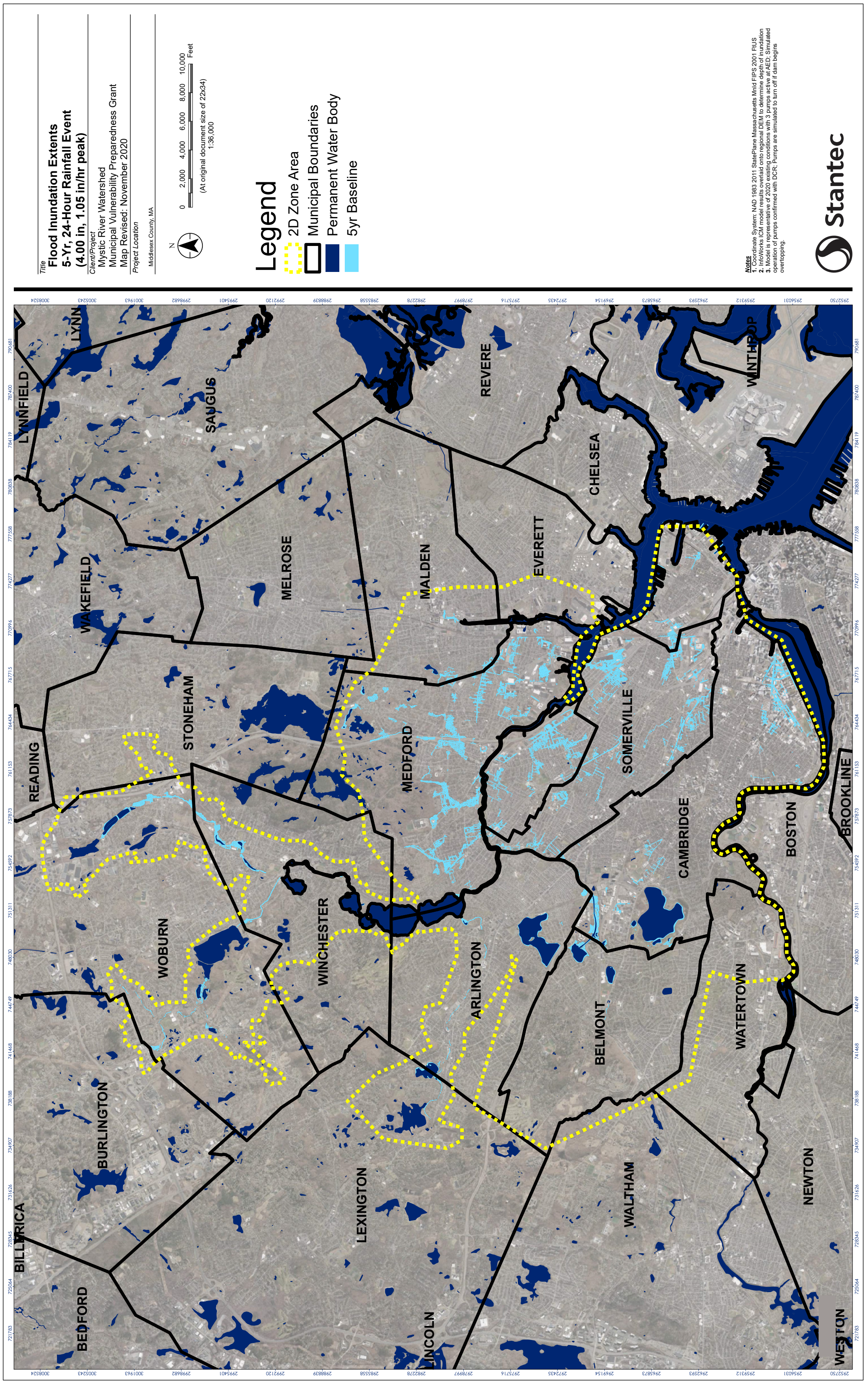
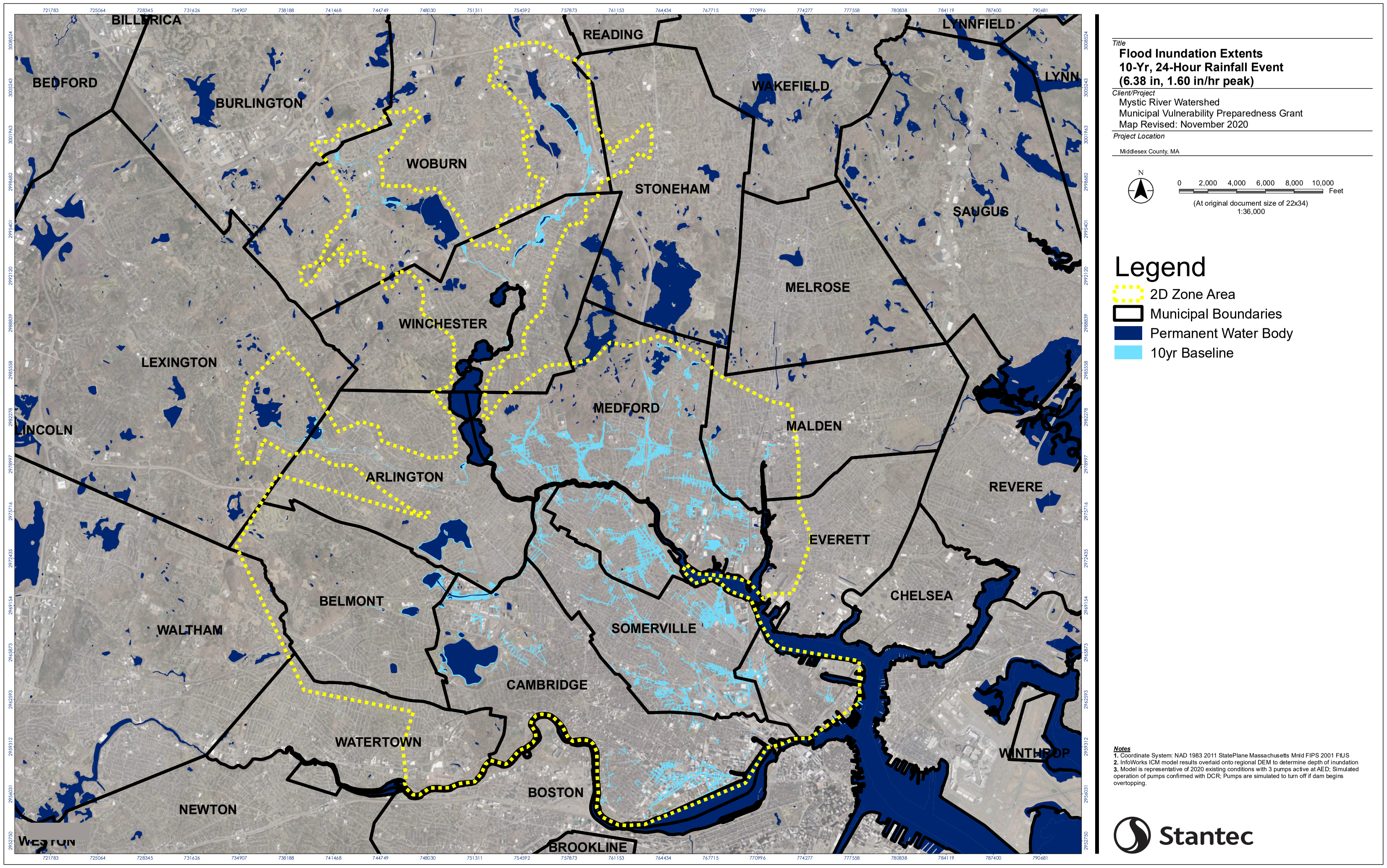


Figure 35 – Baseline Flooding: 5-year Present Day Storm, with Existing Tides



Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Figure 36 – Baseline Flooding: 10-year Present Day Storm, with Existing Tides

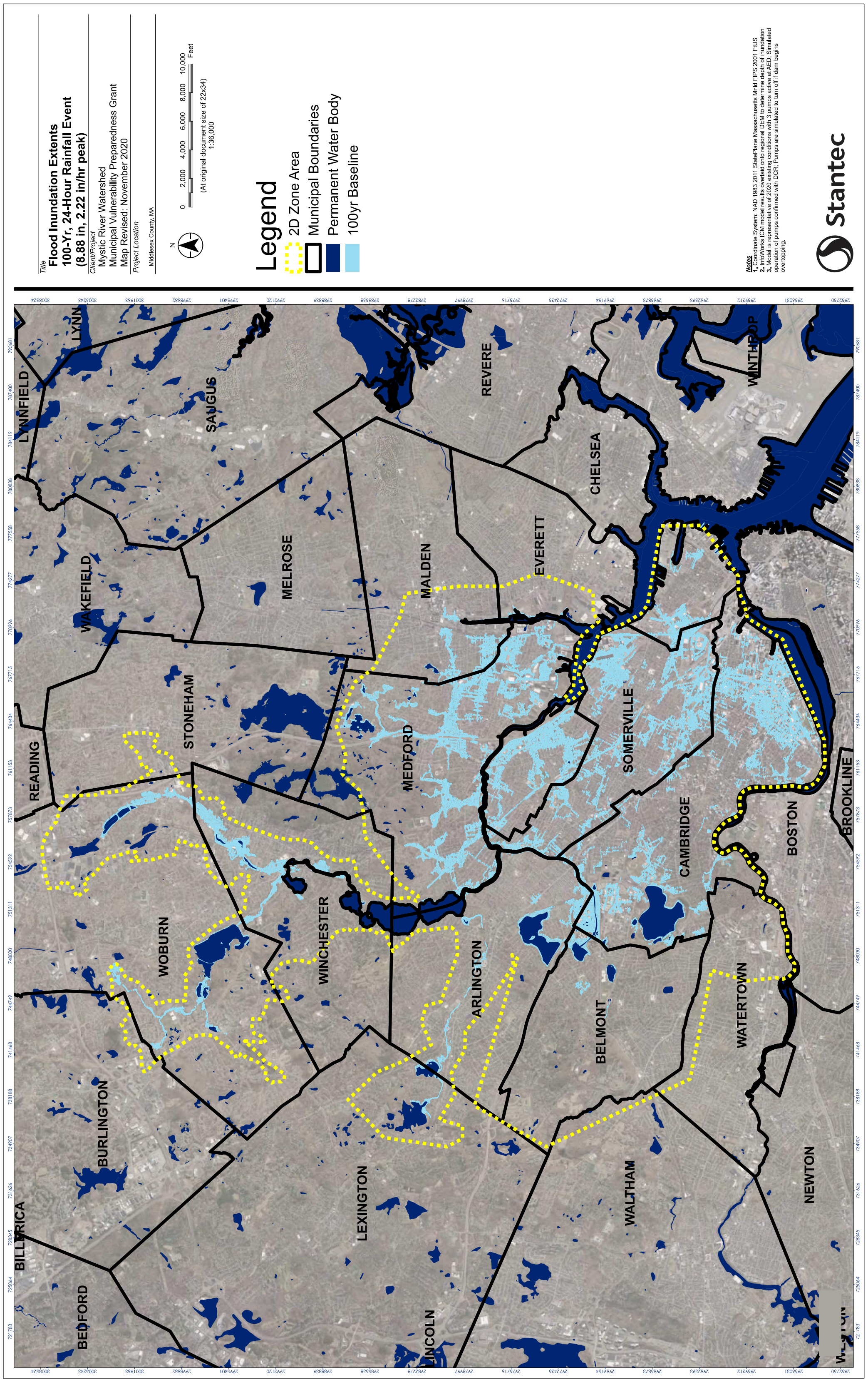


Figure 37 – Baseline Flooding: 100-year Present Day Storm, with Existing Tides

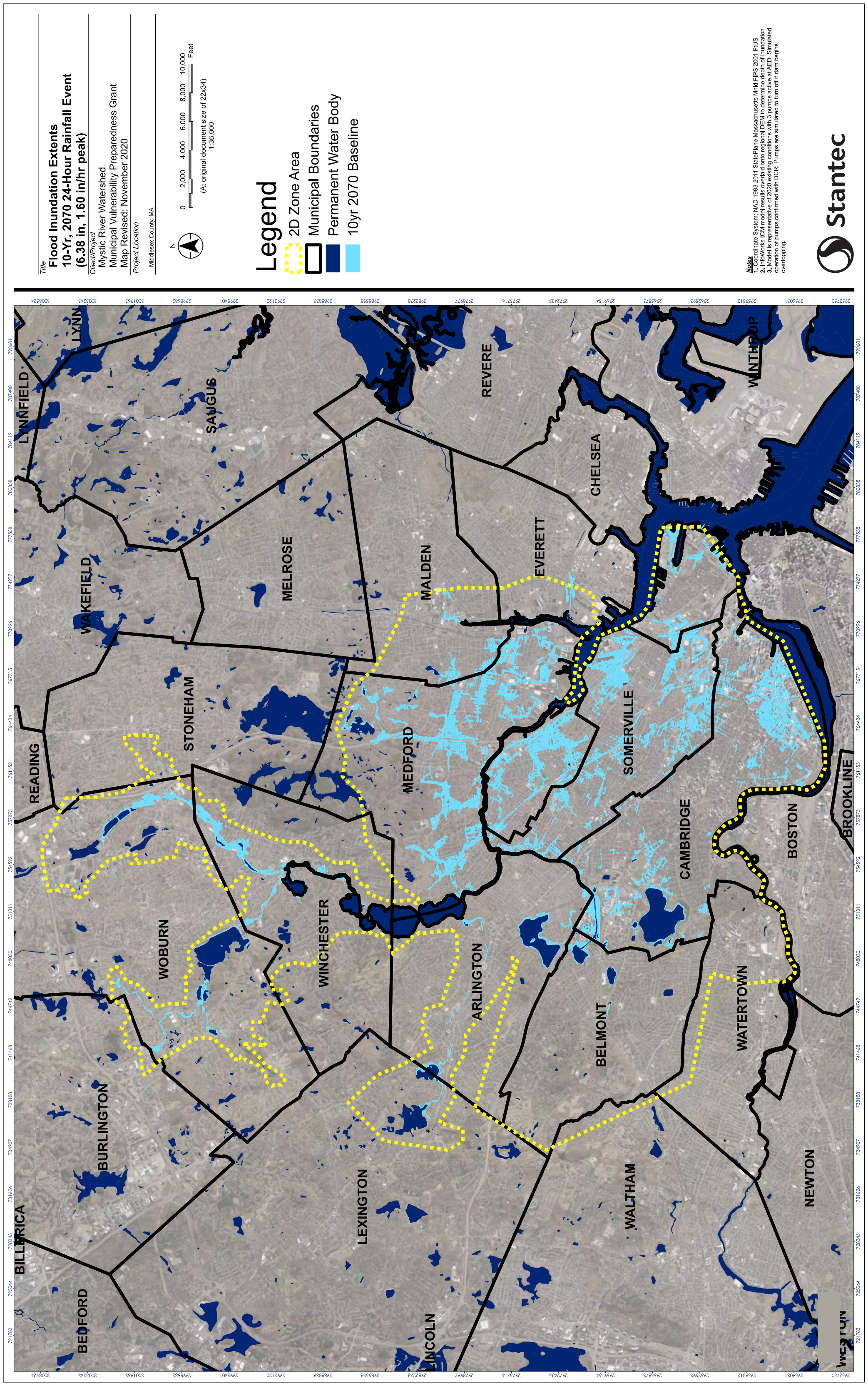


Figure 38 – Baseline Flooding: 10-year 2070 Storm, with Existing Tides

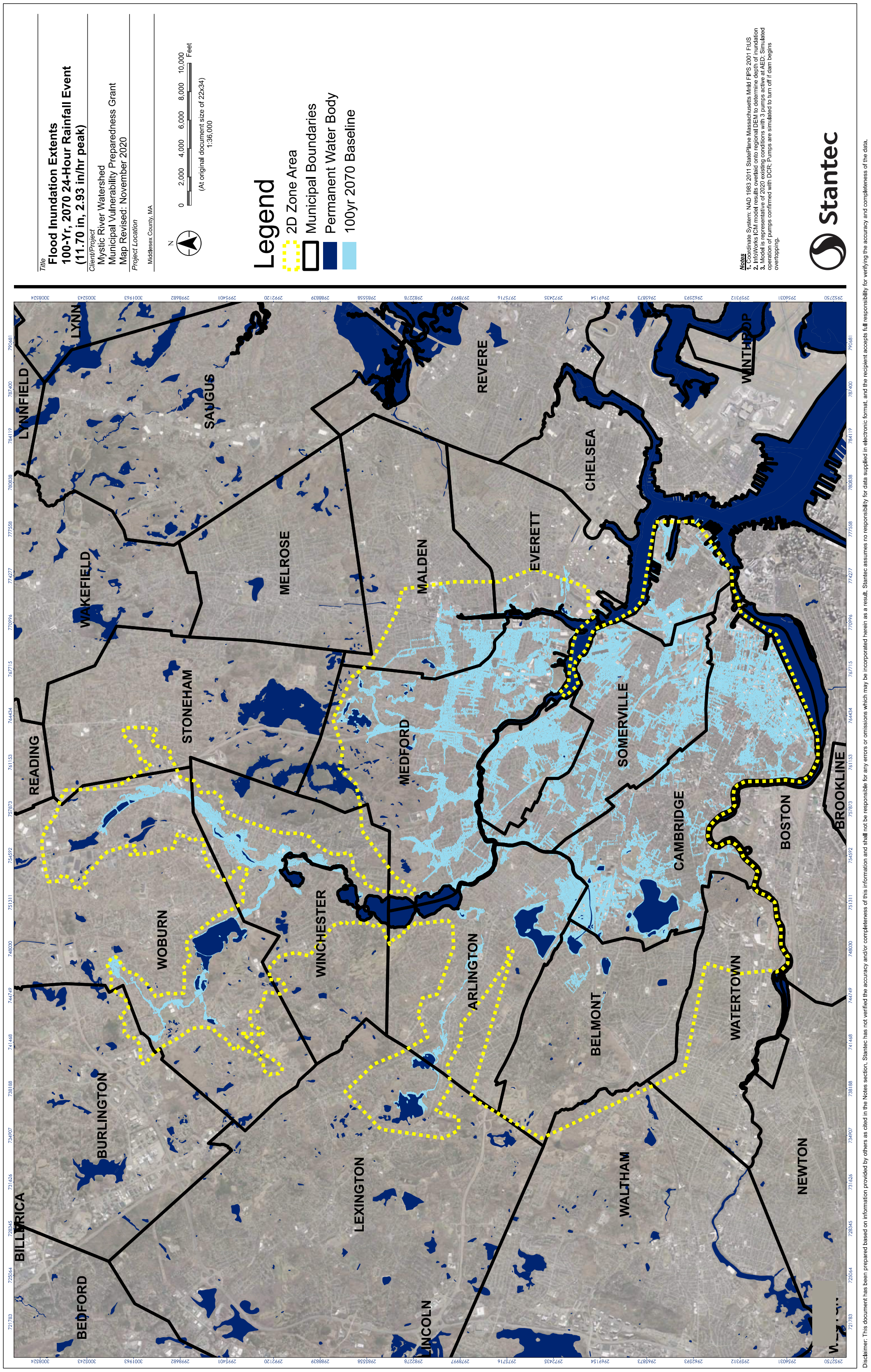


Figure 39 – Baseline Flooding: 100-year 2070 Storm, with Existing Tides

Modeling Results – GI + ARM in Large Storms

The Mystic River Regional Model was used to evaluate whether implementing the specific projects identified in **Tasks 5** and **6a** would mitigate flooding regionally. Two model runs were compared for the same storm event: current conditions versus a scenario in which the identified projects (i.e., 6 GI projects and 2 ARM pilot sites) are implemented. **Table 10** summarizes the Water Surface Elevation (WSEL) differences at varying locations in the watershed, and **Table 11** shows the difference in total flooded area within

Table 10 – Scenario Water Surface Elevations: GI+ARM for 5- and 10-year Storm Events

Event Recurrence	5-Year, 24-hour Storm			10-Year, 24-hour Storm		
	Peak WSEL (CCB datum)		Difference (feet)	Peak WSEL (CCB datum)		Difference (feet)
Scenario	Baseline	GI+ARM		Baseline	GI+ARM	
Spy Pond	16.10	16.10	0.00	17.05	17.05	0.00
Alewife @ Turnpike	14.62	14.62	0.00	15.27	15.27	0.00
Alewife @ Broadway	14.02	14.02	0.00	14.91	14.91	0.00
Mystic / Alewife Confluence	13.81	13.80	0.00	14.76	14.76	0.00
Mystic @ Main St Bridge	12.14	12.14	0.00	12.89	12.89	0.00
Lower Mystic Lake	14.47	14.47	0.00	15.56	15.56	0.00
Amelia Earhart Dam	11.20	11.20	0.00	11.68	11.68	0.00
Wright's Pond	148.80	146.25	- 2.55	148.68	146.64	- 2.04
Arlington Reservoir	165.40	165.40	0.00	165.81	165.81	0.00
Mill Brook @ Fottler Ave	174.27	174.27	0.00	174.60	174.60	0.00
Mill Brook @ Park Ave	159.31	159.31	0.00	159.88	159.88	0.00
Mill Brook @ Cemetery	17.09	17.09	0.00	17.65	17.65	0.00
Mill Brook @ High School	56.29	56.29	0.00	57.03	57.03	0.00
Aberjona @ Cranberry Bog	51.78	51.78	0.00	52.58	52.58	0.00
Aberjona @ Cross St	35.88	35.88	0.00	37.00	37.00	0.00
Aberjona @ Mystic Valley Pkwy	20.57	20.57	0.00	21.00	21.00	0.00
Cummings Brook @ Bedford Rd	84.82	84.77	- 0.05	85.18	85.18	0.00
Horn Pond	49.81	49.73	- 0.08	50.30	50.30	0.00
Wedge Pond	30.14	29.95	- 0.19	31.15	31.15	0.00

Table 11 –Scenario Modeling Results: GI+ARM for 5- and 10-year Storm Events – Flooded Area

Total Flooded Area (Acres)			
Storm	**Baseline**	**GI+ARM**	**% Reduction (GI+ARM)**
10-Year	1009	1008	0.1%
5-Year	761	760	0.2%

the watershed.

The WSEL difference in Wright's Pond is directly attributed to lowering the water level as part of the ARM strategy. In the model runs that include ARM, the WSEL for Wright's Pond starts three feet lower than in the baseline. Over the course of the storm, Wright's Pond fills with more water in a 10-year event than in a 5-year event, as indicated by the peak WSEL values. More information on Wright's Pond is presented in a case study in the next section.

GI and ARM projects at the scale proposed in **Tasks 5** and **6a** were not anticipated to produce a regional benefit in such large storms. The model results confirmed this assumption.

Modeling Results – Enhanced GI + ARM in Moderate Storms

The City of Somerville participated in an MVP-funded study to better understand the benefits of GI for flood reduction and concluded that GI is more effective in managing flooding in small to moderate storm events. Based on that study's conclusions, the Project Team decided to evaluate the benefits of a future enhanced GI implementation at the watershed scale. This "Enhanced GI" scenario was modeled as a 30% DCIA reduction, as described at the beginning of **Task 6b** section, in moderate storm events (1-year and 2-year storms).

Flood comparisons were made for 1-year and 2-year storms with baseline conditions versus a scenario that incorporates the ARM projects and the Enhanced GI scenario. **Table 12** summarizes the WSEL differences at varying locations in the watershed. The Enhanced GI scenario was a sensitivity analysis and does not equally distribute DCIA reductions across the watershed. For this reason, WSEL reductions at specific locations in **Table 12** relate to the spatial distribution of modeled GI, as summarized in **Table 8**. The differences in WSEL is not always greater from the 2-year storm event versus the 1-year storm event, as increases in rainfall and associated runoff result in different baseline WSELs from which reductions are calculated.

Table 13 shows the difference in total flooded area within the watershed.

There are notable benefits shown in 1-year and 2-year storm events in the Enhanced GI scenario (i.e., 30% DCIA disconnection via watershed-wide implementation of GI and other strategies). The Enhanced GI scenario leads to noticeably lower

Table 12 – Scenario Modeling Results: Enhanced GI+ARM for Moderate Storms – WSEL

Event Recurrence	1-Year, 24-hour Storm			2-Year, 24-hour Storm		
	Peak WSEL (CCB datum)		Difference (feet)	Peak WSEL (CCB datum)		Difference (feet)
Scenario	Baseline	Enhanced GI		Baseline	Enhanced GI	
Spy Pond	15.53	15.52	- 0.01	15.67	15.66	- 0.01
Alewife @ Turnpike	13.80	13.28	- 0.52	14.18	13.67	- 0.51
Alewife @ Broadway	12.87	12.57	- 0.30	13.24	12.93	- 0.31
Mystic / Alewife Confluence	12.22	11.98	- 0.24	12.93	12.62	- 0.31
Mystic @ Main St Bridge	11.40	11.33	- 0.07	11.71	11.58	- 0.13
Lower Mystic Lake	12.67	12.41	- 0.26	13.48	13.14	- 0.34
Amelia Earhart Dam	10.93	10.92	- 0.01	11.15	10.99	- 0.16
Wright's Pond	148.23	145.65	- 2.58	148.35	145.91	- 2.44
Arlington Reservoir	164.82	164.68	- 0.14	165.06	164.92	- 0.14
Mill Brook @ Fottler Ave	173.71	173.56	- 0.15	173.94	173.80	- 0.14
Mill Brook @ Park Ave	158.45	158.21	- 0.24	158.82	158.59	- 0.23
Mill Brook @ Cemetery	16.12	15.78	- 0.34	16.54	16.21	- 0.33
Mill Brook @ High School	55.13	54.75	- 0.38	55.62	55.23	- 0.39
Aberjona @ Cranberry Bog	50.63	50.50	- 0.13	51.08	50.93	- 0.15
Aberjona @ Cross St	34.37	34.14	- 0.23	34.91	34.74	- 0.17
Aberjona @ Mystic Valley Pkwy	19.86	19.77	- 0.09	20.16	20.08	- 0.08
Cummings Brook @ Bedford Rd	84.42	84.36	- 0.06	84.59	84.53	- 0.06
Horn Pond	49.06	48.98	- 0.08	49.38	49.30	- 0.08
Wedge Pond	29.00	28.93	- 0.07	29.36	29.25	- 0.11

Table 13 – Scenario Modeling Results: Enhanced GI+ARM for Moderate Storms – Flooded Area

Total Flooded Area (Acres)					
Storm	Baseline	GI+ARM	% Reduction (GI+ARM)	Enhanced GI+ARM	% Reduction (Enhanced)
2-Year	554	553	0.2%	522	5.8%
1-Year	426	N/A	N/A	397	6.9%

river stages in some areas, especially near Wright's Pond, resulting in a 6-7% reduction in the total land area of flooded. Other land areas where flood depths are reduced (but not eliminated) are not shown.

Figures 40 through **45** illustrate how flooding is reduced throughout the watershed in 1-year and 2-year storms. A few localized neighborhoods are shown where notable flood reduction was achieved during modeling. In these figures, flooding with Enhanced GI and ARM projects are depicted in green, and baseline flooding is depicted underneath in red. The area in red represents areas where flooding is eliminated. While flood benefit does not appear at the watershed scale, looking at certain neighborhoods reveals areas of flooding in baseline 1-year and 2-year storms that is eliminated when the Enhanced GI and ARM is implemented.

The 2-year storm results have been uploaded to the Mystic Flood Viewer, which can zoom in to areas and display the flood comparison in greater detail. The portal may provide the most effective platform for exploring specific municipalities and neighborhoods.

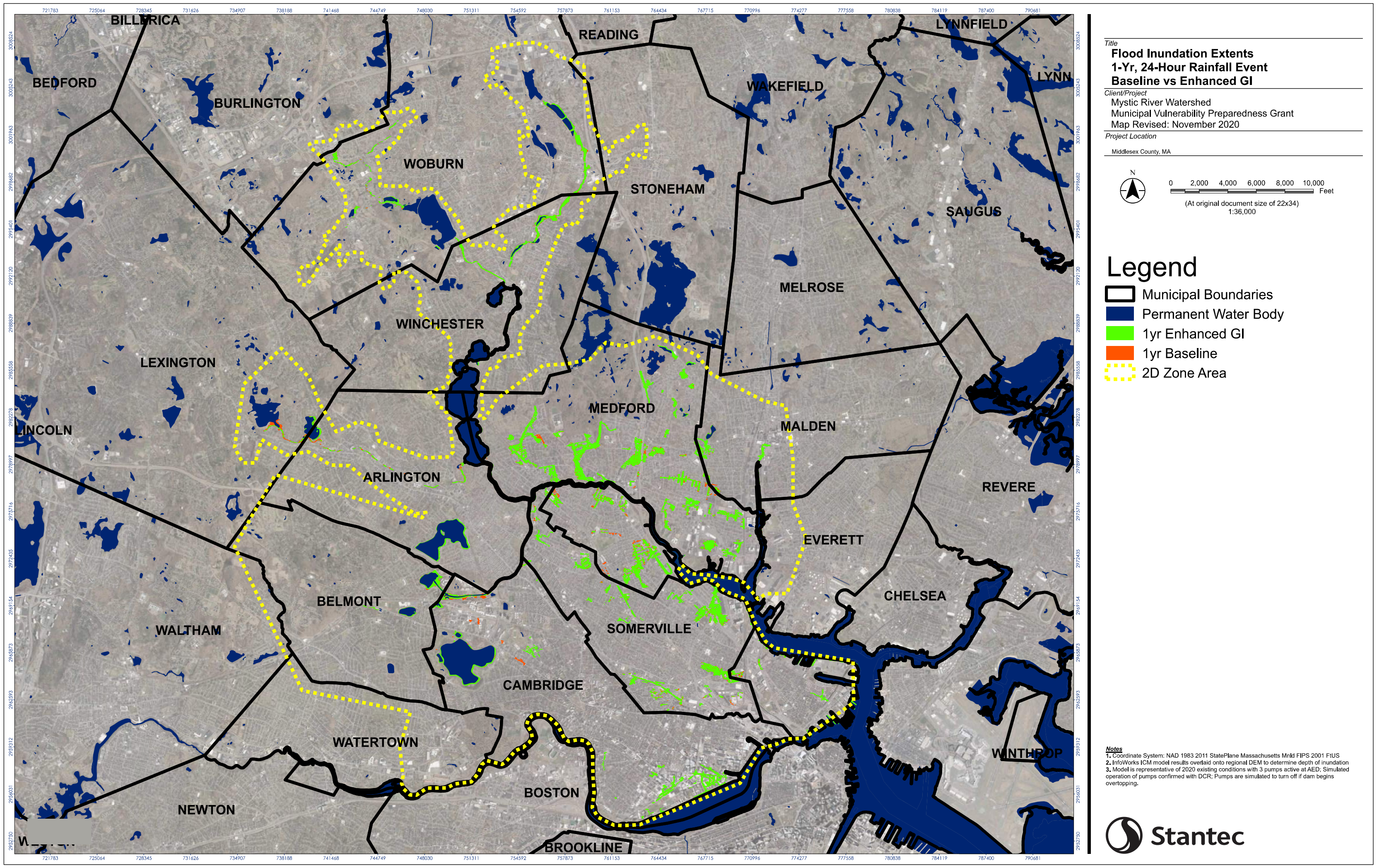


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Figure 40 – Modeling Results: 1-year Storm, Enhanced GI + ARM Flood Reduction, Watershed Scale

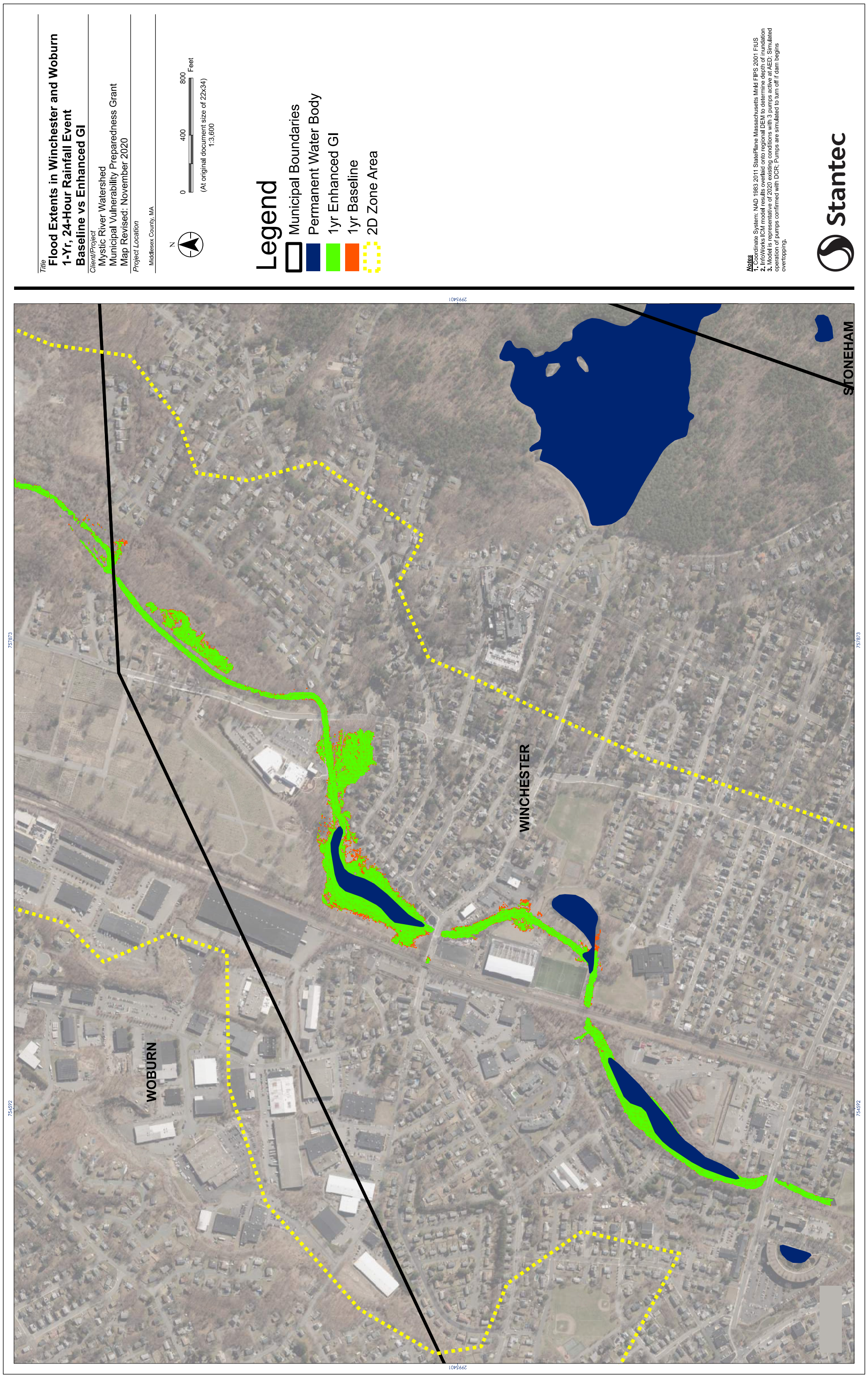

Figure 41 – Modeling Results: 1-year Storm, Enhanced GI + ARM Flood Reduction, Winchester area

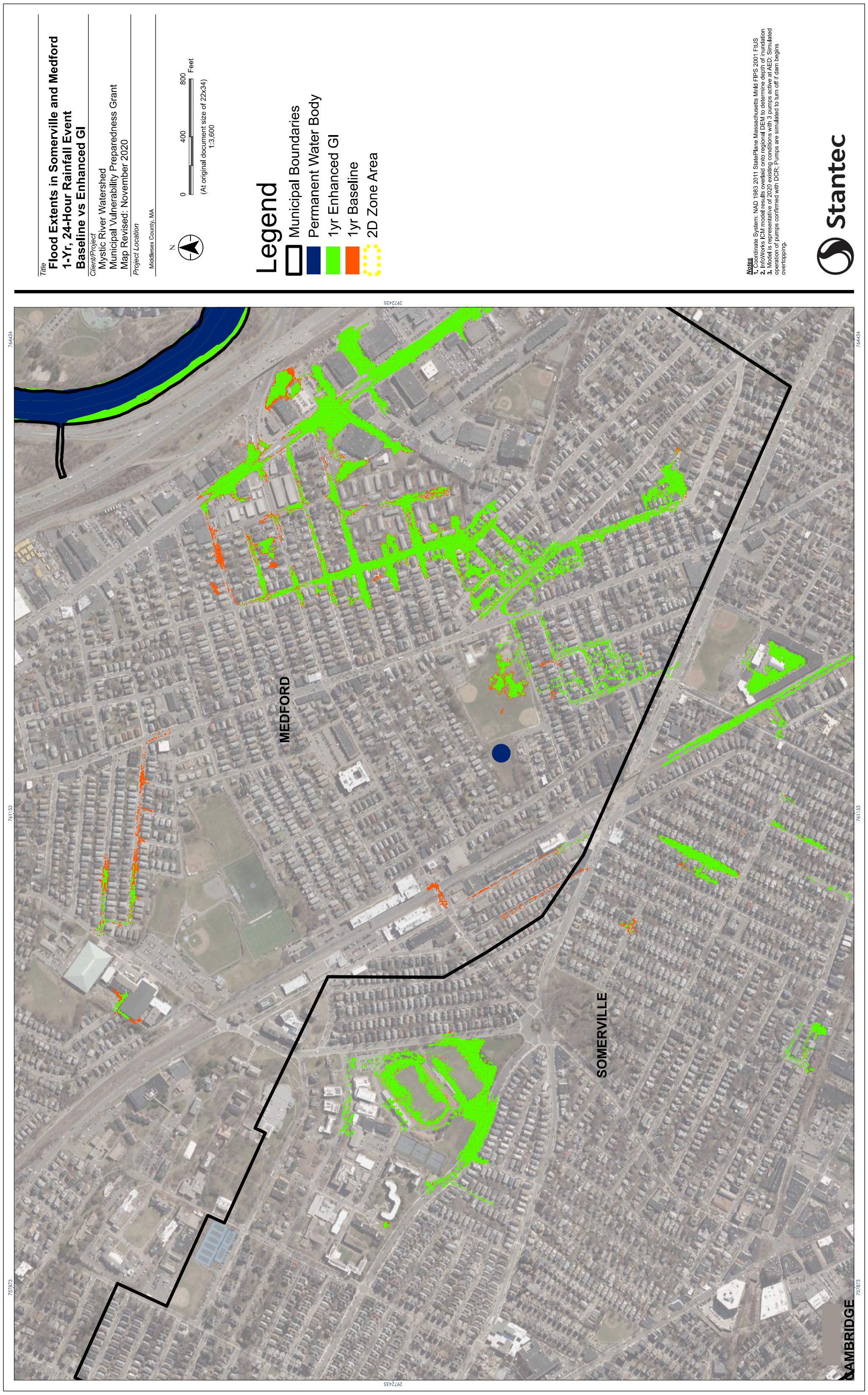

Figure 42 – Modeling Results: 1-year Storm, Enhanced GI + ARM Flood Reduction, Somerville/Medford

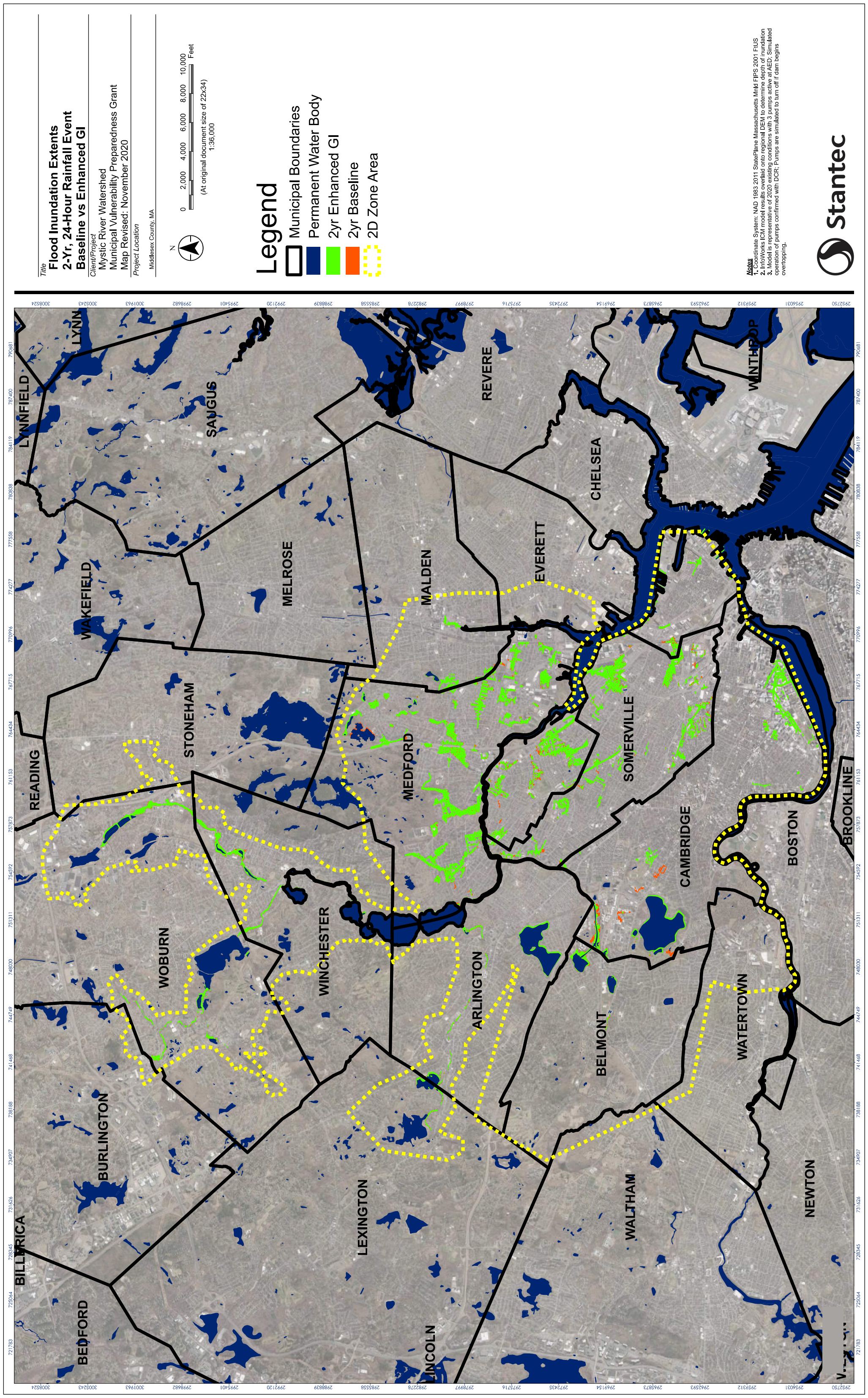

Figure 43 – Modeling Results: 2-year Storm, Enhanced GI + ARM Flood Reduction, Watershed Scale

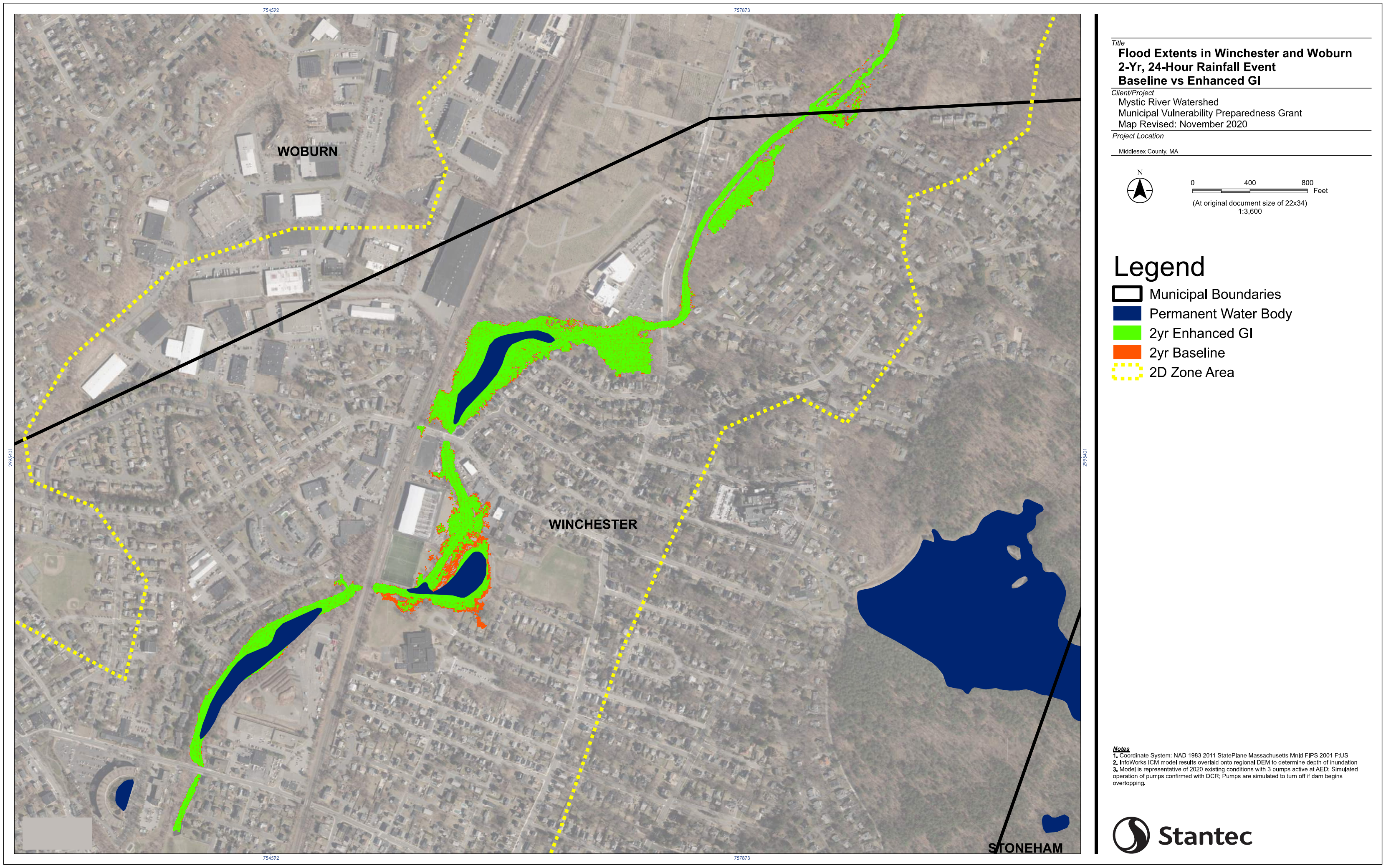

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Figure 44 – Modeling Results: 2-year Storm, Enhanced GI + ARM Flood Reduction, Winchester area

Figure 45 – Modeling Results: 2-year Storm, Enhanced GI + ARM Flood Reduction, Somerville/Medford

Modeling Results – ARM Case Study in Moderate Storm

As noted above, ARM was simulated by lowering the water surface elevation prior to the start of the model run. It was assumed that lowering basin water elevation was achieved via active controls, which may include pumping or gravity-drainage through actuated valves. Wright's Pond and Spy Pond were evaluated in this way.

In large storms, both reservoirs filled before peak rainfall and provided no benefit. However, in moderate storms, ARM at Wright's Pond appeared to reduce flooding downstream. As shown in **Figure 46**, the water surface elevation was modeled starting three feet lower, and Wright's Pond was able to contain the entire storm, with additional capacity at the end. This indicates that the proposed concept may provide benefit in larger storm events as well.

By capturing these storm flows, one neighborhood downstream showed a noticeably reduced area of flooding. **Figure 47** shows flooding in the baseline model in red, with Wright's Pond having an initially lowered water surface in green. With ARM at Wright's Pond, the flooding along Foss Street would not occur in a 2-year storm, according to the modeling tool.

ARM concepts with real-time dynamic pump controls could also provide greater benefit if they are pumped down during the storm's onset, allowing the additional storage capacity to be used during peak rainfall or when downstream pipes/waterways are full. The dynamic simulation exercise required to optimize performance (based on upstream-downstream interactions, and piped network capacity) is a modeling analysis that is specific to basin characteristics at each large water body. This type of optimization exercise could be performed at a later stage in project development.

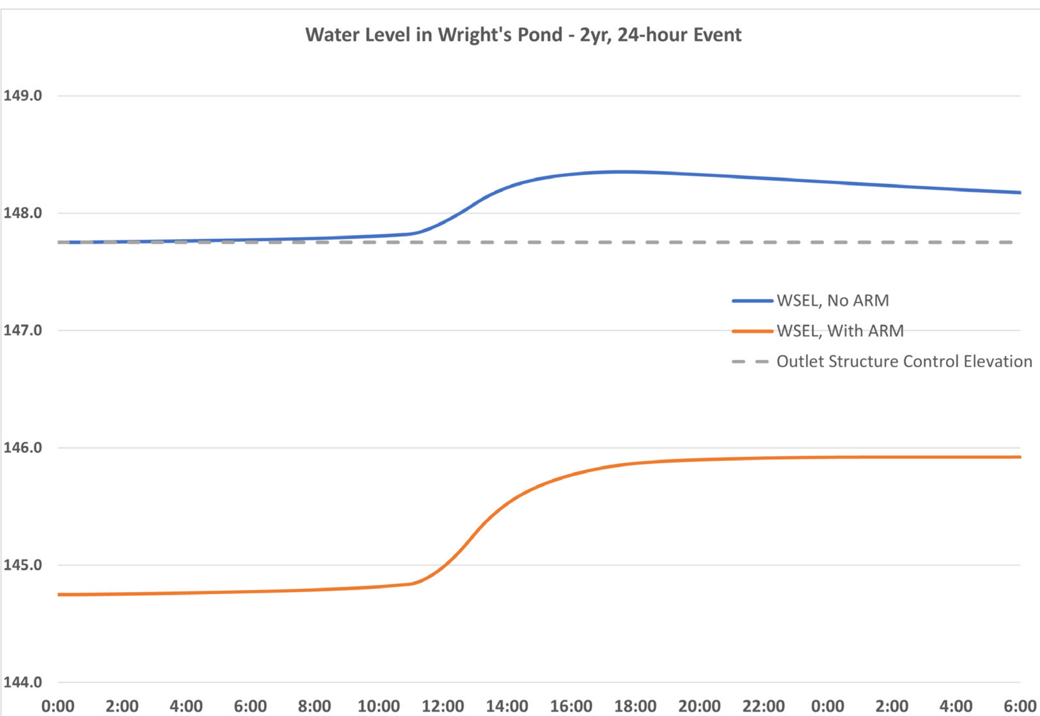

Figure 46 – Scenario Modeling Results: 2-year Storm, ARM at Wright's Pond

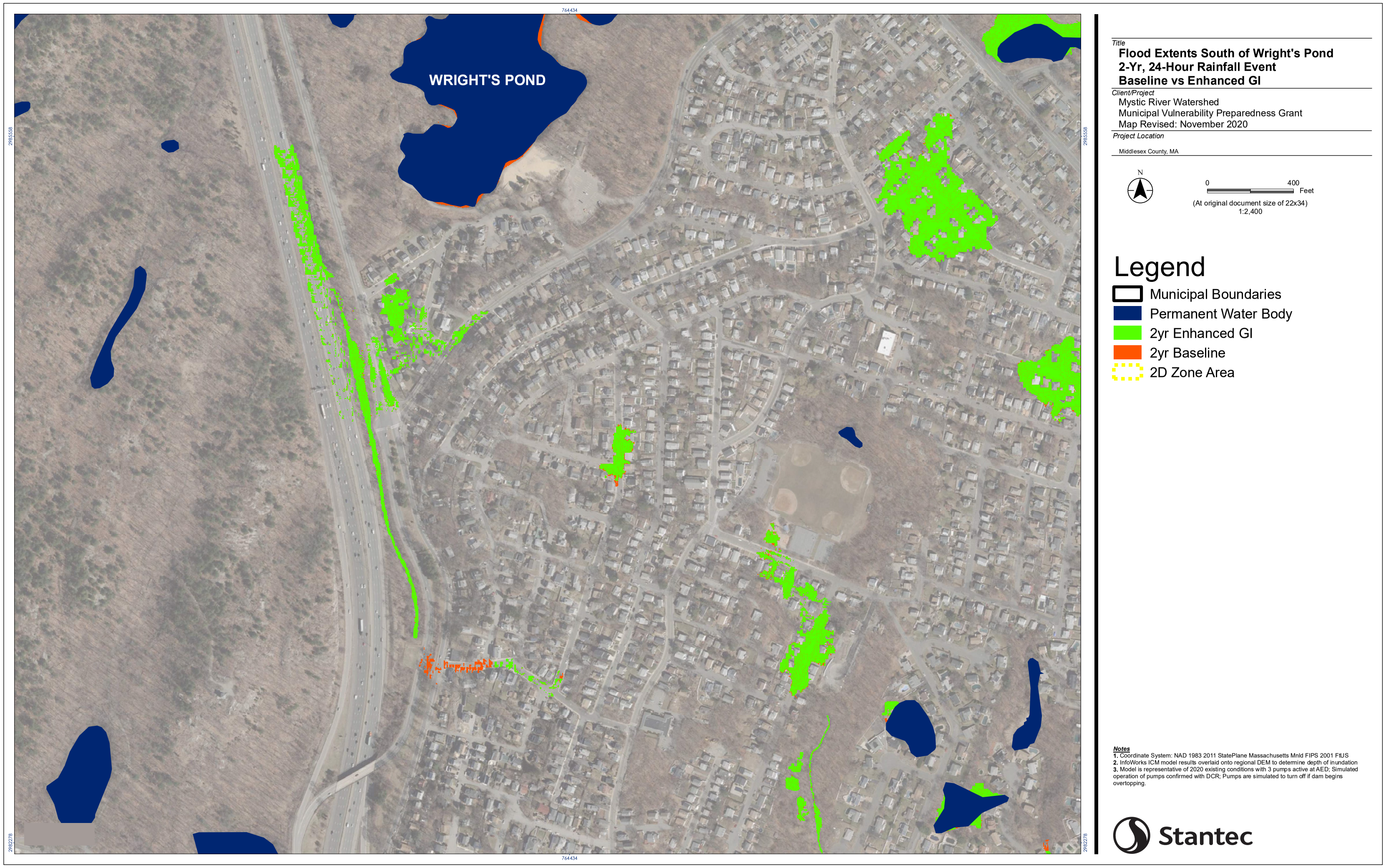

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Figure 47 – Scenario Modeling Results: 2-year Storm, Enhanced GI + ARM Flood Reduction, Wright's Pond area

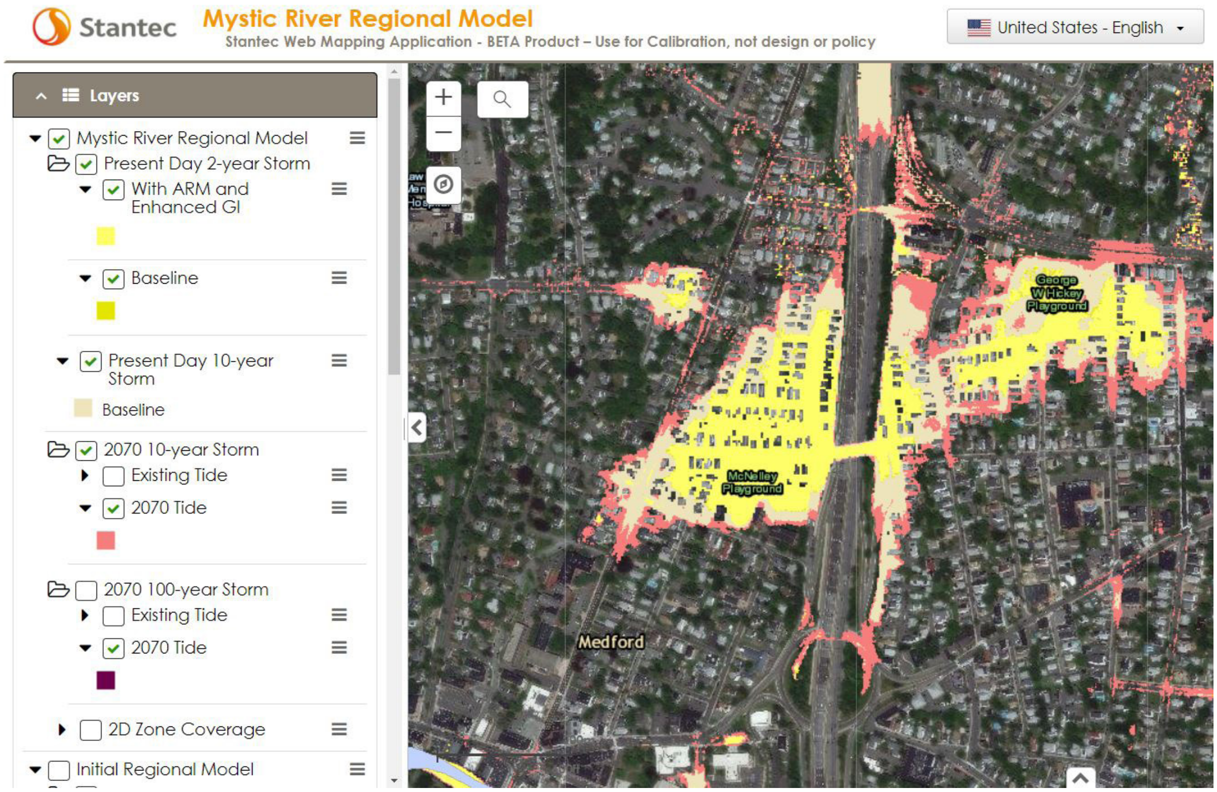

Figure 48 – Mystic Viewer Tool - Medford Baseline Flooding, south of Wright's Pond

In the case of Wright's Pond, it was there was a post-event model WSEL change of ~2.5 feet in Wright's Pond for the 2-year, 24-hour event (between baseline and ARM scenario), indicating the Pond does not return to its pre-storm water level. Less gravity-driven outflow from the Wright's Pond primary outlet may free up significant downstream conveyance capacity in the culvert system along I-93 during the onset of small and moderate storm events (i.e., 1- to 10-year recurrence events; "moderate" relative to larger events such as 2070 10-year or 100-year recurrence events). While additional analysis of these events is needed to better understand specific drivers of modeled flooding downstream (areas to the east and west of I-93 south of Middlesex Fells Reservation), ARM may also be considered as potential strategy for reducing flood hazard risk during large storm events. The City of Medford Hazard Mitigation Plan[13] delineates the downstream areas within the Wright's Pond Inundation Area where overtopping of Wright's Pond could result in flooding of regionally critical infrastructure, including multiple I-93 exits, a Mass Electric power station, a senior citizens center, Winchester Hospital-Medford, and City Hall (see **Appendix P**). Large portions of these areas are also mapped as flood areas in the Present Day 10-year model condition (see **Figure 48**).

13 City of Medford Hazard Mitigation Plan Update (2013): http://docshare01.docshare.tips/files/14759/147594144.pdf

While the benefits of the Wright's Pond pilot ARM opportunity alone do not immediately result in large reductions ile the benefits of the Wright's Pond pilot ARM opportunity alone do not immediately result in large reductions in flood extents, the pairing of upstream ARM and other sub-basin DCIA reduction strategies (e.g. subsurface storage/infiltration projects, distributed GI) may work collectively as a regional strategy. For example, if Wright's Pond ARM can free up significant downstream conveyance capacity in the culvert system along I-93 during the onset of storms, the additive impacts of these strategies may help alleviate surcharge conditions and modeled downstream flooding associated within the Wright's Pond Inundation Area. As in many urbanized areas, the benefits downstream DCIA reduction strategies in low-lying areas may not be fully realized without wet-weather conveyance capacity freed up by system-wide optimization measures, which may include ARM.

Cost Considerations for ARM/ CMAC

The costs of ARM and CMAC project costs are variable, however overall project costs are largely driven by the hard infrastructure retrofit components (e.g., pipe upsizing, addition of pumps, outflow structure modification or replacement, associated earthwork), rather than the design and forecast-based control elements. For CMAC projects, the cost of forecast-based control and information technology elements is less (on the order of $70,000-$200,000). Previously implemented CMAC projects at this scale have demonstrated considerable benefits (i.e., 60% or greater reduction wet weather volume, 30% or lower peak flow in large events), as compared to passive storage systems (Opti, 2017[14]).

For larger sub-basin scale ARM projects, such as Wright's Pond or Spy Pond pilot sites, the costs of hard infrastructure retrofits - such as addition of pumps, or upsizing of outlet pipe to Little River at Spy Pond - would be greater (on the order of $500,000 - $2,000,000, or greater), depending on design and level-of-service. While there is potential to implement such technologies at less cost that constructed stormwater wetlands, holistic cost-benefit analyses should consider co-benefits of nature-based solutions, such as the creation of new passive recreation amenities and water quality treatment. Further, ARM and CMAC technologies may work collectively as a regional strategy with other DCIA reduction strategies (e.g., constructed stormwater wetlands, subsurface storage/infiltration, distributed GI) to mitigate regional flooding by optimizing system-wide performance.

14 Addressing Stormwater Goals with CMAC (Opti, 2017): https://www.wef.org/globalassets/assets-wef/3---resources/online-education/webcasts/presentation-handouts/presentation-handouts---opti-eshow-case-7-27-17.pdf

CONCLUSIONS, RECOMMENDATIONS, AND NEXT STEPS

Key Project Takeaways and Next Steps

Climate change will exacerbate precipitation-based flooding in Massachusetts and will add stress to an aging stormwater infrastructure already operating at capacity. Regional scale stormwater management provides great opportunities to address the entirety of the watershed and expand the possibility for grey and green infrastructure. Watershed-wide stormwater management also presents challenges, particularly around coordination and consensus of priorities.

The modeling scenario analysis shows that the near-term priority GI & ARM projects that were identified and brought to conceptual-level design through this project represent a key first step to regional solutions. However, the regional scenario results also highlight the need for additional flood mitigation strategies beyond the addition of watershed storage.

Key deliverables created through Phase I of this project allowed RMC member municipalities to build consensus around six priority wetland-scale opportunities which will be advanced to design and permitting, while also building a larger portfolio of future GI and ARM opportunities for future phases for stormwater management at the regional scale.

Key takeaways include:

- **The development of the *regional flood model* constitutes a novel data-sharing effort, allowing municipalities to better understand current and future climate change-related shared flood vulnerabilities and help bridge data gaps between communities.** This improved modeling approach dynamically simulates riverine floodplains, specific large water bodies, and piped infrastructure. It provided greater resolution to the calibration of the upper watershed catchment hydrology. This pioneer modeling tool can also be used to explore the scale of benefits for different strategies to manage runoff from DCIA. These management strategies (to attenuate, store, and/or treat runoff via "disconnection" of DCIA) include new or restored stormwater wetlands, active reservoir management, distributed green infrastructure and infiltration-based measures, and depaving. Now these strategies can be explicitly modeled to determine at the same time regional stormwater management and localized co-benefits of potential projects.

- **The modeling effort also helped produce *new baseline datasets* and scenario modeling to analyze precipitation-driven flooding and consider factors and scenarios beyond what is provided by FEMA, or individual communities' models.** The model includes dynamic downstream boundary conditions at the Amelia Earhart Dam that are inclusive of sea level rise impact on tides and Dam operations, while also adding catchment-scale resolution to simulate urban flooding outside of the riverine floodplain. Scenario events simulated within the model also consider the future impacts of climate change on precipitation events, and can consider more frequent events (e.g., 2- thru 10-year recurrence events) that are not provided by FEMA or are greatly simplified in other rainfall-runoff models that do not explicitly model piped infrastructure.

- ***New mapping tools* open the door to exciting new possibilities.** These tools identify flooding hot spots and model areas along or near municipal boundaries, where stormwater storage or conveyance may be shared between multiple communities, thereby facilitating potential shared projects. Such opportunities for collaboration are likely to be more effective from a watershed perspective. **At a higher level, the improved modeling tools may also be used to assess watershed-specific benefits of non-structural strategies** to inform joint benefits/ impacts of projected land use and zoning recommendations. Such recommendations could include reducing new impervious cover and depaving strategies, conveyance of floodwaters to low-criticality lands and "floodable" open spaces, and other source control measures.

Future Model Uses and Recommendations

- The Mystic Viewer Tool (regional model webtool) can be accessed via the following link: https://geo.stantec.com/MysticRiver/viewer/ For log-in credentials - or other inquiries related to the webtool – contact the RMC / UMSWG (email Emily Sullivan esullivan@town.arlington.ma.us or Patrick Herron patrick@mysticriver.org).

- It is recommended that the regional model be used as a planning tool (i.e., to analyze portfolios of flood mitigation/DCIA reduction alternatives applied at the watershed-scale), or otherwise be updated periodically to quantify the regional flood mitigation benefits of multiple projects that have been designed or implemented. It is also recommended that the regional model should also be updated when major changes are made that impact the watershed hydrology such as changes to AED operations, bridge replacements along the rivers, or more comprehensive studies or data collection are undertaken.

- While the regional model can be used to inform future projects, it is not recommended that the regional model be used for detailed design of individual projects. For design purposes it is recommended that municipal or site-specific H+H models be used to analyze performance of individual projects. Local flood mitigation benefits are largely dependent on conditions best modeled at a finer scale (e.g., catch basin and conveyance restrictions, site-specific grading, detailed storm drain and sewer system elements). Although there is significant model detail within the 2D Zone Coverage area, it does not include all piped infrastructure and makes other simplifying assumptions and calibrations at the subcatchment level.

- As a planning-level tool, the regional model can be used to analyze additional scenarios, such as other DCIA reduction targets (e.g., 20% or 50% DCIA disconnection), representing different levels of investment. Spatial distribution of DCIA reductions (i.e., how these are applied across subcatchments in the model) can also be modified, as informed by site feasibility analyses or cost effectiveness tools (such EPA's Opti-Tool for Stormwater and Nutrient Management). The regional model can also be used to assess nonpoint solutions for DCIA disconnection, such as reduction of new impervious cover, depaving strategies, and other source control measures applied at the watershed scale. It can also be used to inform alternative flood management strategies such as strategic conveyance of floodwaters to low-criticality lands and "floodable" open spaces.

- As part of a regional flood mitigation strategy, ARM and wetland-scale GI are complementary strategies. It is recommended that ARM (or CMAC) be further analyzed for localized benefits in the Alewife Brook sub-watershed and downstream of Wright's Pond in Medford, specifically:

    - Alewife Brook sub-watershed: Exploring the localized benefits of ARM for Spy Pond is recommended to be done as part of a study to optimize flood reduction in the Alewife Brook sub-watershed. Hydraulic analysis of flow attenuation, peak flow travel time, and impacts of dry weather releases to downstream reaches was also recommended as the next step in the *Spy Pond Stormwater Capture Feasibility Study* (2019), produced by Walker Environmental Research and MyRWA. This study could include a portfolio of proposed flood mitigation measures, including but not limited to: ARM at Clay Pit Pond (Belmont), projects along this corridor identified in the desktop screening analysis, and other specific opportunities as recommended in DCR's *Alewife Master Plan*[15] (2003).

- Wright's Pond: The modeling results demonstrated that this ARM pilot can significantly reduce Pond water levels and outflow to downstream conduits, potentially freeing up additional downstream conveyance capacity during the onset of a storm event. While the benefits of the ARM project alone do not immediately result in large reductions in flood extents, the pairing of upstream ARM and other sub-basin DCIA reduction strategies (e.g. subsurface storage/infiltration projects, distributed GI) can work collectively as a regional strategy to alleviate surcharge conditions and modeled downstream flooding associated within the Wright's Pond Inundation Area.

- It is also recommended that site-scale CMAC be considered during the detailed design of wetland-scale GI. The marginal costs of adding active controls for large-scale stormwater storage/infiltration systems or constructed stormwater wetlands may be incremental (on the order of $70,000-$200,000) and cost-effective for projects creating up to 1MG of new storage.

Lessons Learned

Key lessons learned include:

- With the new Alternative TMDL's participatory approach in the Mystic River watershed, many communities also recognize how nature-based projects have localized benefits, such as nutrient reduction and ecological restoration. For urbanized watersheds, these projects should be considered for all of the values they impart (e.g., flood storage, nutrient reductions, wildlife habitat, passive recreation, temperature moderation).

- The ongoing pandemic has shed new light on the importance of open space recreational areas. The co-benefit of wetland parks as passive recreation facilities was very clear and served as an additional driver for some participating communities to consider these multi-benefit, performance-based natural infrastructure concepts.

- Through engagement activities and site investigations, it was noted that another significant driver beyond flood mitigation was the potential water quality benefits that could be achieved through wetland GI projects of this scale. Water quality benefits would help municipalities achieve MS4 compliance.

- Significant insights and ideas were shared by engaging municipal conservation staff early in the project. Flood mitigation and water quality analyses are often performed by planning and engineering staff. However, the identification of opportunities for large-scale nature-based solutions and GI requires a watershed perspective and knowledge of natural lands that many conservation staff can readily contribute. Such knowledge can

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15 https://www.mass.gov/doc/findings-and-recommendations/download

greatly supplement top-down processes, such as those using GIS methods and aerial imagery, and save substantial effort in identifying target opportunities.

- As discussed during multiple rounds of planning workshops and community engagement, long-term strategies for implementing nature-based solutions for flood mitigation may require addressing structural barriers to implementation. For instance, many low-quality wetland areas, both from hydrologic and ecological perspective, often have local protections or State protections, such as deed restrictions or Article 97. While these may seem like upfront barriers to a project, additional coordination of restoration objectives and co-benefits may help unlock greater value in these natural resource areas.

- The Project Team acknowledges that the future maintenance responsibility for wetland-scale GI may require additional future protections to preserve these sites as natural infrastructure. As this project advances to future phases, it is anticipated that additional green infrastructure interventions will be designed and implemented across the watershed. The Stormwater Working Group is discussing possibilities for coordination of operations & maintenance responsibility for these sites, such as the identification of a regional provider of these services, or consistent guidance for O&M activities for these regionally significant sites.

Co-production and Data Sharing Outcomes

Over the course of this regional project, there were multiple opportunities for collaboration and data-sharing across concurrent projects such as the following examples:

- Updates to the shared regional model were a good opportunity to collaborate with ongoing analysis at the Amelia Earhart Dam, led by the City of Cambridge. The City is working with the Project Team and Woods Hole Group to provide data inputs for sea-level rise impacts on tidal conditions and AED operations. The AED served as the downstream boundary conditions for the regional modeling analysis performed in this project.

- The project team had several coordination calls and participated in a joint UMSWG meeting with an EPA Project Team led by Horsley-Witten Group, focused on the integration of GI into Hazard Mitigation Plan updates. The UMSWG and MyRWA hosted the collaboration meeting (March 2020), and data was shared between the project teams.
- The Harvard Graduate School of Design offered a spring studio course, "The Dam(n) Studio: Climate Change Along the Mystic," which was led by Kleinfelder senior planner, Nathalie Beauvais. Several contributors to this regional project - including staff from MyRWA, Kleinfelder, and Weston & Sampson - were guest speakers for this course, which focused on the resilience of the Upper Mystic River Watershed under the perspective of planning and design. The graduate student studio teams were provided some interim project data by the RMC and the graduate students developed their own studio projects (accessible at https://damnstudio.cargo.site/)

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Appendices

Appendix A Task 1-1 Recap Nemo and Task 1-2 Supporting Documentation

Appendix B Task 1-2 Model Updates and Piped Infrastructure

Appendix C Task 1-2 Updated Flood Model Outputs (Mapbook)

Appendix D GIS Mapbook of 3-acre Opportunity Sites by Land Use (January 2020 workshop)

Appendix E Land Use Codebook (Classifications for GIS Desktop Analysis)

Appendix F GIS-based Suitability Screening of Potential Wetland GI Sites

Appendix G Full List of Suitable Opportunity Sites for Regional Wetland GI

Appendix H Initial Scoring Methodology

Appendix I Revised Scoring Methodology

Appendix J Task 2-2 Maps and Tables of Additional GI Opportunities

Appendix K Ranking Tool Dashboard and Supporting Materials

Appendix L Task 3-2 Feedback on Top 35 watershed opportunities (One-Pager Summaries)

Appendix M Stakeholder Engagement and Outreach Materials

Appendix N Task 4 Site Investigations Recap Notes and Photos

Appendix O Conceptual Wetland GI - Supporting Documentation

Appendix P Active Reservoir Management - Supporting Documentation

Appendix Q Overview of Water Bodies, Piped Infrastructure Constrictions, and Control Structures (Summary Map)